

THIRD GENERATION AIR TRAFFIC CONTROL SYSTEM

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The public acceptance and the continuing growth of aviation and air transportation are facts we cannot deny. Projections of future traffic growth, of course, are subject to many uncertainties, but some long-term trends are clear.

The annual growth in revenue passenger miles (kilometers) during the last 2 decades has at times been more than 10 to 15 percent, but appears to be settling down to perhaps 8 or 9 percent a year. The production of general aviation aircraft has gone above 10,000 per year. We export almost a third of this, but we are adding about 10,000 aircraft a year to our large general aviation fleet.

When these numbers and projections are translated into the various measures of air traffic activity—aircraft flying along the nation's airways or operations at airports—optimistic projections indicate a growth in most of these measures at a rate of 6 or 7 percent a year, and pessimistic projections indicate a growth of 3 to 4 percent a year. A good number for discussion is a growth of 5 percent a year.

Five percent a year means that the air traffic activity that the nation must handle will double by 1995. This is the starting point for looking at the future air traffic control system. How will we handle a doubling of air traffic activity by the end of the century?

Airport owners and operators look at this growth from one perspective, based on their experience, outlook, and constraints. I will try to give the perspective of the Federal Aviation Administration—the operators and designers of our air traffic control system. This, then, is the airside view of this growth. It has some unique problems, objectives, and constraints.

We are engaged at this time in a major engineering and

development effort to provide the basis for an improved air traffic system to meet the requirements of the 1980s and 1990s. We call this the Upgraded Third Generation System (UTGS), and this signifies, first, that it is an evolutionary upgrading and, second, that it starts from the base of the current air traffic control system, which is now in its third generation of growth from a small start in the late 1930s.

Let me give some idea of the extent of the present air traffic control system. The FAA operates some 20 en route centers that are fed by 91 long-range radars. We operate 386 towers, of which 130 have short-range airport surveillance radar (ASR). We operate more than 700 very high frequency omnirange stations with distance measuring equipment (VOR DME), 416 instrument landing systems (ILS), 652 microwave links, and more than 400 ground-air radio sites. It is a large and complex system.

The personnel in the FAA number just over 55,000. Of these, 10,000 are controlling traffic at centers, another 10,000 are controlling traffic at towers and terminals, another 5,000 are providing flight service station assistance, and another 10,000 are installing and maintaining all of this equipment. Thus, some 35,000 people are directly related with the operations and maintenance of this large system.

This all translates into a budget of just under \$2 billion a year. As we look ahead, then, the question is, What happens when we double the traffic? Unfortunately there is a tendency for all of the numbers that I mentioned to almost go up in direct proportion to this traffic. So we must double the capacity while we try to restrain the costs and yet maintain safety. And we must do this in 15 years.

Fifteen years is not a long time. We can measure time from when someone has an idea of what generally can be done, that is, a concept. We put it into design. We do the engineering and development. We buy the "breadboards" and then preproduction prototypes and test them. We then go back to Congress, get the money for the major production procurement, let the contracts, accept the equipment, install it, check it out, and start to use it operationally. With most of these systems, it takes several years between the time the first one is operating and the last one is operating. Fifteen years, then, is a short time in which to accomplish all of these activities.

The doubling of traffic is an equally difficult prospect because there are a number of things that will not double. We are not going to double the number of major hub airports. We are not going to double the number of runways. We are not going to double the altitudes at which these aircraft will fly. We are not going to double the preferred minimum time routes over the ocean areas. We are not going to double the radio spectrum. Congress would not permit a doubling of the FAA's budget, and the public would not stand for a doubling of midair collisions.

Improving the performance of the system to handle such a doubling of air traffic is but one of our goals. A second goal, of course, is to maintain or improve safety. The third goal is to do all this in a way that constrains or reduces the cost, not only the capital costs of the ground system but also the maintenance and operations cost as well as the cost to the user of the system.

In addition to these 3 major goals—performance, safety, and cost—there are certain guiding considerations: protection of the environment, minimization of air pollution and noise, conservation of energy, and 2 other ones that are somewhat difficult to state.

The first is that we want to maintain the maximum freedom of flight for each user without compromising the safety of the other users of the air space. We want to have the maximum freedom of flight so that several airlines can dispatch aircraft along the same route or so that any general aviation aircraft owner can jump into his or her aircraft and fly. This sort of freedom is a problem that other countries in the world do not face because they generally do not have a general aviation problem. They have state-run airlines with little or no competition. This concept of freedom of flight—that the air space is free and people can use it—is an interesting one and one that is difficult to design a system for.

The second is the question of whether the users of the air space should not pay for the services they receive. Clearly airline companies are paying the bulk of the cost of operating the system. General aviation pays a much lower share, and the question is, Should something be done to rectify this?

Engineering and development in the FAA are further complicated because we have a number of customers. We have operators of the system and 3 major categories of users: air carrier, general aviation, and military. They all have different objectives, intents, abilities to buy and service avionics, and ideas of how to use the air space.

I have mentioned the objectives and the customers. I should now like to discuss some of the problems. First, the objectives of performance, safety, and economy are not mutually exclusive. Almost anything that improves the performance of the system derogates the safety or adds to the cost. Similarly, the safest system is obviously the one that has no performance; that is, no one flies. And the highest performance system is generally going to be the most expensive.

A second problem is that the needs and the desires of the customers are not entirely compatible. If you have paid \$25 million for an aircraft, the idea of paying \$25,000 for a piece of avionics is not very absurd; but if you have only paid \$25,000 for an aircraft, the idea of carrying a \$25,000 piece of avionics does appear to be quite absurd.

The third problem relates to the complex interrelation of people and machines in the traffic control system. It is hard to analyze or describe or simulate how these 20,000 controllers do their jobs and what the forces are upon them. This entire system has not proved to be susceptible to any reliable, quantitative analysis. Application of queuing theory and all sorts of sophisticated simulation programs have not even provided much insight into what is happening. We generally have to resort to actually experimenting with new features, and it is hard to do this except in a live situation. We go to great lengths to simulate the environment and run such tests to be sure that what we are doing is safe enough to try out on live traffic.

Against this background and these engineering problems, we are proceeding to do the engineering and development of the Upgraded Third Generation System (UTGS). The schedule is the 15-year period that I mentioned earlier. The original idea that some things could be done to the Third Generation System to provide significant improvements in capacity came from the Air Traffic Control Advisory Committee appointed by the U.S. Department of Transportation. The committee published its report in 1969; now in 1975 we are in the middle of the test and evaluation, the design validation, the refinement of the design and the analysis, and the analysis of the cost-benefit aspects to determine whether these features should, in fact, be installed nationwide.

Those decisions will be made in 1977 and 1978; procurement will start for those parts that receive favorable decisions in 1978 and 1979. Initial deliveries begin in 1979 and 1980. By the mid-1980s, we could have a large part of the system becoming operational throughout the country.

The UTGS has 9 major features that I will briefly describe.

1. Improved separation assurance. This is another way of saying the prevention of midair collisions. Midair collisions are not numerous in relation to the large number of aircraft that fly in the air space. The number of lives lost in midair collisions averages 78 a year; in comparison, 500 lives of people riding bicycles are lost each year. There are, on the average, 39 midair collisions a year. The large part of these are between general aviation aircraft. But occasionally, some uncontrolled aircraft flying under visual flight rules (VFR) will move into protected air space and hit an aircraft flying under instrument flight rules (IFR). If that aircraft is an air carrier loaded with people, then it is a disaster.

We have an extensive ground-based system to guard against midair collisions, but we do not have positive control of all the air space. We do not provide radar coverage of all of the air carrier routes. The question is, What can we do to augment the separation assurance capabilities of the system that we have?

Quite a bit of time and effort has gone into technology related to airborne collision avoidance systems. What can be put into an aircraft that will detect other aircraft that may be near and detect whether aircraft are in fact on a collision course? Ten years ago we did not think there were any possibilities. Five years ago, we thought that a synchronized system in which everyone carried a precise clock could do it. Today 3 or 4 systems appear to be possibilities. The problem is price. One of these systems would cost in the range of \$25,000 to \$35,000 installed in an air carrier aircraft and

more than \$1,000 installed in a general aviation aircraft.

The other technique for improving separation assurance is to provide an even larger ground-based system and to make greater use of computers so that we do not increase the number of controllers. With this technique, known as intermittent positive control (IPC), all aircraft flying in the air space would be tracked by ground computers. If the system of ground computers detected 2 aircraft on a collision course, it would send data link instructions to the aircraft, and a simple indicator would tell the aircraft to turn left, turn right, climb, or dive.

The tests on IPC and on the airborne collision systems are now under way, and the FAA must approach Congress and recommend what we should do, if anything, to handle this problem of separation assurance.

2. Discrete Address Beacon System (DABS). The use of radar to detect aircraft in the air space has a number of problems. Today all air carrier aircraft, all military aircraft, and most general aviation aircraft carry beacon transponders. FAA calls this the Air Traffic Control Radar Beacon System (ATCRBS), a system adopted from equipment developed during the war. It has a number of problems, which can and should be solved. We are fortunate in that we found a way to do this in a compatible fashion. In other words, we can upgrade ground equipment and airborne equipment, and old ground equipment can work with new airborne equipment and vice versa. If we did not have a compatible system, we would have to operate 2 separate systems on the ground and in the air, and that is difficult and expensive.

DABS is under development today. The system provides each aircraft with a unique address, includes a data link, and improves surveillance capability. The quality of the surveillance data is the key to providing greater use of the air space.

3. Area navigation. This is not a developmental feature but involves the use of small computers in aircraft to achieve a better navigational capability. It provides much more flexibility than flying straight segments along the VOR-DME network. The problem with area navigation is to convince the users of the air space and the operators of the system that it can be introduced in a reasonable fashion, it will increase benefits, and it will not severely increase pilot or controller workload.

4. Microwave Landing System (MLS). We have more than 400 instrument landing systems (ILS) in use today. Large airports such as Chicago (O'Hare) have 8 or 9 systems. The tendency in the next 10 to 15 years will be to double or triple this number of landing systems.

ILS was designed at a low VHF frequency. It has problems with the terrain, and it is susceptible to hills or uneven terrain, taxiing aircraft, and new hangars. Today the FAA pays about as much money preparing a site to put in an ILS as it does for the equipment itself and then spends quite a bit of money doing flight checking. Clearly a new landing system, built at microway frequencies, would provide better service at lower costs.

MLS is an international program. The FAA has just made the basic decision that we will use the time reference scanning beam technique for MLS. This has put us in opposition to the United Kingdom, which favors the Doppler technique. That issue will presumably be resolved by the International Civil Aviation Organization.

Unfortunately, MLS is not compatible with ILS, and for a number of years, ten or longer, FAA will have to have dual systems at a number of places, and air carrier aircraft will have to carry dual equipments.

5. Automation. In the Third Generation System, we have just completed the installation of massive computing capability at 20 en route centers, where flight plan and radar data are automatically processed and presented on cathode ray tube displays. We have been fully operational for some months with Automated Radar Terminal System (ARTS) III at 61 major terminals and will soon be operational with ARTS II, a lesser capability system, at another 60 to 80 terminals. But this is just the first step on the automation ladder.

If we do not find a way to use computers to first decrease the work load and then achieve improved productivity as we double traffic, we will find that we are doubling the number of air traffic controllers. As I mentioned earlier, this would double the budget.

6. Flight service station. For general aviation aircraft, the FAA runs a large number of dispatch offices where we provide capability for preflight briefing of weather information and filing of flight plans. This is now done manually at the flight service stations, which are rather old installations where people tear pieces of paper off of teletypes, file them away or post them on boards, and answer the telephone as pilots call in. General aviation pilots get personalized weather briefings for their routes either over the phone or at the counter.

Automation can be used at these stations for data retrieval from computers and for generating voice recordings of weather. Within 5 years (and in fact on a demonstration basis today), you will be able to pick up a phone, call the flight service station, press the right sequence of buttons, and get a computer-generated weather briefing of the route that you have filed.

7. Airport surface traffic control. Providing these improvements in the air space does not do any good if in poor weather the pilots cannot see their way along the taxiways or if the controllers cannot see them. New buildings may also obstruct the controller's view from the towers. Therefore, better surveillance on the airport surface through improved radars or the beacon system with some novel trilateration techniques is another major development that is under way.

8. Wake vortices. All aircraft generate counter-rotating, trailing wake vortices. I suppose anyone behind the Wright brothers would have been upset by a wake vortex, but we did not notice these or become concerned about them until the wide-bodied jets.

When we discovered that these trailing wake vortices persisted for several minutes and that if pilots flew into them they would encounter velocities as strong as several hundred feet (meters) per second, we increased the separation under IFR from 3 miles (4.8 km) to 4 and 5 miles (6.4 to 8.0 km) depending on aircraft type. So, today a heavy jet should be 4 miles behind another heavy jet.

Unfortunately this increase in separation is in the wrong direction, for the only way we will ever increase airport capacity is to cut that separation from 3 to 2 miles (4.8 to 3.2 km). The only way to do that is to be able to know when the wake vortices have been carried away or have, in fact, collapsed.

For the past 2 years, with the assistance of the Transportation Systems Center, we have been using some laser sensors and propeller anemometers to collect data at a number of airports, primarily New York (Kennedy), Denver, and London (Heathrow), on some 30,000 cases.

The problem of wake vortices is the worst in the approach phase when all aircraft are following the same profile. Under certain wind conditions, the vortices either collapse quickly or are carried away. If we can determine when those wind conditions exist, we could go back to separations of 3 miles or less. We are optimistic about doing this, for it appears that most of the time the winds at most airports will move the vortices away.

A predictive system that will actually track the wake vortices themselves and determine when they are clear of the approach path is being put together and will be tried at Chicago (O'Hare) Airport later this year.

9. Aeronautical satellite program. This program is oriented to oceanic air traffic control and is intended to replace the current high-frequency communications, which are poor and limited in capacity, and to provide some surveillance capability. Over the ocean today, planes fly the same, great circle route, and we have to separate them by a few hundred miles in case there are navigational errors and speed changes.

We have no surveillance capability over oceanic flights, but that capability could be provided by a pair of satellites in synchronous orbit over the Atlantic Ocean. We have a joint program with Canada and 9 countries in Europe under way to demonstrate such a system.

What impact will all this have on airport capacity? The best answer to this question is contained in a report that we prepared for Congress in 1974 on a study of the impact of implementing the engineering and development efforts of the type I have just mentioned. We studied 8 major airports in some detail and believe the results apply to most other major airports. One thing that became clear from this study is that more

system capacity is needed. The things that I mentioned will provide more system capacity, but not enough to eliminate all delays. In fact, all the capacity in the world will not eliminate all delays. For example, we cannot do much about weather delays. Several things that we are doing are specifically oriented to airport capacity. The primary one is in the area of wake vortices. If we can avoid the vortices, we can cut the separations down perhaps to 2 miles (3.2 km). We can use automation to help vector the aircraft and cut the spread in the dispersion of the delivery of these aircraft. We can use more high-speed exits to cut the runway occupancy time from 50 sec or so to 25 to 30 sec. We can improve surveillance by DABS, airport surface traffic control, and MLS so that we know more precisely where the aircraft are on final approach.

IFR capacity at these 8 airports is now about 74 percent of VFR capacity, and we think that with these improvements we can increase that to as high as 90 percent. Specifically, we think that we can increase IFR capacity by about 50 percent (with some variation from airport to airport) and VFR capacity by about 20 percent.

Another conclusion of that report is pertinent to this conference: "With all improvements, both VFR and IFR capacities will be improved significantly to a point where landside aspects will be airport limiting in the 1980s." That conclusion led FAA to be most interested in the question addressed by this conference. What can we do through engineering and development projects to improve landside capacity to match the increase in airside capacity that should result from projects we are now engaged in?