Aviation communication, navigation and surveillance systems for the 21st century

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Abstract:

The Future Air Navigation Systems Committee(FANS) of the International Civil Aviation Organisation(ICAO) has developed a global system concept for communication, navigation and surveillance together with the evolution of air traffic management to overcome the limitations of the present systems and to meet the needs of aviation into the 21st century. Australia must integrate into this global system and has much to gain from it in the provision of more cost-effective services and the more efficient use of airport and airspace capacity to meet aviation growth.

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Introduction

Aviation Administrations have to provide communications, navigation and surveillance (CNS) services in the airspace for which they are responsible These airspaces can be very large (eg the airspace for which Australia is responsible covers one ninth of the world's surface) and covers oceans as well as land masses CNS are the fundamental elements of an air traffic system and are also the building blocks essential for the development of an air traffic management (ATM) system

With the exception of some "on-board" aircraft navigation systems, aeronautical CNS systems rely on electromagnetic propagation for their operation and this puts constraints on the present day CNS. The high quality CNS systems require line-of-sight between the aircraft and the ground station Thus a large number of ground stations are required for CNS services over land masses Over the oceans it is obviously impractical to provide CNS services by such systems Long range (over the horizon) systems can cover large areas of land and ocean from few ground stations but are not able to provide high quality services due to the variability of electromagnetic propagation characteristics. This in turn results in larger separations being required between aircraft with consequent economic penalties. Thus the present terrestrially based systems have limited the implementation of services and their quality which in turn has limited the efficiency of aircraft operations.

In Australia it has always been difficult to provide CNS services by terrestrial means over our large areas of continental and oceanic airspace. Even over continental Australia, there are large areas of desert where there is a lack of communication infrastructure. In the early 1980's, the Civil Aviation Authority (CAA) turned to satellite systems to overcome the problem of communications over continental Australia The Australian aviation satellite communication system was implemented in 1986 and uses satellite links to relay communications from air traffic centres to remote ground stations and then to the aircraft via line-of-sight transmission in the very high frequency (VHF) band Thus the high quality VHF communication coverage has been extended over continental Australia using the domestic satellite system - AUSSAT - and 94 satellite ground stations which are owned and operated by the CAA. This is a uniquely Australian development to solve a particular problem which has not only led to better communication services, but has contained costs and laid the foundation for future systems. However, the navigation and surveillance problems still remain as does communication over the ocean.

The Future Air Navigation Systems (FANS) Committee

In the early 1980's there was a worldwide recognition, not only of the difficulties of the existing CNS systems in meeting current needs, but also that these systems were unlikely to cope with the demands of growth and meet future needs Thus "more of the same" was not going to be the solution to aviation needs It is a salutary thought that the increase in airports and runways have not kept pace with aviation growth, but even worse the amount of airspace can never be increased. A great increase in the efficiency of airports and airspace would be required to keep congestion delays at tolerable levels in the face of air traffic growth and to accommodate the optimum flight paths of aircraft.

In response to this recognition, the International Civil Aviation Organisation (ICAO) established in 1983 the Special Committee on Future Air Navigation Systems (FANS). The task of FANS was to study, identify and assess new concepts and technology and to make recommendations for the coordinated evolutionary development of communications, navigation, surveillance and air traffic management over a timescale of the order of twenty-five years. In ICAO, the term "air navigation systems" includes communication, navigation, surveillance and air traffic management. The membership was drawn from twenty-two States and International Organisations together with ten others with observer status. Australia was represented on FANS since its establishment and our representative was its vice Chairman for its initial task. FANS first met in 1984 and decided it would have to complete its task in five years for the results to be relevant and for the necessary developments to take place. The timescale of twenty-five years may seem a long time, but remembering the long timescales for the worldwide implementation of new systems in civil aviation, the task had to be commenced in the 1980's for implementation in the 1990's and operations after 2000.

FANS critically examined the existing systems for their capabilities and potential for development and to assess whether they could be modified or developed to meet present and future needs. FANS concluded that the shortcomings of the existing systems were due essentially to three factors:-

(1) the propagation limitations of current line-of-sight systems and/or the accuracy and reliability limitations imposed by the variability of propagation characteristics of other systems;

(2) the difficulty, caused by a variety of reasons, to implement present CNS systems and operate them in a consistent manner in large parts of the world;

(3) the limitations of voice communication and the lack of digital air-ground data interchange systems to support automated systems in the air and on the ground.

FANS determined that these limitations are intrinsic to the systems themselves and thus the problems cannot be overcome worldwide except by new concepts and new CNS systems.

FANS then proceeded with its study of new concepts and new technologies and concluded that the exploitation of satellite technology is the only viable solution that would overcome present limitations and meet future needs on a cost effective global basis. However, FANS recognised that some line-of-sight systems would continue to be appropriate where their propagation limitations were not a problem eg. the use of VHF communications in terminal areas. Thus the FANS concept is a sensible mix of satellite technology and the best of the line-of-sight systems to achieve an overall optimum result. FANS completed this task in 1988.

The FANS System Concept

The essential elements of the CNS system proposed by FANS are as follows:

Communication

Communication with aircraft for both voice and data would be by direct satellite-aircraft link operating in the frequency band allocated to the aeronautical satellite service In terminal areas and where line-of-sight propagation limitations are not a problem, VHF communications would be used together with an added data link to Secondary Surveillance Radar (SSR). The communication architecture developed by FANS provides for a range of capabilities from basic low speed data only (the "core" capability) to high speed data and voice. This communication system thus will provide world-wide, high quality, high integrity, interoperable aviation safety services.

Navigation

For navigation, FANS developed the concept of Required Navigation Performance Capability (RNPC) which sets out the navigation performance required in a variety of airspaces. RNPC thus concentrates on system performance rather than specifying a particular system at the outset. Most RNPC requirements could be met by the development of the global navigation satellite systems now being deployed by the USA-GPS and the USSR-GLONASS. These systems would provide a worldwide positioning accuracy of 100 metres (95% probability).

FANS was confident that these global navigation systems will evolve to be suitable as the sole means of navigation for en-route, terminal and non-precision approach In accordance with the ICAO transition plan, the Microwave Landing System (MLS) will be the standard system for precision approach and landing.

Surveillance

For surveillance, FANS developed the concept of Automatic Dependent Surveillance (ADS) where the aircraft automatically transmits its position (and other relevant data) via satellite (or other communication link) to the air traffic centre. The aircraft position would be determined by the navigation systems described above The aircraft track can then be displayed in a similar manner to advanced radar displays An important feature of ADS is that not only is the aircraft position transmitted to the air traffic centre, but also such information as aircraft heading, speed and intentions. Thus more information would be available to the air traffic centre than from the present radar systems SSR, augmented with improved antennas and selective addressing, will continue to be used in terminal and high density airspace. For the first time, aviation will have a high quality surveillance system to cover oceanic airspace and continental areas remote from the present radar systems.

Air Traffic Management (ATM)

FANS recognised that the new CNS systems would provide for a closer interaction between the ground system and the aircraft system before and during flight. Thus the new CNS systems are the basis for the improvement of ATM for which the primary objective is to expedite and maintain the safe and orderly flow of traffic. This is an increasingly important consideration because the demands of air traffic growth require substantial increase in the efficiency of the air traffic system both en-route and in terminal areas. Otherwise there will be a dramatic increase in congestion and delays.

FANS envisaged that the improvements in the CNS systems would result in:-

(1) improved data handling and transfer of information between operators, aircraft and air traffic units;

(2) extended surveillance by ADS;

(3) advanced ground-based data processing systems.

The above would then allow ATM to evolve by permitting

(1) advantage to be taken of improved navigation accuracy in four dimensions of modern aircraft;

(2) improved accommodation of a flight's preferred profile in all phases of flight, based on the operator's objectives;

(3) improved conflict detection and resolution, automated generation and transmission of conflict-free clearances and adaption to changing traffic conditions.

These developments together with improved flight planning will lead to the more dynamic airspace and air traffic management, particularly in high density airspace, and are essential for coping with growth and reduction of congestion and delays.

Validation

FANS carried out a validation of the system concept by a cost-benefit analysis on a global basis. A summary of the methodology is as follows. Ten different air traffic scenarios were identified as representing several parts of the world and when taken together characterised the global air traffic environment. The scenarios ranged from complex, high traffic density airspace through low density oceanic airspace to a fictitious "Terra X" representing an underdeveloped area. Capital and operating costs for both the ground and airborne components of the new CNS system were estimated. The total cost was then annualised which gave a global figure of $1 billion (1987 US dollars). The replacement and operating costs for those parts of the present CNS system (both ground and airborne) which would be rendered redundant by the new CNS system were similarly estimated and converted into an annual cost. This also gave a global figure of $1 billion. A second benefit stream was the increased efficiency in aircraft operations (direct routing, optimum flight profiles, etc) made possible by the new CNS system. Estimates were made of the minimum and maximum percentage gains in efficiency in various airspaces. The total value of the global efficiency gain was obtained from the percentage efficiency improvements and the operating hours and operating costs of various aircraft types in each region. This gave a minimum figure of $4 billion and a maximum figure of $5.5 billion (1987 US dollars). Thus the FANS system would cost no more to provide and operate than the present system and there would be global benefits of between $4 billion and $5.5 billion

The CAA has made some preliminary estimates of the costs and benefits of the FANS system in Australian airspace using the FANS methodology. The annual cost (in 1987 Australian dollars) to implement and operate the ground and airborne components of the new system would be approximately $38 million, the avoided costs would be approximately $35 million and the annual benefits from the efficiency increase would be between $76 million and $152 million

Global Planning and Coordination of Development

The achievement of full benefits from the FANS system requires its implementation on a global scale. This in turn requires global planning and coordination of development to ensure that implementation takes place in a globally cost-effective manner The implementation of satellite systems in particular raises new issues and requires arrangements different from those of the present terrestrial system. This is due to satellite systems having coverage which extends over many countries. It is therefore necessary to plan at the worldwide level for the global implementation of the FANS system.

FANS recommended the establishment of a new ICAO Committee to advise on the overall monitoring, coordination of development and transition planning ICAO gave these tasks to the FANS Committee in 1988 on an interim basis pending the establishment of the new Committee. The Australian representative was Chairman of the interim Committee In this interim phase analysis of the plans from member States and organisations was commenced to identify critical dates when developments would take place and thus the timescales for actions by ICAO and for the implementation of system elements in various regions of the world. Data bases were designed for information on worldwide plans and R&D programs to identify overlaps and deficiencies. A generic model of a global satellite system has been developed showing how this would be made up of all the elements from various civil aviation administrations, service providers and users

The ICAO Council has now established the new Special Committee for the Monitoring and Coordination of Development and Transition Planning for the Future Air Navigation System (FANS Phase II). The specific tasks are:-

(1) to identify and make recommendations for acceptable institutional arrangements, including funding, ownership and management issues for the global future air navigation system;

(2) to develop a global coordinated plan, with appropriate guidelines for transition including the necessary recommendations to ensure the progressive and orderly implementation of the ICAO global future air navigation system in a timely and cost-beneficial manner;

(3) to monitor the nature and direction of research and development programs, trials and demonstrations in CNS and ATM so as to ensure their coordinated integration and harmonisation;

(4) to develop policy guidelines for the evolution of ATM to maximise the efficient use of airport and airspace capacity;

(5) to prepare, as required, the necessary documentation to support the ICAO Air Navigation Conference in 1991.

The FANS Phase II Committee now consists of 38 representatives from States and International Organisations. The first meeting of the Committee took place in Montreal in May-June 1990 and the Australian representative was elected Chairman.

Australian Developments

The CAA recognises the considerable national and international benefits which will be obtained from the implementation of the FANS system. The CAA is thus proceeding with the planning and development needed for the transition to the new system.

An indicative timescale for transition could be along the following lines:-

1990-1997	:	Research, development, trials and demonstrations in CNS and ATM.
1993-2002	:	Gradual implementation of various elements of the system. Some aircraft and Administrations will use the FANS CNS system with the terrestrial system as backup. Eg, satellite based communications and ADS would be used by some aircraft to give a higher quality service than High Frequency (HF) Radio, but HF would be used as the backup.
1998-2005	:	Full FANS CNS services available in parallel with existing systems so that appropriately equipped aircraft could operate solely on the FANS system and have operating credits for doing so.
2005-2010	:	The terrestrial system, not required for FANS, is progressively dismantled.
2010-	:	FANS is the sole system.

Two of the CAA's major development programs for the transition to FANS are as follows:-

One of the first satellite air-ground data link programs is the Automatic Dependent Surveillance (ADS) demonstration over the Pacific which will be commenced in 1990 as a joint cooperative program between the United States, Japan and Australia. In this program a number of international aircraft (and experimental ground mobiles) from the participating countries will transmit their position (derived from their on-board navigation systems) via the INMARSAT Pacific satellite. The position data will be received by a number of ground stations then distributed to the participants via various networks for display in air traffic centres. In Australia, the aircraft position from ADS will be displayed on a general purpose aircraft display along with aircraft positions derived from flight plans and pilot reports. These electronic colour displays were developed by the CAA for this project and the initial installations will be in the Sydney and Adelaide air traffic centres. The ADS data link will be initially limited to aircraft identity and position information, but will eventually be developed to include other data such as waypoints, track, speed, meteorological data, etc. in accordance with the FANS recommendations for ADS.

The CAA has commenced a program to develop an air traffic flow management system based on the application of advanced techniques including artificial intelligence. Containment of delays and delay costs to industry requires the development of more sophisticated traffic management and planning techniques. Firstly, a versatile real-time flow planning and management system has to be developed which will minimise congestion in both a single and a multi-airport environment. Secondly, air-ground data links are required to acquire real-time data from the aircraft for the flow management determinations and to provide real-time advice to the aircraft to assure that the aircraft complies with the time/position/ speed requirements. A prototype air traffic flow management system based on artificial intelligence techniques is being developed for installation at Sydney airport during 1991 for evaluation. During this program an assessment is being made of obtaining real-time meteorological and trajectory data from aircraft using a VHF data link.

Conclusion

FANS has produced a system concept to overcome the limitations of the existing systems and to meet the needs of aviation into the 21st century. The CAA recognises the benefits of the FANS system for Australia and has commenced the necessary planning and development to integrate Australia into the future global system and to meet the needs of Australian aviation. In particular, the FANS system is a key element in increasing the efficiency of airport and airspace capacity to meet the demands of air traffic growth.

References

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