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The Future Air Navigation System:
Implementation Issues

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Abstract

Over the next ten years there will be significant improvements in the navigation performance of modern aircraft because of the implementation of future oceanic Air Traffic Control (ATC) systems such as Data Link (DL), and the concept of Automatic Dependent Surveillance (ADS) using the Global Navigation Satellite System (GNSS). These are integral parts which make up the overall environment known as the Future Air Navigation System (FANS). FANS is a way of using new technology to enhance communication links between aircraft and air traffic controllers; improve air navigation safety; and increase air traffic controller's capacity to monitor flights.

Because the implementation of FANS requires special design considerations, the airline sector and aircraft equipment manufacturers have an immediate problem of deciding, in difficult economic times, whether to proceed with the retrofitting of current aircraft systems and designs of future aircraft. Industry needs a reliable prediction of the benefits it will receive from the new system before it is willing to invest the large amount of money it will take to implement the change. Besides an overview of FANS, the potential benefits and current issues are discussed, as well as the current and future conditions that are pushing towards an overhaul of the current system.

**The Future Air Navigation System:
Implementation Issues**

Introduction

Two aviation organizations are largely responsible for the design and coordination of the Future Air Navigation System (FANS). One of these organizations is the International Air Transport Association (IATA) which is a non-governmental organization that participates in the work of the International Civil Aviation Organization (ICAO). The ICAO was created in 1944 to promote the safe and orderly development of civil aviation in the world. A specialized agency of the United Nations, it sets international standards and regulations related to the safety, security, efficiency and regularity of air transport and also serves as the medium for cooperation in all fields of civil aviation among its 183 contracting States (World Almanac 1996, 1995:845). Other non-governmental organizations that also participate in ICAO's work include the Airports Council International, the International Federation of Air Line Pilots' Associations, and the International Council of Aircraft Owner and Pilot Associations.

The second organization that produces information about FANS is the Federal Aviation Administration (FAA). Today there are two important responsibilities of the FAA: (a) conducting research and development of new aviation technologies; and (b) working with the ICAO to establish and maintain worldwide aviation standards (Nader and Smith, 1994:6-13).

What is FANS? FANS, or the Future Air Navigation System, is a way of using modern technology to: enhance communication links between aircraft and air traffic controllers; improve a pilot's ability to safely navigate his aircraft; and increase an air traffic controller's capacity to monitor flights (IATA, 1996:1-6; FAA, 1996a:1-31). FANS is also known as CNS/ATM (Communications, Navigation, Surveillance, and Air Traffic Management)

Communications. Communications satellites positioned around the equator enable moving objects, such as aircraft or ships, to communicate with each other and with fixed points on land. Messages can be sent from a cockpit, or from passengers on board, using radio signals that are bounced off one of these satellites. A station on the ground receives these messages from the satellite and routes them to their final destination which could be an Air Traffic Control unit, or an airline's operations center or the passenger's home or office. Messages to the aircraft are sent in the opposite direction.

Satellite communication systems are especially useful over oceans and other remote areas where no alternative communications systems are in place. In more densely populated areas and at airports, ground-based communication systems can still be used. For the international telecommunication industry the key challenge is to link these alternative systems into a seamless global network, similar in concept to the Internet. In the world of civil aviation this global network is known as the Aeronautical Telecommunication Network or ATN and is being designed to handle data transmissions (Dornheim, 1995:46). While verbal communications between pilots and controllers will still be possible, voice communication will rarely be needed. Data communications will allow information to be transmitted more concisely, accurately, and efficiently. The ATN is a concept for a worldwide data network connecting civil aviation authorities, aircraft, airline operators, and other members of the aeronautical community. Because the ATN will provide a standard means for aeronautical communications, including communications with aircraft in flight, it is of great importance to future planning. A key benefit of the ATN will be the use of inter-operable transmission media (i.e., satellite, HF, VHF, and Mode S) for air/ground communications. ATN protocols and interface standards are currently under development in ICAO and RTCA Inc. (Formerly the Radio Technical Commission for Aeronautics) working groups (FAA, 1996a: 1-8).

Navigation. With FANS, aircraft navigation is becoming safer and more accurate though the use of navigation satellites orbiting the earth. The United States has offered its military Global Positioning System (GPS) to the international aviation community, and it is in use today by a growing number of airlines. The Russian Federation has a similar system, also offered for civil use, called Global Orbiting Navigation Satellite System (GLONASS) which is not yet fully operational. Eventually, both systems will probably be used by the airlines (FAA, 1995:1-5).

GPS and GLONASS require augmentation systems to monitor signal reliability and enhance accuracy to make them suitable for civilian use. These augmentation systems are currently being developed (Clarke, 1996:99).

Navigation satellites are being used today to land aircraft on runways in good weather conditions. These types of approaches are called non-precision approach and landings. For landings in poor weather conditions, called precision approach and landings, the current Instrument Landing System (ILS) or, in certain locations, Microwave Landing System (MLS) will be in use for some time. Eventually, navigation satellite systems will be used even in poor weather conditions (FAA, 1996a:11).

Surveillance. Under FANS, air traffic controllers will continue to use ground-based radar to monitor aircraft over densely populated areas. When flying over oceans and remote areas, however, where no radar systems exist, aircraft can now relay their positions to ATC centers via communications satellites. This concept, known as Automatic Dependent Surveillance (ADS) ensures air traffic controllers know exactly where every aircraft is (FAA, 1996a:13).

Air Traffic Management (ATM). The following is the mission needs statement that provides an insight to the FAA designs on the direction and background of ATM

> * **FAA MISSION NEEDS STATEMENT.** The overall mission of the Federal Aviation Administration (FAA) is to provide a safe, secure, and efficient aviation system that contributes to national security and the promotion of U.S. aviation. The basic responsibilities of the FAA are detailed in the Federal Aviation Act of 1958 (as amended by Public Law 89 670). This Act requires that the FAA manage the national airspace for the benefit of all users and that air travel be accomplished in a safe, orderly, and efficient manner. The specific part of the FAA mission discussed in this Mission Need Statement (MNS) is that of air traffic operations and communications in support of these operations. Demand for air traffic control (ATC) services is predicted to increase dramatically in the next 10 years. Air carrier hours flown and numbers of air carrier aircraft are expected to increase by over 50 percent. The number of Instrument Flight Rules (IFR) aircraft handled at the Air Route Traffic Control Centers (ARTCCs) and Terminal Radar Approach Control Facilities (TRACONs) is expected to increase by over 30 percent. To support the increased global air traffic demand, the International Civil Aviation Organization (ICAO) Future Air Navigation Systems (FANS) committee has identified a future Air Traffic Management (ATM) system based on a structure of communications, navigation, and surveillance (CNS) functions, which in turn support flight planning, aircraft operations, and air traffic separation on a global basis (FAA, 1996b:WWWeb).

The ATM system of the future will provide improved services to users of the airspace system and will support the goals of increased efficiency and safety as demand grows. Major user needs identified for the future ATM system include: the ability to select and fly an optimal route at the user's desired departure and arrival times; access to information that can be used to determine an optimal flight plan or to modify an active flight plan based on user criteria; access to air traffic and flight information services with minimal delay and error; delivery of safety-critical information and instructions to pilots with minimal delay and error; receipt of information that is current, accurate, relevant to operational objectives, easily understood, and applied (IATA, 1996b:WWWeb)

The FAA has established an operational plan for the ATM system of the twenty-first century. To realize the FANS concepts for ATM, the National Airspace System (NAS) will rely increasingly on advanced capabilities provided by ground and airborne automation systems and will require the communication and management of timely and accurate air traffic, flight information, navigation, and surveillance data in all operational domains. In this future ATM environment, it will no longer be possible to rely exclusively on voice messages for the exchange of information. Digital data communications will become the primary means of exchanging information among NAS users and their supporting automation systems. To this end, transition from voice to data communications has been identified as a key goal for ATC (FAA, 1996a:20-23).

The Aeronautical Data Link System (ADLS) has been identified to provide many of the capabilities crucial to implementation of the future ATM system. The ADLS comprises both the services and the communications infrastructure that support aeronautical information exchange among all members of the aviation community. The ADLS services will allow the presentation and management of data to be tailored to the user's capabilities and requirements to maximize the utility of air traffic services. The ADLS communications infrastructure will implement the FAA's portion of the ATN and will provide the global air/ground data communications capability required to alleviate communications problems in the current voice environment and to support advanced capabilities in the future environment. The ADLS must support the ATM user needs identified previously and must also accomplish the following: provide a selected set of ATC, weather, flight service, navigation, surveillance, and aeronautical information and services directly to the cockpit using digital data link technology; support seamless transition for aircraft across and within all NAS operational domains, (tower, terminal, en route, and oceanic); provide a distributed networking infrastructure, which will allow communications services to be carried via any of the possible air/ground transmission technologies over the ATN and incorporate ATN protocols which utilize internationally standardized Open Systems (FAA, 1996b:WWWeb).

FANS Implementation. Starting in the South Pacific, the introduction of FANS is now spreading to other regions and gaining momentum. FANS is gradually being implemented as regions and individual countries move from traditional methods for navigation and communications to these more advanced systems.
Benefits are available today for airlines and ATS providers willing to embark upon FANS CNS/ATM implementation. The target date for global FANS implementation as set by ICAO (the International Civil Aviation Organization) is 2010 (IATA, 1996:4).

An example of the implementation of FANS in the Pacific took place in August 1995 when a United Airlines 747-400, flying from San Francisco to Sydney, Australia sent GPS positions by data link that led to key certifications of ATC stations. The aircraft was equipped with the FANS-1 suite, which combines navigation and satellite data link communications and costs approximately $5 million per aircraft (Nordwall, 1995b:28-29).

To achieve the full benefit of FANS, air traffic control procedures will need to change and the separation distances between aircraft will need to be reduced. Ultimately, airlines hope to gain total freedom for pilots to select their routes and to change these routes in flight, safely and efficiently. This goal, known as Free Flight, will ensure the most economic, fastest, or most direct route will be flown according to the requirements of each individual flight (Hinson, 1995).

Free Flight

Free Flight is an innovative concept that will improve the efficiency of the National Airspace System. Using supporting procedures and technologies, pilots operating under instrument flight rules (IFR) will be able to select the aircraft's course, speed, and altitude in real time. From pre-flight planning to destination parking, Free Flight provides the aviation community with maximum flexibility and safety. This concept is being developed jointly by the FAA and the aviation community.

Currently, a pilot establishes a flight plan with air traffic control. This plan requires the aircraft to fly along a specific route. Any deviation from the designated route must be pre-approved by an air traffic controller. For example, if a thunderstorm is encountered along the flight path, the pilot must notify the air traffic controller of the need to change course, and the controller would designate a course for the plane to avoid the weather. Under the Free Flight concept, the pilot will be able to choose the route, speed and altitude to achieve the desired results, notifying the air traffic controller of the new route. The pilot's flexibility will be restricted only:

- To ensure separation, when traffic density at busy airports or in congested airspace, precludes Free Flight
- To prevent unauthorized entry into special use airspace
- To ensure safety of flight.

Generally speaking, any activity that removes restrictions represents a move toward Free Flight. Full implementation of Free Flight requires varying degrees of modifications to procedures, along with the use of current and new technologies and new ground- and air-based communications, navigation, and surveillance equipment and avionics. Free Flight continues clear-cut lines of authority and responsibility between the pilot and controller. Technology will be designed to allow the pilot and controller to perform their jobs with improved accuracy, efficiency, and coordination (FAA, 1996c:WWWeb; Hinson: 1996b).

Free Flight Concept. The Free Flight idea is based on two airspace zones, protected and alert, the sizes of which are based on the aircraft's speed, performance characteristics, and communications, navigation, and surveillance equipment.
The protected zone, the one closest to the aircraft, can never meet the protected zone of another aircraft. The alert zone extends well beyond the protected zone. Upon contact with another aircraft's alert zone, a pilot or air traffic controller will determine if a course correction is required. In principle, until the alert zones touch, aircraft can maneuver freely.

The protected zone, the one closest to the aircraft, can never meet the protected zone of another aircraft. The alert zone extends well beyond the protected zone and, upon contact with another aircraft's alert zone, signals that a conflict exists.

If alert zones do touch, a controller may provide one or both pilots with course corrections or restrictions to ensure separation. Eventually, most commands will be sent via data link, an integrated network of air, ground, and airborne communications systems. Additionally, onboard computers and Global Positioning System satellites will allow pilots with airborne traffic displays to choose solutions, with the concurrence of the controller. The Free Flight concept ranges from total flight-path flexibility to controlled separation due to traffic density and the complexity of traffic flow (FAA, 1996c:WWWeb; Nordwall, 1995a:38-39; Hinson, 1996b).

Free Flight Benefits. Free Flight is designed to provide the user community with the flexibility to better manage its operations and the capability to derive benefits from advanced avionics. By providing for more efficient routes, Free Flight will reduce user operating costs. Free Flight will also allow the user's aircraft to reach its destination at the prescribed time. The FAA predicts a near 70 percent increase in domestic air traffic by the year 2000, reflecting an increase from 480 million passengers in 1995 to 800 million by the end of the century (FAA, 1996c:WWWeb) Free Flight will enable air traffic controllers to accommodate this future growth through a decision support system, at a lower cost to users. By providing the user with incentives to modernize their equipment, the FAA will move to a modern infrastructure, reducing the FAA operations and maintenance burdens while increasing safety (FAA, 1996c:WWWeb; Hinson, 1996b).

Free Flight Stakeholders. Free Flight is a joint initiative of the aviation industry and the FAA. In 1994, the FAA asked the Radio Technical Commission for Aeronautics, Inc. (RTCA), an independent organization that serves in an advisory capacity to the FAA, to form a select committee to study Free Flight. The committee that convened in October 1994 was composed of representatives from general aviation, pilot and controller unions, the airline industry, civilian contractors, and government policy makers. In January 1995, the committee presented a report to the FAA Administrator defining the Free Flight concept and the first steps for its implementation. In April 1995, at the request of the FAA Administrator, RTCA formed Task Force III on Free Flight to further define the procedures, system architecture, and transition recommendations. "The Final Report of RTCA Task Force 3: Free Flight Implementation," was given to the FAA in October 1995 (Hinson, 1996a).

Free Flight Progress. Elements of the Free Flight concept are part of the current expanded National Route Program, the Central Pacific Oceanic program, and future communication, navigation, surveillance, and air traffic management technologies. The National Route Program Expansion is designed ultimately to permit aircraft flying above 29,000 feet to select their routes as alternatives to published preferred IFR routes, thereby removing the restrictions and constraints currently imposed on these users. The National Route Program Expansion is successfully using a phased approach. As of June 1, 1995, the expanded National Route Program includes all flights above 35,000 feet. In the western U.S., the level was lowered to 33,000 feet (FAA, 1996c:WWWeb; Phillips, 1996a:27).

The FAA estimates that the National Route Program saved the aviation industry $40 million in 1994 by allowing pilots to fly more optimal routes (FAA, 1996c:WWWeb; Nordwall, 1995a:39). The Managed Arrival Reservoir is another philosophy embraced by the FAA and aviation community for removing restrictions and moving toward Free Flight. By removing departure and en route restrictions, this procedural change maximizes the use of arrival slots to take advantage of unused capacity, ensuring the most efficient use of the airport and airspace (Nordwall, 1995a:39).

Air carriers flying in the airspace over the Central Pacific, are using advanced satellite voice and data communication to provide faster, more reliable transmission to enable reductions in vertical, lateral and longitudinal separation, more direct flights and tracks, and faster altitude clearances (Nordwall, 1995b:29).

Europe. Eurocontrol has a parallel effort within its Program for Harmonized Air Traffic Management Research -- or PHARE. Free Flight and PHARE have more similarities than differences. Under the PHARE project, an aircrew would request a flight path, which is then approved by ground controllers who continue to maintain positive control throughout the flight, from airport to airport. Free Flight, in contrast, envisions an aircraft flying any trajectory with controller intervention only in cases of conflict. Eventually, the two approaches will be highly compatible, if not operationally equivalent.

Both the PHARE project and Free Flight depend on some of the same enabling technologies, and several of these are already in use throughout the world. They are the key elements in the global system of air traffic management that is rapidly evolving (Morrocco, 1996:29-30; Hinson, 1996b).

Tomorrow. In the long term, technologies are needed to improve conflict identification; resolution and data transmission; and display. Direct exchange among aircraft, airline operation centers, controllers, and pilots are critical to a successful evolution to Free Flight. Such technologies include: Global Positioning System (GPS), Wide Area Augmentation System (WAAS), Traffic Alert and Collision Avoidance System (TCAS), two-way data link (TWDL), Automatic Dependent Surveillance-Broadcast (ADS-B), Aeronautical Telecommunication Network (ATN), and a decision support system including Final Approach Sequencing Tools (FAST), Conflict Probe/Resolution and Surface Management Program (Nordwall, 1996:28-29; FAA, 1995:3-6).

Issues

Systems seem to change overnight when there are rapid advances in technology. What was once considered impossible is today a reality. Some elements that were once dreamed of were even bypassed by new technologies. The system of currently flying an aircraft from one location to another is outdated and in need of change. The basic elements of FANS and Free Flight were previously discussed and delineated the major participants that are pushing for change to the current system Attention will now focus on three major issues that lie ahead for FANS implementation in; technology, concepts and cost.

Technology. As technology explodes, there are often setbacks where technology does not solve all the problems it is designed to fix. There are numerous cases where the new technology causes more problems than was there initially.

Citing a multitude of contractural violations and program failures, the FAA is threatening to terminate its $475 million contract with Wilcox Electric Inc., for development of the Wide Area Augmentation System (WAAS) unless the company makes sweeping reforms (Phillips, 1996b:28). WAAS is designed to provide civilian pilots with an accurate, reliable en route navigation system using corrected signals from the Global Positioning System. GPS is one of the major elements needed in FANS and Free Flight implementation. One of the major misunderstandings is that GPS alone can perform all the desired steps in reliable navigation. Corrected signals play a large part in the overall design, especially for future precision approaches. The Air Force states, under deficiencies, for the C-17, "Current GPS equipment has no integrity monitoring capability or fault detection and exclusion equipment. Aircrews are unable to determine the accuracy of the GPS signal being received" (HQ AMC, 1995:C-17 Roadmap). This is one of the major problems of defense funding for future avionics packages. Changes in technology are happening so rapidly that contracts need to be written to ensure what is funded for the future is what is really needed for the future.

Another major technology that is critical to the FANS and Free Flight concept is Automatic Dependent Surveillance-Broadcast (ADS-B). The conclusion at a recent RTCA symposium is that ADS-B is clearly essential to the development of Free Flight (Nordwall, 1996:28). The air traffic control system will need the additional information provided by ADS-B to ensure safety as separation is decreased to accommodate increasing numbers of aircraft.

One of the central elements to ADS-B is Data Link. Still unresolved is the issue of what radios and frequencies to use. The Mode-S transponder from Traffic Alert and Collision Avoidance Systems (TCAS) is currently being pushed as the leading contender. More than six thousand commercial aircraft currently have TCAS installed. Stephen Brown, senior vice president, Aircraft Owners & Pilots Association said "a key point of leverage to obtain benefits is the design of an affordable Data Link for general aviation." "There is not now an affordable Data Link for much of general aviation or regional airlines" (Nordwall, 1996:29). While commercial competition can lead to emerging technologies, leaning forward in anticipation of the entire structure taking one avenue can prove disastrous when the development decides to go another direction. The drawback is the potential to miss an opportunity while it exists.

Decisions on what ends up being the system of choice often become motivated by what a particular firm or agency has already invested money or research. Special interest then becomes the driving factor to exert influence on the decision making body.

Radical Concepts. A major push behind the modernization of the airway system is to reduce inefficiencies that exist today. The transition from an air traffic controller to that of a system observer will require extensive training in the new roles and procedures expected of ATC personnel on the ground. It will also require a change in philosophy of the pilots who will be required to become active participants in the shared responsibilities of their flight. Defining the roles and responsibilities will be hard since many of the procedures have been fixed over a long period of time. Alternatives that were once deemed impossible may be appropriate tomorrow. Procedures and human factors will be the real hurdle to Free Flight (Phillips, 1996a:27). Realizing that the human factors issue requires further study, the FAA has implemented a working group to determines future needs and requirements in this area (FAA, 1996d:19)

"As the role of the air traffic controller moves from that of controller and director to that of safety monitor and airspace manager, the relationship of the controller to the pilots in the cockpit needs careful human factor analysis" (FAA, 1996d:19). For example, a prime cause of accidents on training flights, is the gray area where the trainee has direct control of the aircraft and the instructor fails to intervene until it is too late. The future authority relationship between aircrews and controllers as air traffic managers has the same potential for gray area accidents and needs to be addressed (FAA, 1996d:19). Knowledge of the workings of the system will not be achieved overnight. It will take a serious training regime with a proactive standardization and evaluation system to ensure the safety in its use.

Cost. On August 9, 1994, a Congressional hearing was held by The Honorable Collin Peterson on the RMB Associates study *Free Flight - Reinventing ATC: The Economic Impact* (June 1994). Testimony showed examples of waste in the current ATC system. Flights from Nashville to Boston are forced to fly 18% longer, simply to meet the needs of an antiquated, manually run system. The excess operating cost to American Airlines for this one route is $1 million annually. United Airlines estimates excess costs of $670 million annually due to the ATC system and additional $1.3 billion in lost productivity. (Baiada, 1995:1)

The Clinton Administration is requesting $37.5 billion to fund the U. S. Transportation Department in Fiscal 1997. This includes $8.25 billion to operate the FAA and implement upgrades to the nation's navigation and air traffic control systems. The FAA would spend $41 million for transoceanic air traffic services and $72 million to develop a fully digital infrastructure upgrade at terminal approach control radar facilities. It would also spend $117 million for Voice Switching and Control System improving controller pilot communications. Finally $74 million would be spent on the Wide Area Augmentation System (Phillips, 1996c:28). Funding is not entirely certain for 1998. Currently for 1998 there is no funding for Data Link in the FAA budget and as J. Roger Fleming says "If there is no Data Link there is no Free Flight" (Fleming, 1996; Nordwall, 1996:28).

There is an important area that needs to be included if the hurdles are overcome and the changes do take place. That area is the potential cost savings that would be generated by these changes. A NASA study estimates that airlines in the United States could save as much as 1.47 billion dollars a year by 2005 if Free Flight is fully implemented (Coluris and Dorsky, 1995) Not only will fuel savings be affected by the more direct routing, reduced personnel will be needed to fly some oceanic flights. The savings of fifty minutes of flying time on the San Francisco to Seoul, Korea route could eliminate a fourth pilot saving the airlines an estimated $2.5 million a year (Nordwall, 1995b:28).

Summary

One of the main justifications for FANS and Free Flight is the prospect that growth in air travel is expected to double in the number of passengers and aircraft by the year 2015 (Hinson, 1996b). The issues which comprise hurdles to the implementation of FANS (technology, concepts, and costs) were discussed, and although there are unique problems associated with each of the issues, the most important fact to understand is the reality that change will take place. Some form of the future vision will become reality. The chief causal factor will be economics. The airlines are in the business for one reason, to make a profit. Inefficiencies are replaced by cost effective implementation of operations. There does not seem to be a competing system for FANS, and unless one is developed, the airlines must work together to implement FANS under a universal system of standards.

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