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Airspace Flow Programs (AFPs) represent a new type of air traffic flow management strategy that was first introduced during the summer of 2006. They are similar to ground delay programs which are used to control arrivals into an airport, but instead control "arrivals" into some region of enroute airspace. This paper describes the functioning of AFPs, and the strategies used by National Airspace System (NAS) customers, including the swapping of flights to accommodate customer priorities and routing out of an AFP.

Background

Over the summer of 2006, a new strategy was introduced for air traffic management for use when pop-corn thunderstorms developed over the Northeastern U.S. This strategy, referred to as airspace flow programs (AFPs), had three goals:

- More precisely manage traffic so that only those aircraft that were truly passing through the constrained airspace would be delayed.
- Provide the NAS users with the ability to determine which of their aircraft would be allowed to make use of available capacity.
- Allow the NAS users to route out of the constraint, thus avoiding any departure delays for those flights that no longer were filed to pass through constrained airspace.

Figure 1 illustrates the application of this new Traffic Flow Management (TFM) strategy. In this example, all flights scheduled or filed to land in New York Center (ZNY), Boston Center (ZBW) or Washington Center (ZDC) that pass through the blue lines (flow constrained areas or FCAs) above 12,000 feet are included in the program. If it is determined by TFM (in collaboration with the users) that traffic flow into this area should be reduced by 25% over some timeframe (based on expected arrival times at the FCAs), then the included flights are assigned the departure delays necessary to slow traffic into this region by 25%. To assign such delays, flights are allowed to depart based the order in which they would have arrived at the FCAs, but are delayed appropriately so that arrivals per hour at the FCAs are slowed by 25%. These assigned departure times are referred to as EDCTs or Expected Departure Clearance Times.

As with ground delay programs (Smith, et al., 2007), the users are allowed to swap flights within the AFP (moving one flight up to an earlier arrival time by giving it the AFP arrival slot that had been assigned to one of its other flights, while at the same time moving the other flight to the later slot).

Figure 1. AFPS based on two FCAs for flights into ZBW, ZNY and ZDC

A Sample Day Using AFPs

On August 7, 2006, at roughly 1445Z the two AFPs corresponding to the two FCAs shown in Figure 1 were put into effect starting at 1800Z. This decision was based on the current weather forecast as shown in the CCPF (Collaborative Convective Forecast Product), as well as consideration of other available weather forecasts (see Figure 2 at the end of the paper). The advisories indicated that these two AFPs would last from 1800-0259Z (see Figure 3). Because the weather turned out to be less severe than expected, the AFPs were actually ended at 2259Z. Figure 4 shows the actual weather and air traffic in this region at 2000Z on August 7, 2006.

Actual Performance

An analysis was conducting using the POET or the Post-Operations Evaluation Tool (Smith, et al., 2005) to look at overall performance for flights that were in the AFPs (had EDCTs) and at the strategies used by customers. For the scheduled carriers, there were 7 cancellations. Comparing the controlled times (EDCTs) with scheduled off times, the average delay was 22.7 minutes. Figure 5 shows a histogram indicating the range of the delays that were planned. The average actual delay (actual off time – scheduled off time) for scheduled carrier flights was 28.0 minutes. Figure 6 shows the range of actual delays.

The customers demonstrated the use of a number of strategies that allowed them to adjust the delays for particular flights. One such strategy was to simply swap a low priority flight so that it had a long delay (thus making it possible to reduce the delays for other higher priority flights by moving them up to take advantage of the empty slot created by the low priority flight). Another variation of this swapping strategy was to make the swap and to then route the delayed flight out of the AFP. Because it was no longer in the AFP, its EDCT was removed and, in principle, it could then depart normally.

Figure 7 shows the 39 flights that were routed out of the AFPs to take advantage of this latter strategy. These 39 flights had an actual departure delay (actual off-scheduled off) of 24.3 minutes. (They also had extra air time added on because of the longer routes.) Thus, although routing out of the AFPs eliminated the controlled delays due to EDCTs and could in principle have made it possible for those flights to depart on time, other system constraints (such as miles-in-trail restrictions for flights flying through Canada) introduced delays. Thus, in applying this strategy, the dispatcher must look at the tradeoffs of:

- Reducing delays for a number of flights due to the swapping process
- Adding extra air time and fuel burn to the flight routed around the AFP
- The potential for non-AFP delays for the flights routed around the AFP.

Because of these tradeoffs, it might very well be worthwhile to move a flight out of the AFP onto a Canadian route that had significant delays due to miles-in-trail restrictions because the AFP slot that was made available to move other flights up could result in significant delay reductions for those other flights. (Figure 8, for instance, shows POET data for one flight that was scheduled to depart at 2111Z, was originally assigned a controlled departure time (EDCT) of 2221Z, but after swapping ultimately had a controlled departure time of 2137Z. Thus, it started with a planned departure delay of 70 minutes but ended up with a planned departure delay of 26 minutes. The flight actually departed at its controlled time of 2137Z.)

A third variation on this swapping strategy involves the cooperation of a major carrier and its subcarriers. In many cases, the major handles the slot swapping for both their own flights and those of their subcarriers. This gives them more options for rearranging delays. In some cases, the implications of this is that the subcarrier flights (which generally have fewer passengers) are considered lower in priority and are swapped to given them greater delays, thus reducing the delays for flights that have more passengers. As an example of this, one carrier swapped to manipulate delays such that the major's average planned delay was 12.8 minutes, while the subcarrier's average planned delay was 41.8 minutes.

Human Factors Issues

As the discussion above suggests, the use of AFPs gives the NAS customers considerable flexibility in determining which flights are going to take the greatest delays. This requires the dispatcher to make decisions about what flights to swap, what flights to route out of the AFP and what flights, if any, to cancel. (The customer keeps the slot when a flight is cancelled, using it to reduce delays for other flights.)

When a flight is moved out of the AFP, the dispatcher has software that provides an estimate of how much total delay has been reduced for the flights that remain in the AFP. However, the dispatcher must then make an educated estimate of the delay that will be encountered by the flight that has been routed out of the AFP, and the relative importance of that cost vs. the benefit for the flights left in the AFP. Thus, there is still a significant need for better information (such as estimates of the mile-in-trail delays expected for the flights through Canada in this analysis), and for tools that help to assess the relative priorities of flights. There is also a need to better support collaboration between dispatchers (who select routes for flights) and ATC coordinators (who swap slots for flights), as these two individuals could be working at cross-purposes.

Reservoirs To Maintain Throughput

Because the AFPs were to the west of Cleveland Center, departures by those flights were to be controlled by miles-in-trail restrictions and call for release (see Figure 9). Since the weather was less severe than expected, those flights were largely allowed to depart unrestricted, with an average actual delay of 9.3 minutes.

References

Smith, P.J., Geddes, N. and Beatty, R. (2007). Human-centered design of decision support systems. In A. Sears and J. Jacko (eds.*),* Handbook of Human-Computer Interaction, 2nd Edition. Mahwah, NJ: Lawrence Erlbaum Associates.

Smith, P.J., Klopfenstein, M. Jezerinac, J. and Spencer, A. (2005). Distributed work in the National Airspace System: Providing feedback loops using the Post-Operations Evaluation Tool (POET). B. Kirwan, M. Rodgers and D. Schaefer (eds.), Human Factors Impacts in Air Traffic Management. Hampshire England: Ashgate.

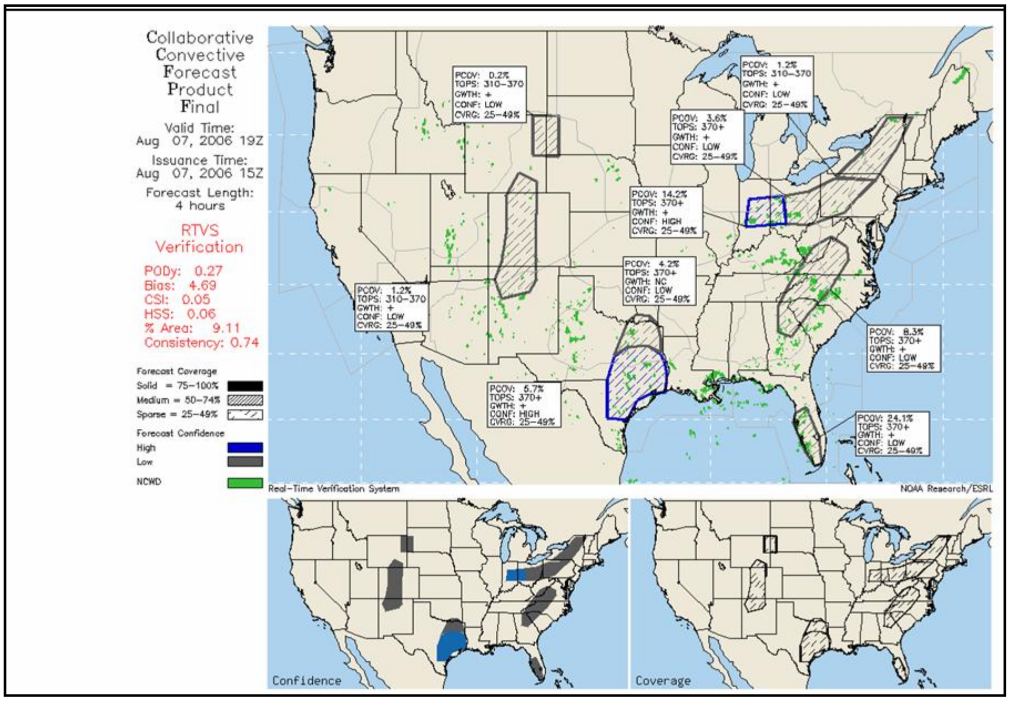


Figure 2. CCFP for 1900Z on August 7, 2006

Date: 08/07/2006 14:43 Advn: 32 Origin: ATCSCC Facid: FCAA05 Title: CDM AIRSPACE FLOW PROGRAM
CTL ELEMENT: FCAA05 ELEMENT TYPE: FCA ADL TIME: 1439Z
DELAY ASSIGNMENT MODE: DAS
ENTRY ESTIMATED FOR: 07/1800Z - 08/0259Z
PROGRAM RATE: 90/85/85/80/80/80/90/90/100
FLT INCL: ALL FLIGHTS IN FCAA05 DYNAMIC FLIGHT LIST
DEP SCOPE: (ALL) ZSE ZAB ZLC ZFW ZLA ZAU ZMP ZDV ZKC ZME ZID ZMA ZHU ZJX ZOB ZBW ZTL ZNY ZDC ZOA
CANADIAN DEP ARPTS INCLUDED: NONE
MAXIMUM DELAY: 387 AVERAGE DELAY: 57.6
REASON: WEATHER / TSTMS IN ZOB
REMARKS:

Date: 08/07/2006 14:47 Advn: 33 Origin: ATCSCC Facid: FCAA06 Title: CDM AIRSPACE FLOW PROGRAM
CTL ELEMENT: FCAA06 ELEMENT TYPE: FCA ADL TIME: 1443Z
DELAY ASSIGNMENT MODE: DAS
ENTRY ESTIMATED FOR: 07/1800Z - 08/0259Z
PROGRAM RATE: 140/132/132/124/124/124/140/140/155
FLT INCL: ALL FLIGHTS IN FCAA06 DYNAMIC FLIGHT LIST
DEP SCOPE: (ALL) ZSE ZAB ZLC ZFW ZLA ZAU ZMP ZDV ZKC ZME ZID ZMA ZHU ZJX ZOB ZBW ZTL ZNY ZDC ZOA CANADIAN DEP ARPTS INCLUDED: NONE
MAXIMUM DELAY: 27 AVERAGE DELAY: 5.0
REASON: WEATHER / TSTMS IN ZDC
REMARKS:

Figure 3. Advisory indicating the use of two AFPs corresponding to the two FCAs in Figure 1

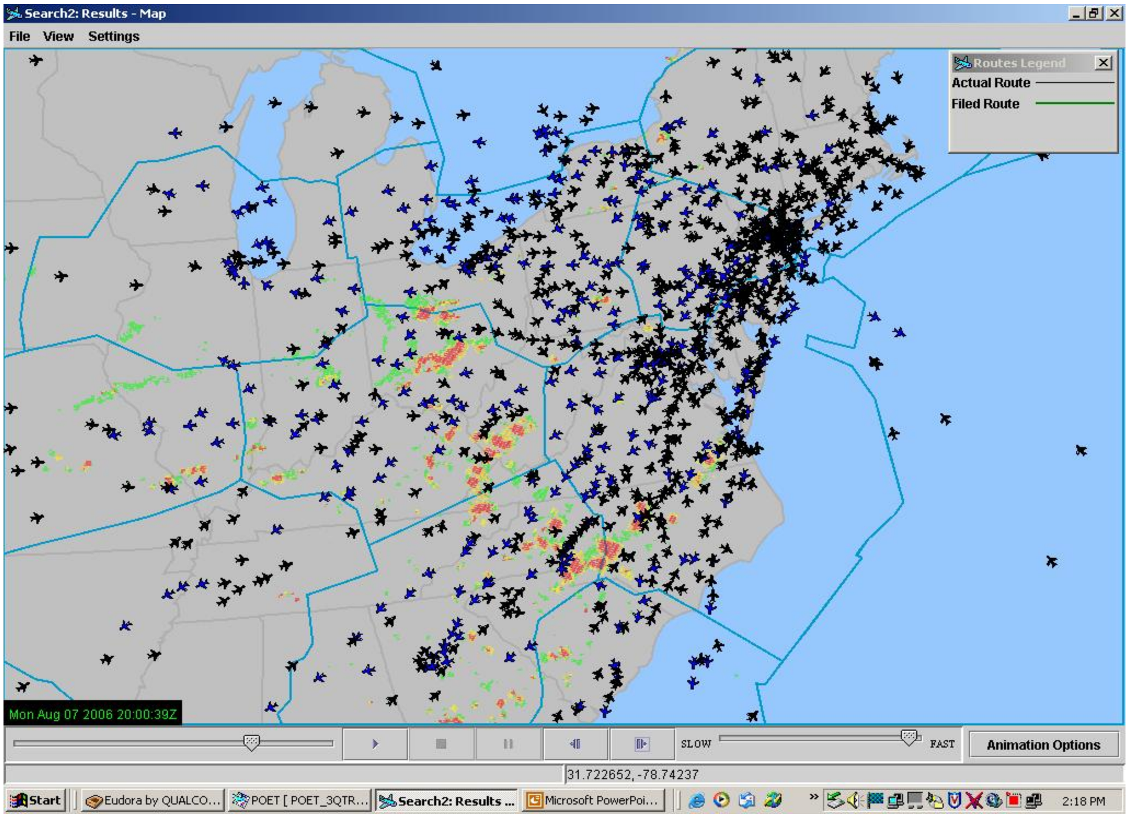


Figure 4. Weather and traffic through the AFPs at 2000Z (black aircraft are ZBW, ZDC and ZNY arrivals; blue aircraft are ZBW, ZDC and ZNY departures)

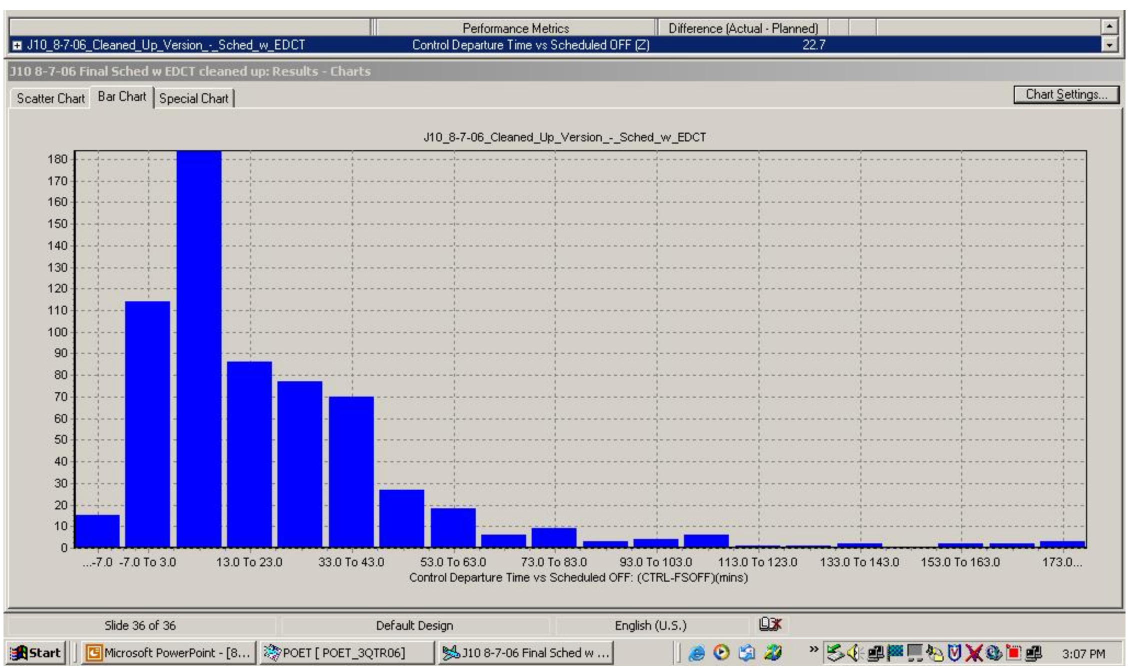


Figure 5. Planned departure delays for scheduled carrier flights in the AFP

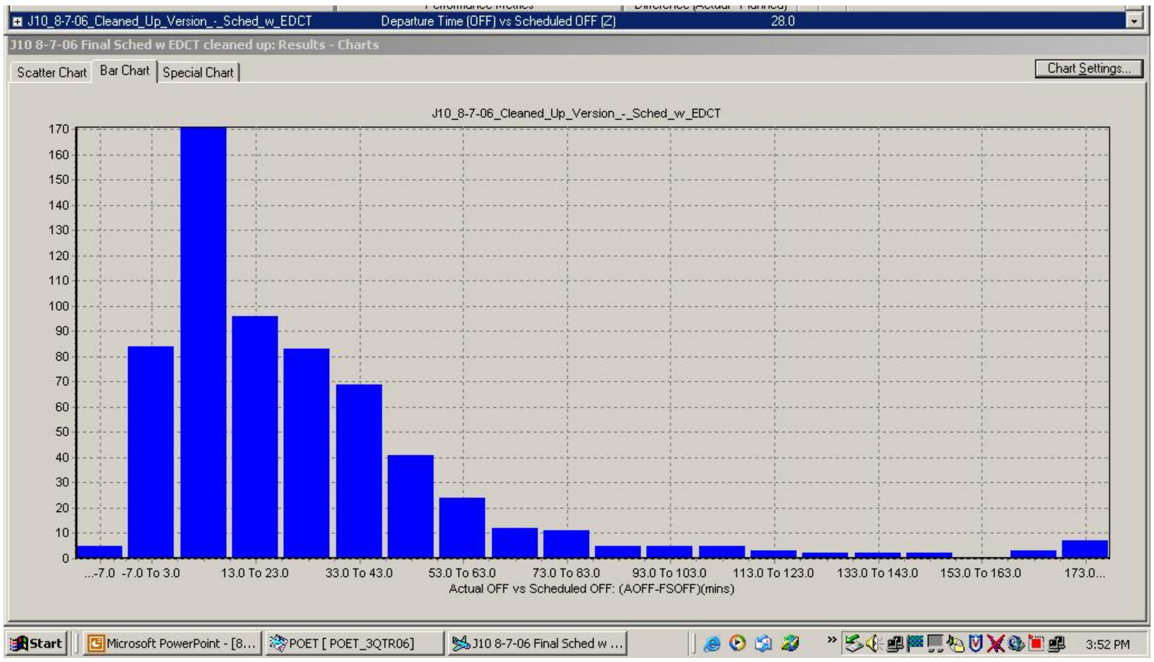


Figure 6. Actual departure delays for scheduled carrier flights in the AFP

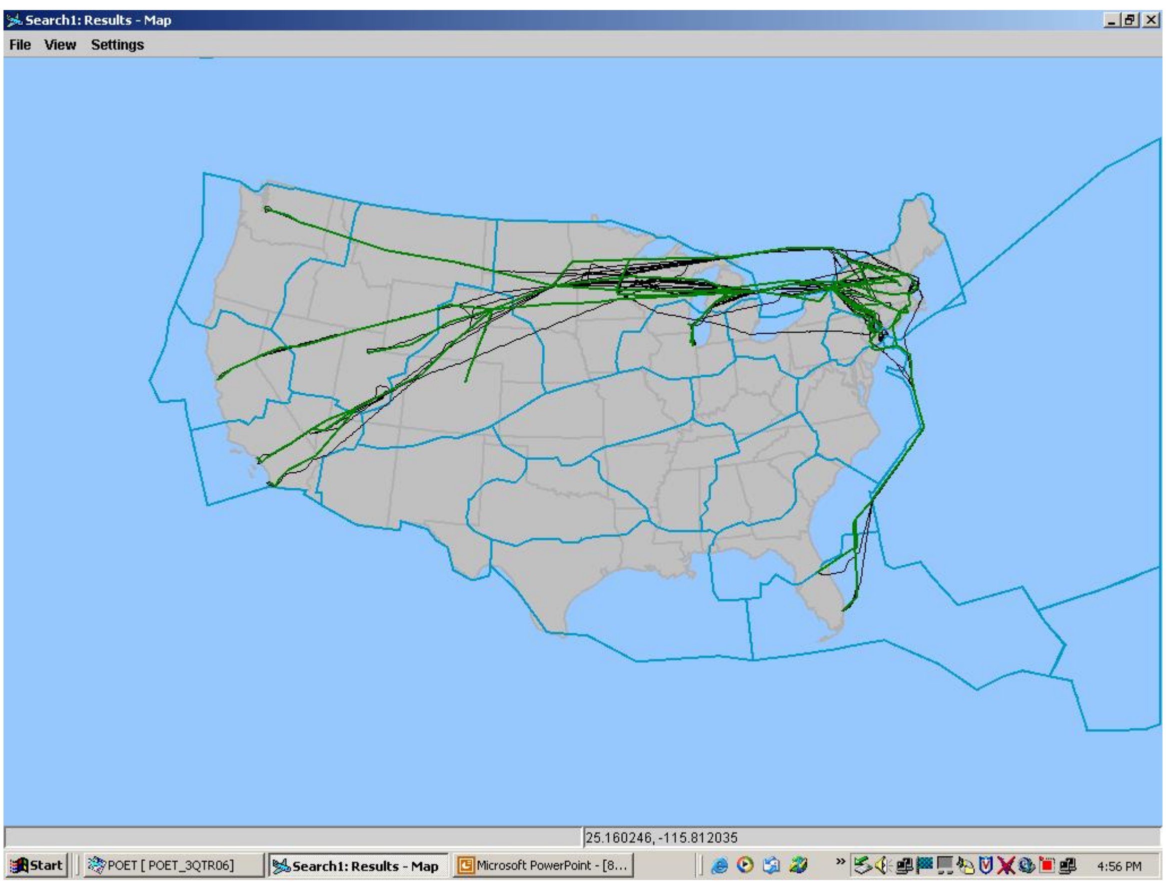
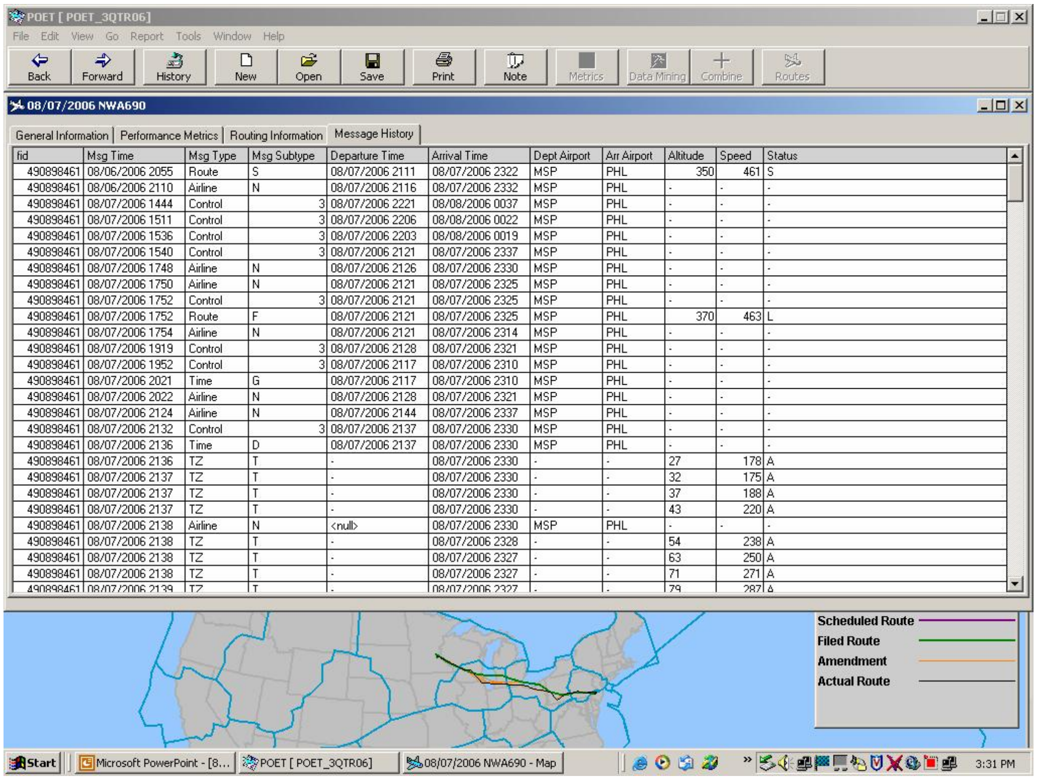


Figure 7. Flights routed around the AFPs



fid	Msg Time	Msg Type	Msg Subtype	Departure Time	Arrival Time	Dept Airport	Arr Airport	Altitude	Speed	Status
490898461	08/06/2006 2055	Route	S	08/07/2006 2111	08/07/2006 2322	MSP	PHL	350	461	S
490898461	08/06/2006 2110	Airline	N	08/07/2006 2116	08/07/2006 2332	MSP	PHL	-	-	-
490898461	08/07/2006 1444	Control	3	08/07/2006 2221	08/08/2006 0037	MSP	PHL	-	-	-
490898461	08/07/2006 1511	Control	3	08/07/2006 2206	08/08/2006 0022	MSP	PHL	-	-	-
490898461	08/07/2006 1536	Control	3	08/07/2006 2203	08/08/2006 0019	MSP	PHL	-	-	-
490898461	08/07/2006 1540	Control	3	08/07/2006 2121	08/07/2006 2337	MSP	PHL	-	-	-
490898461	08/07/2006 1748	Airline	N	08/07/2006 2126	08/07/2006 2330	MSP	PHL	-	-	-
490898461	08/07/2006 1750	Airline	N	08/07/2006 2121	08/07/2006 2325	MSP	PHL	-	-	-
490898461	08/07/2006 1752	Control	3	08/07/2006 2121	08/07/2006 2325	MSP	PHL	-	-	-
490898461	08/07/2006 1752	Route	F	08/07/2006 2121	08/07/2006 2325	MSP	PHL	370	463	L
490898461	08/07/2006 1754	Airline	N	08/07/2006 2121	08/07/2006 2314	MSP	PHL	-	-	-
490898461	08/07/2006 1919	Control	3	08/07/2006 2128	08/07/2006 2321	MSP	PHL	-	-	-
490898461	08/07/2006 1952	Control	3	08/07/2006 2117	08/07/2006 2310	MSP	PHL	-	-	-
490898461	08/07/2006 2021	Time	G	08/07/2006 2117	08/07/2006 2310	MSP	PHL	-	-	-
490898461	08/07/2006 2022	Airline	N	08/07/2006 2128	08/07/2006 2321	MSP	PHL	-	-	-
490898461	08/07/2006 2124	Airline	N	08/07/2006 2144	08/07/2006 2337	MSP	PHL	-	-	-
490898461	08/07/2006 2132	Control	3	08/07/2006 2137	08/07/2006 2330	MSP	PHL	-	-	-
490898461	08/07/2006 2136	Time	D	08/07/2006 2137	08/07/2006 2330	MSP	PHL	-	-	-
490898461	08/07/2006 2136	TZ	T	-	08/07/2006 2330	-	-	27	178	A
490898461	08/07/2006 2137	TZ	T	-	08/07/2006 2330	-	-	32	175	A
490898461	08/07/2006 2137	TZ	T	-	08/07/2006 2330	-	-	37	188	A
490898461	08/07/2006 2137	TZ	T	-	08/07/2006 2330	-	-	43	220	A
490898461	08/07/2006 2138	Airline	N	<null>	08/07/2006 2330	MSP	PHL	-	-	-
490898461	08/07/2006 2138	TZ	T	-	08/07/2006 2328	-	-	54	238	A
490898461	08/07/2006 2138	TZ	T	-	08/07/2006 2327	-	-	63	250	A
490898461	08/07/2006 2138	TZ	T	-	08/07/2006 2327	-	-	71	271	A

Figure 8. Sample delay reductions for a flight

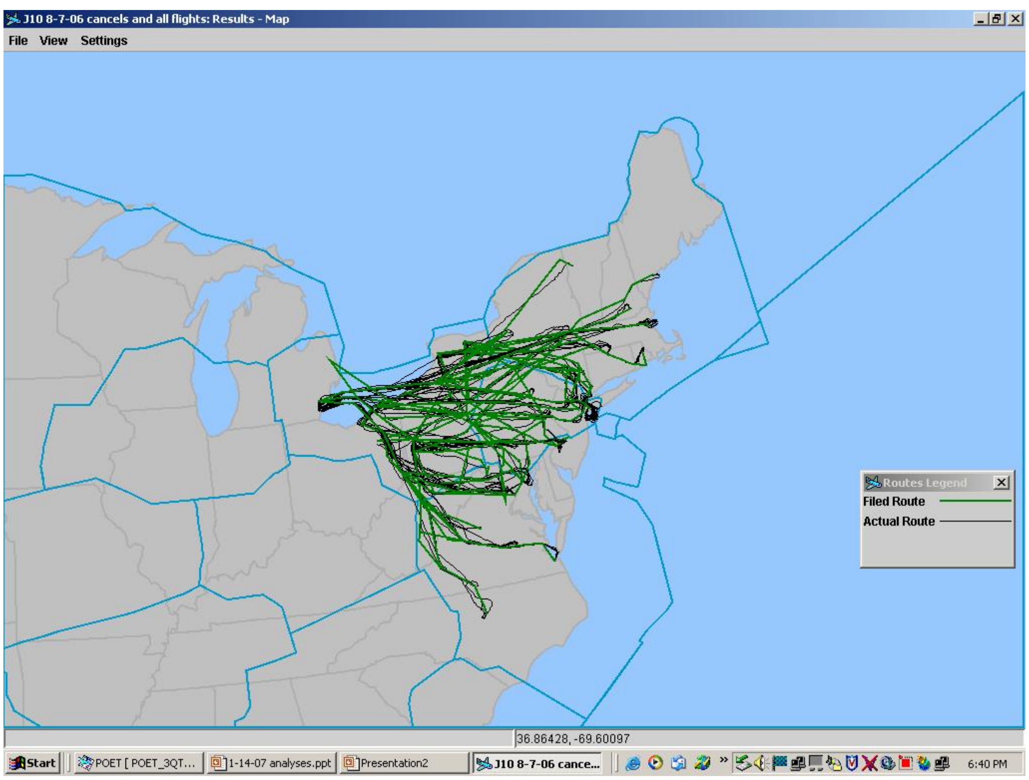


Figure 9. Flights out of Cleveland Center used to maintain higher throughput when the weather was less severe than expected