

N83-22571

ADVANCED AIR TRAFFIC MANAGEMENT

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Air traffic worldwide continues to grow, and this growth is predicted to continue in the coming decades. Air traffic management (ATM) systems in several parts of the world have now reached their operating limits. The external symptoms of this are increases in the number of delays experienced by the system, and a rise in the frequency of near-misses. If the ATM system fails to develop to provide more capacity, then the result will be a decrease in safety levels, and increasing delays, or a limit on the number of permitted aircraft operations.

- In 1989 a 3% increase in traffic in the USA caused a 17% increase in ATC delays
- 64m operations at towered FAA airports in 1990; 80m operations predicted for 2000
- Delta suffered 2800 minutes of delay per day (1989)
- BA 767 flights from London to Paris are scheduled to take 5 minutes more than Vanguard flights 30 years ago

There is a need for more capacity in the airspace system without degrading safety.

In recent years a number of new technologies have emerged that could allow a radically different ATM structure to be used, rather than the present geographically spread system, designed around radar monitoring and radio communications. Some of these technologies are listed below.

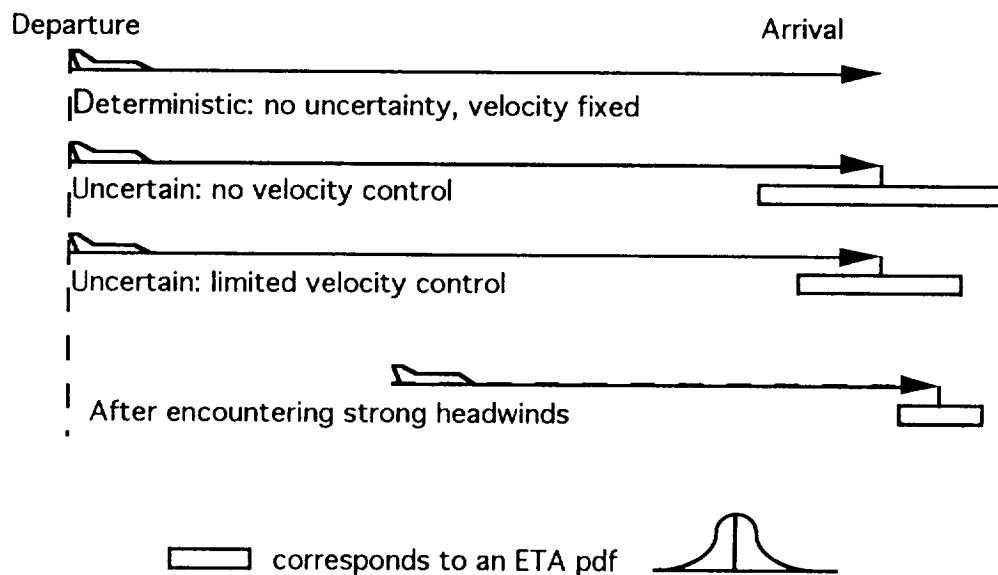
- GNSS (GPS/GLONASS) Satellite Navigation Systems - aircraft are no longer dependent on ground based aids for navigation
- TCAS systems allow aircraft to monitor their separation from other traffic
- Mode S transponders allow air-to-air and air-to-ground data communications
- FMS/FCS systems allow routings and trajectories to be computed rapidly
- MLS and D/GPS allow more complex approaches to airports
- Communications satellites allow air to ground communications over long distances

**Trends: aircraft are increasingly autonomous;
surveillance and communications not limited to
radio/radar range**

This new technology could allow the ATM system to change in a number of ways. The increased use of data transmissions, satellite communications, and GPS could be used to enhance the present system, while still leaving the present responsibilities of pilots and controllers unchanged. This is the basis of ICAO's Future Air Navigation System (FANS) concept. Alternatively, the increased navigational accuracy and use of 4-D Flight Management Systems (FMS) gives aircraft the capability to follow a flight plan more closely than they can at present. This could allow more strategic planning to be carried out, on the basis of the flight plan, reducing the amount of tactical control needed to ensure safety. This could be characterized as a more centralized or planned system. Equally, the same technologies make aircraft less dependent on ground based services for both position information and separation from other aircraft. This could allow a more autonomous ATM system, with far less control exercised from the ground.

- **Centralized/Planned Control System**
- **Evolutionary FANS system**
- **Distributed/Autonomous System**

In a centralized system that strategically plans flight paths to ensure aircraft do not conflict while meeting a scheduled arrival time, the main problem is the handling of uncertainty. If there were no winds and it was known exactly what speed, altitude, and track the aircraft would fly then the touchdown time could be deterministically computed. The presence of variable winds in the atmosphere causes a variation in the length of time a journey will take. An aircraft can overcome this to an extent by controlling its airspeed, but the range of wind speeds that can be encountered at altitude is greater than can be matched by variation in aircraft speed. As the time remaining to touchdown decreases the uncertainty in touchdown time decreases. Any strategic planning has to account for this temporal uncertainty: there will also be a spatial uncertainty due to navigation system errors and possible re-routings during the flight. If the uncertainty can be characterized as a probability density function (p.d.f.) then the problem could probably be tackled by a form of probabilistic reasoning.



If the problem of handling the temporal and spatial uncertainties of a flight can be overcome, then strategic planning using flight plans can offer several advantages over the existing system. Possibly the main increase in capacity would come from the ability to fly any 4-D profile within permissible airspace, rather than following a fixed route structure which has the effect of concentrating aircraft in a small percentage of the available airspace. Combined with satellite communications, such a system would also allow the destination airport, or Terminal Maneuvering Area (TMA or TCA), to revise an aircraft's target arrival time while en-route. The flight plan would then be recomputed for the new required arrival time. This would benefit congested airports and TMAs by providing a smoother, more predictable, flow of aircraft into a TMA, reducing the amount of vectoring and maneuvering required to produce the maximum safely separated flow rate of aircraft onto the runway. This would help ensure that airports operate at close to their maximum runway capacity, while reducing controller workload.

- **The proposed system would compute conflict-free 4-D trajectories that aircraft would then accurately follow.**
- **Accurate planning leads to fewer conflicts**
- **Early TCA involvement leads to smooth flows in terminal area**
- **Reduced controller workload**
- **Increased capacity**
- **Fewer delays**

The thrust of this research is to construct an Intelligent Aircraft Airspace System. Intelligence can be characterized as having both the knowledge required and the ability to manipulate that knowledge in order to carry out some function (such as planning or control). At present almost all the knowledge (position data, weather data etc.) is concentrated in the ground controllers, and it is their human intelligence that allows the system to operate, applied through tactical control of aircraft in the system. The centralized system outlined here uses the increased guidance and navigation capabilities of aircraft to allow intelligent strategic flight path planning to occur (as opposed to system level flow management planning). It does not use any of the separation monitoring capabilities that TCAS gives aircraft (other than as an extra safety level), and the control of the system is still on the ground, though partially transferred from tactical controllers, to the strategic flight path planning function.

In an autonomous system, the aircraft has to be more intelligent. If the level of ground control required is to be reduced then an aircraft has to at least partly be able to plan a conflict-free trajectory for a reasonable time ahead, and also has to navigate without explicit ground control guidance. The field of Artificial Intelligence has developed in a number of areas that could be applicable to this problem. Work will now focus on defining an outline of an autonomous aircraft airspace system.