Testimony before the US House of Representatives Committee on Appropriations Subcommittee on Transportation

Hearing on the Causes of Air Transportation Delays
Thursday March 15, 2:00pm, Rm. 2358 Rayburn Office Bld.

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Abstract

The US Hub and Spoke air transportation system is approaching a serious capacity crisis. Both safety and capacity are intertwined. NASA and the FAA are working hard at coordinating their research agendas, even though they have very different missions and cultures. The FAA and NASA have set some very ambitious goals that are not technically achievable without a fundamental rethinking of the operation of the air transportation mode. Specifically, the increase in system throughput by a factor of three is not achievable using large aircraft at hub airports. A reduction in accident rates by an order of magnitude is an equally daunting goal. Both the FAA and NASA need to do more in the analysis, operational demonstration, and certification of automatic aircraft sequencing, separation and collision avoidance. The development of an international, spectrally efficient, broad-band, wireless transportation Internet, required for ADS-B and the Aeronautical Telecommunications Network (ATN), is essential. DoD has a major stake in the development of this system and should take the lead development responsibility away from the FAA. The Air Traffic Management service should begin to be outsourced to the private sector to implement and operate a new air traffic management system.

Automatic collision avoidance is routinely discussed in the context of the FHA ITS program, where it is extremely difficult to implement, and seldom discussed for aviation where the technology is much more mature and the problem is much more tractable. This technology will be required in the future to increase both the safety and the capacity of the air transportation system. Although runways at hub airports represent a fundamental limitation to the NAS capacity, diseconomies of scale limit the amount of capacity that can be realized by more runway construction at major hub airports. Substantial funding for research to both NASA and the FAA will be required if goals of increased capacity and safety are to be achieved.

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Mr. Chairman and honorable members of the committee, it is a privilege to appear before your committee this afternoon to testify on the FAA research program and the increasing problem of airline schedule delays and flight cancellations. The delays and flight cancellations experienced in 1999 and 2000 will continue to increase for the foreseeable future. Do to a number of pressures, the FAA NAS Architecture 4.0 is not designed to substantially increase the air transportation system safety or capacity in the near future. The NAS 4.0 represents a fiscally constrained, government/union/industry compromise.

Background

It is widely recognized that air commerce, i.e., the transportation of people and goods throughout the United States and overseas for business or leisure purposes, is strongly linked to the nation's economy [1]. Since 1960, DOT statistics indicate that the air mode of transportation has grown at 4 (passenger) to 7 (cargo) times the rate of GDP growth. This is also 4 to 7 times greater than any other mode of transportation. ***Thus, any indication that the air transportation system might constrain future air travel because of the inherent capacity or safety limitations of the National Airspace System (NAS) is a justifiable cause for concern.***

Such indications exist. Captain Russ Chew of American Airlines, in a study referred to in the National Civil Aviation Review Commission report [2], put forth an analysis suggesting that the limited capacity of the NAS would lead to unacceptable delays by approximately 2010, only a decade from today. According to Chew, these delays could significantly disrupt airline schedules, bringing into question the efficacy of the current hub-and-spoke system that most major airlines use. Figure 1 [3] supports this hypothesis and shows that the overall system is currently at 58% of maximum capacity (at current aircraft separation technology). Table 1 [4] shows how this capacity fraction is distributed throughout the United States. At current growth rates, it is predicted to reach 70% of maximum capacity by 2010. The nature of transportation queues leads to a predicted hyperbolic growth in delays as indicated in Figure 2 [4].

Computing the maximum capacity of the total system understates the seriousness of the capacity crisis. Figure 3 shows the estimated capacity fraction for the top 31 US hub airports under favorable weather conditions [R. Shaver, the RAND Corp.]. The figure shows both the capacity fraction today and the estimated capacity fraction in 2010 (incorporating all of the airport improvements identified in the FAA ACE plan). Due to the lack of airport slot controls at most of these airports, the random access, first-come first-serve queuing system dictated by FAA operational procedures leads to large queuing delays above capacity fractions of 80 to 90% (illustrated in Figure 2). You will notice that some of the major airports are at this capacity fraction today and even more are predicted to be so in 2010 (even with planned airport improvements).

A much more serious problem exists when the airports are operated under poor weather conditions. Figure 4 illustrates the same estimated capacity fractions under IFR aircraft spacing and arrival rate restrictions. You will note that even today, almost half of the major US airports are scheduled to operate at levels above their maximum capacity. This situation is expected to get only worse over the next ten years. Only a fraction of these airports need to be restricted to IFR operations to put major disruptions into the national NAS network schedule.

The resulting consequence of this capacity limitation is increased inconvenience and cost to the flying public. It is expected that this situation will significantly reduce the public's incentives to fly, thereby stifling further growth in the airline industry. While the resulting impact on air travel is hard to quantify, the ***predicted annual growth in passenger enplanement of 3-4% is unlikely to occur without a major insertion of new technology and operational concepts***, with significant consequences for both the airline industry and tourism within the United States [1].

However, predictions of serious problems with the NAS, with airline schedules, or with truncated demand for air travel should not be taken out of the context within which they are made. Many of the predictions about growing delays at specific airports will not occur because they are already operating at maximum capacity. Common sense tells us that the airlines using that airport would adjust their schedules and fleet mixes to "manage" their operations and avoid unnecessary delays caused by unachievable demand for additional access. And common sense also tells us that airport authorities will seek to expand airport capacity, to the extent they can, when demand so dictates. However, recent analysis by Hansen, et. al. [5] indicate that adding runways and redesigning the airspace may not be, by themselves, adequate to satisfactorily mitigate the increasing delays at most large hub airports.

The overall capacity of the NAS is a function of a variety of important factors, including the design and operation of the airspace itself and the equipment that facilitates that operation. At present, NASA and the FAA are engaged in substantial efforts to modernize the equipment and procedures to enable significant changes to both how the available airspace can be more efficiently used and how safety can be enhanced. In addition, new operating concepts (e.g., "free flight") are under consideration; and new decision support tools for the controllers promise to open opportunities for better adaptation to congested airspace situations, while augmenting the controller's ability to handle a greater number of aircraft safely. ***It is still a matter of debate, however, about***

whether these actions, by themselves, will successfully deal with the capacity and subsequent delay problems.

In a recent set of papers by Donohue and Shaver [3] [4], we describe how the NAS capacity might be evaluated and what might happen if technology and new procedures are not put in place to ameliorate the expected growth in NAS congestion. As a minimum, we expect the airlines to respond by changing their schedules, increasing block times between city-pairs, increasing ticket prices and (hopefully) purchasing larger aircraft. If the airlines were left to handle this problem on their own, the result for the passengers and air commerce in general would be serious—reduced access, increased prices, reduced convenience, and somewhat increased delays. Our analysis indicates that the future cost of air transportation will not be determined by the cost of designing or building large commercial aircraft but by ticket-price-setting (yield-management) software in a largely unregulated supply and demand market. Unfortunately, the supply of hub and spoke aircraft operations is technically limited (i.e. number and configuration of runways, runway occupancy time, wake vortex separation, and surveillance accuracy) and the demand for high-speed transportation is steadily increasing.

Any policy on how to make investments to ameliorate NAS congestion must recognize that there are a number of important stakeholders. For the U.S., the six principal stakeholders are the FAA and NASA, the airlines, the aviation industry, the airport authorities, Congress, and (perhaps the most important) the flying public. Others include foreign Civil Aviation Authorities (CAA's) and the international organizations (e.g., International Civil Aviation Organization (ICAO)) that oversee and (to some degree) regulate global aviation activities. Each of these stakeholders have their own incentives regarding responses to NAS congestion. The incentives motivating one stakeholder are often not parallel to those of the others. Worse, they are occasionally diametrically opposed.

The primary motivation of an airline is to make money. While airlines do make long term investment decisions (especially regarding fleet sizing and mix), most of their focus is on near-term profitability, i.e., return on investment. ***Through experience, most of the major airlines have found that hubbing is an economical way to make the best use of their fleet.***[ii] Passenger convenience, measured by serving a wide variety of cities with frequent flights from their hubs, has proven to be a reliable way to gain customer loyalty, repeat business and a steady revenue stream. Hub domination (i.e., one major carrier serving the hub) has often been the result, with mixed blessings for the flying public.

The current manifestation of this strategy is airline investments in small and mid-sized aircraft suitable for frequent flights to and from the major hub airports. The convenience this provides to those flying from smaller regional cities to major urban areas (and in the future, directly from one mid-sized city to another) is substantial, and has spurred the recent remarkable growth in regional jets and business jets in the United States. ***It is noteworthy that the average number of seats per commercial airliner has been dropping in the last couple of years and is expected to continue to drop for several more years. This airline behavior is exacerbating hub congestion and has implications for the new NASA SATS and AvSTAR initiatives.***

Airports are also interested in making money. Profitable customers (the airlines) are critical to their success. They benefit from frequent flights, and only secondarily suffer from the costs of congestion. They benefit from growth in passenger enplanements. For the most part, major airport expansion happens only when the airline(s) operating from the airport threaten expansion elsewhere or the dominant airline feels expansion will not threaten it's hub monopoly position. Once an airline has established itself as the dominant carrier at the hub, incentives for expansion are lessened unless that dominant carrier can see further growth. ***In most cases, airport expansion is significantly limited by environmental factors (noise, pollution), and requires local public support and approval. Recently, such approval hasn't been forthcoming [6].***

The flying public wants both the convenience associated with frequent flight schedules and the current low airfares. As demand grows and congestion becomes worse, the leisure flyers will be most impacted as they are highly sensitive to the almost certain rise in airline ticket prices resulting from the increased demand to supply ratio. They constitute approximately 70% of the current passengers, and are the primary beneficiaries of airline deregulation. Business travelers, on the other hand, are likely to continue to fly in growing numbers as they are far less sensitive to price, often paying "full fare". They are considered essential to the profitability of most airlines but may begin to turn increasingly to private air transportation.

No matter how business use develops, airline revenues are likely to continue to rise, and their interest in alternative hubbing strategies will be limited to cities that can provide a solid business-flying base. However, this also has implications for the importance of the new SATS and AvSTAR initiatives. Unmitigated flight delays and cancellations will lead to increased use of air taxi services and private ownership of corporate aircraft for business transport. While this will bypass hub congestion, it will increase en-route sector controller workload, thus contributing to en-route system saturation.

Finally, Congress has the joint incentives of supporting the nation's interest while also serving the needs of its constituents. Occasionally, these incentives are in conflict, with shorter-term needs and local priorities often getting the largest share of a tightly constrained federal budget. Long range research investment and planning, something needed to successfully deal with the NAS congestion problem, is often the victim.

Implications for the Future

Despite claims to the contrary, it is unlikely that the impending NAS congestion problem will lead to total gridlock or the economic dismantling of the airlines. The airlines will adapt their behavior to ensure their economic viability, and the flying public will modify their demand for air travel as the convenience and cost of such travel changes. The consequences are higher ticket prices, less convenience for the travelers, and a curtailing of the anticipated growth in air commerce. ***This implication for the U.S. economy is that the growth in U.S. Gross Domestic Product (GDP) will be negatively impacted.***

What does this mean in terms of policy implications for the United States Government? First, it is important to understand that it is unlikely that the Government will dictate how airlines or the various airport authorities will respond to congestion. Also, congestion is not necessarily bad for either. While greater NAS capacity would offer opportunities for more growth, it seems likely that many of the airlines will still be able to retain their profitability under conditions of moderated growth bounded by capacity problems. To some extent, the higher airline operating costs implied by a congested airspace will be offset by the likely percentage increase in business travelers who pay on the average significantly higher fares per trip.[iii] The airports would also benefit financially from increased traffic and may even benefit from the increased delays where the number of passengers within the airports at any time is likely to grow, increasing opportunities for the selling of food and other merchandise at the airport. The semi-monopolistic status of specific airlines at many major hubs will also add to the inertia resisting change.

Second, as noted at the start, neither NASA nor the FAA has any magic response they can take to solve the congestion problem on their own. Modernization of the NAS can help ameliorate the problem, deferring the date when the airlines and the air transportation system as a whole will be forced to react. But without complementary actions by the FAA, the states, the airports, the airlines, and the traveling public, that deferral could be short-lived.

Perhaps the most straightforward way to think about how the three major actors could productively work together to meet everyone's interest is ask who is going to pay the cost of mitigating the impacts of congestion. For the airlines, it is clear that the passengers will pay for whatever changes the airlines must make to adapt. For airports, it is also true that the passengers will, for the most part, pay for airport improvements, albeit indirectly through the airline tickets, Passenger Facility Charges (PFCs), and services and merchandise they buy at the airport. For the FAA, there is at present no direct tie to the passengers, but the ticket tax that they pay can be considered to be the principal source of FAA funding for both NAS modernization and operation. Thus, whatever the cost of mitigating the growing congestion, the passengers are going to pay most, if not all of it. Thus, it only makes sense to look for the combination of actions undertaken by the traveling public, the airlines, the airports, the FAA and NASA that adds to the lowest total cost to the passenger.[iv]

Reduce Accident Rates

It is now well known that the commercial aircraft accident rate has been essentially constant for over a decade. Human factors have been the most significant elements in both commercial and private aviation safety for almost a half-century. The insertion of automation on the flight deck of commercial aircraft, although not without some problems and controversy, has been a significant factor in the dramatic decrease in commercial aircraft accidents over the last two decades. Accidents happen due to a complex sequence of events. Better analysis of existing flight data is required to understand these relationships in total. Most experts would agree that aircraft collision avoidance systems have greatly helped keep accident rates down over the last 10 years. Due to funding limitations, however, the FAA has virtually eliminated its technical support and further development of the onboard aircraft collision warning system, Tactical Alert and Collision Avoidance System (TCAS II). This technology has saved countless lives since its introduction in the US in 1990 and is now being installed on aircraft worldwide. TCAS II v.7 is far from perfect and continued development is required. It is fundamental, in order for system capacity to grow, aircraft need to be spaced closer together***. Closing the loop from collision warning to collision avoidance has yet to be done.***

Figure 5 shows a new way of looking at capacity and safety on a common graph. This research is still in progress and the safety-capacity substitution curve shown is only hypothesized at this point. World wide commercial aviation is currently operating at roughly 20 million departures per year with a hull loss rate of approximately one to two million departures per hull loss. The US is operating at about 12 million departures per year at approximately 6 million departures per hull loss. The safety-capacity substitution curve shown in Figure 3 illustrates that to increase capacity at a constant annual hull loss rate, the fundamental system of aircraft separation must be improved***. I believe that with today's techniques of aircraft control and separation, capacity cannot be increased very much without a decrease in system safety.***

Increase System Throughput

As my opening comments have suggested this is an extremely important goal. However, this goal cannot be accomplished within the constraints of the commercial hub and spoke operations alone (as shown in Figure 1). NASA and the FAA have been cooperating for the last several years on technology that can improve aircraft arrival spacing, airport surface movement and wake vortex monitoring. There are five primary limitations to the current hub and spoke system:

1. **Aircraft spacing is limited by the surveillance system accuracy**. There is at least a one to two mile buffer that is added between aircraft so that these inaccuracies will not violate either runway occupancy time separation criteria or wake vortex separation criteria. NASA and the FAA are investigating the human factors of moving to a GPS/digital data linked surveillance system with a distributed control paradigm. The aviation community calls this system Automatic Dependant Surveillance–Broadcast (ADS-B). NASA has been emphasizing ground-based control using the CTAS program for evaluation and implementation. Although this program is addressing the central terminal capacity limitation, there is data to suggest that the time delays inherent in a radar-scan-controller-in-the-loop based system cannot significantly improve aircraft separation [7]. It has, however, been very beneficial in aircraft sequencing and runway assignment at complex airports in relatively simple airspace.

   In addition to human factors concerns, a major barrier to the adoption of ADS-B has been the search for the correct wireless digital data communications system that meets wireless bandwidth concerns and international standards. The FAA and ICAO have not made significant or satisfactory progress in this area and can use the technical talent that DoD can bring to bear. The funds that the FAA has identified for this effort are insufficient to make a dent in this problem. I would recommend that the FAA should partner with DARPA's program to develop the broadband follow-on to the Internet. This future aviation system broadband Internet, with wireless tail circuits, can be designed to meet the stringent integrity, availability, security and time latency criteria required for aviation or ground ITS***. The need for a high integrity, wireless, broadband Internet is one of the major technical barriers to providing an increase in aviation system capacity and safety.***

2. **Bad weather causes the FAA Air Traffic Control system to increase separation** between aircraft (or institute a Ground Delay Program), thus greatly reducing the system capacity during times of severe winter weather or spring / summer storms. The resultant delays are propagated throughout the NAS. The National Weather Service (under FAA funding) is investigating better weather forecasting. Much more funding is required in this area. Today's convective weather forecasting technology is not adequate to provide a high confidence 1 to 6 hour convective forecast. This becomes a problem for the FAA Central Flow Control Facility and the Collaborative Decision Making (CDM) system that the Airlines and the FAA have adopted. Using inherently inaccurate information in a 2 to 6 hour input to aircraft/airport operational capability is leading to overall system instability under bad weather scenarios. The inherent nature of the weather prediction equations may mean that the Air Traffic Control Centers and the TRACON's may be the best place to control traffic due to tactical weather movements. The FAA Central Flow Control Facility may act primarily as a central data collection and dissemination facility. It's primary control function may be to coordinate decisions between Airline Operation Centers (AOC's) and regional ATC centers on tactical routing decisions. There is much to be learned about how this system should be operated.

3. **Wake vortex separation sets the closest that aircraft can approach on landing**. New technology is required to sense and monitor the location of aircraft wake vortices. NASA has a program in this area that needs more emphasis, including flight deck monitoring and display systems. This is an area that has received much rhetoric but little serious technical attention. Increasingly, this factor will set the maximum capacity of the air transportation system. The FAA does not have significant technical expertise in this area and I applaud NASA for continuing to pursue research into determining aircraft wake vortex location. It has been observed that frequently, the preceding aircraft wake vortex has experienced either rapid decay or has been convected away from the succeeding aircraft flight trajectory by the atmospheric boundary layer. For this reason, the current FAA wake vortex separation criteria are extremely conservative. This was not a concern when the system capacity was operating below 50**.**

4. **En-route sector loading constraints due to human factors cognitive workload** limitations reduces capacity in a limited number of high density /high workload sectors. The FAA is conducting most of the research in this area. If the NASA SATS program is successful, this problem will change dramatically. One of the advantages of the Hub and Spoke system is that it is economical in aircraft movements. One needs only 2(N-1) movements to connect N cities (i.e. for N= 100 cities, 198 flights). The bad news is that all of these flights go through the hub and the hub eventually gets congested. Direct flights between N cities does not concentrate flights at any one hub but can potentially generate N(N-1) flights (i.e. for N=100, 9,900 flights). This

will pose the enroute air traffic control system with a very complex traffic management problem. This problem should be addressed in both the NASA AvSTAR and SATS research programs.

5. **The number of runways and runway configurations are a fundamental limitation to NAS capacity.** Unfortunately, computer model simulations and operational data indicate that the existence of more than approximately 3 to 4 runways at hub airports does not greatly increase overall system capacity. Due to the complexity and distances involved in the ground movement of aircraft at large hub airports, diseconomies of scale begin to manifest themselves. Also, the close proximity of hub airports (as seen in the New York City metro-plex) produces airspace complexity that limits the arrival and departure aircraft spacing. System wide, time coordinated slot allocations may ultimate have to be auctioned to air carriers by the FAA (similar to FCC spectrum auctions) in order to make maximum use of hub airport capacity.

Conclusions

In the short time that I have been allotted in this testimony, I have tried to provide the committee my views on an extremely complex problem and research agenda. Both safety and capacity are intertwined in this research agenda, as they are in actual operations. I believe that the increase in system throughput by even a factor of two is not achievable using large aircraft at hub airports with today's aircraft separation technology. A reduction in accident rates by a factor of two must accompany any significant increase in capacity.

Both the FAA and NASA need to do more in the analysis, operational demonstration, and certification of automatic aircraft sequencing, separation and collision avoidance. The development of an international, spectrally efficient, broad-band, wireless transportation Internet, required for ADS-B and the Aeronautical Telecommunications Network (ATN), is essential. DoD has a major stake in the development of this system and should take the lead development responsibility away from the FAA. The Air Traffic Management service should begin to be outsourced to the private sector to implement and operate a new air traffic management system.

Automatic collision avoidance is routinely discussed in the context of the FHA ITS program, where it is extremely difficult to implement, and seldom discussed for aviation where the technology is much more mature and the problem is much more tractable. This technology will be required in the future to increase both the safety and the capacity of the air transportation system. Although runways at hub airports represent a fundamental limitation to the NAS capacity, diseconomies of scale limit the amount of capacity that can be realized by more runway construction at major hub airports. Substantial funding to NASA and the FAA will be required if these stated goals are to be achieved.

Thank you for inviting me here today and I will be happy to answer any questions.

REFERENCES

1. Kostiuk, P., E. Gaier, and D. Long, The economic Impacts of Air Traffic Congestion, the *Air Traffic Control Quarterly***,** 1999**.**
2. Mineta, N.Y., *Avoiding Aviation Gridlock & Reducing the Accident Rate: A Consensus for Change*, National Civil Aviation Review Commission, (http://www.faa.gov/ncarc/), December, 1997.
3. Donohue, G., A Macroscopic Air Transportation Capacity Model: Metrics and Delay Correlation, proceedings of the *Workshop on Advanced Technologies and their impact on Air Traffic Management in the 21st Century*, 26-30 September, Capri, Italy, 1999.
4. Donohue, G., and R. .Shaver, " United States Air Transportation Capacity: Limits to Growth Part I (modeling) and Part II (policy)", National Research Council Transportation Research Board 79th Annual Meeting (CD-ROM papers 00-0582 and 00-0583), January 2000.
5. Hanson, M., H.S.J. Tsao, S. C. A. Huang, W. Wei, (1999) "Empirical Analysis of Airport Capacity Enhancement Impact: Case Study of DFW Airport", National Research Council Transportation Research Board 78th Annual Meeting (CD-ROM), January, 10-14, 1999.
6. Motoko, S., " Air Transportation Growth and the Noise Problem: Case Study of Ronald Reagan Washington National Airport" George Mason University, PUBP 801 final report, May 1999.
7. Donohue, G. L. and A. Zellweger (Editors), ***Air transportation Systems Engineering***, AIAA Press, forthcoming summer 2001.

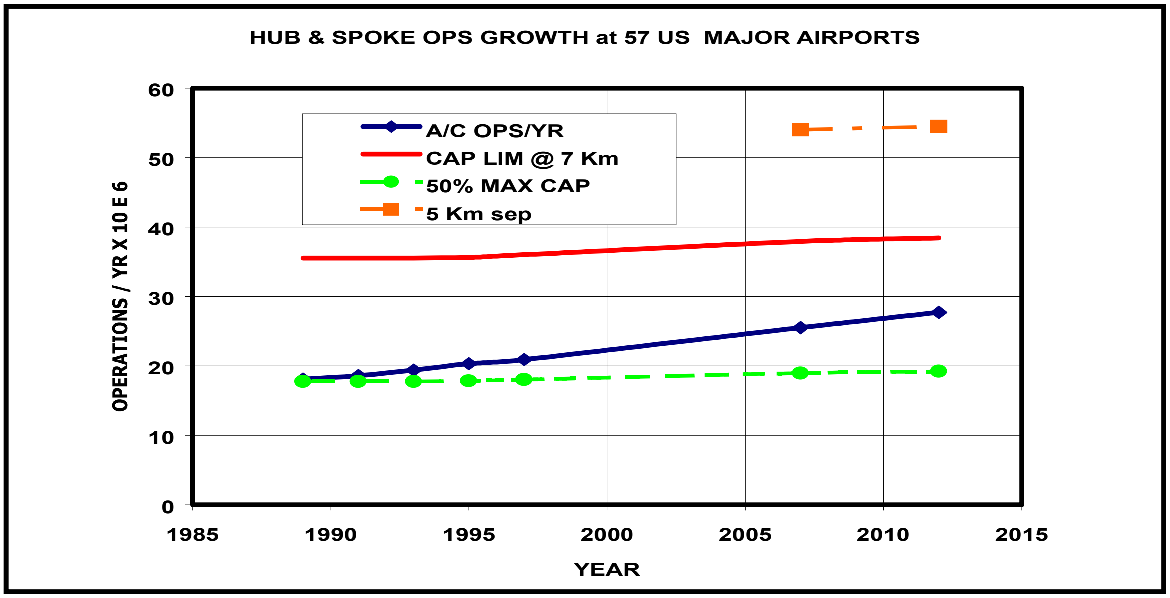

Figure 1. Current US Hub and Spoke operational capacity using the GMU Macro Capacity Model. Dashed line represents 50% capacity threshold above which noticeable delays increase Hyperbolically [3]. Capacity fraction was 58% (1997) and predicted to be over 70% (2010).

TABLE 1 Regional Air Transportation Capacity Fraction For (57) Major Airports

REGION	NUMBER HUB R/W	Estimated # A/C TURN POINTS	Number Ops/Hr MODEL	Number Ops/Hr 1997	% Cap97/ CapMAX	Avg 8 yr Growth Rate %	TAF 1997 ENP X10E6	OPERATIONS 2012	OPERATIONS 1997
NORTH EAST	14	420	348	294	**84**	9	54	1,950,000	1,645,786
PACIFIC SOUTHWEST	9	262	403	298	**74**	10	43	2,205,000	1,670,280
PACIFIC NORTHWEST	22	353	693	455	**66**	8	62	3,364,000	2,549,603
NOTHERN MIDWEST	42	773	1090	684	**63**	32	99	5,522,000	4,040,088
ATLANTIC COAST	13	269	438	241	**55**	8	31	1,701,000	1,347,458
CENTRAL MIDWEST	12	205	237	131	**55**	3	19	1,496,000	1,114,207
WEST	22	415	758	405	**53**	9	62	3,180,000	2,270,307
SOUTHEAST	21	424	776	391	**50**	-2	54	2,704,000	2,190,557
FLORIDA & LATIN AM	14	322	602	287	**48**	18	48	2,114,000	1,608,673
SOUTH SOUTHWEST	27	380	892	433	**48**	16	59	3,468,000	2,424,105
TOTAL	**196**	**3823**	**6239**	**3620**	**58**	**11**	**532**	**27,704,000**	**20,861,064**
% NATIONAL TOTAL							**89**	**78**	**77**

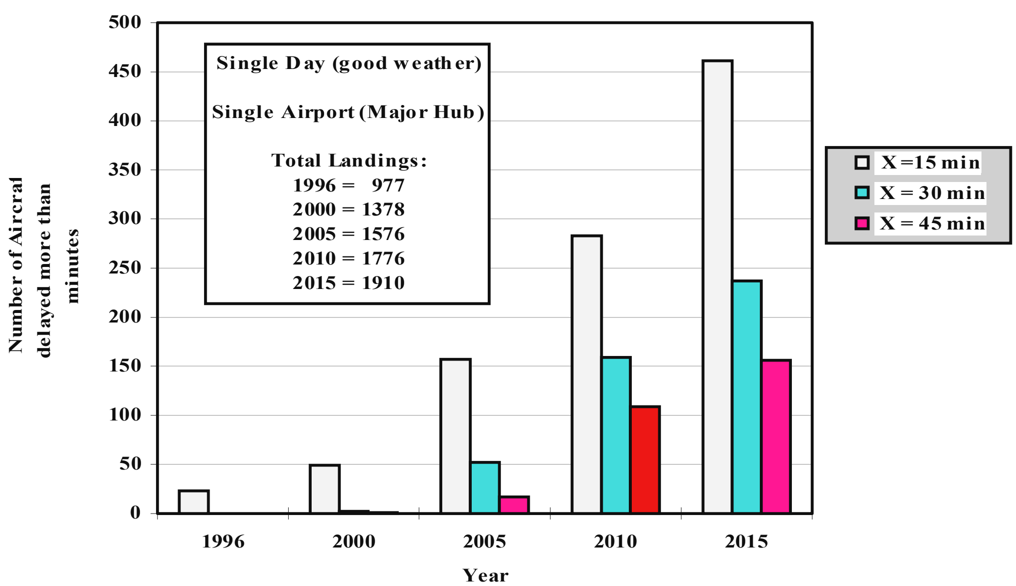

Figure 2. Predicted delay increase at a major hub airport using the MITRE DPAT model [4].

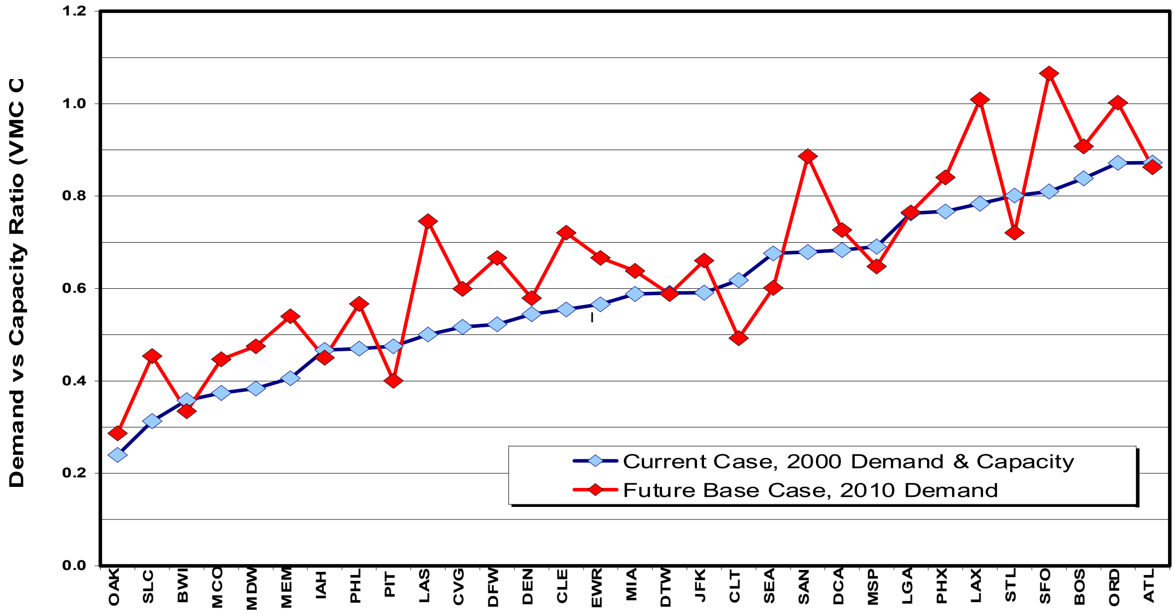

Figure 3. Estimated Hub Airport Capacity Fractions for 31 Major US Airports under Favorable weather conditions. The 2010 Scenario assumes all major runway additions forecast in the FAA ACE plan. Note that delays are projected to increase hyperbolically at capacity fractions in excess of 80 %. Source: R. Shaver, The RAND Corp. 2001 TRB presentation.

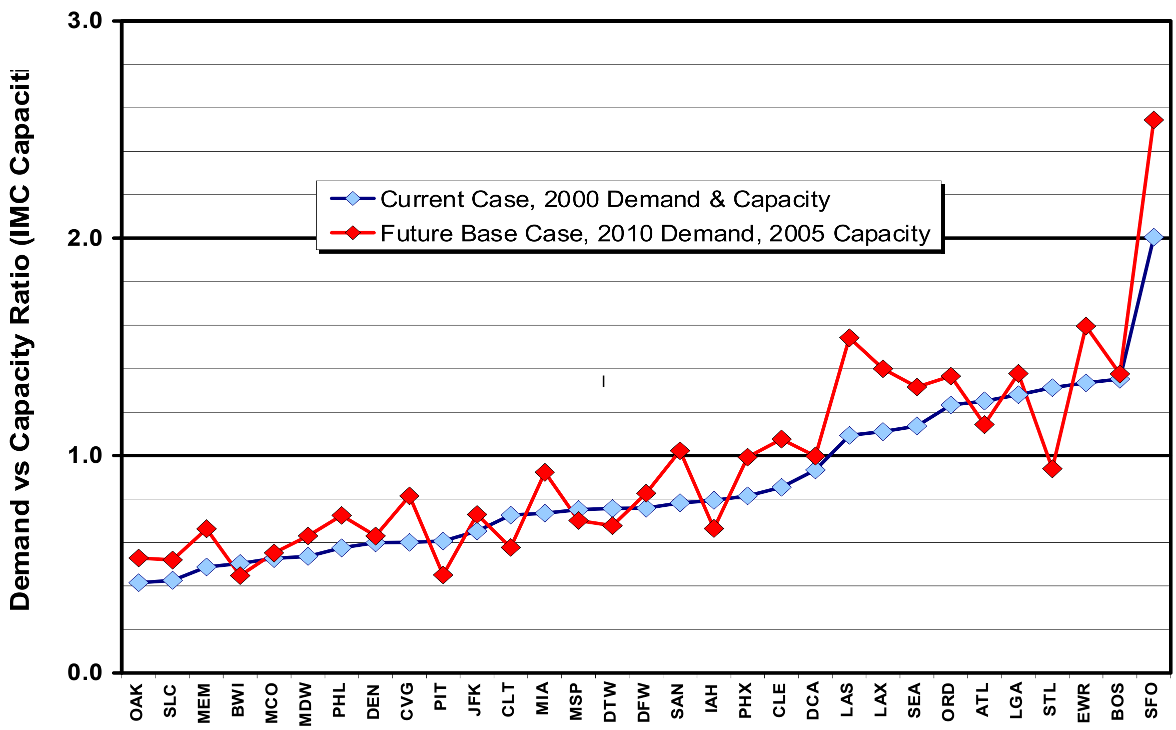

Figure 4. Estimated Hub Airport Capacity Fractions for 31 Major US Airports under Bad Weather conditions. The 2010 Scenario assumes all major runway additions forecast in the FAA ACE plan. Note that delays are projected to increase hyperbolically at over half of the airports today and it is projected to be much worse in 2010. Source: R. Shaver, The RAND Corp. 2001 TRB presentation.

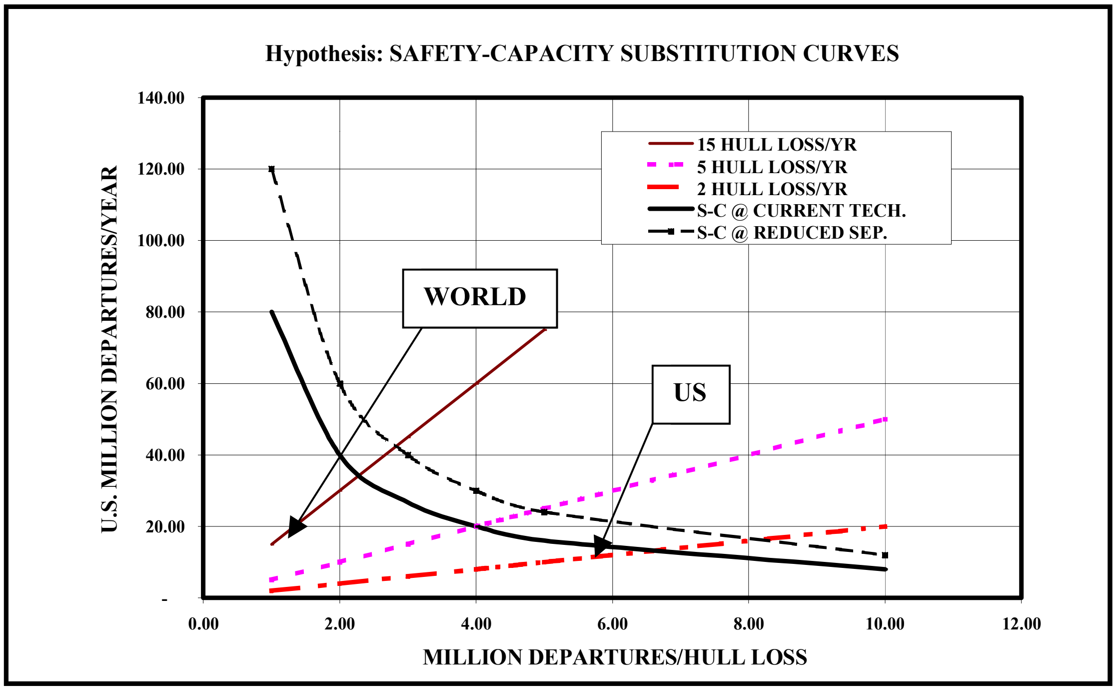

Figure 5. Hypothesized relationship between Capacity and Safety. The solid Hyperbola line represents the potential limit of today's aircraft separation technology. The dashed Hyperbola represents the potential capacity increase that could be achieved by migrating to a GPS based ADS-B aircraft self-separation technical paradigm. International air transportation is currently operating close to the 15 Hull Loss per Year line, while the US is operating close to the 2 Hull Loss per Year Line.

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[i] Dr. Donohue was formerly the Associate Administrator of Research and Acquisitions at the Federal Aviation Administration from 1994 to 1998. Prior to this appointment he was a vice president of The RAND Corp. in Santa Monica, Calif. From 1989 to 1994 and Director of the Aerospace and Strategic Technology Office at DARPA from 1988 to 1989. He is a Fellow of the AIAA , a member of the NRC TRB and a member of the Goals subcommittee of the NASA Aero Space Technology Advisory Council (ASTAC). Donohue holds a Ph.D. in Mechanical and Aerospace Engineering from Oklahoma State University and is a licensed private pilot.

The views expressed in this testimony are his alone and do not represent the official views of George Mason University or the Logistics Management Institute, MIT/LL, MITRE/CAASD, the RAND Corp. or Aviation Systems Engineering, Inc., for which Dr. Donohue consults. Dr. Donohue has received research funding from the FAA for ATM model evaluations and from DARPA for aviation applications of the next generation Internet technology.

[ii] Operating a hub is expensive. But this expense is more than compensated by the high load factors and the revenues that are generated by hubbing.

[iii] If the growth in passenger demand exceeds the growth in seats available, then the airlines will be able to fill their aircraft with a higher fraction of business travelers who, on the average, are willing to pay much higher prices for the available seat. Whether the average increase in revenue that results is greater or less than the added cost from congestion is not known.

[iv] This leaves aside the complementary question of just how the FAA, the airports, and even the airlines actually are financed. For the purposes of this testimony I am assuming no fundamental change in the pricing structure or in FAA financing.