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MITRE PRODUCT

The Impacts of Regional Jets on Congestion in the NAS

February 1999

Dr. William W. Trigeiro

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MITRE

Center for Advanced Aviation System Development
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MITRE Department
and Project Approval: ______________________________

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Systems Analysis

Acknowledgements

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Introduction

This briefing summarizes the results of an analysis performed by the MITRE Corporation's Center for Advanced Aviation System Development (CAASD) to examine the potential effects of regional jets (RJs) on the performance of the National Airspace System (NAS). The study was part of a Mission Oriented Investigation and Experimentation (MOIE) project conducted in fiscal years (FY) 1998–1999. The intent was to provide a "heads up" to aviation planners about the ability of the NAS to accommodate the significant changes anticipated in the regional airline fleet through 2003.

The study was conducted in two phases. First, an analysis of the airline industry was performed to determine the degree to which RJs are now in use and the plans of the airlines for expanding their deployment in the future. The final result of the first phase was a scenario reflecting expected RJ usage at the end of 2003. Second, that scenario was used to create a prototype airline schedule (format-compatible with the Official Airline Guide, or OAG). This, in turn, served as the basis of a simulation of air traffic flows at the end of 2003. In turn, this model produced results that suggest the expected influence of RJs on congestion in the NAS at the end of 2003. The analysis considered only traffic within the continental United States (CONUS).

The scenarios investigated come from the OAG of February 1998 and two scenarios set in December 2003. In one, we increased traffic based on the Federal Aviation Administration (FAA) Office of Aviation Policy, Plans, and Management Analysis (APO) Terminal Area Forecast (TAF). In the other scenario, we used the TAF as the basis for jet traffic growth but constructed a custom schedule for RJs and propeller-powered aircraft based on the results of our own investigations.

We found that en route air traffic grew more than the national average in nine centers which roughly form a triangle from Michigan to Florida to Texas. Traffic in the other eleven centers, two in the northeast and nine in the north-central and western U.S., grew at a pace below the national average.

The resulting elevated traffic loads due to RJ traffic appear to pose the greatest potential congestion problems at eight centers (in which at least 10 percent of their sectors face congestion problems), five of which are growing at an above-average pace. Those results are depicted in a map in this briefing.

Airports experiencing high RJ traffic growth can be classified by the presence or absence of plans for new runways within the next five years.

Summary

A “bottom up” approach was taken to develop a current picture of the number of RJs employed by the airlines and the roles to which they are assigned. Current literature, public announcements by airlines and the plans of RJ manufacturers were analyzed to describe the existing RJ fleets and the direction the airlines plan to take them. The industry-wide forecast was based upon forecasts prepared by the FAA and others. Our study concluded that at the end of 2003 there will be approximately 800 RJs in airline service in the continental U.S.

While both aircraft manufacturers and airlines are inclined to announce plans for production and acquisition of aircraft, airlines are usually reluctant to publicize their specific plans for using new equipment or retiring older aircraft from their fleets. Thus, our forecast of the retirements of turbo prop aircraft and RJ route structures for the end of 2003 rests on less solid ground than our projections of the overall RJ fleet size.

We made the assumption that the airlines’ strategies will not depart markedly from current trends. Thus, care was taken in constructing the synthetic OAG to assign new RJs to routes that are logically consistent with existing hub-and-spoke networks. Scheduled banks of flights at the various hubs and traffic patterns were preserved by assigning RJs first to replace flights of turbo props that were forecast for retirement and to new routes that take advantage of their speed and range.

We assumed that the kinds of relationships now existing between mainline airlines and their regional affiliates will continue, and that airlines will be able to realize their plans. The “scope” clauses in the contracts of mainline pilots regarding their airline’s code-sharing partners are expected to be a key issue determining the numbers of RJs and applications to which they are assigned in the coming five years, but we assumed that they remain unchanged.

The actual OAG for February 1998 was used as the baseline for developing a December 2003 schedule. The aggregate mainline and regional airline fleet sizes were based on the FAA’s forecasted growth rates of air traffic. RJ traffic was based on the scenario developed during Phase 1.

The 1998 and 2003 scenarios were used with MITRE’s Detailed Policy Assessment Tool (DPAT) simulation of the NAS for the purpose of identifying changes in airspace and airport congestion that could be attributed directly to the introduction of RJs in airline fleets. To isolate these effects, the model was run assuming that neither weather nor any other external event that could impede the flow of traffic in the NAS was a factor.

The results showed that nine of the 20 continental U.S. Air Route Traffic Control Centers (ARTCCs), those included in a triangle with corners in Michigan, Florida and Texas, will see air traffic grow at a rate that exceeds the national average. Within this area, the highest levels of congestion are expected to occur in Indianapolis Center followed closely by the Cleveland and Dallas-Fort Worth Centers. Six of the ten most-congested en route sectors are located in a cluster to the north and east of Cincinnati. These high-altitude sectors are contiguous and form a line across major air traffic routes. Therefore, even if the margin of error in our traffic forecast for this area were substantial, we cannot escape the conclusion that this area, in terms of congestion, will be one of major concern for the NAS by the end of 2003; there is simply no reasonable way for air traffic to avoid this congested airspace. On the other hand, we anticipate that the western U.S. will see only minimal introductions of RJs in the near future and will experience below-average growth in traffic volume and airspace congestion. In general, we believe that the conclusions we have reached are sufficiently valid and robust; we feel that they would hold up even if the details of our assumptions were successfully challenged.

The regional jet is like an emerging technology that permits airlines to explore modes of operation that in the past may not have been within their reach—the RJ should be thought of as an enabling technology. Therefore, the degree to which the RJ will influence the structure and operations of the air transportation industry is not yet totally clear. Only over time, as the industry is able to explore the new avenues the RJ has opened to it, will the picture crystallize. This study is intended to help clarify one uncertainty, namely the ability of the air traffic control infrastructure to handle the changes in operations that will occur with the rapid deployment of RJs into the U.S. airline industry's fleet.

Demand Scenario Update

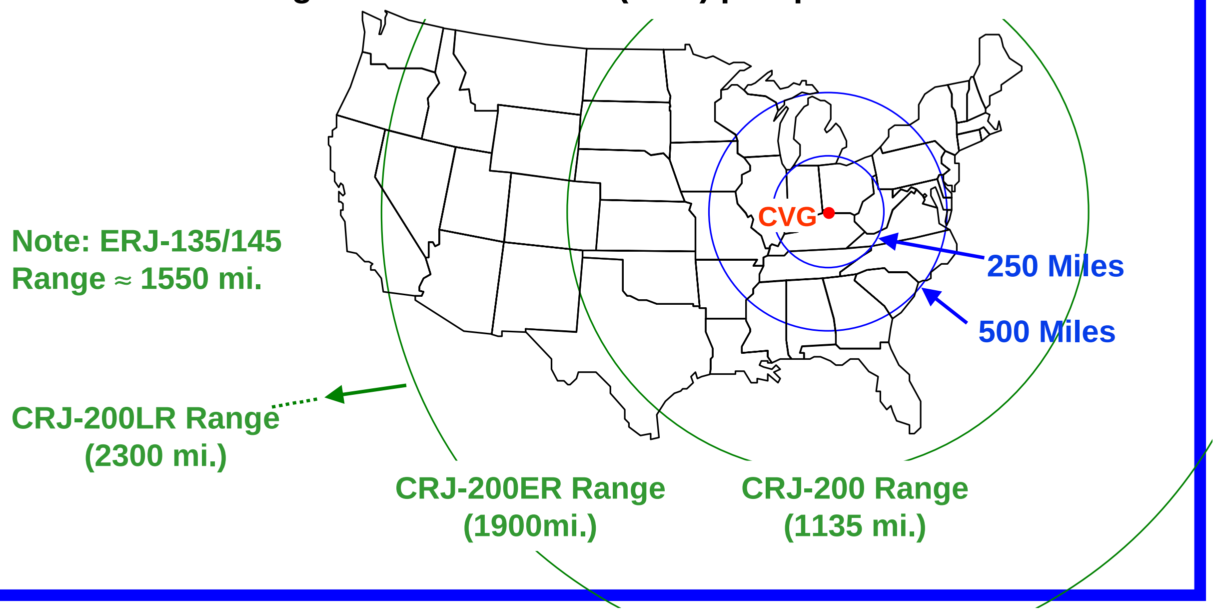
Our analysis was based on a demand scenario which was frozen in June 1998. Since that time, we have tracked changes in procurement plans by airlines for consistency with our scenario. Based on the changes which we have seen, as enumerated below, we are confident that our scenario involving 800 aircraft is a conservative estimate of the RJ fleet in December 2003.

By our count, there are now well over 200 RJs in service and firm orders for more than 500 more for a total of approximately 760 aircraft. Most of these will be in operation by 2003. In addition, options are in place for about 660 more RJs; some of those options will be exercised and therefore some of those RJs will also be delivered within five years.*

** Based on restricting definition of RJs only to Canadair CRJs, Embraer ERJs, Avro ARJs and Fairchild-Dornier 328JET aircraft (i.e., not including Fokker F-28 or BAe-146), and only U.S. airlines.*

What is a Regional Jet?

- RJs currently contain 50-85 seats, soon to be 32-90 seats
- Operational performance of some current popular models similar to Boeing 737 from the ATC (FAA) perspective



In some sense, regional jets are an enabling technology that may change the basic operating philosophy of airline competition. Whether the capabilities are fully exploited depends on potential airline and air traffic control constraints as discussed in this briefing.

RJs have reduced the breakeven point for efficiency of prop versus jet operations down to about 250-300 miles; however, increased revenue potential of jets versus props is a key consideration.

What is an RJ?

- Most likely it is operated by a regional airline
- Contains 32-90 seats, the same as medium and large turboprops
- Jet speed and range enable challenging competitors' hubs
  - Flight range of Canadair CRJ-200 ≈ 1100 mi (Extended Range ≈ 1900, Long Range ≈ 2300)
    - Some are capable of trans-continental flight, even though they are targeted at medium-range routes.
  - Maximum cruise speed of CRJ is Mach 0.81
  - Passengers strongly prefer jets over turboprops, due to quieter ride, faster speed and perceived safety and quality
  - CRJs can outperform many mainline jets from the FAA's air traffic control perspective (e.g., speed, altitude, climb rate)
    - Embraer ERJs have somewhat lower ATC performance than CRJs (e.g., speed and altitude)
    - Details of Fairchild-Dornier 328Jets are still somewhat unknown
    - BAe-146/Avro-ARJ, F28 are based on older technology designs
    - 328Jet and 146/ARJ have much shorter runway length requirements than CRJ and ERJ (5,000 feet vs. 6,000 feet)

How RJs Will Affect the NAS

- **Increased competition at "spoke" airports between airlines and competition for traffic feed to associated hub airports**
  - **Overall change in traffic patterns is unclear**
  - **May provide opportunity for less congested hubs to grow faster than badly congested hubs**
- **Aggregate increase in traffic volumes may worsen congestion in en route airspace and at some airports**
  - **But rate of retirements of small props and older props is unclear**
  - **Increased congestion and complexity in transition airspace (climb and descent) may be a problem**
- **No *major* structural impacts anticipated on the following programs:**
  - **Data link, Passive FAST, CTAS, TMA, SMA, etc…**
  - **GPS, other advances in avionics**

RJs require longer runways than the turboprops they replace. It is not possible to fly a fully loaded CRJ or ERJ off a 5000-foot prop runway. This may prove a bottleneck at some airports as RJ flights replace prop flights.

As the continued introduction of RJs accelerates the growth of jet traffic overall, more arrival/departure routes will be needed. This is an issue in terminal area airspace.

Transition airspace may be the biggest problem—it is a big unknown for now—this topic was not included in this project's investigation—but it merits further research. Its potential for becoming a problem was raised as an issue in several interviews with CAASD domain experts.

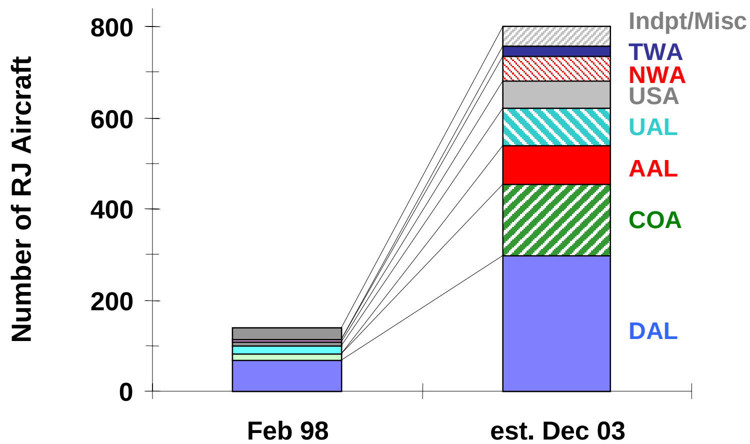
In en route airspace, RJs are expected to behave as conventional jets—no special provisions or treatment by Air Traffic Control/Air Traffic Management (ATC/ATM) is required—but overall high-altitude airspace congestion is likely to worsen as RJs flying at higher altitudes replace props flying at lower altitudes.

The overall traffic patterns in the U.S. are likely to change, relative to what they would have been if regional airlines had continued to fly mostly prop aircraft. However, without knowing the result of increased competition between hubs for spoke-city traffic, it is unclear exactly what the net effect will be. However, it is known that traffic is growing faster because of passenger preference for jets over props, and RJs are being primarily deployed in the eastern and central U.S., and to a much lesser degree in the west.

As part of our effort to understand the overall effects of increasing RJ use on NAS performance, we conducted a series of interviews with CAASD domain experts. Their judgments were that most FAA investment projects (e.g., data link) would not be structurally affected by RJs. The primary effect would be via the change in the traffic levels and traffic mix, which would somewhat change the timing and values of benefits from investment projects, but would not likely change the basic "go/no go" decisions as to their deployment.

Regional Jets in Support of Major Airlines*

- Greatest growth will occur with regional airlines that code-share with major airlines having non-restrictive pilot scope clauses
  - Renewals coming up over next few years
  - Outcomes of pilot unions' negotiations will determine RJ growth



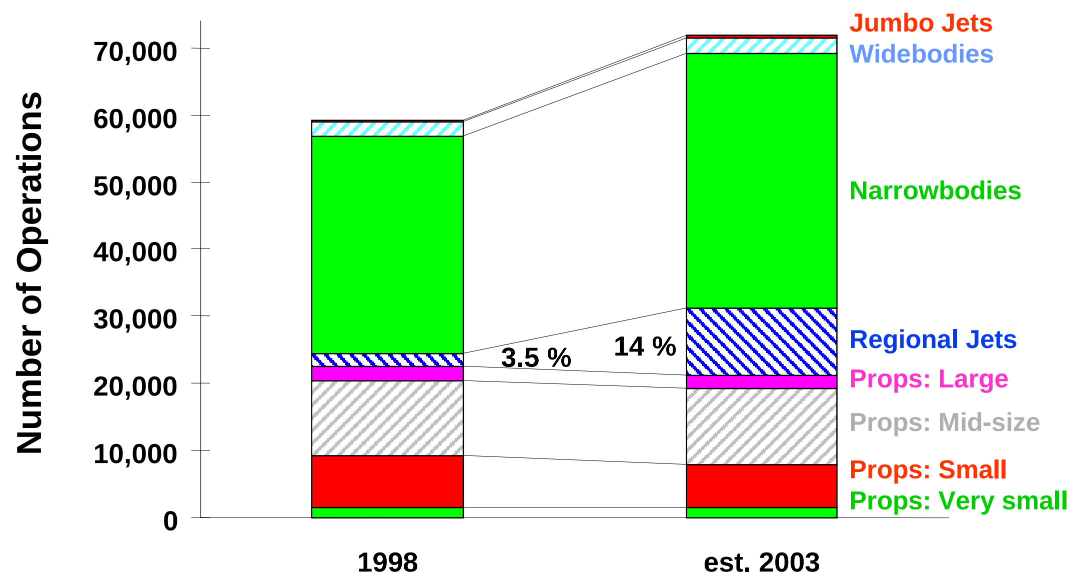
* Operated by Code-sharing Regional Airlines

The greatest single factor limiting the growth of RJs is the set of "scope" clauses in place in the pilots unions' contracts with major airlines which restrict code-sharing between airlines. The terms currently vary considerably by company. Many contracts/clauses are up for renewal or re-negotiation within the next few years.

Pilots' unions of major carriers have scope clauses in their contracts which place limits on the number of RJs the mainline carrier or its regional affiliates can operate, and place restrictions on their operations. This issue is very important to the pilot unions and has been a source of labor-management contention in the recent past. In some cases, the scope clauses are very restrictive while in other cases the limits are not currently operationally significant.

It is likely that the extent of restrictions of scope clauses will change in the future. However, it is not yet certain what direction or magnitude this change will be. We have taken a mainstream path with our scenario by assuming no change in scope clause restrictions. We did not undertake an analysis of any alternative assumptions which would entail greatly more or less restrictive limits.

Composition of Operations at CONUS Airports (Scheduled Passenger Flights Only)



The fleet mix of CONUS traffic in February 1998 and anticipated in December 2003 is depicted above, based on the number of passenger-carrying flights flown departing from or arriving at CONUS airports. These numbers are based on scheduled passenger flights as appeared in the February 1998 OAG and in our 2003 RJ demand scenario.

Note that this measure of fleet mix tends to amplify the impact of aircraft that fly a large number of flight legs per day, due to their short route structure. Thus, larger jets flown on longer routes appear disproportionately smaller than if the fleet was measured by the number of aircraft or by the number of miles or hours flown. Also, international flights produce only one CONUS airport operation whereas domestic flights entail two—both a departure and an arrival.

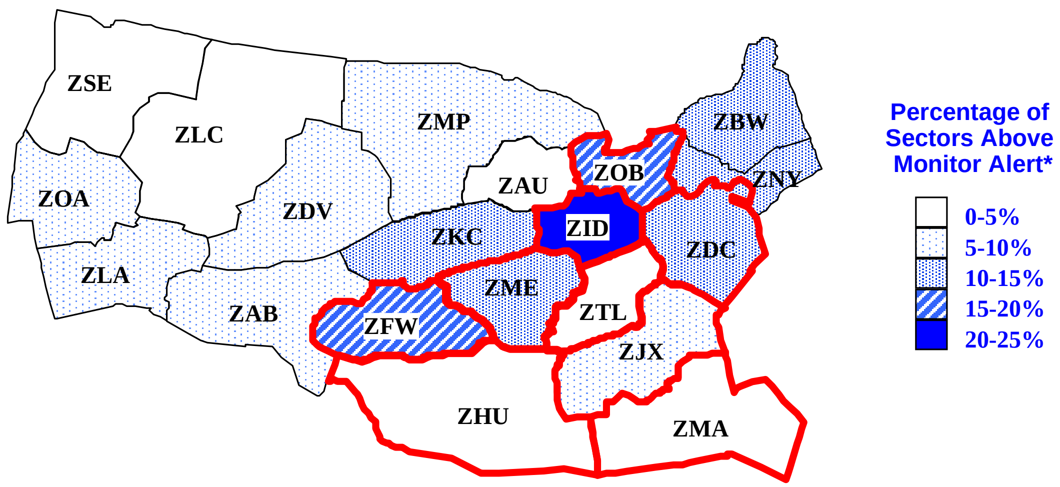
This measure is most appropriate when considering the effects on the congestion at airports during the day or on how changes in the prop/jet fleet mix on airport arrival/departure routes may affect airport and terminal area airspace capacity.

Note also that large jet traffic (non-RJ) occurs at only about 200 airports.

Note: Very small props were defined as having 15 or fewer seats, small props have 18–19 seats, mid-size props have 28–37 seats, and large props have 42 or more seats.

2003: En Route Congestion Across Centers

● **ZDC/ZOB/ZID/ZKC/ZME/ZFW: core of U.S. is problematic**



* Sectors with average 15-minute density > Monitor Alert threshold at least once per day

Shaded boundaries indicate centers with above average increases in traffic 1998-2003

This chart presents two categories of information. The map shows the boundaries of the 20 continental U.S. (CONUS) Air Route Traffic Control Centers (ARTCCs). The boundaries of nine of the 20 ARTCCs are drawn with heavy lines to identify them as the areas with above-average increases in air traffic from 1998 to 2003. The interiors of the ARTCCs are shaded to indicate the extensiveness of sector congestion within them.

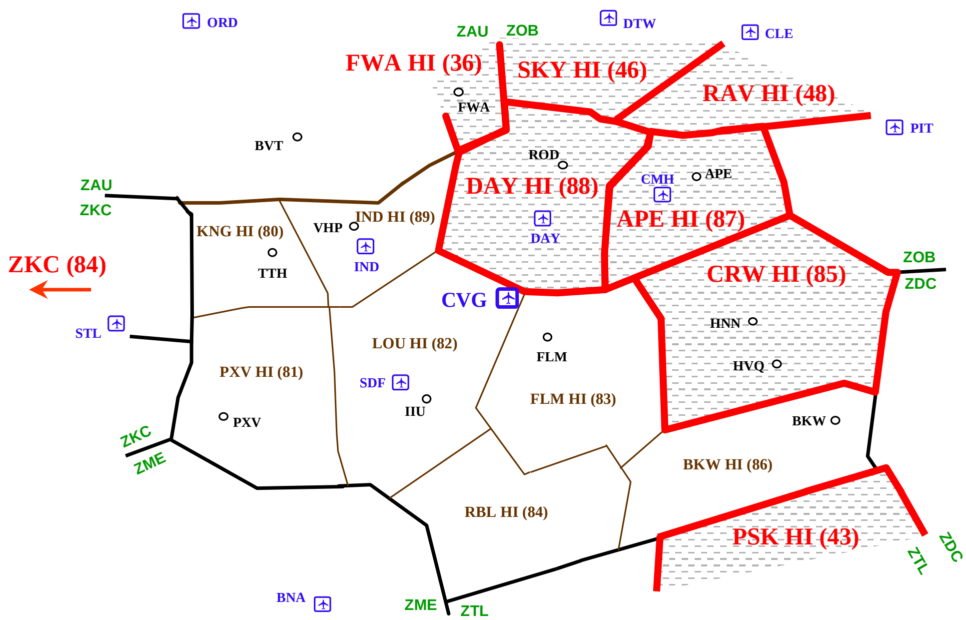
The unit of measure for congestion used here is the average aircraft density per 15-minute interval. A sector was identified as congested when this average traffic level exceeded its monitor alert threshold. Identified for each center in the map above is the proportion of sectors for which this occurred at least once during the day for the 2003 scenario which we developed for RJs. The shading in the map shows the percentage of an ARTCC's sectors which exceed their thresholds.

Note that Kansas City (ZKC), New York (ZNY), and Boston (ZBW) receive below-average traffic growth yet nonetheless face above-average congestion problems. In contrast, Atlanta (ZTL), Houston (ZHU), Jacksonville (ZJX), and Miami (ZMA) receive above-average traffic growth yet did not exhibit systematic congestion problems, although there was one sector in ZTL which became measurably congested (see next page).

Chicago center (ZAU) appears to be relatively unaffected by increased traffic, despite being surrounded by areas with growing traffic. This result may be because O'Hare Airport's (ORD) traffic growth is severely limited because it is slot-controlled (which smoothes out the traffic flow) and it is the dominant airport in the center.

Key Problem Area in ZID and ZOB: Congestion at Individual Sectors

- **Group of six high-altitude sectors between CVG, PIT, CLE, DTW leaves no way for traffic to avoid congestion**



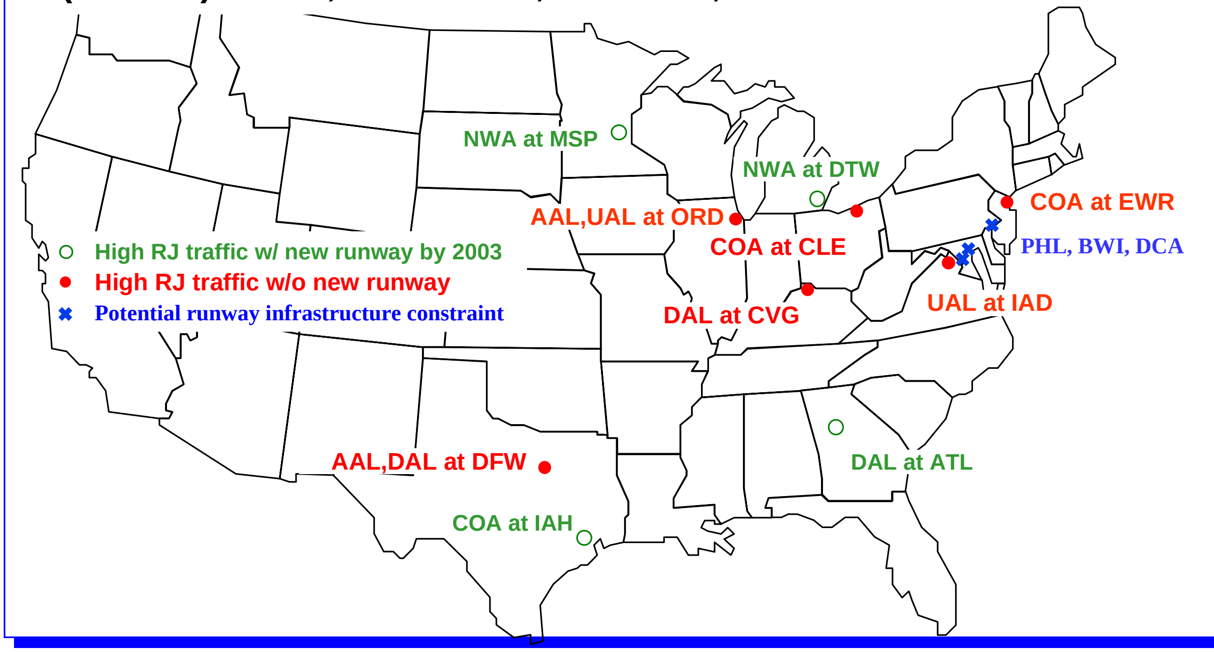
This high-altitude sector map of Indianapolis center and surrounding airspace demonstrates the critical pressure that is likely to be faced by this part of the U.S. in the near future unless a major change occurs. Six of the ten most congested sectors in the U.S. form a contiguous group, with two other sectors nearby. The term "most congested" is based on a definition of enduring sustained congestion throughout much of the day (sectors with more than two hours of sustained traffic averaging above their monitor alert threshold, i.e., more than eight such 15-minute blocks of time per day).

Because of the proximity of these problem sectors, the particular details of how we implemented flight schedules and routes are not likely to affect our overall airspace conclusions. The congestion problems in this part of the U.S. occur over a wide time span and over a wide geographical area. One cannot simply fly at a slightly different time or take a slightly different route to avoid the congestion problem. Thus, our conclusion can be considered to be fairly robust to changes in modeling assumptions.

Note that there is currently underway an airspace design review program for the airspace in the vicinity of Cincinnati Airport (CVG). We anticipate that congestion could get much worse without a major change in airspace design, procedures, and/or technology to alleviate constraints imposed by existing airspace capacity. Otherwise, in order to maintain safety, restrictions force a reduction in flexibility and efficiency on flights through this area. The FAA's current NAS modernization plans that address these concerns include the deployment of new tools in this area (e.g., the conflict probe tool known as the User Request Evaluation Tool, or URET, which is designed to assist controllers handle high levels of traffic).

Potential Significant RJ Effects on Hub Airports

- **Significant growth desired by airlines at selected hubs of (in order): Delta, Continental, American, United**



New runway capacity is predicted to relieve potential airport congestion at Detroit (DTW), Houston Intercontinental (IAH), Minneapolis/St. Paul (MSP), and St. Louis (STL). Note that Atlanta (ATL) has a new 6000-foot runway approved for 2002, but is proposing that it be lengthened considerably. If approved at 9000 feet or longer, it will not likely be available until at least 2004.

The most significant congestion problems appear to be at Cincinnati (CVG), with Dallas/Fort Worth (DFW) not far behind. There is also pressure on Chicago O'Hare (ORD), despite its slot-controlled status, due to airline desires to fly RJs in place of, or in addition to, props. Congress may grant additional slots to such a degree as to potentially significantly affect on-time performance there. In our simulation of traffic in 2003, no other airport other than Cleveland (CLE) and Newark (EWR) seemed to be ***substantially*** effected in terms of delays.

Short runways which are usable by props but not by CRJs or ERJs may impose operational constraints on the plans of airlines at Baltimore (BWI), Reagan Washington National (DCA), and Philadelphia (PHL). Without other mitigating solutions, airlines serving those airports may be limited in their deployment plans or else limited in their choice of RJs to those which have short distance runway capabilities. A more extensive analysis of airport infrastructure may identify other airport constraints, such as the noise abatement limits on runway 13L at DFW.

Relevance of RJ Traffic Growth to NAS Modernization

- **Regional jets are growing in numbers and importance**
- ***Selected*** **airports/airspace will be particularly affected**
  - **Free Flight Phase 1 airport and TRACON deployment plans should account for airline plans for growth**
- **Most significant en route airspace congestion problems likely to occur along corridor from Fort Worth to Cleveland en route centers**
  - **URET may be most needed at these centers**
- **Magnitude of benefits of NAS modernization programs may be affected, but involves second-order effects in comparison to congestion concerns**

Growth in regional jet traffic will in large part be determined by the outcome of pilot union negotiations with major airlines over their scope clauses over the next few years. As a result, growth may occur at an even more rapid pace than that predicted by our study, or may be significantly stunted. In contrast, the overall U.S. economic performance will likely have less of an impact on regional jet traffic growth than will the outcome of pilot negotiations. We feel that by far the most likely outcome is that our scenario's estimate of RJ deployment will be met or exceeded, with only a very small chance that we have overstated the problem.

If airline plans for RJ growth are largely realized, of particular concern is that the high-altitude airspace in the vicinity of Cincinnati, Detroit, Cleveland, and Pittsburgh may become increasingly congested. Airlines may have difficulty achieving their desired levels of RJ traffic at Cincinnati, Newark, Dallas/Ft. Worth, Cleveland, and possibly Atlanta unless further improvements in capacity are achieved at those airports.

The NAS modernization effort may want to consider this scenario for RJ growth and factor into its decisions increased growth concerns in airspace and at airports when selecting technologies and deployment locations.

A potential problem area that was not addressed in this study was noted on page five, namely the possibility of increased complexity and congestion in transition airspace, where aircraft are climbing and descending while transitioning between the terminal and en route phases of flight.

Appendix
(Backup Slides)

Demand Scenario Assumptions

- **Note: scenario was "frozen" in June 1998**
- **Most 1998 airline plans for RJs reach fruition**
- **Average stage length of RJs continues to expand**
  - **RJs routinely fly legs of 800–1000 miles**
- **Existing relationships between carriers remain constant (e.g., Delta & Comair, USAirways & Mesa, United & Atlantic Coast)**
  - **No regional carrier code or benefit program established**
- **Renegotiated contracts between pilots and airlines do not change existing restrictions on the use of RJs**
- **Few additional slots at controlled airports for RJs**
  - **Airlines assign RJs as prop replacements in response to consumer preference for jets over props**

We believe that our assumptions are quite conservative, in that they posit no major departure from the present structure of the airline industry and the environment in which it operates. We feel that this approach is reasonable because, even though the airline industry has undergone and continues to experience considerable change, the patterns of change have been evolutionary rather than revolutionary. We have therefore assumed that the industry will continue to evolve along its established paths and will not experience radical change.

Further, our intent is to focus upon the changes that are expected to result primarily from the introduction of the regional jet. By assuming an orderly pattern of growth, the likelihood that the attention of the study would be diverted from its primary goal is minimized. Having established a logically sound basis for analysis, we will have created the basis from which further work that could explore the sensitivity of our results to changes in the underlying assumptions could proceed.

A Time of Rapid Change

- **Two-thirds of all RJ orders have been placed in the past 1 1/2 years**
- **Currently, approximately 200 RJs in U.S. fleet**
  - **There may be 800–1,000 within 5 years**
- **Type of deployment is beginning to change**
  - **Long-haul, non-hub-feed service is slowly developing (initial use is primarily of a prop-like hub-feed nature)**
- **Because our project is striving to provide an early "heads up" to the FAA and other stakeholders**
  - **Our answers would be different if we were to wait one more year to perform these analyses**
  - **Since freezing our demand scenario in late spring, the environment has already changed (e.g., microjets)**

As with all forecasts, our demand scenario for December 2003 will not be completely correct. However, given the nature of our assumptions, it is not likely that we have greatly overstated the degree of RJ adoption. We feel that it is much more likely that even more RJs will be in the U.S. fleet in five years, rather than fewer than we have predicted. We provided evidence of this on page 3, where an update of airline procurement plans was shown.

Since freezing our scenario to changes in June, 1998, the rapidly changing environment has continued apace. In particular, new announcements have been made regarding microjets, RJs with seating capacity of 32–37 (due for delivery beginning in 1999). Significant orders have been placed by American Eagle and Continental Express, and others are expected to follow. This situation was entirely predictable and was predicted by us (17 percent of the RJs in our 2003 scenario are microjets). Because we chose a mainstream future in which nothing radical would change from the pattern which existed at that time, we chose only a moderate rate of adoption of microjets.

The primary shortcomings of our assumptions are that the prop/jet fleet mix will be different than we have stated, and the total number of aircraft will likely be different. However, it is not yet clear to what degree they will be different. For example, even while placing orders for new small turbojet aircraft and stating that they would be based out of Dallas-Fort Worth airport, American Eagle has not yet stated the extent to which these will *replace* turbo props versus expand (augment) existing turbo prop service. The outcome will depend on the overall economic environment at the time of RJ deployment, as well as the degree of passenger demand stimulation from RJs, potential problems with air traffic congestion, and other factors not now fully understood.

Demand Scenario
As Implemented In OAGs for DPAT

- **Compounded annual growth rate in airport aircraft operations (departures + arrivals)**
- **Stage lengths of RJs are growing while props are shrinking slightly**

Annual Traffic Growth Rate	
02/98-12/03	
Jets	+ 2.6 %
Props	- 1.0 %
RJs	+ 29.8 %
Total	+ 3.2 %

Average Flight Length		
(miles)	1998	2003
Jets	700	700
Props	190	180
RJs	375	455
Total	495	515

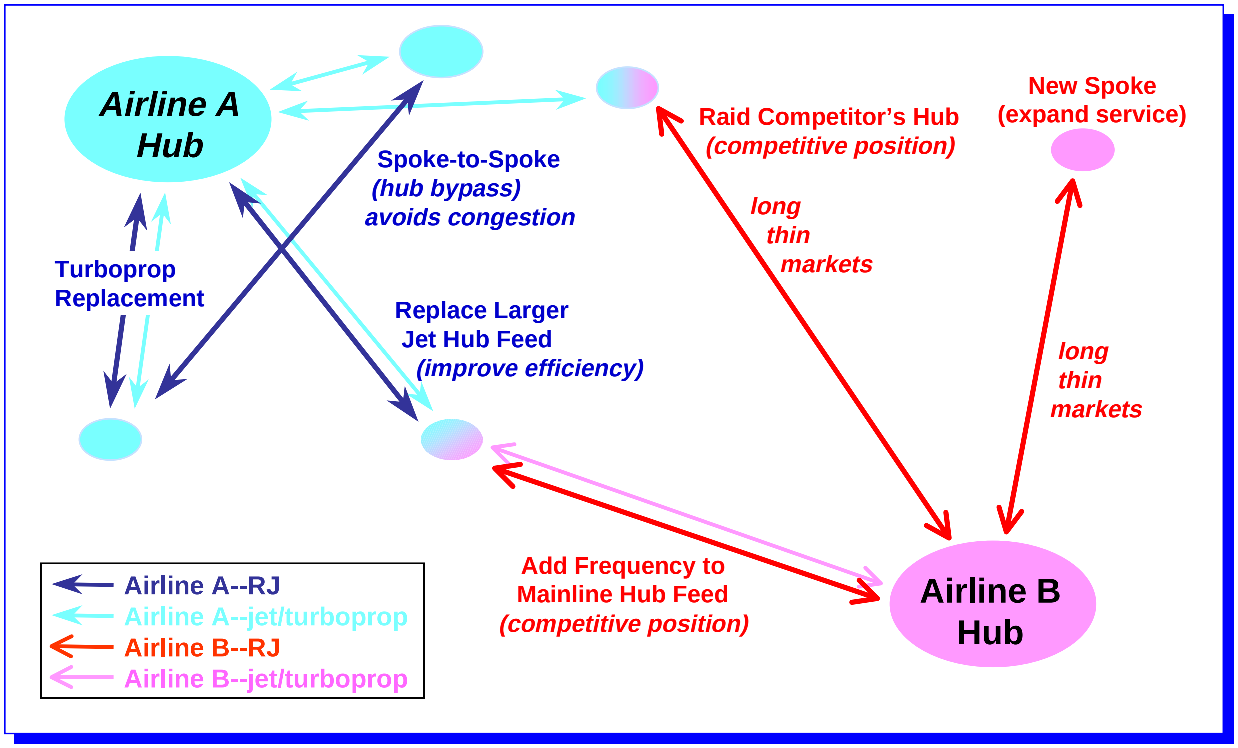
The annual growth figures in the chart above represent the compounded growth rate of U.S. air traffic from February 1998 to December 2003, the timeframes of our analysis.

Overall, our demand scenario shows greater growth in total air traffic than does the FAA forecast of 2.3 percent for CONUS traffic.† We anticipate that the net effect of significantly increased RJ traffic will more than offset the effect of reduced turboprop traffic. We assumed the FAA's jet traffic growth rates without modification.

Note that in the February 1998 OAG, the average stage length for CONUS flight legs was 190 miles for prop aircraft versus 375 miles for RJs (note that it was 700 miles for all other jet aircraft flights). In the future, props are likely to fly even shorter routes on average (in part because RJs are replacing them on longer routes) while RJs are likely to fly even longer routes than today. Each aircraft type will focus more on the market niches consistent with its operational strengths.

† This differs slightly from the aggregate FAA forecast because it is based on a bottom-up aggregation of scheduled traffic at CONUS airports as shown in the FAA's Terminal Area Forecasts. Note that FAA's Office of Aviation Policy and Plans currently predicts an aggregate 2.3 percent growth rate for overall U.S. (not just continental U.S.) air carrier traffic for the twelve-year period of 1998–2009 [*FAA Aviation Forecasts Fiscal Years 1998-2009*; a summary is accessible through http://api.hq.faa.gov].

Roles of RJs in the NAS



Hub feed. In this use, regional captives like American Eagle, affiliated independent regionals, and regionals like Mesaba (for Northwest) and Mesa (for US Airways) under long-term contracts feed the hubs of major carriers from "catchment" areas with radii of several hundred miles from the hub.

Prop Replacement. Airlines "move up" by flying jets on existing routes, replacing prop aircraft.

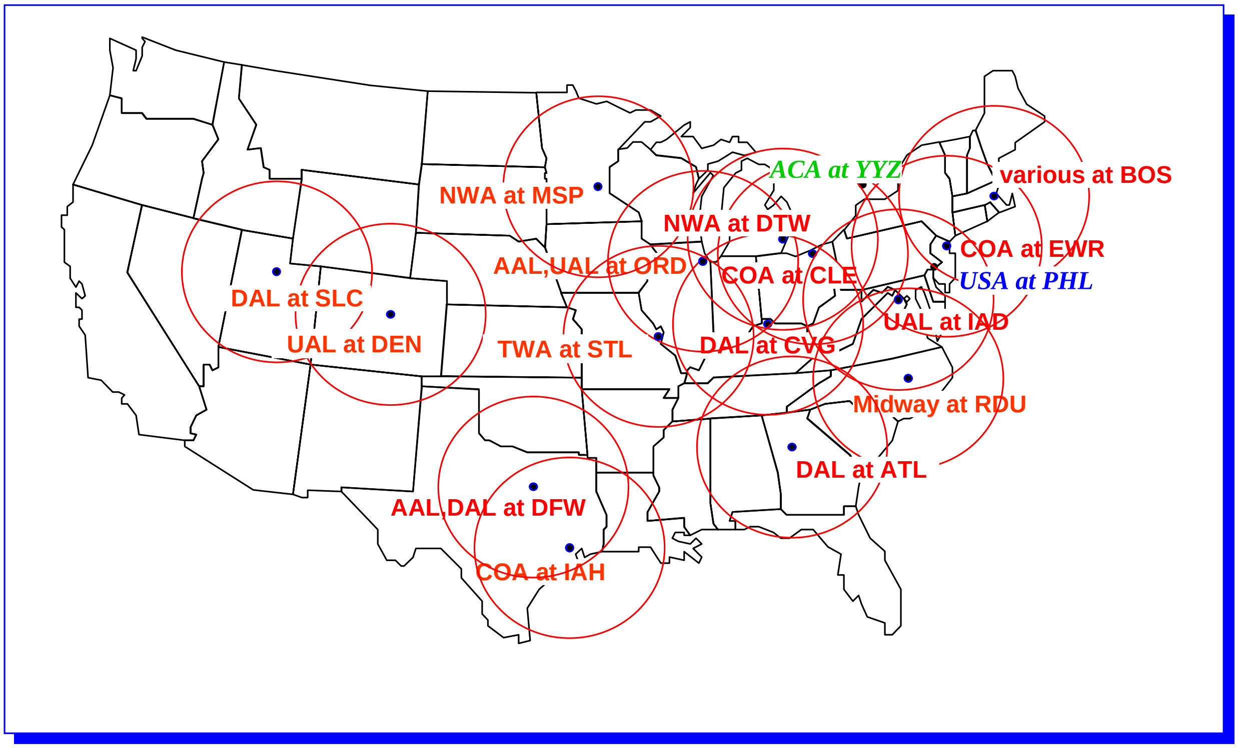
Mainline Augmentation. In this use, RJs supplement the large jets of majors by flying at off-peak times when lower demand does not justify use of larger aircraft.

Mainline Replacement. Major carriers sometimes transfer routes that are marginal for larger mainline aircraft to RJ-equipped regional airlines. This usage heightens concerns of the pilots' unions at major air carriers about job security.

Hub By-pass. In this role, airliners fly directly between the spoke cities of the same hub, eliminating traffic through the hub in favor of direct service; a motive for this is to make room at the hub for other traffic of the same airline. This use is also known as *hub busting* if the motive is to divert traffic from a competitor's hub.

Spoke-to-spoke. These operations involve initiation of new service between cities that do not have direct service because their markets are not large enough to support mainline airliners. The driving airline motive is to serve viable markets and generate new revenues, not by-pass a hub. We expect such usage to be particularly common in the northeastern U.S.

Competition Between Key RJ Hubs: 300 Mile Radius



In order to demonstrate the effect on traffic congestion and competition, this map shows the primary hub airports which will receive RJ service by 2003, with circles of approximately 300 miles to provide a notional range of existing prop traffic feeder effects (the regional airlines' "catchment areas").

Two points are important here. First, these airports are concentrated particularly densely in the area between Chicago and Cincinnati and Boston. Thus, one would anticipate the greatest impacts of RJs on airspace in that region of the country. As mentioned earlier in this report, our simulation analysis confirmed this.

Second, the circles would overlap much more significantly if they had been drawn consistent with RJ traffic (because RJs have much greater ranges) rather than prop traffic. Thus, the competition between hub airports for service to spoke airports could intensify greatly in the next few years. If that happens, it is unclear how the mix of traffic along particular air routes will change, so precise predictions of en route traffic loads are problematic. However, our predictions of the general patterns of traffic loads are likely to be reasonably accurate.

Increase in En Route Airspace Congestion

# Centers with % Sectors Exceeding MAT*		
	1998	2003
0-5 %	15	6
5-10 %	4	6
10-15 %	1	5
15-20 %	0	2
20-25 %	0	1

# Sectors Having Average 15-Minute Density Greater Than MAT*		
# Times	1998	2003
0	671	633
1	9	22
2	8	9
3	3	6
4	2	3
5	1	6
6	0	4
7	1	2
8	1	1
10+	0	10

* MAT = Monitor Alert Threshold

In our simulation analysis, we did not enforce the types of airspace restrictions normally used by the ATC system to maintain safety as congestion develops. As such, what we have in effect identified are sectors which are likely causes of restrictions that result in flights facing delays and other performance degradations due to airspace congestion. Restrictions are enforced by controllers in order to maintain high safety standards at all times, at a cost of flexibility and efficiency to the airlines.

The anticipated growth in en route airspace demand appears to be significant. If airspace capacity were to remain constant for the next five years, the number of sectors which face congestion and the severity of congestion within those sectors will grow significantly, resulting in further reductions in flexibility and efficiency. The FAA is currently studying a combination of factors to address the problem, including airspace redesign, procedural changes, and technological improvements which increase controller productivity (i.e., increase the number of aircraft that a controller can handle).

In a summary of the 1998 traffic levels, a map of the U.S. of the type shown on page eight would show centers much less congested than in 2003 (which compared 2003 demand versus 1998 capacity). Only five of 20 centers would have had more than 5 percent of their sectors experiencing congestion at least once per day, whereas that was true for fourteen of the twenty centers in our 2003 scenario. Our analysis showed that Indianapolis Center (ZID) is the most congested center today as well as in five years, with the level of congestion expected to spread greatly in the coming five years. The only other centers having more than five percent of their sectors facing congestion in 1998 traffic were Boston (ZBW), New York (ZNY), Kansas City (ZKC), and Fort Worth (ZFW).

During the simulated day of 1998 traffic, only 25 sectors experienced a single sustained 15-minute period of time in which their average traffic demand level exceeded their monitor alert threshold. However, 63 sectors experienced that level of demand in our 2003 scenario. In 1998, none of the approximately 700 sectors in the continental U.S. faced a congestion level which would be classified as seriously congested (more than eight such congested 15-minute blocks of time per day), with ten sectors facing those traffic levels five years from now.

Glossary

APO	FAA Office of Aviation Policy, Plans, and Management Analysis
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATL	Atlanta Hartsfield International Airport
ATM	Air Traffic Management
BWI	Baltimore/Washington International Airport
CAASD	Center for Advanced Aviation System Development
CLE	Cleveland Hopkins Airport
CONUS	Continental United States
CVG	Cincinnati/Northern Kentucky Airport
DCA	Ronald Reagan National Airport
DFW	Dallas/Fort Worth Airport
DTW	Detroit Metro Wayne County Airport
EWR	Newark Airport
FAA	Federal Aviation Administration
IAH	Houston Intercontinental Airport
MOIE	Mission Oriented Investigation and Experimentation
MSP	Minneapolis/St. Paul Airport
NAS	National Airspace System
OAG	Official Airline Guide
ORD	Chicago O’Hare Airport
PHL	Philadelphia International Airport
PIT	Pittsburgh International Airport
RJ	Regional Jet
SLC	Salt Lake City International Airport

STL	St. Louis Lambert Airport
TAF	Terminal Area Forecast
URET	User Request Evaluation Tool
U.S.	United States
ZAU	Chicago ARTCC
ZBW	Boston ARTCC
ZDC	Washington DC ARTCC
ZFW	Fort Worth ARTCC
ZHU	Houston ARTCC
ZID	Indianapolis ARTCC
ZJX	Jacksonville ARTCC
ZKC	Kansas City ARTCC
ZMA	Miami ARTCC
ZNY	New York ARTCC
ZOB	Cleveland ARTCC
ZTL	Atlanta ARTCC