A1J05: Committee on Airfield and Airspace Capacity and Delay
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Airspace and Airports
Critical Issues for the 21st Century

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History tells us that the progress and development of transportation actually defined the road map of civilization and mankind. The history of aviation and air transport is no different. Man fantasized for centuries about being able to fly. Flying became the dream and the myth of mankind until it finally became reality. Aviation's greatest technological leaps were actually realized by the military, technologies successfully employed in wars and commercialized later in economic quests. Examples are ample, from aircraft engines and design to surveillance radars and ever-improving communication technologies and satellite-based technologies for airspace navigation and air traffic control.

The air transport industry commercialized these wartime technologies by gradually integrating them into a performance-based, commercially viable, and market-responsive system operating in a global, liberalized, and deregulated environment.

CRITICAL ISSUES

Today we are experiencing significant change in the roles and responsibilities affecting this system. Technology is once again shaping how aviation and air transport influence today's world and the global civilization of the early 21st century:

- Automation and more extensive use of advanced digital communications and computer technologies are streamlining air traffic control and navigation and airlines operations management and marketing.
- The Internet is fast becoming today's time-to-market catalyst, with instantaneous marketing and purchasing of products promoting even more pressure on reducing the time between order and receipt of goods purchased.
- The integration of road vehicle, ship, rail, and now air transport of passengers and cargo is providing truly seamless, intermodal transport service.

In this global marketplace, it is connectivity that ensures success. The airlines' response to this New World era is the provision of multimodal door-to-door service. In this new environment, success requires common systems (reservations, scheduling, air service, etc.) and more focused efforts to compete and cooperate as appropriate. In this environment, marketplace consolidation will occur whereby global air carrier alliances, both airline and cargo, will replace individual national air carriers. With the more advanced technologies adopted for airspace navigation [Free Flight, automatic dependent surveillance-broadcast (ADS-B), area navigation (RNAV), etc.], air traffic management (ATM) systems, and airport ground control, the aviation and air transport system of the 21st century will be harmonized, more efficient, and safer.

The International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA) were formed after the end of World War II. Traditionally, the major players in post-war air transport and aviation systems were the following:

- *National Civil Aviation Authority (CAA)* [e.g., the Federal Aviation Administration (FAA) in the United States]: Charged with centralized control over regulating airlines and airports, funding authority to upgrade and expand the system, and research and development (R&D) to improve the system.
- *Airlines:* Responsible for all aspects of customer service (in flight and on the ground) and funding authority for fleets and airport facilities (exclusive-use in the United States, shared-use elsewhere).
- *Airports:* Custodian of property operated by CAA and airlines and provider of service to the public to accommodate the air–ground transport mode transfer.

In the United States, the focus for most of the 1990s was on balancing the federal budget, which resulted in reduced funding for FAA. To bridge the funding gap, airports were empowered to finance part of their need to upgrade facilities and expand capacity through the development of the passenger facility charge. As such, airports are transitioning from the caretaker role of a public necessity to service provider role and landlord of a highly valued community asset. Airport customers used to be the air carriers (airlines, cargo carriers), but now the airport tenants, including airlines, cargo carriers, service providers such as concessionaires, and so on, plus the primary customer—the flying public are all seen as customers, too. This trend is by no means a U.S. one; it is global. Invariably, in the final years and months of this millennium, the airports' goal is shifting more toward identifying customer needs, widening the service base, and ensuring that customers are appropriately satisfied with cost-effective and performance-based quality service.

The primary questions that need to be addressed as we enter the new millennium are the following:

- What is the "end game" in the evolution of the new global air transport and civil aviation systems?
- What technologies, systems, and approaches will be or should be adopted?
- What are the logical roles and responsibilities of the stakeholders in this new environment?

SYSTEM CAPACITY

With the rapid increase in air passenger traffic and the proliferation of airline hubs since deregulation, the issues of airport and airspace capacity, delay, and related financial implications have been the most critical. FAA has established several efforts to address these issues at the national airspace system (NAS) level and also for hub airports and to explore measures to expand airport capacity. FAA publishes the Annual Aviation Capacity Enhancement (ACE) Plan updating the implementation of these measures at major U.S. airports, as well as aviation demand forecasts for the coming 10 to 12 years. FAA and stakeholders of NAS are challenged to maintain a critical balance of demand and capacity on the system and facility levels. What are the incremental measures to enhance system capacity for the long run?

Microlevel Measures

Major capacity enhancement alternatives considered by the FAA in addressing the intricacies of the microanalysis of capacity versus demand are

- Addition of new runways at specific locations, properly placed to allow independent arrival or departure streams, or both;
- Procedural changes and technology innovations to allow simultaneous use of existing runways in all weather conditions; and
- Delay-driven demand management incorporating technical and procedural changes that will reduce actual interarrival and interdeparture spacings to and from runways.

In addition to the foregoing measures, needed technical and procedural changes to improve capacity can be derived from the Capacity Enhancement Team (CET) reports, which are contained in the ACE Plan. These changes include simultaneous use of existing runways, reduced interarrival and interdeparture spacing, and better management of arrival, departure, and surface flows.

However, although all these measures form a general set of needs across NAS, the needs for such techniques and the impact of improvements vary from airport to airport. Furthermore, the related demand-capacity interactions on the system level are also dependent on other exogenous factors, which would include aircraft design trends and environmental, political, social, and economic considerations.

There seems to be a need for a systematic delineation of operational needs for each airport and the impact on capacity and delay of improvements to meet those needs. The list of capacity enhancement techniques is known; the generic impact of improvements is known; what is lacking is an NAS-wide estimate of the impact of the improvements as applied at specific airports.

Macrolevel System Capacity

U.S. Department of Transportation statistics reveal that air transportation has been growing six times faster than any ground mode of transportation since 1960 and four times faster than the gross domestic product (GDP). Between 1997 and 2008, the FAA predicts a 51 percent increase in passenger enplanements and a 50 percent increase in the air carrier transport fleet. As the congressionally chartered National Civil Aviation Review Commission (NCARC) pointed out in its 1997 report, no other U.S. government activity so totally dominates such a vital economic endeavor as does the air traffic control (ATC) function of the FAA.

This growth comes at a price, however. At current growth rates, the U.S. air transportation system will be operating at approximately 75 percent of maximum capacity by 2010, assuming that all new runways are added to the system that are now anticipated. This may not sound serious until one correlates delay with capacity utilization rates. These data indicate that delays in the effectively random access queueing system of airport arrivals begins to rise exponentially at 40 percent of maximum capacity.

At this point, even with the fastest adaptation of new technology and new operational concepts, we will see significant increases in air transportation congestion and delay over the next decade. These delays can be translated into economic impacts such as an increase in airfares, the loss of over 700 billion revenue passenger miles, and the loss of over 400,000 work-years.

Since 1992, three independent blue-ribbon commissions have reported that the infrastructure for air traffic management is deteriorating and has an inadequate source of capital funds for modernization. The problem is exacerbated by the rapidly changing technologies in space-based air navigation, digital communications, and computer decision support systems. Both managers and engineers in the aviation industry require new technical skills that the federal civil government finds nearly impossible to attract.

The U.S. Congress has decided to go slow in dealing with these problems for several reasons. Certainly, one is the concern for public safety in a privatized ATM corporation. Fortunately, there is now adequate evidence that more than six other nations have been able to successfully address this issue. The businesslike manner that is being demonstrated by ATM organizations represented by the Civil Air Navigation Services Organization (CANSO) is indeed encouraging. In like manner, airport authorities themselves are taking on increasing responsibility for planning and financing the many structural and technical infrastructure improvements required by the expanding system.

Privatization of ATM services would provide the new technology and procedures for international commerce to grow. The courts have ruled that the FAA can only charge user fees to oceanic international air traffic if it can be demonstrated (through an industrial-type cost-accounting system) that its fares are representative of its cost of service. Thus, a private oceanic provider of communication, navigation, and surveillance (CNS) and ATM services, with such an accounting system, would pay for itself without an increase in U.S. taxpayer funds. In addition, both the traditional high-frequency voice communications and the new satellite digital communications functions have always been outsourced to a private service provider in the oceanic sectors. Finally, some of the nations adjacent to U.S. airspace (with the exception of Japan and Central and Latin America) have privatized ATM operations.

SYSTEM TECHNOLOGIES

Communication, Navigation, and Surveillance

In September 1991, the ICAO endorsed the transition to new CNS technologies in order to overcome shortcomings and limitations of the air navigation system. Simply put, the member states of ICAO agreed to transition to satellite, data link, and automation technologies while retaining the best features of the current terrestrial, line-of-sight, voice-only CNS systems. Much progress has been made in implementing this vision. However, progress in transitioning to the new CNS technologies has been and will continue to be influenced by industry realities and issues, which include national sovereignty concerns.

As for communications, key technological issues remain regarding data link protocols and civil aviation access to newer technology. An emerging consensus on the advantages of multimodal transceivers may obviate the protocol issue. However, key navigation issues remain regarding Global Positioning System (GPS) sole-source integrity suitability in the light of international concerns. Although it is not a technological issue, it is noted that there is as yet no generally accepted transnational management solution for the Global Navigation Satellite System (GNSS), of which the U.S. GPS system will be only a component.

Last, but not least, are the unresolved technical issues related to surveillance, particularly the ADS-B means of onboard aircraft surveillance and ATC surveillance. This surveillance system may be required to safely reduce aircraft separation in the terminal environment, a fundamental constraint on air transportation capacity. Not only are there significant differences of opinion on the appropriate frequency for this subsystem, but, more important, there is no consensus on the overall role for ADS-B in the airspace system. Early resolution of this issue is unlikely but fundamental to increasing capacity.

Air Traffic Management

As part of the new NAS architecture effort, the FAA plans deployment of and R&D on ATM decision support (automation) technologies, mapped to needs as expressed in the previous section on system capacity. The most important concept being readied by the FAA, in collaboration with the other stakeholders, for deployment in the first few years of the new millennium to enhance the ATM of the NAS is Free Flight–Phase 1 (FFP1).

FFP1 effort is characterized by (*a*) combined user-FAA R&D activity that takes proven technology used in the field and implements it at other selected sites by 2002 and (*b*) toolset-oriented approaches toward better management of arrival and surface traffic flows, such as arrival management [Traffic Management Advisor (TMA)], runway assignment [Passive Final Approach Spacing Tool (PFAST)], collaborative decision making (on traffic flows) (CDM), and airport surface management [Surface Movement Advisor (SMA)].

Moreover, in collaboration with the FAA, the National Aeronautics and Space Administration (NASA) is increasing its focus and applying more resources to critical airfield and airspace capacity issues. This collaboration is captured in the joint NASA-FAA ATM Research and Technology Development Plan.

This change to a user-FAA collaborative approach, seen both in deployments and in R&D, provides several advantages, including user involvement in deployment decisions and user collaboration incorporated into operational concepts (not just static user preferences, but real-time user input).

SYSTEM PERFORMANCE

The FAA has identified the following NAS system measures of performance (MOPs): safety, delay, predictability, flexibility, and access. The use of these measures for airports and airport systems specifically covers delay-capacity analysis of rates of return (ROTS), predictability, and access. As the average age of NAS equipment increases, using such MOPs for NAS performance as reliability, availability, capacity, delay, maintainability, and safety becomes more critical.

Reliability is needed to translate failure rates from lower-level systems into higher-level service success. In complex systems, such as NAS, high reliability by itself is not sufficient to ensure that the system will be available when needed. The systems also need to be repaired quickly, and here another MOP is important, maintainability. Maintainability is also needed to estimate the impact of maintenance costs as a function of increasing failure rates. These MOPs can then be combined to assess system availability, and the service availability levels can be used as inputs to estimate MOPs such as capacity, delay, and safety. The capacity MOP is needed to assess the impact of systems unavailability on delay and NAS capacity. Safety, the most important MOP, is essential to the quality of air traffic service and would assess the impact on subsystem availability with respect to probability of aircraft accidents or any other related accidents.

Gradual introduction of new technologies, such as GPS-based navigation and landing, digital air-ground data link communications, and ADS-B, is expected to improve NAS performance, capabilities, and performance. Replacement of aging infrastructure through new and advanced equipment units and systems will directly influence NAS reliability since the probability of failures in any given period will be significantly reduced. Also, a better NAS Infrastructure Management System (NIMS) is expected to improve the availability of equipment units and systems through more efficient coordination of maintenance activities, monitoring of systems and outage reports, and faster responses to problems.

Airport capacity is expected to improve when new automation tools such as the Center Terminal Arrival Control (TRACON) Automation System (CTAS), the Controller Automation Spacing Aid (CASA), and ADS-B are introduced. Capacity on oceanic routes will also be increased by replacing the existing oceanic automation displays and by introducing data links, thus reducing aircraft mile-in-trail separation distance. With capacity, safety is expected to improve by implementation of new capabilities such as conflict probe, conflict resolution, collaborative decision making, and data link data-sharing. Specifically, the risk of aircraft accidents and other incidents caused by potential wind shear and runway incursions will be reduced by the Low-Level Wind Shear Alert System (LLWAS) and the Airport Surface Detection Equipment/Airport Movement Area Safety System (ASDE/AMASS), respectively.

In summary, technical developments as part of the NAS architecture can offer prospects for significant improvements in system MOPs, namely, reliability, availability, capacity, and safety, in the short- and medium-term future.

SYSTEM SAFETY

In the next century, technological advances in the use of satellite-based communications and computer technology will work together to keep air traffic moving safely along more efficient routes than are currently available today. There will be a steady stream of information flowing from digital computers on board the aircraft. These powerful computers will monitor or control virtually every function of the plane, often with very little interaction by the cockpit crew. The flight crew and the air traffic controller will exchange information over high-speed digital data links. Airline and ATC computers on the ground will relay weather updates and safety alerts quickly and accurately to the pilot. On-board collision avoidance and advanced traffic display systems will allow the pilot be an active participant with the controller in ensuring the safe separation of aircraft. The cockpit will be so "information rich" that pilots will be able to operate their aircraft under conditions of free flight, in which long-term route, speed, or altitude clearances are no longer necessary.

As this future on-board intelligent environment evolves, it is vitally important that we ensure the integrity of these data and their secure, reliable transmission between aircraft and ground computers. We must also find technological and human solutions to issues concerning information collection, dissemination, display, and use. It is crucial that we begin planning today to determine how technology improvements, system integration, human-computer interface, and other factors will affect the course of modernization and the safety of the overall system. It is clear that even the most advanced technology cannot be effective if it is not integrated carefully into the system and properly used.

Ensuring the safety of the future NAS is dependent on a clear understanding today of what that system will look like tomorrow. Currently the FAA is examining NAS architecture and is making recommendations to increase its responsiveness to near-term, mid-term, and long-term information and communications demands. Researchers are examining requirements for NAS information, a key component of the NAS architecture, to determine its definition and structure, its ability to assist in meeting operational requirements, its deployment in system development activities, and its cost-effectiveness. A number of recent studies and trends have highlighted the need for FAA systems to deliver a higher quality and quantity of information than they have to date.

As new sophisticated technologies are introduced and situational awareness in the cockpit improves, it is critical that flight crews obtain the proper training and decision support tools to operate effectively and safely in this new environment. One of the goals of FAA's Free Flight–Phase I program is to provide the training and support tools necessary for creating the free-flight system of the future. These new capabilities will allow for more flexible routes and efficient altitudes and will streamline the delivery of information to systems and people, enhance decision support, and provide more efficient throughput at adapted airports. Perhaps more important, deployed systems will be integrated with operational procedures and training to minimize risks while maximizing greater user satisfaction.

Not only is it important to understand how pilots and flight crews will react to this new information-rich environment, but we must also explore the emerging role and impacts of advanced automation on air traffic controllers. These systems provide computer assistance in anticipating future conflicts of an aircraft with other aircraft, restricted military airspace, or adverse weather and will help identify different trajectories that will safely maneuver the aircraft around those problems. Other decision aids have been developed and field tested to expedite the efficient arrival of aircraft during peak periods at busy airports. Decision support will also provide controllers with the tools by which they can more effectively accommodate the preferred routing of pilots in flying to their destinations, which will result in reduced fuel costs.

The future free-flight environment will depend heavily on the enhanced exchange of information among people and between people and systems. To ensure safety in this new environment, FAA is working now to identify the most efficient and reliable ways to display and exchange information; determine what, when, and how that information can best be displayed and transferred; design the system to reduce the frequency of information transfer errors and misinterpretations; and minimize the impact of errors. The results of this research will guarantee that the changes brought by increased automation and other system modernization efforts do not introduce new and unique problems for the users and operators of the global air transportation system.

CONCLUSIONS

In answer to the primary questions in the Critical Issues section that need to be addressed as we enter the new millennium, we offer the following answers, as supported by the previous discussion:

- The implementation of the new FAA NAS architecture and related advanced technologies will lead to the harmonization of the current system as it evolves into a safer, more efficient and globally accessible system. In addition, implementation of the free-flight concept will cause the system to evolve from an airspace control regime into one of interactive airspace management.
- Regional ATC-airspace enhancement initiatives [e.g., NASA's Tactical Area Positioning System (TAPS), Integrated Terminal Weather System (ITWS), and new runway development] will be supported and funded by regional users.
- Pilots and controllers will become the "customers" of R&D initiatives with the common goal of transforming an information-rich environment into an intelligence-based system whereby pilots and controllers are aided by decision support tools and effective situational awareness systems.
- Marketplace consolidation will occur, whereby global air carrier alliances, both airline and cargo, will replace individual national air carriers.
- Airports will assume the role of on-ground customer service provider to consolidate airport services, ensure that adequate customer service is provided, and recognize that customer service functions are not competitive items to global alliance members. Furthermore, airports will position themselves to fund their own initiatives to ensure cost efficiencies.

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