RTO-37 En route User Deviation Assessment

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ABSTRACT

The Distributed Air-Ground Traffic Management (DAG-TM) research team at NASA is developing new air transportation concepts for the 2015 time frame. These concepts are intended to significantly increase the efficiency, flexibility and predictability with which air transportation is conducted. By investigating the current inefficiencies in the NAS and identifying areas in which efficiency, predictability, and flexibility can be improved, we can provide information to assist NASA in prioritizing the various DAG-TM research efforts.

In this study we have attempted to apply recently developed post-operation analysis capabilities to help answer the following questions:

1. What problems in terms of flight deviations and delays are regularly occurring in the NAS?
2. Where, when and how often are they occurring?
3. What is the impact of these problems?

In doing this study we have conducted a range of high level and detailed analyses with the aid of the FAA's Post Operations Evaluation Tool (POET) and a large representative data set spanning approximately a year of NAS activity. This initial analysis serves to help identify where and when problems are arising in the NAS, and to quantify their impacts. It also begins to provide insight into the nature of these problems, both in terms of the cause (such as the overloading of arrival fixes) and in terms of the type of ATC actions that are being employed to deal with these problems (such as airborne holding or the use of MIT restrictions). Equally important, this analysis starts to demonstrate the types of large-scale analyses that can be automated using data mining tools in order to develop an even more complete picture of the state of the NAS.

The results of this effort also demonstrate the types of analyses that can be conducted to evaluate the benefit of DAG-TM concepts, and the tools that are available to conduct such analyses. As simulation and modeling exercises are conducted within the DAG-TM research effort, these analyses can be applied to simulation results to compare DAG-TM performance against baseline performance.

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1. INTRODUCTION

The Distributed Air-Ground Traffic Management (DAG-TM) research team at NASA is developing new air transportation concepts for the 2015 time frame. These concepts are intended to significantly increase the efficiency, flexibility and predictability with which air transportation is conducted. By investigating the current inefficiencies in the National Airspace System (NAS) and identifying areas in which efficiency, predictability, and flexibility can be improved, we can provide information to assist NASA in prioritizing the various DAG-TM research efforts. For example, the results of this study clearly indicate that en-route airspace capacity is a limiting factor in some parts of the CONUS airspace, and DAG-TM concepts hold the potential to increase en-route airspace capacity. In doing this study we have conducted a range of high level and detailed analyses with the aid of the FAA's Post Operations Evaluation Tool (POET) and a large representative data set spanning approximately a year of NAS activity.

The goal of this report is twofold. First, it illustrates the different techniques that we have developed thus far for using POET and its associated database in order to identify, quantify, and understand the nature of inefficiencies in the NAS. Second, we have applied these analysis techniques on a large-scale to data from different time periods from the past several months in order to identify and understand problems in the NAS.

The results of this effort also demonstrate the types of analyses that can be conducted to evaluate the benefit of DAG-TM concepts, and the tools that are available to conduct such analyses. As simulation and modeling exercises are conducted within the DAG-TM research effort, these analyses can be applied to simulation results to compare DAG-TM performance against baseline performance.

There are essentially three approaches that we have taken. The first has been the use of performance metrics (such as planned vs. actual air times) to ask where, when, and how often inefficiencies have arisen. The second has been the use of data mining tools to automatically look for evidence of certain types of air traffic initiatives (such as airborne holding) and to relate the patterns found by these data miners to the inefficiencies indicated by specific performance metrics. The third has been to conduct more detailed manual analyses (which it may be possible to automate at a later date) in order to study in greater depth the relationships among different patterns that have been identified.

This study was done under contract to the Honeywell Technology Center as part of NASA's Advanced Aviation Technology Transfer (AATT) program. This report documents the results of this effort. The remainder of this paper is organized into three sections in which we summarize the results, discuss the details of our analyses, and make specific recommendations for follow-on efforts.

2. SUMMARY OF RESULTS

The objective of this effort has been to begin applying recently developed post-operation analysis capabilities to help answer the following questions:

1. What problems in terms of flight deviations and delays are regularly occurring in the NAS?
2. Where, when and how often are they occurring?
3. What is the impact of these problems?

In trying to understand some of the problems in the NAS we must first realize that some of the metrics that we can measure do not directly relate to the root causes of the problems. The table below lists some of the measurable symptoms of problems within the NAS, as well as the root causes and the primary ATC control actions. All of these elements can be interrelated. For example, a reduced airport acceptance rate may require any number of the listed control actions to be put in place, which in turn will contribute to the overall measured delays. Additionally the control actions may be interrelated. For example, a flight may be rerouted or held in the air in order to meet particular MIT restrictions. Therefore, it is often difficult to directly attribute measured delays to specific control actions and/or root causes. To complete this study we used a variety of different approaches looking at different elements in the matrix to gain insights into the times, locations, and nature of inefficiencies that arise in the NAS.

Causes	Weather	En route Volume	Airport Acceptance Rate	Airspace Configuration & Current Procedures	Special Use Airspace (De)activation
Control Actions	Ground Delay Programs	Ground Stops	Miles in Trail	Airborne Holding	Reroutes
Symptoms		Departure Delays	Airborne Delays	Arrival Delays	

2.1 High Level Analyses

We began with some very high level analyses, developing ranked lists indicating the inefficiencies associated with particular arrival fixes as a function of the time of day. For example, when looking at departure delays, we found that the worst case for the week of July 12-18, 1999 was flights filed into DTW over POLAR scheduled to arrive from 1400-1500Z. These flights on average experienced a 91-minute departure delay.

Similarly, when looking at airborne delays, the worst case for that week was flights over RAAMS into DEN scheduled to arrive from 2200-2300Z. For these flights, the actual air time was on average 84% greater than the planned air time.

This type of analysis, allowing us to rank flights grouped in terms of the arrival fixes and specific times of day, provided a good starting point for trying to identify the locus and magnitude of performance problems in the NAS, as measured by off times and air times. In addition, by looking at consistencies across different times of the year, we were able to begin to assess how stable the underlying bottlenecks were. The results for airborne delays were remarkably consistent across different times of the year. Using a rank order correlation, for example, the rankings of problem areas for the months of April and September 1999 were correlated at 0.8244. This suggests that, if we can characterize the underlying causes of the inefficiencies associated with these particular places and times of day, it may be possible to find solutions that can be applied routinely to improve performance. Such a characterization, however, requires a much more detailed evaluation focusing on particular kinds of problems.

2.2 Detailed Analyses

The high level analysis served to focus attention on specific collections of flights (those filed over the same arrival fix) that were routinely encountering inefficiencies at particular times of day. There could, however, be a number of different underlying causes for the delays encountered by different cases. We therefore conducted several more detailed analyses to get a better understanding of what was occurring to cause these routine delays. This included looking for evidence of arrival fix overloading, airborne holding, rerouted flights, congestion along specific jet route segments, miles-in-trail restrictions, and diversions. Some of these categories overlap in terms of the underlying cause that they reflect, thus providing converging evidence about the nature of the problem.

Departure and Airborne Delays Associated with Particular Arrival Fixes

One useful analysis to detect system bottlenecks is to look at the departure delays and airborne delays associated with flights filed over particular airport arrival fixes during specific time periods. This analysis serves to detect situations where the arrival load at a given fix is, by itself, causing a problem. In many other cases, however, it is a symptom indicative of a problem elsewhere in the airspace (such as a congested enroute sector or jet route segment that these flights were filed to traverse).

Fix Overloading Due to High Arrival Rates

One possible cause of both departure delays and airborne delays is the filing of too many flights into the same arrival fix during some time. This could necessitate the use of airborne holding, cornerpost swaps, reroutes, ground delay programs, ground stops, or miles-in-trail restrictions. Our analysis clearly identified those fixes where the arrival load itself was a major problem and provided quantitative data on its impact. Over the week of July 12-18, 1999 for example, 144 flights were filed into ATL over HUSKY, 144 over TIROE, and 134 over LOGEN from 2000-2100 Z. As one example, the flights over LOGEN experienced an average airborne delay that was 28% greater than the planned air time.

It is important to note that this analysis, like that for the ranking flight groupings according to the magnitudes of the associated departure and airborne delays, was done automatically using POET. Using POET we produced for the entire NAS a rank ordered list of arrival fixes and times like this ATL example where the fix loading due to the arrivals themselves (as opposed to competing departures or overflights) was a significant contributor to the problem. Among the worst cases based on departure delays for this category were flights filed over

- ARD into LGA scheduled to arrive from 2200-2300Z
- TONTO into PHX scheduled to arrive from 0300-0400Z
- RBV into EWR scheduled to arrive from 2300-2400Z

Similarly, the worst cases based on airborne delays included flights filed over

- TWINZ into MSP scheduled to arrive from 0200-0300Z
- VTU into LAX scheduled to arrive from 1700-1800Z
- HUSKY into ATL scheduled to arrive from 2000-2100Z.

Delays Associated with Arrival Fixes as a Symptom of Problems Elsewhere in the NAS

As discussed in the previous subsection, the obvious possible cause of the routine delays associated with flights filed over a given arrival fix is an overloading of that fix with arrivals. While our analysis indicated that there were airports where this was indeed occurring, in the majority of the cases the number of filed arrivals into a given arrival fix was too low to be the major contributor to the problem. Thus, in these cases the delays associated with the flights filed into that fix were a symptom of some other problem. In some cases this could still turn out to be a problem associated with the arrival fix, such as competition for the airspace by departures or overflights. However, in many other cases, it is actually a symptom of a problem further upstream in the NAS. For example, if we look at flights filed over LENDY into JFK scheduled to arrive from 0300-0400Z, we find that they regularly experienced significant departure delays. The flights from LAX to JFK, for example, on average experienced a 41-minute departure delay. However, in that one-hour time frame, there were only 2 commercial flights to JFK per day involved. Further analysis revealed that the real bottleneck was a segment of J554 in Cleveland Center that these flights into JFK were filed on. That jet route segment had traffic filed to numerous other destinations that was competing for the airspace and, like the flights into JFK, these other flights were also experiencing significant departure delays. Flights to BOS, SYR and BUF filed on J554, for example, all experienced average departure delays of over an hour.

Airborne Holding

Further insight into the nature and location of specific problems was provided by the use of a data mining algorithm in POET that identifies airborne circular holding. In the Atlanta example, this algorithm provided clear evidence regarding one of the ways the ATC system has been dealing with overloading of the arrival fix. Again using the ATL LOGEN example, flights scheduled to arrive over LOGEN from 2000-2100Z represented one of the most significant cases where holding was used. 40% of the flights scheduled to arrive in this time period over LOGEN were put into holding patterns, resulting in a 49% average increase over the planned air time. More generally, this data miner was used to produce a ranked list for the NAS of all the cases where holding was used, providing an estimate of the frequency of holding for each case and the increase in air time associated with this holding.

Reroutes

Another ATC tactic used to deal with sector loading, arrival fix loading or airport surface movement constraints is to reroute flights. Rerouting could include cornerpost swaps to deal with fix balancing problems, or en route reroutes to deal with an en route sector capacity problem. Another POET data mining tool supports this type of analysis. Overall, we found that approximately 37% of all flights were significantly rerouted in some manner. When looking at the correlation of some of the flight groupings by arrival fix and scheduled arrival hour we found a reasonably high correlation over different times of year indicating that there are some cases where flights are being rerouted on a regular basis.

Use of this data miner also allowed us to rank centers, sectors, or jet routes in terms of the frequency of reroutes. For example, for July 12-18, 1999 we found that over 40% of the flights filed to fly through ZLA, ZMA, ZBW, ZFW, ZHU, ZJX, and ZSE were significantly rerouted. Looking at sectors, we found that flights filing through certain sectors were rerouted as much as 60 – 70% (not necessarily rerouted in these sectors).
We also found that flights filed along certain airways were also heavily rerouted. For example, 84% of the flights filed on J548 were rerouted.

Miles-in-Trail (MIT) Restrictions

Along with holding and reroutes, another traffic management tool to deal with system constraints is to initiate miles-in-trail restrictions. Our analysis of the use of these restrictions indicated that, over the entire data set available for this analysis, 33% of MIT restrictions were imposed because of excess volume, 31% because of weather, 13% because of traffic demand, 8% because of airport arrival rate restrictions, and 15% for other reasons. Furthermore, restriction on arrivals into five airports (ORD, CVG, ATL, DTW and IAD) accounted for nearly half of the uses of MIT restrictions.

We found that on average there were 186 restrictions per day, but this number ranged from 69 to 346. On average 13.5 flights were impacted by each restriction, or in terms of restriction hours we found that on average 8.5 flights were affected for each hour that an MIT restriction was in place.

Diversions

Another symptom of a problem in the NAS is the occurrence of diversions. Our analysis found that on average there were 547 diversions per day, or about 1% of the total traffic. Almost 60% of these diversions can be attributed to general aviation aircraft. For the air carriers we found an average of 109 diversions per day (with a maximum of 219 in 1 day and a minimum of 47).

For approximately 18% of the diverted flights we were able to identify the diversion recovery flight. On average a diversion cost the flight a delay of 136 minutes (79 on the ground and 57 in the air).

2.3 Results Summary - Overall Conclusion

This initial analysis using POET serves to help identify where and when problems are arising in the NAS, and to quantify their impacts. It also begins to provide insight into the nature of these problems, both in terms of the cause (such as the overloading of arrival fixes) and in terms of the type of ATC strategy employed to deal with these problems (such as airborne holding or the use of MIT restrictions). Equally important, this analysis starts to demonstrate the types of large-scale analyses that can be automated using data mining tools in order to develop an even more complete picture of the state of the NAS. In the future a variety of additional data mining tools could be added to POET's current capabilities (such as automatic pattern detectors for cornerpost swaps or for specific types of holding such as no-notice airborne holding), which would provide the capability to do an even more complete large-scale evaluation for identifying and quantifying NAS inefficiencies.

3. ANALYSIS DETAILS

In this section we discuss the details of our analyses and their results. It is divided into five primary sub-sections. In the first section we discuss the data sets that we used in this analysis followed by a discussion of the limitations and caveats that apply to this analysis. The remaining three sub-sections cover our investigations of inefficiencies as indicated by performance metrics, data mining, and detailed analyses.

3.1 Available Data Sets

In conducting these analyses, we have made heavy use of POET and its underlying database that was developed under the FAA's Collaborative Decision Making Program. This database primarily consists of archived ETMS data, provided by the FAA's ATA-200 organization. The ETMS data consists of complete Flight Plan and Flight Amendment information as well as actual track information for every flight that flew in the NAS. The POET database also includes processed information regarding sectors transited, filed versus flown track comparisons, and calculations determining airborne holding.

In addition to the POET database we also had access to log data from the ATCSCC. These data contain information on system restrictions and advisories, including information on Miles in Trail (MIT), ground stops, and ground delay programs (GDPs).

Because the volume of data is quite large (~500-700 MB per day) we had to select a subset that represented a year's worth of NAS activity. The dates within our subset include:

11-25-1998	Day before Thanksgiving (historically the busiest day of the year)
12-25-1998	Christmas day (historically the slowest day of the year)
1-8-1999	Bad winter day (widespread snowstorms, many GDPs)
1-14-1999	An unpredictably bad winter day (snow and icing in Northeast as far south as Richmond, no GDPs, but many ground stops)
5-18-1999	Bad spring day (widespread thunderstorms).

It also includes a week in April (4/24-4/30), September (9/20-9/26), and October (10/5-10/10), as well as the month of July, all in 1999. The week in September is missing two days (9/24 & 9/25) due to data loading errors. In all, our data set encompasses information on 3,408,553 flights. Figure 1 illustrates the extent of our data set and when these flights occurred.

Note that not all of these data were used in each analysis that comprises this study. Individual analyses required different subsets of the larger set depending on the complexity and degree to which the processing could be automated. For most of the analyses we used data from the individual days and the three one-week periods listed above and the week of 7/12/99 – 7/18/99.

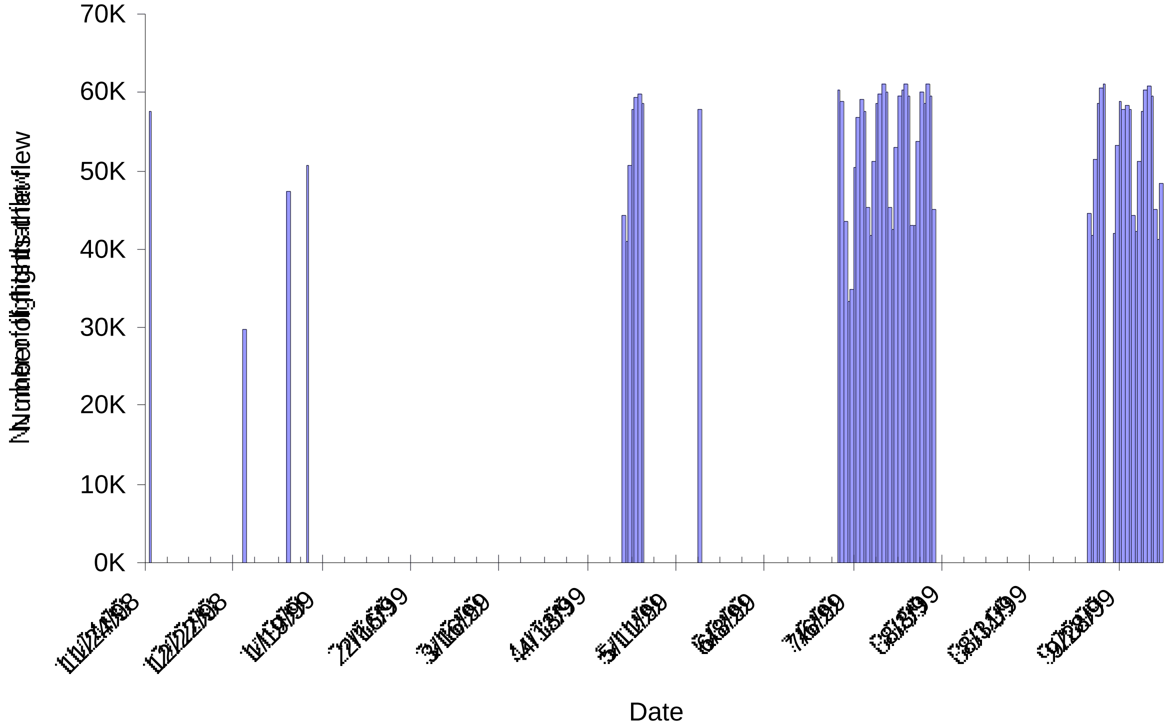


Figure 1: Number of flights that actually flew comprising our data set

To provide a sense of the distribution of the flights studied in this analysis, Table 1 shows a list of the top ten Air Route Traffic Control Centers (ARTCC) in terms of departures and arrivals for July 12-18, 1999.

Table 1: Number of flights by departure/arrival center (top 10)

Depart. Center	Number of Flights	% of Total	Arrival Center	Number of Flights	% of Total
ZTL	21200	7.3%	ZTL	21162	7.3%
ZAU	20654	7.1%	ZAU	20498	7.1%
ZNY	19493	6.7%	ZNY	19658	6.8%
ZDC	19304	6.7%	ZDC	19383	6.7%
ZOB	19156	6.6%	ZOB	19002	6.5%
ZLA	17235	5.9%	ZLA	17425	6.0%
ZID	15485	5.3%	ZID	15189	5.2%
ZMP	15182	5.2%	ZMP	15088	5.2%
ZFW	14563	5.0%	ZFW	14438	5.0%
ZBW	14247	4.9%	ZBW	14059	4.8%

3.2 Limitations and Caveats

Two points should be kept in mind while interpreting the data presented in this report. The first is that we rely on the archived ETMS data provided by the FAA's ATA-200 organization for use with POET. On the whole we have found this to be a very good data source. However, there are several issues to consider:

1. Sometimes bad data makes it into records for individual instances (such as negative times). As part of this analysis, we have developed filters to remove all of these instances that we have identified. It is possible, however, that there could be some cases that we have not yet identified.
2. The airlines are not completely consistent in their reporting of predicted off times. Some airlines really report their planned off times, while others report their planned out times as though they are planned off times. As a result, some of the estimates of average off time and air time delays may be too large by a few minutes. However, in general the values of particular interest in this report tend to be fairly large (e.g., 30-90 minute average off delays) compared to this inaccuracy, so that the major points should still be valid.
3. The ETMS actual departure (DZ) and arrival (AZ) times are not exact wheels off and on times. Previous studies comparing these times with ACARS data provided by the airlines have concluded that the DZ and AZ times are reasonable estimates of the actual take-off and landing time. Specifically, one study[1] showed that DZ times are typically 0–2 minutes after the actual wheels off time, and AZ times are typically between 1–4 minutes after the actual wheels on time.
4. Several of the ARTCCs underwent transition to the new Display System Replacement (DSR) during some of the time periods covered in this analysis. Table 2 lists the DSR transitions that may impact our results. During these transitions restrictions were temporarily put in place to keep the traffic at a more manageable level.
5. POET does not have access to weather data. As a result some of the measures used will include weather impacts. To minimize this confounding, we have looked for data indicative of trends over time, which should tend to highlight routinely occurring events (thus making weather less likely as the primary underlying causative factor). Nevertheless, it is important to consider such potential contributors when interpreting the results presented.
6. Some airlines report planned air times that include padding based on historical data about average delays, while others report unpadded estimates that represent the expected air time if a flight does not encounter any air traffic delays or weather delays while airborne. Hence, the estimates of airborne delays based on a comparison of planned and actual air times could tend to slightly underestimate actual airborne delays.

[1] Mark Klopfenstein, David Cook, and Rose Hsu, "An Initial Look at the Value of Dynamically Contributed Airline Schedule Data to Air Traffic Management," Metron, Inc. August, 1997

Table 2: DSR transitions that potentially affect analysis results

ARTCC	Date of DSR Transition	Analysis dates affected*
ZFW	4/24/99	4/24-4/30
ZAU	4/24/99	4/24-4/30
ZNY	4/29/99	4/29, 4/30, 5/18
ZHU	6/11/99	7/1
ZTL	7/30/99	7/30
ZOA	9/15/99	9/20-9/26
ZAB	10/2/99	10/5-10/10

* Based on nominal three week transition period

3.3 Inefficiencies as Indicated by Performance Metrics

As discussed above, there were three primary types of performance metrics available: planned and actual departure (off) times, air times, and arrival (on) times. Since the on times are determined by the combination of off and air times, our analysis focused on these latter two measures.

To begin our evaluation, we developed ranked lists based on the performances of flights into the arrival fixes at different airports at different times of day. This initial analysis focused on domestic commercial flights.

Delays in Off Times

To begin our analysis, inefficiencies indicated by delays in off times and air times were organized in terms of flights filed into the different arrival fixes at each airport in specific one-hour periods. This aggregation was selected because it starts to characterize problems in terms of bottlenecks that are associated with particular locations (arrival fixes) and times.

As an example, Table 3 lists the worst average off times (as measured by the differences in minutes between planned and actual off times), averaged across the one week period of July 12-18, 1999. The groupings are flights scheduled into a particular airport (such as DTW) that were filed over a given arrival fix (such as POLAR) and were scheduled to arrive at that destination in a specific one hour time period (such as 1400-1500Z). In this table, an arrival fix of <null> simply indicates that ETMS software does not identify arrival fixes for that airport (the FAA software only identifies planned and actual arrival fixes for major airports). In addition, only groupings with a minimum average of 7 flights over the 7 days were included. (Appendix A shows similar results for all of the time periods studied.)

Table 3: Worst Off Time Performances for July 12th - July 18th, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Departure Delay (mins)
DTW	1400	POLAR	8	91.1
MFE	2000	<null>	7	64
MCO	2200	MINEE	8	60
LAX	0100	RIFFT	11	58.8
SJC	0300	HYP	9	55.7
DTW	2300	SPICA	11	55.2
MEM	1100	WLDER	12	53.8
HRL	2100	<null>	12	52.6
PDX	1100	BONVL	7	52.4
SEA	0200	JAKSN	27	52.3
BUF	1000	<null>	8	52
MKE	1000	<null>	12	50.9
MCI	1000	TYGER	20	50.7
SEA	0400	JAKSN	12	49.9
DTW	0100	POLAR	8	49.5
ABY	2200	<null>	7	49.1
JAN	1500	<null>	12	48.8
MYR	1900	<null>	12	47.9
BFI	1100	<null>	10	47.7
MSP	1000	ZIBBY	7	47.6
MLI	0300	<null>	7	46.9
SNA	0200	<null>	35	46.5
TJSJ	0100	<null>	10	46.5
SGF	1000	<null>	10	46.1
CLE	2300	CXR	16	46
BWI	2300	CSN	12	45.8
SJC	0300	HYP	13	45.6
CRP	2000	<null>	7	45.6
MHT	1000	<null>	9	45.4
CYYZ	0100	LINNG	10	45.3
FNT	2100	<null>	7	45.3
DET	2200	<null>	10	45.2
LGA	2200	ARD	83	45.1

Note that for the groupings shown in Table 3, the worst case is DTW from 1400-1500Z, with an average difference between actual and planned off times of 91 minutes, averaged over 8 flights. Note also that there are considerable differences among the numbers of flights per grouping. This worst case at DTW has only 8 flights over the 7 days, while the last grouping listed (flights into LGA over ARD from 2200-2300Z) has 83 flights, with an average difference between actual and planned off times of 45 minutes. The 83 flights into LGA over ARD suggest that, for that grouping, these scheduled arrivals by themselves may be a major contributor to the bottleneck at LGA through ARD at that time of day. By contrast, it is unlikely that the 7 flights arriving at PDX through BONVL from 1100-1200 over a week period (1 flight per day) are a significant contributor to delay. Rather, those flights are probably experiencing a delay because of a bottleneck that is due to something other than arrivals into PDX through BONVL (such as a congested en route sector along the filed route or high demand or complexity in the arrival sector into PDX due to competing departures or overflights).

Table 4 shows (for the top 10 groupings) how this metric (number of flights scheduled to arrive at the same fix in the same time period) can be used to identify fixes with heavy arrival loads that have associated long off time delays. (Similar data is provided for all of the full–week time periods in Appendix B.)

Table 4: Worst Off Time Performances for July 12th – July 18th 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations for Flights with >= 48 Flights

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Departure Delay (mins)
LGA	2200	ARD	83	45.1
PHX	0300	TONTO	65	39.1
EWR	2300	RBV	70	38.9
SFO	0300	CEDES	54	36.6
LGA	2100	ARD	86	36.5
ORD	2100	PLANO	75	35.8
SFO	1800	SKUNK	53	35.4
SFO	1700	SKUNK	56	35.2
IAH	2100	DAS2	79	34.5
SFO	0200	CEDES	52	34.5

Departure delays associated with ground delay programs

As part of our investigation of departure delays, we focused on departure delays associated with ground delay programs. For this, we looked at flights departing other airports whose scheduled arrival time coincided with a GDP being run at their destination. Table 5 summarizes our findings for the one-week period in July. In this table, we see that average departure delays varied from 40 minutes to just over two hours, with delays of 40-50 minutes being typical. For the one GDP run at ORD on 7/17/99, the delays were more than twice this average. At that time, about 4:00 PM local time, thunderstorms were blocking departure routes to the East, severely restricting departures to the East Coast.

In comparing Table 5 with Table 4 we see that delays due to GDPs may have contributed to many of the worst cases of departure delays on some days. For example, on 7/7/1999 there was a GDP at LGA in effect during the 2200 hour, which would have impacted the flights scheduled to arrive LGA during that hour over ARD. In fact, GDPs impact six of the ten entries in Table 4 on at least one of the days in the week period. This gives addition evidence to the idea that the cases listed in Table 4 are problems in the terminal environment.

Table 5: Ground Delay Programs between 7-12-99 and 7-18-1999

			Departure Delay (mins)	
Airport	Date	Time of GDP	Average	Stand Dev
PHX	7-15-1999	1430-1655	0:47	0:43
SFO	7-16-1999	1600-1946	0:51	0:33
SFO	7-17-1999	1600-1730	0:49	0:43
SFO	7-18-1999	1600-1715	0:40	0:29
EWR	7-17-1999	2000-2351	1:00	0:45
EWR	7-18-1999	1830-0059	0:46	0:27
LGA	7-17-1999	1830-0059	0:52	0:37
ORD	7-17-1999	2100-2320	2:01	2:51

Delays Associated with Air Times

Table 6 provides similar results for air times for the same one-week period in July, 1999. In this case, the groupings are ordered by worst average performances as indicated by the airborne delay (actual – planned air time) as a percentage of the planned air time. Note, to prevent distortion of the severity of the delay in terms of percentage of planned air time (e.g., 5 minutes delay is 50% of a 10 min flight) we only list those cases where the airborne delay was 10 minutes or more. For flights into DEN via RAMMS from 2200-2300Z, for example, the average difference between actual and planned air times (19 minutes) was 84% greater than the average planned air time (23 minutes). Appendix D has similar tables for the air times for each of the time periods included in this analysis.

Table 6: Worst Air Time Performances for July 12-18, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations (Minimum of 7 flights)

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Air Time (mins.)	Actual Air Time (mins.)	Difference (Actual - Planned) in mins.	Percent Air Time Increase (Difference/Planned)
DEN	2200	RAMMS	7	22.7	41.9	19.1	84.3%
BNA	0000	GUITR	10	51.1	92.2	41.1	80.4%
BFL	2100	<null>	7	23.1	36.3	13.1	56.8%
LAX	0200	VTU	27	32.1	50.1	18	56.2%
EUG	1600	<null>	7	22.4	33.4	11	49.0%
YKM	1700	<null>	7	22.4	33.3	10.9	48.4%
BFL	1400	<null>	7	22.7	33.7	11	48.4%
YKM	1500	<null>	7	22.4	33.1	10.7	47.8%
PDX	0100	HARZL	7	25.9	38.1	12.3	47.5%
MDT	0000	<null>	8	29.9	43.6	13.8	46.0%
LAX	1300	VTU	27	26.3	38.3	12	45.5%
LBB	1800	<null>	7	43.1	62.7	19.6	45.4%
MSP	1200	SHONN	17	38.7	56.1	17.4	45.0%
LAX	2200	VTU	45	32.6	46.5	13.8	42.3%
ATL	0100	DALAS	7	28	39.9	11.9	42.3%
PDX	1800	HELNS	7	27.1	38.4	11.3	41.6%
MGM	2200	<null>	8	26	36.8	10.8	41.3%
MSP	1500	OLLEE	25	50.2	70.1	20	39.8%
RKD	1800	<null>	7	38	53.1	15.1	39.8%
PDX	1700	HARZL	7	26.3	36.7	10.4	39.7%
PDX	2100	HELNS	7	27.1	37.9	10.7	39.5%
MSP	1100	TWINZ	21	47.1	65.5	18.4	39.0%
PDX	1200	HARZL	7	26.1	36.3	10.1	38.8%
APF	2100	<null>	7	26.6	36.7	10.1	38.2%
RSW	1200	<null>	8	27.1	37.1	10	36.9%
PSP	0100	<null>	11	36.8	50.4	13.5	36.8%
MSP	0200	TWINZ	60	58.1	79	20.9	36.0%

Table 7 shows (for the top 10 groupings) how our secondary metric (the number of flights scheduled to arrive at the same fix in the same time period) can be used in combination with this measure of airborne delay to identify fixes where heavy arrival loads may be a major contributing factor to the airborne delays. (Similar data is provided in Appendix E for air times for all of the studied one-week time periods.)

Table 7: Worst Air Time Performances for July 12-18, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations for Flights with >= 48 Flights

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Air Time (Z)	Actual Air Time (Z)	Difference (Actual - Planned Air Time) in minutes and %	
MSP	0200	TWINZ	60	58.1	79	20.9	36.0%
MSP	0200	ZIBBY	71	59.5	78.9	19.4	32.6%
MSP	2200	ZIBBY	73	64	83.1	19.1	29.9%
ATL	2000	HUSKY	147	62.4	80.6	18.1	29.1%
ATL	2000	TIROE	144	66.2	85	18.8	28.5%
MSP	2200	OLLEE	94	76.1	97.1	21	27.7%
ATL	2000	LOGEN	134	78.8	100.6	21.8	27.6%
LAX	2100	VTU	53	38.9	49.6	10.7	27.5%
LAX	1400	VTU	70	41.7	52.5	10.8	25.9%
CYYZ	2200	LINNG	62	64.8	80.9	16.2	25.0%

Table 3 through Table 7, along with those in Appendices A-D serve as a starting point to discover where and when we have bottlenecks in the NAS associated with flights filed into particular arrival fixes. For groupings such as flights filed over HUSKY and TIROE into ATL in the 2000-2100Z time period (see Table 7), these data suggest that a major contributor to the observed delays could be the large number of filings into that arrival fix in that time period, and that this heavy loading of the arrival fix can impact off times and air times. For other groupings such as the flights filed through RAMMS to DEN from 2200-2300Z (the worst case for the average delay in air time) the number of flights (7) is too small to account for the bottleneck. Thus the problem must be due to some other factor, such as departures and over-flights near that arrival sector, or some bottleneck elsewhere in the NAS. More detailed analyses are therefore needed to understand the nature and location of the problems. These are provided in later sections. Note that although we are looking at repeated patterns over time to look for evidence of routine bottlenecks due to air traffic congestion, it is also possible that some of the identified groupings could be due to repeated weather delays as well.

Consistency Across Time Periods

Before looking at more detailed analyses, it is useful to look at the consistency of these off time and air time results over time. To address that question we computed the Spearman's rank order correlation coefficients to determine the extent to which airborne delays and off time delays occur consistently in terms of the scheduled arrival fix and the time of day.

For airborne delays, there was a very high consistency in the ranking of arrival fix/time of day groupings across times of the year (meaning that those fixes with large average air time delays for one of the one-week periods studied tended to have large average air time delays for all of the one-week periods studied). This is indicated by the rank order correlations (Spearman Rho) in the Table 8 between each of the one-week periods studied in the different months. All of the correlations are statistically significant at $p<0.01$. Indeed these correlations are remarkably high given the known variations among these weeks (seasonal differences in traffic patterns, the DSR transition, seasonal weather differences, etc.). The results appear to indicate that bottlenecks leading to some type of airborne delay arise fairly consistently at particular points and times of day in the NAS.

Table 8: Rank Order Correlations Across Different Times of the Year

Month	Month	Spearman Rho
April	July	0.7213
April	Sept.	0.7395
April	Oct.	0.8244
July	Sept.	0.7756
July	Oct.	0.7838
Sept.	Oct.	0.8366

Interestingly, there are no such high correlations over time of year for the off time delays. For the combinations of the one-week time periods, these correlations range from only 0.1357 to 0.3707. (They are all, however, still statistically significant at $p<0.05$.)

The consistency of airborne delays over time is further illustrated by Table 9. This shows the airborne delays or Delays En route (DE) for the different scheduled arrival fixes during specific one-hour periods. For flights filed over VTU into LAX from 1200-0100Z, for example, the airborne delays averaged 76% greater than the planned air times for April, 63% for September, and 86% for October. (July is not listed as we only looked cases with average airborne delays greater than or equal to 10 minutes.) These delays put VTU from 1200-0100Z in greater than the 99th percentile for airborne delays in April, September and October.

Table 9: Consistency of airborne delays over different times of the year

Arrival Airport	Sched Arrival Hour	Arrival Fix	Airborne Delay (%)				Percent Rank				Average Percent Rank
			Apr	Jul	Sep	Oct	Apr	Jul	Sep	Oct	
LAX	12:00	VTU	75.9		63.4	86.0	100.0		100.0	99.6	99.9
MSP	12:00	SHONN		45.0	47.5	55.1		95.9	97.5	98.8	97.4
YKM	17:00	<null>	43.3	48.4		48.4	93.8	97.9		97.7	96.5
LAX	17:00	VTU	43.4		51.5	41.9	94.3		99.5	95.1	96.3
LAX	13:00	VTU		45.5	40.5	42.7		96.5	96.6	95.5	96.2
MSP	11:00	TWINZ		39.0	47.7	43.4		92.5	98.0	96.6	95.7
MSP	0:00	OLLEE		33.3	39.8	87.6		87.7	95.6	100.0	94.4
MDT	0:00	<null>	61.5	46.0		33.0	99.4	96.9		86.8	94.4
MSP	12:00	OLLEE		31.7	48.0	49.7		84.0	99.0	98.1	93.7
LAX	2:00	VTU	45.4	56.2	36.2	33.1	95.8	98.9	91.7	87.6	93.5
LAX	22:00	VTU	40.4	42.3	32.5	42.9	91.2	94.8	88.8	95.8	92.7
LAX	20:00	VTU	31.4	35.0	47.9	41.8	80.4	89.4	98.5	94.7	90.8
PSP	1:00	<null>	34.9	36.8	33.2	33.0	86.0	91.1	90.2	86.8	88.5
LAX	3:00	VTU		30.8	36.4	31.6		83.6	92.7	85.3	87.2
LAX	1:00	VTU	30.8	32.1	36.3	40.0	77.8	85.0	92.2	93.6	87.2
LAX	15:00	VTU		28.9	32.6	34.2		80.9	89.3	88.7	86.3
MCO	17:00	MINEE	35.8	32.1	31.8	32.2	86.5	85.0	87.3	85.7	86.1
PSP	2:00	<null>		28.8	33.3	32.9		80.2	90.7	86.5	85.8
LAX	16:00	VTU	55.4		30.9	23.9	98.9		86.8	71.1	85.6
CLT	1:00	CTF	45.9	22.4	40.6		96.9	62.2	97.0		85.4

Inefficiencies as Indicated by Performance Metrics – Summary

The analyses above begins to indicate where and when inefficiencies arise in the NAS as reflected in off time and air time delays. We have categorized these delays in terms of their association with specific arrival fixes and times of day, as this helps to start understanding where and how often these delays arise and how significant they are. Given the high correlations over the different times of year for airborne delays, these data suggest that there are certain places and times in the NAS where there are routinely arising bottlenecks. For those arrival fix/time combinations that had large numbers of flights (scheduled arrivals) as indicated in Appendices B and D, the data further suggest that the location of the bottleneck is likely to be in the vicinity of the arrival airport, the arrival fix, or a jet route near the arrival fix that these flights share. More detailed analyses follow, which help to further localize and understand the nature of these bottlenecks in the system.

3.4 Inefficiencies as Detected by Data Mining Tools

The high level analysis described above provides an initial indication of where there are significant departure and/or airborne delays in the NAS. The next question we addressed is the nature and frequency of deviations of the actual route from the filed route which can be the result of air traffic initiatives that are being implemented to deal with congestion at these bottlenecks. These initiatives can be traffic flow management programs (such as the use of miles-in-trail or ground delay programs) or more tactical air traffic control responses such as the use of airborne holding.

Airborne Holding

While the statistics based on off times and air times discussed above are useful for indicating that bottlenecks exist, they do not provide much insight into the nature of the problem. We therefore developed a collection of data mining algorithms to detect and characterize certain types of deviations of the actual route from the filed route. In some cases it is possible to provide a more definitive description of the route deviations encountered by a flight. One such example is provided by our data miner for detecting circular airborne holding. This algorithm is designed to detect instances where a flight has been put into circular holding, either near an arrival fix or while en route (the latter often referred to as “no-notice high altitude holding). For this analysis, the data miner is not designed to determine whether the holding occurred while en route or near an arrival fix, as that was outside of the scope of this study. In the future, however, that determination could be added to this type of analysis. We have however, evaluated the performance of the holding data miner against data that is manually recorded at Atlanta Center for all flights into Atlanta. A comparison of these data from Atlanta Center with the performance of our algorithm indicated that it correctly identified 83% of the occurrences of circular holding with zero false alarms. Thus, the statistics provided below are likely to slightly underestimate the occurrences of holding.

Table 10 shows the 10 arrival fixes with the highest percentage of flights held in a one hour period for July 12-18, 1999. For flights over DAS2 into IAH, for example, 64% of the flights scheduled to arrive between 2000-2100Z were held. For these flights over DAS2, those that were held had an average increased air time that was 34% greater than the planned air time (those that were not held had an average increase in air time of only 2% for this case). Appendix E contains similar results for all of the one-week periods studied.

Table 10: Arrival fix/time of day combinations that were most often held in the air (7/12/99-7/18/99)

ARR_APRT	Sch_ArrBin	ARRIVAL_FIX	Num Held	Total	% Held	Avg_PairTime-held	Avg_AairTime-Held	Airtime_Delay-Held	Airtime_Delay_%-Held
IAH	20:00	DAS2	14	22	63.6%	100	134	34	34.0%
ATL	1:00	DALAS	4	8	50.0%	80	106	26	32.5%
ATL	20:00	LOGEN	54	135	40.0%	77	115	38	49.4%
MSP	2:00	TWINZ	8	21	38.1%	107	177	70	65.4%
CLE	15:00	KEATN	21	57	36.8%	66	91	25	37.9%
SEA	18:00	JAWBN	7	21	33.3%	196	206	10	5.1%
IAH	19:00	DAS2	32	97	33.0%	135	169	34	25.2%
ATL	20:00	TIROE	46	145	31.7%	70	107	37	52.9%
ATL	13:00	DALAS	40	130	30.8%	84	108	24	28.6%
ATL	13:00	HUSKY	24	78	30.8%	70	97	27	38.6%

Use of the Spearman rank order correlation indicates a moderate consistency in the use of holding for flights scheduled to arrive through the different arrival fixes in the one-hour periods. This is indicated in Table 11, where all of the correlations (Spearman Rho) are modest, but still statistically significant at $p<0.01$. -

Table 11: Spearman rank order correlation coefficients for percent holding during the four one week periods studied

Month	Month	Spearman Rho
April	July	0.4029
April	Sept.	0.3855
April	Oct.	0.3580
July	Sept.	0.3694
July	Oct.	0.3601
Sept.	Oct.	0.3087

To get a more detailed sense of what is happening with holding, we completed a more detailed case study of flights into ATL from 2000-2100Z over the period April 24-30, 1999. This airport was selected because ATL is one of the airports that most consistently uses airborne holding as an air traffic control tactic. In April, for example, for the 4 arrival fixes, LOGEN shows a higher percentage of flights with holding from 2000-2100Z than any other arrival fix in the country for a one hour period. DALAS into ATL is the second highest, HUSKY into ATL is the third and TIROE into ATL is the fifth highest.

If we use POET to look at flights scheduled to arrive at ATL from 2000-2100Z during the week of April 24-30, 1999, we find that there were 656 flights and that the actual air times were on average 28% greater than planned. This is shown in Figure 2, along with a scatter chart showing the differences between actual and planned air times as a function of the date for all 656 flights.

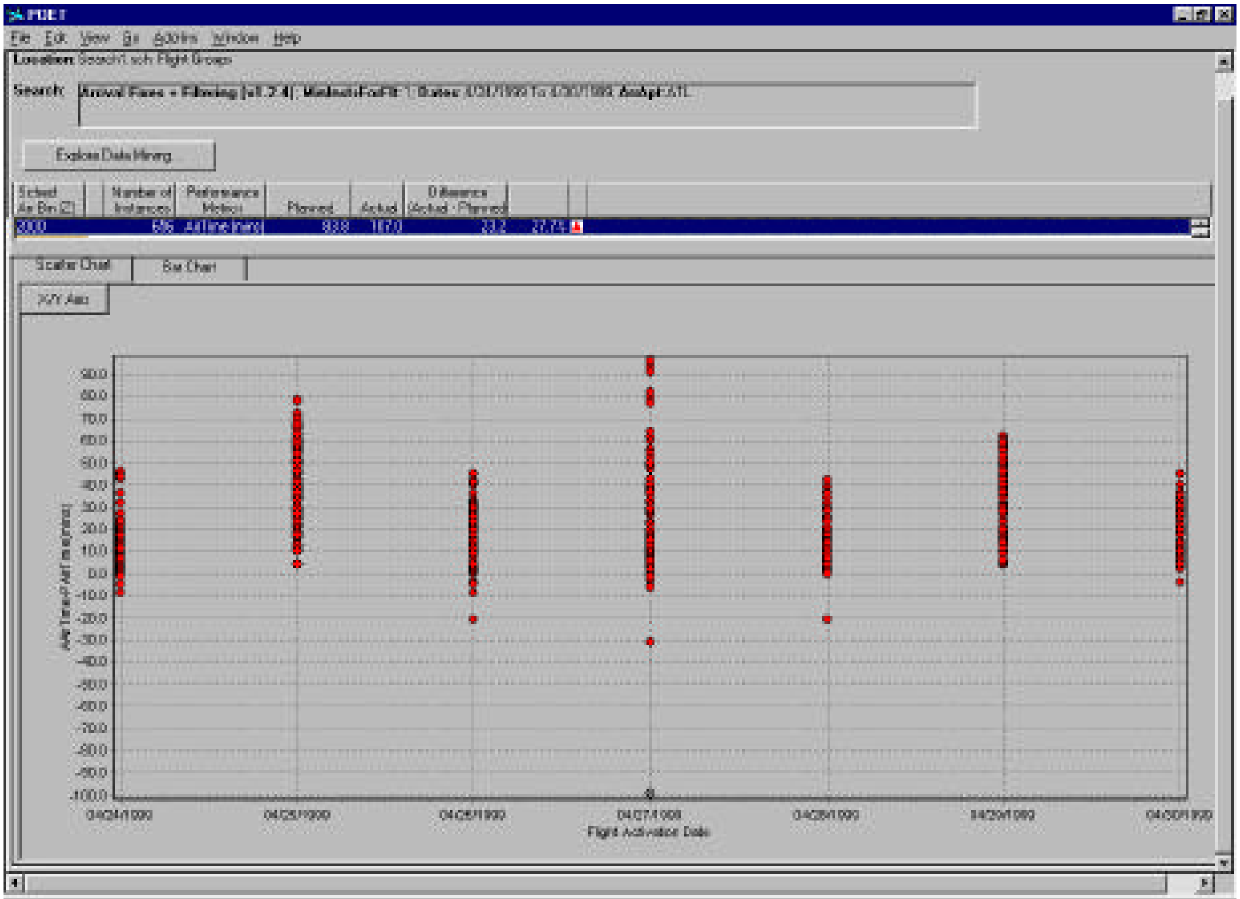


Figure 2: Flights Scheduled to Arrive at ATL from 2000-2100Z During the Week of April 24-30, 1999. (The scatter chart shows the differences between actual and planned air times as a function of date.)

Figure 3 shows a breakdown of the 656 flights in terms of their filed arrival fixes. LOGEN, for instance, has 169 flights filed for arrival from 2000-2100Z.

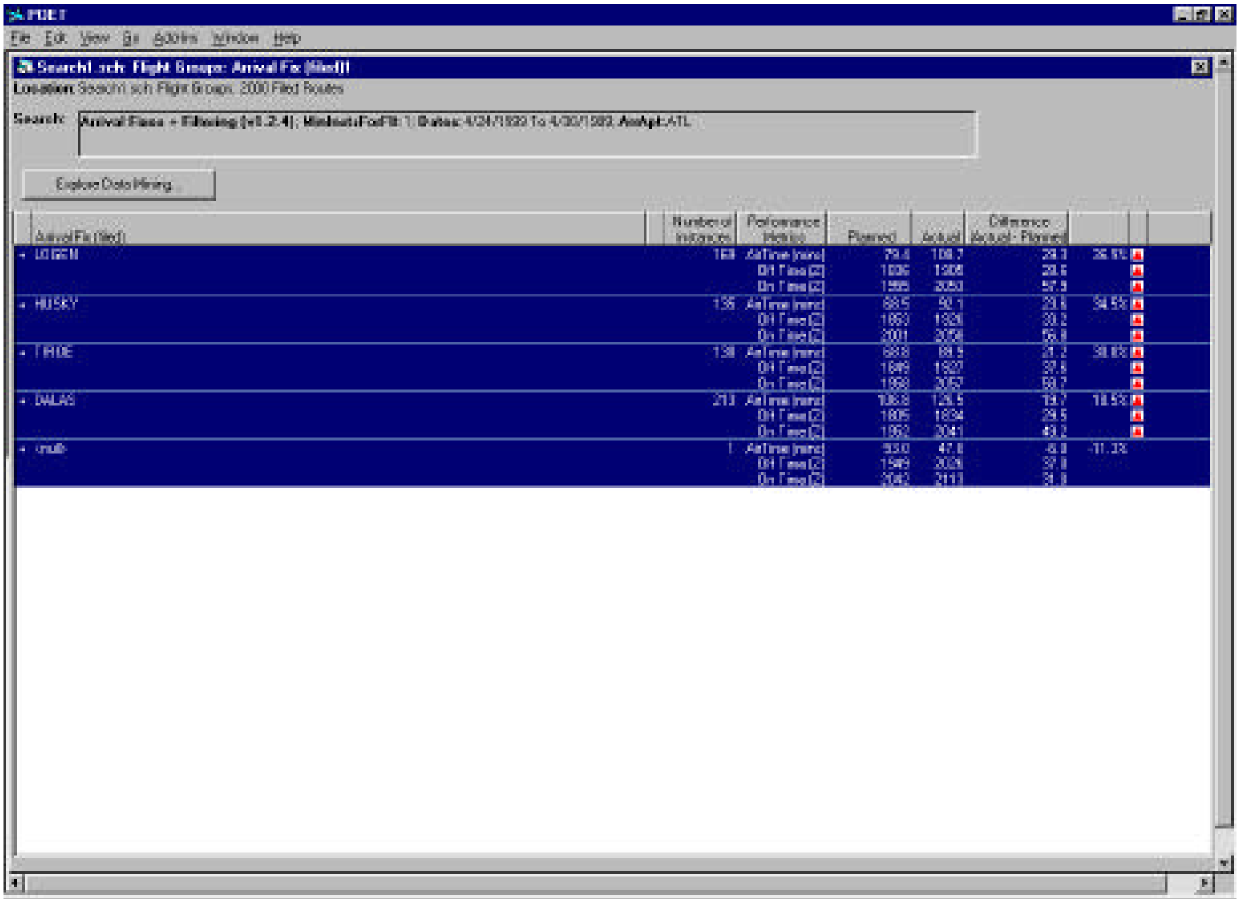


Figure 3: Flights Filed into Different Arrival Fixes at ATL

Figure 4 shows a map of all of the filed routes into ATL through all 4 arrival fixes for this time period.

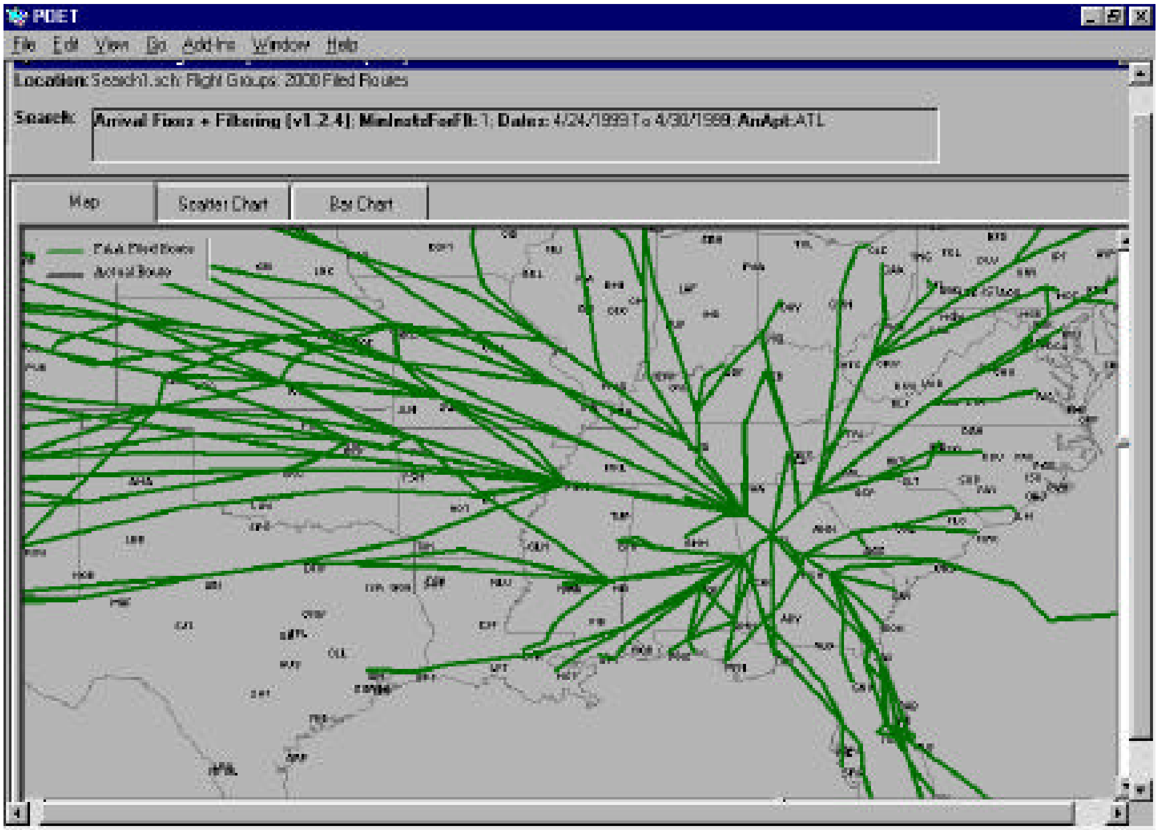


Figure 4: Routes Filed into ATL through all 4 Arrival Fixes

Figure 5 shows the filed routes (the lighter gray lines) vs. actual routes (the black lines) for flights filed into HUSKY.

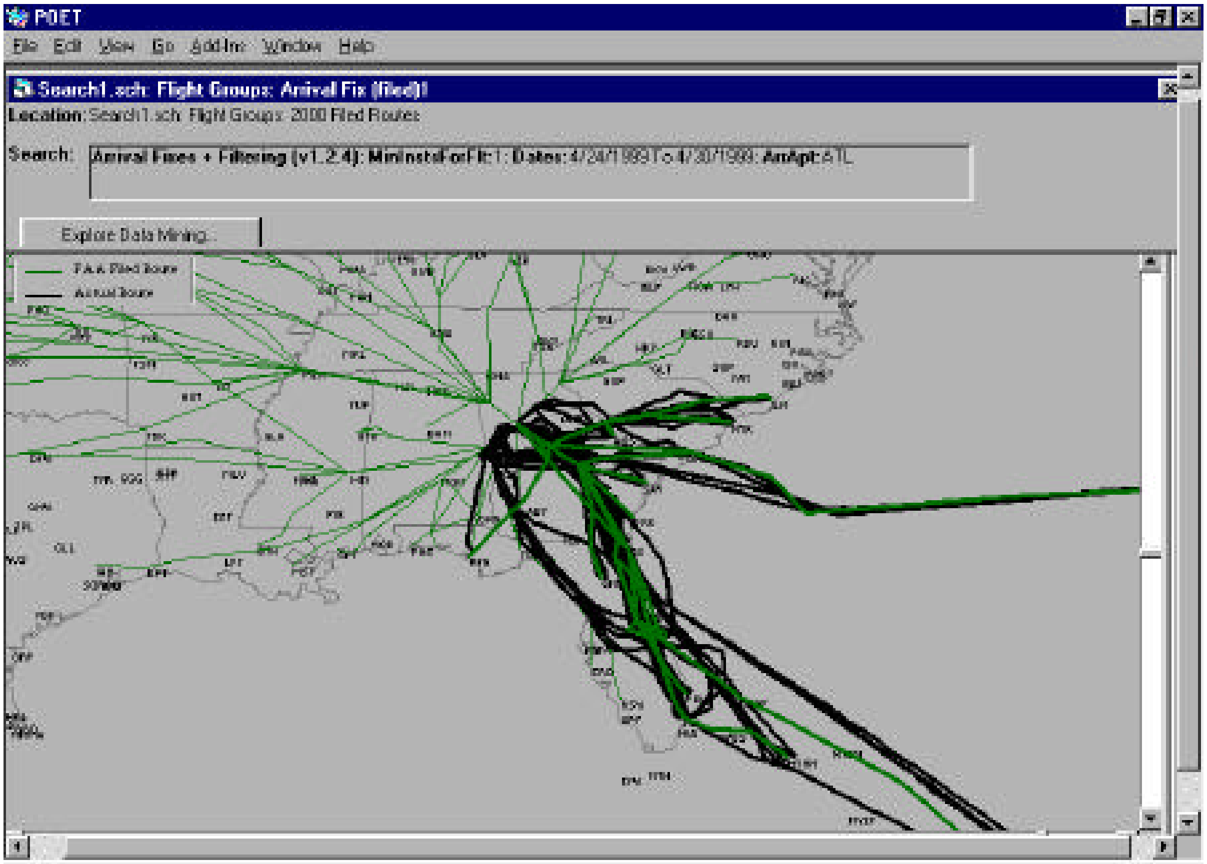


Figure 5: Filed and Actual Routes for Flights Filed Over HUSKY

Figure 6 shows the filed routes (light gray lines) and actual routes (black lines) for flights filed over DALAS into ATL.

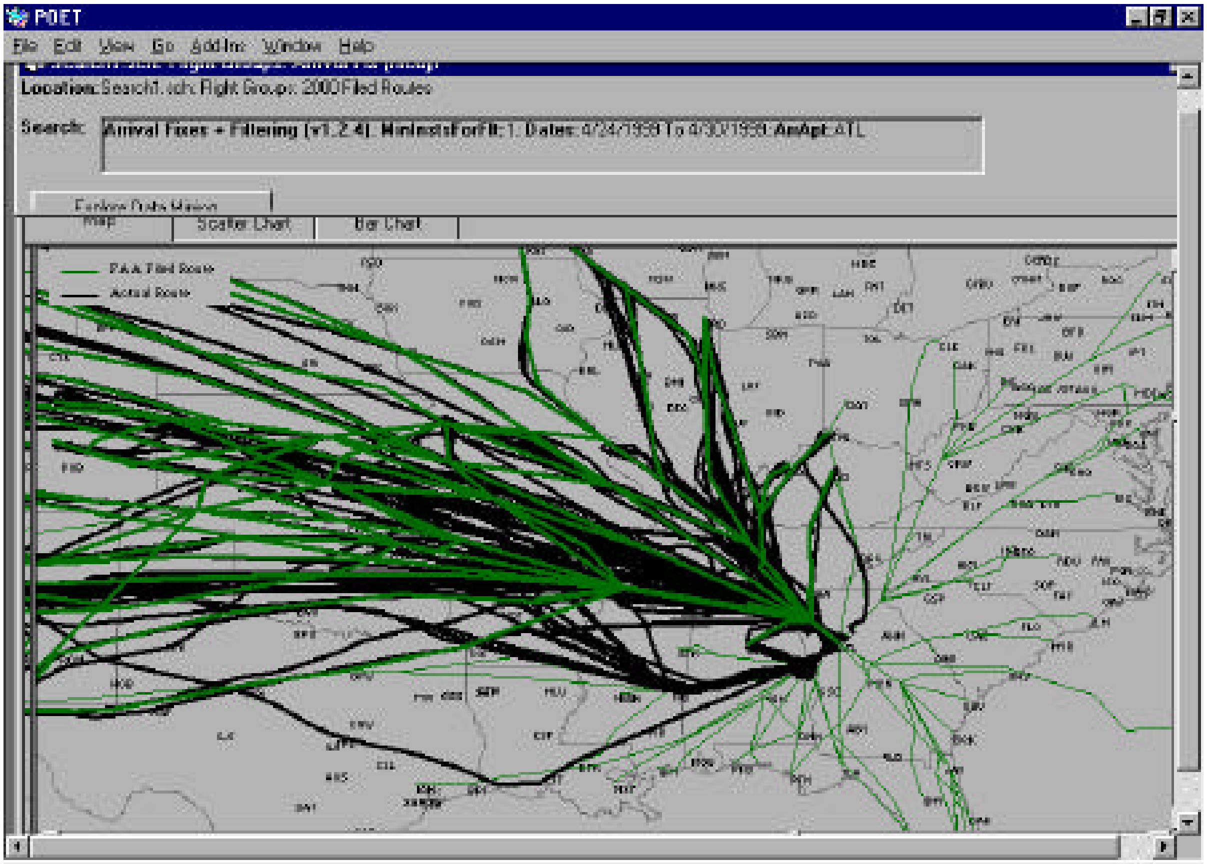


Figure 6: Filed and Actual Routes for Flights Filed Over DALAS

Figure 7 shows the same information as Figure 6 for flights filed over TIROE.

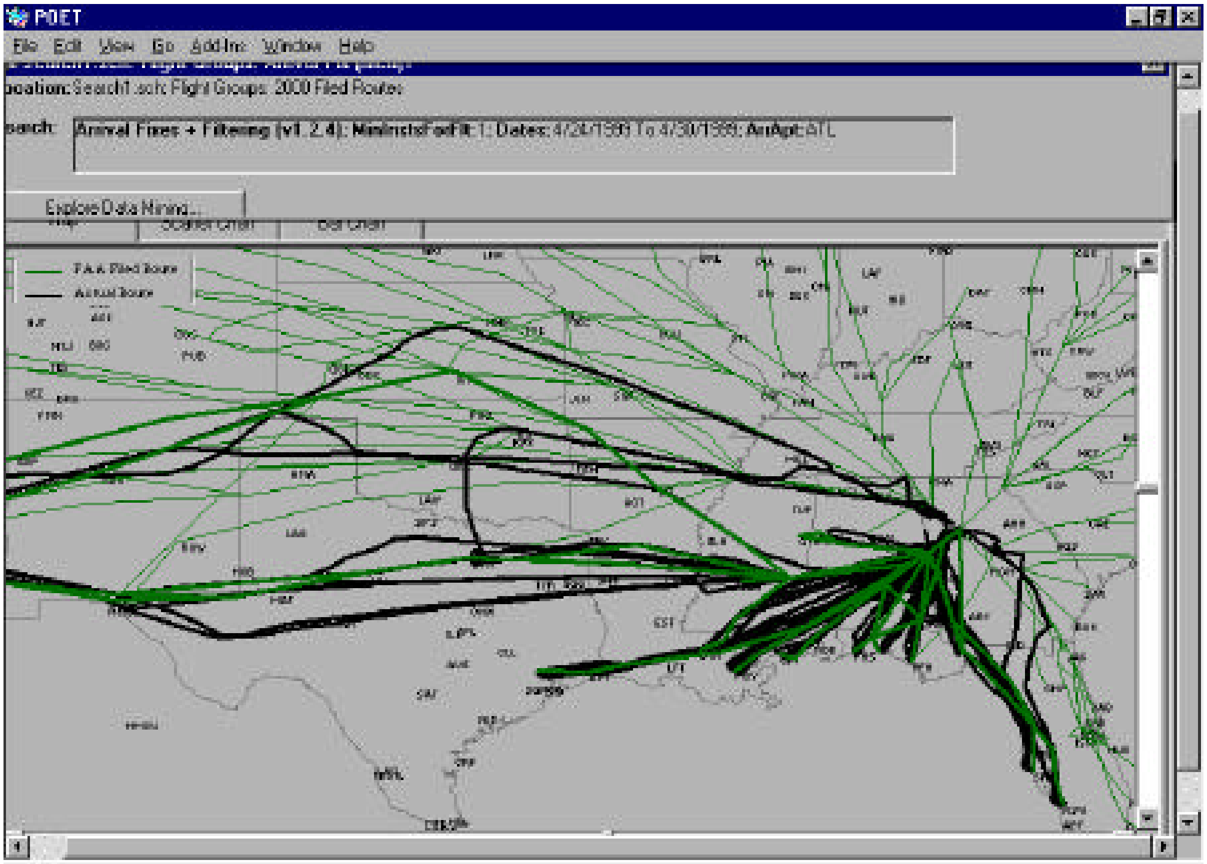


Figure 7: Filed and Actual Routes for Flights Filed Over TIROE

Finally, Figure 8 shows the routes filed (light gray lines) and routes actually flown (black lines) for the flights filed over LOGEN.

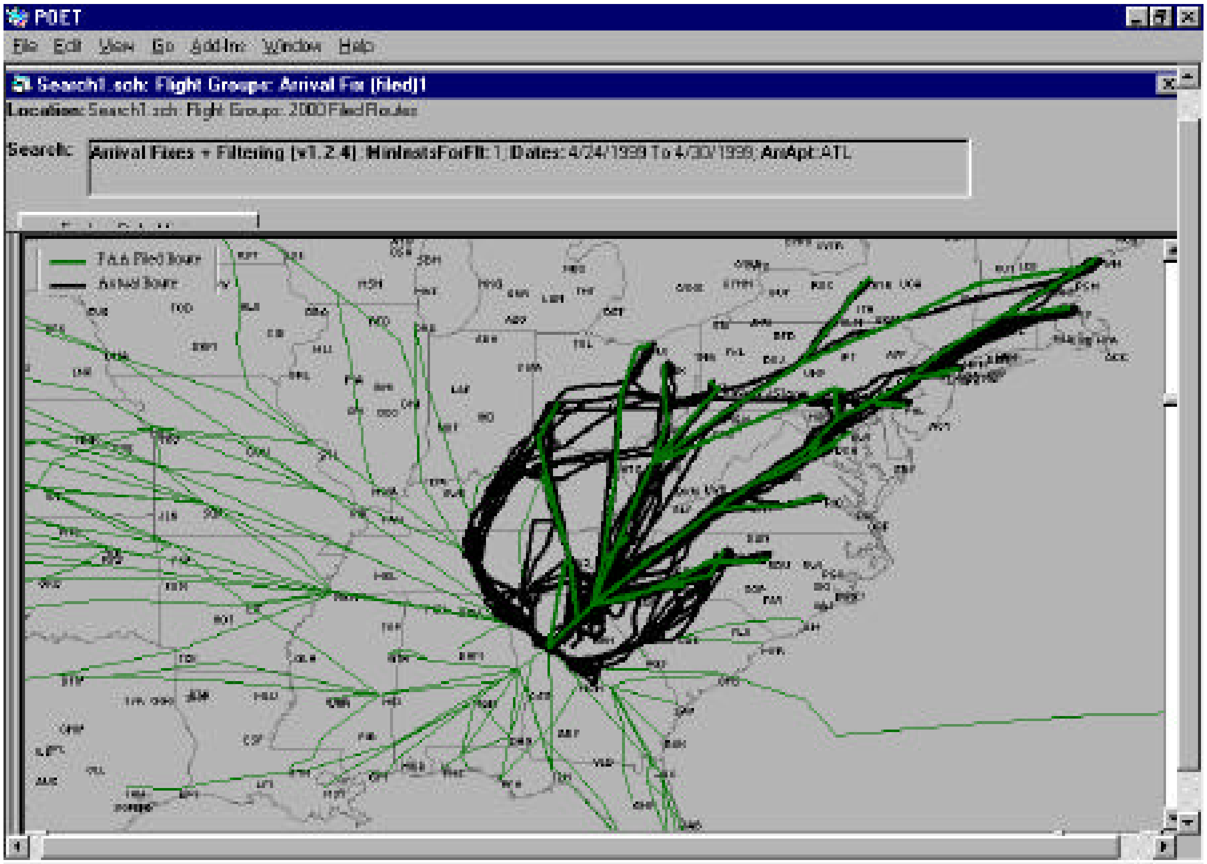


Figure 8: Filed and Actual Routes for Flights Filed Over LOGEN

To provide a more detailed sense of what is happening, Figure 9 provides statistics on some individual flights into LOGEN.

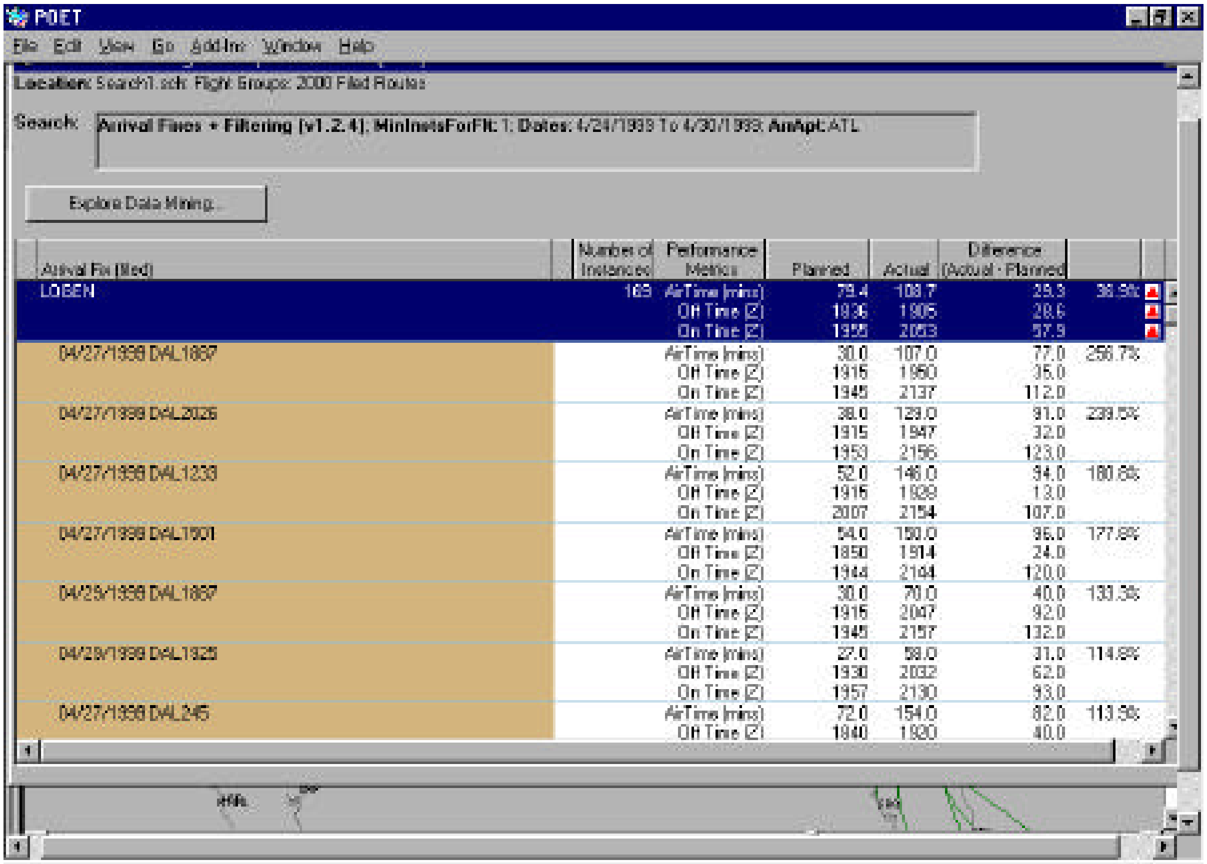


Figure 9: Data on Some Individual Flights into LOGEN

Finally, Figure 10 provides statistics on the 82 flights filed over LOGEN that were held. (Note that some of them are swapped to other cornerposts as well. (The black lines are the flights filed into LOGEN that were put in holding patterns.

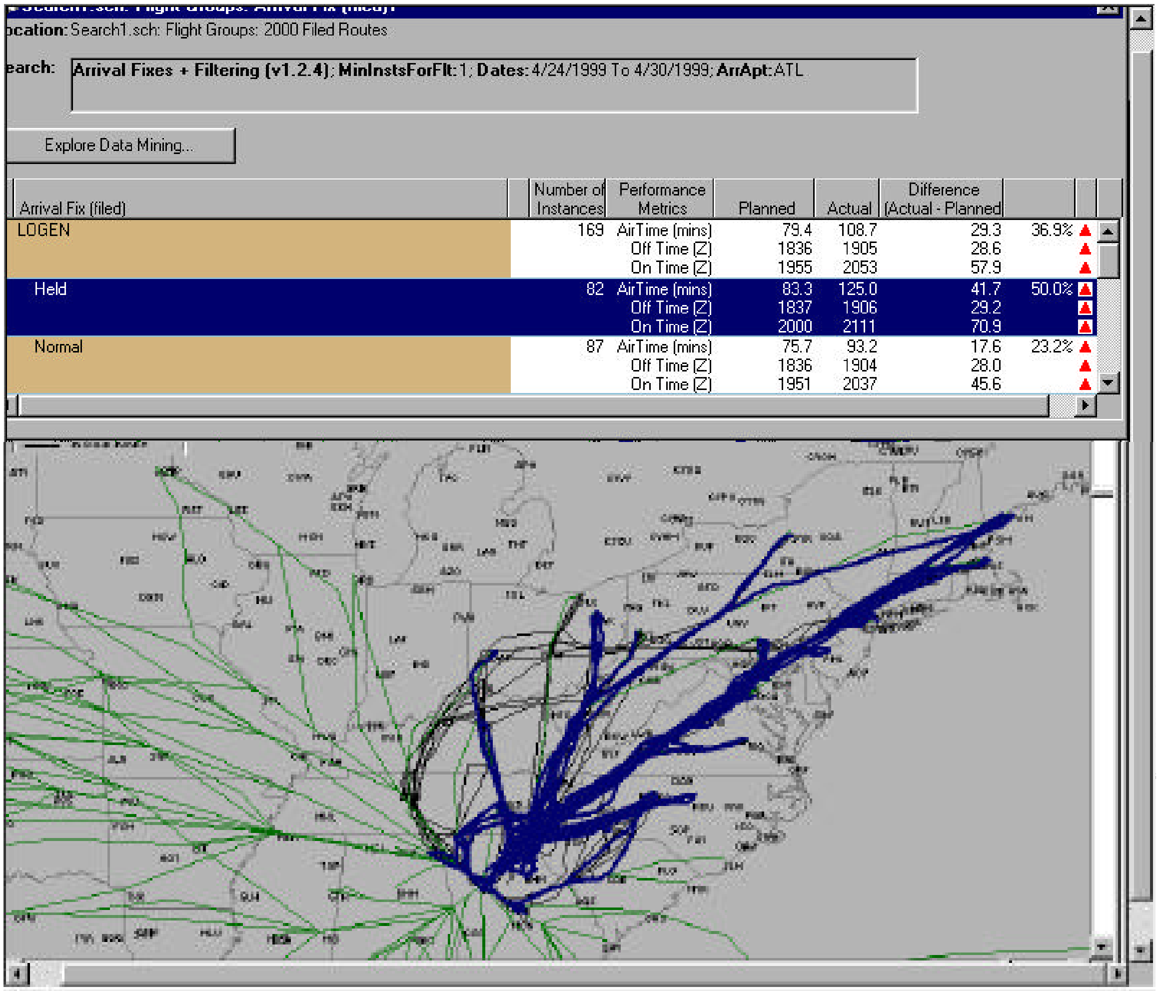


Figure 10: Flights Over LOGEN that were Held

In summary, use of the data miner for holding makes it clear that a significant contributor to airborne delays at some airports is the use of circular holding, with ATL serving as the most pronounced example. POET makes it easy to identify and quantify the use of this ATC tactic in terms of location, time, frequency, and impact on air times.

Significant Reroutes

In this section we identify the flights that were significantly rerouted and then examine the rerouted flights as a function of various parameters including time of year, time of day, and different types of airspace elements. Except where noted, these analyses were performed using the entire data set available to us.

Identifying Significant Reroutes

During a flight there are many actions that can cause it to deviate from its filed flight plan. These include reroutes, vectoring, changing speed, changing altitude, holding, etc. To determine which flights were significantly rerouted from their filed flight plans we used an algorithmic approach developed in a previous study.[2]

In this approach we algorithmically compare the track length and the spatial similarity of the proposed flight track in the filed flight plan with the actual track for each flight. By doing both of these comparisons we can detect flights that are significantly rerouted and begin to understand the nature of the deviation. For example, flights that fly roughly along their planned routes (spatially similar), but end up flying a much longer distance were likely vectored or held along the planned route. Another example is a flight with an actual track shorter than its planned route that is also spatially dissimilar. In this case, the flight likely received some sort of direct routing which depending on the situation may not always be considered beneficial (e.g. if it negatively impact different sectors).

To compare the track lengths we computed the sum of the distance between each waypoint in the proposed flight track and, similarly, the sum of the distance between each position report that comprises the actual track. We then grouped the flights into four categories of track-length similarity:

- short—actual track more than 5% shorter than proposed track
- same—actual track within ± 5% of the proposed track
- long—actual track between 5-15% longer than proposed track
- longer—actual track more than 15% longer than proposed track

Next we calculated the spatial similarity of the proposed flight track with that actually flown using Metron's Spatial Similarity Algorithm (SSA). The SSA quantifies the degree of similarity between two ground tracks with the same starting and ending points, but different intermediate points. It returns a small number for tracks that are very similar and a large number for tracks that are very dissimilar. This is accomplished by measuring the lateral displacement between selected points along the tracks, summing, and normalizing the total displacement at these points by the average length of the two tracks. This procedure is somewhat similar to determining the area enclosed by the two tracks and dividing that area by the average length of the two tracks, thus obtaining a measure of the average separation between the tracks.

[2] Mark Klopfenstein, Bryan Evans, Terry Thompson. "Routing Inefficiency in the NAS: A High-Level Look," Metron, Inc. October, 1998.

Figure 11 and Figure 12 show some examples of the spatial variance parameter (SVP) that is returned by the SSA for several pairs of proposed (thicker line) and actual tracks (thinner line). We grouped the flights into two categories of spatial similarity based on whether the SVP was greater or less than 0.5:

- spatially similar—SVP less than 0.5
- spatially dissimilar—SVP greater than or equal to 0.5

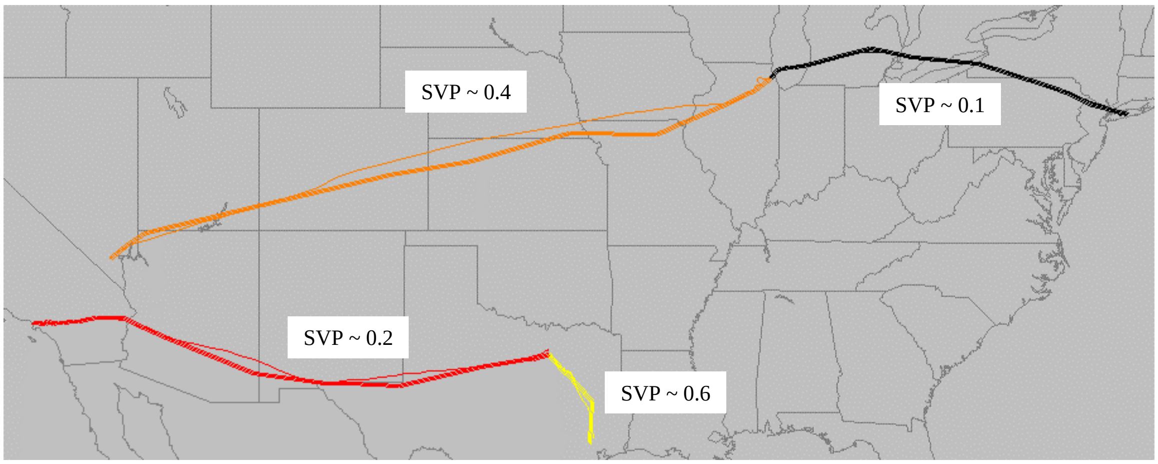


Figure 11: Spatial variance examples (SVP = 0.1 to 0.6), thick line = filed route, thin line = actual route

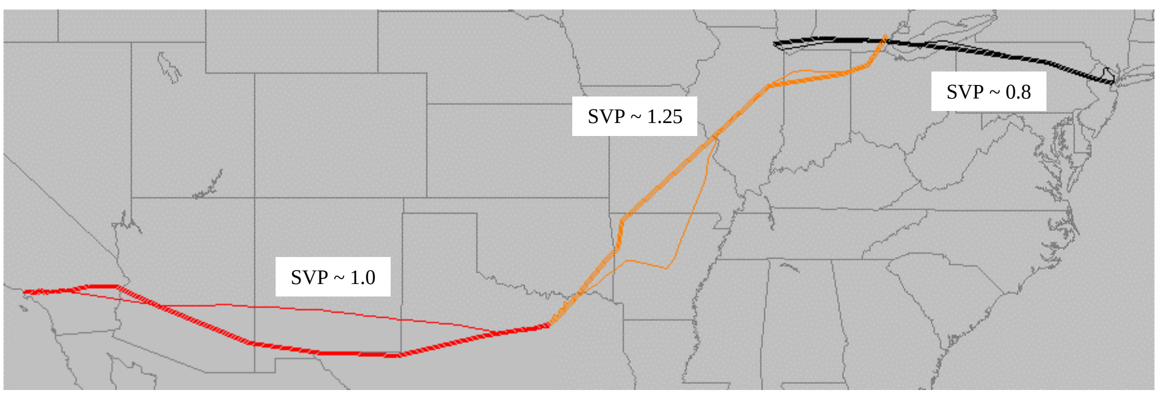


Figure 12: More spatial variance examples (SVP = 0.8 to 1.25), thick line = filed route, thin line = actual route

Table 12 summarizes the results of the track length and spatial comparison of the proposed versus actual flight tracks for all of the flights examined in this study. Using the same criteria from the prior study, the shaded cells represent flights that were significantly rerouted. Thus, the table shows that according to this metric 37% of all the flights across all of the dates included in this study were significantly rerouted in some manner from what was filed.

Table 12: Rerouted flights categorized by track length and spatial similarity of actual routes versus proposed routes. Shaded cells show significantly rerouted flights

Track Length Similarity	Spatially Similar	Spatially Dissimilar	Total
Shorter	27.1%	13.6%	40.7%
Same	33.6%	12.5%	46.1%
Long	2.8%	3.9%	6.7%
Longer	1.6%	5.0%	6.5%
Total	65.0%	35.0%	100.0%

Reroutes by Time of Year

After determining which flights were significantly rerouted we then looked at which flights were rerouted as a function of time of year. Figure 13 shows the percent of flights that were rerouted for each day available in our data set. The figure shows that some days were better than others, but the variation is all within normal statistical bounds. Thus, no particular seasonal trend is evident.

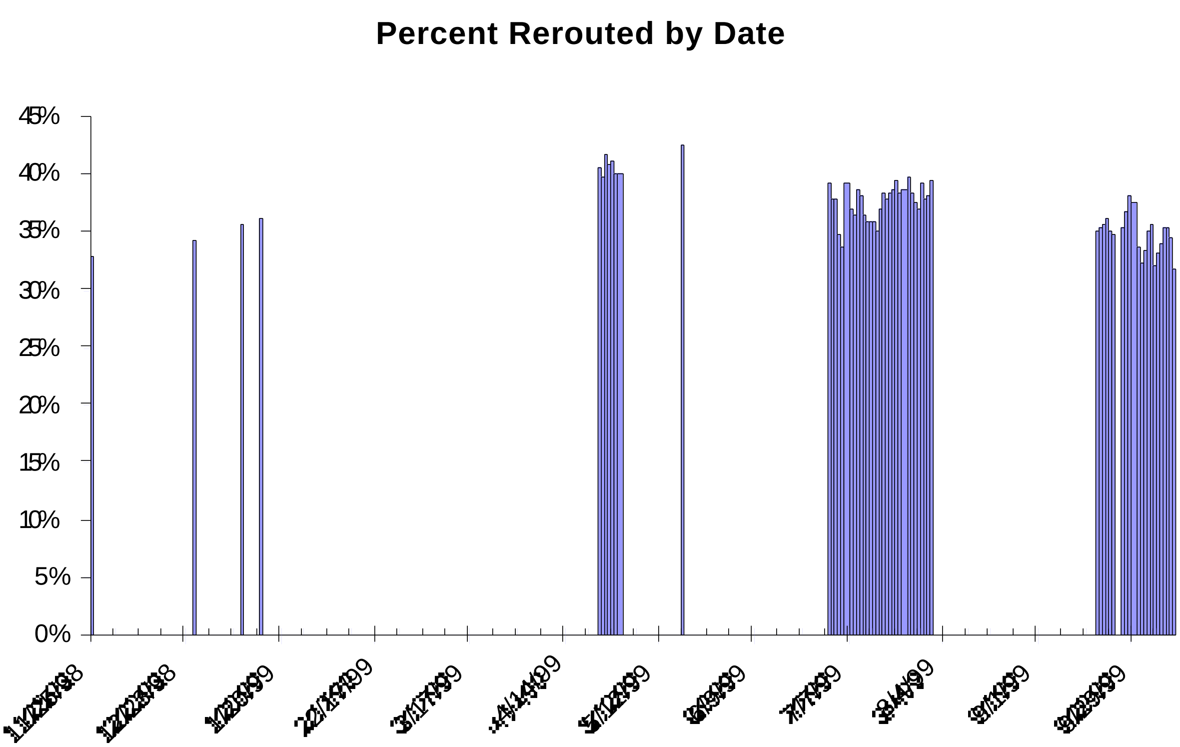


Figure 13: Percent of flights significantly rerouted by time of year

Reroutes by Time of Day

Next we looked for daily variations in the number of rerouted flights. Figure 14 shows a number of metrics plotted as a function of a flight's departure hour. The figure shows an increase in the percentage of flights that are rerouted departing between 0400Z and 0900Z, which corresponds to the late night/early morning hours when the number of departures drops significantly. To explore this further we broke out the percentage of flights that were in the dissimilar-shorter category of significant reroutes. The rerouted shorter line on the graph shows a corresponding increase in the flights that actually flew a shorter route (i.e. rerouted direct) during the times of lower overall traffic demand. This result is as expected and adds confidence to our methodology for detecting significant reroutes.

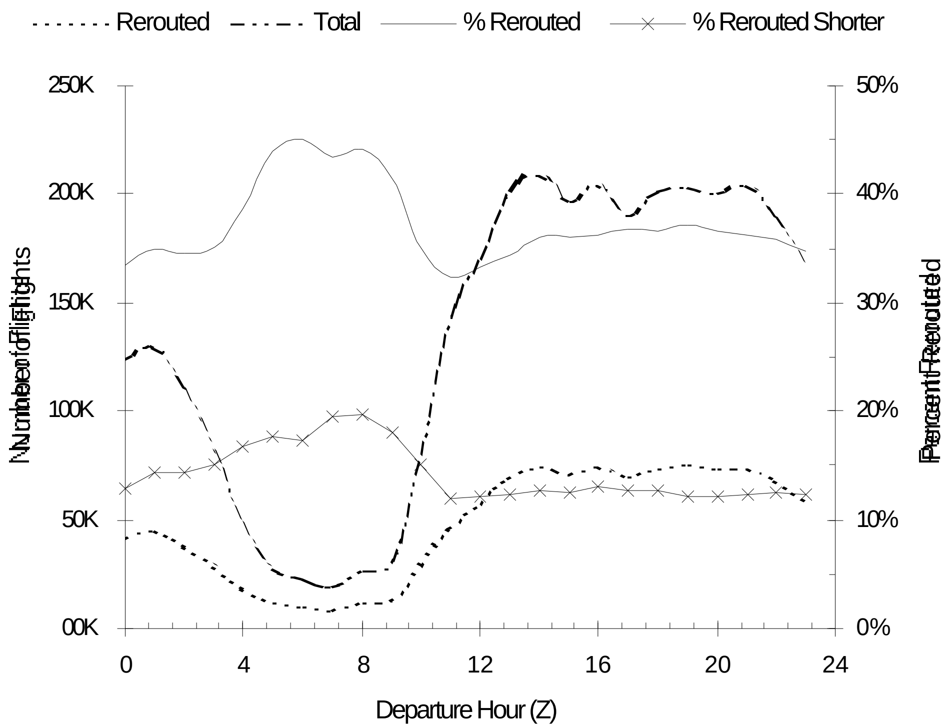


Figure 14: Reroutes by time of day

Rerouted by Arrival Fix and Hour

In a manner similar to those presented in previous sections we examined the occurrence of significant reroutes for flights scheduled to arrive through different arrival fixes in one-hour periods. The percentage of flights that were rerouted varied from zero to 100 percent for the various arrival fixes and one-hour bins.

Use of the Spearman rank order correlation indicates a reasonable consistency in the occurrence of reroutes for flights scheduled to arrive through the different arrival fixes in the one-hour periods. This is indicated in Table 13, where all of the correlations (Spearman Rho) are statistically significant at $p<0.01$. -

Table 13: Spearman rank order correlation coefficients for reroutes occurring during the four one week periods studied

Month	Month	Spearman Rho
April	July	0.664
April	Oct.	0.650
April	Sept	0.655
July	Oct.	0.686
July	Sept	0.685
Sept.	Oct.	0.762

Reroutes by Airspace Elements

To better understand where in the NAS these reroutes were occurring we looked at the reroutes as a function of filed centers, sectors, and airways. For each flight, ETMS determines all centers, sectors, and airways that a particular flight will encounter on its planned flight route. For each center, sector, and airway, we looked at all of the flights that filed to use that element between 7/12/99 and 7/18/99, divided them into those flights that were and were not rerouted, and ranked them according to percent rerouted.

We should also note that flights were included in the grouping for a particular airspace element if the ETMS processing of the flight plan indicated that a particular flight would encounter a particular element. This does not necessarily mean that the flight was rerouted while in (or on) that particular element.

Table 14 lists the number of rerouted flights by filed center for the 20 CONUS centers. The complete list, including the non-CONUS centers appears in Appendix F. The table shows that over 42% of the flights filed through ZLA and ZMA were rerouted. It is also interesting that the two busy Midwest centers (ZAU and ZOB) are at the bottom of the list, suggesting that flights that file through these centers are perhaps held to their filed routes somewhat more rigidly.

When looking at individual sectors we found that flights filing through them were significantly rerouted between 13% and 74% of the time. Table 15 lists the top 20 (CONUS) en route sectors in terms of the percent of filed flights that were significantly rerouted. A more complete list of both the top and bottom sectors appears in Appendix F. Table 15 shows that sectors in ZFW and ZMA dominate the top 20.

Finally, when looking at reroutes by airways we found that for particular airways the percentage of flights filed along them that were significantly rerouted varied from 93% to 2% . Table 16 lists the top 15 airways where flights filed on them were rerouted excluding those airways with less then 70 total flights (an average of 10 flights/day). A more complete list of both the top and bottom airways appears in Appendix F.

Table 14: Rerouted flights by (CONUS) centers along filed flight route between 7/12/99 and 7/18/99

Center	Rerouted	Total	Percent
ZLA	16074	37495	42.9%
ZMA	11440	27158	42.1%
ZBW	16107	38456	41.9%
ZFW	15682	38302	40.9%
ZHU	12987	32016	40.6%
ZJX	15620	38525	40.5%
ZSE	8678	21468	40.4%
ZNY	23936	61902	38.7%
ZAB	9633	25693	37.5%
ZOA	9258	26107	35.5%
ZLC	7606	22867	33.3%
ZTL	17352	53150	32.6%
ZDV	9472	29392	32.2%
ZDC	18893	58725	32.2%
ZME	12303	39508	31.1%
ZMP	11176	37405	29.9%
ZKC	11386	38242	29.8%
ZID	13746	48968	28.1%
ZAU	14554	51872	28.1%
ZOB	15639	57402	27.2%

Table 15: Rerouted flights by en route sectors along filed flight route (top 20 CONUS sectors) between 7/12/99 and 7/18/99

Sector	Rerouted	Total	Percent
ZMA38	471	636	74.1%
ZSE33	279	396	70.5%
ZSE03	1778	2587	68.7%
ZFW34	765	1151	66.5%
ZNY00	83	125	66.4%
ZMP80	101	156	64.7%
ZFW23	213	330	64.5%
ZHU58	1103	1769	62.4%
ZMA03	443	711	62.3%
ZMA39	875	1421	61.6%
ZFW64	615	1020	60.3%
ZAN15	634	1066	59.5%
ZFW36	973	1654	58.8%
ZFW25	341	580	58.8%
ZMA45	246	420	58.6%
ZLA06	1530	2635	58.1%
ZBW06	1715	2974	57.7%
ZLA13	1496	2611	57.3%
ZMA63	895	1576	56.8%
ZMA34	821	1446	56.8%

Table 16: Rerouted flights by airways along filed flight route (top 15) between 7/12/99 and 7/18/99

Airway	Rerouted	Total	Percent
J889R	96	103	93.2%
V153	73	81	90.1%
V215	75	84	89.3%
V385	229	259	88.4%
V102	179	207	86.5%
J502	212	249	85.1%
J195	94	111	84.7%
V585	147	174	84.5%
J548	130	155	83.9%
V571	105	127	82.7%
J133	687	834	82.4%
J483	88	107	82.2%
J478	57	72	79.2%
J570	213	270	78.9%

3.5 Inefficiencies as Indicated by Manual Detailed Analyses

Bottlenecks along Select Route Segments

The above analysis provided a general assessment of the frequency of reroutes and delays associated with flights filed on different jet routes. In order to get a more specific picture of where the bottlenecks arose along such jet routes, we conducted a more intensive manual analysis. (This analysis could be automated at a later date.)

To illustrate this type of analysis, consider the following case study. (Additional examples are provided in Appendix G). Flights scheduled to travel to airports in the New York area are known to frequently encounter departure delays. One of the airports involved is JFK. In order to understand the nature of this problem, we first looked at flights filed into JFK along particular jet routes. Similar to our earlier analyses, we looked at off time delays as a function of the scheduled arrival time into JFK (looking at one-hour time periods) for the week of July 12-18, 1999. We found that flights filed on J554 experienced significant delays.

Figure 15 shows the result for one time period in particular; flights scheduled to arrive at JFK between 0300-0400Z. What this figure shows is that, in spite of the fact that there were a relatively small number of such flights (5 from MDW, 6 from LAX and 1 from SFO), they frequently encountered substantial delays.

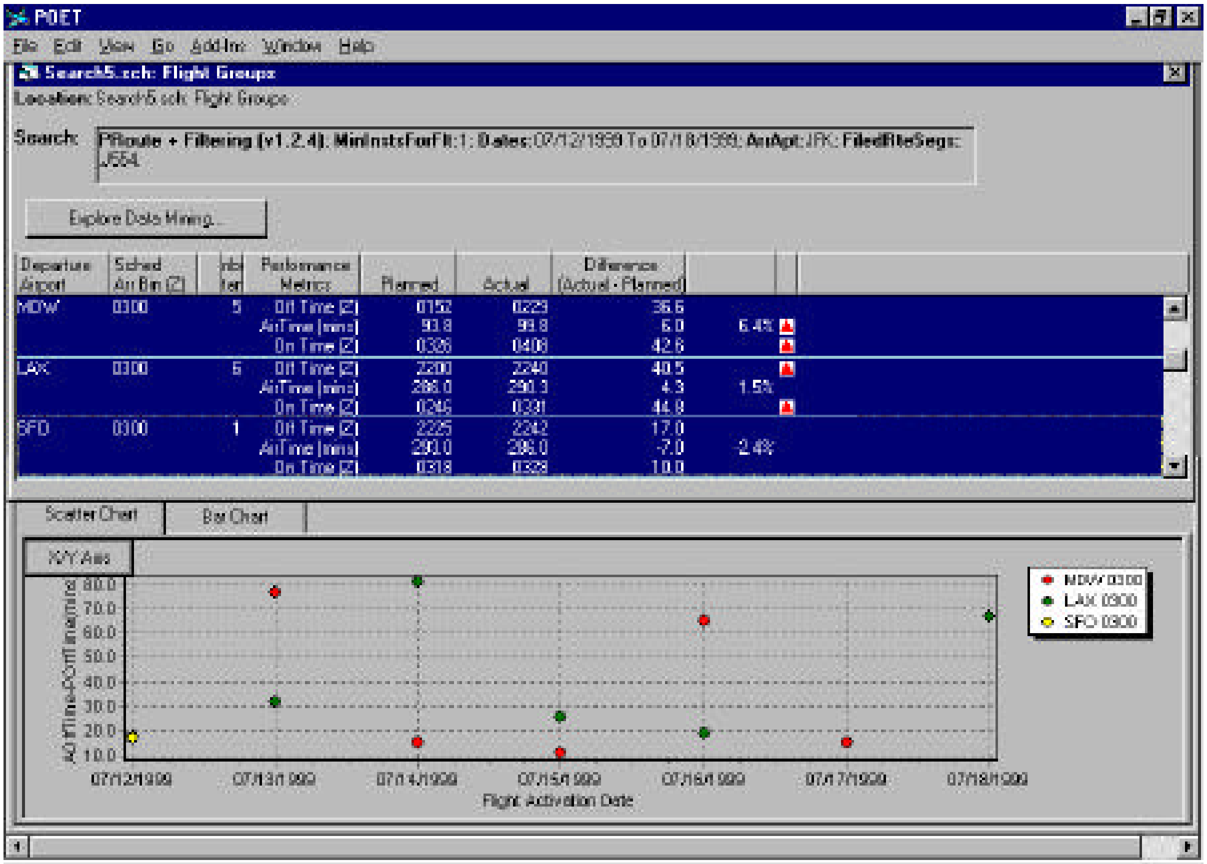


Figure 15: Flights Filed into JFK along J554

It is clear, however, that these 12 flights alone are not sufficient to cause the bottleneck, so they can only be taken as evidence that there could be a problem somewhere along J554 between 0200-0300Z (the time when these flights into JFK were scheduled to fly along J554). Thus, the problem must involve something beyond the impact of these 12 flights alone. One hypothesis would be that there are flights from a number of other cities that are going to airports other than JFK, but have also been filed to use the airspace around J554 in the same time frame. To investigate this possibility, we used another POET data mining tool that allows us to identify all of those flights filed to fly in a particular geographic area in a specific time period. When that data miner was applied for the area around this segment of J554 for 0200-0300Z, we found a convergence of a large number of planned routes from different origins to different destinations, as shown in Figure 16. This particular figure (for the date of July 16,1999) shows there was a total of 116 flights filed in the vicinity of this segment of J554 from 0200-0300.

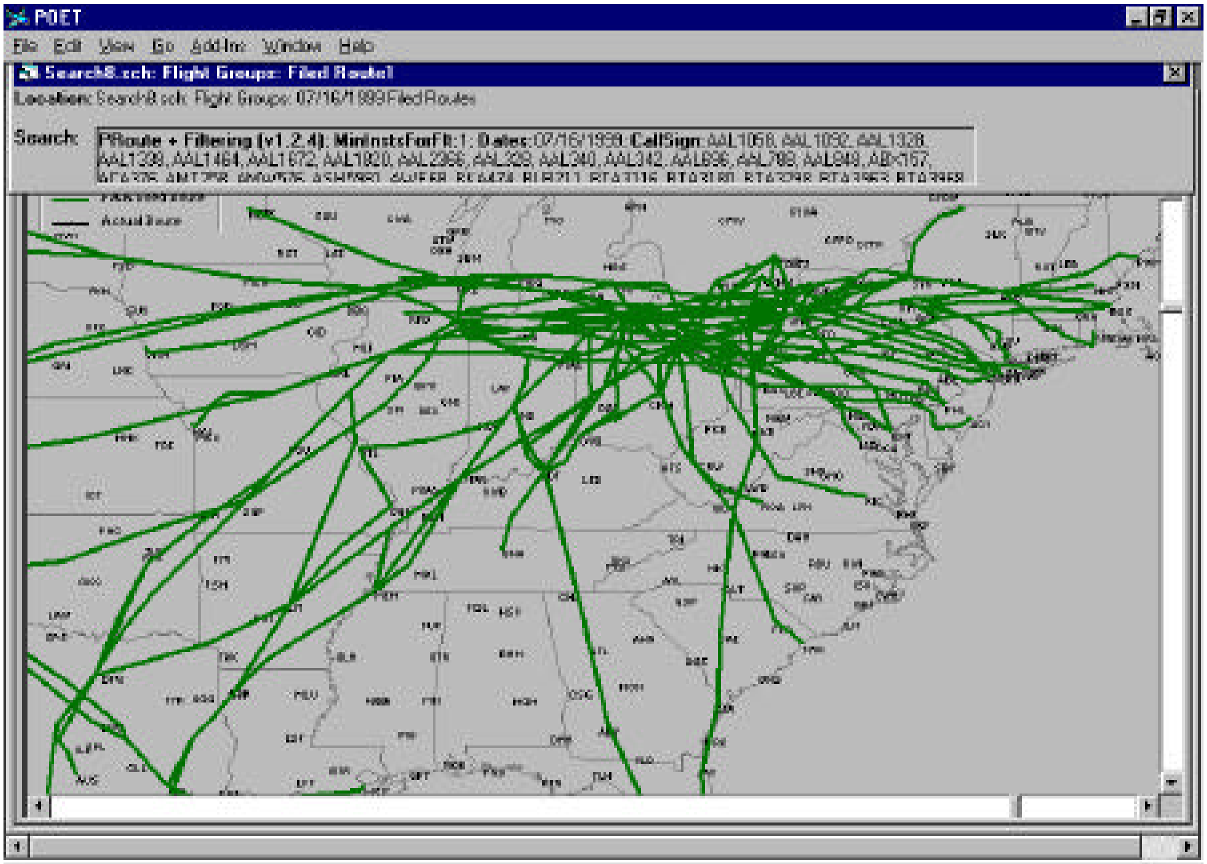


Figure 16: Flights filed on select segment of J554 from 0200-0300Z

Further investigation showed that, like the flights into JFK, many of these flights using this segment of J554 to other destinations from 0200-0300 were also experiencing significant departure delays as shown in Table 17.

Table 17: Departure Delays of other Flights using J554

Origin	Destination	Average Departure Delay (mins.)
CLE	BOS	80
CLE	SYR	75
CLE	BUF	63
JFK	ORD	57
DTW	MDW	56
CLE	ORD	50
CLE	ROC	49
PHL	DTW	44

In summary, this manually applied analysis serves as a method to identify congested jet route segments that are associated with departure delays for particular time periods, and to quantify the impact of this congestion on delays. The logic is that, if the flights flying into a particular airport that are experiencing significant departure delays are all filed along the same jet route segment, then one hypothesis is that the congestion along that jet route segment may be a major contributor to delays. There are other competing hypotheses as well, such as overloading of the associated arrival fix with flights converging at that point along a number of different jet routes. If further analysis shows that there are many additional flights with *different destinations* that also are filed along that jet route segment during the same time period, and that these additional flights are also experiencing significant departure delays, then it is quite likely that congestion along the identified jet route segment is a major contributor to the departure delays.

Thus this analysis provides a method for identifying the locations and time periods where particular jet route segments represent major bottlenecks in the system. The analysis could also provide quantitative data regarding the impact of these bottlenecks on departure delays. Finally, the analysis could be further extended to determine whether miles-in-trail restrictions were in place along those jet routes either during or just before the identified critical time period. Such restrictions would explain how this congestion resulted in the observed departure delays. This final piece of the picture is beyond the scope of this study.

Miles in Trail (MIT) Restrictions

In the previous section we explored the possibility of congestion along a shared jet route as a contributor to delays. In this section look at another possible contribution to delay, Miles in Trail (MIT) restrictions. We obtained MIT information from the ATCSCC, which maintains a database of all the restrictions imposed by one field facility upon another. We also took a more in-depth look at some of these time periods. Some of the questions we were trying to answer were:

- What is the frequency of miles in trail?
- What were the reasons for these restrictions?
- What destinations were most often impacted?
- How many flights were impacted?

There is one caveat to this analysis. The MIT restriction database is an electronic capture of handwritten log data. The data do not always follow specific formats and can vary in detail and completeness. Due to this fact, we were not able to process some of the data.

What is the frequency of MIT?
Figure 17 shows how many MIT restrictions occurred during the days that we examined. On average there were 186 restrictions per day, but the number of restrictions per day ranged from 69 (9 October 1999) to 346 (28 April 1999).

Figure 18 shows the weekly trend of the number of MIT restrictions which tends to mirror the weekly trend in total number of daily flights (shown in Figure 19).

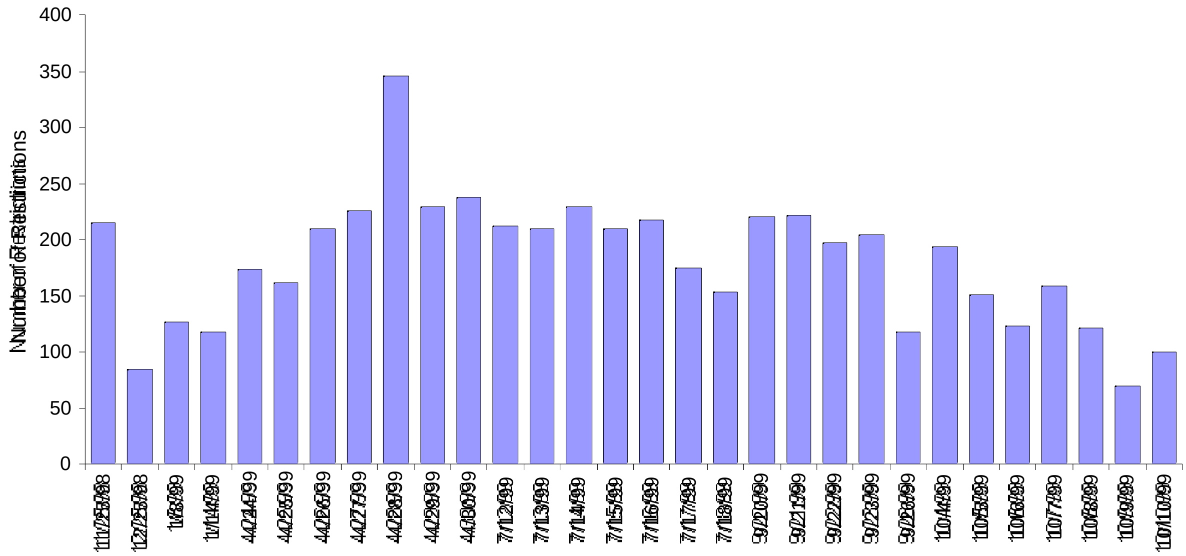


Figure 17: Number of MIT restrictions by day

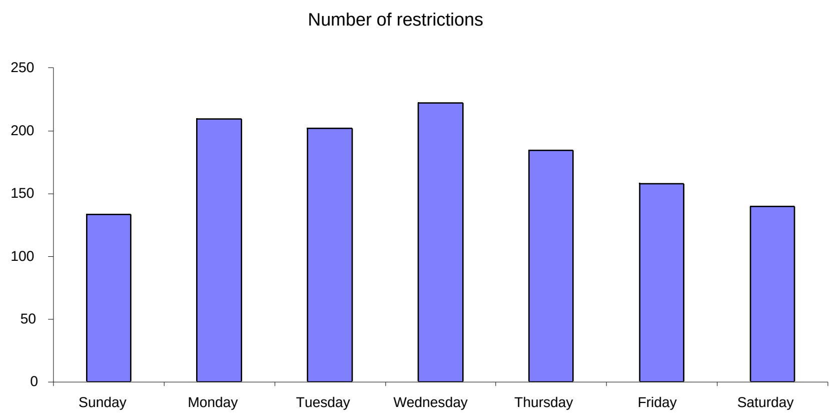


Figure 18: Weekly trends of restrictions

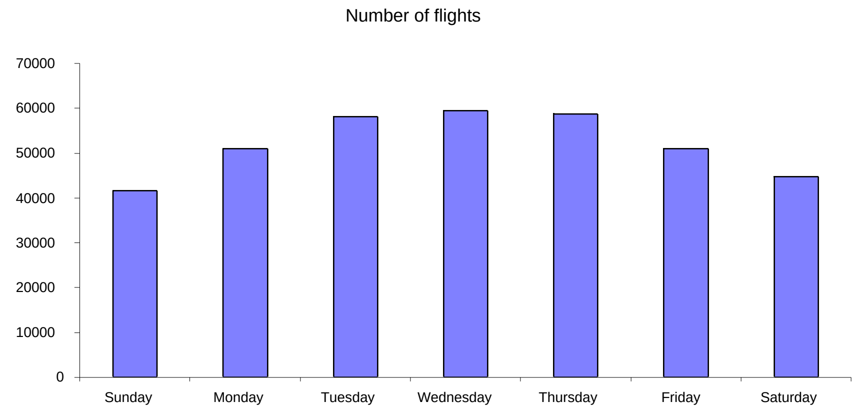


Figure 19: Weekly trends of flights

What were the reasons for these restrictions?
Figure 16 lists the top four listed reasons for the MIT restrictions. These four occurred consistently everyday, and accounted for 85% of the total restrictions. A fifth significant reason for restrictions is a passback. While passbacks are not as high in number, they also occur every day. In working with the data we noticed that several of the restrictions appear to be passbacks, but were not labeled as such. It is clear to us that there is some inconsistency in the reasons listed in the restriction data.

Table 18: Top 4 Reasons for MIT Restrictions

Reason	Number	% of Total
VOLUME	388	33%
WEATHER	362	31%
DEMAND	158	13%
AAR	91	8%
	999	85%

What destinations are most often impacted?
Table 19 lists the top 5 airports whose arrivals were subject to MIT restrictions, which accounts for almost half the total restrictions. The rest of our MIT analysis focuses on restrictions to these destinations.

Table 19: Top 5 destinations that were affected by MIT

Airport	Number	% of Total
ORD	164	14%
CVG	126	11%
ATL	119	10%
DTW	78	7%
IAD	70	6%
	557	47%

How many flights were impacted?

Using POET and the restriction database we were able to determine which flights were affected by a particular restriction. We did this by using POET to find the flights matching the parameters of the different restrictions. On average 13.5 flights were impacted for by each restriction; however, the number of flights impacted varied greatly from 1 to 442 depending on when, where, and the duration of the restriction. For example,

> ZJX put a 20-mile MIT restriction on ZTL for flights arriving in Atlanta (ATL) between 1215 and 1445 due to weather that affected 60 flights.
>
> ZID put a 30-mile MIT restriction on ZAU for flights arriving in Atlanta (ATL) between 1745 and 1845 due to weather that affected only 6 flights.

In terms of the flights impacted per hour of restriction the average was 8.5 flights affected for each hour that an MIT restriction was in place. In terms of daily averages, 1332 flights were affected per day, but this ranged from 300 (9 October 1999) to 1912 (28 April 1999) flights affected per day.

We next broke out the number of MIT impacted flights by destination and reason for the restriction. Table 20 and Table 21 show these results. Notice that by destination the number of flights affected does not necessarily follow the number of restrictions.

Table 20: Number of MIT impacted flights by destination

Airport	# of Restrictions	# of Flights Affected	% of Total NAS Flights
ORD	164	2695	0.89%
CVG	126	982	0.33%
ATL	119	2119	0.70%
DTW	78	856	0.28%
IAD	70	1341	0.44%

Table 21: Number of MIT impacted flights by reason for restriction

Reason	# of Restrictions	# of Flights Affected	% of Total NAS Flights
VOLUME	388	2621	0.87%
WEATHER	362	2097	0.70%
DEMAND	158	1703	0.56%
AAR	91	702	0.23%

Diversions in the NAS

Every day, a significant number of flights file for a given destination, but ultimately fly to another destination. Some of these flights are true diversions—they have been diverted due to mechanical problems, weather, or other problems either at their filed destinations or en route. Other flights regularly divert from their filed destination. When the diverted flights are commercial air carriers, air taxis and freight delivery aircraft, the diversions pose an immediate problem both to airline dispatchers and to the FAA. These aircraft must be expedited to their filed destination and, if possible shielded from any further causes of delay such as ground delay programs or other departure delays. Action must be taken as soon as possible both for the sake of the passengers and to minimize delay costs to the airlines. The purpose of this analytical subtask was to determine how big the diversion problem typically is (using our representative database), where the diversions occur, and how big the delay penalty is for diverted flights.

For this analysis we originally looked at just the one-week period in July (7/12/99 – 7/18/99), and then we expanded it to include 18 days total spanning the rest of our data set. Looking ahead to Figure 20 the days considered are shown. To determine which flights were diverted we queried the POET database for flights that actually landed at different locations from their filed destinations. We found two interesting cases

- Aborts: The actual destination was the same as the origin (but different from the filed destination)
- Diversions: The aircraft landed at a destination other than the one filed

Table 22 summarizes these above cases, averaging over the 18 days considered in the analysis.

Table 22: Diversion query results averaged over 18 days

	number	percent	Average/Day	max.	min.
aborts	1187	0.12	66	112	31
diversions	9844	1.02	547	834	182
total	11212	1.17	623	950	214
flights in NAS	961303	100	53406	61090	29811

At first sight, the average number of diversions per day seems very high. Even percentage-wise, a one-percent diversion rate appears questionable. We therefore examined the diversions listed in Table 22, separating the flights by user class. Table 23 presents the daily diversions by user class, averaged over the 18 days of data considered.

Table 23 is interesting for several reasons. First, we see that, on average, general aviation (GA) contributes almost 60 percent of the so-called diversions. Because GA aircraft are not scheduled, it is not surprising that they frequently divert from their filed flight plans—people who fly for recreation can be expected to land where and when they want; business aircraft may file for a particular destination but often stop en route for various reasons. Similarly, military aircraft are frequently on training missions, or may be ferrying personnel between various destinations on a loosely-scheduled basis. The real concern is with the number of commercial air carriers diverted; Table 23 shows that this number averages 20 percent of all diversions, or more than 100 flights per day on average.

Table 23: Daily diversions by user class

user class	number	percent	Average/Day	max.	min.
C	1959	20	109	219	47
F	331	3	18	87	4
G	5725	58	318	412	87
M	1232	13	68	108	3
O	311	3	17	26	7
T	286	3	16	44	6
total	9844	100	547	834	182
C+F+T	2576	26	143	350	85

Key: C = air carrier
F = freight
G = general aviation
M = military
O = other
T = air taxi

The FAA gives priority to getting air carrier, freight and air taxi flights back on schedule if they are diverted, so this combined category is listed separately. The C + F + T category comprises 143 diversions, about a quarter of the daily diversions, on average. Note that this number is rarely spread evenly among the ARTCCs. When weather causes diversions, it is generally localized to a particular area of the country, hence the diversion problem is in a sense concentrated.

Diversions by arrival center

Weather problems at the filed destination, or along routes leading to those destinations, cause most diversions. When we analyzed diversions as a function of arrival center, this view is supported. The center having the most diversions varies from day to day, but generally coincides with areas of bad weather. On a majority of the days when the New York airports were running ground delay programs due to storms, New York ARTCC had a large proportion of diversions, both C and G-class. An exception occurs for military flights; Houston ARTCC has the most military diversions for about half the days considered in the database.

Daily variations in diversion activity

Table 22 presents a summary of diversion activity averaged over a representative 18-day sample. As should be expected, there are significant deviations from the average value. Figure 20 shows the daily values for diversions by user class for each of the 18 days.

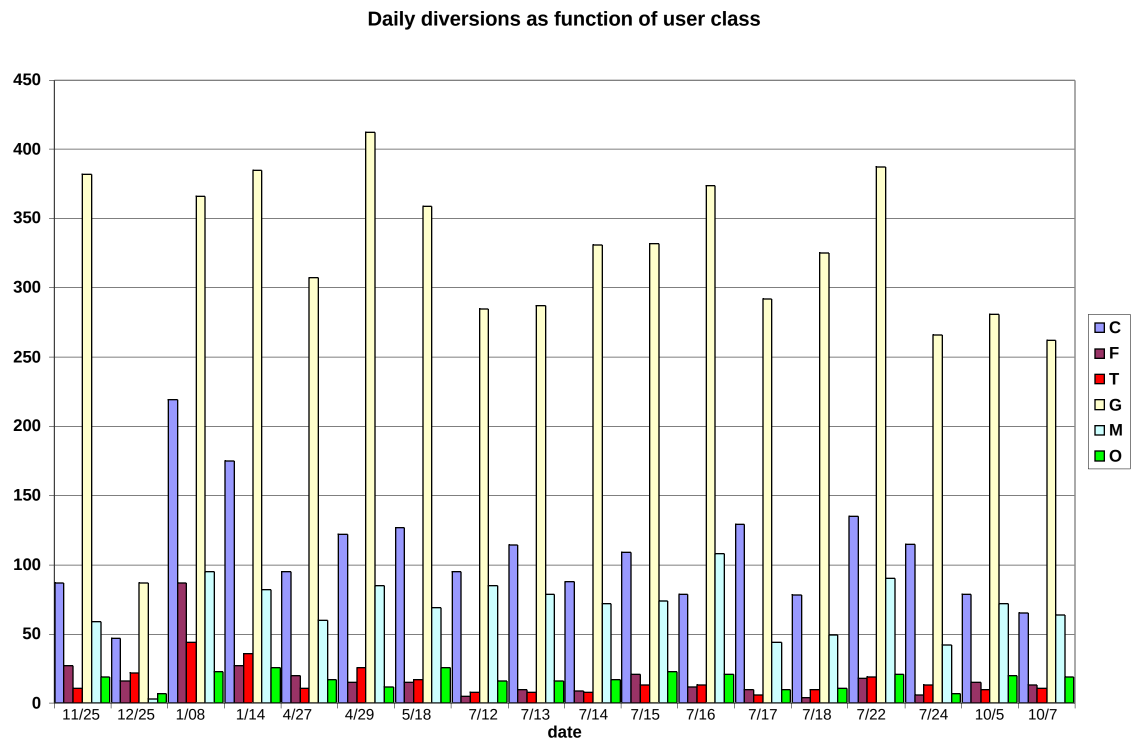


Figure 20: Daily diversions as function of user class

If we rank the diversion count by user class for each day, a clear pattern emerges. For 17 of the 18 days, the two highest counts are for G and C, in that order. Only on one day, 7/16/99, did this change; military diversions outnumbered commercial ones. The third rank was for military flights on 16 of the 18 days. As mentioned, on 7/16/99, military flights ranked second. On 12/25/98 (Christmas) air taxi flights were ranked third, and military flights had the fewest diversions of all user categories due to a holiday stand-down.

O, F and T user-class diversions occupy the fourth, fifth and sixth-ranks for all but 12/25, when military flights ranked sixth. As can be seen from Figure 20, O, F and T class diversions were almost always insignificant in number compared to G, C and M-class.

The C user class is the most important from an air traffic control perspective, because these are the flights that both the users and the FAA want to get to the filed destination as soon as possible. Table 24 is a rank-ordered count of C-class diversions by day, together with some weather information. Not surprisingly, Table 24 shows that diversions, bad weather and ground delay programs (GDPs) go hand-in-hand. The greatest number of C-class diversions occurred on 1/08/99, a known bad weather day. The greatest total count of diversions for all user classes also occurred on this day. The second greatest number of C-class diversions (and the second-highest total) occurred on 1/14/99, another day with icing and snow throughout the Northeast, the mid-Atlantic states and many other areas of the country.

Table 24: Rank-ordered count of C-class diversions by day

Date	C-count	Comments
1/8/99	219	snowstorms, 9 GDPs at six airports
1/14/99	175	snow and icing, one SFO GDP
7/22/99	135	Thunderstorms on east coast, 4 GDPs
7/17/99	129	bad weather, 4 GDPs
5/18/99	128	bad weather, 3 GDPs
4/29/99	122	one ATL GDP
7/24/99	115	bad weather, one SFO GDP
7/13/99	114	no GDPs
7/15/99	109	bad weather, PHX GDP
4/27/99	95	
7/12/99	95	
7/14/99	88	
11/25/98	87	
7/16/99	79	one SFO GDP
10/5/99	79	
7/18/99	78	bad weather, 3 GDPs
10/7/99	65	one SEA GDP
12/25/98	47	

Impact on the user

Diversions are a problem for both the user and the FAA. The users want to minimize delay and inconvenience to passengers and keep aircraft on schedule. The FAA wants to help the users by prioritizing the departures of diverted aircraft from diversion sites, and avoiding any additional delay penalties. We attempted to determine the exact amount of delay for each of the diverted flights in the 18-day database under consideration. This delay can be measured simply as time-on-ground at the diversion site, or more accurately as the difference between the estimated time-en route (ETE) of the flight and the actual time from origin to filed destination.

To determine delay penalties, we queried the POET database for the next flight (with the same ACID as the diverted flight) that began at the diversion site and landed at the filed destination for this flight. We found that, on average, we were able to obtain these data for only 18% of the diverted flights. It is possible that many of the flights that continued on to the filed destination did so under a different ACID, so that our queries could not find the continuing flight.

Table 25 summarizes the delays for the flights for which we were able to determine the continuation flight. On average the time on ground was 79 minutes for all user classes. Average flying time after departing from the diversion site was 57 minutes.

Air carriers spent 83 minutes on the ground, on average. Freight aircraft spent an average of 73 minutes on the ground, and air taxi an average of 67 minutes. It is not known how much of this time on the ground was due to the original problem (e.g. weather) and how much was due to problems getting the aircraft routed to its filed destination after the proximate cause of the diversion was over.

Table 25: Summary of diversion delays

All user classes	average	max
time on ground	79	1112
last leg	57	336
delay, diversion to destination	136	1169

"C" (air carrier) user class	average	max
time on ground	83	1081
last leg	55	260
delay, diversion to destination	138	1093

"G" (G/A) user class	average	max
time on ground	82	1112
last leg	63	336
delay, diversion to destination	146	1169

"F" (freight) user class	average	max
time on ground	73	537
last leg	60	159
delay, diversion to destination	137	546

"T" (air-taxi) user class	average	max
time on ground	67	224
last leg	39	106
delay, diversion to destination	106	242

4. RECOMMENDATIONS

At the beginning of this report in Section 2 (Summary of Results), we provided a synopsis of the specific findings discussed in detail in Section 3. Hence, we will not repeat that summary here. However, there are some recommendations for future work that developed as a result of this work. In particular, because this analysis was rather limited in scope there are several areas of investigation that we were not able to explore within the allotted resources. For this study we developed some useful methodologies for detecting and analyzing various inefficiencies in the NAS and applied them to a large subset of flight information. Based on this analysis and our results we feel there are several areas that need to be expanded on to more fully understand existing NAS inefficiencies. Specifically, we recommend the following should be pursued:

- Develop and apply additional reroute metrics that focus on different measures of operational significance (e.g., flights rerouted from one sector to another)
- Further investigate reroutes from the perspective of “good” or “bad” reroutes (e.g., directs) and study their effects
- Explore the causes of inefficiencies in specific sectors (such as detecting overflights through arrival and departure sectors and crossing traffic within en route sectors—i.e., flights cutting across major flows)
- Investigate altitude and speed constraints encountered by flights
- Discriminate among the causes of diversions (such as low fuel diversions because of restricted arrival rates at an airport)
- Automate some of the detailed analyses that we did by hand so they could be run on the entire NAS and the results ranked (one example is examining jet route segments that are bottlenecks at particular times of day, causing departure delays and/or reroutes)
- Look (on a larger scale) for evidence of the impact of using alternative strategies. We found examples where flights that receive reroutes (probably before takeoff) are avoiding the departure delays that other flights are experiencing (i.e., a study of the tradeoffs among the strategies currently being used).
- Develop/refine the data mining algorithms to detect where certain problems are arising (e.g., arrival sector vs. en route, etc). The simplest example is high altitude holding vs. holding at an arrival fix. Another example is to determine where and when along a flight's track reroutes and deviations are occurring.
- Further explore how many MIT restrictions are in effect actually passbacks
- Further correlate the various types of “problems” explored in this analysis to provide a more complete picture of what is happening with particular traffic flows
- Explore the interaction of significant reroutes and airborne holding with ground hold traffic management initiatives (e.g. GDPs and ground stops) and the use of MIT restrictions (e.g., look at how often flight affected by MIT were held and/or significantly rerouted)
- Examine the distribution of delays, deviations, and other en route problems across different NAS users. Any solutions or new approaches will must be applied in an

equitable fashion, or improve the equity of the existing system, and this could help establish a baseline.

APPENDIX A

Worst Cases in Terms of Off Times for Different Time Periods

(Top 20 groupings for each time period studied)

Worst Off Time Performances for Nov 25, 1998, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
EBBR	1800	<null>	1	1115	1538	263
BOS	1900	SCUPP	1	950	1349	239
EGLL	1200	<null>	3	138	502	203.3
RIC	1100	<null>	1	830	1129	179
MEM	1200	WLDER	1	830	1129	179
PIT	1100	WISKE	1	830	1127	177
PIA	1100	<null>	1	830	1115	165
TRI	1100	<null>	1	830	1113	163
PHL	2200	KNOLE	1	2100	2343	163
MDW	1100	CGT	1	830	1111	161
BNA	1100	GUITR	1	830	1109	159
MDT	1100	<null>	1	830	1108	158
GJT	2300	<null>	1	2030	2307	157
CID	1100	<null>	1	830	1102	152
ENBR	1900	<null>	1	1805	2033	148
BSM	1300	<null>	1	830	1054	144
ISP	1100	<null>	1	830	1050	140
GRR	1100	<null>	1	830	1048	138
IAH	1200	DAS2	1	830	1045	135
BHM	1100	<null>	1	830	1044	134

Worst Off Time Performances for Dec. 25, 1998, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
CYVR	700	HARAS	1	430	1034	364
EGLL	1500	<null>	1	450	903	253
ORD	900	KUBBS	1	700	1002	182
CSG	200	<null>	1	105	356	171
GPT	200	<null>	1	120	402	162
LAX	1300	GUITR	1	1125	1402	157
CYOW	300	CYRIL	1	215	441	146
IAD	2200	TRIXY	1	1945	2202	137
LRD	1800	<null>	1	1701	1913	132
LEB	300	<null>	1	230	442	132
AEX	400	<null>	1	250	500	130
GJT	2300	<null>	1	2025	2232	127
MIA	2100	HEATT	1	2120	2325	125
GPT	400	<null>	1	315	516	121
GTR	1900	<null>	1	1835	2034	119
FLL	1800	KUBIC	1	1758	1956	118
DEN	600	DANDD	1	310	508	118
PIT	0	CUTTA	1	150	347	117
BWI	300	TRISH	1	230	426	116
SAV	100	<null>	1	40	234	114

Worst Off Time Performances for Jan. 8, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
DFW	2300	CIVET	1	1700	2331	391
EWR	2000	COATE	1	1930	2352	262
EWR	2000	CMK	1	1855	2312	257
EWR	2100	RBV	4	1849	2304	254.8
PHL	1600	<null>	1	1506	1905	239
SEGU	900	<null>	1	345	742	237
STS	1500	<null>	1	1449	1823	214
EWR	2200	RBV	3	2003	2337	213.3
DTW	2100	SPICA	1	2000	2329	209
PIT	900	WISKE	1	835	1157	202
MDT	1000	<null>	1	850	1209	199
DSM	1500	RADDY	1	1000	1312	192
SAT	1100	<null>	1	858	1209	191
STL	100	QBALL	1	35	341	186
UNV	1900	<null>	1	1856	2157	181
MEM	1000	WLDER	1	907	1207	180
DEN	1100	DANDD	1	905	1202	177
MHT	1000	<null>	1	840	1136	176
DCA	1700	BILIT	1	1700	1954	174
IND	1800	SHB	1	1740	2033	173

Worst Off Time Performances for Jan. 14, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
SRQ	1500	<null>	1	1235	1929	414
TLPC	1800	<null>	1	1400	1957	357
EGLL	1400	<null>	1	600	1124	324
EWR	1800	PVD	1	1700	2159	299
BOS	100	PVD	2	25	518	293
TBPB	1700	<null>	1	1400	1827	267
JFK	200	LENDY	1	15	414	239
PWM	1200	<null>	1	1057	1444	227
OAK	1400	HYP	1	830	1208	218
CYUL	200	PLB	1	105	440	215
STS	1500	<null>	1	1449	1822	213
ILN	2200	LEESE	1	2010	2343	213
LIRF	1000	<null>	1	250	615	205
EGLL	1700	<null>	1	1245	1605	200
CID	1100	<null>	1	830	1149	199
SBGR	1100	<null>	1	200	518	198
LBB	1200	<null>	1	830	1146	196
LFPG	900	<null>	1	250	556	186
IPT	1400	<null>	1	1345	1650	185
PIA	1100	<null>	1	830	1133	183

Worst Off Time Performances for April 24-30, 1999,
by Arrival Airport, Scheduled Arrival Time Bin, Filed
Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
DAB	2200	<null>	7	2125	2236	70.6
MEM	1100	WLDER	8	835	939	63.8
RDU	300	ARGAL	7	120	222	61.6
BOS	300	PVD	7	155	256	61.4
CYYZ	100	LINNG	12	10	109	58.8
TOL	500	<null>	9	313	411	58
DEN	100	LARKS	7	5	101	56.4
ILM	2100	<null>	7	2025	2121	55.7
CLE	100	CXR	12	10	104	54.8
ATL	1000	LOGEN	9	848	943	54.8
MGM	2200	<null>	7	2149	2243	54.7
ROC	100	<null>	17	28	123	54.6
TOL	400	<null>	9	231	323	52.3
BDL	400	<null>	7	204	256	51.7
TNCM	1500	<null>	7	1150	1241	51.3
JAN	1500	<null>	10	1328	1419	51
CVG	400	TIGRR	9	151	242	50.9
SEA	400	JAKSN	7	2200	2251	50.6
MBPV	2200	<null>	7	2105	2155	49.7
FLL	300	MRLIN	18	41	130	49.3

Worst Off Time Performances for May 18, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
ORD	200	KUBBS	1	15	354	219
DLH	100	<null>	1	15	346	211
CRP	300	<null>	1	405	728	203
ORD	400	BEARZ	1	235	554	199
ORD	200	PLANO	3	48	357	188.3
PHL	100	BUNTS	1	5	313	188
GFK	2000	<null>	1	1940	2248	188
DEN	400	QUAIL	1	200	503	183
DTW	200	SPICA	2	125	420	175
PIT	2200	CUTTA	1	2100	2353	173
BWD	100	<null>	1	30	315	165
IND	100	DECEE	1	35	319	164
SEA	800	JAKSN	1	405	639	154
ORD	100	BEARZ	2	101	330	149.5
DTW	100	POLAR	1	111	340	149
LEB	2000	<null>	1	1920	2149	149
LIT	400	<null>	1	340	607	147
PHX	400	SUNSS	2	140	408	147
AUS	100	<null>	3	41	308	146.3
MAF	300	<null>	1	234	456	142

Worst Off Time Performances for July 12th - July 18th, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
DTW	1400	POLAR	8	1041	1212	91.1
MFE	2000	<null>	7	1934	2038	64
MCO	2200	MINEE	8	2059	2159	60
LAX	100	RIFFT	11	24	123	58.8
SJC	300	HYP	9	151	247	55.7
DTW	2300	SPICA	11	2148	2243	55.2
MEM	1100	WLDER	12	910	1004	53.8
HRL	2100	<null>	12	1941	2034	52.6
PDX	1100	BONVL	7	725	817	52.4
SEA	200	JAKSN	27	2120	2212	52.3
BUF	1000	<null>	8	837	929	52
MKE	1000	<null>	12	744	835	50.9
MCI	1000	TYGER	20	834	924	50.7
SEA	400	JAKSN	12	2227	2317	49.9
DTW	100	POLAR	8	2147	2236	49.5
ABY	2200	<null>	7	2205	2254	49.1
JAN	1500	<null>	12	1328	1416	48.8
MYR	1900	<null>	12	1645	1733	47.9
BFI	1100	<null>	10	827	914	47.7
MSP	1000	ZIBBY	7	830	918	47.6

Worst Off Time Performances for Sept. 20-26, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
SFO	1700	SKUNK	36	1608	1740	92.4
TJSJ	1800	SAALR	8	1506	1618	72.1
SFO	1800	SKUNK	39	1703	1814	71.2
SFO	1700	PYE	25	1548	1658	70.2
BOS	2100	WOONS	15	2008	2114	65.5
SFO	1800	PYE	44	1620	1722	61.5
SFO	1900	PYE	21	1717	1813	55.8
HYA	1700	<null>	9	1622	1718	55.7
PHL	2100	VCN	8	2011	2106	54.4
SFO	1900	SKUNK	23	1850	1944	53.7
LGA	2200	ARD	63	2018	2110	52.2
EWR	1900	SHAFF	15	1624	1716	51.5
BOS	2000	WOONS	15	1922	2013	51.3
BOS	2200	WOONS	11	2118	2208	50.1
JAN	1500	<null>	9	1327	1416	48.8
DEN	2200	LARKS	9	2052	2141	48.8
IAH	1100	DAS2	10	934	1022	47.8
SBA	2000	<null>	16	1908	1956	47.8
MCI	1000	TYGER	11	824	911	47.1
MFR	2200	<null>	9	2115	2202	46.7

Worst Off Time Performances for Oct. 4-10, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
MLB	2200	<null>	7	2110	2219	69.3
MEM	1100	WLDER	7	847	954	66.4
TJSJ	1800	SAALR	10	1458	1602	64.2
BOS	2100	PVD	94	1931	2035	63.4
DET	200	<null>	10	122	222	60.4
CVG	400	TIGRR	7	158	257	59
GPT	2100	<null>	7	2005	2103	58.3
CYYZ	100	LINNG	8	13	111	58.1
ABY	1500	<null>	7	1420	1516	56
BOS	2000	LWM	22	1934	2030	55.6
PHF	2300	<null>	7	2135	2231	55.6
DHN	1700	<null>	7	1614	1708	53.9
BOS	2200	PVD	93	2035	2128	53.1
BTV	100	<null>	8	26	119	52.8
LGA	2200	VIKKY	27	2119	2211	52.6
IND	1300	CLANG	9	1123	1215	51.6
RIC	1000	<null>	7	835	926	51.4
CYUL	100	PLB	10	15	106	51.3
CVG	500	TIGRR	7	304	355	51.1
BOS	2000	PVD	67	1844	1935	51

APPENDIX B

Fixes with Heavy Arrival Loads and Associated Departure Delays for the Different Time Periods

Worst Off Time Performances for April 24-30, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations for Flights with >= 48 Flights

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
ATL	2200	LOGEN	205	2038	2124	46.6
ATL	2200	HUSKY	137	2100	2146	46
ATL	2300	LOGEN	110	2140	2226	45.9
ATL	2200	TIROE	162	2054	2136	42.3
ATL	2000	TIROE	138	1849	1927	37.6
STL	200	VLA	67	108	144	36
BOS	2300	PVD	89	2139	2214	35.7
ILN	300	<null>	76	142	217	35.4
ILN	500	<null>	123	247	323	35.3
STL	2200	VLA	67	2105	2140	35
MCO	2200	LEESE	53	2008	2042	34.4
CMH	2300	<null>	56	2201	2235	33.4
ATL	2000	HUSKY	136	1852	1925	33.1
STL	200	QBALL	59	55	128	33.1
BOS	2300	LOBBY	54	2050	2123	32.8
BOS	2200	PVD	105	2022	2055	32.6
SFO	600	CEDES	49	255	328	32.5
ILN	400	<null>	147	227	300	32.5
ATL	2100	LOGEN	109	1927	2000	32.4
ATL	0	LOGEN	110	2230	2302	32.3
ATL	2300	DALAS	62	2035	2107	31.9
PVD	300	<null>	52	136	208	31.9
SFO	300	CEDES	64	2140	2211	31.3
MCO	0	LAMMA	51	2153	2224	30.9
MDT	200	<null>	51	121	152	30.5
ATL	2200	DALAS	151	2017	2047	30.5
SFO	1800	SKUNK	48	1712	1743	30.4
ATL	200	LOGEN	137	102	132	30.3
ORD	0	KUBBS	86	2219	2249	30.3
BOS	200	PVD	58	110	140	30.2
PVD	2100	<null>	50	2017	2047	30

Worst Off Time Performances for July 12-18, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations for Flights with >= 48 Flights

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
LGA	2200	ARD	83	2015	2100	45.1
PHX	300	TONTO	65	2228	2307	39.1
EWR	2300	RBV	70	2102	2141	38.9
SFO	300	CEDES	54	2151	2228	36.6
LGA	2100	ARD	86	1931	2008	36.5
ORD	2100	PLANO	75	1915	1951	35.8
SFO	1800	SKUNK	53	1655	1731	35.4
SFO	1700	SKUNK	56	1620	1655	35.2
IAH	2100	DAS2	79	1856	1931	34.5
SFO	200	CEDES	52	2126	2201	34.5
DTW	2200	SPICA	53	2004	2038	34.4
ATL	2100	LOGEN	124	1933	2007	34.1
IAH	2100	CUGAR	82	1914	1948	34
ILN	300	<null>	70	140	213	33.8
ILN	500	<null>	112	253	326	33.3
ATL	2300	HUSKY	48	2152	2225	33.1
EWR	2000	PENNS	110	1705	1738	33
MCO	2200	LAMMA	58	1947	2019	32.6
LAX	200	RIFFT	53	2145	2218	32.5
LAX	200	CIVET	54	2121	2154	32.4
ILN	400	<null>	148	225	258	32.4
ORF	2100	<null>	49	2010	2042	32.3
EWR	2200	PENNS	142	1933	2005	31.9
MCO	2100	LEESE	69	1934	2006	31.9
SFO	1900	CEDES	78	1605	1637	31.6
ORD	2100	KUBBS	82	1855	1927	31.5
ORD	2100	KRENA	129	1857	1928	31
CVG	2200	TIGRR	74	2057	2128	31
LAX	100	CIVET	60	2022	2053	30.9
CYYZ	2200	LINNG	62	2045	2116	30.8
BOS	2300	PVD	97	2137	2208	30.8
ORD	2100	BEARZ	138	1950	2021	30.8
LGA	2000	ARD	104	1839	1909	30.2
LAX	2300	RIFFT	66	2034	2104	30.2
SFO	100	CEDES	76	2012	2042	30.2

Worst Off Time Performances for Sept. 20-26, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations for Flights with >= 48 Flights

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
LGA	2200	ARD	63	2018	2110	52.2
SFO	2000	CEDES	55	1746	1831	44.5
ATL	2300	LOGEN	67	2135	2217	41.3
BOS	1900	PVD	61	1723	1802	39.6
LGA	2300	ARD	50	2144	2223	38.7
EWR	2000	PENNS	90	1706	1745	38.7
SFO	1800	CEDES	124	1418	1456	38.4
BOS	2200	PVD	81	2024	2102	38.3
BOS	2300	PVD	54	2133	2211	37.9
ATL	2200	TIROE	139	2054	2131	37.9
DTW	2200	SPICA	53	1951	2028	37.4
SFO	1700	CEDES	66	1307	1343	36.5
ATL	2200	LOGEN	133	2035	2111	36.2
ATL	2000	HUSKY	91	1857	1933	36
ATL	2100	LOGEN	63	1926	2001	35.7
BOS	1700	PVD	53	1549	1624	35.5
ILN	500	<null>	69	250	325	35.2
ORD	2100	KUBBS	72	1857	1933	35.2
LGA	2100	ARD	61	1921	1956	35
LAX	2000	FIM	70	1834	1908	34.6
BOS	2100	PVD	68	1924	1959	34.5
SFO	1600	CEDES	81	1333	1407	34.3
ORD	2200	KUBBS	116	1928	2002	34.1
EWR	2200	PENNS	92	1940	2014	34.1
ATL	2200	HUSKY	101	2058	2132	34.1
ATL	1900	TIROE	48	1738	1812	34
SFO	2100	CEDES	68	1726	1800	33.6
EWR	2300	PENNS	51	2014	2047	33.2
LGA	1900	LIZZI	52	1741	1814	33
ORD	2100	BEARZ	107	1946	2019	33
SAN	2100	<null>	75	2003	2036	32.8
ORD	2200	BEARZ	119	2023	2056	32.8
SFO	2100	PYE	48	1904	1936	32.6
BOS	2000	PVD	52	1853	1925	32
SFO	300	CEDES	53	2153	2224	31.8
ILN	400	<null>	91	228	259	31.6
ATL	2000	LOGEN	127	1839	1910	31.5
LAX	300	CIVET	60	2202	2233	31.5
ORD	2300	KUBBS	82	2108	2139	31.4

EWR	0	PENNS	60	2129	2200	31.3
PHL	2200	TERRI	50	2047	2118	31.3
ATL	2300	DALAS	58	2054	2125	30.8
LAX	2200	CIVET	85	1755	1825	30.7
SFO	1900	CEDES	57	1544	1615	30.7
ATL	0	LOGEN	89	2232	2302	30.3
PHL	2100	BUNTS	49	1948	2018	30.3
EWR	2100	RBV	62	1903	1933	30.1
LAX	2300	FIM	49	2209	2239	30

Worst Off Time Performances for Oct. 4-10, 1999, by Arrival Airport, Scheduled Arrival Time Bin, Filed Arrival Fix Combinations for Flights with >= 48 Flights

Arrival Airport	Scheduled Arrival Time Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual – Planned Off Time) in mins.
BOS	2100	PVD	94	1931	2035	63.4
BOS	2200	PVD	93	2035	2128	53.1
BOS	2000	PVD	67	1844	1935	51
ATL	2000	LOGEN	148	1840	1930	49.9
ATL	2200	LOGEN	158	2034	2122	48.5
ATL	2000	TIROE	125	1852	1939	47
EWR	2200	RBV	67	2008	2054	46.3
BOS	2300	PVD	57	2147	2233	46.2
MCO	0	LAMMA	51	2142	2227	45.8
ATL	2000	HUSKY	113	1847	1932	45.2
EWR	2100	RBV	61	1923	2008	44.7
ILN	600	<null>	50	204	247	43.7
BOS	2100	LOBBY	59	1817	1900	43
BOS	0	PVD	54	2201	2244	42.8
CLE	1900	CXR	68	1748	1830	42.1
ATL	2300	LOGEN	115	2114	2156	42
ATL	1900	HUSKY	59	1805	1847	42
ATL	2200	HUSKY	133	2051	2133	41.8
ATL	2200	TIROE	155	2057	2139	41.5
ATL	1800	HUSKY	117	1701	1742	41.4
ATL	2100	LOGEN	111	1933	2014	40.9
ATL	1900	LOGEN	141	1711	1751	40.6
ATL	2000	DALAS	161	1820	1859	39
ATL	1900	TIROE	56	1745	1823	38.2
BOS	2200	LOBBY	61	2004	2042	37.5
ATL	100	LOGEN	52	2250	2327	37.2
ATL	1500	DALAS	66	1345	1421	36.7
ATL	1800	TIROE	148	1658	1734	36.5
ATL	1600	LOGEN	143	1446	1522	36.5
LGA	2200	ARD	100	2030	2106	36.5
ATL	1500	LOGEN	152	1330	1406	36.3
LGA	2300	ARD	85	2136	2212	35.9
ATL	1300	LOGEN	212	1116	1152	35.9
EWR	2100	PENNS	60	1821	1857	35.8
EWR	2000	PENNS	133	1707	1743	35.3
ILN	300	<null>	65	145	220	34.9
LAX	400	CIVET	57	2244	2319	34.5
EWR	2200	PENNS	119	1932	2007	34.5
ATL	1800	LOGEN	199	1632	1706	34.1
ATL	1400	LOGEN	137	1239	1313	33.9

ATL	2200	DALAS	158	2005	2039	33.9
EWR	2000	RBV	50	1812	1846	33.9
CLE	1500	WAKEM	76	1335	1409	33.8
EWR	0	PENNS	72	2139	2213	33.7
ILN	400	<null>	144	228	302	33.7
LGA	2100	ARD	78	1930	2003	33.5
ILN	500	<null>	107	252	325	33.4
BOS	2000	LOBBY	92	1647	1720	33
ATL	1700	LOGEN	68	1503	1536	32.7
RDU	2200	ARGAL	56	2112	2145	32.5
MCO	2200	LAMMA	57	1949	2021	32
EWR	2300	RBV	60	2102	2134	32
BOS	1900	PVD	87	1716	1748	31.9
BUF	2200	<null>	48	2118	2150	31.7
SFO	100	CEDES	68	2013	2045	31.7
CLE	1700	KEATN	60	1603	1634	31.6
ATL	1900	DALAS	99	1644	1716	31.6
LGA	2100	LIZZI	60	1939	2011	31.5
EWR	2300	PENNS	78	2004	2035	31.2
PHX	300	TONTO	71	2229	2300	31
ATL	1600	HUSKY	119	1501	1532	30.9
CYYZ	1400	LINNG	60	1239	1309	30.8
ATL	0	LOGEN	120	2226	2256	30.5
DAY	1500	<null>	58	1339	1410	30.5
ATL	1400	HUSKY	87	1308	1338	30.4
ATL	1600	DALAS	173	1439	1509	30.2

APPENDIX C

Worst Cases in Terms of Air Times for Different Time Periods

(Top 20 groupings for each time period studied)

Worst Air Time Performances for Nov. 25, 1998, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual - Planned Off Time) in minutes and %	
ESMK	1400	<null>	1	100	554	454	454.00%
MVY	200	<null>	1	10	39	29	290.00%
PHL	2200	KNOLE	1	73	221	148	202.70%
MEM	1200	<null>	1	25	67	42	168.00%
LNS	1100	<null>	1	9	22	13	144.40%
VPS	400	<null>	1	43	105	62	144.20%
ATL	1200	<null>	1	50	121	71	142.00%
CUL	1700	<null>	1	113	264	151	133.60%
HOU	1800	VLA	1	45	97	52	115.60%
PLB	1500	<null>	2	12	25.5	13.5	112.50%
IAH	400	<null>	1	33	70	37	112.10%
CEC	1800	<null>	1	11	23	12	109.10%
BWI	300	JOT	1	35	73	38	108.60%
MWA	300	<null>	1	15	31	16	106.70%
AUG	200	<null>	1	10	20	10	100.00%
CYUL	2300	FRANX	1	69	136	67	97.10%
ELM	100	<null>	1	14	27	13	92.90%
ELM	2100	<null>	1	14	27	13	92.90%
UIN	1900	<null>	1	12	23	11	91.70%
DVL	2000	<null>	1	18	34	16	88.90%

Worst Air Time Performances for Dec. 25, 1998, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual - Planned Off Time) in minutes and %	
ESMK	1400	<null>	1	100	554	454	454.00%
MVY	200	<null>	1	10	39	29	290.00%
PHL	2200	KNOLE	1	73	221	148	202.70%
MEM	1200	<null>	1	25	67	42	168.00%
LNS	1100	<null>	1	9	22	13	144.40%
VPS	400	<null>	1	43	105	62	144.20%
ATL	1200	<null>	1	50	121	71	142.00%
CUL	1700	<null>	1	113	264	151	133.60%
HOU	1800	VLA	1	45	97	52	115.60%
PLB	1500	<null>	2	12	25.5	13.5	112.50%
IAH	400	<null>	1	33	70	37	112.10%
CEC	1800	<null>	1	11	23	12	109.10%
BWI	300	JOT	1	35	73	38	108.60%
MWA	300	<null>	1	15	31	16	106.70%
AUG	200	<null>	1	10	20	10	100.00%
CYUL	2300	FRANX	1	69	136	67	97.10%
ELM	100	<null>	1	14	27	13	92.90%
ELM	2100	<null>	1	14	27	13	92.90%
UIN	1900	<null>	1	12	23	11	91.70%
DVL	2000	<null>	1	18	34	16	88.90%

Worst Air Time Performances for Jan. 8, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual - Planned Off Time) in minutes and %	
ORD	1200	<null>	1	20	102	82	410.00%
BKW	1900	<null>	1	10	35	25	250.00%
DEN	2200	<null>	2	20.5	70.5	50	243.90%
ORD	1100	<null>	2	22	70.5	48.5	220.50%
OWB	500	<null>	1	7	21	14	200.00%
SLN	400	<null>	1	29	86	57	196.60%
SLN	300	<null>	1	15	43	28	186.70%
CDR	400	<null>	1	12	34	22	183.30%
STL	2000	CGT	1	46	127	81	176.10%
MMZC	1000	<null>	1	55	151	96	174.50%
SFO	300	<null>	1	16	43	27	168.80%
DEN	1700	<null>	1	27	72	45	166.70%
MSP	1800	KRENA	1	45	118	73	162.20%
MYV	200	<null>	1	10	26	16	160.00%
STL	2100	<null>	1	38	98	60	157.90%
WRL	2100	<null>	1	14	36	22	157.10%
UIN	500	<null>	1	13	33	20	153.80%
CYYZ	1200	<null>	1	35	87	52	148.60%
MCI	2100	CGT	1	58	140	82	141.40%
GCK	500	<null>	1	22	53	31	140.90%

Worst Air Time Performances for Jan 14, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual - Planned Off Time) in minutes and %	
DEN	1200	<null>	1	10	81	71	710.00%
MCI	1100	<null>	1	15	74	59	393.30%
ORD	0	<null>	1	17	64	47	276.50%
DEN	1300	<null>	1	28	105	77	275.00%
PDX	1500	SNS	1	52	170	118	226.90%
PIT	2100	MRB	1	41	120	79	192.70%
SAN	1600	SNS	1	51	146	95	186.30%
CEC	1800	<null>	1	12	33	21	175.00%
EWR	1800	PVD	1	36	97	61	169.40%
PKB	200	<null>	1	18	47	29	161.10%
WRL	1900	<null>	1	14	36	22	157.10%
WRL	2100	<null>	1	14	36	22	157.10%
DCA	1600	<null>	1	46	117	71	154.30%
BRD	1600	<null>	1	14	35	21	150.00%
UIN	500	<null>	1	12	30	18	150.00%
LAX	1500	HYP	1	43	106	63	146.50%
CYYZ	1400	VALRE	1	50	123	73	146.00%
PIT	2000	<null>	1	37	91	54	145.90%
DTW	2100	<null>	1	31	74	43	138.70%
SNA	1500	HYP	1	70	165	95	135.70%

Worst Air Time Performances for April 24-30, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual - Planned Off Time) in minutes and %	
LAX	1200	VTU	14	18.6	32.8	14.1	75.90%
MDT	0	<null>	7	19.3	31.1	11.9	61.50%
LAX	1600	VTU	35	22.7	35.3	12.6	55.40%
EUG	1300	<null>	7	22	33.6	11.6	52.60%
LAX	1900	VTU	48	28.6	42.3	13.7	48.00%
LBB	1300	<null>	11	45.6	66.9	21.3	46.60%
CLT	100	CTF	29	37.2	54.3	17.1	45.90%
YKM	400	<null>	7	23.6	34.3	10.7	45.50%
LAX	200	VTU	42	26.2	38	11.9	45.40%
YKM	0	<null>	7	23.3	33.6	10.3	44.20%
BFL	1800	<null>	7	24.6	35.4	10.9	44.20%
LAX	1700	VTU	42	33.5	48.1	14.5	43.40%
YKM	1700	<null>	7	23.4	33.6	10.1	43.30%
PDX	700	HELNS	10	23.4	33.4	10	42.70%
BFL	1300	<null>	7	24.4	34.6	10.1	41.50%
PDX	100	HARZL	7	25.1	35.6	10.4	41.50%
LAX	0	VTU	29	27.1	38.2	11.1	41.00%
LAX	2200	VTU	31	30.1	42.3	12.2	40.40%
APF	1900	<null>	7	28.3	39.3	11	38.90%
AVP	2100	<null>	7	39.7	55	15.3	38.50%

Worst Air Time Performances for May 18, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual - Planned Off Time) in minutes and %	
DFW	300	JEN	1	14	129	115	821.40%
BSM	200	<null>	1	22	100	78	354.50%
MSP	0	<null>	1	20	73	53	265.00%
MCN	200	<null>	1	14	44	30	214.30%
DAY	200	<null>	2	31	74.5	43.5	140.30%
IAD	2000	WISKE	1	29	66	37	127.60%
SPW	2100	<null>	1	21	46	25	119.00%
MIA	2100	FAMIN	1	32	68	36	112.50%
BNA	2200	GUITR	2	77.5	164	86.5	111.60%
CEC	500	<null>	1	13	27	14	107.70%
IAH	200	CUGAR	2	34.5	70.5	36	104.30%
PIR	1700	<null>	1	39	79	40	102.60%
DFW	300	<null>	1	113	220	107	94.70%
UNV	2000	GRACE	1	52	99	47	90.40%
DAL	100	<null>	6	43.8	83	39.2	89.40%
LAX	1200	DARTS	1	26	49	23	88.50%
MCN	400	<null>	1	17	32	15	88.20%
GNV	1700	<null>	1	42	79	37	88.10%
SPW	300	<null>	1	16	29	13	81.30%
MQT	1600	<null>	2	14.5	26	11.5	79.30%

Worst Air Time Performances for July 12-18, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual - Planned Off Time) in minutes and %	
DEN	2200	RAMMS	7	22.7	41.9	19.1	84.3%
BNA	0000	GUITR	10	51.1	92.2	41.1	80.4%
BFL	2100	<null>	7	23.1	36.3	13.1	56.8%
LAX	0200	VTU	27	32.1	50.1	18	56.2%
EUG	1600	<null>	7	22.4	33.4	11	49.0%
YKM	1700	<null>	7	22.4	33.3	10.9	48.4%
BFL	1400	<null>	7	22.7	33.7	11	48.4%
YKM	1500	<null>	7	22.4	33.1	10.7	47.8%
PDX	0100	HARZL	7	25.9	38.1	12.3	47.5%
MDT	0000	<null>	8	29.9	43.6	13.8	46.0%
LAX	1300	VTU	27	26.3	38.3	12	45.5%
LBB	1800	<null>	7	43.1	62.7	19.6	45.4%
MSP	1200	SHONN	17	38.7	56.1	17.4	45.0%
LAX	2200	VTU	45	32.6	46.5	13.8	42.3%
ATL	0100	DALAS	7	28	39.9	11.9	42.3%
PDX	1800	HELNS	7	27.1	38.4	11.3	41.6%
MGM	2200	<null>	8	26	36.8	10.8	41.3%
MSP	1500	OLLEE	25	50.2	70.1	20	39.8%
RKD	1800	<null>	7	38	53.1	15.1	39.8%
PDX	1700	HARZL	7	26.3	36.7	10.4	39.7%

Worst Air Time Performances for Sept. 20-26, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual - Planned Off Time) in minutes and %	
LAX	1200	VTU	10	21.6	35.3	13.7	63.40%
LAX	1700	VTU	37	29.3	44.4	15.1	51.50%
MSP	1200	OLLEE	12	33.2	49.1	15.9	48.00%
LAX	2000	VTU	27	30	44.4	14.4	47.90%
MSP	1100	TWINZ	16	42.6	62.9	20.3	47.70%
MSP	1200	SHONN	8	40.5	59.8	19.3	47.50%
CLT	100	CTF	19	31.9	44.8	12.9	40.60%
LAX	1300	VTU	14	26.8	37.6	10.9	40.50%
MSP	1100	ZIBBY	22	45.9	64.5	18.5	40.40%
MSP	0	OLLEE	7	34.9	48.7	13.9	39.80%
LAX	1800	VTU	16	35.8	49.7	13.9	39.00%
PDX	100	HELNS	13	27.1	37.5	10.5	38.60%
FLO	300	<null>	8	39.8	54.9	15.1	38.10%
LAX	2300	VTU	30	39.7	54.5	14.8	37.20%
PDX	500	HELNS	7	28.6	39	10.4	36.50%
LAX	300	VTU	23	33.4	45.6	12.2	36.40%
LAX	100	VTU	23	33.9	46.2	12.3	36.30%
LAX	200	VTU	25	36.4	49.6	13.2	36.20%
AVP	2100	<null>	9	42.3	57.4	15.1	35.70%
PSP	200	<null>	8	33.8	45	11.3	33.30%

Worst Air Time Performances for Oct. 4-10, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations

Arrival Airport	Scheduled Arrival Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned Off Time (Z)	Actual Off Time (Z)	Difference (Actual - Planned Off Time) in minutes and %	
MSP	0	OLLEE	11	33.8	63.5	29.6	87.60%
LAX	1200	VTU	13	19.8	36.9	17.1	86.00%
LYH	1400	<null>	7	32.6	51.6	19	58.30%
MSP	1200	SHONN	10	39	60.5	21.5	55.10%
AVP	1200	<null>	7	34.9	53.1	18.3	52.50%
MSP	1200	OLLEE	18	34.7	51.9	17.2	49.70%
YKM	1700	<null>	7	22.1	32.9	10.7	48.40%
PDX	1600	HARZL	7	26.1	38.1	12	45.90%
PDX	500	MCCOY	7	22.3	32.4	10.1	45.50%
MSP	1100	TWINZ	25	48.4	69.4	21	43.40%
BOS	1800	GDM	12	45.1	64.6	19.5	43.30%
LAX	2200	VTU	40	27	38.5	11.6	42.90%
LAX	1300	VTU	17	26.1	37.2	11.1	42.70%
LAX	1700	VTU	52	27.7	39.3	11.6	41.90%
LAX	2000	VTU	35	29	41.2	12.1	41.80%
MSP	200	OLLEE	13	47	66.3	19.3	41.10%
MSP	1900	OLLEE	17	48.6	68.4	19.8	40.80%
LAX	100	VTU	30	31.2	43.6	12.5	40.00%
MDT	1800	<null>	7	28.7	40.1	11.4	39.80%
CYVR	600	CASDY	7	27.3	38.1	10.9	39.80%
MDT	1200	<null>	8	30	41.9	11.9	39.60%

APPENDIX D

Fixes with Heavy Arrival Loads and Associated Airborne Delays for the Different Time Periods

Worst AirTime Performances for April 24-30th, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations (Air time delay >= 10 minutes) for Flights with >= 48 flights

Arrival Airport	Sched Arr Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned AirTime (mins)	Actual AirTime (mins)	Difference (Actual - Planned) AirTime (mins)	Percent AirTime Increase (Difference/Planned)
LAX	1900	VTU	48	28.6	42.3	13.7	48.00%
ATL	2000	LOGEN	169	79.4	108.7	29.3	36.90%
LAX	1400	VTU	81	36.4	48.7	12.4	34.00%
ATL	2000	HUSKY	136	68.8	91.5	22.7	33.00%
ATL	2000	TIROE	138	68.8	89.9	21.2	30.80%
IAH	1300	CUGAR	64	68.2	85.1	17	24.90%
ATL	2200	LOGEN	205	76.6	95.6	19	24.80%
DAL	1300	<null>	59	43.6	54.2	10.6	24.30%
ATL	2200	HUSKY	137	66.6	82.3	15.6	23.50%
MSP	2200	ZIBBY	80	65.7	79.9	14.3	21.70%
LAX	100	FIM	49	47.4	57.4	10	21.10%
ATL	1900	HUSKY	65	71.7	86.5	14.7	20.50%
LAX	1800	FIM	84	65.6	78.6	13	19.80%
ATL	1800	HUSKY	120	67.5	80.8	13.2	19.60%
ATL	1500	LOGEN	123	72.7	86.7	14	19.30%
ATL	2100	LOGEN	109	102.8	122.6	19.7	19.20%
ATL	0	TIROE	94	78.6	93.5	14.9	19.00%
ATL	2000	DALAS	213	106.8	126.5	19.7	18.50%
PHL	1300	BUNTS	84	65.3	77.3	12	18.30%
ATL	2200	TIROE	162	74.8	88.3	13.5	18.10%
ATL	1300	LOGEN	191	85.6	100.6	15	17.50%
ATL	1300	HUSKY	82	70.8	83.2	12.3	17.40%
ATL	1600	TIROE	160	63.4	74.3	10.9	17.10%
LAX	1700	FIM	70	65.7	76.8	11.1	17.00%
ATL	1300	DALAS	114	78.5	91.5	13	16.60%
ATL	2200	DALAS	151	99	115.5	16.5	16.60%
ATL	1800	LOGEN	216	85.3	99.3	14.1	16.50%
ATL	0	LOGEN	110	85.3	99.3	14	16.40%
ATL	200	LOGEN	137	73.3	85.1	11.8	16.20%
CYYZ	2200	LINNG	63	76.8	88.5	11.7	15.20%
CYYZ	1400	LINNG	62	78.8	90.5	11.8	14.90%
ATL	1300	TIROE	135	70.5	80.5	10	14.30%
ATL	1600	LOGEN	194	77	87.5	10.6	13.70%
ATL	1900	TIROE	66	89.9	101.7	11.8	13.10%

ATL	1900	LOGEN	135	149.1	168.5	19.4	13.00%
CVG	1700	FLM	84	76.7	86.7	10	13.00%
ATL	2300	LOGEN	110	92.2	104	11.8	12.80%
CYYZ	1800	LINNG	59	104	117	13.1	12.60%
ATL	0	DALAS	144	106	119.4	13.4	12.60%
LAX	1900	FIM	59	85.6	96	10.4	12.20%
CYYZ	1900	YWT	63	90.8	101.5	10.7	11.80%
CYYZ	2000	YWT	54	96.2	107.5	11.3	11.70%
ATL	1600	DALAS	170	93.7	104.4	10.7	11.40%
EWR	1800	RBV	109	111.4	123.4	12	10.80%
ATL	1900	DALAS	70	121.9	135	13.1	10.70%
EWR	1900	RBV	86	123.7	134.7	11.1	9.00%
EWR	2200	PENNS	93	134.3	145.8	11.5	8.60%
PHL	0	BUNTS	134	132.1	143.2	11.1	8.40%
EWR	2100	PENNS	74	148.1	159.7	11.5	7.80%
ATL	2300	DALAS	62	151.5	162.8	11.2	7.40%
EWR	2000	PENNS	136	166.6	178.2	11.6	7.00%
EWR	1900	PENNS	57	206.9	219.2	12.3	6.00%

Worst AirTime Performances for July 12-18, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations (Air time delay >= 10 minutes) for Flights with >= 48 flights

Arrival Airport	Sched Arr Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned AirTime (mins)	Actual AirTime (mins)	Difference (Actual - Planned) AirTime (mins)	Percent AirTime Increase (Difference/ Planned)
MSP	200	TWINZ	60	58.1	79	20.9	36.00%
MSP	200	ZIBBY	71	59.5	78.9	19.4	32.60%
MSP	2200	ZIBBY	73	64	83.1	19.1	29.90%
ATL	2000	HUSKY	147	62.4	80.6	18.1	29.10%
ATL	2000	TIROE	144	66.2	85	18.8	28.50%
MSP	2200	OLLEE	94	76.1	97.1	21	27.70%
ATL	2000	LOGEN	134	78.8	100.6	21.8	27.60%
LAX	2100	VTU	53	38.9	49.6	10.7	27.50%
LAX	1400	VTU	70	41.7	52.5	10.8	25.90%
CYYZ	2200	LINNG	62	64.8	80.9	16.2	25.00%
ATL	2200	HUSKY	155	66.2	82.7	16.5	24.90%
MSP	1900	TWINZ	69	63.9	79.8	15.9	24.80%
ATL	2200	LOGEN	184	74.2	92.2	18	24.20%
ATL	1500	HUSKY	91	49	60.5	11.5	23.40%
ATL	1300	HUSKY	78	62.3	76.4	14	22.50%
ATL	2200	TIROE	152	69.3	84.9	15.6	22.50%
MSP	0	ZIBBY	119	96.1	117.6	21.6	22.40%
MSP	2200	TWINZ	88	82.7	100.7	18	21.80%
MSP	1700	ZIBBY	82	71.2	86.3	15.1	21.10%
MSP	0	TWINZ	177	101.8	123.1	21.3	20.90%
ATL	1500	DALAS	99	59.4	71	11.7	19.70%
MSP	1400	TWINZ	52	82.8	98.8	16	19.30%
MSP	1700	OLLEE	90	95.6	113.9	18.3	19.10%
MSP	1500	ZIBBY	137	89	105.6	16.6	18.70%
MSP	1300	ZIBBY	85	78.1	92.6	14.5	18.60%
ATL	1800	HUSKY	123	62.5	73.9	11.4	18.20%
MSP	2100	TWINZ	77	89.8	106	16.2	18.00%
MSP	2000	ZIBBY	111	89.3	105.2	16	17.90%
CYYZ	1400	LINNG	64	74.3	87.4	13.1	17.70%
ATL	1300	DALAS	130	75.1	88.2	13	17.40%
MSP	1300	TWINZ	145	89	104.2	15.2	17.10%
MSP	1800	ZIBBY	86	94.8	110.9	16	16.90%
ATL	1300	LOGEN	189	88.4	103.1	14.6	16.60%
MSP	2200	SHONN	133	127.2	148.3	21.2	16.60%
ATL	1500	LOGEN	147	74.7	86.9	12.2	16.30%
CLE	1500	KEATN	57	72.2	83.8	11.7	16.20%
ATL	1300	TIROE	140	73.9	85.9	12	16.20%
ATL	2300	LOGEN	119	86	99.5	13.5	15.80%
PHL	1300	BUNTS	70	70.8	82	11.1	15.70%
ATL	1800	TIROE	108	65.6	75.8	10.2	15.60%
SEA	1800	OLM	76	85.4	98.5	13	15.20%
MSP	1500	TWINZ	155	99.5	114.5	15.1	15.10%

ATL	0	HUSKY	112	70.8	81.5	10.7	15.00%
ATL	2000	DALAS	226	118.9	136.3	17.5	14.70%
MSP	1700	TWINZ	61	88.1	100.5	12.5	14.10%
MSP	2000	TWINZ	136	110.2	125.6	15.4	14.00%
CYYZ	1900	YWT	61	90.9	103.6	12.7	13.90%
ATL	0	LOGEN	114	80	91	11	13.80%
ATL	2200	DALAS	164	110.7	125.1	14.5	13.10%
MSP	1800	SHONN	94	137.1	154.8	17.8	13.00%
MSP	1700	SHONN	74	142.3	160.8	18.5	13.00%
ATL	1800	LOGEN	195	81.3	91.9	10.6	13.00%
CYYZ	1800	LINNG	53	97.2	109.6	12.4	12.70%
MSP	200	SHONN	72	165.9	186.7	20.8	12.50%
SEA	1900	OLM	59	96.1	108	11.9	12.40%
ATL	2100	LOGEN	124	96.1	108	11.9	12.40%
CYYZ	2200	YWT	51	86.3	96.7	10.4	12.10%
IAH	1900	CUGAR	99	106.5	119.1	12.6	11.80%
CYYZ	2000	YWT	57	115.9	129.4	13.5	11.60%
LGA	1900	LIZZI	61	93.7	104.1	10.4	11.10%
LAX	0	CIVET	82	182	202	20	11.00%
ATL	0	DALAS	179	107.4	119.1	11.7	10.90%
ATL	1400	LOGEN	159	92.9	102.9	10	10.70%
IAH	1900	DAS2	97	135.7	149.6	13.9	10.30%
MSP	1800	TWINZ	81	103.7	114.1	10.4	10.00%
BOS	0	PVD	65	112.4	123	10.5	9.40%
PHL	2000	BUNTS	134	121.9	133.1	11.2	9.20%
ATL	1800	DALAS	135	115.3	125.7	10.4	9.00%
TPA	2100	DADES	48	133.9	146	12.1	9.00%
ATL	2300	DALAS	61	139.6	151.5	11.9	8.50%
SEA	1900	RADDY	52	155.9	167.9	12	7.70%
EWR	2200	PENNS	142	146.6	157	10.4	7.10%
EWR	1900	PENNS	86	168.5	180.4	11.9	7.00%
SEA	1800	RADDY	85	169.5	180.1	10.6	6.30%
EWR	2100	PENNS	49	163.2	173.3	10.2	6.20%
EWR	2000	PENNS	110	172.3	182.4	10	5.80%
SFO	100	CEDES	76	273	286.6	13.7	5.00%

Worst AirTime Performances for Sept. 20-26, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations (Air time delay >= 10 minutes) for Flights with >= 48 flights

Arrival Airport	Sched Arr Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned AirTime (mins)	Actual AirTime (mins)	Difference (Actual - Planned) AirTime (mins)	Percent AirTime Increase (Difference/ Planned)
MSP	2200	ZIBBY	58	63.8	84.8	21	33.00%
MSP	1900	TWINZ	48	70.1	89.5	19.4	27.70%
ATL	2000	TIROE	102	71.8	91.5	19.8	27.50%
MSP	1700	ZIBBY	69	68.4	86	17.6	25.80%
MSP	2100	TWINZ	62	79.3	99.1	19.8	25.00%
ATL	2000	HUSKY	91	60	74.9	14.9	24.70%
MSP	2200	TWINZ	74	81.6	101.4	19.8	24.20%
MSP	2200	OLLEE	59	76.5	94.4	17.9	23.40%
MSP	1500	ZIBBY	93	90.2	109.7	19.5	21.60%
MSP	1300	TWINZ	80	84.6	102.4	17.8	21.00%
MSP	1800	ZIBBY	59	89.4	108.2	18.8	21.00%
MSP	0	ZIBBY	81	96.4	116.6	20.2	20.90%
ATL	2000	LOGEN	127	81.2	98.1	16.8	20.70%
ATL	1500	HUSKY	61	49.1	59.3	10.1	20.60%
MSP	2000	ZIBBY	85	95.7	114.8	19.1	20.00%
MSP	0	TWINZ	161	101.1	121.2	20.1	19.90%
IAD	2000	BARIN	81	73.6	88	14.4	19.60%
MSP	1300	ZIBBY	53	71.7	85.5	13.8	19.20%
MSP	1500	TWINZ	111	100.6	118.7	18.1	18.00%
MSP	1800	TWINZ	53	96.1	112.9	16.8	17.50%
ATL	2200	HUSKY	101	64	74.8	10.7	16.80%
BOS	1300	PVD	49	67.2	78.2	11	16.30%
ATL	1600	TIROE	121	63.4	73.5	10.1	15.90%
ATL	0	HUSKY	59	68.2	79	10.8	15.90%
ATL	2200	TIROE	139	72.9	84.4	11.5	15.80%
ATL	0	TIROE	91	72.7	84.1	11.4	15.70%
MSP	2000	TWINZ	90	111.8	129	17.2	15.40%
BOS	1500	PVD	55	74.2	85.4	11.2	15.10%
ATL	1500	LOGEN	99	72.8	83.2	10.4	14.30%
ATL	2000	DALAS	143	112.5	127.7	15.3	13.60%
MSP	2200	SHONN	94	133.1	151.1	18.1	13.60%
ATL	1900	TIROE	48	82.1	93.1	11.1	13.50%
ATL	1300	LOGEN	135	87	98.6	11.6	13.40%
ATL	1900	LOGEN	82	112.1	126.5	14.4	12.80%
ATL	1800	LOGEN	151	87.4	97.9	10.5	12.00%
MSP	1800	SHONN	66	124.8	139.5	14.7	11.80%
ATL	2200	DALAS	116	104.8	116.9	12.1	11.50%
BOS	1400	PVD	72	95.8	106.5	10.8	11.20%
EWR	2200	RBV	57	109.8	121.8	12	11.00%
ATL	0	DALAS	125	101.2	112.3	11.1	11.00%
EWR	1800	RBV	86	104.8	116.2	11.5	10.90%
EWR	2300	RBV	51	115.3	127.2	12	10.40%

MSP	1700	SHONN	53	143.5	157.9	14.5	10.10%
CYYZ	2000	YWT	52	112.9	124.1	11.2	9.90%

Worst AirTime Performances for Oct. 4-10, 1999, by Arrival Airport, Scheduled Arrival Bin, Arrival Fix Combinations (Air time delay >= 10 minutes) for Flights with >= 48 flights

Arrival Airport	Sched Arr Bin (Z)	Arrival Fix (filed)	Number of Flights	Planned AirTime (mins)	Actual AirTime (mins)	Difference (Actual - Planned) AirTime (mins)	Percent AirTime Increase (Difference/ Planned)
LAX	1700	VTU	52	27.7	39.3	11.6	41.90%
ATL	1300	DALAS	126	78.3	106.2	27.9	35.60%
LAX	2100	VTU	52	35.6	47.7	12.1	33.90%
ATL	1300	HUSKY	68	68.5	89.1	20.7	30.20%
LAX	1400	VTU	62	40.1	51.8	11.7	29.10%
MSP	1100	OLLEE	65	56.2	71.7	15.5	27.60%
ATL	1300	LOGEN	212	91.9	115.3	23.5	25.50%
MSP	2200	OLLEE	79	77	96.3	19.3	25.10%
MSP	2200	ZIBBY	67	69.2	86.2	17	24.60%
ATL	1300	TIROE	123	74.8	92.8	18.1	24.20%
ATL	1900	HUSKY	59	59.8	74.2	14.3	23.90%
ATL	2000	TIROE	125	65.1	80.3	15.2	23.40%
ATL	1500	HUSKY	78	53.6	65.8	12.1	22.60%
ATL	1200	TIROE	86	51.7	63.2	11.5	22.30%
MSP	1700	ZIBBY	98	69.4	84.8	15.4	22.30%
ATL	1500	LOGEN	152	76.9	93.7	16.7	21.80%
MSP	1700	OLLEE	71	85.9	104.6	18.7	21.80%
MSP	2100	TWINZ	72	78.9	95.5	16.6	21.00%
MSP	200	ZIBBY	49	59.1	71.2	12.2	20.60%
ATL	1500	DALAS	66	68.2	82.3	14	20.60%
ATL	1100	TIROE	48	50.9	61.3	10.4	20.40%
MSP	1900	TWINZ	58	80.3	96.7	16.4	20.40%
ATL	2200	HUSKY	133	67.9	81.7	13.8	20.30%
ATL	2000	LOGEN	148	80.5	96.8	16.3	20.20%
MSP	1500	ZIBBY	139	90.2	108.2	18.1	20.00%
ATL	1200	DALAS	71	60.2	72.1	12	19.90%
MSP	1300	ZIBBY	69	70.2	83.7	13.4	19.10%
ATL	1400	HUSKY	87	66.6	79.3	12.7	19.10%
ATL	2000	HUSKY	113	71.2	84.5	13.3	18.80%
MSP	1800	ZIBBY	73	89.5	106	16.5	18.50%
MSP	0	ZIBBY	120	102.3	121.2	18.9	18.40%
IAD	1200	ROBRT	182	55.7	65.8	10.1	18.20%
CYYZ	2200	LINNG	63	68	80.1	12.1	17.90%
ATL	1100	LOGEN	112	59.6	70	10.5	17.60%
ATL	1200	HUSKY	139	62.3	73.1	10.8	17.30%
ATL	1400	TIROE	78	62.6	73.3	10.7	17.20%
MSP	2000	ZIBBY	118	99.4	116.5	17.1	17.20%
ATL	1600	TIROE	165	65.9	77.1	11.3	17.10%
CYYZ	1400	LINNG	60	77.4	90.7	13.3	17.10%
IAD	0	ROBRT	97	58.8	68.8	10	17.00%
MSP	1400	TWINZ	61	97.9	114.2	16.3	16.70%
MSP	1300	TWINZ	133	88	102.4	14.4	16.40%

LGA	2300	LIZZI	48	81.6	94.7	13.1	16.10%
ATL	1400	LOGEN	137	93.3	108.3	15	16.10%
ATL	0	HUSKY	77	67.7	78.4	10.7	15.90%
MSP	2200	TWINZ	93	90.5	104.9	14.4	15.90%
ATL	1600	HUSKY	119	70.8	81.8	11	15.60%
MSP	0	TWINZ	192	106	122.4	16.3	15.40%
ATL	1600	LOGEN	143	77.9	89.8	11.9	15.30%
ATL	2200	LOGEN	158	78.6	90.5	11.9	15.20%
ATL	2100	LOGEN	111	98.5	113.2	14.6	14.80%
ATL	2200	TIROE	155	68.1	78	10	14.70%
PHL	1600	BUNTS	115	71	81.1	10.2	14.30%
MSP	1800	TWINZ	64	95.9	109.6	13.7	14.30%
ATL	1600	DALAS	173	85.8	97.8	12	14.00%
MSP	1800	SHONN	90	125.9	143.5	17.6	14.00%
ATL	1400	DALAS	76	78.5	89.2	10.7	13.60%
ATL	1200	LOGEN	147	77.7	88.3	10.6	13.60%
MSP	2200	SHONN	112	129.9	147.5	17.6	13.50%
MSP	1200	TWINZ	58	100.3	113.6	13.3	13.30%
PHL	1300	TERRI	54	88.8	100.5	11.8	13.30%
LGA	1400	LIZZI	61	82.8	93.8	10.9	13.20%
MSP	1700	SHONN	62	141.2	159.7	18.6	13.20%
BOS	2000	PVD	67	79.6	89.9	10.3	13.00%
CYYZ	1800	LINNG	57	98.1	110.7	12.6	12.80%
ATL	2000	DALAS	161	91	102.7	11.7	12.80%
SEA	1400	JAKSN	52	80.9	91.2	10.3	12.70%
MSP	1100	SHONN	48	140.5	158	17.6	12.50%
MSP	1500	TWINZ	146	109.7	122.8	13	11.90%
LGA	2100	LIZZI	60	89.5	100.1	10.6	11.80%
BOS	1800	PVD	96	93.7	104.7	11	11.70%
BOS	2100	PVD	94	87.5	97.6	10.1	11.60%
PHL	2200	BUNTS	130	94.6	105.5	10.8	11.50%
ATL	1800	LOGEN	199	91.1	101.4	10.4	11.40%
MSP	2000	TWINZ	113	120.1	133.6	13.5	11.20%
BOS	1900	PVD	87	107.3	119.2	11.9	11.10%
LGA	1900	LIZZI	64	92.1	102.2	10.2	11.00%
ATL	1900	LOGEN	141	112.4	124.6	12.2	10.90%
ATL	2200	DALAS	158	110.8	122.7	11.9	10.80%
CYYZ	1900	YWT	55	96.7	106.9	10.2	10.60%
PHL	2100	BUNTS	71	100.2	110.3	10.2	10.10%
EWR	1900	RBV	72	117.1	128.7	11.5	9.90%
LGA	2000	LIZZI	48	114.7	124.9	10.1	8.80%
CYYZ	2000	YWT	49	124.2	135	10.7	8.60%
BOS	1900	LOBBY	57	140.5	151.4	11	7.80%
BOS	2100	LOBBY	59	150.8	162.5	11.7	7.80%
SFO	2100	PYE	56	136.6	146.7	10.1	7.40%
EWR	2100	PENNS	60	150.6	161.2	10.6	7.00%
ATL	1900	DALAS	99	149.4	159.8	10.4	7.00%
EWR	2000	PENNS	133	159.4	169.9	10.5	6.60%
EWR	1900	PENNS	73	174.9	185.9	11	6.30%
SEA	1900	RADDY	53	165.3	175.6	10.2	6.20%

APPENDIX E

Worst Cases in Terms of Circular Holding for Different Time Periods

(Top 20 groupings for each time period studied)

April 24-30, 1999

ARR_APRT	Sch_ArrBin	ARRIVAL_FIX	Num Held	Total	% Held	Avg_PAirTime-held	Avg_AAirTime-Held	Airtime_Delay-Held	Airtime_Delay_%-Held
ATL	20:00	LOGEN	82	169	48.5%	83	125	42	50.6%
ATL	20:00	DALAS	80	213	37.6%	118	151	33	28.0%
ATL	20:00	HUSKY	60	136	44.1%	66	104	38	57.6%
ATL	13:00	LOGEN	59	191	30.9%	95	121	26	27.4%
ATL	20:00	TIROE	53	138	38.4%	80	117	37	46.3%
ATL	19:00	LOGEN	43	135	31.9%	157	188	31	19.7%
ATL	22:00	TIROE	41	162	25.3%	93	124	31	33.3%
ATL	13:00	DALAS	36	114	31.6%	93	113	20	21.5%
ATL	0:00	DALAS	36	144	25.0%	119	150	31	26.1%
ATL	22:00	LOGEN	35	205	17.1%	79	123	44	55.7%
ATL	21:00	LOGEN	32	109	29.4%	106	141	35	33.0%
ATL	22:00	DALAS	32	151	21.2%	108	142	34	31.5%
IAH	13:00	CUGAR	29	64	45.3%	81	108	27	33.3%
ATL	18:00	LOGEN	26	216	12.0%	85	119	34	40.0%
ATL	22:00	HUSKY	25	137	18.2%	78	117	39	50.0%
STL	18:00	VLA	25	145	17.2%	83	103	20	24.1%
STL	19:00	TRAKE	24	131	18.3%	128	145	17	13.3%
STL	17:00	TRAKE	23	79	29.1%	130	151	21	16.2%
ATL	0:00	TIROE	23	94	24.5%	97	123	26	26.8%

July 12-18, 1999

ARR_APRT	Sch_ArrBin	ARRIVAL_FIX	Num Held	Total	% Held	Avg_PAirTime-held	Avg_AAirTime-Held	Airtime_Delay-Held	Airtime_Delay_%-Held
ATL	20:00	DALAS	60	227	26.4%	121	158	37	30.6%
ATL	20:00	LOGEN	54	135	40.0%	77	115	38	49.4%
ATL	22:00	LOGEN	48	184	26.1%	77	109	32	41.6%
ATL	20:00	TIROE	46	145	31.7%	70	107	37	52.9%
ATL	13:00	TIROE	43	140	30.7%	84	108	24	28.6%
ATL	20:00	HUSKY	42	147	28.6%	60	98	38	63.3%
ATL	13:00	DALAS	40	130	30.8%	84	108	24	28.6%
ATL	22:00	HUSKY	37	156	23.7%	77	107	30	39.0%
ATL	13:00	LOGEN	36	191	18.8%	94	122	28	29.8%
IAH	19:00	DAS2	32	97	33.0%	135	169	34	25.2%
ATL	22:00	TIROE	32	152	21.1%	75	107	32	42.7%
ATL	22:00	DALAS	31	164	18.9%	125	156	31	24.8%
IAH	19:00	CUGAR	30	99	30.3%	131	161	30	22.9%
ATL	0:00	DALAS	28	179	15.6%	122	155	33	27.0%
CLE	15:00	CXR	25	103	24.3%	75	94	19	25.3%
ATL	13:00	HUSKY	24	78	30.8%	70	97	27	38.6%
ATL	15:00	LOGEN	22	153	14.4%	-3	111	114	-3800.0%
MSP	0:00	TWINZ	22	179	12.3%	109	140	31	28.4%
CLE	15:00	KEATN	21	57	36.8%	66	91	25	37.9%
ATL	23:00	LOGEN	20	119	16.8%	88	123	35	39.8%

Sept. 20-26, 1999

ARR_APRT	Sch_ArrBin	ARRIVAL_FIX	Num Held	Total	% Held	Avg_PAirTime-held	Avg_AAirTime-Held	Airtime_Delay-Held	Airtime_Delay_%-Held
ATL	20:00	TIROE	40	102	39.2%	84	115	31	36.9%
ATL	20:00	LOGEN	33	127	26.0%	89	125	36	40.4%
ATL	20:00	DALAS	26	143	18.2%	105	146	41	39.0%
ATL	13:00	LOGEN	21	135	15.6%	92	117	25	27.2%
CLE	15:00	KEATN	20	37	54.1%	66	88	22	33.3%
ATL	20:00	HUSKY	19	91	20.9%	68	98	30	44.1%
ATL	22:00	DALAS	18	116	15.5%	115	140	25	21.7%
CLE	15:00	CXR	17	93	18.3%	78	94	16	20.5%
ATL	0:00	DALAS	17	125	13.6%	99	125	26	26.3%
ATL	22:00	TIROE	16	139	11.5%	91	123	32	35.2%
ATL	13:00	DALAS	15	96	15.6%	87	106	19	21.8%
ATL	16:00	LOGEN	14	109	12.8%	68	97	29	42.6%
ATL	22:00	LOGEN	13	133	9.8%	86	110	24	27.9%
BOS	14:00	PVD	13	72	18.1%	90	114	24	26.7%
LAX	18:00	CIVET	12	166	7.2%	240	264	24	10.0%
BOS	16:00	PVD	12	61	19.7%	93	111	18	19.4%
CLE	15:00	WAKEM	12	58	20.7%	81	102	21	25.9%
CYYZ	20:00	YWT	12	52	23.1%	114	136	22	19.3%
PHX	2:00	ARLIN	11	66	16.7%	59	77	18	30.5%
ATL	16:00	DALAS	11	125	8.8%	94	121	27	28.7%

Oct. 4-10, 1999

ARR_APRT	Sch_ArrBin	ARRIVAL_FIX	Num Held	Total	% Held	Avg_PAirTime-held	Avg_AAirTime-Held	Airtime_Delay-Held	Airtime_Delay_%-Held
ATL	13:00	LOGEN	83	212	39.2%	99	134	35	35.4%
ATL	13:00	DALAS	76	126	60.3%	87	126	39	44.8%
ATL	13:00	TIROE	50	123	40.7%	81	112	31	38.3%
ATL	20:00	TIROE	39	125	31.2%	64	90	26	40.6%
ATL	20:00	LOGEN	37	148	25.0%	82	112	30	36.6%
ATL	16:00	DALAS	36	173	20.8%	94	124	30	31.9%
MSP	0:00	TWINZ	35	194	18.0%	108	136	28	25.9%
ATL	22:00	DALAS	31	158	19.6%	128	151	23	18.0%
BOS	20:00	LOBBY	30	92	32.6%	195	218	23	11.8%
ATL	13:00	HUSKY	27	68	39.7%	81	114	33	40.7%
ATL	20:00	HUSKY	27	113	23.9%	59	85	26	44.1%
ATL	22:00	HUSKY	27	133	20.3%	83	110	27	32.5%
ATL	15:00	LOGEN	26	152	17.1%	83	114	31	37.3%
ATL	16:00	LOGEN	26	143	18.2%	91	119	28	30.8%
STL	15:00	QBALL	26	150	17.3%	104	123	19	18.3%
BOS	19:00	PVD	23	87	26.4%	126	157	31	24.6%
ATL	20:00	DALAS	22	161	13.7%	85	112	27	31.8%
ORD	19:00	KRENA	21	113	18.6%	89	115	26	29.2%
BOS	21:00	LOBBY	21	59	35.6%	147	170	23	15.6%
BOS	21:00	PVD	21	94	22.3%	80	100	20	25.0%

APPENDIX F

Additional Significant Reroute Results

Rerouted flights by centers along filed flight route between 7/12/99 and 7/18/99

Center	rerouted	Total	Percent
ZPA	1459	2176	67.0%
ZAN	3412	5753	59.3%
CZV	4795	8248	58.1%
ZSU	2667	4598	58.0%
CZE	3868	7133	54.2%
CZU	4565	8857	51.5%
CZW	3177	6169	51.5%
CZY	6415	14349	44.7%
ZEU	10784	24502	44.0%
ZLA	16074	37495	42.9%
ZMA	11440	27158	42.1%
ZBW	16107	38456	41.9%
ZFW	15682	38302	40.9%
ZHU	12987	32016	40.6%
ZJX	15620	38525	40.5%
ZSE	8678	21468	40.4%
ZNY	23936	61902	38.7%
ZAB	9633	25693	37.5%
ZOA	9258	26107	35.5%
CZM	2602	7422	35.1%
ZSA	3758	10845	34.7%
ZLC	7606	22867	33.3%
ZTL	17352	53150	32.6%
ZDV	9472	29392	32.2%
ZDC	18893	58725	32.2%
ZME	12303	39508	31.1%
ZMP	11176	37405	29.9%
ZKC	11386	38242	29.8%
ZHN	241	843	28.6%
ZID	13746	48968	28.1%
ZAU	14554	51872	28.1%
CZX	1098	3942	27.9%
ZOB	15639	57402	27.2%

Rerouted flights by en route sectors along filed flight route (top/bottom 100 CONUS sectors) between 7/12/99 and 7/18/99

Top 100					Bottom 100			
Sector	Rereouted	Total	% Rerouted		Sector	Rereouted	Total	% Rerouted
ZMA38	471	636	74.1%		ZAU81	538	4093	13.1%
ZSE33	279	396	70.5%		ZAU82	592	4310	13.7%
ZSE03	1778	2587	68.7%		ZME07	355	2246	15.8%
ZFW34	765	1151	66.5%		ZDC05	474	2926	16.2%
ZNY00	83	125	66.4%		ZOB28	536	3285	16.3%
ZMP80	101	156	64.7%		ZSE18	262	1588	16.5%
ZFW23	213	330	64.5%		ZKC58	535	3176	16.8%
ZHU58	1103	1769	62.4%		ZLA25	433	2558	16.9%
ZMA03	443	711	62.3%		ZOB11	498	2905	17.1%
ZMA39	875	1421	61.6%		ZOB62	350	1973	17.7%
ZFW64	615	1020	60.3%		ZKC72	251	1386	18.1%
ZFW36	973	1654	58.8%		ZDV07	427	2332	18.3%
ZFW25	341	580	58.8%		ZOA12	351	1887	18.6%
ZMA45	246	420	58.6%		ZAU56	423	2263	18.7%
ZLA06	1530	2635	58.1%		ZOA21	260	1371	19.0%
ZBW06	1715	2974	57.7%		ZKC44	74	389	19.0%
ZLA13	1496	2611	57.3%		ZKC40	467	2449	19.1%
ZMA63	895	1576	56.8%		ZOB27	845	4351	19.4%
ZMA34	821	1446	56.8%		ZOB35	349	1792	19.5%
ZMA04	448	796	56.3%		ZOB47	859	4373	19.6%
ZSE12	917	1630	56.3%		ZKC32	571	2877	19.8%
ZNY70	126	224	56.3%		ZAU14	75	375	20.0%
ZMA26	571	1018	56.1%		ZID80	946	4698	20.1%
ZFW62	1027	1837	55.9%		ZMP33	366	1816	20.2%
ZLA16	1270	2278	55.8%		ZHU79	179	886	20.2%
ZMA66	233	420	55.5%		ZAU90	471	2330	20.2%
ZFW24	159	289	55.0%		ZOB46	828	4069	20.3%
ZFW53	1342	2469	54.4%		ZME42	413	2006	20.6%
ZMP13	1143	2105	54.3%		ZKC12	923	4483	20.6%
ZOA42	873	1616	54.0%		ZOB14	414	1995	20.8%
ZNY51	909	1685	53.9%		ZAU92	659	3145	21.0%
ZBW53	979	1817	53.9%		ZAU36	809	3825	21.2%
ZMP34	1037	1929	53.8%		ZAU77	655	3059	21.4%
ZFW97	197	368	53.5%		ZOB15	606	2816	21.5%
ZBW05	1285	2411	53.3%		ZBW17	442	2050	21.6%
ZSE30	443	832	53.2%		ZAU80	477	2211	21.6%
ZMA07	549	1037	52.9%		ZAU85	445	2059	21.6%
ZHU92	488	922	52.9%		ZOB57	639	2956	21.6%
ZBW47	1904	3610	52.7%		ZOB48	919	4244	21.7%
ZMP12	1299	2486	52.3%		ZME15	560	2577	21.7%
ZHU83	1492	2857	52.2%		ZMP05	386	1774	21.8%
ZMP25	1066	2042	52.2%		ZAU55	441	2023	21.8%
ZBW52	1245	2398	51.9%		ZOB49	1278	5834	21.9%
ZHU56	609	1180	51.6%		ZAU33	560	2538	22.1%
ZMA59	806	1571	51.3%		ZOB77	968	4381	22.1%
ZNY67	1066	2080	51.3%		ZKC50	330	1489	22.2%
ZBW20	2121	4139	51.2%		ZOB10	354	1588	22.3%
ZHU53	727	1421	51.2%		ZOB41	529	2372	22.3%
ZBW15	913	1792	50.9%		ZOB40	658	2930	22.5%

Top 100					Bottom 100			
Sector	Rereouted	Total	% Rerouted		Sector	Rereouted	Total	% Rerouted
ZJX10	845	1678	50.4%		ZOA14	673	2982	22.6%
ZFW26	223	443	50.3%		ZTL30	514	2265	22.7%
ZHU84	342	681	50.2%		ZOB21	644	2835	22.7%
ZMA47	838	1674	50.1%		ZAU73	716	3144	22.8%
ZBW21	983	1967	50.0%		ZMP37	293	1283	22.8%
ZJX00	1041	2084	50.0%		ZME40	356	1557	22.9%
ZMA01	954	1910	49.9%		ZID87	1229	5374	22.9%
ZMA24	903	1812	49.8%		ZLC51	41	179	22.9%
ZFW65	1184	2387	49.6%		ZKC74	472	2056	23.0%
ZLA38	1724	3498	49.3%		ZOB32	619	2695	23.0%
ZFW38	1079	2190	49.3%		ZOB29	826	3594	23.0%
ZJX57	1145	2328	49.2%		ZDV15	324	1405	23.1%
ZNY68	1376	2819	48.8%		ZDV08	597	2586	23.1%
ZJX75	1195	2456	48.7%		ZID33	817	3513	23.3%
ZMA67	941	1944	48.4%		ZID31	637	2733	23.3%
ZAB21	241	501	48.1%		ZMP26	484	2072	23.4%
ZSE13	908	1893	48.0%		ZME14	570	2432	23.4%
ZFW75	1309	2732	47.9%		ZDC15	684	2913	23.5%
ZBW09	1173	2459	47.7%		ZOB71	543	2279	23.8%
ZAB45	486	1020	47.6%		ZAU27	721	3020	23.9%
ZMA64	920	1937	47.5%		ZID98	1435	6008	23.9%
ZBW39	1627	3431	47.4%		ZAU64	305	1276	23.9%
ZAB43	1137	2398	47.4%		ZMP39	1209	5035	24.0%
ZAB42	1220	2592	47.1%		ZMP03	377	1570	24.0%
ZFW20	141	301	46.8%		ZAB78	329	1370	24.0%
ZAB37	935	2001	46.7%		ZDV67	410	1706	24.0%
ZOA13	1776	3805	46.7%		ZAU37	472	1961	24.1%
ZLA60	1051	2253	46.6%		ZME01	333	1382	24.1%
ZJX52	994	2133	46.6%		ZDC27	616	2552	24.1%
ZFW63	596	1279	46.6%		ZNY81	161	666	24.2%
ZDV42	328	705	46.5%		ZDV09	679	2805	24.2%
ZJX11	870	1881	46.3%		ZKC52	403	1653	24.4%
ZBW01	1215	2628	46.2%		ZOB64	610	2498	24.4%
ZDV12	655	1417	46.2%		ZTL48	285	1166	24.4%
ZJX17	1722	3733	46.1%		ZAU94	857	3496	24.5%
ZHU87	927	2013	46.1%		ZAU46	863	3513	24.6%
ZAU41	444	966	46.0%		ZOB12	568	2311	24.6%
ZOA22	711	1561	45.5%		ZOB70	180	732	24.6%
ZLA18	1200	2641	45.4%		ZOB67	924	3756	24.6%
ZNY88	308	678	45.4%		ZID88	1298	5274	24.6%
ZBW08	881	1940	45.4%		ZAU47	312	1266	24.6%
ZFW98	129	285	45.3%		ZOB61	547	2201	24.9%
ZHU72	194	429	45.2%		ZID99	779	3133	24.9%
ZSE32	1226	2717	45.1%		ZKC49	237	952	24.9%
ZOA15	1547	3429	45.1%		ZHU36	307	1233	24.9%
ZFW49	1298	2878	45.1%		ZTL05	747	2996	24.9%
ZHU59	880	1955	45.0%		ZSE09	486	1946	25.0%
ZMA60	1029	2287	45.0%		ZBW18	528	2114	25.0%
ZNY90	288	647	44.5%		ZME05	297	1189	25.0%
ZOB24	765	1721	44.5%		ZOB66	1411	5629	25.1%
ZNY99	72	162	44.4%		ZOB30	679	2707	25.1%

Rerouted flights by airways along filed flight route (top/bottom 50) between 7/12/99 and 7/18/99

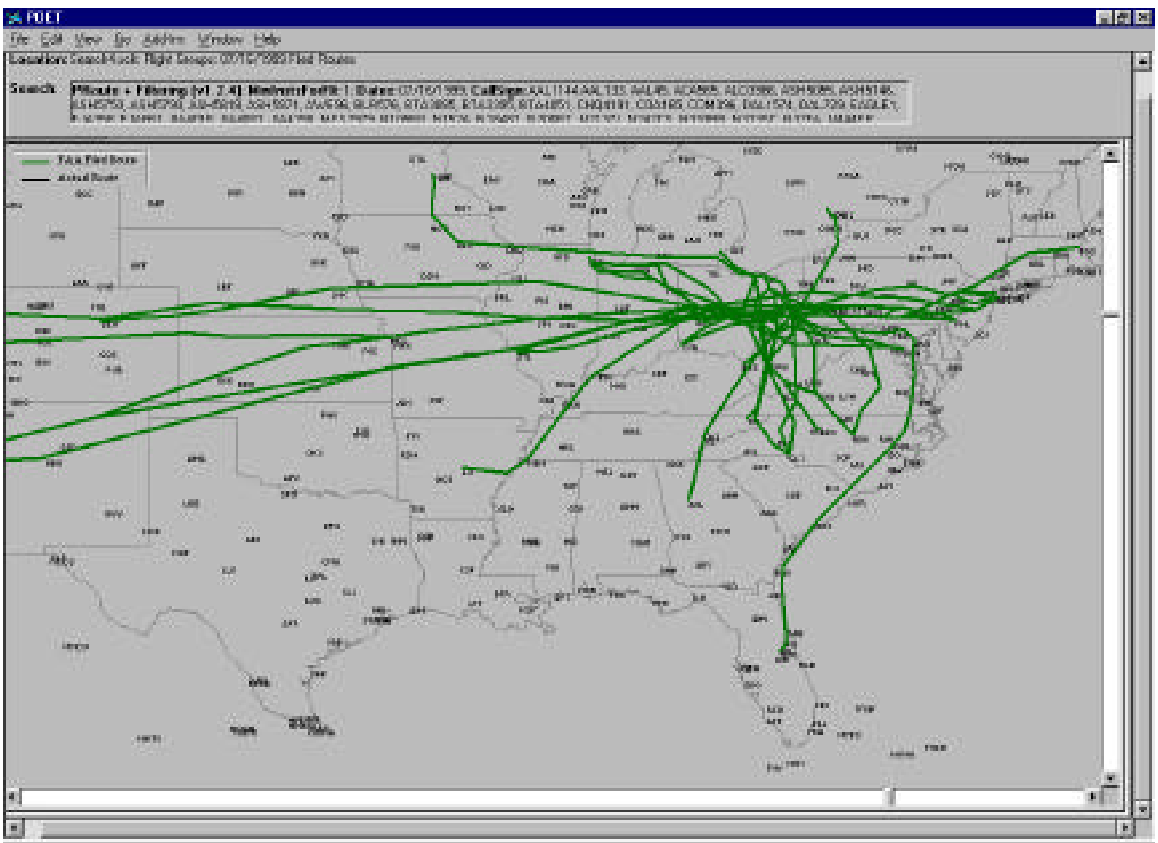
Airway	rerouted	Total	% rerouted		Airway	rerouted	Total	% rerouted
J889R	96	103	93.2%		G9	3	172	1.7%
V153	73	81	90.1%		J178	28	308	9.1%
V215	75	84	89.3%		J93	45	431	10.4%
V385	229	259	88.4%		V412	9	85	10.6%
V102	179	207	86.5%		J188	22	181	12.2%
J502	212	249	85.1%		V90	19	149	12.8%
J195	94	111	84.7%		V172	84	639	13.1%
V585	147	174	84.5%		V173	39	281	13.9%
J548	130	155	83.9%		V534	16	115	13.9%
V571	105	127	82.7%		V124	52	368	14.1%
J133	687	834	82.4%		V488	15	106	14.2%
J483	88	107	82.2%		V397	10	70	14.3%
J478	57	72	79.2%		J518	146	1017	14.4%
J570	213	270	78.9%		V88	52	360	14.4%
V355	55	70	78.6%		G7	26	179	14.5%
V471	76	97	78.4%		J554	656	4447	14.8%
J563	71	91	78.0%		J232	55	369	14.9%
V273	337	432	78.0%		J585	49	325	15.1%
J153	60	78	76.9%		V430	31	205	15.1%
V91	597	784	76.1%		V42	41	270	15.2%
B37	69	92	75.0%		V564	24	144	16.7%
J524	249	339	73.5%		J156	51	301	16.9%
J587	85	117	72.6%		J149	244	1440	16.9%
A1	580	802	72.3%		J33	68	392	17.3%
J559	170	236	72.0%		J88	203	1130	18.0%
V230	71	99	71.7%		J130	137	760	18.0%
V46	417	586	71.2%		V291	26	143	18.2%
V300	394	555	71.0%		J213	189	1030	18.3%
V548	82	116	70.7%		J118	147	800	18.4%
J47	125	179	69.8%		J62	191	1036	18.4%
V587	620	889	69.7%		V526	375	2004	18.7%
V193	78	112	69.6%		J182	76	406	18.7%
J804R	80	115	69.6%		V120	337	1782	18.9%
J523	413	604	68.4%		V294	39	206	18.9%
V104	110	161	68.3%		J147	165	863	19.1%
J511	181	265	68.3%		V247	18	93	19.4%
J477	83	122	68.0%		V523	92	474	19.4%
V419	1057	1558	67.8%		V435	224	1151	19.5%
J505	59	87	67.8%		V190	129	654	19.7%
V167	697	1031	67.6%		V457	138	696	19.8%
V374	989	1464	67.6%		V144	113	569	19.9%
V109	214	319	67.1%		V330	48	240	20.0%
V137	134	200	67.0%		V80	16	80	20.0%
J531	483	730	66.2%		V536	89	443	20.1%
J503	71	108	65.7%		J162	194	964	20.1%
V487	600	914	65.6%		J584	772	3826	20.2%
J140	137	209	65.6%		R50	19	94	20.2%
V258	61	94	64.9%		V290	56	277	20.2%
V505	175	270	64.8%		J152	477	2347	20.3%
J115	289	447	64.7%		J575	74	363	20.4%

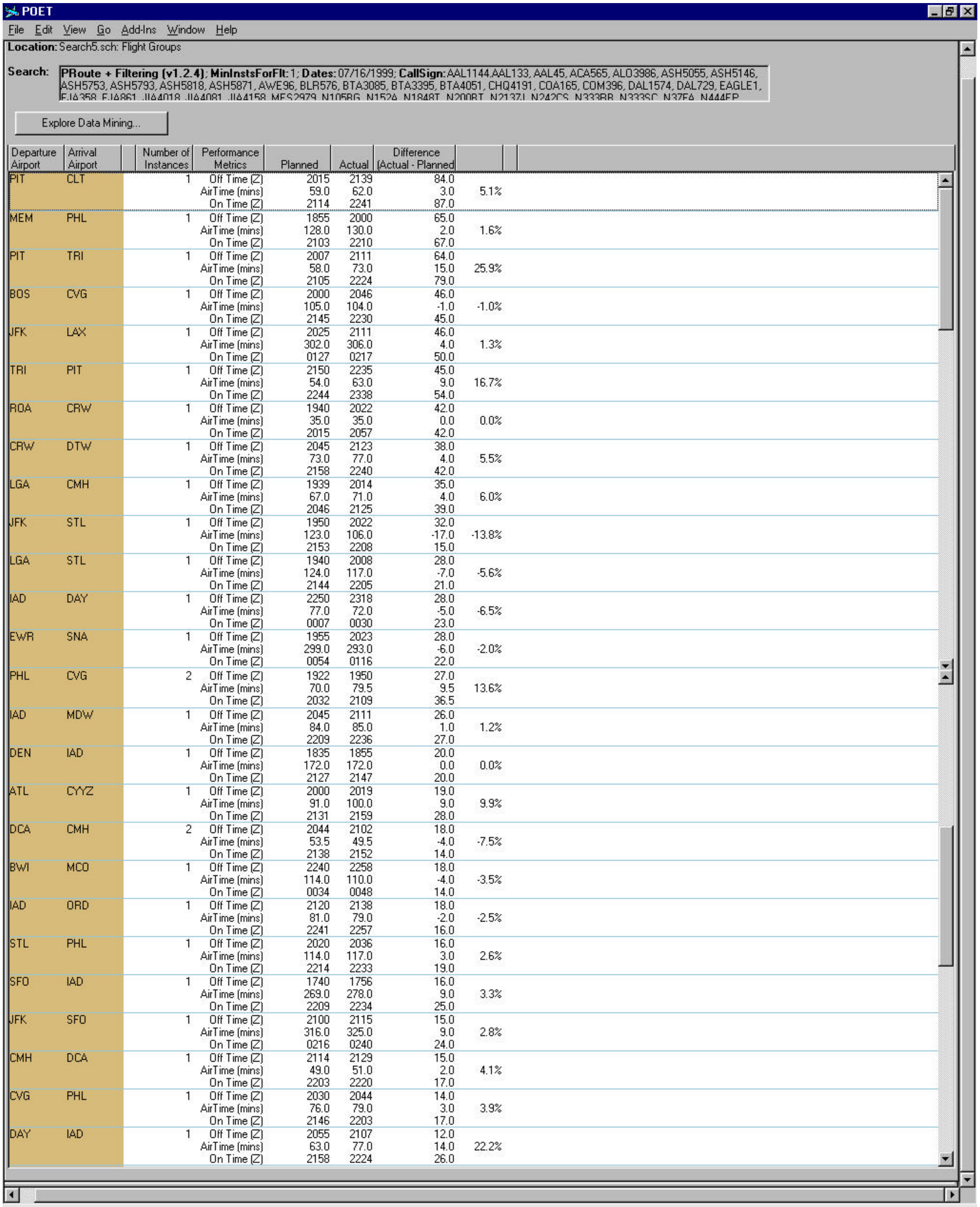
APPENDIX G

Additional Analyses to Identify Bottlenecks Associated with Jet Route Segments

Below are two other sample analyses that we conducted to identify jet route segments that appear to represent significant bottlenecks that result in routine departure delays.

Example 1. This example was detected by looking at flights filed into CVG along J80 scheduled to arrive from 2200-2300Z. The first figure shows the filed routes for the flights into CVG along with those that have routes that converge on J80 in the same timeframe. The second figures shows that, as expected, it is not just CVG that is getting the departure delays.





POET

File Edit View Go Add-Ins Window Help

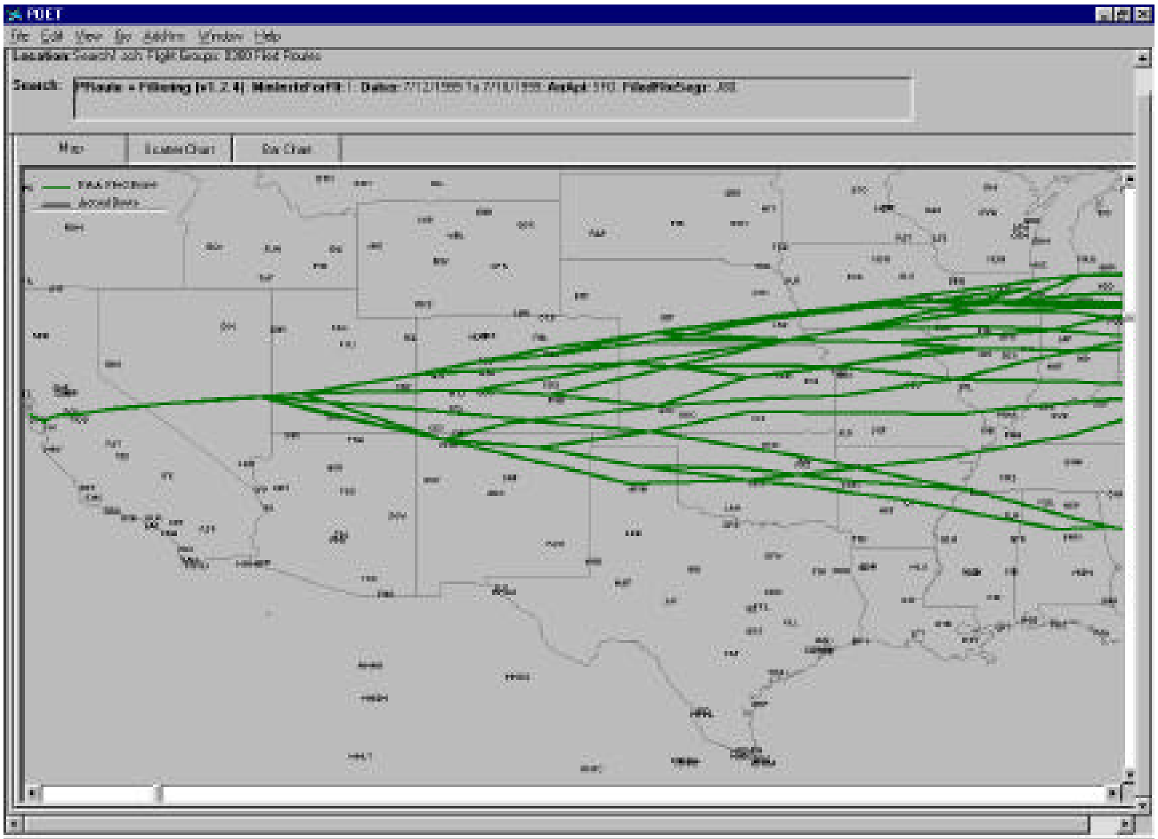
Location: Search5.sch: Flight Groups

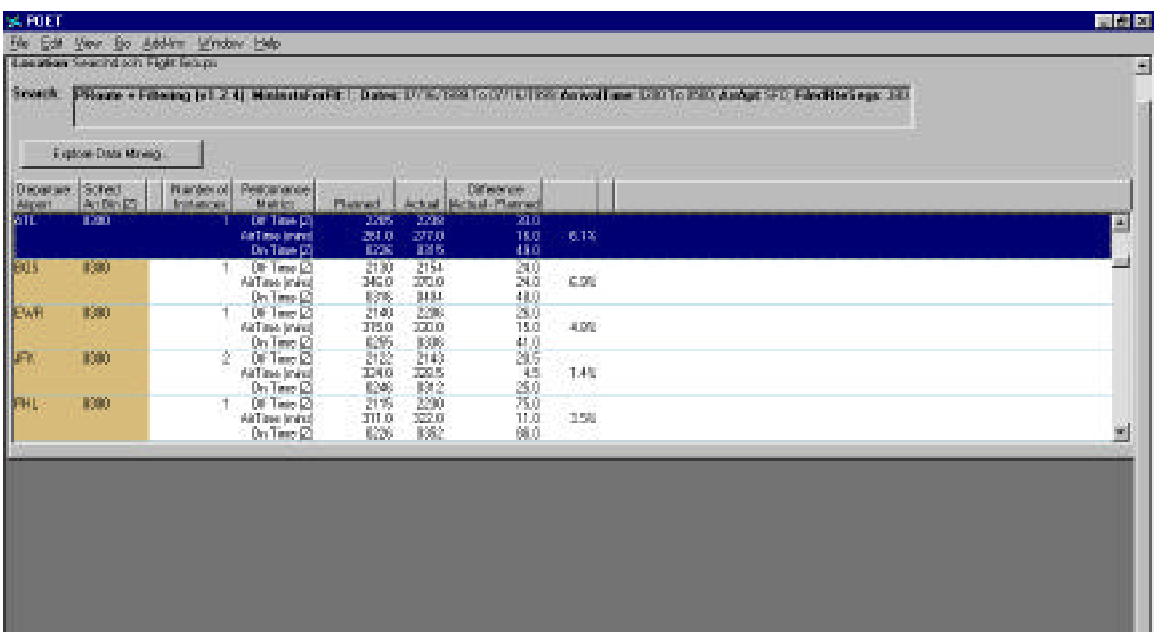
Search: **PRoute + Filtering (v1.2.4)**; **MinInstsForFlt:** 1; **Dates:** 07/16/1999; **CallSign:** AAL1144,AAL133, AAL45, ACA565, ALO3986, ASH5055, ASH5146, ASH5753, ASH5793, ASH5818, ASH5871, AWE96, BLR576, BTA3085, BTA3395, BTA4051, CHQ4191, COA165, COM396, DAL1574, DAL729, EAGLE1, EJA358, EJA861, JIA4018, JIA4081, JIA4158, MES2979, N105BG, N152A, N1848T, N200BT, N2137J, N242CS, N333BB, N333SC, N37FA, N444EP

Explore Data Mining...

Departure Airport	Arrival Airport	Number of Instances	Performance Metrics	Planned	Actual	Difference (Actual - Planned)	
PIT	CLT	1	Off Time (Z)	2015	2139	84.0	
			AirTime (mins)	59.0	62.0	3.0	5.1%
			On Time (Z)	2114	2241	87.0	
MEM	PHL	1	Off Time (Z)	1855	2000	65.0	
			AirTime (mins)	128.0	130.0	2.0	1.6%
			On Time (Z)	2103	2210	67.0	
PIT	TRI	1	Off Time (Z)	2007	2111	64.0	
			AirTime (mins)	58.0	73.0	15.0	25.9%
			On Time (Z)	2105	2224	79.0	
BOS	CVG	1	Off Time (Z)	2000	2046	46.0	
			AirTime (mins)	105.0	104.0	-1.0	-1.0%
			On Time (Z)	2145	2230	45.0	
JFK	LAX	1	Off Time (Z)	2025	2111	46.0	
			AirTime (mins)	302.0	306.0	4.0	1.3%
			On Time (Z)	0127	0217	50.0	
TRI	PIT	1	Off Time (Z)	2150	2235	45.0	
			AirTime (mins)	54.0	63.0	9.0	16.7%
			On Time (Z)	2244	2338	54.0	
ROA	CRW	1	Off Time (Z)	1940	2022	42.0	
			AirTime (mins)	35.0	35.0	0.0	0.0%
			On Time (Z)	2015	2057	42.0	
CRW	DTW	1	Off Time (Z)	2045	2123	38.0	
			AirTime (mins)	73.0	77.0	4.0	5.5%
			On Time (Z)	2158	2240	42.0	
LGA	CMH	1	Off Time (Z)	1939	2014	35.0	
			AirTime (mins)	67.0	71.0	4.0	6.0%
			On Time (Z)	2046	2125	39.0	
JFK	STL	1	Off Time (Z)	1950	2022	32.0	
			AirTime (mins)	123.0	106.0	-17.0	-13.8%
			On Time (Z)	2153	2208	15.0	
LGA	STL	1	Off Time (Z)	1940	2008	28.0	
			AirTime (mins)	124.0	117.0	-7.0	-5.6%
			On Time (Z)	2144	2205	21.0	
IAD	DAY	1	Off Time (Z)	2250	2318	28.0	
			AirTime (mins)	77.0	72.0	-5.0	-6.5%
			On Time (Z)	0007	0030	23.0	
EWR	SNA	1	Off Time (Z)	1955	2023	28.0	
			AirTime (mins)	299.0	293.0	-6.0	-2.0%
			On Time (Z)	0054	0116	22.0	
PHL	CVG	2	Off Time (Z)	1922	1950	27.0	
			AirTime (mins)	70.0	79.5	9.5	13.6%
			On Time (Z)	2032	2109	36.5	
IAD	MDW	1	Off Time (Z)	2045	2111	26.0	
			AirTime (mins)	84.0	85.0	1.0	1.2%
			On Time (Z)	2209	2236	27.0	
DEN	IAD	1	Off Time (Z)	1835	1855	20.0	
			AirTime (mins)	172.0	172.0	0.0	0.0%
			On Time (Z)	2127	2147	20.0	
ATL	CYYZ	1	Off Time (Z)	2000	2019	19.0	
			AirTime (mins)	91.0	100.0	9.0	9.9%
			On Time (Z)	2131	2159	28.0	
DCA	CMH	2	Off Time (Z)	2044	2102	18.0	
			AirTime (mins)	53.5	49.5	-4.0	-7.5%
			On Time (Z)	2138	2152	14.0	
BWI	MCO	1	Off Time (Z)	2240	2258	18.0	
			AirTime (mins)	114.0	110.0	-4.0	-3.5%
			On Time (Z)	0034	0048	14.0	
IAD	ORD	1	Off Time (Z)	2120	2138	18.0	
			AirTime (mins)	81.0	79.0	-2.0	-2.5%
			On Time (Z)	2241	2257	16.0	
STL	PHL	1	Off Time (Z)	2020	2036	16.0	
			AirTime (mins)	114.0	117.0	3.0	2.6%
			On Time (Z)	2214	2233	19.0	
SFO	IAD	1	Off Time (Z)	1740	1756	16.0	
			AirTime (mins)	269.0	278.0	9.0	3.3%
			On Time (Z)	2209	2234	25.0	
JFK	SFO	1	Off Time (Z)	2100	2115	15.0	
			AirTime (mins)	316.0	325.0	9.0	2.8%
			On Time (Z)	0216	0240	24.0	
CMH	DCA	1	Off Time (Z)	2114	2129	15.0	
			AirTime (mins)	49.0	51.0	2.0	4.1%
			On Time (Z)	2203	2220	17.0	
CVG	PHL	1	Off Time (Z)	2030	2044	14.0	
			AirTime (mins)	76.0	79.0	3.0	3.9%
			On Time (Z)	2146	2203	17.0	
DAY	IAD	1	Off Time (Z)	2055	2107	12.0	
			AirTime (mins)	63.0	77.0	14.0	22.2%
			On Time (Z)	2158	2224	26.0	

Example 2. This example was detected by looking at flights filed into SFO along J80 scheduled to arrive from 0300-0400Z. The first figure shows the filed routes for the flights into SFO along with those that have routes that converge on J80 in the same timeframe. This example is different than the previous one, in that the bottleneck is closer and is caused by flights all scheduled to the same arrival airport (SFO). The second figure below shows some examples of how the delays are spread among different originating airports with flights into SFO.





APPENDIX H

Partial listing of airport three-letter identifiers

Code	Airport Name	Location
ABY	SOUTHWEST GEORGIA REGIONAL	ALBANY,GEORGIA,USA
APF	NAPLES MUNI	NAPLES,FLORIDA,USA
ATL	THE WILLIAM B HARTSFIELD ATLANTA	ATLANTA,GEORGIA,USA
BFI	BOEING FIELD/KING COUNTY INTL	SEATTLE,WASHINGTON,USA
BFL	MEADOWS FIELD	BAKERSFIELD,CALIFORNIA,USA
BNA	NASHVILLE INTERNATIONAL	NASHVILLE,TENNESSEE,USA
BOS	GENERAL EDWARD LAWRENCE LOGAN	BOSTON,MASSACHUSETTS,USA
BUF	GREATER BUFFALO INTL	BUFFALO,NEW YORK,USA
BWI	BALTIMORE-WASHINGTON INTL	BALTIMORE,MARYLAND,USA
CLE	CLEVELAND-HOPKINS INTL	CLEVELAND,OHIO,USA
CLT	CHARLOTTE/DOUGLAS INTL	CHARLOTTE,NORTH CAROLINA,USA
CRP	CORPUS CHRISTI INTL	CORPUS CHRISTI,TEXAS,USA
CVG	CINCINNATI/NORTHERN KENTUCKY	COVINGTON/CINCINNATI,
CYYZ	LESTER B. PEARSON INTL	TORONTO,ONT,CANADA
DEN	DENVER INTL	DENVER,COLORADO,USA
DET	DETROIT CITY	DETROIT,MICHIGAN,USA
DTW	DETROIT METROPOLITAN WAYNE	DETROIT,MICHIGAN,USA
EUG	MAHLON SWEET FIELD	EUGENE,OREGON,USA
EWR	NEWARK INTL	NEWARK,NEW JERSEY,USA
FNT	BISHOP INTERNATIONAL	FLINT,MICHIGAN,USA
HRL	VALLEY INTL	HARLINGEN,TEXAS,USA
IAD	WASHINGTON DULLES INTERNATIONAL	WASHINGTON,DIST. OF
IAH	HOUSTON INTERCONTINENTAL	HOUSTON,TEXAS,USA
JAN	JACKSON INTERNATIONAL	JACKSON,MISSISSIPPI,USA
JFK	JOHN F KENNEDY INTL	NEW YORK,NEW YORK,USA
LAS	MC CARRAN INTL	LAS VEGAS,NEVADA,USA
LAX	LOS ANGELES INTL	LOS ANGELES,CALIFORNIA,USA
LBB	LUBBOCK INTL	LUBBOCK,TEXAS,USA
LGA	LA GUARDIA	NEW YORK,NEW YORK,USA
MCI	KANSAS CITY INTL	KANSAS CITY,MISSOURI,USA
MCO	ORLANDO INTL	ORLANDO,FLORIDA,USA
MDT	HARRISBURG INTERNATIONAL	HARRISBURG,PENNSYLVANIA,USA
MDW	CHICAGO MIDWAY	CHICAGO,ILLINOIS,USA
MEM	MEMPHIS INTL	MEMPHIS,TENNESSEE,USA
MFE	MC ALLEN MILLER INTL	MC ALLEN,TEXAS,USA
MGM	DANNELLY FIELD	MONTGOMERY,ALABAMA,USA
MHT	MANCHESTER	MANCHESTER,NEW
MKE	GENERAL MITCHELL INTERNATIONAL	MILWAUKEE,WISCONSIN,USA
MLI	QUAD-CITY	MOLINE,ILLINOIS,USA
MSP	MINNEAPOLIS-ST PAUL INTL/WOLD-	MINNEAPOLIS,MINNESOTA,USA
MYR	MYRTLE BEACH INTL	MYRTLE BEACH,SOUTH

ORD	CHICAGO O'HARE INTL	CHICAGO,ILLINOIS,USA
PDX	PORTLAND INTL	PORTLAND,OREGON,USA
PHX	PHOENIX SKY HARBOR INTL	PHOENIX,ARIZONA,USA
PSP	PALM SPRINGS REGIONAL	PALM SPRINGS,CALIFORNIA,USA
RKD	KNOX COUNTY REGIONAL	ROCKLAND,MAINE,USA
RSW	SOUTHWEST FLORIDA INTL	FORT MYERS,FLORIDA,USA
SEA	SEATTLE-TACOMA INTL	SEATTLE,WASHINGTON,USA
SFO	SAN FRANCISCO INTL	SAN FRANCISCO,CALIFORNIA,USA
SGF	SPRINGFIELD-BRANSON REGIONAL	SPRINGFIELD,MISSOURI,USA
SJC	SAN JOSE INTERNATIONAL	SAN JOSE,CALIFORNIA,USA
SNA	JOHN WAYNE AIRPORT-ORANGE COUNTY	SANTA ANA,CALIFORNIA,USA
SYR	SYRACUSE HANCOCK INTL	SYRACUSE,NEW YORK,USA
YKM	YAKIMA AIR TERMINAL	YAKIMA,WASHINGTON,USA