Near Term Procedural Enhancements in Air Traffic Control

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ABSTRACT

As the National Airspace System (NAS) of the United States grows in usage and complexity, there is continuous improvement in the procedures that support the NAS. Of particular interest are the improvements that can be made to the NAS, without requiring the acquisition of new automation or systems. Fundamentally, these are changes to how operations are performed today, that make better use of the tools and capabilities that are currently available to the users and service providers. These changes are collectively called "procedural enhancements". The Federal Aviation Administration (FAA) has identified a number of procedural enhancements that can be implemented in the 1998-2002 timeframe, which has been labeled the "near term" timeframe. Due to financial constraints, not all of the enhancements can be implemented, so the FAA has selected several that could yield efficiency benefits to the NAS. In partnership with FAA, MITRE's Center for Advanced Aviation System Development (CAASD) is assisting with the implementation of several of these near term procedural enhancements. This paper outlines four of these efforts, and discusses the results and improvements to date. These include Lifting the 250 Knot Speed Limit, Improving North American Route Program (NRP) Transitions, Reducing Flow Restrictions, and Eliminating Air Traffic Control (ATC) Preferred Routes. Each of these procedural enhancements was found to provide incremental benefits, and has helped to validate how well the NAS is currently operating. Analysis and implementation of procedural enhancements by FAA and CAASD continues, to assist system efficiency while new automation and tools are being procured.

Keywords: air traffic control, procedures, enhancements

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INTRODUCTION

There is an extensive series of initiatives by the Federal Aviation Administration (FAA) to improve the Air Traffic Control (ATC) system in the United States. Many of these initiatives involve new automation capabilities or aides for the controller or pilot, while others strive to improve the infrastructure on which the system rests. However, while these improvements are being developed, there are a number of procedural changes that are being introduced to provide efficiency benefits to the National Airspace System (NAS). These procedural changes are not associated with changes to systems or the introduction of new capabilities. These are typically changes to how operations are performed today, that make better use of the tools and capabilities that are currently available to the users and service providers. These changes are collectively called "procedural enhancements".

To establish the context for these improvements, several strategies were identified by the FAA Administrator's NAS Modernization Task Force *[1]* in late 1997 to provide measurable steps toward the RTCA concepts of Free Flight *[2, 3]*. One key strategy is to deliver early benefits to users by 2002, through the fielding of low-risk capabilities at specified locations throughout the NAS. This activity is entitled Free Flight Phase 1 (FFP1), consisting of the limited deployment of selected core Air Traffic Management (ATM) capabilities *[4]*. The intent is to deploy these capabilities, currently in development status or in limited operational use at some FAA facilities, to other facilities or locations as quickly as possible (to allow for evaluation by 2002) in order to provide early benefits to NAS users. This timeframe (1998-2002) has been established as the "near term" timeframe.

Concurrently, in the near term timeframe of FFP1, a series of 25 procedural enhancements has been identified by the FAA *[5]*. These "near term procedural enhancements" can provide rapid benefit to the NAS, can be made with relatively little expenditure of program funds or resources, and are fundamentally independent of the other near term NAS initiatives, such as FFP1. However, due to financial constraints, not all 25 of the enhancements can be implemented in the near term timeframe. The FAA has reviewed these procedural enhancements and is in the process of implementing those that have been judged to be most potentially beneficial to the NAS users.

In partnership with the FAA, MITRE's Center for Advanced Aviation System Development (CAASD) is assisting with the implementation of several of these near term procedural enhancements. CAASD's analytic and operational experts have helped with the design or redesign of procedures, the analysis of benefits and impacts, the evaluation of field trials, and the coordination of service providers and the users. This paper outlines four of these efforts and discusses the results and improvements to date. These include Lifting the 250 Knot Speed Limit, Improving North American Route Program (NRP) Transitions, Reducing Flow Restrictions, and Eliminating ATC Preferred Routes.

LIFTING THE 250 KNOT SPEED LIMIT

In response to a 1995 RTCA Task Force recommendation *[2]*, the FAA initiated a study of modifying Federal Aviation Regulation (FAR) 91.117 to change or eliminate the 250 knot speed restriction for departing aircraft operating below 10,000 feet within Class B airspace. The FAA asked CAASD to evaluate the effects and potential benefits of lifting the 250 knot speed limit.

The first step in the evaluation process consisted of controller-in-the-loop laboratory simulations conducted at CAASD in 1996. These high fidelity simulations modeled Dallas/Fort Worth and St. Louis terminal airspace, with and without the 250 knot speed restriction in effect for departing aircraft, and employed teams of controllers from those facilities. No major safety concerns or appreciable increases in controller workload were discovered during the simulations, and as a result, the FAA decided to go forward with a field test of the procedure. Houston Terminal Radar Approach Control (TRACON) was selected, and a field test was begun in the summer of 1997.

To provide a comprehensive evaluation of the field test, three areas likely to be impacted by the modification of the speed restriction were identified: Air Traffic Controllers; Flight Crews; and the Environment, specifically in the area of noise. Several metrics to support the assessment of each area were developed, including controller and pilot workload, fuel and time savings, improvements in flight profile, and changes in noise profiles and community complaint frequency.

The preliminary evaluation of the on-going field test at Houston provided partial validation of the operational feasibility of modifying or removing the 250 knot speed limit for departing aircraft only. The results of the preliminary evaluation were, for the most part, positive *[6]*. Major findings included:

- The vast majority of controllers interviewed believed that it is operationally acceptable for departures to fly faster than 250 knots, below 10,000 feet, within Class B airspace.
- When authorized to do so, a substantial number of controllers removed the speed restriction for departing aircraft.

- Most of the controllers interviewed preferred to have the departure controller retain the option of removing the speed restriction. This remains the procedure today.
- There was no significant impact on controller workload resulting from the change in procedure during the period studied.
- Changes to departure speed and altitude profiles varied, but in general seemed to conform to the anticipated result that aircraft would generally trade altitude for speed. As an example, the average MD-80 (without the speed restriction) attained higher speeds in the window between two and four minutes after take-off, and crossed 10,000 feet roughly five nmi further downrange.
- There was an apparent increase in the number of aircraft operating below 10,000 feet, outside of the lateral limits of Houston's Class B airspace, at speeds greater than 250 knots, when higher speeds were authorized, as opposed to when they were not authorized.
- All pilots interviewed during the test agreed that it was operationally acceptable for departures to fly faster than 250 knots, below 10,000 feet within Class B airspace.
- There was a modest saving per individual flight: a typical flight (i.e., a B737-300 with 20k pound thrust engines, 105,000 pound take-off weight, and a 100 minute flight time) would save 9.6 pounds of fuel and 0.1 minutes of flying time.
- There was no significant noise impact (as defined by FAA Order 1050.1D, 1986) in the Houston area, and no noise impacts perceived by the community surrounding the airports.

Prior to transitioning out of this work area in September 1998, CAASD recommended the formation of a joint FAA/Industry Working Group that would review the program's status and make recommendations concerning the advisability of continuing/expanding the program. At this time, the Houston trial is continuing, and the FAA is considering the extension of the program to the other TRACONs with Class B airspace that extend to 10,000 feet or higher.

IMPROVING NRP TRANSITIONS

In December 1998, the FAA released Advisory Circular AC90-91C, North American Route Program (NRP) *[7]*. The advisory circular replaces AC90-91B, National Route Program *[8]*. NRP is now a joint FAA and

NAV CANADA program that integrates the U.S. national route program and the Canadian equivalent. Under NRP, flights were required to file and fly Departure Procedures (DPs), Standard Terminal Arrival Routes (STARs), or published Instrument Flight Rules (IFR) routes within 200 nautical miles of the departure and destination airports. A recent advisory update *[9]* identifies 286 transition fixes on 69 DPs in 29 airport areas and 296 transition fixes on 118 STARs in 39 airport areas. NRP flights may now file and fly to/from these transition fixes in lieu of the 200-nmi restriction. The FAA intends to expand NRP to all major U.S. terminal areas. The initial advisory did not extend into the following Centers: Anchorage, Boston, Cleveland, Honolulu, Jacksonville, Los Angeles, New York, or Miami. The update extends the scope of the advisory into the Jacksonville, Los Angeles, and Miami centers.

The advisory lessens the restrictions on NRP flights within 200 nmi of designated airports. Consequently, NRP flights are now often able to fly user-preferred routes for longer distances than before. Because of the often greater flexibility in route selection, NRP flights now have the capability of maintaining greater separation from non-NRP aircraft that are adhering to published routes.

CAASD has assisted the FAA's Air Traffic Control System Command Center (ATCSCC) by assessing the operational impacts of NRP changes. Metrics analyzed include ATC sector counts, which represent the maximum number of aircraft within a sector during consecutive 15-minute intervals. They are indicators of sector traffic congestion and controller workload. They were calculated using three-dimensional sector boundary data and flight track data from the Enhanced Traffic Management System (ETMS). Each sector's counts were compared to its Monitor Alert Parameter (MAP), which is a dynamic integer value determined by the FAA and indicates the number of aircraft beyond which sector efficiency may be degraded. When traffic within a sector is projected to exceed the MAP, the monitor alert function of ETMS sends an alert to traffic managers *[10]*. Sector counts were calculated on busy traffic days before the advisory took effect, as well as two months afterwards. No sector in the U.S. was found to experience a sector count increase over the MAP due to implementation of the advisory.

Due to the large number of terminal areas affected and the significant shift in many transition points, potential user flying time and operating cost savings across the NAS can safely be estimated to be in the millions of dollars. In February 2000, as part of a recommendation to the FAA on additional NRP transitions, CAASD estimated the potential yearly NRP fuel cost saving at just seven airports to be over $250,000. This estimate assumed no increase in NRP traffic and a jet fuel cost of $0.60 per gallon which has increased dramatically since that time. The seven airports were Atlanta, Charlotte, Dallas-Ft. Worth, Los Angeles, San Francisco, Chicago

O'Hare and Washington Dulles. In April 2000, the FAA implemented eight of CAASD's eleven suggestions for NRP arrival transitions at O'Hare. At that time, no suggested departure transitions were implemented at O'Hare, though the FAA is regularly updating the advisory.

In June 2000, CAASD met with representatives of the ATCSCC as well as Washington Center and Washington Dulles airport to discuss CAASD's study of suggested NRP transitions at Dulles. Since many FAA en route centers now have teams of controllers and traffic management personnel investigating the redesign of their airspace, the suggestions have been incorporated within the larger investigation which offers the potential for more widespread user savings in distance flown and fuel burn. Whether any particular NRP flight actually realizes a benefit depends on whether its departure and destination airports are covered by the NRP advisory, the filed route, and weather-related factors such as the winds.

Many DPs and STARs now contain multiple NRP transitions often located much closer than 200 nmi of the departure or arrival airport. The new NRP transitions on the Denver vector departure procedure are identified in Figure 1. Usually these transitions are located at the intersection of jet routes. If NRP flights continue to file these published routes, then the impact on traffic patterns should be minimal. If, however, they file unpublished en route sequences from/to these transitions, then the possibility exists for an increase in ATC workload to assure safe separation during peak hours.

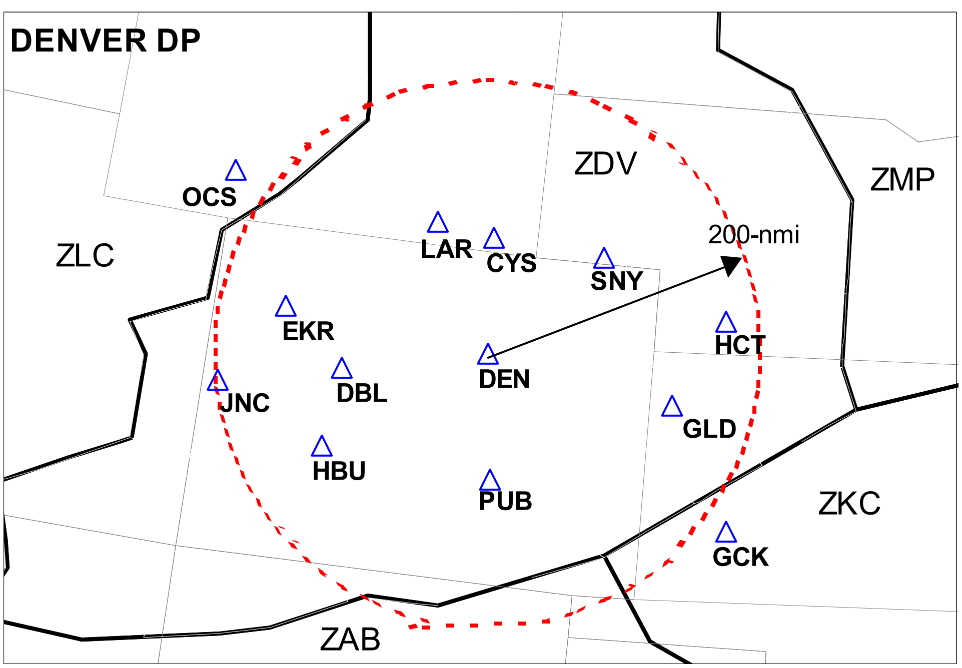

FIGURE 1 NRP Transitions on Denver Departure Procedure.

REDUCING FLOW RESTRICTIONS

Over the past several years, the FAA's ATCSCC has worked aggressively to reduce restrictions throughout the NAS. In particular, major steps have been taken to remove static restrictions and to carefully scrutinize restrictions passed back from one en route center to another. CAASD has worked with the ATCSCC to try to understand the effects of restrictions and evaluate the operational impacts of eliminating specific restrictions.

In the past few years, very detailed case studies have been undertaken in Chicago, Atlanta and San Francisco in order to understand the extent to which restrictions can be lessened. During calendar year 1999, an analysis of the restrictions that are passed back from Washington center (ZDC) to major airports in New York center (ZNY) due to en route congestion in ZDC was performed. The ATCSCC is concerned that these south gate restrictions are having a serious impact on the New York metro airports' ability to launch departures and that they might be causing large delays at these airports.

The analysis of the ZNY south gate restrictions was performed based on three months of data (from December 1998 though February 1999) from a wide variety of sources. After a lengthy data reduction effort, numerous statistics and a series of regression models were used to try to explain whether the delays could be caused by the restrictions under investigation. This particular analysis showed the following:

- There were relatively few south gate restrictions (compared to the north and west restrictions). Less than ten percent of the flights were restricted, except for six hours of the day where 10-20% of the flights were delayed. Most of the restrictions were very short (i.e., less than 15 minutes) ground delays.
- When the Miles-In-Trail (MIT) restrictions were in place, the additional delay due to the restriction was "in the noise" (typically 0-3 minutes). The average aircraft spacing through the restriction point was more than 50% larger than the MIT restriction.
- In general, for south gate departures, no relationship could be found between departure delays and the MIT restrictions. To the contrary, the largest average push-back delays to flights entering the concerned ZDC sectors occurred when there were no south gate restrictions (after 11PM local). It was estimated that the ground stops added an additional 5-8 minutes of delay.
- Aircraft counts in the concerned ZDC sectors do not reach the MAP thresholds as frequently as some other ZDC sectors. Traffic in these sectors came predominantly from the New York metro area, but traffic from

Philadelphia, Baltimore-Washington and National and other nearby airports was also a significant factor when restrictions are in place.

- MIT restrictions do not appear to cause a significant increase in average taxi-times for flights following restricted flights in the departure queue.
- During time periods when restricted southbound New York departures reach the key ZDC sectors studied, other departures from nearby airports entering these sectors (specifically Baltimore-Washington, National, and Dulles) were not usually restricted. However, a high percentage of Philadelphia departures are restricted during these times.

Taken together, these results suggest that the need for these south gate restrictions must be called into question. As in prior restriction case studies, these results will be discussed with the affected facilities; and, where possible, agreement will be reached on the extent to which the restrictions can be reduced.

A thorough analysis of en route and departure flow restrictions that affected flights passing through Cleveland center (ZOB) was performed during calendar year 2000. The goal of this analysis was to provide quantitative metrics to decision makers in the ATCSCC that can be used to evaluate proposed Historically Validated Restrictions (HVR). An HVR is an MIT restriction that is put in place during specific hours of the day and days of the week by a facility. It must be approved by the ATCSCC prior to implementation. ZOB contains one of the most complex set of HVRs in the NAS, which have been put in place both to meter flights to control local sector volume and to meter flights to meet downstream HVRs at the center boundary. About 85 separate HVRs affect ZOB traffic on a typical day.

Four days of flight plan data (from January 2000) were collected for the entire NAS. This data, representing the original user intent, was used to generate flight paths by the Collaborative Routing Coordination Tool (CRCT). CRCT is a prototype for an interactive suite of tools developed by MITRE to assist the Traffic Management Units (TMU) in a center to quickly evaluate the effect of proposed reroutes on sector MAP levels. For this analysis, CRCT was used to generate flight trajectories. The resulting trajectories were fed to the Detailed Policy Assessment Tool (DPAT), a fast-time simulation of individual flights in the entire NAS, which was used to simulate the movement of traffic through ZOB and the surrounding centers for the four historical days. The modeling and analysis was performed off-line using archived data. Statistics were collected on the instantaneous aircraft counts versus the MAP for each ZOB en route sector and 15-minute period. Delays were also estimated for each HVR modeled. Discussions are ongoing with the ATCSCC as to how to use this information to improve the current HVR approval process.

In addition to the off-line modeling and analysis of MIT restrictions, a capability has been added to CRCT to model individual en route MIT restrictions. This is currently being evaluated as a potential real-time analysis tool to evaluate the use of MIT restrictions in the field prior to their implementation.

Over the course of the restriction case studies performed in the past several years, some common results and lessons learned have emerged.

1. There is no complete knowledge on the level of restrictions in the system. While the ATCSCC evaluates and logs the restrictions that are passed back across center boundaries, local restrictions are extensive and are not generally available for analysis. A substantial amount of effort is required to put this data into format suitable for analysis.
2. There is no good understanding of the true impacts of restrictions (i.e., the amount of unnecessary delay caused). Extensive effort in modeling and data analysis has demonstrated how difficult this problem is.
3. The use of and adherence to restrictions varies greatly across the NAS. Some facilities use large and long-lasting restrictions to transfer delay away from a capacity-bound airport, while other facilities use very short and dynamic restrictions to smooth flows in a metering-like fashion. In some situations, actual flows are adjusted so that they are inline with the restriction. In others, restrictions may be in place, but actual flows are not curtailed and far exceed the restriction.

Over the next year, CAASD will continue to work with the ATCSCC to further reduce the unnecessary use of restrictions in the NAS. The need for special case studies will remain; however, there is also an increasing need to provide simpler, more real-time metrics by which restrictions can be evaluated.

ELIMINATING ATC PREFERRED ROUTES

The FAA has recently eliminated 170 ATC preferred (also call "pref") routes. There are over 2,000 pref routes listed in the *Airport/Facility Directory [11]*. These routes often diminish the capacity of today's airspace and require flights to burn more fuel than necessary. In calendar year 1998 the FAA eliminated an initial set of 70 high-altitude pref routes: 50 serving specific U.S. airports, and 20 special high-altitude route segments into a select few airports. Results of this effort are described in *[12]*, and the 50 airport-airport routes eliminated in calendar year 1998 are shown in Figure 2.

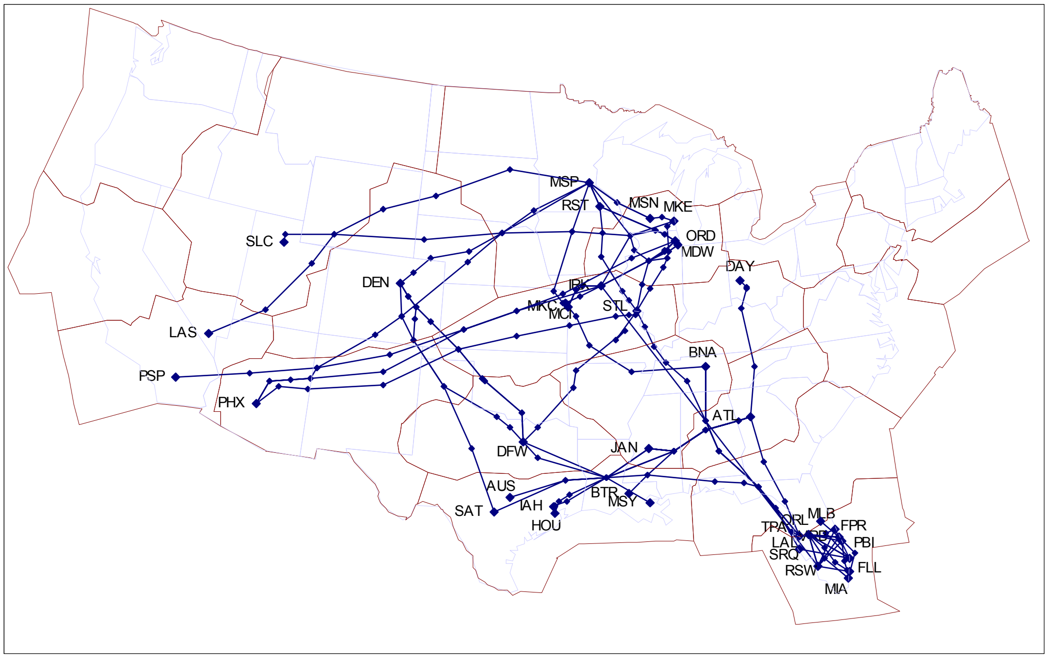

FIGURE 2 ATC-Preferred Routes Eliminated in Calendar Year 1998.

In June 1999, the FAA eliminated an additional 100 high-altitude routes: 81 of these serve specific U.S. airports, and 19 are route segments into the Portland, Seattle and Vancouver terminal areas. The 81 airport-airport routes eliminated in calendar year 1999 are shown in Figure 3.

CAASD has assisted the ATCSCC by providing an operational assessment of eliminating pref routes. Metrics analyzed include route usage, ATC sector counts, flying times, and analysis of graphical plots of traffic patterns. CAASD found little effect from eliminating the 170 routes. This was due to the fact that (1) most airport-to-airport routes eliminated had little traffic and (2) users were already short-cutting or deviating from the routes in order to save time and fuel. Only a few routes had a significant amount of traffic before they were eliminated, but no major shift in traffic was detected after the routes were placed on test elimination. No evidence was found that any ATC sectors in the U.S. have experienced sector count increases over the MAP due to eliminating a pref route.

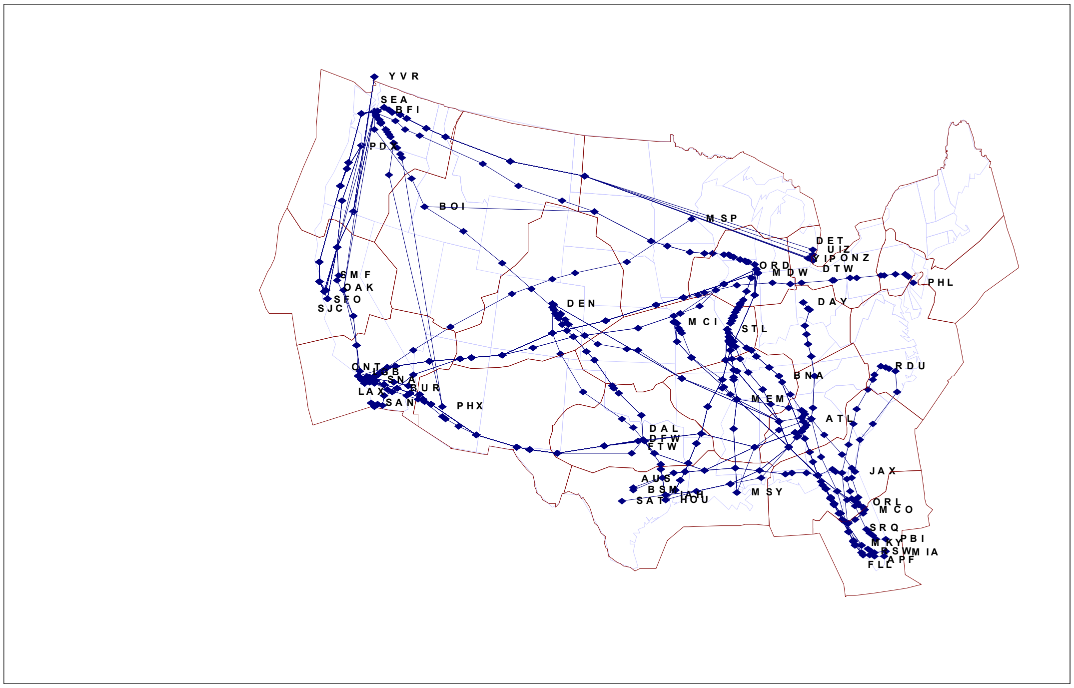

FIGURE 3 ATC-Preferred Routes Eliminated in Calendar Year 1999.

The economic benefits to users from eliminating the 131 airport-airport routes are so far marginal, since little measurable flying time saving has yet been found that can be directly attributed to route elimination. From track data, CAASD has found a small flown distance saving (one to five miles) for a few flights after eliminating two of the special high-altitude route segments into Portland.

CAASD has confirmed that eliminating pref routes reduces pilot-controller communications by necessitating fewer reroutes after takeoff. Before the second set of 100 routes was eliminated, the percentage of flights filing one of the 81 airport-airport pref routes was 44 percent. After these routes were eliminated, that percentage was 37 percent. Before the routes were eliminated, the percentage of flight tracks approximating one of these routes was 17 percent. After the routes were eliminated, the percentage was 11 percent. Thus, many more flights actually file a pref route prior to takeoff than fly close to it from takeoff to landing. When traffic and weather conditions permit, many pilots are being cleared after takeoff by ATC direct to a point farther down the route. By eliminating pref routes, users have more freedom to file different, more direct routes. Thus, pilot-controller communications are being reduced due to fewer reroutes after takeoff.

CAASD has also examined an additional 160 high-altitude pref routes. These include a top-down look at the high-altitude pref routes serving the 50 airport pairs in the U.S. having the heaviest connecting traffic, as well as 133 high-altitude pref routes whose potential elimination was questioned by one of the involved ATC en route Centers. Four routes in the top-down set were successfully eliminated by the FAA in calendar year 1999. The statistics again show that many pref routes serve little to no traffic. They also show that for many of the routes that serve pairs of airports with significant connecting traffic, either most flights do not file the route, or most flights divert from the route after takeoff in order to fly more direct. This analysis will be used in subsequent consideration of route elimination candidates.

While examining the effects of eliminating routes, CAASD investigated the ability of several metrics to predict flight patterns after a pref route is eliminated. The most useful metrics were found to be the following:

1. Pref route distance
2. Pref route relative inefficiency. The relative inefficiency of a pref route is defined as the pref route distance minus the Great Circle Route (or direct) distance, divided by the Great Circle Route distance. If the pref route is direct from airport A to airport B, then its relative inefficiency is zero. The average relative inefficiency of all the high-altitude pref routes in the NAS is 0.04. A few pref routes have a relative inefficiency above 0.3.
3. Number of aircraft that fly the pref route. For present purposes, a flight is said to fly a pref route if its track averages within six nmi lateral distance of the route during the effective hours of the route, and given that the flight's filed altitude is consistent with the pref route being either a high- or low-altitude route.
4. Number of aircraft that do not fly the pref route but could. This is the number of aircraft that fly from airport A to airport B at an appropriate filed altitude, but do not fly the pref route.

Based on analyses of traffic and the above metrics, in late 1999 CAASD recommended to the FAA the following strategy for eliminating future ATC preferred routes. The strategy is based on the principle of maximizing the number of deleted routes while minimizing, if not eliminating, negative impacts.

- First, routes with little or no filed traffic should be eliminated. These routes serve either airport pairs no longer having any significant traffic, or airport pairs with significant traffic but where users no longer are filing the route.
- Second, very efficient or almost direct routes having a relative inefficiency of 0.01 or less should be eliminated. These are most often short routes but are also occasionally over 500 nmi. They offer little to no benefit over flying direct.
- Third, pref routes where most flights short-cut or divert from the route after takeoff are good candidates for elimination or restructuring. These include inefficient routes with significant short-cutting as well as longer routes serving cities with NRP traffic. Longer pref routes tend to have little traffic unless they are wind-optimal. Ninety-four percent of the airport-airport pref routes eliminated in fiscal year 1999 fall into one of the above three categories. This indicates that eliminating these types of routes often has no negative ATC or airspace user impacts.
- Fourth, inefficient (relative inefficiency > 0.05) pref routes not in congested airspace, but with a significant amount of traffic filing and closely approximating the route, should be considered for elimination. Eliminating these routes may significantly benefit users without negatively impacting surrounding traffic. Only three percent of routes eliminated in 1999 fall into this category, and only three percent of the routes eliminated fall near this category with a relative inefficiency between 0.01 and 0.05.

Eliminating or modifying any further routes beyond these four categories may be difficult without interfering with other traffic patterns in nearby congested airspace, as in the Northeast corridor. Because of this and the presence of airspace redesign teams at many ATC centers, further pref route elimination apart from such redesign efforts has reached an incremental stage. In parallel with this, however, is the fact that new, more fuel-efficient pref routes are also being instituted by the FAA. These new routes are a direct result of FAA discussions with the airlines that do not wish to wait for inefficient routes to be eliminated.

CONCLUSION

Near term procedural enhancements are being implemented to help improve the NAS today. This paper has reviewed the analysis and implementation of four of these enhancements, each of which has yielded incremental efficiency benefits to the NAS. Although the specific benefits of some of these enhancements are relatively small, they are positive and quite real. Study of these enhancements has also shown how well the NAS is currently operating, since only small improvements can be realized in the near term. As these and other procedural enhancements *[5]* are implemented, the NAS users will continue to benefit from gradual improvements, until FFP1 and longer term automation improvements become available. CAASD will continue to help design, analyze and implement those enhancements that provide the most benefit to the NAS.

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DISCLAIMER

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FIGURES AND TABLES

FIGURE 1 NRP Transitions on Denver Departure Procedure.

FIGURE 2 ATC-Preferred Routes Eliminated in Calendar Year 1998.

FIGURE 3 ATC-Preferred Routes Eliminated in Calendar Year 1999.