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Course Material

**M.A. (AVIATION LAW AND
AIR TRANSPORT MANAGEMENT)**

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1.2.8. AIR SPACE & AIR TRAFFIC MANAGEMENT

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MODULE I:

INTRODUCTION TO AIR SPACE AND AIR TRAFFIC MANAGEMENT

CONCEPTUAL FRAMEWORK

INTRODUCTION

In order to ensure that the limited usable airspace is effectively and efficiently utilized by civil aircraft for their safe, orderly and economic operations, it is essential that an efficient airspace management is available on a global basis. Airspace, therefore, have been defined in terms of lateral and vertical limits, and the different types services that are required to be provided are also identified. Rules and regulations governing the operation of flights within, across and into such airspace are framed and published. Air Traffic Services Routes (ATS) or airways along which aircraft are to operate while proceeding from one point to another in the airspace is earmarked and established, and the radio-navigational aids essential to provide the necessary navigational guidance to aircraft so as to enable the aircraft to stay within the specified limits of established air corridors are installed and operated with minimum guaranteed accuracy.

AIR TRAFFIC SERVICES

Air Traffic Services (ATS) are for the purpose of preventing collisions (i) between aircraft, and (ii) on the maneuvering area, between aircraft and obstructions, and expediting and maintaining an orderly flow of traffic; provide advice and information useful for the safe and efficient conduct of flights; notify appropriate organizations regarding aircraft in need of search and rescue aid and assist such organizations as required.

For the purpose of ATS, the air space is further divided as Flight Information Regions (FIR), Airways, Air Traffic Scheduled (ATS) Routes, Controlled Airspace, and Advisory airspace, Control Zone, Approach Control, Aerodrome Control and Surface Movement Control. Necessary unit(s) are set up to provide air traffic control services, flight information service and search and rescue services, manned by appropriately qualified and adequately trained personnel. In general, ATS units include, Surface Movement Control/Surface Detection Radars, Control Tower, Approach Control, Area Control, Terminal Marshaling Area(TMA) / Terminal Control Area (TMA) and Flight Information Centre (FIC).

Flight Information Centre (FIC) is the coordinating unit for the respective FIR and the Area Control Centers (ACC) for the Area Control services. There is a close coordination between military authorities and air traffic services authorities, coordination between Aeronautical Information Services (AIS) and ATS, and between meteorological and ATS. Relevant ICAO Standards and Recommended Practices (SARPs) and formulation of own State Standards (when required) are implemented for airspace management. It is duly supported by provision of various radio-radar /satellite navigational aids and communication / surveillance facilities, and air traffic management units.

ICAO has allocated the respective air space by way of Flight Information Regions (FIR) to various States which have the expertise and the wherewithal to manage such air space, For the purpose of safe air traffic control/ navigation services. Since operation of international flights involves flights through the national airspace of several States and high seas, it is essential that the rules and regulations governing these flights should enjoy global application. ATS are thus governed by the ICAO -SARPs for uniform application, recognized as a necessary step for safe conduct of flights. ICAO /Annex 2-International Standards, Rules of the Air, Annex 11-International Standards and Recommended Practices, Air Traffic Services and DOC 4444-Procedures for Air Navigation Services, Rules of the Air and Air Traffic Services are key References.

CONTROLLED AIRSPACE

Controlled air space is an air space within which air traffic control services and alert services are available and they include, Control Zones, Control Areas, and Airways etc. Control Zone is an air space of defined dimensions around an aerodrome extending vertically from ground to a specific height, and Control Area is an air space of defined lateral dimensions with vertical limits commencing at specified height above sea level and extending upwards to predetermined altitudes established at or around aerodromes for the provision of air traffic control services. Generally, Control Zones are of a radius of 25 NM (nautical mile) around aerodromes with vertical limit of 5000 ft. These limitations may be varied to meet the specific local conditions.

ATS routes /Airways meant for international traffic is referred to as International ATS routes and one meant for domestic traffic is referred to as Domestic ATS routes. Establishment of International ATS routes/ Airways and their designations are coordinated by the respective ICAO regional offices. Establishment of an International ATS route involves the cooperation and co ordination between a numbers of States and is a time consuming process. While, it is ideal to have straight and short routes, the national air space requirements of the concerned State may impose restrictions on the alignment of direct/straight routes due to national security and defense air space requirements etc. Since 1980, there have been concerted efforts to reduce route millage through effective civil/military coordination and progressively more and more airspace are being transferred to civil authorities.

SEPARATION STANDARDS

There is a clearly laid down minimum vertical and/or lateral separation which should exist between two aircraft. The Flight levels are therefore according to Quadrantal or Semi - Circular Pattern. In the Quadrantal system, 360 degrees (Magnetic tracks) are divided into four sectors (000-089, 090- 179,180-269 and 270 to 359 degrees), whereas, in the semi-circular system, there are two sectors namely, 000-179 and 180 -359 Degrees. Quadrantal system is applicable up to Flight Level 29,000 (FL 290) and semi -circular pattern above FL 290.

The minimum vertical separation between two aircraft flying in opposite directions but on the same route has been established to be 1,000 feet up to FL 290 and 2,000 feet for flights above FL290. There are clearly laid down norms for separation (ICAO /DOC 4444) under different circumstances. These operation standards take into account different types of navigation aids, reliability of airborne systems and sophistication of the surveillance capabilities.

In order to ensure that the separation standards as prescribed by the ICAO, or as stipulated by the State concerned are strictly adhered to, it is essential that the units established to provide air traffic services are in receipt of all information pertaining to intended flights and have means of establishing two-way communication with all flights within their area of responsibility. In case of reduced vertical minim a, capability to maintain continuous surveillance of all aircraft within such area needs to be ensured. The notification of intended operation of a flight is made by the filing of what is known as a 'Flight Plan'. The format and contents of a flight plan have been specified by the ICAO (DOC 4444). Information regarding the intended operation of a flight should thus be available with the concerned ATS unit well in advance of the expected time of departure (ETD). Maintenance of a two-way contact is essential and all aircraft on flights are under the positive control of ATS or necessary regulatory mechanism. There are 'reporting points' on the ATS routes and prompt reporting systems exist through appropriate en-route communication channels and such reporting by the aircraft is mandatory.

COMMUNICATION, NAVIGATION, SURVEILLANCE AND AIR TRAFFIC MANAGEMENT (CNS/ATM)

The world's air traffic system is undergoing the most radical change in its history. It will see a switch from conventional ground-based radio navigation aids to satellite-based systems that, will allow positive surveillance and high quality communications. It will cover the world's oceans and other remote or inaccessible areas where it is either impracticable or impossible to site and maintain radar or radio stations.

In 1980's ICAO recognized the increasing limitations of the existing air navigation system, as well as the need for improvements to take the civil aviation into the twenty-first century. In 1983, ICAO established a special committee- Future Air Navigation System (FANS) Committee to identify and assess new concepts and technology for the evolutionary development of a world air navigation system- CNS/ATM. In October, 1993, the 'Global Plan' was completed and has become the corner-stone for planning the global air navigation system. CNS/ATM plan envisages a time bound replacement of the present ground based communication, navigation and surveillance system with more effective satellite based system by 2010. This also brings in a change in the existing voice communication towards data communication which will permit aircraft flight management computers to directly communicate with ground based air traffic management computers for coordination and position reporting. A new Aeronautical Telecommunication Network (ATN) when introduced will allow full interoperability between different air and ground sub systems. The satellite based navigation will give a global accuracy in order of at least 100 m of actual position. This will allow it to be used en-route, terminal and for non precession approach phases of flight. With suitable ground augmentation, it will achieve accuracy which will permit precision approaches to be conducted at any airfield, heliport or landing strip. Timely implementation of the CNS/ATM is vital for the flight safety.

The increased navigation accuracy means that aircraft know much more precisely where they are at any given time, and that data can be used by ground control in much the same way as radar data is currently used, for surveillance purposes. In order to transmit that data to the ground, a new communications vehicle was needed that would allow the airborne and the ground-based computers to communicate directly, that would not impinge on the already congested VHF voice frequencies, and that would allow VHF quality communications in areas outside VHF coverage.

The solution was data link, an electronic message system whereby data and message can be transferred directly from the aircraft to the control centre without resource to voice. Communications arrive on the pilot's and/or controller's screen in the form of a text message, with additional capability to print a hard copy, leaving voice channels free for non-routine and emergency communications. Like Voice Communications, data can be transmitted via VHF.HF and satellite, that controllers and pilots are able to communicate anywhere in the world- Controller Pilot Data Link Communications or CPDLC.

Data link supports a host of other applications, including Airline Operational Communications (AOC), up linking clearances and weather data, and it also facilitates positive surveillance using Automatic Dependent Surveillance (ADS). This is a system where the aircraft automatically transmits its position reports to the ground, which are then processed and displayed on the controller's information display. Here again, the satellite element means that the data can be generated and transmitted even if the aircraft is in the middle of the Pacific Ocean. Satellite Navigation, CPDLC, and ADS are the technical cornerstones of CNS/ATM., how to use them and apply them is much of the work effort is being directed today.

Conceptually, aircraft no longer have to follow the well-worn airways anchored on conventional ground-based nav aids, and in theory can fly anywhere in the airspace without losing accurate navigation, communication or indeed positive surveillance from the ground. Aircraft should be able to fly their most preferred route between two points, which will generate substantial cost saving for airlines, and open up substantial amount of airspace capacity while reliving congestion on the conventional airways. This is the 'Free Flight' concept.

Air traffic controllers will become air traffic managers. Rather than having their route defined by a fixed route structure, the aircraft operators will be able to select individual flights, taking into account prevailing wind and weather conditions along the way. Air Traffic Managers will continue to be responsible for ensuring separation between aircraft. The controller will be equipped to predict conflicts well in advance of them occurring and will therefore be able to resolve conflicts before they happen, coming up with a solution that will generate the least penalty to aircraft causing the conflict. Automatic conflict detection and resolution are crucial to the changing role of controllers-the extent which they can be relied is the real ATM challenge.

New Global Positioning System (GPS) satellite technology forms the basis of a new global air navigation system. Transit 1B the world's first navigation satellite was launched in 1960, the launch took place in less than three years after the flight of first satellite, the soviet Union's sputnik I in October 1957. The 121 Kg spacecraft, launched from Cape Canaveral, Florida, was placed into a 373 km by 478 km orbit inclined to equator at 51 degrees. Transit was the forerunner of today's GPS satellite which is vital to air navigation and is direct descendants of the venerable 121 kg spherical transit spacecraft. GPS form part of the Global Navigation Satellite System (GNSS) which are becoming operational in phases from 2008 and 2015.

Today, at least a fleet of 24 US-built and operated Navstar block II A and IIR GPS satellites, weighing 2,220 kg are always in orbit in constellations consisting of six orbital planes, with a minimum of four satellites in each plane, in approximately 20,000 km circular orbits, inclined to the equator at 54 degrees, making one orbit of the earth every 12 hours. The satellites are, therefore, spaced in orbit so that at any one time, a minimum of six satellites will be in view to users anywhere in the world. Emitting continuous navigation signals in two L band frequencies, these satellites are available to all types of military and civilian users worldwide who, with proper equipment can receive the signals to calculate time, location and velocity to an accuracy of one millionth of a second, a fraction of a km per hr, and to a location to within 30m.

GPS system is augmented by Russia's Global Navigation Satellite System (GLONASS) fleet, ideally, the GLONASS constellations is again composed of 24 satellites , eight in each of the three orbital planes operating in circular 19,100 kn orbit inclined at 64 degrees to the equator, making one orbit every 11hrs 15 min. GPS and GLONASS satellites for aeronautical civil use are extended by CNS/ATM in which aviation authorities plan to bring together radar, ground controllers, pilots, aircraft and satellites in one advanced system. One concern with the use of GPS and GLONASS is the sharing of the systems with the military. A new system, therefore, is planned, called GNSS 2, dedicated solely to civilian use. GNSS is being implemented in phases between 2008 and 2015. Europe has an overlay augmentation system called EGNOS using other communication satellites to augment the use of GPS and GLONASS satellites.

The GPS navigation has also certain challenges like, the air navigation routes are defined by reference to national maps and to achieve maximum benefits from GPS satellites, all these maps must be upgraded and combined, an effort which is ongoing. Not all air traffic control centers are equipped to use satellite data and they continue to relay on radar and radio stations.

OTHER IMPORTANT CONCEPTS

Advisory Area: A designated area within a flight Information Region (FIR) where air traffic advisory services are available.

Advisory Route: A route within a FIR along which air traffic advisory services is available.

Air Route: The navigable airspace between two points, identified to the extent necessary for the application of flight rules.

Air Traffic Control Centre: An organization established to provide:

- Air traffic control within a control area
- Flight Information Services
- Alerting Services for search and rescue

Airway: A Control Area or portion thereof established in the form of a corridor equipped with radio navigation aids.

Area Control Centre: A unit established to provide air traffic control services to IFR Flights

ATS Route: A specified route designed for channeling the flow of traffic as necessary for the provision of air traffic services.

Ceiling: The height above the ground or water of the base of the lowest cloud below 20,000 feet (6000 mtrs) covering more than half the sky.

Reporting Point:- A specified geographical location in relation to which the position of an aircraft can be reported.

Runway Visual Range(RVR): The maximum distance in direction of take-off or landing at which the runway or the specified lights or markers delineating can be seen from a position above a specified point on its centre-line at a height corresponding to the average eye-level of pilots at touchdown.

Visibility: The ability, as determined by atmospheric conditions and expressed in units of distance, to see and identify prominent unlighted objects by day, and prominent lighted objects by night.

VMC: Visual Meteorological Conditions expressed in terms of **visibility, distance from cloud and ceiling, equal or better than the certified minima.**

INTERNATIONAL EMERGENCY PROCEDURE

States of Emergency are classified as being of two standards:

Distress- The aircraft is threatened by serious and imminent danger and is need of immediate assistance. Transmission: MAYDAY (3times) on air-ground frequency or SOS (3 times) on telegraphy.

Urgency: The calling station has a very urgent message to transmit concerning the safety of an aircraft or of some person on board or within sight. Transmission: PAN (3 times) on air-ground frequency or XXX (3times) on telegraphy.

AVIATION METEOROLOGICAL SERVICES

Meteorological services are provided to the Pilots by issuing Route Forecast (RFOR), Flight Forecast (FFOR), Terminal Area Forecast (TAFOR) and significant meteorological reports (SIGMET) if any. The Meteorological office is generally co-located with ATS block. Forecasts and weather briefings are provided while filing the 'flight plan'. Airport Met offices also issue hourly weather observations.

Satellite weather observations from the World Met Office (WMO) are procured by Meteorological Department Office and in turn, they pass it on to Main Meteorological Offices (MMO). Supplementary Met Offices (SMO) and Dependent Met Offices (DMO) located at various stations, and these stations gather the weather elements and prepare the relevant flight forecasts for specific flights on request. General briefing to Pilots/Flight crew are based on the weather charts prepared by the met offices.

Significant weather such as thunderstorm**,** gale, cyclonic storm and such severe weather conditions are reported as 'SIGMET'. Airport Met offices issue routine hourly met reports (METAR) and Special weather reports (SPECI) are issued when weather conditions deteriorate, such as fog, poor visibility etc.

Based on the minimum visibility and cloud criteria, flight conditions are reported as Visual Flight Rules (VFR) and Instrument Flight Rules (IFR).

America's Television and Infra-Red Observation Satellite (Tiros) was the first weather satellite launched in 1960. It provided television pictures of cloud cover along with information on the flow of heat passing from the earth and out into space. It was succeeded by the National Oceanic and Atmospheric Administration (NOAA) series. From the mid-1970s onwards, as the first US Geostationary operational Environmental Satellite System (GOES) was launched, orbiting in the plane of the equator at 36,000 km altitude, geostationary satellites appear to be motionless in the sky. GOES. European Metosats and Japanese GMS – maintain a continuous watch around the globe, capable of imaging major weather features as frequently as once every 30 minutes. Up to date graphical weather displays are available in the cockpits, with the "Aviation Weather Information (AWIN) installed since 2003. Weather is a factor in about 30% of aviation accidents and is also responsible for about two-thirds of air-carrier delays, costing almost US$ 4 bn out of which nearly 1.7 bn worth of delays are considered avoidable. A major milestone in the AWIN programme saw a NASA -Industry team develop and evaluate a cockpit weather information system (CWIN), which combined and presented weather information from multiple data link sources. A fleet of carefully controlled and organized meteorological satellites, launched by almost every nation with a space programme, are circling the earth in low polar and geostationary orbits. These provide minute-by- minute snapshots of weather systems and the environment in visible light, as the eye sees, and in other wavelengths such as infra red, which reveal much more details than the eye can see, such as temperatures inside cloud and water content in the atmosphere. The international World Weather Watch involves geostationary orbiting satellites from the US, Europe, India and Japan, supported by China and Russia, which cover the Atlantic, Indian and Pacific Oceans. At the same time,, polar orbiting National Oceanic and Atmospheric Administration satellites provide more regular views of the environment from lower altitudes, the whole globe covering in a day, making 17 orbits as the earth rotates once in 24 hrs.

The weather satellites are complimented by fleets of environmental spacecraft, such as European Remote Sensing Satellites and NASA Earth Observing System Satellites. Space technology has helped to improve air safety and will become even more important part of the AWIN system.

Terminology, Specifications to Denote Sky Conditions

Fine: Clear Sky with sunshine during day and moon/star light during night

Fair: 1to 2 oktas of cloud. (Total sky is 8 oktas)

Partially cloudy: 3to 4 oktas of clouds

Cloudy: 5 to 6 oktas of clouds

MOC (Mainly Over Cast): 7 oktas of clouds

Overcast: Sky totally covered with clouds-8oktas.

Obscured: Sky not discernible due to fog, dust etc.

Atmospheric Obscurity

Fog- Visibility less than 1,000 m and Relative Humidity (RH) 75% or more,

Dense Fog: Visibility 0- 50 m; Thick: 51-200m; Moderate: 201-500m; Light: 501-1,000m

Mist: Visibility 1,000 m to less than 2,000m, RH 75% or more;

Haze: Visibility: between 2,000m and 5,000m, RH 75% or more;

Dust Haze: Visibility 5,000 m or less and RH 75%or less

Smoke/Smog: Small particles of combustion products in suspension reducing visibility to 5,000m or less

LEGAL FRAMEWORK FOR AIR SPACE AND AIR TRAFFIC MANAGEMENT: AN OVERVIEW

Introduction

ICAO Assembly Resolution A37-15, which was cited in the previous chapter, in Appendix W2 recognizes that in accordance with Annex 11 to the Chicago Convention, ICAO member States are required to arrange for air traffic services to be provided in airspaces and at aerodromes for which it has been determined that such services would be required. The Resolution also notes that Annex 11 requires member States to ensure that safety management programmes are established and that cooperative efforts between such States could lead to more efficient air traffic management. Accordingly the Resolution resolves that in implementing air traffic services, States ensure that the services being provided meet established requirements for safety, regularity and efficiency of international civil aviation and, taking into account the need for cost effective introduction and operation of CNS/ATM systems, States give consideration to cooperative efforts for introducing more efficient airspace management, in particular, in the upper airspace. The Resolution in Appendix W also calls upon States to ensure that safety management programmes are introduced by the relevant air traffic services provider in all airspaces and at all aerodromes where air traffic services are provided.

THE CNS/ATM SYSTEM

The number of aircraft movements around the world is increasing consistently, in line with the sustained growth in passenger and cargo traffic, as well as business and general aviation. This is particularly true in densely-populated areas where conges-tion has become a major safety, operational and environmental concern.

The issue was addressed head on at the very successful Eleventh Air Navigation Conference (AN-Conf/11) held at ICAO in 2003. The Conference endorsed the Global Air Traffic Management Operational Concept, the first truly common vision formulated jointly by all stakeholders of the world aviation community for an integrated and globally harmonized air traffic management (ATM) system, with a planning horizon up to and beyond the year 2025. In essence, it was thought of as an interoperable global ATM system that would apply to all users during all phases of flight and meet agreed levels of safety. . .provide for optimum economic opera-tions. . .be environmentally sustainable and meet national security requirements. The Operational Concept outlines a total system performance framework to achieve defined requirements.

Since then, a number of initiatives and decisions have reaffirmed the role of ICAO as the key driving force in the implementation of harmonized air traffic management systems and performance-based efficiency improvements. For its part, the aviation community must respond accordingly when designing, planning, implementing and operating the global air navigation system in order to respond to expectations linked to safety, efficiency, access and equity, capacity, global interoperability, cost-effectiveness, security and protection of the environment.

One of the major innovations was the approval by the ICAO Council in November 2006 of the revised Global Air Navigation Plan. Originally titled Global Air Navigation Plan for CNS/ATM Systems, the revised Plan is based on recommendations of AN/Conf/11 and two related industry roadmaps created subsequent to the Conference. In essence, it is part of an integrated set of tools and guidance material, which includes the Global ATM Operational Concept, ATM Systems Requirements and Performance-Based Transition Guidelines that will guide the implementation of CNS/ATM systems and usher in the global ATM system envisioned in the operational concept.

In the migration from a technology-driven to a performance-based air navigation system, the emphasis on results is directly related the growing reality of privatized air navigation services and the ensuing pressure for greater accountability.

ICAO has integrated this work into its new Business Plan, which stresses the implementation of harmonized air traffic management systems and performance-based efficiency improvements, as well as increased functional integration between ICAO Headquarters and Regional Offices. Through innovative methods, the Global Plan will facilitate planning and implementation of important operational develop-ments that have taken place in recent years, particularly with regards to aircraft capabilities. It will also ensure that opportunities that have emerged as technologies have matured, as research and trials have been successfully concluded, and as procedures and specifications have been finalized, are fully exploited.

Associated guidance and interactive planning tools for States, regional planning groups and air navigation services providers will be used to establish performance objectives and implementation time lines. The Global Plan will thus become the baseline for measurable achievements as the global ATM system continues to evolve from systems-based to performance-based. States and regions will be able to select initiatives tailored to their particular needs in order to meet agreed-upon performance objectives.

ICAO is assisting States to enhance their knowledge and comprehension of technical, organizational, economic and safety issues related to the implementation of a performance-based air navigation system. There is recognition of the essential role of the Organization in advancing work in the operational, technical, safety and economic areas, as well as securing global interoperability between major air navigation initiatives.

Another dimension of the role of ICAO will be to develop and promote mini-mum performance reporting requirements for ANS providers, develop a methodology for measuring performance expectations, and develop guidance material on facilitating collaborative decision-making. This will also entail accelerating work on performance-based navigation (PBN). PBN provides for more direct and precise flight paths, increased safety, reduced fuel burn, more efficient traffic flows and reduced ATC communications.

This includes the implementation of area navigation (RNAV) and required navigation performance (RNP) in accordance with the PBN concept, integration of the ICAO Global Air Navigation Plan in performance-based transition planning, collaboration on establishing performance indicators, use of ICAO-defined key performance areas for performance management, and application of the ICAO Global Aviation Safety Plan (GASP) as a basis for meeting safety performance objectives.

Ultimately, the successful implementation of a global air navigation system depends on cooperation among all members of the civil aviation community and involves greater integration of ICAO regional offices and headquarters. ICAO is committed to meeting the operational expectations of all stakeholders. The task ahead is nothing short of ensuring the viability of the future air navigation system and its continued contribution to global economic development in a safe, secure and efficient manner.

The word "autonomous" is used throughout this chapter to identify air navigation services which, although commercialized, have not moved out of the jurisdiction of government. An autonomous air navigation provider is a self-financing body which has greater freedom from governmental control, particularly in the conduct of its financial affairs, infrastructure funding and income streams. It is also subject to business taxes and is usually geared to achieve a return on its investment. However, an autonomous air navigation service provider should remain in the regulatory control of government, based on the fundamental premise that a facility originally provided by the government of a State, such as air traffic management, does not completely detach itself from the purview of responsibility that the government continues to hold over it, even if it were to be privatized. As such, a government cannot completely abdicate its responsibility for the provision of air navigation services, particularly since international treaty requires that governments retain such responsibility.

AIR TRAFFIC SERVICES

The Chicago Convention which came into effect on 7 April 1947, contains certain provisions demarcating the responsibility of Contracting States of ICAO. Article 28 of the Convention obligates contracting States to provide in their territories airports, radio services, meteorological services and other air navigation facilities to facilitate international air navigation, in accordance with the standards and practices established from time to time pursuant to the Convention.3 This fundamental concept of State responsibility has to be viewed from the perspective of modern exigencies of the supply and demand curve of air traffic services where such services are currently being provided both regionally and on a flight information region (FIR) basis. The need for a shift of focus of the modern air navigational system is determined by two factors: the growing air traffic demand and the need for enhanced and more efficient air traffic services; and the transition into a seamless air traffic management system calculated to obviate inconsistencies caused by boundaries. The goals of a global seamless air traffic management system are: to provide greater flexibility and efficiency by accommodating user-preferred flight profiles; to improve existing levels of safety; to accommodate the full range of aircraft types and airborne capabilities; to improve the provision of information to users, including weather conditions, the traffic situation and the availability of facilities; to organize air space in accordance with air traffic management (ATM) provisions and procedures; to increase user involvement in ATM decision making, including air-ground computer dialogue for flight plan negotiation; to create, to the extent possible, a single continuum of airspace where boundaries are transparent to users; and to increase capacity to meet future traffic demand.

THE PROVISION OF AIR NAVIGATION SERVICES

Article 12 of the Chicago Convention unambiguously states that over the high seas, the rules in force shall be those under the Convention and each Contracting State undertakes to insure the prosecution of all persons violating the regulations appli-cable. This peremptory principle,6 of adherence by States and aircraft bearing their nationality to any Standards and Recommended Practices (SARPs) adopted in regard to the high seas, effectively precludes any possible reliance by States on Article 38 of the Convention which allows States to deviate from SARPs in general. In other words, Annex 2 on Rules of the Air, which contains provisions relating to the operation of aircraft over the high seas, is sacrosanct and inviolable. The first legal issue that would emerge from this clear principle is the question of applicability of Annexes (other than Annex 2) to the high seas and whether their provisions, if directly related to the principles of manoeuvre and navigation of aircraft over the high seas, would be binding with no flexibility offered by Article 38 of the Convention. Kaiser offers the opinion:

Over the high seas, the rules of the air have binding effect under Article 12, of the Chicago Convention. It should be clarified that rules of the air have a broader meaning than Annex 2 and encompass the Standards and Recommended Practices of all other Annexes as far as their application makes sense over the high seas.7

Kaiser is of course referring mainly to Annexes 10 and 11 to the Chicago Convention relating to air traffic services and air traffic management, while at the same time drawing the example of Annex 16 (on environmental) protection being applicable in a future date if extended beyond noise and engine emissions to the high seas under Article 12 of the Chicago Convention.8 This argument, which would ascribe to the ICAO Council wider control over larger spans of the world’s air space, would be acceptable only if provisions of other Annexes (other than those of Annex 2) would directly have a bearing on the manoeuvre and navigation of aircraft over the high seas, as exclusively provided for by Article 12 of the Chicago Convention.

The ICAO Council, in adopting Annex 2 in April 1948 and subsequently in November 1951 when Amendment 1 to the Annex was adopted, resolved that the Annex constitutes rules relating to the flight and manoeuvre of aircraft within the meaning of Article 12 of the Convention. Therefore, the Council explicitly recognized that the rules in the Annex applied to the manoeuvre and operation of aircraft without exception. Annex 2, in its Foreword, states that the Standards in the Annex, together with the Standards and Recommended Practices of Annex 11, govern the application of the Procedures for Air Navigation Services Rules of the Air and Air Traffic

Services, and the Regional Supplementary Procedures. The Regional Supplementary Procedures are subsidiary procedures of regional applicability. It is clear that by this introduction, there is established a distinct disparity between Annex 2 and Annex 11 where the provisions of the former remain unquestionably mandatory, and the provisions of the latter remain subject to Article 38 of the Chicago Convention and capable of being deviated from. However, it is clear that the purpose of Annex 11 is to ensure that flying on international routes is carried out under uniform conditions designed to improve the safety and efficiency of air operation and, therefore, provisions relating to air traffic control services, flight information services, and alerting services of Annex 11 when linked to the provisions of Annex 2, have a coercive effect that may in certain circumstances, transcend the parameters set in Article 38 of the Convention.

The second issue in determining the legal status of rules of the air over the high seas in relation to sovereignty is the element of control exercised by a State over aircraft operations over the high seas. Article 2.1.2 of Annex 2 provides that a Contracting State may deem to have accepted (unless ICAO is otherwise advised) that it provides air traffic services through an appropriate ATS Authority as designated to be responsible for providing air traffic services over parts of the high seas. An appropriate ATS Authority is defined in the foreword of the Annex as the relevant authority designated by the State responsible for providing air traffic services in the air space concerned. A contracting party accepts an appropriate ATS authority pursuant to a regional air navigation agreement, which is an agreement approved by the Council of ICAO usually based on the outcome of the findings of Regional Air Navigation Meetings.

It is somewhat disconcerting that neither the legal status of the regional air navigation plan or agreement, nor its definition is clear. In November 1996, at the 38th meeting of the European Air Navigation Planning Group, it was recorded that an Air Navigation Plan consisted of an authoritative internationally agreed reference document, which corresponded to a contract between States covered by the Plan regarding air navigation facilities to be provided, to be approved by the ICAO Council in accordance with the provisions of the Chicago Convention.9 It was deemed that the Council, in any given instance, would be acting on behalf of all Contracting States, including those not covered by the Plan. There is a marked dichotomy in the terminology used, which refers to the Plan on the one hand as a contract between parties and on the other hand as a reference document. Buergenthal offers a more coherent view, by saying that ICAO Annexes, Plans, SUPPS10 and Regional Air Navigation Plans constitute an integral body of aviation legislation comparable both in structure and content to comprehensive domestic air navigation codes. Yet another view is that the Regional Air Navigation Plan, not involving the process of ratification, signature or adoption, is a technical and operational document. Confusion is further confounded by the fact that there is no direct consequence for any State which does not perform its obligations under a Regional Air Navigation Plan.

The provision of air navigation services are mainly regulated by three Annexes to the Chicago Convention, namely Annex 2 (Rules of the Air), Annex 3 (Meteo-rological Service for International Air Navigation) and Annex 11 (Air Traffic Services).13 Of these, compliance with

Annex 2 is mandatory14 and does not give the States the flexibility provided in Article 38 of the Chicago Convention to register differences from any provisions of the Annex.

With regard to navigation over the high seas, the United Nations Convention on the Law of the Sea UNCLOS, Article 39, lays down the duties of ships and aircraft involved in transit navigation to the effect that ships and aircraft, while exercising the right of transit passage, should: proceed without delay through or over the strait; refrain from any threat or use of force against the sovereignty, territorial integrity or political independence of States bordering the strait, or in any other manner in violation of the principles of international law embodied in the Charter of the United Nations; refrain from any activities other than those incident to their normal modes of continuous and expeditious transit unless rendered necessary by force majeure or by distress; and comply with the relevant provisions of the Convention. Article 39(3) explicitly states that aircraft in transit passage shall observe the Rules of the Air established by ICAO as they apply to civil aircraft and that state aircraft will normally comply with such safety measures and will at all times operate with due regard for the safety of navigation. The provision further states that at all times aircraft shall monitor the radio frequency assigned by the competent internationally designated air traffic control authority or the appropriate international distress radio frequency.

Standard 2.1.1 of Annex 2 to the Chicago Convention provides that the rules of the air shall apply to aircraft bearing the nationality and registration marks of a Contracting State, wherever they may be, to the extent that they do not conflict with the rules published by the State having jurisdiction over the territory over-flown.15 The operation of an aircraft either in flight or on the movement area of an aerodrome is required to be in compliance with the general rules and, in addition, when in flight, either with: visual flight rules (VFR); or the instrument flight rules (IFR).16 Standard 2.3.1 further provides that the pilot-in-command of an aircraft shall, whether manipulating the controls or not, be responsible for the operation of the aircraft in accordance with the rules of the air, except that the pilot-in-command may depart from these rules in circumstances that render such departure absolutely necessary in the interests of safety.

METEOROLOGICAL INFORMATION

Annex 3 to the Chicago Convention provides in Standard 2.1.1. that the objective of meteorological service for international air navigation shall be to contribute towards the safety, regularity and efficiency of international air navigation. This objective has to be achieved by supplying the following users: operators, flight crew members, air traffic services units, search and rescue services units, airport managements and others concerned with the conduct or development of international air navigation, with the meteorological information necessary for the performance of their respective functions.

The Annex, in Standard 2.1.3 calls for each Contracting State to determine the meteorological service which it will provide to meet the needs of international air navigation. This determination should be made in accordance with the provisions of this Annex and with due regard to regional air navigation agreements; it should include the determination of the meteorological service to be provided for international air navigation over international waters and other areas which lie outside the territory of the State concerned. Furthermore, each contracting State is required to designate the authority, hereinafter referred to as the meteorological authority, to provide or to arrange for the provision of meteorological service for international air navigation on its behalf. Details of the meteorological authority so designated shall be included in the State aeronautical information publication.

State responsibility for the provision of meteorological information is provided for in Standard 2.1.4. where each Contracting State is required to ensure that the designated meteorological authority complies with the requirements of the World Meteorological Organization in respect of qualifications and training of meteorological personnel providing service for international air navigation.

It is also provided in the Annex that close liaison shall be maintained between those concerned with the supply and those concerned with the use of meteorological information on matters which affect the provision of meteorological service for international air navigation.19 Furthermore, States have responsibility establish one or more aerodrome and/or other meteorological offices which shall be adequate for the provision of the meteorological service required to satisfy the needs of international air navigation.

The Annex provides that an aerodrome meteorological office shall carry out all or some of the functions as necessary to meet the needs of flight operations at the aerodrome in the preparation of: forecasts and other relevant information for flights with which it is concerned; the extent of its responsibilities to prepare forecasts shall be related to the local availability and use of en-route and aerodrome forecast material received from other offices; preparation of e and obtaining forecasts of local meteorological conditions; maintaining a continuous survey of meteorological conditions over the aerodromes for which it is designated to prepare forecasts; providing briefing, consultation and flight documentation to flight crew members and/or other flight operations personnel; supplying other meteorological information to aeronautical users; displaying the available meteorological information; exchanging meteorological information with other meteorological offices; and supplying information received on pre-eruption volcanic activity, a volcanic eruption or volcanic ash cloud, to its associated air traffic services unit, aeronautical information service unit and meteorological watch office as agreed between the meteorological, aeronautical information service and ATS authorities concerned.

Chapter 5 of the Annex includes further responsibilities of States. Standard 5.1. provides that each Contracting State is required to arrange, according to the provisions of this chapter, for observations to be made by aircraft of its registry operating on international air routes and for the recording and reporting of these observations. Aircraft observations are required with regard to routine aircraft observations during en-route and climb-out phases of the flight; and special and other non-routine aircraft observations during any phase of the flight.

AIR TRAFFIC SERVICES

The provision of air traffic services is addressed in Annex 11 to the Chicago Convention which provides in limine that Contracting States shall determine, in accordance with the provisions of this Annex and for the territories over which they have jurisdiction, those portions of the airspace and those aerodromes where air traffic services will be provided. They shall thereafter arrange for such services to be established and provided in accordance with the provisions of this Annex, except that, by mutual agreement, a State may delegate to another State the responsibility for establishing and providing air traffic services in flight information regions, control areas or control zones extending over the territories of the former.

The Standards and Recommended Practices in Annex 11, together with the Standards in Annex 2, govern the application of the Procedures for Air Navigation Services—Air Traffic Management23 and the Regional Supplementary Procedures—Rules of the Air and Air Traffic Services, contained in Doc 7030, Annex 11 pertains to the establishment of airspace, units and services necessary to promote a safe, orderly and expeditious flow of air traffic. A clear distinction is made between air traffic control service, flight information service and alerting service. Its purpose, together with Annex 2, is to ensure that flying on international air routes is carried out under uniform conditions designed to improve the safety and efficiency of air operation.

The Standards and Recommended Practices in Annex 11 apply in those parts of the airspace under the jurisdiction of a Contracting State wherein air traffic services are provided and also wherever a Contracting State accepts the responsibility of providing air traffic services over the high seas or in airspace of undetermined sovereignty. A Contracting State accepting such responsibility may apply the Standards and Recommended Practices in a manner consistent with that adopted for airspace under its jurisdiction.

Standard 2.1.2 of the Annex stipulates that those portions of the airspace over the high seas or in airspace of undetermined sovereignty where air traffic services will be provided shall be determined on the basis of regional air navigation agreements. A Contracting State having accepted the responsibility to provide air traffic services in such portions of airspace shall thereafter arrange for the services to be established and provided in accordance with the provisions of the Annex. The Annex goes on to say that when it has been determined that air traffic services will be provided, the States concerned shall designate the authority responsible for providing such services. Situations which arise in respect of the establishment and provision of air traffic services to either part or whole of an international flight are as follows:

Situation 1: A route, or portion of a route, contained within airspace under the sovereignty of a State establishing and providing its own air traffic services.

Situation 2: A route, or portion of a route, contained within airspace under the sovereignty of a State which has, by mutual agreement, delegated to another State, responsibility for the establishment and provision of air traffic services.

Situation 3: A portion of a route contained within airspace over the high seas or in airspace of undetermined sovereignty for which a State has accepted the responsibility for the establishment and provision of air traffic services.

For the purpose of the Annex, the State which designates the authority responsible for establishing and providing the air traffic services is:

in Situation 1: the State having sovereignty over the relevant portion of the airspace;

in Situation 2: the State to whom responsibility for the establishment and provision of air traffic services has been delegated;

in Situation 3: the State which has accepted the responsibility for the establish-ment and provision of air traffic services.

LIABILITY OF STATES

As the overall liability of the State to provide air navigation services has been clearly identified by international treaty and, as already discussed, there are various kinds of air service providers ranging from State instrumentalities to private service providers, the liability regime could be varied and contentious. Clearly, liability of the State can be bifurcated into two areas under administrative law where liability of the State, its agency or a private body can be detained within the territory of a State, and international law, the latter involving principles of State responsibility and the liability of a State for causing injury to another State or its subjects.

Liability Under Administrative Law

State liability under administrative law can in turn be divided into two limbs: liability for acts of instrumentalities of State; and liability for privatized service providers for whose acts, relating to the provision of air navigation services, the State would still bear responsibility. The traditional model of administrative responsibility and accountability of the administrative State is based on the premise that Parliament controlled the executive but was in turn controlled by the people. Added to this, the fundamental postulate lay in the overarching principle that the judiciary played its role in keeping instrumentalities and agencies of the State intact. Accountability of the State for its agencies' actions was twofold: one stemming from a statutory power given to that agency by the State; and the other arising from delegation of authority by the State to the agency concerned. In the latter instance, however, the legislature could intervene and share some control of the agency. This gave rise to the inexorable principle that administrative law and judgments of courts on such agencies could be involved only in the former instance, when the State had provided a statutory base for a private agency or entity. In the 1983 British case of O'Reilly & Mackman,27 the House of Lords limited the circumstances in which a public law remedy, such as a declaratory judgment or injunction, could be brought outside of Section 31 of the Supreme Court Act of 1918, which prescribed instances of legal actions to be brought against the State for an act of its statutory agent. This is notwithstanding the fact that Section 21 of the Crown

Proceedings Act 1949 allows the Court in civil proceedings to issue a declaratory order against the State, although there could be no injunction specific performance orders against a State. Furthermore, a later case established that although the claim for judicial review might be brought against the Crown, the Crown's involvement is merely nominal and the ultimate dispute would be between the claimant and the defendant. It is with the 1990 decision in the Factorframe Case where Lord Bridge stated that injunctive relief against the Crown or its officers was not possible.

In the instance of a privatized service provider, the situation calls for a discussion of the reasons for privatization leading to the legal nature of a privatized entity. The reasons for privatization could well range from improvement of efficiency to reducing government involvement in industrial decision making. The corollaries to privatization are often the widening of share ownership; encouraging share ownership by employees; providing more flexibility to pay policies; and enhancement of economic freedom. There could be two types of privatized service providers: the first being large companies which were once instrumentalities of state, which, even after privatization, do not possess potential for undue competition in the market. These would easily transit to a position in which large companies had been private in the first place, and would not be subject to principles of public law. The second category of the privatized service provider is one which has market power and consequent potential for untrammelled competition. In such cases, the State may regulate the provider by bringing it under the administrative purview of a State agency. These privatized bodies may be vulnerable under public law through the agencies having administrative control over them.

One of the analogies in the United Kingdom of a privatization of a utility can be observed in the legislative initiative of 1984 with the adoption of the Telecommunications Act which brought about the privatization of a major public utility. The 1984 legislation privatized the public corporation British Telecom (BT) and abolished BT's monopoly in providing telecom services, thus opening the doors to competition. The Director General of Telecommunications, established by the Act, can grant licenses to operators of telecom systems. The Director General is also empowered to refer a matter to the Monopolies and Mergers Commission, particularly on issues related to public interest such as pricing. If this particular feature were to be applicable to a privatized air navigation service provider appointed under Statute, there would be the interesting consideration under public law whether that provider complied with Article 15 of the Chicago Convention32 on charges for services.

The operation of the administrative process in a State becomes somewhat complex when viewed in the context of competition policy where the State takes measures to curb the ill-effects on society of monopolies and cartels. An initial difficulty that arose was the nineteenth Century control of trade, which was aimed at promoting competition proved counter productive, resulting in controlling competition. This difficulty was compounded by the early twentieth Century State policy of reluctance to interfere with citizens striking bargains for their benefit. How-ever, after World War 1, some British Governmental measures introduced comprehensive control of market power.

British legislators can be proud of three legislative stages of unfair competition control. The first came in the form of the 1948 Monopolies and Restrictive Practices (Inquiry and Control), Act which devolved regulatory responsibility on an agency—the Monopolies and Restriction Practices Commission (MRPC)—a body outside the normal departmental framework. The second stage commenced with the 1956 Restrictive Trade Practices Act which addressed the competitive threat of cartels and the Restrictive Practices Court was established to adjudicate an anti-competitive and privy issues. The third stage took on with the expansion of the Monopolies Commission which investigates monopolies issues. Merger irregularities were added to the jurisdiction of the Commission with the Monopolies and Mergers Act of 1968. The 1980 Competition Act which followed gave the Commission power to investigate particular anti-competitive practices. The final stage of the evaluation demarcates choice of institutions to investigate and adjudicate on anti-competitive practices. From an administrative perspective, the citizen has been known to challenge these State instrumentalities, the most notable of which has been the challenge offered to the various governmental institutions created under Statute to define their extent of duty to give reasons for competition legislation.

A Government's approach to regulation of a public utility, whether public or privatized, is usually based on the public interest rationale where individual consumer choice will determine the demand and supply for goods and their pricing and quantity. In the United Kingdom, these factors are intrinsically related to transparency, accountability, proportionality, consistency and targeting.

Quite apart from the connotation of Article 15 of the Chicago Convention, setting international obligation, a State in a common law jurisdiction would be questioned in its Courts for its responsibility over iniquitous charges for services provided. An early nineteenth Century decision established the fact that the sovereign could not impose an unfair charge on services provided.

With regard to tortuous liability of air navigation service providers for acts negligently committed that cause damage to aircraft and passengers, the basic premise is that a public body acting ultra vires is as liable for an act committed beyond tis powers as is a private individual.40 In the 1995 Case of X (Minors) v. Bedfordshire CC, Lord Browne Wilkinson envisioned that there would be three possible causes of action where a plaintiff might bring a cause of action against a public entity: a breach of statutory duty without the necessity to prove carelessness; a common law breach of duty of care resulting from a breach of a statutory duty or a performance of a duty; and misfeasance in a public office. His Lordship ruled out any liability for carelessness in the performance of a duty imposed by statute.

In terms of compensation for torts of negligence, liability can be imposed on several counts: illegality or actions which are ultra vires per se; actions of ordinary negligence; a serious beach of duty; international wrong doing; and a lawfully caused governmental loss. Compensation for these torts could be either on an ex gratia basis or in the nature of restitutory relief. Illegality or an act ultra vires is the label given to fault in many civil law jurisdictions including France.

Common law jurisdictions, such as the United Kingdom distinguished between illegality and fault, the latter being identified with negligence and the former being considered an act ultra vires.

Where a breach of statutory duty imposed on a State authority was an issue, the remedy in early times was predicated upon the premise that if a person responsible for the act in question had a statutory duty of care which was breached, an action lay at the suit of the aggrieved person. In the early twentieth Century, Courts slightly adapted their fundamental approach to look at the intent of the statute on legislation particularly whether the law intended to create a cause of action for its breach. The overall judicial philosophy was that if there was room for awarding compensation under the principles of tort law, there would be no room for action under the statute itself. Additionally, for there to be compensation for a breach of statutory duty, the Courts looked for a prescribed penalty within the Statute, together with a link between harm suffered and the risk which the statute intended to prevent. A social interest statute enacted for the benefit of society at large would usually not give rise to a breach of duty action, unless negligence can be proved. This principle was based on the fact that social legislation affects a class of persons and accommodation of an individual within that legislation was grounded on the discretion of the authority vested with power under the legislature concerned.

As the Bedfordshire case illustrated, no action would lie for mere carelessness in the performance of a statutory duty unless there is a specific common law right of action and that action is predicated upon a common law duty of care to be established by the plaintiff. Courts cannot impose their judgment on a discretion vested in an authority because such discretion is purely for the authority to exercise and decide upon. The discretion can only be impugned if the plaintiff shows manifest unreasonableness on the part of the authority vested with discretion, making the action fall outside the purview of the discretion. In the 1990 case of Caparo Industries plc v. Dickman the court set specific standards for determining whether a challenged decision fell outside a common law duty of care. They were: whether injury caused by the defendant was foreseeable; was there sufficient proximity between the parties; and whether the imposition of a duty of care on the authority was just, equitable and fair.

In the 1996 case of Stovin v. Wise the Court established that, on the issue of breach of statutory authority, the consideration of a public duty to act under statute was not the only criterion. There was also the consideration as to whether the action in question breaches a private law duty to act which would ground a claim in damages. An omission to exercise statutory power was actionable if the authority was proved to have been irrational in not exercising the power and that there was provision in the statute for the award of compensation if an action prescribed under statute was not taken. The reliance on policy explicit or implicit in a statute under question, that compensation would accrue to a plaintiff in the instance of a breach of statutory duty, was to be based on the fact that the purpose of the statute was to devolve responsibility on an authority whose actions within the statute would accomplish what members of a society could not accomplish by themselves.

With regard to negligence, in the early case of Mercy Docks and Harbour Board Trustees v. Gibbs, decided in 1866, the court of first instance held that a public body could be held liable in negligence when exercising a statutory power. Blackburn J. rejected the argument of the defendant that a remedy lay only within statutory bounds, a decision which was upheld later by the House of Lords. The duty of care lay pursuant to a statutory power but was not prescribed both in terms of content and compensability within it. However, the scope of the statute and the persons it was meant to protect is important. Enforcement of regulations and bylaws becomes an important criterion in the determination of negligence. In Anns v. London Borough of Merton, decided in 1998, Lord Wilberforce held that negligence of the defendant Borough Council would ensue if he did not take reasonable care in securing compliance with bylaws and regulations.

Discretion and negligence are not mutually exclusive. The operational criterion is whether, in the exercise of discretion, there was a breach of a duty of care. This liability and consequent consideration that grounds an action based on a break of a duty of care depends entirely on policy considerations whether it would be fair, just and reasonable to impose such a duty. Clearly on the basis of Barret and Phelps one could conclude that a duty of care is owed by an air navigation service provider (whether he is an agent of the government or a private body) to both the operators of the aircraft as well as those who use the operator's services in the given instance.

With regard to applicable law in the United States, the Federal Tort Claims Act of the United States although not creating any specific liability regime for the United States government, asserts that the US Government approves of its being treated as a legal person in terms of tortuous liability, with no right to immunity. In Downs v. United States the Court held that the fundamental purpose of the Act was to relieve Congress of the burden of cases where the plaintiff was seeking redress for an act of an employee of the United States under a customary principle of US governmental liability that had to be invoked in every single instance. In the 1962 case of Richards v. United States, the US Supreme Court held that the Act was designed to remove sovereign immunity from the United States from actions grounded in tort and to create specific exceptions where the Government might not be liable. One of such exceptions is that the US Government may not be held liable for the performance, or failure to perform a discretionary function. The rationale for this exception from liability is that in a discretionary function there is an element of choice or selection for which there is logical or ethical basis to hold the Government liable. In Dalehite v. United States the Court held that discretion accorded to persons by the Government in laying out a plan of action would legitimately form an exception to the state liability principle. It is arguable that the Dalehite principle could be applied in an instance where the US Government gives the authority to a person to develop, apply and be accountable for a air navigation plan. However, 2 years after the decision, the case of Indian Towing Co. Inc v. United States was handed down by the Supreme Court recognizing that the Government was liable for damage caused by the Coast Guard personnel in negligently failing to repair and make a lighthouse operative.

In 1985, the case of Eastern Airlines v. Union Trust Co68 involved a mid air collision between two aircraft which were on final approach resulting in personal injury and property damage. The position of the US Government was that the air traffic controllers were exercising a discretionary function which exempted the government from liability under the Act The Court, in rejecting the Government's position, concluded that the discretion was vested in the Federal Aviation Administration in handing over the tower to the air traffic controllers responsible for the negligent act and that the controllers had no discretion to be negligent in their duties. According to the reasoning of the Court, the controller and tower operator merely handled the operational details which were outside the purview of discretionary functions. Furthermore, the court distinguished between discretion at the operational level and the planning level and attributed to the Government responsibility at the planning level.

The interpretation of the Courts in the Eastern Airlines case has exposed the judicial decision making process to criticism on the ground that the air traffic controller does indeed exercise some form of discretion at various points in the exercise of his duties. For example, in an earlier case70 in which the judgment was inconsistent with the Eastern Airlines judgment, it was held that the air traffic controller had a duty to warn the pilot of inclement weather which seriously jeopardized the safety of the aircraft. The rationale for the judgment was that, although the final decision regarding the course of the aircraft was within the pilot's discretion, the failure of the controller to warn was the proximate cause of the accident. The argument of the Government, that there was a discretion on the part of the controller in providing information to the aircraft crew, was rejected by the Court on the same basis as in Dalehite, Indian Towing and the earlier Eastern Airlines cases, in that the discretion was in handing over the operation of the tower to the operator and that neither the operator nor the controller had a discretion to provide services negligently. On this basis, the decision by the Government to select the equipment for the landing systems is a planning activity and a discretionary one attributable to the Government. If equipment were to be chosen by the Government and the service provider used the equipment negligently in giving crucial instructions to the pilot, it is arguable that the Government may not be able to claim the benefit of the discretionary function exemption in exonerating itself from liability.

The question arises as to whether a breakdown of equipment would make the government strictly liable. An ICAO study, conducted in 1984 stated that a breakdown of equipment should not exonerate the provider of the services (in the case of the United States the FAA which an instrumentality of State) because the provider would have a cause of action against the manufacturer. The Study, which was commissioned by the ICAO Council with a view to developing a Convention on air traffic controllers' liability, went on to say that:

Privileges and immunities whatever their nature and extent, should in no way be granted to air traffic control agencies whatever their status may be (private, public or multinational agencies) since they would defeat the purpose of a convention aiming at compensating victims of damage resulting from the negligence of air traffic control agencies; air traffic control agencies provide a public service and the responsibility involved carries with it obligations which cannot be eliminated by laws or otherwise; Furthermore, privileges and immunities in this field of activities might be considered in many countries to be contrary to the public order.

The Study recommended that claims against air traffic controllers must be supported by evidence of negligence on the part of the provider of the services or of failure of the equipment whether or not with the fault of the service provider. This is consistent with the United States jurisprudence that the pilot's negligence, if more serious than that of the controller, should be taken as the main cause of the damage even if the controller was negligent.

Liability Under Public International Law

The sovereign jurisdiction of a State does not extend beyond its territories. There-fore, a State cannot adjudicate against another State's acts in Courts of its own whether the weather was good enough to allow a flight to go through. The responsibility of the State both at administrative law and public international law in certain circumstances of the provision of air navigation services, does not presuppose that there is no liability of the air traffic controller individually. There have been instances of the air traffic controller's individual liability, in common law jurisdictions (both jointly with the State concerned and severally)for negligence. See Crister S. Dahl, Air traffic Control in Norway, Unpublished LL.M thesis, McGill: Montreal, at 43. jurisdiction, since the other State has sovereign immunity. The link between territorial jurisdiction and sovereign immunity is illustrated in a strong cursas curiae, commencing with an early nineteenth Century case where Marshall C.J. held in the United Sates Supreme Court that a State's sovereignty does not extend beyond its territories to encompass the jurisdiction of other States.

The principle of sovereign immunity recognized by Marshall CJ has been upheld through the centuries to follow. In the 2000 case of Ex Parte Pinochet (No. 3),77 Lord Browne Wilkinson held that it is a fundamental principle of international law that one sovereign State does not adjudicate on the conduct of another sovereign State. The immunity extends both to civil and criminal liabilities. The same year, Lord Millett held in the case of Holland v. Lampon-Wolfe that State immunity is a corollary of customary international law and is based on the equality of sovereign States. It is not a legal principle that the United Kingdom [or any other State] places upon itself but inherits from the community of nations and its equality at international law. A corollary to this basic theory is the Act of State which generally relates to the activities of the executive with regard to other States. The non justiciability of an Act of State applies both domestically and internationally to matters of State, such as those concerning security and territorial integrity are concerned.

Sovereign immunity can be asserted as a justifiable exclusion to adjudication depending on the extent of control a State exercises over the issuant land. Thus, in the case of ships at foreign ports, the principle has veered from an extremity where the Court recognized the mere interest of a State in a ship which was operated privately for commercial purposes to rejecting a defective interest in a vessel which did not afford sovereign immunity to the State claiming its exclusion from a jurisdiction of a foreign Court. The United States courts have insisted on adequate State control of a vessel.

In view of the many developments in the modern context where States have commercial interests beyond their boundaries, giving State enterprises an advantage over other national enterprises, many States recognize the practice of restrictive immunity of States in commercial issues. The most compelling principle at public international law with regard to the liability of a State and with regard to the act of an air navigation service provider, is the principle of State responsibility which is entrenched as a fundamental principle of international law, in particular, since the responsibility of a State in providing air navigation services to foreign as well as its own carriers is recognized by the Chicago Convention. Treaty obligation, as an integral part of State responsibility, was recognized in the 1990 Rainbow Warrior arbitration between France and New Zealand where the Court recognized that the law relating to treaties was relevant in determining one State's responsibility to another. The Court also recognized that at international law, there was no distinction between contractual and tortuous liability and consequently State responsibility gave rise to reparation.

State responsibility is anchored on certain basic fundamental facts. Firstly, there should be international obligation between two States or more. Secondly, an act or omission by one State must violate that obligation which can be directly attributed or imputed to the State concerned. Thirdly, loss or damage must be incurred by the aggrieved State. These requirements fit well into the provision of air navigation services by one State to another which is recognized in Article 28 of the Chicago Convention. Therefore, the negligent act or omission of a service provider can be imputed to the State establishing or appointing such provider publicly or on a private basis. In the instance of an aircraft, whether national or foreign, carrying foreign nationals who are injured in an accident due to the negligent provision of air navigation would open a State to responsibility to make reparation to the clai-mants. The objective responsibility theory suggests that a State's responsibility has to be one of strict liability, where good or bad faith is not a consideration, whereas the subjective responsibility test involves fault liability, involving negligence. In the 1926 Neer claim where an American superintendent of a Mexican mine was shot, the General Claims Commission hearing the claim of the United States applied the objective test and rejected the claim that Mexico was responsible for not pursuing the investigation diligently. Three years later, the French-Mexican Claims Commission, when considering the shooting of a French citizen by Mexican soldiers, applied the objective test and held the Mexican Republic responsible to maker reparation to France. The subjective approach involving an enquiry into negligence has been applied in the case of damage caused to one State by the rebels of another State as a result of a tax imposed by a third State where there was found to be no fault on the part of the third State.

In the famous Corfu Channel case, the International Court of Justice applied the subjective test and applied the fault theory. The Court was of the view that:

It cannot be concluded from the mere fact of the control exercised by a State over its territory and waters that the State necessarily knew, or ought to have known, of any unlawful act perpetrated therein, nor yet that it necessarily knew, or should have known the authors. This fact, by itself and apart from other circumstances, neither involves prima facie responsibility nor shifts the burden of proof.

The Court, however, pointed out that exclusive control of its territory by a State had a bearing upon the methods of proof available to establish the involvement or knowledge of that State as to the events in question.

Apart from the direct attribution of responsibility to a State, particularly in instances where a State might be guilty of a breach of treaty provisions, or violate the territorial sovereignty of another State, there are instances where an act could be imputable to a State. Imputability depends upon the link that exists between the State and the legal person or persons actually responsible for the act in question. The legal possibility of imposing liability upon a State wherever an official could be linked to that State encourages a State to be more cautious of its responsibility in controlling those responsible for carrying out tasks for which the State could be ultimately held responsible. In the same context, the responsibility of placing mines was attributed to Albania in the Corfu Channel case since the court attributed to Albania the responsibility, since Albania was known to have knowledge of the placement of mines although it did not know who exactly carried out the act. It is arguable that, in view of the responsibility imposed upon a State by the Chicago Convention on the provision of air navigation services, the principles of immutability in State responsibility could be applied to an instance of an act or omission of a public or private official providing air navigation services.

The provisions of the Chicago Convention, which is an international treaty, are binding on contracting States to the Convention and therefore are principles of public international law. The International Court of Justice (ICJ), in the North Sea Continental Shelf Case, held that legal principles that are incorporated in Treaties, such as the “common interest” principle, become customary international law by virtue of Article 38 of the 1969 Vienna Convention on the Law of Treaties.91 Article 38 recognizes that a rule set forth in a treaty would become binding upon a third State as a customary rule of international law if it is generally recognized by the States concerned as such, which in turn becomes a principle of customary international law, or jus cogens. Obligations arising from jus cogens are considered applicable *erga omnes* which would mean that States using space technology owe a duty of care to the world at large in the provision of such technology. The ICJ in the Barcelona Traction Case held:

An essential distinction should be drawn between the obligations of a State towards the international community as a whole, and those arising vis a vis another State in the field of diplomatic protection. By their very nature, the former are the concerns of all States. In view of the importance of the rights involved, all States can be held to have a legal interest in their protection; they are obligations erga omnes.

The International Law Commission has observed of the ICJ decision:

[I]n the Courts view, there are in fact a number, albeit limited, of international obligations which, by reason of their importance to the international community as a whole, are- unlike others - obligations in respect of which all States have legal interest.

The views of the ICJ and the International Law Commission, which has sup-ported the approach taken by the ICJ, give rise to two possible conclusions relating to jus cogens and its resultant obligations erga omnes:

(a) Obligations erga omnes affect all States and thus cannot be made inapplicable to a State or group of States by an exclusive clause in a treaty or other document reflecting legal obligations without the consent of the international community as a whole;

(b) Obligations erga omnes pre-empt other obligations which may be incompatible with them.

Some examples of obligations erga omnes cited by the ICJ are prohibition of acts of aggression, genocide, slavery and discrimination. It is indeed worthy of note that all these obligations are derivatives of norms which are jus cogens at international law.

International responsibility relates both to breaches of treaty provisions and other breaches of legal duty. In the Spanish Zone of Morocco Claims case, Justice Huber observed:

[R]esponsibility is the necessary corollary of a right. All rights of an international character involve international responsibility. If the obligation in question is not met, responsibility entails the duty to make reparation.

It is also now recognized as a principle of international law that the breach of a duty involves an obligation to make reparation appropriately and adequately. This reparation is regarded as the indispensable complement of a failure to apply a convention and is applied as an inarticulate premise that need not be stated in the breached convention itself. The ICJ affirmed this principle in 1949 in the Corfu Channel Case97 by holding that Albania was responsible under international law to pay compensation to the United Kingdom for not warning that Albania had laid mines in Albanian waters which caused explosions, damaging ships belonging to the United Kingdom. Since the treaty law provisions of liability and the general principles of international law as discussed complement each other in endorsing the liability of States to compensate for damage caused by space objects, there is no contention as to whether in the use of nuclear power sources in outer space, damage caused by the uses of space objects or use thereof would not go uncompensated. Furthermore, under the principles of international law, moral damages based on pain, suffering and humiliation, as well as on other considerations, are considered recoverable.

The sense of international responsibility that the United Nations ascribed to itself had reached a heady stage at this point, where the role of international law in international human conduct was perceived to be primary and above the authority of States. In its Report to the General Assembly, the International Law Commission recommended a draft provision which required:

Every State has the duty to conduct its relations with other States in accordance with international law and with the principle that the sovereignty of each State is subject to the supremacy of international law.

This principle, which forms a cornerstone of international conduct by States, provides the basis for strengthening international comity and regulating the conduct of States both internally—within their territories—and externally, towards other States. States are effectively precluded by this principle of pursuing their own interests untrammelled and with disregard to principles established by international law.

Principles of modern treaty law demand that an ICAO contracting State, which has placed its instrument of ratification to the Chicago Convention has consented to be bound by the provisions of that treaty. The word "contracting State" refers legally to a State which is bound by the treaty concerned, irrespective of whether the treaty is in force or not. This goes to the root of international responsibility as already discussed and it is improbable at common law that a court would consider otherwise and disregard a State's obligation in the provision of air navigation services, particularly in the context of governmental agencies and other instrumentalities of State. This however, does not completely exonerate the privatized service provider, who could be held liable at private law. Legally, as was discussed, neither the State nor the service provider can avoid liability on account of privatization. The State entails liability primarily at public international law and also at public law in general, and the provider incurs liability on a private basis in a private action that may be brought, under tort law principles or under contract law, as the case may be.

Paul Stephen Dempsey sums it up well, when he says that the issue has two critical considerations, one relating to legal issues and the other impacting public policy. Dempsey states correctly that the skies belong to the public and the sovereign is but the trustee in this regard. Under any circumstances, whether on fiscal profit making or political motivation, States cannot abdicate or pass on their responsibility and accountability of their traditional function and fiduciary responsibility. Besides, holding governments responsible will ensure proper quality control in the provision of air navigation services.

THE AIR TRAFFIC SERVICE PROVIDER'S LIABILITY

States have to be mindful of the fact that their overall responsibility under the Chicago Convention in providing air navigation services extends to the air traffic controller, whose service is of a unique nature. The special feature in the provision of air traffic control is brought to bear by the nature of the service provided, be it in the relaying of information on meteorology or on traffic. Globally, air traffic control services offer information relayed by people by means of radio communication involving extremely short time periods and using a standard set of terminology in the English language, even in regions of the world where English is not the first language. ICAO endorses this view when it says:

The air traffic controller's job consists of complex tasks demanding a high degree of skill and active application of unique cognitive abilities such as spatial perception, information processing, reasoning and decision making. The controller must know where all the aircraft under his/her responsibility are, and determine how and when to take action to ensure that they remain separated from each other, while also seeing to their requests and needs for descent, climb, take off, departure etc.

In view of the arduous task performed by the air traffic controller, ICAO has stretched the responsibility of the State, from a fundamental statement of state responsibility reflected in Article 28 a) of the Chicago Convention, to a more detailed pronouncement in its guidelines, calling on States to make improvements to the air traffic management system through supporting software that could assist the controller with conflict prediction, detection, advisory and resolution.104 ICAO's focus of concentration is on a unified strategy which establishes a mechanism integrating the efforts to increase transparency and disclosure of safety related information. Although the unified strategy extends to encompass all areas of safety of flight including airworthiness, it is incontrovertible that the overall philosophy of the strategy will apply to the provision of air navigation services as well. One of the most fundamental aims of ICAO, as enshrined in Article 44 a) of the Chicago Convention, is to ensure the safe and orderly development of international civil aviation. To this end, and as part of its unified strategy, ICAO is suggesting the establishment of regional safety oversight organizations105 along the lines of European Aviation Safety Agency (EASA) of Europe.

At the 35th Session of the ICAO Assembly, contracting States adopted Resolution A35-7,which urges all contracting States to share with other contracting States critical safety information which may have an impact on the safety of international air navigation and to facilitate access to all relevant safety information. This resolving clause is based on the premise, explicitly recognized in the Resolution, that the improvement of the safety of international civil aviation on a worldwide basis requires the active collaboration of all stakeholders. By adopting Resolution A35-7, the 189 ICAO contracting States at that time arrogated to themselves increased responsibility for the safety of international civil aviation, irrespective of the nature of the provider of services that ensure such safety. This strategic approach of global safety oversight was further endorsed at the ICAO Conference on a Global Strategy for Aviation Safety convened of the Directors General of Civil Aviation from 20 to 22 March 2006 in Montreal, where all States consensually agreed that there should be an effective implementation of Safety Management Systems (SMS) in States, established according to a performance based approach in three steps: Firstly, where oversight authorities and operators and service providers agree on the safety performance to be expected from them while conducting their core business functions; secondly, that oversight authorities and service providers agree on the safety requirements necessary to achieve the safety performance agreed upon in the first step; and thirdly and finally, that oversight authorities verify achievement of the agreed safety performance or its lack thereof, and operators and service providers correct observed deviations.

All the above goes to demonstrate the heavy responsibility placed by States on themselves in undertaking that they and they alone will be accountable for the safety of aviation within their territories as well as cooperating on a global basis to implement a seamless air navigation system. Of course, any change in the provision of air traffic services, particularly with regard to the commercial nature of the service provider, will remain subservient to the fundamental concept of State sovereignty, which was endorsed by the Eleventh ICAO Air Navigation Conference held in Montreal from 22 September to 3 October 2003.

However, although the overall responsibility of the State to ensure the provision of air navigation services is immutable, there is no legal impediment to a State handing over the physical task of provision of services to a private entity while retaining its oversight role. Accordingly, in the present context, it is common to see a State largely in a supervisory role retaining its ownership of air space, drafting national legislation; determining governance over air navigation service providers; continuing to hold responsibility for certification and designation of service providers a well as setting regulations, while the service provider provides a public function in managing airspace with the broad spectrum of safety and efficiency. Within the overarching umbrella of State responsibility, there are various models of air navigation service providers. The first category is the original one which has not changed, where a State instrumentality continues to provide air navigation services. Examples of these are the Federal Aviation Administration109 of the United States and the national authority of France (DSNA). The second category is the privatized or profit service provider such as NATS and third is the privatized service provider for nonprofit purposes such as Nav Canada. There is a fourth category of a corporatized service provider for profit and those that come into this group are New Zealand Airways and Air Services Australia. A fifth category also exists, corporatized for non profit such as the air navigation service providers of Continental Europe. All these types of service providers, with the exception of the first category are autonomous, but remain undisputedly under the administrative super-vision of their respective States.

In August 2006, a Swiss court indicted eight employees of the Swiss air traffic control authority, Skyguide, for their involvement in the plane crash which occurred in 2002 in Ueberlingen.. The Skyguide staff were charged with negligent manslaughter for their role in the air crash in which 71 people died when two jets collided over Swiss-controlled airspace in southern Germany. The defendants were accused of organizational shortcomings that led to a single air traffic controller being left in charge of the area where the crash occurred on July 1, 2002, and with providing insufficient information to him about technical work in progress that decisively affected the communications and radar systems.

In their May 2004 report, German investigators stated that Skyguide's main control tower radar had been switched off and the main telephone line was down. However, according to the public prosecutor, the trial is unlikely to take place this year. In a parallel development, a German court ruled on July 27 that Germany wrongly subcontracted its airspace control to Skyguide and was partly liable for the air crash. The ruling was in response to a civil lawsuit filed by the Russian airline company that owned the passenger jet.

The exponential increase in air traffic movements over airspace has overburdened the air navigation system. The logical assumption would be that the need of the hour is to find alternate ways of optimal use of air space. This would require some discretion to be given to the pilot to find shortcuts in manoeuvring his aircraft in order to obviate airspace constraints. However, this flexibility is almost non-existence as the present air navigation system, particularly in terms of air traffic control, is based on the "positive control" concept which prescribes that pilots have to generally follow the instructions of the air traffic controller even if there is perfect visibility. However, as will be discussed later, common law courts, particularly in the United States have not strictly adhered to this overarching concept.

In a world of congested airways, the additional problem of faulty communication between the players involved, particularly the air traffic controller and the technical crew of an aircraft in flight, does not help. NASA B 727 study has indicated that specific language variables are moderately to highly co-related with individual performance, individual error rates and individual communication ratings. During the course of their studies, NASA researchers analyzed causes of jet air transport accidents and incidents between 1968 and 1976 and came up with the conclusion that pilot error was more likely to reflect failures in team communication and coordination than deficiencies in technical proficiency. The percentage of accidents which resulted from faulty communications ranged between 70% and 80% of the total rate.112 There is also the considered view that aeronautical language should b considered as a variable of interest in crew factors since language is a coping mechanism in that it casuists individuals to lessen and mage both causes and effects of stress. Analogically this should apply as well to the air traffic controller who, if well trained in the language of communication would not be exposed to stress at the work place.

There are no international rules governing the liability of the air traffic controller. However, there are various international guidelines that would give individual States both an impetus and direction to enact their own internal laws in this regard.

The Chicago Convention contains certain provisions demarcating the responsibility of Contracting States of the International Civil Aviation Organization. Article 28 of the Convention obligates contracting States to provide in their territories airports, radio services, meteorological services and other air navigation facilities to facilitate international air navigation, in accordance with the standards and practices established from time to time pursuant to the Convention. The "other air navigation facilities" referred to in article 28 of the Chicago Convention include Air

Traffic Services, which is a combination of services provided to support the safe and expeditious flow of air traffic.

ICAO has established Standards and Recommended Practices for licensing of air traffic controllers Part of this licensing process recognizes that there are pre-scribed ICAO language proficiency requirements based on a proficiency rating scale identifying Holistic Descriptors. These descriptors in turn require the air traffic controller, as a proficient speaker, to communicate effectively in voice only (telephone/radiotelephone) and in face to face situations; communicate on common, concrete and work related topics with accuracy and clarity; use appropri-ate communicative strategies to exchange messages and to recognize and resolve misunderstandings in a general and work related context; handle successfully and with relative ease the linguistic challenges presented by a complication or unexpected turn of events that occurs within the context of a routine work situation or communicative task with which the air traffic controller is otherwise familiar; and use a dialect or accent which is intelligible to the aeronautical community.

"Air traffic service" is a generic term meaning variously, flight information service, alerting service, air traffic advisory service, and air traffic control service. Air traffic control services comprise three services: area control service, which provides air traffic control services for controlled flights; approach control service, which provides air traffic control services for those parts of controlled flights associated with arrival and departure, and aerodrome control service, which relates to the provision of air traffic control services for aerodrome traffic. An alerting service is provided for all aircraft provided with air traffic control service and, to the extent practicable, to al other aircraft which file a flight plan or aircraft which are known to be in a particular portion of airspace and need such services. This service is also provided to any aircraft known to be the subject of unlawful interference.

The provision of air traffic services is addressed in Annex 11 to the Chicago Convention which provides in limine that Contracting States shall determine, in accordance with the provisions of this Annex and for the territories over which they have jurisdiction, those portions of the airspace and those aerodromes where air traffic services will be provided. They shall thereafter arrange for such services to be established and provided in accordance with the provisions of this Annex, except that, by mutual agreement, a State may delegate to another State the responsibility for establishing and providing air traffic services in flight information regions, control areas or control zones extending over the territories of the former.

As for the provision of meteorological services, Annex 3 to the Chicago Convention provides in Standard 2.1.1. that the objective of meteorological service for international air navigation shall be to contribute towards the safety, regularity and efficiency of international air navigation. This objective shall be achieved by providing operators, flight crew members, air traffic services units, search and rescue services units, airport managements and others concerned with the conduct or development of international air navigation, with the meteorological information necessary for the performance of their respective functions. Annex 11 to the Chicago Convention requires that air traffic services units shall be provided with up to date information on existing and forecast meteorological conditions as necessary for the performance of their respective functions. The information must be provided in such a manner and form so as to require a minimum of interpretation on the part of air traffic services personnel and with a frequency that satisfies the requirements of the air traffic services units concerned. It is also recommended that meteorological offices should be so situated as to facilitate personal consultation between meteorological personnel and personnel of units providing air traffic services.

Technical Standards and Recommended Practices for aeronautical telecommunications are contained in Annex 10 to the Chicago Convention (Aeronautical Tele-communications) which includes inter alia, general provisions for radio navigation aids, Global Navigation Satellite System (GNSS), specifications for Instrument Landing Systems (ILS) and other navigational aids. The basic principle underlying the use of these navigational aids is found in ICAO's Procedures for Air Navigation Services which requires States to ensure that the level of air traffic services and communications, navigation and surveillance, as well as air traffic procedures applicable to the airspace or aerodrome concerned, are appropriate services.

Liability issues of an air traffic controller are intrinsically linked to the controller's relationship with the pilot with whom the former communicates. This relationship, between the controller and the pilot, has been called the "continuum of dependence". It has been generally recognized that the fundamental principle of liability is based on whether the pilot was flying under Visual Flight Rules (VFR) which gives the pilot absolute freedom to manoeuvre his aircraft, or Instrument Flight Rules (IFR) when visibility could be nil. In the former instance, the air traffic controller would not be generally held liable for a mid air collision as the pilot has full visibility. This is based on the pilot's responsibility to "see and be seen".

In the latter case, where the pilot was flying under IFR and had no visibility he would have been dependent on the communications of the air traffic controller.

One of the issues that arise in litigation pertaining to the liability of the air traffic controller is the weightage expected to given to the Air Traffic Control Procedures Manual and the extent to which the pilot is required to adhere to instructions therein. In the 1975 US case of Baker v. United States, the Court held that the manual cannot be considered as "the Bible" of air traffic control or a set of regulations having the force of law. Earlier, in a decision handed down by the Fifth Circuit Court, the court held that the air traffic controller's duties are not hampered or limited within the narrow limits of the Manual. This does not mean, however, that the air traffic controller has untrammelled discretion to override his controller's manual. In the 1974 case of Todd v. United States, the court held that the controller was negligent in allocating a cruise clearance height to the pilot which was lower than the altitude recommended in the Manual for mountainous terrain, particularly in an instance of adverse weather. The case of Rudelson v. United States, decided in 1979 is quite significant, in that the court held an air traffic controller's duties should not be circumscribed to tasks described in the FAA Manuals and that the controller has the discretion to go beyond the scope and content of the manual if the safety of passengers and crew was at stake.

There is no doubt that liability of the air traffic controller is an expanding concept and the continuum of dependence is no longer an absolute concept. Courts are showing a greater willingness to ascribe to the controller liability for negligent performance of duty, irrespective of whether such duty is incorporated or inscribed in the controller's manual or not.

With the introduction in 1994 of the concept of free flight It became evident that eventually pilots might be able to use onboard instruments and electronics to maintain a safe distance between planes and to reduce their reliance on ground controllers. Full implementation of this concept would involve technology that made use of the Global Positioning System to help track the position of aircraft. In 1998, the Federal Aviation Administration of the US (FAA) and industry began applying some of the early capabilities developed by the Free Flight program.

Free flight is essentially a US practice which has spread to many parts of the world as a practical solution for the implementation of the ICAO CNS/ATM concept. It is a safe and efficient flight operating capability under IFR in which the operators have the freedom to select a path and speed and real time. Air traffic restrictions are only imposed to ensure separation to preclude exceeding airport capacity, to prevent unauthorized flights through special use air space and to ensure safety of flight. Restrictions are limited in extent and duration to correct the identified problem. Any activity which removes restriction represents a move toward the flight. There is a "Free Routing system being developed in Europe which is similar to free flight except that the former will be subject to ATC clearance and the latter will not be". Both systems could plan the routes and altitudes of such flights. In both instances, the air traffic controller can and must intervene if there is a potentially dangerous situation arising as a result of a free flight. Therefore The controller is not always exempt from liability merely because there is interaction between the controller and the pilot.

The liability of the air traffic controller in free flight situations where accidents have occurred has been subject to some discussion. One commentator is of the view that the respective responsibilities and liabilities of pilots and controllers for most accidents should not be altered by the free flight system, but that in air crash situations involving free flight where air traffic control is a factor, it is up to the courts to clarify the rules of liability to ensure safety under the new system. Another sates that the final authority of the pilot in command will prevail.

There is also the established principle that the negligence of the pilot would not necessarily exonerate the air traffic controller. In the 1987 case of Rodriguez v. the United States the court as of the view that the notion that a pilot's negligence in performing his duties must, as a matter of law, free the air traffic controller from liability had already been rejected. The question arises as to whether both the pilot and the controller are liable if both of them are at fault. This principle of "shared liability" is common at tort law. However, the difficulty would be in apportioning damages between the pilot and the air traffic controller. Here the principle could be that the plaintiff's recovery is limited to the proportion of damages the defendant's negligence proximately caused. The Court went on to say in the Rodriguez case that although it was recognized that the pilot bears full authority for aircraft operation and is held to the highest degree of care, air traffic controllers could be held liable if negligence on the part of such person has a causal nexus or relationship to the occurrence of the accident.

The above notwithstanding, the fundamental principle that the aircraft com-mander has final authority over the flight still holds good. However, this principle is conditional upon the fact that air traffic control clearances and directives are binding on flight crews, and pilots are required to comply. If an air traffic control clearance is not satisfactory for a pilot, he may request and receive an amended clearance. There is a consistent cursus curiae that establishes the principle that air traffic control services do not substitute the pilot's substantive duties and that once a pilot has been given clearance he remains responsible for the movement of his aircraft. In this respect, although the air traffic controller remains responsible and accountable for his instructions to the pilot, the pilot should not blindly follow such instructions, particularly if the pilot is not convinced that the instructions received should be followed without question.

Air traffic controllers cannot shift liability to the State on the basis of State responsibility to provide air traffic services, which is a responsibility recognized by the Chicago Convention. A case in point, was in Eastern Airlines v. Union Trust Co. which established the rule that air traffic controllers had no discretion to be negligent in their work and that they could not shelter themselves behind the fact that they worked for an instrumentality of State in matters pertaining to their individual liability which clearly established liability criteria regarding the provision of air navigation services in the United States.

Communication is vital to the modern world. In this sense miscommunication in human interaction is a critical factor. A misrepresentation in the law of torts is actionable at negligence148 and an aeronautical miscommunication, negligently delivered could be construed as gross negligence. The operative criterion would be that the aircrew would place reliance upon communications received from the air traffic control centre. In the 1997 case of Hercules Management Ltd. v. Ernst & Young the court de-emphasized the language of special relationship and the importance of an assumption of responsibility and stressed the importance of the concept of foreseeable and reasonable reliance by the plaintiff.

SATELLITE IMAGERY

On 3 February 1998, a U.S. Marine EA-6B Prowler Jet conducting a low-altitude training mission near Cavalese, Italy, hit a cable supporting a gondola transportation system being operated across a wide valley. The impact of the jet on the cable severed it, immediately cutting off support for the gondola which plummeted to the ground nearly 600 feet. The accident killed 20 people.

The only manner in which a pre-trial presentation could show the jury exactly what occurred during the accident was by recreating the incident. The Italian Government absolutely refused the defence attorneys, who had obtained a jet to recreate a flight path in the same valley, in order to recreate the incident. The only viable alternative available to the defence attorneys was to recreate the flight path with computer-based simulation, which was offered by a firm called Visual Forensics. Although such recreation through digital technology was possible using a helicopter-based global positioning system through a recording of a low speed flight through the valley followed by a digital recalibration of the film simulating the jet's air speed of 600 mph, by the time Visual Forensics were ready for the digital reconstruction, snow and ground conditions had been rendered significantly different from the photographic record of the accident scene.

Another debilitating factor was that no one was able to map out with precision the exact flight path during the critical last phase of the jet's approach. The jet's black box was not sophisticated enough to provide spatial coordinates to pinpoint the aircraft's precise altitude and trajectory.

The entire accident, to the most precise detail, could have been captured in earth photos taken from space platforms which now reveal precise and sharp spatial, temporal and spectral information about happenings on earth. This is accomplished by satellites circling the earth from 400 miles in space at 16,000 miles per hour and having the capacity to transmit data to the ground at high speed rates. Assisted by the global positioning system (GPS), these satellites are able to determine their orbital position in a precise and sharp way which permits them to position with high accuracy ground features for mapping and other applications within a few meters. Additionally, high-resolution space cameras which have the capability of multi-spectral (blue, green, red and near infra-red) imagery, have the capacity and ability to identify objects positioned on the ground which have hitherto been invisible to the human eye. This incredibly sophisticated technology makes detection and identification of objects as small as one meter now possible. The ultimate result could be that satellite imagery could not only be invaluable for agricultural, environmental, land use, hydrocarbon exploration and disaster assessment but it could also be an innovative evidentiary tool for litigators.

The Commercial availability and capability of production of higher resolution spaceborne imagery is now establishing space imagery as a compelling tool in litigation. Therefore, a legal community poised to enter the frontiers of space age technology will find in space imagery cogent and clear evidence analogous to DNA evidence that is now being used in the forensic determination of bio medical identification.

Satellite imagery involves a process which uses cameras or sensor systems usually mounted on an orbiting satellite that capture light reflected from the earth's surface. The fundamental principle of this imagery process is that natural and man-made materials absorb and reflect varying quantities of light in different wave-lengths and, through this absorption and reflection process, energy (light) enables satellite sensors to collect data by interacting with objects on the surface of the earth such as plants, soils and buildings in a way that makes possible the extraction of such data and information. Such information is absorbed by the camera/sensor system on the orbiting satellite and transmitted back to earth in a digital format and transformed or converted to images that are capable of being interpreted by sophisticated image processing software. This process makes satellite imagery ideally applicable to the requirement for detail pertaining to large area coverage such as regional cartography, environmental assessment, infrastructure planning and agricultural monitoring.

A significant development in recent satellite imagery through spatial information is the launching of the highest resolution commercial remote sensing satellite with an on-board digital camera having the capability of producing one-meter or better resolution at nadir to focus on the lowest point in the panchromatic, full spectrum mode and four-meter resolution imagery in the red, green, blue and near infra-red (NIR) bands. Such a one-meter resolution will enable the user to distinguish between objects which are one meter in size on the ground if they have distinguish-able physical and visual characteristics. Easily detectable under this spatial recognition system are stripes in parking lots, swimming pools, cars, trucks, boats, tennis courts, landscape features, all within their surroundings and environs.

Satellite imagery is not restricted to photography. New sophisticated electronic sensors enable even more powerful imagery that mere photos—digital data that can be analyzed processed and interpreted on computers—computer analysis in digital format admits of possibilities for data to be used in multifarious ways using differences in spectral responses from ground features. The usefulness of this process is emphasized and highlighted when satellite imagery is used in conjunction with the geographic information system (GIS) and the global positioning system (GPS), which together can construct a complete model of an area.

The dynamic applications of a spatial satellite imaging system will be invaluable to attorneys, insurers and risk managers in acquiring data and information on natural and man-made disasters. The Chernobyl Nuclear Plant disaster and the Exxon Valdez oil spill in Alaska are two such incidents which were tracked and recorded for use by television and major newspaper media. The most significant area of contribution is in prediction or preparation where, a satellite just overhead of a disaster area can identify through its imagery an impending disaster or occurrence.

SPACE LAW APPLICATIONS

The essential activity which forms a basis for satellite imagery is remote sensing. Remote sending is the use of satellite technology in obtaining pictures of a territory on earth. This activity is covered by the Outer Space Treaty of 1967151 which came into force on 10 October 1967. This treaty obliges signatory States to inform the United Nations Secretary General, the public and the international scientific com-munity of the “nature, conduct, locations and results” of space activities.152 The Space Treaty also imposes international responsibility upon signatory States regarding private sector activities conducted within their territories resulting in activities in space by such private sector entities.153 This, notwithstanding the collection of satellite images through remote sensing or other technology, is not prohibited under international law since no international treaty contains any specific provision precluding the satellite imaging of objects or places on earth. Moreover, there is no known definition of remote sensing which is essentially the science or art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation.

At the incipient stage of remote sensing applications, the deployment of remote sensing satellites were for military strategic purposes, remote sensing can now be used to further scientific and discovery objectives. Commercial pursuit of remote sensing for scientific and discovery objectives, called civil remote sensing, is usually conducted by agencies, organizations and individuals who exploit remote sensing systems and data to promote the general welfare and provide for the public good. Commercial remote sensing may be impelled by the motive to make profit, either through procurement or sale of data obtained through sensing.

A legal regime applying a codification of customary legal principles calculated to bind nations and private enterprises through nations was set up in 1987 by the United Nations, when it adopted Resolution 41/65. This resolution was a care-fully thought out one, which took the United States and other nations involved 13 years to draft, beginning 1974. The remote sensing principles, as established by Resolution A41/65 admit of access and distribution of data and information generated by remote sensing systems. This activity has its genesis in the Outer Space

Treaty of 1967 which stipulates that the exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit of and in the interest of all countries, on the basis of equality. Article IX of the Treaty embodies a principle of cooperation between nations and provides that the exploration and use of outer space shall be carried out by States parties in a spirit of cooperation and mutual assistance and with due regard to the corresponding interests of all other parties to the Treaty.

AERODROME DATA AND WARNING

KEY TERMS IN AERODROME STANDARDS AND WARNINGS

- Accuracy. A degree of conformance between the estimated or measured value and the true value.

- Aerodrome. A defined area on land or water (including any buildings, installations, and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.

- Aerodrome beacon. Aeronautical beacon used to indicate the location of an aerodrome from the air.

- Aerodrome Certificate. A certificate issued by the appropriate authority under applicable regulations for the operation of an aerodrome.

- Aerodrome elevation. The elevation of the highest point of the landing area.

- Aerodrome identification sign. A sign placed on an aerodrome to aid in identifying the aerodrome from the air.

- Aerodrome reference point. The designated geographical location of an aerodrome.

- Aerodrome traffic density.

  a) Light. Where the number of movements in the mean busy hour is not greater than 15 per runway or typically less than 20 total aerodrome movements.

  b) Medium. Where the number of movements in the mean busy hour is of the order of 16 to 25 per runway or typically between 20 to 35 total aerodrome movements.

  c) Heavy. Where the number of movements in the mean busy hour is of the order of 26 or more per runway or typically more than 35 total aerodrome movements.

Note 1.C The number of movements in the mean busy hour is the arithmetic mean over the year of the number of movements in the daily busiest hour.

Note 2.C Either a take-off or a landing constitutes a movement.

- Aeronautical beacon. An aeronautical ground light visible at all azimuths, either continuously or intermittently, to designate a particular point on the surface of the earth.

- Aeronautical ground light. Any light specially provided as an aid to air navigation, other than a light displayed on an aircraft.

- Aeroplane reference field length. The minimum field length required for take-off at maximum certificated take-off mass, sea level, standard atmospheric conditions, still air and zero runway slope, as shown in the appropriate aeroplane flight manual prescribed by the certificating authority or equivalent data from the aeroplane manufacturer. Field length means balanced field length for aeroplanes, if applicable, or take-off distance in other cases.

  Note.C Attachment A, Section 2 provides information on the concept of balanced field length.

- Aircraft classification number (ACN). A number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade category.

  Note.C The aircraft classification number is calculated with respect to the center of gravity (CG) position which yields the critical loading on the critical gear. Normally the aftmost CG position appropriate to the maximum gross apron (ramp) mass is used to calculate the ACN. In exceptional cases the forwardmost CG position may result in the nose gear loading being more critical.

- Aircraft stand. A designated area on an apron intended to be used for parking an aircraft.

- Apron. A defined area, on a land aerodrome, intended to accommodate aircraft for purposes of loading or unloading passengers, mail or cargo, fuelling, parking or maintenance.

- Apron management service. A service provided to regulate the activities and the movement of aircraft and vehicles on an apron.

- Barrette. Three or more aeronautical ground lights closely spaced in a transverse line so that from a distance they appear as a short bar of light.

- Certified aerodrome. An aerodrome whose operator has been granted an aerodrome certificate.

- Capacitor discharge light. A lamp in which high-intensity flashes of extremely short duration are produced by the discharge of electricity at high voltage through a gas enclosed in a tube.
- Clearway. A defined rectangular area on the ground or water under the control of the appropriate authority, selected or prepared as a suitable area over which an aeroplane may make a portion of its initial climb to a specified height.

- Cyclic redundancy check (CRC). A mathematical algorithm applied to the digital expression of data that provides a level of assurance against loss or alteration of data.

- Data quality. A degree or level of confidence that the data provided meet the requirements of the data user in terms of accuracy, resolution and integrity.

- Declared distances.

  a) Take-off run available (TORA). The length of runway declared available and suitable for the ground run of an aeroplane taking off.

  b) Take-off distance available (TODA). The length of the take-off run available plus the length of the clearway, if provided.

c) Accelerate-stop distance available (ASDA). The length of the take-off run available plus the length of the stopway, if provided.

d) Landing distance available (LDA). The length of runway which is declared available and suitable for the ground run of an aeroplane landing.

- Dependent parallel approaches. Simultaneous approaches to parallel or near-parallel instrument runways where radar separation minima between aircraft on adjacent extended runway centre lines are prescribed.

- Displaced threshold. A threshold not located at the extremity of a runway.

- Effective intensity. The effective intensity of a flashing light is equal to the intensity of a fixed light of the same colour which will produce the same visual range under identical conditions of observation.

- Ellipsoid height (Geodetic height). The height related to the reference ellipsoid, measured along the ellipsoidal outer normal through the point in question.

- Fixed light. A light having constant luminous intensity when observed from a fixed point.

- Frangible object. An object of low mass designed to break, distort or yield on impact so as to present the minimum hazard to aircraft.

- Geodetic datum. A minimum set of parameters required to define location and orientation of the local reference system with respect to the global reference system/frame.

- Geoid. The equipotential surface in the gravity field of the Earth which coincides with the undisturbed mean sea level (MSL) extended continuously through the continents.

  Note.C The geoid is irregular in shape because of local gravitational disturbances (wind tides, salinity, current, etc.) and the direction of gravity is perpendicular to the geoid at every point.

- Geoid undulation. The distance of the geoid above (positive) or below (negative) the mathematical reference ellipsoid.

  Note.C In respect to the World Geodetic System C 1984 (WGS-84) defined ellipsoid, the difference between the WGS-84 ellipsoidal height and orthometric height represents WGS-84 geoid undulation.

- Hazard beacon. An aeronautical beacon used to designate a danger to air navigation.

- Heliport. An aerodrome or a defined area on a structure intended to be used wholly or in part for the arrival, departure and surface movement of helicopters.

- Holding bay. A defined area where aircraft can be held, or bypassed, to facilitate efficient surface movement of aircraft.

- Holdover time. The estimated time the anti-icing fluid (treatment) will prevent the formation of ice and frost and the accumulation of snow on the protected (treated) surfaces of an aeroplane.

- Human Factors principles. Principles which apply to aeronautical design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration to human performance.

- Human performance. Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.

- Identification beacon. An aeronautical beacon emitting a coded signal by means of which a particular point of reference can be identified.

- Independent parallel approaches. Simultaneous approaches to parallel or near-parallel instrument runways where radar separation minima between aircraft on adjacent extended runway centre lines are not prescribed.

- Independent parallel departures. Simultaneous departures from parallel or near-parallel instrument runways.

- Instrument runway. One of the following types of runways intended for the operation of aircraft using instrument approach procedures:

    a) Non-precision approach runway. An instrument runway served by visual aids and a non-visual aid providing at least directional guidance adequate for a straight-in approach.

    b) Precision approach runway, category I. An instrument runway served by ILS and/or MLS and visual aids intended for operations with a decision height not lower than 60 m (200 ft) and either a visibility not less than 800 m or a runway visual range not less than 550 m.

    c) Precision approach runway, category II. An instrument runway served by ILS and/or MLS and visual aids intended for operations with a decision height lower than 60 m (200 ft) but not lower than 30 m (100 ft) and a runway visual range not less than 350 m.

d) Precision approach runway, category III. An instrument runway served by ILS and/or MLS to and along the surface of the runway and:

A C intended for operations with a decision height lower than 30 m (100 ft), or no decision height and a runway visual range not less than 200 m.

B C intended for operations with a decision height lower than 15 m (50 ft), or no decision height and a runway visual range less than 200 m but not less than 50 m.

C C intended for operations with no decision height and no runway visual range limitations.

Note.C Visual aids need not necessarily be matched to the scale of non-visual aids provided. The criterion for the selection of visual aids is the conditions in which operations are intended to be conducted.

- Integrity (aeronautical data). A degree of assurance that an aeronautical data and its value has not been lost nor altered since the data origination or authorized amendment.

- Intermediate holding position. A designated position intended for traffic control at which taxiing aircraft and vehicles shall stop and hold until further cleared to proceed, when so instructed by the aerodrome control tower.

- Landing area. That part of a movement area intended for the landing or take-off of aircraft.

- Landing direction indicator. A device to indicate visually the direction currently designated for landing and for take-off.
- Lighting system reliability. The probability that the complete installation operates within the specified tolerances and that the system is operationally usable.

- Manoeuvring area. That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, excluding aprons.

- Marker. An object displayed above ground level in order to indicate an obstacle or delineate a boundary.

- Marking. A symbol or group of symbols displayed on the surface of the movement area in order to convey aeronautical information.

- Movement area. That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and the apron(s).

- Near-parallel runways. Non-intersecting runways whose extended centre lines have an angle of convergence/divergence of 15 degrees or less.

- Non-instrument runway. A runway intended for the operation of aircraft using visual approach procedures.

- Obstacle. All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that are located on an area intended for the surface movement of aircraft or that extend above a defined surface intended to protect aircraft in flight.

- Obstacle free zone (OFZ). The airspace above the inner approach surface, inner transitional surfaces, and balked landing surface and that portion of the strip bounded by these surfaces, which is not penetrated by any fixed obstacle other than a low-mass and frangibly mounted one required for air navigation purposes.

- Orthometric height. Height of a point related to the geoid, generally presented as an MSL elevation.

- Pavement classification number (PCN). A number expressing the bearing strength of a pavement for unrestricted operations.

- Precision approach runway, see Instrument runway.

- Primary runway(s). Runway(s) used in preference to others whenever conditions permit.

- Road. An established surface route on the movement area meant for the exclusive use of vehicles.

- Road-holding position. A designated position at which vehicles may be required to hold.

- Runway. A defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft.

- Runway end safety area (RESA). An area symmetrical about the extended runway centre line and adjacent to the end of the strip primarily intended to reduce the risk of damage to an aeroplane undershooting or overrunning the runway.

- Runway guard lights. A light system intended to caution pilots or vehicle drivers that they are about to enter an active runway.

- Runway-holding position. A designated position intended to protect a runway, an obstacle limitation surface, or an ILS/ MLS critical/sensitive area at which taxiing aircraft and vehicles shall stop and hold, unless otherwise authorized by the aerodrome control tower.

- Runway strip. A defined area including the runway and stopway, if provided, intended:

  a) to reduce the risk of damage to aircraft running off a runway; and

  b) to protect aircraft flying over it during take-off or landing operations.

- Runway visual range (RVR). The range over which the pilot of an aircraft on the centre line of a runway can see the runway surface markings or the lights delineating the runway or identifying its centre line.

- Safety Management System. A system for the management of safety at aerodromes including the organizational structure, responsibilities, procedures, processes and provisions for the implementation of aerodrome safety policies by an aerodrome operator, which provides for control of safety at, and the safe use of, the aerodrome.

- Segregated parallel operations. Simultaneous operations on parallel or near-parallel instrument runways in which one runway is used exclusively for approaches and the other runway is used exclusively for departures.

- Shoulder. An area adjacent to the edge of a pavement so prepared as to provide a transition between the pavement and the adjacent surface.

- Sign.

  a) Fixed message sign. A sign presenting only one message.

  b) Variable message sign. A sign capable of presenting several pre-determined messages or no message, as applicable.

- Signal area. An area on an aerodrome used for the display of ground signals.
- Slush. Water-saturated snow which with a heel-and-toe slap- down motion against the ground will be displaced with a splatter; specific gravity: 0.5 up to 0.8.

  Note.C Combinations of ice, snow and/or standing water may, especially when rain, rain and snow, or snow is falling, produce substances with specific gravities in excess of 0.8. These substances, due to their high water/ice content, will have a transparent rather than a cloudy appearance and, at the higher specific gravities, will be readily distinguishable from slush.

- Snow (on the ground).

  a) Dry snow. Snow which can be blown if loose or, if compacted by hand, will fall apart again upon release; specific gravity: up to but not including 0.35.

b) Wet snow. Snow which, if compacted by hand, will stick together and tend to or form a snowball; specific gravity: 0.35 up to but not including 0.5.

c) Compacted snow. Snow which has been compressed into a solid mass that resists further compression and will hold together or break up into lumps if picked up; specific gravity: 0.5 and over.

- Station declination. An alignment variation between the zero degree radial of a VOR and true north, determined at the time the VOR station is calibrated.

- Stopway. A defined rectangular area on the ground at the end of take-off run available prepared as a suitable area in which an aircraft can be stopped in the case of an abandoned take-off.

- Switch-over time (light). The time required for the actual intensity of a light measured in a given direction to fall from 50 per cent and recover to 50 per cent during a power supply changeover, when the light is being operated at intensities of 25 per cent or above.

- Take-off runway. A runway intended for take-off only.

- Taxiway. A defined path on a land aerodrome established for the taxiing of aircraft and intended to provide a link between one part of the aerodrome and another, including:

a) Aircraft stand taxilane. A portion of an apron designated as a taxiway and intended to provide access to aircraft stands only.

b) Apron taxiway. A portion of a taxiway system located on an apron and intended to provide a through taxi route across the apron.

c) Rapid exit taxiway. A taxiway connected to a runway at an acute angle and designed to allow landing aeroplanes to turn off at higher speeds than are achieved on other exit taxiways thereby minimizing runway occupancy times.

- Taxiway intersection. A junction of two or more taxiways.

- Taxiway strip. An area including a taxiway intended to protect an aircraft operating on the taxiway and to reduce the risk of damage to an aircraft accidentally running off the taxiway.

- Threshold. The beginning of that portion of the runway usable for landing.

- Touchdown zone. The portion of a runway, beyond the threshold, where it is intended landing aeroplanes first contact the runway.

- Usability factor. The percentage of time during which the use of a runway or system of runways is not restricted because of the cross-wind component.

MEANING OF AERODROME WARNINGS

Aerodrome warnings are issued when phenomena like Ice / snow deposits, Strong winds, Heavy showers and thunderstorms, Black ice and Fog and low clouds occur.

ICAO NORMS ON AERODROME DATA AND WARNINGS

Aeronautical data

Determination and reporting of aerodrome related aeronautical data shall be in accordance with the accuracy and integrity requirements set forth in Tables 1 to 5 contained in Appendix 5 while taking into account the established quality system procedures. Accuracy requirements for aeronautical data are based upon a 95 per cent confidence level and in that respect, three types of positional data shall be identified: surveyed points (e.g. runway threshold), calculated points (mathematical calculations from the known surveyed points of points in space, fixes) and declared points (e.g. flight information region boundary points).

Note.C Specifications governing the quality system are given in ICAO Annex 15, Chapter 3.

CAA shall ensure that integrity of aeronautical data is maintained throughout the data process from survey/origin to the next intended user. Aeronautical data integrity requirements shall be based upon the potential risk resulting from the corruption of data and upon the use to which the data item is put. Consequently, the following classification and data integrity level shall apply:

a) critical data, integrity level 1 10-8: there is a high probability when using corrupted critical data that the continued safe flight and landing of an aircraft would be severely at risk with the potential for catastrophe;

b) essential data, integrity level 1 10-5: there is a low probability when using corrupted essential data that the continued safe flight and landing of an aircraft would be severely at risk with the potential for catastrophe; and

c) routine data, integrity level 1 10-3: there is a very low probability when using corrupted routine data that the continued safe flight and landing of an aircraft would be severely at risk with the potential for catastrophe.

Protection of electronic aeronautical data while stored or in transit shall be totally monitored by the cyclic redundancy check (CRC). To achieve protection of the integrity level of critical and essential aeronautical data as classified in above, a 32 or 24 bit CRC algorithm shall apply respectively.

To achieve protection of the integrity level of routine aeronautical data above, a 16 bit CRC algorithm shall apply.

Note.C Guidance material on the aeronautical data quality requirements (accuracy, resolution, integrity, protection and traceability) is contained in the ICAO World Geodetic System C 1984 (WGS-84) Manual (Doc 9674). Supporting material in respect of the provisions of Appendix 5 related to accuracy and integrity of aeronautical data, is contained in RTCA Document DO-201A and European Organization for Civil Aviation Equipment (EUROCAE) Document ED-77, entitled ‘Industry Requirements for Aeronautical Information’.

Geographical coordinates indicating latitude and longitude shall be determined and reported to the aeronautical information services authority in terms of the World Geodetic System C 1984 (WGS-84) geodetic reference datum, identifying those geographical coordinates which have been transformed into WGS-84 coordinates by mathematical means and whose accuracy of original field work does not meet the requirements in Appendix 5, Table 1.

The order of accuracy of the field work shall be such that the resulting operational navigation data for the phases of flight will be within the maximum deviations, with respect to an appropriate reference frame, as indicated in tables contained in Appendix 5.

In addition to the elevation (referenced to mean sea level) of the specific surveyed ground positions at aerodromes, geoid undulation (referenced to the WGS-84 ellipsoid) for those positions as indicated in Appendix 5, shall be determined and reported to the aeronautical information services authority.

Note 1.C An appropriate reference frame is that which enables WGS-84 to be realized on a given aerodrome and with respect to which all coordinate data are related.

Note 2.C Specifications governing the publication of WGS-84 coordinates are given in ICAO Annex 4, Chapter 2 and ICAO Annex 15, Chapter 3.

Aerodrome reference point

An aerodrome reference point shall be established for an aerodrome.

The aerodrome reference point shall be located near the initial or planned geometric centre of the aerodrome and shall normally remain where first established.

The position of the aerodrome reference point shall be measured and reported to the aeronautical information services authority in degrees, minutes and seconds.

Aerodrome and runway elevations

The aerodrome elevation and geoid undulation at the aerodrome elevation position shall be measured to the accuracy of one-half metre or foot and reported to the aeronautical information services authority.

For an aerodrome used by international civil aviation for non-precision approaches, the elevation and geoid undulation of each threshold, the elevation of the runway end and any significant high and low intermediate points along the runway shall be measured to the accuracy of one-half metre or foot and reported to the aeronautical information services authority.

For precision approach runway, the elevation and geoid undulation of the threshold, the elevation of the runway end and the highest elevation of the touchdown zone shall be measured to the accuracy of one-quarter metre or foot and reported to the aeronautical information services authority.

Note.C Geoid undulation must be measured in accordance with the appropriate system of coordinates.

Aerodrome reference temperature

An aerodrome reference temperature shall be determined for an aerodrome in degrees Celsius.

The aerodrome reference temperature shall be the monthly mean of the daily maximum temperatures for the hottest month of the year (the hottest month being that which has the highest monthly mean temperature). This temperature shall be averaged over a period of years.

Aerodrome dimensions and related information

The following data shall be measured or described, as appropriate, for each facility provided on an aerodrome:

a) runway C true bearing to one-hundredth of a degree, designation number, length, width, displaced threshold location to the nearest metre or foot, slope, surface type, type of runway and, for a precision approach runway category I, the existence of an obstacle free zone when provided;

b) strip }
} length, width to the nearest metre or foot,
runway end safety area surface type;
stopway }

c) taxiway C designation, width, surface type;

d) apron C surface type, aircraft stands;

e) the boundaries of the air traffic control service;

f) clearway C length to the nearest metre or foot, ground profile;

g) visual aids for approach procedures, marking and lighting of runways, taxiways and aprons, other visual guidance and control aids on taxiways and aprons, including taxi-holding positions and stopbars, and location and type of visual docking guidance systems;

h) location and radio frequency of any VOR aerodrome check-point;

i) location and designation of standard taxi-routes; and

j) distances to the nearest metre or foot of localizer and glide path elements comprising an instrument landing system (ILS) or azimuth and elevation antenna of microwave landing system (MLS) in relation to the associated runway extremities.

The geographical coordinates of each threshold shall be measured and reported to the aeronautical information services authority in degrees, minutes, seconds and hundredths of seconds.

The geographical coordinates of appropriate taxiway centre line points shall be measured and reported to the aeronautical information services authority in degrees, minutes, seconds and hundredths of seconds.

The geographical coordinates of each aircraft stand shall be measured and reported to the aeronautical information services authority in degrees, minutes, seconds and hundredths of seconds.

The geographical coordinates of significant obstacles in the approach and take-off areas, in the circling area and in the vicinity of an aerodrome shall be measured and reported to the aeronautical information services authority in degrees, minutes, seconds and tenths of seconds. In addition, the top elevation rounded up to the nearest metre or foot, type, marking and lighting (if any) of the significant obstacles shall be reported to the aeronautical information services authority.

Note.C This information may best be shown in the form of charts such as those required for the preparation of aeronautical publications as specified in ICAO Annexes 4 and 15.

Strength of pavements

The bearing strength of a pavement shall be determined.

The bearing strength of a pavement intended for aircraft of apron (ramp) mass greater than 5 700 kg shall be made available using the aircraft classification number C pavement classification number (ACN-PCN) method by reporting all of the following information:

a) the pavement classification number (PCN);

b) pavement type for ACN-PCN determination;

c) subgrade strength category;

d) maximum allowable tire pressure category or maximum allowable tire pressure value; and

e) evaluation method.

Note.C If necessary, PCNs may be published to an accuracy of one-tenth of a whole number.

The pavement classification number (PCN) reported shall indicate that an aircraft with an aircraft classification number (ACN) equal to or less than the reported PCN can operate on the pavement subject to any limitation on the tire pressure, or aircraft all-up mass for specified aircraft type(s).

Note.C Different PCNs may be reported if the strength of the pavement is subject to significant seasonal variation.

The ACN of an aircraft shall be determined in accordance with the standard procedures associated with the ACN-PCN method.

Note.C The standard procedures for determining the ACN of an aircraft are given in the ICAO Aerodrome Design Manual, Part3. For convenience several aircraft types currently in use have been evaluated on rigid and flexible pavements founded on the four subgrade categories in 2.6.6 b) below and the results tabulated in that manual.

For the purposes of determining the ACN, the behaviour of a pavement shall be classified as equivalent to a rigid or flexible construction.

Information on pavement type for ACN-PCN determination, subgrade strength category, maximum allowable tire pressure category and evaluation method shall be reported using the following codes:

a) Pavement type for ACN-PCN determination: Code

Rigid pavement	R
Flexible pavement	F

Note.C If the actual construction is composite or non-standard, include a note to that effect (see example 2 below).

b) *Subgrade strength category:*

High strength: characterized by K = 150MN/M^3 and representing all K values above 120 MN/M^3 for rigid pavements, and by CBR = 15 and representing all CBR values above 13 for flexible pavements.

Medium strength: characterized by K = 80MN/M^3 and representing a range in K of 60 to 120 MN/M^3 for rigid pavements, and by CBR = 10 and representing a range in CBR of 8 to 13 for flexible

b) *Subgrade strength cat*
Code

High A *strength:* characte
rigid pavements, and by

Med B *um strength:* chara
for rigid pavements, an

pavements.

Low strength: characterized by K = 40MN/M^3 and representing a range in K of 25 to 60 MN/M^3 for rigid pavements, and by CBR = 6 and representing a range in CBR of 4 to 8 for flexible pavements.

Ultra low strength: characterized by K = 20MN/M^3 and representing all K values below 25 MN/M^3 for rigid pavements, and by CBR = 3 and representing all CBR values below 4 for flexible pavements.

pavements.

LowC strength: character
rigid pavements, and by

UltrD low strength: cha
for rigid pavements, and

c) Maximum allowable tire pressure category:	Code
High: no pressure limit	W
Medium: pressure limited to 1.50 MPa	X
Low: pressure limited to 1.00 MPa	Y
Very low: pressure limited to 0.50 MPa	Z

d) Evaluation method:

Code Technical evaluation: representing a specific study of the pavement characteristics and application T of pavement behaviour technology.

Using aircraft experience: representing a knowledge of the specific type and mass of aircraft U satisfactorily being supported under regular use.

Note.C The following examples illustrate how pavement strength data are reported under the ACN-PCN method. Example 1.C If the bearing strength of a rigid pavement, resting on a medium strength subgrade, has been assessed by technical evaluation to be PCN 80 and there is no tire pressure limitation, then the reported information would be:

PCN 80 / R / B / W / T

Example 2.C If the bearing strength of a composite pavement, behaving like a flexible pavement and resting on a high strength subgrade, has been assessed by using aircraft experience to be PCN 50 and the maximum tire pressure allowable is 1.00 MPa, then the reported information would be:

PCN 50 / F / A / Y / U

Note.C Composite construction.

Example 3.C If the bearing strength of a flexible pavement, resting on a medium strength subgrade, has been assessed by technical evaluation to be PCN 40 and the maximum allowable tire pressure is 0.80 MPa, then the reported information would be:

PCN 40 / F / B / 0.80 MPa /T

Example 4.C If a pavement is subject to a B747-400 all-up mass limitation of 390 000 kg, then the reported information would include the following note.

Note.C The reported PCN is subject to a B747-400 all-up mass limitation of 390 000 kg.

Criteria shall be established to regulate the use of a pavement by an aircraft with an ACN higher than the PCN reported for that pavement in accordance with 2.6.2 and 2.6.3.

Note.C Attachment A, Section 18 details a simple method for regulating overload operations while the ICAO Aerodrome Design Manual, Part 3 includes the descriptions of more detailed procedures for evaluation of pavements and their suitability for restricted overload operations.

The bearing strength of a pavement intended for aircraft of apron (ramp) mass equal to or less than 5 700 kg shall be made available by reporting the following information:

a) maximum allowable aircraft mass; and

b) maximum allowable tire pressure. Example: 4 000 kg/0.50 MPa.

Pre-flight altimeter check location

One or more pre-flight altimeter check locations shall be established for an aerodrome.

A pre-flight check location shall be located on an apron.

Note 1.C Locating a pre-flight altimeter check location on an apron enables an altimeter check to be made prior to obtaining taxi clearance and eliminates the need for stopping for that purpose after leaving the apron.

Note 2.C Normally an entire apron can serve as a satisfactory altimeter check location.

The elevation of a pre-flight altimeter check location shall be given as the average elevation, rounded to the nearest metre or foot, of the area on which it is located. The elevation of any portion of a pre-flight altimeter check location shall be within 3 m (10 ft) of the average elevation for that location.

Declared distances

The following distances shall be calculated to the nearest metre or foot for a runway intended for use by international commercial air transport:

a) take-off run available;

b) take-off distance available;

c) accelerate-stop distance available; and

d) landing distance available.

Note.C Guidance on calculation of declared distances is given in Attachment A, Section 3.

Condition of the movement area and related facilities

Information on the condition of the movement area and the operational status of related facilities shall be provided to the appropriate aeronautical information service units, and similar information of operational significance to the air traffic services units, to enable those units to provide the necessary information to arriving and departing aircraft. The information shall be kept up to date and changes in conditions reported without delay.

The condition of the movement area and the operational status of related facilities shall be monitored and reports on matters of operational significance or affecting aircraft performance given, particularly in respect of the following:

a) construction or maintenance work;

b) rough or broken surfaces on a runway, a taxiway or an apron;

c) snow, slush or ice on a runway, a taxiway or an apron;

d) water on a runway, a taxiway or an apron;

e) snow banks or drifts adjacent to a runway, a taxiway or an apron;

f) anti-icing or de-icing liquid chemicals on a runway or a taxiway;

g) other temporary hazards, including parked aircraft;

h) failure or irregular operation of part or all of the aerodrome visual aids; and

i) failure of the normal or secondary power supply.

To facilitate compliance with 2.9.1 and 2.9.2 inspections of the movement area shall be carried out each day at least once where the code number is 1 or 2 and at least twice where the code number is 3 or 4.

Note.C Guidance on carrying out daily inspections of the movement area is given in the ICAO Airport Services Manual, Part 8 and in the ICAO Manual of Surface Movement Guidance and Control Systems (SMGCS).

Water on a runway

Whenever water is present on a runway, a description of the runway surface conditions on the centre half of the width of the runway, including the possible assessment of water depth, where applicable, shall be made available using the following terms:

DAMP C the surface shows a change of colour due to moisture.

WET C the surface is soaked but there is no standing water.

WATER PATCHES C significant patches of standing water are visible.

FLOODED C extensive standing water is visible.

Information that a runway or portion thereof may be slippery when wet shall be made available.

2.9.6 A runway or portion thereof shall be determined as being slippery when wet when the measurements specified in 9.4.5 show that the runway surface friction characteristics as measured by a continuous friction measuring device are below the minimum friction level specified by the CAA.

Note.C Guidance on determining and expressing the minimum friction level is provided in Attachment A, Section 7.

Information on the minimum friction level specified by the CAA for reporting slippery runway conditions and the type of friction measuring device used shall be made available.

When it is suspected that a runway may become slippery under unusual conditions, then additional measurements shall be made when such conditions occur, and information on the runway surface friction characteristics made available when these additional measurements show that the runway or a portion thereof has become slippery.

Snow, slush or ice on a runway

Note 1.C The intent of these specifications is to satisfy the SNOWTAM and NOTAM promulgation requirements contained in ICAO Annex 15.

Note 2.C Runway surface condition sensors may be used to detect and continuously display current or predicted information on surface conditions such as the presence of moisture, or imminent formation of ice on pavements.

Whenever a runway is affected by snow, slush or ice, and it has not been possible to clear the precipitant fully, the condition of the runway shall be assessed, and the friction coefficient measured.

Note.C Guidance on determining and expressing the friction characteristics of snow- and ice-covered paved surfaces is provided in Attachment A, Section 6.

The readings of the friction measuring device on snow-, slush-, or ice-covered surfaces shall adequately correlate with the readings of one other such device.

Note.C The principal aim is to measure surface friction in a manner that is relevant to the friction experienced by an aircraft tire, thereby providing correlation between the friction measuring device and aircraft braking performance.

Whenever dry snow, wet snow or slush is present on a runway, an assessment of the mean depth over each third of the runway shall be made to an accuracy of approximately 2 cm for dry snow, 1 cm for wet snow and 0.3 cm for slush.

Disabled aircraft removal

Note.C See 9.3 for information on disabled aircraft removal services.

2.10.1 The telephone/telex number(s) of the office of the aerodrome coordinator of operations for the removal of an aircraft disabled on or adjacent to the movement area shall be made available, on request, to aircraft operators.

2.10.2 Information concerning the capability to remove an aircraft disabled on or adjacent to the movement area shall be made available.

Note.C The capability to remove a disabled aircraft may be expressed in terms of the largest type of aircraft which the aerodrome is equipped to remove.

Rescue and fire fighting

Note.C See 9.2 for information on rescue and fire fighting services.

Information concerning the level of protection provided at an aerodrome for aircraft rescue and fire fighting purposes shall be made available.

The level of protection normally available at an aerodrome shall be expressed in terms of the category of the rescue and fire fighting services as described in 9.2 and in accordance with the types and amounts of extinguishing agents normally available at the aerodrome.

Significant changes in the level of protection normally available at an aerodrome for rescue and fire fighting shall be notified to the appropriate air traffic services units and aeronautical information units to enable those units to provide the necessary information to arriving and departing aircraft. When such a change has been corrected, the above units shall be advised accordingly.

Note.C A significant change in the level of protection is considered to be a change in the category of the rescue and fire fighting service from the category normally available at the aerodrome, resulting from a change in availability of extinguishing agents, equipment to deliver the agents or personnel to operate the equipment, etc.

A significant change shall be expressed in terms of the new category of the rescue and fire fighting service available at the aerodrome.

Visual approach slope indicator systems

The following information concerning a visual approach slope indicator system installation shall be made available:

a) associated runway designation number;

b) type of system according to 5.3.5.2. For an AT-VASIS, PAPI or APAPI installation, the side of the runway on which the lights are installed, i.e. left or right, shall be given;

c) where the axis of the system is not parallel to the runway centre line, the angle of displacement and the direction of displacement, i.e. left or right shall be indicated;

d) nominal approach slope angle(s). For a T-VASIS or an AT-VASIS this shall be angle according to the formula in Figure 5-14 and for a PAPI and an APAPI this shall be angle (B + C) ÷ 2 and (A + B) ÷ 2, respectively as in Figure 5-16; and

e) minimum eye height(s) over the threshold of the on-slope signal(s). For a T-VASIS or an AT-VASIS this shall be the lowest height at which only the wing bar(s) are visible; however, the additional heights at which the wing bar(s) plus one, two or three fly down light units come into view may also be reported if such information would be of benefit to aircraft using the approach. For a PAPI this shall be the setting angle of the third unit from the runway minus 2', i.e. angle B minus 2', and for an APAPI this shall be the setting angle of the unit farther from the runway minus 2', i.e. angle A minus 2'.

Coordination between aeronautical information services and aerodrome authorities

To ensure that aeronautical information services units obtain information to enable them to provide up-to-date pre-flight information and to meet the need for in-flight information, arrangements shall be made between aeronautical information services and aerodrome authorities responsible for aerodrome services to report to the responsible aeronautical information services unit, with a minimum of delay:

a) information on aerodrome conditions (ref. 2.9, 2.10, 2.11 and 2.12 above);

b) the operational status of associated facilities, services and navigation aids within their area of responsibility;

c) any other information considered to be of operational significance.

Before introducing changes to the air navigation system, due account shall be taken by the services responsible for such changes of the time needed by the aeronautical information service for the preparation, production and issue of relevant material for promulgation. To ensure timely provision of the information to the aeronautical information service, close coordination between those services concerned is therefore required.

Of a particular importance are changes to aeronautical information that affect charts and/or computer-based navigation systems which qualify to be notified by the aeronautical information regulation and control (AIRAC) system, as specified in ICAO Annex 15, Chapter 6 and Appendix 4. The predetermined, internationally agreed AIRAC effective dates in addition to 14 days postage time shall be observed by the responsible aerodrome services when submitting the raw information/data to aeronautical information services.

The aerodrome services responsible for the provision of raw aeronautical information/data to the aeronautical information services shall do that while taking into account accuracy and integrity requirements for aeronautical data as specified in Appendix 5 to this Standard.

Note 1.C Specifications for the issue of a NOTAM and SNOWTAM are contained in ICAO Annex 15, Chapter 5, Appendices 6 and 2 respectively.

Note 2.C AIRAC information is distributed by the AIS at least 42 days in advance of the AIRAC effective dates with the objective of reaching recipients at least 28 days in advance of the effective date.

Note 3.C The schedule of the predetermined internationally agreed AIRAC common effective dates at intervals of 28 days, including 6 November 1997 and guidance for the AIRAC use are contained in the ICAO Aeronautical Information Services Manual (Doc 8126, Chapter 3, 3.1.1 and Chapter 4, 4.4).

AERODROME WARNINGS: CRITERIA

The criteria are based on ICAO Annex 3. Warnings will be issued when the following criteria are forecast to affect the aerodrome or are observed at the aerodrome or it's vicinity and are expected to continue. The ICAO definition of vicinity is 8 Km from the perimeter of the aerodrome.

Thunderstorms: The prefix HVY is used for well developed or extensive storms with associated severe weather.

Tropical cyclone: warning issued if TC observed or forecast and the 10 minute surface wind speed at the aerodrome is expected to be 34 Knots or more

Hail: Stones expected to be 5 mm diameter or greater.

Sand storm: Visibility expected to be less than 1000 meters with or without strong surface winds. The prefix HVY is used if the visibility is expected to be 200 meters or less.

Dust storm: Visibility expected to be less than 1000 meters with or without strong surface winds. The prefix HVY is used if the visibility is expected to be 200 meters or less.

Rising sand or dust: Visibility expected to be between 1000 meters and 3000 meters, caused by surface winds at the aerodrome.

Strong surface winds and gusts: Wind reaching mean speeds of 20 knots or more. Gusts will be including if observed or forecast maximum winds are 10 knots or more above the mean speed.

Squall: A sudden increase of the 2 min average wind speed by at least 16 knots, the speed rising to 22 knots or more and lasting for at least one minute.

Volcanic Ash: likely to be associated with the forecast advection of volcanic ash cloud over the aerodrome.

IMPORTANT: Wind shear warning and temperature inversion warnings are NOT classified as aerodrome warnings. By definition aerodrome warnings are issued for conditions that affect aircraft and services on the ground. Wind shear and temperature inversion warnings are only significant to aircraft in flight.

CLEAR AIR TURBULENCE

TURBULENCE AND CLEAR-AIR-TURBULENCE (CAT): MEANING

Turbulence is air movement that normally cannot be seen and often occurs unexpectedly. It can happen because of changes in air pressure, jet streams, waves created by the influence of mountains, cold or warm fronts, and thunderstorms. It can even occur when the sky is clear.

Clear air is a region of the atmosphere with no cumuliform clouds, the region of clear air with probability of turbulence is the high troposphere.

Clear-air turbulence is impossible to detect with the naked eye and very difficult to detect with conventional radar. To predict CAT is hard for meteorologists because it’s so high in the sky that even when caused by factors that can be measured, intensity and location cannot be determined precisely.

The atmospheric region most susceptible to CAT is the high troposphere at altitudes of around 7,000–12,000 metres (23,000–39,000 ft) as it meets the tropopause. Here CAT is most frequently encountered in the regions of jet streams. At lower altitudes it may also occur near mountain ranges. Thin cirrus cloud can also indicate high probability of CAT.

Clear-air turbulence is usually impossible to detect with the naked eye and very difficult to detect with conventional radar with the result that it is difficult for aircraft pilots to detect and avoid it. However, it can be remotely detected with instruments that can measure turbulence with optical techniques, such as scintillometers, Doppler LIDARs, or N-slit interferometers.

Although the altitudes near the tropopause are usually cloudless, thin cirrus cloud can form where there are abrupt changes of air velocity, for example associated with jet streams. Lines of cirrus perpendicular to the jet stream indicate possible CAT, especially if the ends of the cirrus are dispersed, in which case the direction of dispersal can indicate if the CAT is stronger at the left or at the right of the jet stream.

Detecting and predicting CAT is hard for meteorologists because it is at such heights that even when caused by factors that can be measured, intensity and location cannot be determined precisely. However because this turbulence affects long range aircraft that fly near the tropopause, CAT has been intensely studied. Several factors affect the likelihood of CAT. Often more than one factor is present. 64% of the non-light turbulences (not only CAT) are observed less than 150 nautical miles (280 km) away from the core of a jet stream.

CAT can be hazardous to the comfort, and, though very infrequently, even the safety, of air travel. An increase in clear-air turbulence is an expected effect of global warming

FACTORS THAT CAUSE OR INDICATE CLEAR AIR TURBULENCE:

Jet Streams

A Jet Stream is a narrow, fast moving current of air, normally close to the Tropopause and generated as a result of the temperature gradient between air masses. Although not all jet streams have CAT associated with them, there can be significant vertical and horizontal Wind Shear on the edges of the jet stream giving rise to sometimes severe clear air turbulence. Any CAT is strongest on the cold side of the jet stream where the wind shear is greatest. In the vicinity of a jet stream, CAT can be encountered anywhere from 7,000 feet below to about 3,000 feet above the tropopause. Because the strong vertical and horizontal wind shear occurs over short distances, this jet stream related CAT tends to be shallow and patchy so a descent or climb of as little as 2,000 feet is often enough to exit the turbulence.

Wind Shear

Wind Shear (windshear, wind gradient) is described as difference in wind speed and direction over a short distance in the atmosphere. Wind shear is broken down into vertical and horizontal components. Horizontal wind shear is seen across weather fronts and near coastal regions. A vertical wind shear is found near the surface, or at upper levels of the atmosphere. Wind shear is a meteorological phenomenon that occurs over short distances, although it can be associated with larger scale cold fronts.

Wind shear is commonly observed near microbursts or downbursts caused by thunderstorms, or other weather events. Wind shear may also be observed around mountains, buildings, wind turbines, and even sailboats. Radiation differences that occur in clear skies can trigger wind shear as well. Aircraft that is taking off or landing can be affected by wind shear which is sometimes a cause for aircraft accidents. Varying levels of turbulence often associated with wind shear are the main culprit in many aircraft accidents.

Wind shear has a dramatic effect on sound movement through the atmosphere. This can contribute to the bending of sound waves, causing sound to travel in directions it was not intended to go. Wind shear is the common reason why we hear things from a distance that we would not normally pick up on. Strong vertical wind shear in the troposphere is capable of slowing the development of tropical cyclones, but may organize storm cells to give them longer life cycles that can produce severe weather. Thermal wind shear plays a role in horizontal temperature differences, and explains the existence of the jet stream.

There are many weather situations where wind shear is commonly observed. Weather fronts with a big difference in temperature (9 ËšF or more) across the front and movement of 30 knots or more cause significant wind shear. Frontal shear can be observed at any altitude between the surface and troposphere, and is often seen horizontally or vertically. Vertical wind shear is more common at higher altitudes. Wind shear associated with upper-level jet streams is a phenomenon known as clear-air turbulence (CAT). This is caused by horizontal and vertical wind gradients that are connected at the edge of the jet streams. The CAT is strongest on the cold air side of the jet stream, which is usually next to or just below the axis of the jet. Low-level jet streams occur overnight ahead of cold fronts. Low-level vertical wind shear occurs near the surface at the lower end of the jet. Winds that blow over mountains causes vertical wind shear on the lee side. If the flow is strong enough, it causes severe turbulence that poses a threat to ascending or descending aircraft. Nocturnal radiation inversion occurs near the surface when it is calm and clear. This can produce wind shear that does not affect the wind above the inversion layer. These nocturnal flows tend to be greatest toward sunrise. A downburst occurs when a shallow layer of rain-cooled air spreads out near the ground level from a parent storm cell. Stronger outflows result in stronger downbursts which, in turn, result in stronger vertical wind shear.

Cold fronts produce stronger horizontal wind shear than warm fronts. A shear line is produced when a front becomes stationary and a line of differing wind speeds occur in separate regions of the front, though the wind direction typically remains constant across the line. Tropical waves moving from east to west across the Atlantic and Pacific basins can trigger horizontal wind shear. Horizontal shear also occurs along land breeze and sea breeze boundaries. Offshore winds are nearly double that of the speed of onshore winds. This is due to friction between land and sea masses. Thermal wind is a meteorological term not associated with actual wind, but a difference in the geostrophic (forces caused by the Earth's rotation and horizontal pressure) wind between two pressure levels. It is present in the atmosphere when horizontal changes in temperature occur.

Thunderstorms require wind shear to organize the storm in such a way to maintain the storm cell for a longer period of time. Wind shear occurs when the storm's inflow separates from the rain-cooled outflow. A nocturnal low level jet-stream can increase the chances of severe weather by increasing the vertical wind shear in the troposphere. Thunderstorms with virtually no vertical wind shear in the atmosphere will quickly diminish as it sends out an outflow in all directions. This will quickly cut off the inflow of warmer, moist air and thus kills the storm.

The effects of wind shear play a significant role on sound travel. The audibility of sounds from distant sources is dependent on the amount of wind shear. Noise barriers have been implemented in areas where significant noise pollution occurs due to wind shear. Roadways and airports are common areas where noise barriers are used. The speed of sound varies with temperature. Sound speed normally decreases as it travels in altitude.

Wind engineering is a field of engineering based on the effects of wind and wind shear on the natural and manmade environment. Wind engineering draws upon meteorology, aerodynamics and other specialist engineering disciplines. Climate models, wind tunnels, and other numerical models are used to study how wind affects objects.

Temperature Gradient

A temperature gradient is a physical quantity that describes in which direction and at what rate the temperature changes the most rapidly around a particular location. The temperature gradient is a dimensional quantity expressed in units of degrees (on a particular temperature scale) per unit length. The SI unit is kelvin per meter (K/m). Temperature gradients in the atmosphere are important in the atmospheric sciences (meteorology, climatology and related fields).

A temperature gradient is the change of temperature over a distance in some given direction. Where the temperature of a gas changes, so does its density and where the density changes CAT can appear.

It has been observed that aircraft frequently encounter turbulence which is not directly associated with cumulus clouds or thunderstorms. This turbulence, which has become known as clear air turbulence, gives little or no visual or radar indication of its presence. The need to detect such turbulence several miles beforehand and change the speed or course of the aircraft in order to minimize the effect of the turbulence upon the aircraft and its cargo is evident.

There appear to be several causes of clear air turbulence. These include upward deflection of air by mountain slopes, convective processes, vertical wind shear in portions of jet streams, etc. In almost all cases, whether as a feature of the causative conditions or as aresult of the occurrence of turbulence, anomalies occur in the distribution of temperature in the atmosphere at and near the turbulent region.

Air emits microwave and infrared radiation whose power flux at a remote point depends upon the temperature of the air and the attenuation characteristics of the intervening air. The existence of a substantial temperature difference in clear air turbulent regions therefore enables such regions to be remotely detected in time to take the necessary preventative measures. This temperature difference can be detected by receiving the microwave or infrared energy with a radiometric receiver. Similarly, the anomalous variation of the incident of such indicators as ozone or water vapor has been found to be related to turbulent regions.

In order to provide remote warning of clear air turbulence that is directly associated with horizontal temperature gradients a number of radiometric techniques have been proposed and tried to detect such gradients ahead of an aircraft. One prior art system accomplishes this by radiometric scanning in frequency on the skirts of the CO absorption band in order to provide an instantaneous reading of temperature variation along the aircraft path, which will thus show anomalies in gradients. In another prior system there is provided at each instant a single reading of effective temperature which is integrated over the whole path ahead of the aircraft and time history is relied upon to remotely reveal anomalies in the temperature gradients in the direction of the aircrafts path. These systems have, however, had disadvantages. They have been complex and expensive and have required a reference, such as black body for example, with which to compare the signals received by the radiometric receiver or radiometer. There have also been problems in stabilizing the airborne radiometers. Inasmuch as temperature varies considerably with vertical distance or altitude small pitch variations in the radiometers alignment introduces substantial error and noise into its readings.

Special Cloud Formation

A characteristic pattern of cirrus clouds are billows. Often they are a strong signal for CAT. The billows are an indication of breakdown into turbulent flow in the form of Kelvin-Helmholtz instability. Note that even in the stratosphere, where static stability is high, turbulence and breaking waves can still be generated if the wind shear is strong enough. Values of Richardson number Ri (the ratio of potential to kinetic energy) less than 0.25 will allow the production of breaking waves. Values between 0.25 and 1.0 will allow turbulence to persist, whereas values greater than 1.0 will tend to cause any existing turbulence to subside. Mountain wave activity is often very apparent in satellite imagery. Trapped waves are often easily diagnosed, with very clear wave-like patterns in both infrared and visible imagery. Untrapped, or vertically propagating waves, are often indicated by orographic cirrus cloud features. I

Thunderstorms

Thunderstorms are two main classes, Air mass and frontal

a. Air mass thunderstorm

It is appear in a fairly uniform air mass. Storm of this class are most common over land in summer, and arise from the strong solar heating of the lowest layers. Calm conditions together with a high humidity are most favorable and this combination found in shallow low pressure systems. Cols and Troughs, The strong break out about mid afternoon, when the surface temps are highest.

b. Frontal Thunderstorm

The difference between air mass and frontal thunderstorm is that air mass storms are isolated or well scattered. Frontal storms usually occur along narrow belts. Frontal thunderstorms are associated with surface or upper fronts, like cold front storms, warm front storms, storms at occlusions. The most important weather features of a thunderstorm are hail, turbulence, icing, lightning and electrical effects.

IMPACTING STRATEGIES AT AIRPORTS

All Meteorological offices at airports are already taking necessary steps in advance to the smooth functioning of air navigation. Qualified experienced staff quipped with advanced instruments like automatic weather station, satellite monitoring systems, Runway Visual Rang, silometer and so on.

Satellite Receiving Equipment

This system is used for reception of images from the meteosat geostationary satellite such as NOAA and Meteor POLAR OPBITTING SATELLITES. Pictures are visual and infrared images. Meteosat satellite, 36000 Km away from the surface of the earth in a fixed position transmit the images and ground stations receive the pictures direct from the satellite.

FLIGHT DOCUMENTATION

Forecast folders including Terminal Aerodrome Forecast (TAF) are to be provided to all aircraft operating from or transiting through, with prognostic charts. These charts show the wind direction / speed, temperatures, turbulence, tropopause height, cloud boundary etc

Tephigrams

Every day at 0000 UTC the meteorologist plotted a Tephigram. Temperatures are marked by a dot inside a small circle and dew points should be marked by a small cross. Temperature is then joined by a continuous line and the dew points by a pecked line. The standard level winds and maximum winds are entered along the right hand side of the main graph. The tropopause point is marked with ‘T’. After plotting this chart, forecaster can forecast the expected maximum temperature, wind speed and direction of the standard levels and cloud base. This chart is very useful for forecasting purposes.

Radar and other improvements in weather forecasting now make thunderstorms and their lightning easy to avoid.

There are dedicated forecasters who send minute by minute weather information to aircraft to help them avoid hazardous weather. Air traffic controllers also keep an eye on the weather in their area, to help in their effort to guide incoming and outgoing planes. Radar can detect rotating air in storms which can indicate the potential presence of tornadoes etc.

EFFECT OF AIR TURBULANCE ON AIRCRAFT

In the context of air flight, CAT is sometimes colloquially referred to as "air pockets". Standard airplane radars cannot detect CAT, as CAT is not associated with clouds that show unpredictable movement of the air. Airlines and pilots should be aware of factors that cause or indicate CAT to reduce the probability of meeting turbulence.

Aircraft in level flight rely on a constant air density to retain stability. Where air density is significantly different, for instance because of temperature gradient, especially at the tropopause, CAT can occur. Where an aircraft changes its position horizontally from within the jet stream to outside the jet stream, or vice versa, a horizontal temperature gradient may be experienced. Because jet streams meander, such a change of position need not be the result of a change of course by the aircraft.

Because the altitude of the tropopause is not constant, an airplane that flies at a constant altitude would traverse it and encounter any associated CAT.

When a pilot experiences CAT, a number of rules should be applied:

- The aircraft must sustain the recommended velocity for turbulence.
- When following the jet stream to escape from the CAT, the aircraft must change altitude and/or heading.
- When the CAT arrives from one side of the airplane, the pilot must observe the thermometer to determine whether the aircraft is above or below the jet stream and then move away from the tropopause.
- When the CAT is associated with a sharp trough, the plane must go through the low-pressure region instead of around it.
- The pilot must communicate position, altitude and velocity of the turbulence to Air Traffic Control, to warn other aircraft entering the region.

CAN TURBULENCE CAUSE PLANE CRASH?

Severe turbulence forced a New York-bound flight to divert and land shortly after leaving Houston. Passengers were thrown into the ceiling and then back onto the floor. Can turbulence cause a plane to crash?

Yes, but it’s very unlikely these days. In the past, turbulence has stressed planes beyond their tolerances. In 1966, for example, a British Overseas Airways captain veered from his original flight path out of Tokyo so that his passengers could get a look at Mount Fuji. As the Boeing 707 approached the mountain, it experienced unexpectedly powerful winds—probably in excess of 140 miles per hour—that tore the tail fin apart and downed the plane. Aircraft design has come a long way since then, though, and aerospace engineers say modern aircraft are extremely unlikely to suffer a similar fate. Today's commercial airliners are designed to withstand forces one-and-a-half times stronger than anything experienced in the last 40 years of flying, and advances in detection systems help pilots avoid severe turbulence.

There are two types of turbulence, although they feel basically the same from inside the passenger cabin. Storm-related turbulence results when water vapor condenses into droplets, releasing energy that heats the surrounding air. As the heated air rises, it becomes less dense, causing it to rise further and more rapidly. The resulting updraft is what buffets a plane. Storm-related turbulence is relatively easy to identify with Doppler radar or simply by observing cloud formation. Pilots can avoid turbulent air by changing course or altitude, or they can minimize its effects by slowing down. Stormy air can still play a role in aviation accidents, though. In 2009, Air France flight 447 flew into an area of storm activity. Attempting to steer the plane clear of the weather, the pilot seems to have sent the plane into an aerodynamic stall that caused it to crash into the Atlantic. Severe turbulence, along with an airspeed sensor malfunction, likely contributed to the plane's erratic movements.

Clear air turbulence, the sneakier variety, occurs when two air masses moving at different speeds or in different directions contact each other. A classic example is waves of air breaking as they pass over mountain peaks. Planes flying across the jet stream also experience clear air turbulence. This kind of turbulence is much more difficult to detect, and pilots are responsible for notifying air traffic control when they encounter it. (When the pilot says, "We're expecting a smooth ride out to [your destination] today," he means there are no storms and no one flying the route has reported clear air turbulence.) Severe clear air turbulence caused the aforementioned 1966 crash in Japan and has even torn parts off of military planes.

While planes are designed to survive even the most severe forms of turbulence, improper maintenance can leave them vulnerable. After turbulence tore a wing off of Wien Consolidated Airlines flight 55 in Alaska in 1968, many considered the crash a freak natural accident. The National Transportation Safety Board investigation concluded, however, that the plane would have survived the winds if not for cracks that resulted from improper maintenance.

Turbulence may be extremely unlikely to down a commercial aircraft these days, but it causes plenty of injuries and even the occasional fatality. Dozens of flight attendants have been hurt in the last decade when their planes struck unexpectedly rough weather, and one passenger died in 1997 when she was thrown upward from her seat and collided with the armrest on the way back down.

Clear-air turbulence (CAT) still remains a major hazard of modern aviation, which may result in severe damage or even loss of aircraft

AIR NAVIGATION

INTRODUCTION

Finding the way from place to another is called Navigation. Point to point movement of an aircraft is an important task, and in the past, it used to be the task of a specialized member of an aircrew-Navigator. This was done by plotting on the chart/map, a course towards a specific area of the earth, generally done by drawing a straight line joining two points called Rhumb line track. Navigator followed this track by plotting the aircraft position using radio aids and making timely course corrections to reach the destination. Today, navigation has become an art nearing to perfection and Navigator has now been replaced by on board and external radio/radar navigational aids which helps an aircraft to navigate between two points. There are three main methods of air navigation, namely, Pilotage; Dead Reckoning (DR) and Radio.

PILOTAGE OR PILOTING

The most common method of air navigation, in this the pilot keeps on course by following a series of landmark on the ground. Usually, pilot will make a pre-flight planning and will draw a line on the aeronautical map to indicate the desired course. As the pilot flies over each selected landmark, he checks it off on the chart/map and makes the course correction to keep the aircraft on track.

DEAD RECKONING

Is the primary navigation method used in the early days of flying, a method on which Lindberg relied on his first trans- Atlantic flight, DR is used while flying long distance over water, forest and deserts, where normal visual identification becomes difficult. Two points on the chart is marked and the course direction is noted and based on the ground speed of the aircraft,- air speed is to be converted into ground speed, taking into consideration the wind effect (wind speed and direction) position of the aircraft is plotted at regular interval.

RADIO NAVIGATION

It is the common method of navigating an aircraft point to point. Pilot sets the course and tuning various radio /radar aids with the set frequencies, he can note his aircraft position in relation to such aids (the aids show aircraft relative position and thereby making the necessary correction). Air Traffic Control Units are able to trace out the aircraft on their radar screen when the concerned aircraft put on the 'transponder' and also by making use of various radio aids. Long distance navigation, more so, across oceans are carried out by three commonly used methods:

Inertial Navigation – It has computer and other special devices that help the pilot to locate his position.

LORAN: Long Range Navigation, aircraft is equipped with necessary aids for receiving special radio signals that help pilots to know its position.

GPS: Global Positioning System is the system which is able to show aircraft's exact position on the earth anytime, anywhere, and any weather. System receiver on the aircraft will receive the signals from concerned satellites around the globe.

NAV AIDS

ADF: Automatic Direction Finder. An aircraft radio navigation which senses and indicates the direction to a low/medium/ frequency non-directional radio beacon (NDB) ground transmitter.

DME: Distance Measuring Equipment, Ground and aircraft equipment which provides distance information and primarily serves as en-route and terminal area navigation.

EFIS: Electronic Flight Instrument System, in which multi-function CRT displays replace traditional instruments for providing flight, navigation and aircraft system information, forming a so-called 'glass cockpit'.

ILS: Instrument Landing System consists of Localizer, Glide Slope and Marker radio beacons (outer, middle and inner) providing horizontal and vertical guidance for the approach for landing.

INS: Inertial Navigation System, it uses gyroscopes and other electronic tracking systems to detect acceleration and deceleration, and computes an aircraft position in latitude and longitude. It is also called IRS-Inertial Reference System.

LORN C: Long Range Navigation is a low frequency radio navigation system and its range is about 1,200 nm by day and 2,300nm by night.

NDB: Non Directional Beacon: A medium frequency navigational aid which transmits non-directional signals, super imposed with a Morse code identifier and received by an aircraft ADF.

RMI: Radio Magnetic Indicator, it combines DI, VOR and /or ADF display and indicates bearings to stations, together with aircraft heading.

RNAV: Area Navigation. A system of radio navigation which permits direct point-to-point off airways navigation by means of an on-board computer creating phantom VOR/DME transmitters termed way points.

TACAN: Tactical Air Navigation. It combines VOR and DME, and uses UHF frequencies, providing information about the bearing and distance from the tuned in ground stations.

TCAS: Traffic Alert and Collision Avoidance System. Radar based airborne collision avoidance system operating independently of ground-based equipment. TCASA-I generates traffic advisories only. TCAS-II provides advisories and collisions avoidance instructions in the vertical plane.

TRANSPONDER: Airborne receiver/transmitter which receives the interrogation signal from the ground and automatically replies according to mode and code selected. Mode A and B are used for identification, using a four digit number allocated by air traffic control. Mode C gives automatic altitude readout from an encoding altimeter.

VHF: Very High Frequency. Radio frequency in the 30-300 MHz band, used for most civil air to ground communication.

VOR: Very High Frequency Omni directional Range. A radio nav aid operating in the 108-118 MHz band. A VOR ground station transmits a two-phase directional signal through 360 degrees. The aircraft's VOR receiver enables a pilot to identify his radial or bearing from/to the ground station. VOR is the most commonly used radio nav aid in flying.

VORTAC: A special VOR which combines VOR and DME, provides information about the bearing and distance from the tuned in ground station.

TERMINOLOGY

EAT: Estimated Approach/Arrival Time

ETA: Estimated Time of Arrival

ETD: Estimated Time of Departure

HDG: Heading, the direction in which an aircraft nose points in flight in the horizontal plane, expressed in compass degrees (360 degrees-000 or 360 is North, 090 East, 180 South and 270 West)

IFR: Instrument Flight Rules, prescribed for the operation of aircraft in instrument meteorological condition.

KNOT (Kt): Standard unit of speed in aviation and marine transportation, equivalent to one nautical mile per hour. One Knot is equal to 1.1515 mph.

Magnetic Course: Horizontal direction, measured in degrees clockwise from the magnetic North. Compass Course is direction measured in degree clockwise from Compass North. Difference between True North and Magnetic North is 'Deviation' and difference between Magnetic North and Compass North is 'Variation' expressed in + or – degrees.

Mach number: Ratio of the airspeed to the speed of sound. Mach ONE is the speed of sound at sea level; its value is appx 760mph and reduces as we go up.

VFR: Visual Flight Rules. Rules applicable to flights in visual meteorological conditions.

GLOBAL POSITIONING SYSTEM (GPS)

GPS is the system able to show you where you're exact position on the earth at anytime and weather conditions. There are three segments namely, Space Segment, User Segment and Control Segment.

Space Segment: The Space Segment comprises of a network of satellites. The complete GPS space system includes 24 satellites, 11,000 nautical miles above the earth; take 12 hours each to go around the earth once or one orbit. They orbit in six different planes and 55 degrees inclination. We can receive signals from six of them at any point on earth. The satellites are equipped with precise clocks that keep accurate time to within three nanoseconds (0.000000003 of a second or 3e-9). Precession timings are important because the receiver must determine exactly how long it takes for signals to travel from each GPS satellite to receiver. Each satellite contains a supply of fuel and small servo engines so that it can be moved in orbit to correct for positioning errors.

Each satellite contains four atomic clocks which are accurate to a nanosecond. Each Satellite emits two separate signals, one for military purposes and one for civilian use.

- Wt 930 kg (in orbit)
- Size: 5.1m
- Travel Velocity: 4km/sec
- Transmit Signals: 1575.42 MHz and 1227.60 MHz
- Receive at: 1783.74 MHz
- Clocks: 2 Cesium and 2 Rubidium
- Design life: 7.5 year (later model Block II R 10 years)

User Segment: As the pilot fly, the GPS receiver continuously calculates the current position and display the correct position/heading. The GPS unit listens to the satellite's signal and measure the time between the satellite's transmission and receipt of the signal. By the process of triangulation among the several satellites' being received, the unit computes the location of the GPS receiver. GPS receiver has to see at least four satellites to compute a three dimensional position- latitude, longitude and altitude. No frequency tuning is required as the frequency of the satellite transmissions are already known by the receiver.

Control Segment: It consists of Master Control Station (one station) responsible for overall management of the remote monitoring and transmission sites, and Monitor Stations (four stations) which checks the exact altitude, position, speed and overall of the orbiting satellites. A station can track up to 11 satellites at a time. This check -up is performed twice a day by each station as the satellites go around the earth.

THE NAS ATM SYSTEM DEVELOPMENT PROCESS

This section establishes the context for the development of an operational concept and future system architecture to achieve the long-range needs of the air transportation system. The argument advanced in this section is that the industry needs to move from historic, reactive approaches to system modernization, and to begin the systematic development of a new NAS system using the principles of systems engineering. The industry needs to focus on the systems analysis or preliminary design phase of a system development to exercise broad trade studies, to examine new concepts of operation in response to critical air transportation mission needs, to derive technical performance requirements and evaluate human performance abilities in support of mission needs, and to provide analysis tools for evaluating economic consequences of alternative transition paths into the future.

Increasingly, the industry is faced with a sense of urgency regarding the modernization of the air traffic control (ATC) system. The age of systems such as ARTS make it difficult to continue to acquire spare parts, while the personnel qualified to maintain these old systems are retiring. At the same time, there is a lack of a mandate for change. The diverse interests of the FAA's users make a consensus regarding the future needs of the system difficult. Michael S. Nolan (Nolan, 1994) describes the genesis of Project Beacon: "It was apparent that the air traffic control system in the United States had been constructed haphazardly in response to situations instead of in anticipation of them." This statement characterizes the state of system development as well today as in 1961.

The most recent systematic attempt at system modernization was the NAS Plan of 1981 (U.S. FAA, 1981). The initiative of FAA's administrator J. Lynn Helms planned a systematic upgrading of the navigation, communication, surveillance, and weather and ATC infrastructure. The driving premise for this modernization, and the economic justification, was based on the concept of remote maintenance, which would sharply reduce O&M costs. Unfortunately, many of the key elements of the NAS Plan failed to come to fruition. The microwave landing system (MLS) program, the Mode S data link, the Advanced Automation System, the Oceanic Display and Planning System (ODAPS), all ended in failure to achieve full operational usefulness. Where improvements were realized, they were often less than completely successful. En route computers were upgraded, but with no new software.

Today the FAA F&E organization is developing new system architecture. The hope is that this architecture will become the blueprint for modernization. But while there is much definition of technology features of the new architecture, there is a lack of agreement about the fundamental measures of what will constitute a successful air traffic infrastructure, both for the near-term and twenty years into the future, across the range of diverse user needs.

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Today the FAA F&E organization is developing new system architecture. The hope is that this architecture will become the blueprint for modernization. But while there is much definition of technology features of the new architecture, there is a lack of agreement about the fundamental measures of what will constitute a successful air traffic infrastructure, both for the near-term and twenty years into the future, across the range of diverse user needs. The FAA’s R,E&D Advisory Committee met in Washington in September (U.S. FAA, 1997) to recommend research needs for the FAA to facilitate system modernization. High priority recommendations centered on the need for improved system development methods with emphasis on systems engineering, software engineering and human factors. Other issues which received numerous citations included programmatic and management concerns, emphasis on information technologies, need to provide enhanced levels of system capacity, safety and security. Finally, the group agreed that a key priority is the need for credible investment analysis. The systems engineering, software engineering and human factors issues form the core of the discussion on system modernization, which provides the framework for the following discussions on concept of operations, human factors and technology assessment, and transition planning and system alternatives evaluation. These preliminary design activities are key to the establishment of system architecture and the associated research needs, which support the needed air transportation needs of capacity, safety and efficiency of operation for the next twenty years.

Another issue central to the discussions of the R, E&D Advisory Committee was the lack of a mandate for system modernization. The airlines, military, general aviation (GA) and business segment of the industry often disagree on specific technology decisions, as well as policy issues. The concern is that the industry lacks agreement on the high level objectives of system modernization and the mission needs of the system, which should drive the technical requirements, concept of operation and system architecture. The approach identified in this section focuses on the preliminary design phase of the system development life cycle, and the need to clearly identify the long range mission needs of the system. It also examines tools and methods to allocate requirements to subsystems, assign functions to system agents and evaluate the performance objectives over the twenty year life of the system.

The summarizes the system engineering steps which divide the life cycle of a major system development into phases: definition of requirements and objectives, analysis of functions and operations, definition of system architecture, design of the system and subsystem elements, production of the system elements, integration of the system in the laboratory of integration and validation testing, certification, and system operation and maintenance. The discipline of the systems engineering process is vital to the successful completion of an airplane development program, where a large team of thousands of engineers must work a complex, real-time, human-in-the-loop, safety critical system development to produce and certify a system integrating subsystems containing hundreds of thousands of line of code and a system architecture of data busses linking hundreds of 'Line Replaceable Units' of differing criticality. The development of a major ATC system upgrade may be an order of magnitude more complex, because it shares the safety criticality and human-in-the-loop real-time nature of the airplane development, and further requires that the existing system remain operational while supporting transition to the new system.

At the airplane level, the preliminary design process may be conducted over a period of a year or two to establish a baseline production go-ahead configuration. The purpose of the preliminary design phase is to evaluate a broad range of airplane configurations over a large set of potential customer needs (typically payload range studies among various city-pairs) to identify the design mission needs of the production go-ahead configuration. This configuration is also the business case basis for negotiations with the customers on sales. The summarizes the Boeing concept of the preliminary design process for the development of air traffic management systems and components. The approach consists of development of traffic demand scenarios, performance of a mission analysis based on evaluating high level system capacity, safety and efficiency objectives, allocation of operational requirements to subsystem technical requirements, and evaluation of technologies, human factors, and economic factors in defining system transitions from the current operating state to the future concept.

The preliminary design process begins with the development of traffic demand scenarios. These scenarios are, in turn, premised on economic, geopolitical, airline business and other factors which may dictate fundamental changes in the operation of the future air transportation system. The objective of the scenario-based planning approach is the identification of a system whose operation is not necessarily optimized for a specific end state, but is robust when evaluated against a range of possible future states of the world. The analysis of risk and the various forms of uncertainty which can influence system development is summarized here. In this instance, risk may be defined as the chance that predictions of future requirements will be significantly in error or that measures to accommodate growth will be unsuccessful. Major elements of risk can be found in the technical area, in politics, in regulation and in pressure on the stakeholders. Planning major changes over so extended a period carries a great deal of risk and there are many variables which must be taken into account. There are several possible scenarios: Traffic growth projections for the future may be too conservative, and growth may exceed expectations. Such initiatives may also result in growth in unexpected areas increasing the uncertainty associated with regional change. Traffic growth may not meet expectations, which are based on expected passenger demand, in turn dependent on economic growth assumptions. Traffic growth is normally assumed to be linear with time, whereas regional change may be much greater in some markets than others or the nature of the growth (pointto- point versus hub-and-spoke service) may change.

The following material summarizes technical, political, regulatory and stakeholder risk. Technical Risk pace of technological advancement may render solutions under development obsolete even before they are implemented. Users are aware that some of the technologies needed for initial transition steps may need to be replaced or augmented if expected air transportation system (ATS) changes are to occur later, and benefits are to be realized. Users may delay implementation of enhancements, allowing delays to grow, in turn reducing demand. Future operational concepts rely on the benefits (ultimately financial) to be realized through the use of technological and procedural changes, many of which are currently theoretical. Some of these postulated solutions may be shown to be impractical or even impossible. The technological and operational solutions may work but expected benefits may not be realized. The solutions may be too costly, resulting in failure to achieve the critical mass of users. It may prove to be impossible to make technological advances which meet the diverse requirements of users and regulators. The global aviation community may find it impossible to arrive at common technological and operational solutions resulting in excessive cost of full implementation. System and operating standards are developed, to a large degree, by volunteer bodies which meet only on an occasional basis. Such an approach results in slow development of standards and consequent delays in development of hardware, software and procedures. Telecommunications developments like video conferencing could find higher acceptance as alternatives to business travel, traditionally a source of high profits for airlines. Business aviation radio bands might also be taken over by telecommunications interests.

Political Risk Sub-regional implementations of Future Air Navigation System (FANS) (e.g. FANSTAR) could spur the industry into a more aggressive approach to the transition process. Restricted funding of Civil Aviation Authority or privatized service provider programs might delay the airlines' ability to realize benefits from new technologies, which would result in increased delays and less growth. The funding of ground infrastructure improvement might be delayed or accelerated changing the economic benefit picture for users. The trend toward charging system users more directly for services will change airline profitability pictures and/or increase ticket prices or even discourage general aviation proliferation. National or international conflict discourages discretionary travel. Regions in which maximum traffic growth are expected (CIS, China, Africa) are the most volatile politically and thus more vulnerable to the effects of unrest. Changes in diplomatic relations between or among countries may accelerate or delay implementation of more efficient routes. Ratification of bilateral agreements (or failure to ratify) may affect international frequencies. Different technological or procedural solutions may be adopted by different countries or blocs, resulting in escalated cost of compliance. Regulatory Risk Communities located under flight paths or close to busy airports may take legal action to block improvements to airports. New concepts of operations must be developed and accepted by regulatory agencies before new technologies and operational procedures can be developed.

Certification periods might be further stretched by unresponsive regulatory authorities, increasing costs and rendering solutions obsolete before implementation. Stakeholder Risk It has been widely publicized that by the year 2015; if air transport safety standards cannot be improved there will be one hull loss globally per week. The perception of worsening safety may mean that passengers will be less eager to fly.

If system capacity cannot keep pace with demand, resulting delays may also reduce passenger demand. Labor action is likely to have only negative effects since it usually results in increased airline costs and diminishes the traveling public’s confidence in the system. Oil prices directly and significantly affect airline costs and fluctuations in the prices beyond those expected could affect growth. Airlines could absorb increases, reducing profits and thus delaying investment in technology, and/or increases could be passed on to passengers through increased ticket prices, reducing demand. Reduced prices could also be passed on to passengers, increasing demand. Political unrest and forms of fundamentalism have been carried to the more stable areas of the world in the form of terrorism. The threat of terrorist action against the air transportation system (e.g. the recent revelation that GPS jammers are now available on the open market), successful attacks or even suspicions that an attack has occurred (e.g. TWA Flight 800) have an immediate effect on passenger demand which can affect airline finances for years afterward.

All users want to invest the minimum possible, at no risk, with a return on investment, within one to two years. It may not be possible to develop transitional steps which allow these aims to be met. The goals of various users are so diverse that it may prove to be impossible to reach equitable solutions, resulting in dilution of benefits.

Airlines may block improvements for competitive reasons. Scenarios for evaluation of the mission must exercise as many of the key risk areas as possible. Also, the transition evaluation process must address risk as a key element in the evaluation of system alternatives. The development of a comprehensive set of future scenarios is beyond the scope of the current contract activity, but this report presents an initial list of issues from which global scenarios for evaluation can be synthesized. These scenario factors are summarized in Global Scenarios. From various governments, industry, and private documented studies, a sample or collage of texts was assembled from which a single world scenario was constructed. In particular, this subtask broaches a range of general ATM issues, although by no means exhaustive, which highlight potential limitations, costs, constraints, and assumptions which may be of importance to the modus operandi of the envisioned NAS future. To help the development of such a global scenario, six general categories were used:

1. Economics/Markets (E),
2. Organizational/Institutional/Operational (O),
3. Technological/Scientific (T),
4. Social/Political (S),
5. Environmental (ENV), and
6. Human-centered/System-centered (H).

A brief description of each broad category follows:

Economics/Markets (E):-

This category reviews the best estimates and forecasts for future air traffic growth and demand figures including a few corresponding issues associated with increased air traffic. Organizational/Institutional/Operational (O) under this category a select sample of issues such as workload, organizational structure and culture, and operational considerations were collated.

Technological/Scientific (T), the increasingly techno scientific NAS operational infrastructure introduces a number of potential pitfalls as well as promises. Issues related to widely utilized computer and information technology-based support and automation are captured by this category.

Social/Political (S):-

In a growing global context of air traffic flows, this category aims to present some of the Potential political and social issues which may impact future operations. Environmental (ENV) This category focuses on possible constraints stemming from tougher future environmental regulations.

HUMAN-CENTERED/SYSTEM-CENTERED (A)

The human/system related issues such as human-centered ATM design and structure are presented under this category. The above broad categories support a more specific issues list, itself composed of a collage of texts drawn from the various documented sources. This helps to structure the top level issues in meaningful sets of issues which inform the scenario writing process. It should be noted that the list below is structured and generally ordered beginning at the top with the broader, more external issues first (e.g. environmental, changing international relationships, et. following with more internal issues towards the bottom (e.g. airport capacity, FAA organizational culture and workforce etc.

This helps to continuously contextualize the many interrelated issues considered in this scenario.

Global scenario issues are:
Issue # 1: Air traffic growth and demand: twenty year outlook
Issue # 2: Some limitations of future ATM concepts
Issue # 3: Changing international relationships
Issue # 4: FAA funding reform
Issue # 5: Environmental considerations
Issue # 6: Air travel and alternatives
Issue # 7: GPS and satellite-based navigation
Issue # 8: ATC systems architecture
Issue # 9: Ground handling
Issue # 10: Airport capacity
Issue # 11: Management of special use airspace
Issue # 12: Airport safety
Issue # 13: FAA organizational culture and workforce

Section 7.1 presents the single global scenario and Appendix B contains the above issues list as well as the referenced texts from which the scenario was constructed. The approach in this section identifies traffic demand as the single most critical 'driver' of future air traffic system needs. The approach relates the future capacity, safety and efficiency needs of the system to assumed traffic growth. The Boeing Current Market Outlook (Boeing, 1997) summarizes the expected growth in air transport to the year 2015 (Figure 2.3). The balance of this section focuses on economic issues and their impact on the demand scenarios for evaluation. The CMO indicates that about two-thirds of world air travel growth is derived from economic growth. Thus economic considerations are to evaluating future scenarios, but an extensive evaluation needs to consider all of the elements reviewed in Appendix B, Global Scenarios.

The traffic forecasting process begins with a regional analysis of gross domestic product (GDP) and travel share. World GDP rates are assumed to grow between 2 and 3% per year for mature economies. GDP rise accounts for about two-thirds of world air travel growth. Regional differentiation is considerable. From 1997 to 2006 China and Hong Kong are assumed to grow at 7.4% annually, while Western Europe grows at 2.4% and North America at 2.3%. Key assumptions include declining yield and resultant fare changes, the use of flight frequencies in competitive markets, the influence of globalization and world trade and the differentiation of markets by stage length. With these various assumptions, GDP change can be related to travel demand, stated in terms of revenue passenger miles (RPMs) and then to operations counts. Regional flows can be translated into projected schedules, with further assumptions. Ten and twenty year forecasts are produced. Key assumptions stated in the CMO are: gross domestic product and increased value drive air travel, relaxation of airline industry regulation allows increased competition, market forces increasingly determine airline routes, airplane selection and the composition of the world fleet, and air traffic control systems and airport capacities respond to demand.

ANALYSIS OF FUTURE SYSTEM CAPACITY, SAFETY AND EFFICIENCY NEEDS

The traffic demand defined in the previous paragraph is used to drive an analysis of the system mission. A high level statement of mission requirements includes safety, capacity and efficiency goals for all system stakeholders. The goals are stated in terms of metrics against which all proposed operational concepts can be evaluated. The mission analysis quantifies the predicted traffic demand for the period in which the operational concept is expected to be in use. This demand is derived from stakeholder business objectives of growth (capacity), efficiency, affordability, and safety, identifying and accounting for the possible effects of constraints that may limit the achievement of any particular objective. The stakeholders often have competing objectives, and a viable operational concept will include a reasonable compromise among these objectives to reduce political risk to system implementation.

A part of this study has included the conduct of a stakeholder survey of future system needs. This survey is provided as a separate document, NAS Stakeholder Needs. Stakeholders interviewed were: Air Transport Association (ATA), Regional Airline Association (RAA), National Business Aviation Association (NBAA), General Aviation Manufacturers Association (GAMA), Aircraft Owners and Pilots Association (AOPA), Helicopter Association International (HAI), Department of Defense (DOD), Airports Council International - North America (ACI-NA), Air Line Pilots Association (ALPA), National Air Traffic Controllers Association (NATCA), and Airline Dispatchers Federation (ADF). The document identifies a wide-ranging number of stakeholder issues. These are grouped into potential system metrics of capacity, efficiency, safety, affordability.

The industry activities that provide the basis for the beginnings of the air transportation system mission needs analysis necessary for establishing system requirements which drive system architecture definition. The focus is on the capacity, safety and efficiency needs, which are the primary focus of the air carrier segment, but mission needs analysis needs to encompass all of the stakeholders' high level objectives and future system needs, as part of the consensus development process. Affordability is addressed as part of the evaluation phase and discussed in

Section 2.3.6

Transition Planning and Tradeoff Analysis, American Airlines (AA) and Sabre Decision Technologies (SDT) have conducted an NAS simulation of the air carrier operations for the next twenty years to examine the system capacity needs over time. The simulation study summarized here is documented in the.

Free Flight White Paper on System Capacity (Chew, 1997), The objective of the study was the identification of a 'critical' year when the airline hub operating integrity threshold is reached. The American Airline NAS study uses the 1996 Official Airline Guide (OAG) as the starting point for analysis, representing over 18,000 flights per day.

A simulation was conducted representing the jet traffic operating over 4,000 routes among the 50 busiest U.S. airports. An annualized traffic growth of 2.3% was assumed, based on a 4% growth in passenger enplanements. These values are consistent with FAA and Boeing 1996 market outlook estimates. Current NAS separation standards were estimated at 7 nm en route, 2 nm in the terminal area and between 1.9 and 4.5 nm for wake vortex avoidance. Figure 2.5 indicates the model output compared with observed. American Airlines data on system delay. The comparison shows that the 1996 simulation data agrees well with empirical results. The analysis examines the change in the average delay system wide, with growth in traffic, as well as the growth in the percentage of flights which experience more than 15 minutes of delay in the system. The 15 minute delay figure is considered key to maintaining hub integrity and provides a good indicator as to the hub viability. The simulation results in the indicate that the 15 minute delay statistic grows faster than the average delay value. American's study indicates delay problems in the NAS will become significant by the 2005 to 2007 time frame. The next step in the analysis was to postulate several system improvements: reduced en route separations from 7 nm to 3 nm, reduced terminal area separations from 4 nm to 2 nm, reduced wake vortex separations from 4.5 to 1.9 nm down to a range of 2.5 to 1.5 nm, and the addition of departure runways. The postulated system enhancements provided system growth for 20 to 25 years from the 1996 base. Figure 2.7 shows the reduction in the system-wide delay with the postulated enhancements. Future traffic demand affects safety and efficiency requirements in the future National Airspace System, just as it does capacity needs. A recent analysis by the Safety organization of the Boeing Commercial Airplane Group (Higgins, 1997) considers the impact of increasing operations, with a flat safety rate (number of fatal or hull loss accidents per million departures) projected into the future. Shows the growth in operations, the extrapolated safety rate and the consequent predicted frequency of accidents.

Growth in Operations, Safety Rate, and Frequency of Accidents (1980-2015), the worldwide accident analysis shows the substantial variation in accident rate by region of the world. The U.S. has the safest and most efficient air transportation system in the world. By region of the world the civilian air transport accident rate (accidents per million departures) is:

Africa 10.7
Asia & Pacific Islands 2.6
China 4.2
Japan 0.8
Europe 0.8
Latin America and Caribbean 4.5
Middle East 2.0
Oceania 0.3
USA & Canada 0.5
Data indicating the primary factor causing accidents is found in Figure 2.9, in this case comparing causal factors between the U.S./Canada and Latin America. ATC is cited for hull loss

accidents between 1982 and 1992 in 19% of the cases in the U.S. and 14% of Latin American hull loss accidents.

The last issue of the system performance factors is efficiency. We define efficiency as the cost, or degree to which the current or future system penalizes the airplane operations, versus a minimal (or optimal) cost. Factors which are contained in the efficiency costs include: route circuitry, other procedural restrictions such as special use airspace prohibitions, and flight delay, often due to inadequate airport or airspace capacity. An ATA study was performed on the base year of 1993 to examine these infrastructure related costs. The ATA assessment was that the current system operation costs $4 billion annually over best operation. United Airline estimated they incur costs of $670 million annually (Cotton, 1994). These costs will increase with traffic loads, and that the delay related component will increase with exponential growth, especially as potential saturation is approached. A key cost avoidance issue is the magnitude of the unimproved system user costs in ten or twenty years.

The above analysis considered the operational costs in the current system against a closeto- ideal operation (no flight delays, no excess routing and other procedural restrictions, access to optimal flight levels). The inefficiency costs in the present system were thus quantified. Another issue which also needs to be addressed is the cost of services provided by the FAA to the users of the system. In many parts of the world, user charges for ATC and navigation services are a recognized (and fast-growing) component of the airline direct operating cost structure. The International Air Transport Association (IATA) recently reported that a “concerted effort to improve operational efficiency, reflected in airline profits of US$4 billion on international scheduled services by IATA members last year. The same improvement ... is not reflected in airport and airspace management operations. ... Pointing to a 36 percent improvement in capacity between 1991 and 1995, coupled with a 30 rise in costs, the airlines say that airport charges have risen by 48 per cent and en route charges 75 per cent.” (Jane’s Airport Review, 1997) In the U.S., the ticket tax currently masks the impact of ATC system operational efficiency, on airline productivity. But changes in the funding basis for the agency, as recommended in the National Civil Aviation Review Commission (NCARC) report (NCARC, 1997) portend a much higher level of user awareness and concern on the ATC system effectiveness.

OPERATIONAL CONCEPT: SYSTEM AGENTS AND FUNCTIONAL ALLOCATION

The summaries at a high level the primary system agents involved in the daily planning and execution of flights in the system. The left side of the figure shows the air traffic planning element, the Traffic Flow Management System, and its agent, the Traffic Flow Manager. The Traffic Flow Management System can be further partitioned into the national level (Central Flow Control Facility at Washington Dulles), center level and airport level elements. These people and their system determine the daily schedule demand for resources (airport and airspace) and restrict or constrain flight, as deemed necessary, consistent with safety of flight, controller workload, etc. The airline planning counterpart is the dispatcher and the in-flight control agents, parts of the Airline**,** Operational Control (AOC) system.

On the flight execution side (right side of the figure), the sector controllers, planning and execution, provide the separation assurance function of ATC between instrument flight rules (IFR) flights in the system. The execution controller is in very high frequency (VHF) radio contact with the flight crew, providing flight plan amendments, as necessary, for separation assurance.

Section 3 describes, at a functional level, the complex interrelationships among the planning and execution elements, and how the system efficiency, capacity (as measured by throughput) and safety measures are supported. The system operational concept is fundamentally the assignment of roles and responsibilities to system agents and to their automation support systems. As the future mission needs of the air traffic system are defined and quantified, a critical question to be asked is: how must the roles and responsibilities be changed to assure the maximum likelihood that the future mission needs will be met.

The basic air traffic management services of the system include: air traffic control, air traffic flow management, airspace management, flight information services, navigation services and search and rescue. We have assumed, in the mission analysis, that satisfaction of system demand is the key driver on system modernization needs. Central to the air traffic control function is separation assurance. Separation minima, as enforced between IFR flights, are the primary determinants of the realized safety and theoretical throughput of a given air traffic system. The correct sizing of the long term system needs is a central modernization issue. Section 3 of this report examines implications of operating roles and responsibilities, given the postulated system needs, and focuses on research issues central to the development of a system whose capacity, safety, efficiency and productivity levels meet projected user needs over the system life.

SYSTEM TECHNICAL REQUIREMENTS

Boeing believes that the separation assurance function is to realizing fundamental system capacity and safety long range needs. In support of this thesis, Boeing has postulated a concept, Required System Performance (RSP), intended to characterize airspace and/or aircraft operating in airspace, and the level of separation service applicable. In 1996, a white paper was prepared for the RTCA Technical Management Committee on RSP (Nakamura and Schwab, 1996). This paper was endorsed by the RTCA group, and was the basis for the coordinated development of RSP across several existing RTCA Special Committees. The paper, with minor modifications, was also submitted to the International Civil Aviation Organization (ICAO) Separation Panel meeting later in 1996.

The paper states that the definition of required air navigation system performance should encompass navigation, communications and monitoring (or surveillance) performance and provide a related, high level characterization of the air navigation environment, RSP. The thesis of the paper is that RSP is best characterized by the traditional airspace attribute of separation minima. The paper asserts that the concept of separation minima is the primary airspace performance determinant.

In the procedural environments, this separation standard is primarily related to navigation performance. In radar environments, however, with direct controller-pilot voice communications, each of the communications, navigation and surveillance (or monitoring) factors becomes important in a complex interaction of aircraft navigation, air-ground communications, radar surveillance and air traffic service-airplane interaction. Thus the concept of RSP necessarily contains elements of navigation, communications and surveillance performance. These RSP components establish the basis for an environment in which operational access approval is explicitly performance-based, in place of current practice in which the basis of approval is indirect and implicitly related to capability, based on equipage sets including navigation sensors used.

A key element to the successful definition of system performance is that the rare- and no normal system performance will fundamentally drive system safety-related performance. Thus, required navigation performance (RNP) must address 95% accuracy for navigation availability and navigation system integrity level supported. Similarly, for communications and monitoring, the normal, rare-normal, and non-normal (both detected and undetected failure rates) must be specified, to insure system design that will support the future mission capacity, safety and efficiency levels.

The RSP model described above relates the system level performance (capacity and safety) to the sub-system performance elements for communications, navigation and surveillance (CNS). Additionally, in an intervention ATC environment such as radar, models and safety assessment techniques are needed to determine the impact of human performance, together with decision support performance and CNS element performance on system performance levels. In Section 3 of this document, a first-cut system separation model is developed, identifying the separation functions into: detection, response and response frequency considerations. These provide the basis for the allocation of performance objectives to subsystem elements, and the quantification of expected safety and system throughput levels.

TECHNOLOGY AND HUMAN FACTORS ANALYSIS

A vital issue to the development of a successful new air traffic system is ensuring that human performance capabilities and responsibilities are respected as new technologies are deployed. The safety criticality of the system magnifies the importance of the need to respect human performance and capabilities. Especially, in the preliminary design phase of program development, we lack tools and methods for examining the issues of functions and task design and allocation, and thus are unable to clearly determine which are best done by humans and those activities which are best automated. A number of issues explored in Section 4 of this report identify the need for developing a comprehensive, integrated description of human behavior (both physical and cognitive) in the system; consideration of human performance capabilities and limitations, starting at concept definition; the need for human factors support through implementation, including education and training requirements for transition and maintenance of new systems; and the need to consider the entire range of possible operating condition in assessing human performance. Specific domain issues include dependency on decision support systems; situational awareness; and intent. Other issues identified include the need for structure while maximizing throughput, and the problems with shared responsibility. Current and planned technology elements are cataloged in Section 5. They are described in terms of their potential application to air traffic services; their constituent performance, and their expected system level, installed performance. These technologies can be compared with the allocated technical requirements in order to trade-off the costs and benefits of the alternatives.

TRANSITION PLANNING AND TRADEOFF ANALYSES

A critical element of air traffic services planning is the determination of workable system transition steps. To assess the tradeoffs of technology and operational changes, it is necessary to develop tools and methods which organize airspace changes into workable transitions. The CNS/ATM Focused Team (CAFT) is a group of airlines, airframe manufacturers, and service providers. The CAFT process is aimed at making credible investment analyses of alternative system transitions. The analysis process is summarized. The tools used in this process includes: (1) cost databases and forecasting tools, (2) a capacity23 efficiency-constraints model that identifies key elements of the system affecting system performance, (3) transition logic diagrams linking operational improvements, technology solutions, and benefit mechanisms in phased steps, and (4) economic modeling that assesses the costs, benefits, and risks of the improvements to industry and all stakeholders.

Regional Priorities: The process begins with an examination of regional priorities resulting from assessing current system operational effectiveness. As an example of the regional priority of an airline, consider which presents the distribution of airport delay by weather and duration. Thunderstorms cause the largest percentage of delay for longer duration events at 20 major U.S. airports. As the duration increases, so does an airline's operational difficulty and disruption of schedule. This kind of data indicates relative impact of airport operations disruptions by cause of disruption.

CONSTRAINTS ANALYSIS MODEL:

The next part of the process is the constraints analysis Modeling, an example of which is presented in detail in Section 6.3, the primary factors that affect throughput in the various phases of the aircraft's flight through the system are: gate, apron, taxiway, runway, initial climb/final approach, vectoring, standard instrument departures (SID) and standard terminal arrival routes (STAR), and en route operations. Constraints modeling can be performed for system safety, capacity, efficiency, or productivity. The methodology allows examination of the economic, technological, and operational implications of the complex interrelationships among demand, capacity, and delay.

With no capacity for growth, the system will adapt in some less than optimal way. Examples include (1) schedules spread from desired peak times, (2) aircraft size increases more rapidly than desired, (3) ability to compete with frequency is limited, (4) slot constraints increase, (5) smaller cities lose service, (6) delays increase, (7) block times increase, and (8) other transportation modes become more competitive. Each of these adaptation mechanisms has an associated cost. Ultimately, any adaptation the system is forced to take because of a lack of capacity causes 'waste', increasing the cost of air travel. Constraints on the system limit the ability of carriers to compete freely. Some carriers may lose the ability to respond competitively to the marketplace.

Transition Analysis Model: The constraints model is used as a template for determining specific technology initiatives by phase of flight and by benefit category. A time-phased approach, considering short- and long-term technologies, is then applied to determine the phasing of technology for an airspace region of interest. The procedures and technologies must be in place in each transition phase for throughput to increase. This modeling process provides the basis for a systematic evaluation of alternative technologies. It also supports the development of ATM operational concepts. The output of these phased technologies provides an input to an economic model evaluation. Each transition has potential user benefits, costs, timing, and risk elements that can be evaluated in the economic modeling.

These can be used as the basis of the performance of the technology and procedural tradeoff studies that need to be conducted. Depending on the results of the mission analysis, transitions can be developed, based on capacity, safety, efficiency or productivity needs. Detailed NAS future capacity transitions, for each of the operating phases, are provided in Section 6 of this report.

Economic Modeling: The development of economic models is the last step in the CAFT process. These models evaluate costs, benefits, timing, and risk for each phase of transition. For a given phase, the return on investment is evaluated for each technical solution for each alternative. It illustrates the typical steps in the development of an economic model.

MODULE II:

AIR SPACE & AIR TRAFFIC MANAGEMENT

INTRODUCTION TO AIR SPACE AND AIR TRAFFIC MANAGEMENT

Safe and efficient Air Traffic Management (ATM) is essential to face the challenge of the increasing demand and complexity of air traffic. The challenge is to provide fast and effective connections and to maintain a high level of safety at the same time. ATM is a very dynamic changing field regarding new techniques, innovative procedures and legal situation.

The ATM System Functional Structure

This section discusses the primary functions involved in air traffic management and presents a framework through which their performance can be related to the system metrics of capacity, efficiency and safety. A top level functional structure for air traffic management is presented in Section 3.2, along with a discussion of current roles and responsibilities of system agents. Section 3.2 takes a close look at flow management and traffic separation, and at the performance factors that combine to provide a safe minimum separation standard for a given operation. Section 3.3 details the technical and operational changes that are likely to be needed to support the system capacity, efficiency and safety goals for 2015. Section 3.4 presents an overview of the CNS/ATM technologies that are likely to be needed to support the new operational concept. Section 3.5 discusses the airspace implications of the proposed operational improvements, Section 3.6 discusses airport impact, and Section 3.7 takes a brief look at Flight Service Stations.

Air Traffic Management Objectives

The air traffic management component of the NAS is a very complex system whose primary objective is to safely and efficiently accommodate the demand for flight through U.S. airspace. Figure 3.1 illustrates a top level view of the system, showing air traffic demand as the primary input, traffic flow as the output, disturbances as unwanted inputs, and capacity as the system resource that allows traffic to flow. System **capacity** in this report is used to denote the theoretical maximum flow rate supported by the separation standard. **Throughput** is the rate of flow that is realized in operation, which is never more than the system capacity, and often considerably less due to the need to accommodate operational uncertainty and disturbances without compromising safety. **Efficiency** is a measure of how close the real operation is to achieving ideal flight, which is influenced partly by the balance between capacity and demand, and partly by airspace restrictions such as special use airspace. The primary capacity objective is to maximize flow rate, up to the actual traffic demand. This goal is challenging due to several factors: The highly peaked nature of air traffic demand, caused by passenger desired travel times and airline hubbing operations. The diversity of aircraft performance capabilities competing objectives among system stakeholders, the primary safety objective of air traffic management is to assure safe separation between aircraft (and ground vehicles) on the airport surface and in the airspace. The system efficiency objective is to minimize the cost of operating flights through the system, both under normal conditions, and in the face of disruptions due to weather or other causes.

The objectives of the air traffic services shall be to:

a) prevent collisions between aircraft;
b) prevent collisions between aircraft on the manoeuvring area and obstructions on that area;
c) expedite and maintain an orderly flow of air traffic;
d) provide advice and information useful for the safe and efficient conduct of flights;
e) notify appropriate organizations regarding aircraft in need of search and rescue aid, and assist such organizations as required.

CAPACITY AND SAFETY OF AIR TRAFFIC MANAGEMENT

The capacity of the air traffic management system is fundamentally bounded by the separation standards in effect for the airspace. Thompson (1997) reviews the history of the development of airspace separation standards and states that the standards for radar controlled airspace have evolved slowly and are not based on a formal model of collision risk. By contrast, the separation standards in MNPS airspace in the North Atlantic were developed through use of a collision risk model developed by Reich (1966). Reich's model takes into account only the aircraft's guidance and navigation error characteristics, due to the absence of air traffic surveillance in oceanic airspace. The model includes a parameter that defines collision risk, and the use of the model involves a decision to accept a certain value for this risk parameter. System capacity, and therefore throughput, are bound up in the definition of separation standards, and thus to accommodate the demand for growth in the NAS through 2015 it is fundamentally important that a rational approach to separation standards development be put in place. Risk management is at the heart of this process, which must find an acceptable balance between collision risk and airspace throughput through a clear definition of a collision risk parameter for controlled airspace.

The process of establishing separation standards must include a model of the nominal system performance, along with failure modes and effects, all of which combine to provide a certain probability of spatial overlap of pairs of aircraft. The factors that contribute to the performance of the separation assurance function are discussed in more detail in Section 3.2.6.

Throughput and Efficiency

It is important to consider the relationship between throughput and efficiency in the current system. There is a need on part of system users to retain a certain level of flexibility in routing to achieve an efficient operation. But, when considering that current separation assurance methods are fundamentally based on a controller's highly tuned knowledge of a sector and its fixed path geometry, it becomes apparent that flexibility could have a negative impact on airspace throughput. In addition, a controller handles more aircraft by assuming that pilots stick to their assigned trajectories with a high probability.

Thus, in effect, flexibility is restricted in the system today to gain capacity and/or controller productivity. In the future system, it is conceivable that a better balance could be found between throughput and efficiency, but this balance will depend on limitations of human and technology performance, of which the human performance is the more difficult issue. This is discussed in more detail in Section 4.3.3 from the human factors point of view. To guide the design decisions regarding throughput and efficiency, the system developers must continue to keep in mind the fundamental system mission of providing sufficient traffic throughput.

A Functional View of the Current Concept, Throughput and Safety

System throughput is a measure of the realized flow through the system in a given time period. Whereas separation standards are established through an analysis of collision risk, throughput is dependent on the controller's ability to accommodate traffic demand in the face of uncertainty and disturbances. Periods when demand exceeds capacity in parts of the system can cause an increase in collision risk, and it is important to include functions in the system that prevents such overload. In the NAS operation this is done through flow planning, where a planning horizon of 24 hours is both feasible and appropriate given the daily traffic demand cycle.

Levels of Flow Planning in the System

The traffic flow planning function is complicated by the fact that the system is subject to a variety of sources of uncertainty. The three most important ones for the daily plan are: Weather prediction uncertainty, which affect primarily the arrival phase of flights through airport arrival rates. Aircraft pushback readiness due to a variety of factors in aircraft turnaround at the gate, which affects primarily the departure phase of flights. NAS equipment status, which can affect any phase of flight, the uncertainty inherent in the daily flow plan often results in situations where the plan is out of phase with the unfolding situation, leading to possible overloads or wasted capacity.

To deal with the uncertainty, the system could: Reduce the uncertainty level (difficult, but progress is being made) Provide plenty of room to safely absorb the uncertainty (wasteful) Modify the plan dynamically to manage the situation as it unfolds. The last option, to modify the plan dynamically, is what the NAS is evolving toward in an effort to achieve an acceptable balance between throughput and safety. Thus the NAS includes several levels of planning: National and regional flow planning, Facility-level flow planning, Sector-level flow planning

Each level has a certain planning time horizon and range of possible planning actions.

Levels of Plan Execution in the System

Flight and flow plans in the system are executed through a number of functions, the primary ones being: Aircraft guidance and navigation, Separation assurance, Aircraft on-board collision avoidance.

FUNCTIONAL STRUCTURE

The functional structure of the air traffic management system in terms of functions directly affecting the process that links real-time traffic demand with actual flight through NAS airspace illustrates the processes and information flow that make up the traffic planning and separation assurance functions of the system. Figure 3.2 is only one of many possible cross sections through a very large and complex system and hides a considerable amount of detail, but is conceptually valid and useful to serve this discussion of system safety, capacity and efficiency. It is also important to note that idealized diagram of a system that is very adaptable due to the predominant presence of human operators, and in which assignment of functions to agents is dynamic.

The path, starting at the left, from a desired flight schedule and a weather forecast, through filed flight plans, to real aircraft movement on the extreme right. Each block in the diagram indicates a function that is performed in the system today, and the arrows denote either real aircraft state, communication of a plan or intent, measurements or requests. The functions can be divided roughly into planning and execution, with a substantial overlap in the sector controller team. The diagram indicates the approximate planning time horizons for each function, ranging from a day for national flow planning to minutes or seconds for the aircraft guidance and navigation. The actual time horizons employed by system operators vary greatly depending on the airspace and traffic levels, but the numbers in reasonable for most components of the NAS.

An approximate analogy to the current assignment of functions to agents is shown in the figure through reference to the R-side (radar) and D-side (data) controllers, Traffic Flow Management (TMU) positions and Central Flow Management (CFMU). The separation assurance function is here considered to be assigned to the sector controller team, using radar display and flight plan information, with the aircraft crew as a collision avoidance backup, through visual observation of traffic and through the Traffic Alert and Collision Avoidance System (TCAS).

It is worth noting that the criticality level of the system functions increases from left to right on the diagram. Criticality level is fundamentally important in all discussions about required performance to support a function, and for the level of attention to human factors that a function requires. Section 3.2.6 discusses the execution loop and separation standards in more detail. Uncertainty is accommodated through several levels of replanting in the system. Traffic situation data feedback to the planning levels is a weakness in the system today, and therefore there is not an ability to update the flow plan comprehensively across facilities or regions.

To relate back to the system objectives, that safety is the primary responsibility of the aircraft, with separation assurance assistance from the sector controller. System throughput is maintained primarily by the execution loop, with assistance through overload protection from the planning functions. Efficiency is worked primarily by the flow planning functions, through negotiations of flight plans, with assistance from the execution loop through in-flight rerouting.

FLIGHT AND FLOW PLANNING

The functions that make up air traffic management are connected in an overall process to allow safe and efficient traffic flow through the NAS. The agents that perform the flight and flow planning functions are Airline operational control and/or dispatch the flight planning function, performed by AOC, local dispatch, or an individual pilot. Airline operational control agents and dispatchers have detailed knowledge of their airline's business objectives and the nature of the airline's operation, much of which cannot be shared with outside agents for competitive reasons. In addition, their operational objectives can change so rapidly that it may not be practical to express them in much detail to outside organizations. Thus, it is necessary in today's business climate to allow each operator to make some of the decisions that influence the efficiency of their daily operation.

The national flow planning function, which is assigned to central flow managers, this function originated as a safety net to protect the sector controller team, but has a large impact on operator efficiency through its interaction with the operator's flight planning activity. In addition, due to the competition between operators that is inherent in operating in an overloaded system, there is a need for arbitration, and this is a natural role for the flow management agent. The art is to manage effectively, while allowing the individual agents sufficient room to optimize their operation, and this is the objective of the Collaborative Decision Making (CDM) initiative.

SEPARATION ASSURANCE AND TECHNICAL PERFORMANCE

The guidance and navigation function, which is performed by the cockpit crew, the cockpit crew has the most detailed and up-to-date knowledge of their aircraft performance ability, and of the immediate environment in which the aircraft is being operated. In addition, the crew is the only agent that has control of the aircraft. In today's operational environment, the cockpit crew has very limited information about weather or traffic conditions ahead of it, and therefore must rely on assistance from other system agents for medium to long term flight planning. It is interesting to note, though, that the cockpit crew must maintain a planning horizon, often shared with AOC, ranging from the duration of the flight (hours) to immediate control action (seconds). In this sense the crew has a unique responsibility among the agents listed above, and herein raises the question of where to put the emphasis for the cockpit, in light of the increased ability to provide information through data link. The sector controller team performs the function of separation assurance, which as illustrated in can be divided into two functions, sector traffic planning and traffic control. Depending on traffic complexity and volume, the sector controller team is anywhere from one to four or five persons, with a variety of active and backup roles.

Considerable detail on the current nature of this function, and the issues that face the industry regarding potential future changes to roles and responsibilities. It is clear that the performance, both normal and non-normal, of the separation function is at the heart of any discussion about system throughput, and thus the focus in this report is on this critical inner loop in the system. The separation assurance loop, with additional detail showing the primary sub-functions in the loop, the sector planning function's primary objective is to manage the intervention rate in the sector, i.e. the number of potential conflict situations the sector controller may need to process. The set of flight plans inbound and inside the sector can be considered the primary data input to this function, along with the real-time traffic situation as it currently affects the sector controller's workload. The sector planner may also need to assist the controller with clearance requests from aircraft that he cannot immediately process. Thus, the sector planner function helps manage the sector controller workload, and is therefore the primary agent in managing exposure to collision risk.

The sector controller in today's radar control operation is the only traffic management agent that communicates directly with the aircraft. The functions performed by the sector controller are conformance monitoring and short-term conflict detection and intervention, along with receiving, granting or rejecting route modification requests from the aircraft. This function directly affects the performance of detection and intervention of conflicts. Detection performance depends on the accuracy of the aircraft state sensor, the display resolution and update rate, and the controller's ability to predict the aircraft trajectory into the future. Intervention performance involves the decision to act on a potential conflict, and the communication of the action to the cockpit crew, which then must intervene and change the flight path. The sector controller is thus a critical component of detection and intervention, and today's system has very limited backup for failures in either the performance of the function or in the surveillance and communication equipment the function relies on.

The cockpit crew is responsible for guidance and navigation according to an agreed upon flight plan, along with replanting for reasons of safety, efficiency or passenger comfort. The cockpit crew contributes to the performance of the intervention function through its response to ATC vectors. The crew also has a safety responsibility to monitor and avoid other aircraft in its immediate vicinity, either visually or through TCAS. This is currently a limited safety backup for the sector controller's separation assurance. In addition, separation assurance is transferred to the cockpit crew in some well defined scenarios to increase throughput or efficiency (e.g., visual approaches or oceanic in-trail climb). The intervention rate, intervention and detection combine in an overall separation assurance function, and list the performance factors involved in each component. Nakamura and Schwab (1996) propose a framework where the performance of each of these fundamental factors is combined in an overall Required System Performance parameter, which is then directly related to a minimum allowable separation between aircraft. The navigation function performance has been formalized through the definition of Required Navigation Performance, as described in the RTCA Special Committee 181 document DO-236 (RTCA, 1997). RNP includes a definition of accuracy, integrity and availability levels, which are functions of navigation sensors and their sources, cockpit-crew interface design and pilot performance. To compose an overall performance index (RSP) for the separation assurance function, consideration must be given to Required Communication Performance (RCP) and Required Monitoring Performance (RMP), along with an additional potential metric relating to the performance of the traffic planning function that manages intervention rate.

The operational concept presented in this report is centered on needed increases in NAS capacity to accommodate the predicted growth in traffic demand through 2015. The system operational enhancements that make up the concept are centered on changes in the performance of the separation assurance and navigation functions depicted in since these are the primary influences on system capacity. The phasing that is suggested in Section 3.3, and described in Section 6.2, is one where the intervention rate performance is worked first, then the intervention performance, and finally the core detection function. The rationale for this phasing is twofold: There is capacity to be gained by reducing the spacing buffers inserted in today's operation above the minimum separation standard, to account for uncertainty in sector traffic planning.

It is probable that the process of reducing separation standards from current radar separations will be slow, and a great many interrelated factors will have to be worked. The factors and technology performance issues involved in the system development process, and Section 8 contains a list of the primary research topics that the team has identified to support this concept.

A Functional View of the Proposed Concept, Airspace Characteristics: High Vs. Low Traffic Density

The operational concept presented here treats traffic density as the characteristic that determines what operational improvements are suggested for a particular airspace. Given that this concept is primarily concerned with capacity improvements, high density airspace is the primary concern here. Based on the discussion in regarding capacity and routing flexibility, it will be assumed here that throughput has priority, and that flexibility will be allowed to the extent that it does not detract from full utilization of system capacity. Low density airspace allows more flexibility to optimize operator efficiency, and thus the concept includes operational improvements to this end. If it is found to be necessary to restrict traffic flexibility to maintain acceptable throughput, then this must be the overriding concern.

Traffic density in the NAS is highest in terminal areas around large airports, or where many airports are located in close proximity. Most en route airspace in the NAS can be considered low density from the point of view of installed CNS technologies. There are, however, areas such as the northeast corridor that have very high density en route traffic, complicated by climbing and descending traffic to airports below. The detail the operational improvements proposed in this concept for the range of airspace density found in the CONUS.

THROUGHPUT IN DENSE TERMINAL AIRSPACE

For dense terminal airspace, capacity and throughput are the primary concern, and the discussion in Section 3.2 is the basis for the concept. The operational enhancements that are proposed in this concept are as follows, prioritized in the order in which they are presented, Reduce intervention rate, and the associated spacing buffers applied above the basic separation minimum. This will be achieved through the following improvements, Precision 4-dimensional (3-D space, plus time) guidance and navigation, based on area navigation (RNAV) capability, vertical guidance and a common and accurate time source. This will effect an improvement in trajectory planning and conformance by suitably equipped aircraft, and thus contribute to a lower intervention rate.

Precision sequencing and spacing of arriving and departing aircraft through improvements in the sector and/or facility planning functions, Inherent in this improvement will be the same time source as onboard the aircraft, knowledge of key aircraft performance parameters and better wind information. Automation aids to process this information and calculate trajectory predictions will be required, along with tools to assist in optimizing arrival and departure sequences. Air/ground data link to exchange trajectory and weather information will be required to take full advantage of navigation and sequencing capabilities. Careful consideration must be given to who the agents in the data link exchange should be, because the improved navigation, sequencing and spacing functions may allow much less reliance on ATC vectors, and thus the nature of the communications may be shifting away from execution and toward medium-term planning. Thus, it may be that AOC will take on a more active role in decisions regarding aircraft sequencing priority, and that the flow manager or sector planner will need to communicate directly with AOC or the aircraft through data link. Improved intervention performance this may allow further reduction in spacing buffers, and will help set the stage for eventual reductions in separation standards.

The following performance factors must be addressed, more reliable clearance delivery. This refers to a lower error rate in communicating clearances to aircraft, which may be achieved partly through the use of data link and partly through a lower intervention rate due to improved planning and conformance described in improved intervention response time. This may be enabled by data link, given appropriate controller and crew interfaces that allow quicker execution onboard, and where frequency congestion can be alleviated. The improved planning and conformance described in item may also result in a higher probability that the sector controller issues clearances in a timely manner. More accurate prediction of time-to-go in a conflict situation the improvements in trajectory prediction and conformance described in item, combined with automation that provides estimated time-to-go, may result in lower false alarm rates and thus reduced spacing buffers. Improved conflict detection, coupled with the improvements should allow reductions in separation standards in dense terminal airspace. The following factors must be considered for improvement, tracking of radar surveillance data. Current NAS tracker has substantial lag in detecting aircraft maneuvers. Precision position and velocity information from on-board navigation sensors could further improve performance. In particular, an independent velocity measurement would support improved short-term trajectory

Prediction and reduce the lag in detecting maneuvers. Event-based trajectory deviation reporting from the aircraft could allow a reasonable compromise between position update frequency and the need to detect maneuvers or blunders in tightly space traffic scenarios. Short-term conflict alerting tools for the sector controller would reduce the probability of missed detection of true conflicts.

The improvements listed in items 1-3 above pertain primarily to the nominal system performance enhancements that may be required to support growth through 2015, the associated non-normal performance requirements at the point of view of simultaneously maintaining or improving safety in dense terminal airspace.

Efficiency in Dense Terminal Airspace

It is conceivable that high throughput in terminal areas can be maintained with some room for operators to optimize efficiency. These points to the concept of dynamic planning for fleet and flight management, to improve individual or bank efficiency, which would be based on the following operational improvements:

1. Hub schedule updates to maximize passenger throughput.

2. Trajectory negotiation and intent information sharing through data link.

3. Precision 4D navigation to maintain conformance with trajectory plan.

4. Precision sequencing and spacing to aid in maintaining throughput.

As discussed in more detail in there are substantial unresolved issues regarding the effect of trajectory flexibility and reliance on automation on human performance, particularly in non-normal conditions? The above list therefore would need to be subjected to substantial concept validation studies before feasibility is proven.

Safety in Dense Terminal Airspace

The criticality of the detection and intervention functions will lead to a requirement for very high availability and integrity levels, as traffic spacing is reduced in dense terminal areas. It is unlikely that the current functional and CNS architecture will be sufficient to achieve the total system certification and commissioning criteria associated with reduced separations, and thus the following enhancements may be required:

1. Nominal performance parameters, such as accuracy and latency, will be improved as detailed.

2. Establish the level of criticality through risk analysis. It is clear that safety improvements through risk reduction with the lower separations will require higher availability and integrity of the total system.

3. High availability of function may require independent redundancy in communication, navigation and surveillance, and in the separation assurance function element. This may imply independent voice and data link channels, independent navigation sources and two independent surveillance data sources.

4. High integrity of function may require an external monitor to detect failures this taken with points to the potential of the aircraft acting as the redundant backup for the primary separation function, which resides with the sector controller team.

Separation Assurance and CNS/ATM Technologies

Some of the technologies under consideration for the NAS would be applied in the separation assurance loop for dense terminal airspace.

Efficiency in Low Density Airspace

In low density airspace, be it terminal area or en route, users should be allowed to fly preferred trajectories to the extent possible without compromising safety or throughput.

This increased flexibility in trajectories will, however, carry with it:

1. Increased reliance on automation tools to predict and resolve traffic conflicts. This remains an open area for research and concept validation.

2. Substantial changes in traffic flow patterns both daily and hourly, therefore separation assurance agents need to move with the flow. In current operation sectors are split or combined during the day as traffic loads change, but their geometry and the airways within them remain fixed. As discussed a fundamental premise for today's air traffic controls methods. A complete airspace redesign for a facility or a region takes on the order of years to complete, including training of controllers and reprogramming of automation equipment. Thus, dynamic flexible routing calls for an enormous change in the way separation assurance is performed.

3. Criticality of function will drive required performance levels and the feasible architecture. The issues are identical to those must be applied to a different set of automation tools.

Transition from Low to High Density Airspace

This operation refers primarily to the entry of aircraft into high density terminal airspace from low density en route areas, where routing flexibility is assumed. The primary objective must be the maximum throughput of the airport, with hub or individual flight efficiency as the secondary objective. The following operational characteristics are suggested:

1. Structure is applied over a larger area as density increases, up to 200 nm radius or more during peak traffic hours, and down to 10 nm radius during off peak hours.

2. Multiple terminal area entry points are defined, using reduced spacing based on improvements discussed in Sections 3.3.2-5. This will help avoid long in-trail traffic patterns that are wasteful of airspace and reduce opportunity for user preferences.

3. Data communication is used to negotiate trajectories into the terminal area, either between the aircraft and traffic planner, or AOC to traffic planner with uplink to aircraft through Controller-Pilot Data Link Communications (CPDLC).

4. Terminal area entry times are used to allocate arrival slots, and aircraft are responsible to meet those times to ensure expedient handling.

5. Arrival and departure flows are coordinated.

Extended Terminal Areas

This refers to complex terminal areas with multiple airports, and even to entire regions such as the northeast corridor. The following characteristics are suggested:

1. Traffic flow planning is coordinated regionally across airports and en route centers.

2. Arrival and departure management is coordinated.

3. Airport configuration management is improved.

4. Surface routing and scheduling are coordinated with TMA plan.

5. Precision 4D navigation is applied.

6. Data link for 4D trajectory information exchange is in place.

7. Precision sequencing and spacing is performed.

8. Departure time uncertainty for short-haul flights must be accommodated in the plan.

NATIONAL FLOW MANAGEMENT

Planning for Operator Efficiency and Overload Protection

As illustrated in efficiency and overload protection are the dual objectives of flight and flow planning. The figure also illustrates how the system operation goes from a plan to execution, through a sequence of functions that must be coordinated to form a seamless and effective operation. Figure 3.2 illustrates how information and control authority flows through the system, and when considering overall system flow management it is crucial to maintain a whole system view to ensure a sound system design.

Time Horizons and Coordination

Flow planning is fundamentally concerned with balancing the need to plan ahead against the inherent uncertainty in predicting the future. From the aircraft’s point of view there are two distinct periods involved in the flight:

- The period before departure, used for planning, checking and loading, subject to considerable uncertainty, but a wide range of decision options is available.
- The period while airborne, where safe flight is the primary concern, uncertainty level is low, and only a limited range of decision options remain.

Correspondingly, for flow managers to work effectively with flight planners, they should have a wide range of routing and scheduling options available for aircraft prior to departure, and it is reasonable to assume that this implies the function is at the national level. However, as soon as the aircraft is ready for push-back, and can be fit into a departure sequence, the primary concern of the corresponding flow planning function must be safe flight. There is still a need to replan flows to accommodate in-flight operational uncertainty, but immediate flight safety must always be the priority.

The NAS currently operates its central flow planning function with a large level of uncertainty due to lack of real-time schedule updates from Official Airline Guide (OAG) operators, and no predictive knowledge of any other flight plans. This leads to poor overload protection, i.e. strains the separation assurance resources, and also leads to periods of poor capacity utilization whith resources at times idle. Section 3.3.9.3 discusses the requirements to achieve performance improvements through more complete real-time data flow. Section 3.3.9.4 discusses the efficiency gains that may be achievable through collaborative decision making during the flight planning phase. The problem of accommodating in-flight operational uncertainty through re-planning involves the following primary question:

What is the extent of the re-planning need (flight and hub optimization, and disturbances due to weather, aircraft emergency, conflict resolution, etc.), after the information flow and decision making structure at the national level has been optimized?

The answer to this question is likely to vary, primarily due to weather phenomena, and so the system may need to accommodate dynamically a range of options:

- A large level of replanning need implies a flow management mechanism with a larger scope (time and space), i.e. closer to a national or regional level. This might be caused by major weather phenomena moving through the system.
- A limited need for replanning could be handled in a more distributed manner, i.e. at facility or sector level. This is likely to be the ‘normal day’ scenario, when severe weather is not a factor.

The frequency of occurrence, associated operational costs, or safety implications of these options should determine the emphasis in the eventual system design. Section 8.3 discusses the research efforts needed to perform the high level trades involved in the overall flow management strategy.

Information Flow

The thrust of the current initiative to improve information flow between users and the central flow management facility is focused on the following four areas, as described in the operational concept document for ATM-AOC information exchange (RTCA, 1997):

- Current operators, with published OAG schedules, will provide real-time schedule updates to central flow, including flight cancellations, diversions and other decisions made by the operator in response to major disruptions.
- Central flow management will include more users in the gate-hold program, in an effort to reduce the uncertainty associated with non-OAG traffic demand in the system.
- Common weather forecast information will be made available for all users and flow managers, in an effort to build consensus on traffic initiatives.
- NAS status information will be made available to users, to the extent to which it affects traffic flow through the system.

Collaborative Decision Making

This initiative, as described in the RTCA Task Force 3 Report on Free Flight (1995), is focused on giving system users more freedom to make decisions in response to traffic flow restrictions. This is essential to reduce the cost of major disruptions in system throughput.

The primary components of the initiative are:

- Users manage response to delay, after an overall delay allocation from central flow. This involves the user allocating arrival/departure time to individual aircraft in their fleet, or opting to re-route around congestion areas.
- Central flow management will continue to act as an arbitrator to allocate resources fairly, and to help users expedite their flight planning.

PROPOSED CNS/ATM TECHNOLOGY IMPROVEMENTS

Figure 3.9 illustrates the primary technologies that are being proposed as the basis for the NAS modernization through 2015.

Airspace and Airways

The NAS is currently operating at a throughput that is very close to saturation in many of the busiest terminal areas. In areas such as the northeast corridor, the upper airspace has also become quite congested. The concept presented here introduces step-by-step improvements in the system for increased throughput, where initially no major new technology will be required. However, as the system moves beyond the first steps in the transition, the implication is that higher performance levels will be required to achieve higher density operations where they are needed.

As the system transitions to support increased throughput, there will be substantial impact on NAS airspace, including RSP levels to support operation at a given density level. RSP will imply end-to-end performance, i.e. aircraft, communication, navigation, surveillance and air traffic management. Thus, for a given airspace or operation, each system element will be required to perform at a certain level to ensure system performance. Airspace performance requirements should be imposed based the nature of the traffic that will be accommodated in that airspace. High density traffic during peaks at hub airports will require high performance levels, whereas off-peak traffic at those hubs, and traffic in low density areas can be accommodated at a lower performance level. Thus, airspace performance requirements can vary during the day, depending on traffic demand. How best to manage such requirements must be resolved through careful analysis of user needs and of what is feasible in an operational system. In the end, some of the decisions regarding required airspace performance levels will have to be made at the policy level, where a reasonable compromise between potentially competing objectives must be found.

Airports

The throughput growth requirements presented in Section 2 imply a need for additional runways in the system, and it is likely that this will have to be met both at existing hubs and at other airports. As presented in the NAS Stakeholder Needs report that accompanies this document, the system users are unanimous in their concern about continuing access to airports, given that it is becoming increasingly difficult to get approval for any new runway construction.

Airport construction and operational cost is a fundamental issue where economic growth vs. shorter term business objectives must be carefully weighed. As detailed in the NAS Stakeholder Needs report, the NBAA expressed concern about continued economical access to smaller airports, because their members see this as essential for the growth of small business outside the major population centers.

Another issue of interest is the potential introduction of new types of air transport vehicles into the NAS. The current development of a civil tiltrotor aircraft is an example, where a new aircraft user class could potentially contribute to the growth in system capacity. In the case of the tiltrotor, one proposed scenario is that a portion of the current small jet transport market could be served with tiltrotor aircraft that would operate independently into and out of heliport facilities at hub airports. This might bring added throughput without the need for major new runway construction, but would instead require other changes in both airspace and airport facilities. The viability of this concept will ultimately be determined based on economics, where the seat-mile cost will drive the potential market share, but some policy level decision may have to be made regarding the needed infrastructure investment.

Flight Service Stations

The NAS Stakeholder Needs document details the concerns of the NAS users that rely on Flight Service Stations for information needed during flight planning. This concern is focused on flight safety related to weather conditions, and to airspace access through flight plan filing. It must be kept in mind that the safety concern is supported by existing data on accident rates, and it is probable that improvements in content and presentation of weather information at Flight Service Stations would reduce the accident rate in this segment of the system. The cost is probably the primary issue here, and there is an immediate need for innovative economical solutions for this system component.

HUMAN FACTORS IN AIR TRAFFIC MANAGEMENT

This section addresses some of the major thrusts in the role human factors must play in enabling increases to the throughput of the ATM system. The primary focus of Section 4 is on human factors roles and issues in increasing throughput in the terminal area. However, the basic thrust of human factors involvement as well as the issues addressed apply throughout the ATM system. Section 4.1 frames the top level issues. Section 4.2 describes areas where human factors involvement in the system research, development, design and implementation process should be improved. Section 4.3 raises some key human factors issues that require research and development to avoid the unwanted side effects that tend to develop from technically focused initiatives.

The Search For Greater Throughput And The Demands On The Human

Automation will always be beneficial?: the data obtained in experiments employing fine grained performance and workload measurements indicate that many ‘tools’ will not be used as predicted or even at all, especially under high task loading conditions. (Jorna, 1997)

The current ATM system is a large, complex, almost organic system with human interactions as the glue that holds it all together. Controllers and pilots manipulate and manage complex subsystems in real time. They also manage the inherent risks, within these subsystems, through being adaptive and flexible in times of critical circumstances. These factors tend to make the development and design of new systems very complex. The fact that the system has both tightly coupled and loosely coupled components further complicates the task of defining, designing, and implementing changes which will increase the throughput of the system and protect safety levels. It is this need for increased capacity that is driving the need for change. If the American Airlines forecast (Chew,1997) of impending severe throughput limitations in terminal airspace is valid, then change must occur in the entire system. Since humans play central roles within this system, it can be reasoned that a major drive for increased throughput will also drive a requirement for

major changes in the roles of the humans in the system and consequently in the tasks they perform. Human factors input is a key element in determining the way that changes to the human

role should best be managed in order to achieve increased capacity without suffering the unwanted side effects that could adversely affect safety.

The Role of Human Factors In Enabling Change

Before actual changes can be discussed or determined it is essential to have an appropriate framework for the process of research, development, design and implementation itself. Combined with this system development process there is a need to identify and incorporate the right skills and knowledge into a team.

Baseline Data of Human Roles

In order to have a reasonable level of confidence in the successful evolution towards a system that achieves the capacity goals stated in Section 2, there is a need for a comprehensive, integrated description of human behavior (both physical and cognitive) in the system. The description would serve as a baseline against which to compare proposed changes to the system. Such a baseline provides by far the most cost effective way of estimating potential impact of proposed change before the costly process of prototype development and testing is undertaken. The valuable framework that such a database can provide should not be underestimated.

An excellent review of human factors research relevant to various aspects of air traffic control has recently been published by the National Research council's Panel on Human Factors in Air Traffic Control (Wickens, 1997). Many of the references in this work provide pieces of the puzzle of human behavior in the ATM system. The work of the Panel is probably the first comprehensive step in providing a knowledge base for human behavior in the ATM system. The next part of that team's work should add greatly to a knowledge base.

The availability of both the database and knowledge base should provide a powerful tool for focusing the development and assessment of decision support tools.

Involvement Of Human Factors From Concept Development Through Final Design

The role of human factors in system development must not be confined to that of modifying the results of earlier design decisions to ensure user acceptability. Failure to consider human performance capabilities and limitations from the very beginning of concept definition can lead to inappropriate design and serious compromises in system productivity and even safety. Human factors specialists must be full members of interdisciplinary development and design teams from the start of the development cycle, so that both the strengths and weaknesses of the human subsystem can be adequately accommodated in the final design. The design team should include the design engineers and end user personnel as well as the human factors specialists; the latter often play a mediating role between designer and user. The emphasis here on inclusion of end user personnel is important. However, there is a need to ensure that the end users are well versed in the principles and skills used by the other team disciplines. These end users tend to become untypical because of their involvement in the development process, thus there is a need for regular reviews involving more typical end users. The multi-disciplinary design teams should work closely through the entire spectrum of development tasks from concept development and function analysis/allocation through preliminary design and prototype development and system evaluation with special emphasis on human performance testing. Section 4.2.3 discusses the involvement of the team beyond this point, but it cannot be too strongly emphasized that human factors specialists should be full members of such teams from the beginning of their existence.

Human Factors Support For Implementation, Education, And Training

The involvement of human factors should continue beyond the design stage into the implementation process. There is a tendency to allow modifications to the final design to be made by the end user to facilitate implementation. This needs to be carefully controlled by involving human factors and end users together. It is very easy to lose some or much of the effectiveness of the original design concept through misinformed or uninformed final design modifications choices which can lead to loss of efficiency, and possibly have safety implications.

New systems require fully developed implementation plans which include educating the users on the logic, capabilities, and rationale of the new system operation as well as its role in the overall ATM system. The operators of a system will tend to look upon changes in system design as extensions or refinements of current practice and may fail to understand the need for new and different tasks and procedures to realize productivity and safety. This need for education and training was one of the main conclusions of the PD1 simulation report (Eurocontrol (1997), PHARE Development simulation 1). The education process is in addition to the typical training that operators will receive with the introduction of new equipment or procedures. The baseline data, described earlier in Section 4.2.1, will be invaluable in supporting the development of the implementation plan for new equipment and procedures. Without a positive and proactive education and training program there is likely to be considerable transfer of old attitudes and working methods, often referred to as negative transfer. In developing the implementation plan, very careful attention must be paid to the potential for transfer of habits used to accomplish tasks under the old system which, if applied with the new system, would seriously compromise efficiency; but more importantly safety. Such negative transfer is most often evident when operators are under considerable stress. Again, the baseline database will provide an effective tool in the identification of potential negative transfer.

Designing To Support Human Performance Across The Entire Range Of System Operating Conditions

The air traffic domain is comprised of many complex subsystems, it is subject to the vagaries of the weather, it is also operated by many different individual humans each having their own slight differences in behavior as well as each being prone to error or misjudgment. The net effect is a system with many minor disturbances and potential exceptions, the majority of which never develop into reportable incidents - because of the influence of the adaptive human being. There are also the rare-normal and abnormal conditions which develop, but with much less frequency.

It is critical when designing decision support systems to include the capability to explicitly present to the operator the limits of the system with respect to operating conditions. The operator cannot be left to guess or assume system status and shortcomings under specific conditions when asked to step in and perform manually what the system has heretofore been accomplishing automatically. This issue will be treated in more detail when discussing the issue of decision support systems in Section 4.3.1.

Capturing the range of normal, rare-normal, and abnormal conditions is itself difficult. The baseline database must do this for the operations as they occur today. Controllers and other end users must be key members of the team which develops this database. In fact, a number of end users from very different ATC environments should participate and review the database to ensure adequate capture of operating conditions.

Human Factors Issues Affecting Tactical Control

This section identifies the major human factors issues that have an impact on the search for increased capacity in the tactical domain of the air traffic management system. The terminal and tower domains are probably the most dynamic parts of the air traffic control environment. They are both time- and safety-critical, and the central role of the human in these domains is both skill- and practice-critical. These environments are managed by many individual controllers, all in the very exposed situation of having no immediate support for their tasks. This is because in tower and terminal control there is not usually a second controller working in close contact (like the 'D' side of en route). Thus the controller is a potential single point failure which, when combined with the single VHF radio channel for communications, makes for a high level of risk in the event of a failure in either of these two subsystems. The pressure on the controllers and pilots in this environment has a greater significance when taking into account the nature of terminal and

tower operations. It is here that most rare-normal situations occur involving aircraft failures, pilot errors or weather effects. This is also where separation standards are used as the target separation distances to achieve maximum throughput. Allowing a little extra separation reduces throughput, while a judgmental error the other way causes a loss in the safety separation. In addition, there is always the potential for an aircraft to suffer some form of technical problem. The terminal and tower environments are thus very difficult domains in which to implement change and the challenge must not be underestimated. Sections 4.3.1 - 4 attempt to frame the specific human factor issues that affect increasing throughput in the terminal airspace. These issues were raised earlier within Section 3.4. The issues of one section tend to be influenced by issues in other sections. This is the nature of the system, complex and interconnected with adaptive, reasoning humans in a key role.

Decision Support Systems

The term 'decision support' covers many different types and levels of computerized support or guidance to the human operator. The main issues associated with decision support are the growing dependency that tends to occur and the effect that the support could have on the ability to maintain situational awareness. Whatever the nature of the support system, it is clear that controllers and pilots respond in a very similar way to other living organisms by developing a growing dependency on the support. This growing dependency has been described in various sources and has a major impact on the way that human roles should develop within air traffic control systems.

"System designers, regulators, and operators should recognize that over-reliance (on automation) happens and should understand its antecedent conditions and consequences"

(Parasurman, 1997)

This dependency can be expected to grow not only as a function of time and confidence in the system, but it can also be expected to grow as a function of lack of knowledge of how the system functions without the presence of that support. Thus, new (relatively naive) operators who do not have the same skill and experience base as the existing operators, can be expected to display dependency quicker than operators who have this pre-support experience. Growing dependency has implications on how the system copes with failures, errors and exceptions. Therefore it is essential that such dependency is accounted for not only in the development, design and implementation stages but also during the certification procedures where issues of availability, reliability and redundancy are raised. The second issue to be raised about decision support systems is how they affect the operator's ability to maintain the necessary level of situational awareness. A key aspect of situational awareness is the ability to identify when intervention is necessary and then intervene as required.

Controllers formulate a 'tactical plan' which is constantly being executed and modified in real time. This tactical plan is their baseline for actions within their domain of responsibility. The plan demands that certain information is accessed and processed in a timely manner. If the necessary information is not available, then this absence is itself a trigger to change tactics. Thus triggers to tactical actions can be derived from the absence or presence of information. This knowledge of what should be present, but is not, would have to be explicit in the support tool design; lack of required information requires some form of 'flag'. The whole aspect of situational awareness, what it is, where it comes from, what information is needed when (in order to support it), is still not adequately understood. To place decision support systems into such a domain of incomplete knowledge is an action that should be treated with great caution. Most aspects of these two issues can be addressed using a series of questions about the proposed new process or tool:

- Has the level of expected dependency on the new support tool by new operators been identified? What is its availability - how often is it prone to fail?
- What is its reliability - what are the situations when its output is highly variable? •
- What online checks are being made on its reliability - are these continuous or periodic?
- Is it the human operator that verifies the output? If so, is this operator capable of making those reliability checks?
- What are the back-up procedures to take into account failure, degradation or inappropriate outputs?

- What verification procedures are used to ensure required availability of back-up systems/procedures?
- Are these back-up systems and procedures available, online and well practiced?
- What is the certainty that any necessary human intervention skills are of the appropriate level of proficiency and availability - does this change with time and population structure - how is this tested and how frequently?

There needs to be more research in the whole area of decision support tools, and how they are subject to growing dependency and affect the maintenance of appropriate situational awareness.

Intent

There are several issues surrounding the content and availability of intent information that have an impact on the effectiveness of decision support systems and have major implications requiring human factors consideration. The main issues are: •

- Where is the knowledge of the intentions of each aircraft and of the tactical controller?
- Is it in the Flight Management Computer (FMC) or other computer or is it in someone's head?
- How accurate and reliable are these intentions?
- How long are they valid?
- How can these intentions be made available to the decision support system in order to allow it to function with the best quality data available?
- How can the system be kept updated or informed when disturbances occur that demand rapid re-planning on the part of both pilots and controller?

'Intent' is the description of how the future is most likely to unfold, and in it there is an attempt to shape the future. Thus intent involves elements of both prediction and predetermination. Airborne technology has developed to a state that is allowing prediction of the future, from the individual aircraft's point of view, to be realized with a fairly high degree of certainty. This high level of certainty is the result of the FMC's working to ensure that predictions come true; the FMC ensures conformance; the future state(s) is/are constraints that should be achieved. Intent is not confined to the aircraft and its plan; it is also an important aspect of the controller's method of managing a domain of responsibility. The controller's intent is an extension forward in time of the dynamics of the current situation, identifying where modifications will be necessary to maintain safety and achieve pilots' requested profiles. The air traffic control system functions principally through the action of the controller combining all the individual pilot intents with his/her own intent into an overall plan arbitrating wherever intents conflict. The intent information then becomes a constraint to which each pilot and the controller attempt to conform. Controllers that talk of 'having the picture' are referring to knowing not only both the current status and intent, but also of having a plan for the future. They are fully aware of the situation.

The controller's intent currently tends to exist only in the head of the controller. Groundbased decision support systems need to have knowledge of the controller's intent in order to support the execution of the 'tactical plan'. These issues are made more difficult to resolve within the terminal and tower domains by the nature of the operations in those domains. Terminal and tower are very time-critical and tend to have both a high mechanical task loading as well as a high cognitive loading. This places extreme demands on decision support systems for the terminal environment both in terms of task loading and situational awareness.

Thus there are major issues surrounding the requirements for a better understanding of registering intent:

How to get intent into the system

- How to ensure its validity
- How to update it or declare it invalid

There is another set of issues surrounding the possibility of using some decision support system to create its own plan, thus resolving human input problems. The main issue in this approach is how to inform the operator about the system's plan, (especially if the human is the back-up system).

Decision support systems will have limited effect unless they have knowledge of both the pilots' and controller's intentions. It is the sharing of intention and then the formulation of a plan that are key elements in achieving greater throughput whilst maintaining or improving safety.

Using Structure To Maximize Throughput

The usual response of controllers, when the demand for throughput increases, is to impose some structure as to how traffic flows through their domain of responsibility. This has been raised as a possible strategy for maximizing throughput in Section 3.4.7. The imposition of various restrictions, in a structured form, is an attempt to control the complexity which results from having many pilots each with different requirements. As traffic load increases, the controller tends to move from a mode of processing individual requests to one of restricting individual aircraft so that they fit into a certain structure. A number of options are available:

1. The structure can be predetermined and accessible to the pilots for planning; e.g., Airways, SID's, STAR's, or

2. It can be predetermined but not available to the pilots; e.g., letters of agreement between air traffic control facilities on the use of flight levels or routes, or

3. It can consist of predetermined actions based on group or individual experience and not published anywhere, and can be as extreme as stopping all departures from a particular airport if a sector becomes dangerously overloaded.

There are major differences in the controller's cognitive workload between allowing aircraft to fly in a non-airways system, searching for conflicts as the traffic levels grow, using novel strategies for each situation, versus that of enforcing structure and limiting conflicts to particular, well-defined points where pre-determined strategies can be utilized to resolve them.

The current strategy for reducing the cognitive workload on controllers when predicting conflicts is to restrict traffic to conform to a particular structure. In this way, the cognitive load per aircraft can be reduced so that the overall level (resulting from the total traffic) remains at a manageable level.

The degree of detail on each aircraft's passage through a domain of responsibility, which the controller must retain, can be reduced using this structuring technique. If all aircraft are on individual routes and profiles, then the removal of all structure and constraints from the ATC system may well reduce the actual incidence of conflicts. However, although the incidence of actual conflict may be reduced, there would probably be an increase in the controller's cognitive load because of the demand for more detail on each individual flight in order to detect potential conflicts. It is important to keep in mind that the primary role of the controller is to detect and resolve potential conflicts, before they become actual conflicts. The act of tactical planning and its constant revision reflect this responsibility. (See Section 6.4 for a discussion on how to reduce the workload of searching for potential conflicts).

This issue is most obvious in terminal airspace where, due to the uncertainty of aircraft performance in the vertical plane and the lack of good quality intent information currently available, there are many more potential conflicts than for aircraft in a more stable cruise environment. This aspect of detecting potential conflicts and understanding the heuristics for determining what is a potential conflict are important aspects when establishing fast time simulations to forecast the effects of different airspace organizations. It is the potential conflict that creates workload for the controller, and in any situation where aircraft are climbing and/or descending towards each other there is a need to manage the uncertainty of these potential conflicts by close monitoring and probably positive intervention until the situation becomes certain. How controllers assess and manage uncertainty needs to be clearly understood before schemes that involve removal or modification of some of the structures used to manage uncertainty are implemented. Human factors knowledge needs to be used in determining the impact of airspace structure on capacity, and the requirements for support for the controller's cognitive workload in a system that has less structure than at present.

Sharing Responsibility

Responsibility for separation assurance is usually vested in the controller except for very specific situations (i.e. during visual meteorological conditions (VMC) when limited aircraft-to-aircraft separation responsibility can be delegated to the pilots concerned). Controllers assess how all the aircraft are flowing through a sector or area of responsibility, working out where adding structure (perhaps in the form of temporary restrictions) will reduce the incidence of conflicts. When conflicts do occur, there is a balancing of the needs of the individual aircraft and an attempt to confine the side effects of any resolution maneuver to as few aircraft as possible. The controller, in any conflict resolution strategy, balances the demands of each aircraft against the needs of all the aircraft that are implicated. As discussed in Section 4.3.2, controllers impose structure during dense traffic scenarios in order to reduce the incidence of conflicts. This is a stabilizing and throughput maximizing strategy. The controller acts as arbiter where there is a conflict of interest, but does not have time to discuss the resolution strategy. Is it possible to transfer separation assurance to the pilots in the terminal area to achieve VMC-type separation distances in instrument meteorological conditions (IMC) and thereby increase runway utilization? The terminal area encompasses the most demanding phases of flight for pilots: approach and departure. Taking on the additional role of separation assurance would have the potential of considerably increasing that workload in IMC. In the event of any on-board difficulty, pilot workload would rise, probably necessitating a reduction of overall tasks. It is also probable that in order to achieve the goal of safe and stable flight the first task to be off-loaded would be the separation assurance task. The transfer of such a responsibility back to the controller would have to be explicit in order for each party to be aware of the extent of changes in his/her responsibility. Such a sudden transfer at a time of already high pilot workload could also lead to a situation of higher than acceptable risk. The aircraft is already experiencing difficulty, and the intent information required as input to any decision support system may be rapidly changing without either the system or the controller being aware of the extent of these changes. In additional, separation standards associated with airborne separation assurance concepts might be less than those which an unsupported controller could sustain. Thus the controller is presented with a situation where the appropriate separation does not exist for ground-based separation. In this context, the system is potentially fail-dangerous. By going through this type of failure mode analysis, it is clear that if separation assurance is shared with the flight deck in order to achieve reduced separation standards, then adequate redundancy must be provided to prevent the immediate reversion to control by an unsupported controller on the ground. This points to a need for consideration of some critical human factors issues on the flight deck, not the least of which is a major potential shift in pilot roles, tasks and operating procedures. There seems little likelihood that pilots will be able to support aircraft-based separation in potentially high workload scenarios without the integration into the cockpit of major decision support systems. In such a scenario human factors issues which are raised, both in the cockpit and at the controller's workstation, should be examined without delay.

The other issue connected with the sharing of responsibility is that of ensuring that actions chosen by pilots as resolution strategies do not cause other conflicts. There is a need to constrain the possible range of strategies commensurate with traffic conditions.

It is probable, in light traffic conditions, that certain conflicts could be delegated to pilots to resolve without maneuver restriction. But in heavy traffic conditions, restrictions would need to be imposed on available strategies in order to prevent a ripple effect on other aircraft. Once again, unless significant information and suitable support systems are provided to the pilot, the initiative for limiting maneuvers must be provided by someone with an overview of the situation. It is likely that the controller must continue to provide such oversight. In this case, the expectation of aircraft-based separation in anything but the least dense traffic scenarios must be seriously questioned. Any issue that affects the roles of pilots or controllers as well as the tasks they perform to execute those roles needs to have the human factors issues carefully considered in order to prevent unwanted side effects.

AVAILABLE AND EMERGING TECHNOLOGY

System Performance

To achieve reduced airplane separations in part requires a formal definition of system performance that encompasses improved communications, navigation and surveillance performance. In addition, a formal characterization is required of the airspace environment (e.g., airspace configuration, traffic characteristics, available functionality, procedures definitions) for both nominal and rare-normal performance (e.g., failure modes, temporary constraints such as weather, etc.). Experience has shown the need for a formal definition of system performance. For example, more precise departure and approach paths and direct routings for improved airspace operations were expected with the introduction of area navigation technology such as that introduced in the initial 757/67 aircraft fielded in 1982. A more complete characterization of systems capabilities and features (i.e., the airplane operating environment and air traffic infrastructure) since 1982 has led to incremental step benefits. Total system performance characterization of the primary variables enables the higher level of performance and closer permitted separation. The proposed definitions of the required performance components for navigation, communication and surveillance are summarized in the following paragraphs. RNP has been adopted by the ICAO Required General Concept of Separation Panel (RGCSP) and

All-Weather Operations Panel (AWOP), implemented in the Boeing 737, 747, 777 models (757/767 will be certified in early 1998), and is ready for initial operational approval. RCP and Required Monitoring Performance (RMP) are in various stages of development. These performance definitions can be combined in many ways to support the reduction of buffer regions in airplane separation. However, the identification of Required System Performance must find a practical set of CNS capabilities that address operational needs in a way that provides intended efficiency while maintaining or increasing safety. To illustrate the objective of RSP, one can conceive a protection volume around the airplane, whose size depends on the dimensions of the combined communication, navigation, surveillance performance, and synthesizes into an RSP performance characterization.

Communication Performance

Airplane communication requirements for each phase of flight are a function of the controller-pilot communication needs. These vary greatly with traffic complexity and density, the weather conditions, the controller's needs to issue clearances and vector the airplane or simply to establish contact with the crew. Increased communication performance will be provided through air/ground data link communications integrated into the Aeronautical Telecommunication Network (ATN) to complement the current voice communications means. This evolution to more data communications together with increased flexibility in the use of communication technology will enable the use of the several available links depending upon the most efficient communication pathway. The pathway chosen will be transparent to the user, but will be affected by aircraft location, message type, message criticality, and pathway availability.

The draft document on RCP (RTCA, 1997) establishes the end-to-end requirements for the communication component of the CNS/ATM operating environment. The following paragraphs provide further details of the RCP concept.

Required Communication Performance Concept

Required Communication Performance is a statement of the operational communication performance delay, integrity and availability necessary for flight within a defined airspace, or for an aircraft to perform a specified operation or procedure. Figure 5.1 illustrates a generic system configuration for the exchange of air/ground information. An RCP is determined by cognizant authorities in consideration of environmental factors such as target levels of safety, separations, flight operation standards, and hazards associated with the airspace or procedure.

Generic System Configuration for the Exchange of Air/Ground Information as RCP evolves to its formal definition, it will define the communication performance of the individual components (i.e., the aircraft subsystem, the air/ground networks, the ground/ground networks and the ATS subsystem) on an end-to-end basis, both for Voice and Data communications. The requirements must be stated in technology independent terms and, to a degree, independent of architecture, in order to accommodate alternative technologies and architectures.

Installed Communication Performance

Installed communication performance (ICP) is a statement of the aggregate performance of a given communication system, as depicted in Figure 5.1, and the service arrangements and levels that have been arranged for with air/ground service providers. ICP is expressed in the same terms and with the same parameters as RCP. The total user-to-user ICPT is a function of all the ICPs of elements between the users (i.e., communications elements between a pilot and a controller). Once ICPT is determined, it can be compared against a specific RCP to determine if the RCP is met.

Determination of ICPT is part of the process of gaining operational approval for the given RCP airspace or operation. ICP is inherently tied to one or more specific technologies. It is the term used to describe the performance of the particular communication path as certified by the cognizant authority. ICP can be associated with a given aircraft because it is strongly influenced by the aircraft's equipage and the communication support arrangements that have been made for it.

Actual Communication Performance

Actual communication performance (ACP) is an observation of the dynamic operational communication capability of the same communication elements as was used for the determination of ICP. ACP is expressed in the same terms and parameters as are RCP and ICP, but at a given instant may differ from the ICP of a particular path. ACP can be determined by monitoring the communication path or by monitoring the current condition of the elements of the path. It is recognized that various cognizant authorities may wish to specify the necessary reactions of the airspace manager and flight crew when ACP differs from ICP.

Navigation Performance

Airplane navigation requirements for each phase of flight are a function of airplane separation requirements. The separation of aircraft and obstacles also provides requirements especially in the approach/landing phase. A high degree of confidence in the aircraft staying within a specified volume of airspace is needed to establish separation standards. The dimensions of this volume are based on the probability of the aircraft navigation system performance not exceeding a specified error. However, airplane separation criteria established by the FAA also account for the availability and limitations of communications, and surveillance services, as well as operational factors (e.g., the crew/autopilot's use of the navigation information to control the airplane position) in addition to navigation requirements. The increased equipment accuracy and world wide coverage of new systems based on Global Positioning System (GPS) navigation will greatly improve operations because of the performance limitations of ground aids. This is achieved in large part by providing increased integrity monitoring and more reliability. As navigation evolves to satellite based aids, consideration of additional failure modes will have to be considered. These and potentially more sophisticated crew alerting schemes will keep driving new requirements as applications evolve. Cost considerations may become driving factors, but minimizing the impact on crew interfaces as a fundamental design philosophy will help as will the potential use of navigation technology developed for the mass market. RTCA's document DO-236, "Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation" (RTCA, 1997) establishes the requirements for the airborne navigation component of the CNS/ATM operating environment. These standards will be used by the service providers and users to obtainoperational benefits and may be used to varying degrees depending on the operating environment. The following paragraphs provide further details of the RNP concept and the examples in paragraph 5.3 illustrate potential or proposed applications of the RNP MASPS.

Required Navigation Performance Concept

RNP is a statement of the navigation performance accuracy, integrity, continuity and availability necessary for operations within a defined airspace. Boeing's implementations of RNP focuses on horizontal applications and specify the accuracy, integrity and availability of navigation signals and availability of navigation equipment requirements for a defined airspace (Leslie, R.S. (1996) and Tarlton, T. (1995)).

The RNP concept introduces the containment surfaces to define requirements beyond accuracy and provide assurance of navigation performance. It defines a region around the desired airplane path that can be defined, and that the probability that the airplane does not remain within that region can be bounded. The containment integrity and containment continuity requirements define the allowable probabilities of certain types of failures for the navigation system. In particular, the integrity requirement limits the probability of a malfunction of the navigation system which causes the cross-track component of the total system error to exceed the cross-track containment limit associated with the current RNP without annunciation. The continuity requirement limits the probability of the loss of function, which occurs when the system indicates that it is no longer able to meet the containment integrity requirement. The containment surface width is typically set at two times RNP (i.e., the airplane will be located within two times RNP of the FMC estimated position). The containment surface ties this performance measure to the airspace environment and has direct operational implications for flight path, separation minima and obstacle clearance surfaces criteria.

Actual Navigation Performance

Actual Navigation Performance (ANP) is the actual estimated navigation system accuracy with associated integrity for the current FMC position. It is expressed in terms of nautical miles and represents a radius of a circle centered around the computed position where the probability of the aircraft being inside the circle is 95%.

The computed accuracy, ANP, is displayed to the crew as ACTUAL (navigation performance), and annunciation is provided if ANP (ACTUAL) does not comply with the containment integrity requirement of the current RNP.

SURVEILLANCE PERFORMANCE

Required Monitoring Performance

A key concept in the definition of future ATM systems is that of Required Monitoring Performance (RMP). The term ‘Monitoring Performance’ refers to capabilities of an airspace user to monitor other users and be monitored by other users to a level sufficient for participation of the user in specified strategic and tactical operations requiring surveillance, conflict assessment, separation assurance, conformance, and/or collision avoidance functions. RMP is intended to characterize aircraft path prediction capability and received accuracy, integrity, continuity of service, and availability of a monitoring system for a given volume of airspace and/or phase of operation.

Aircraft path prediction is a key function for airspace management and monitoring. Aircraft path prediction capability is defined by a position uncertainty volume as a function of prediction time over a specified look ahead interval. Monitoring integrity (assurance of accurate, reliable information), where there is availability of service, must be defined consistent with desired airspace operations. Continuity of service and availability also must be defined consistent with desired airspace usage. Development of these concepts is currently in progress by various standards organizations.

Surveillance System Objectives Surveillance is a key function for airspace management and supports both tactical separation assurance of aircraft and strategic planning of traffic flows. The primary objective of the surveillance function is to support the following types of airspace management functions:

<u>Short Term Separation Assurance</u>

The surveillance function provides current aircraft state information on controller displays and as inputs to separation automation functions, i.e. the short term Conflict Alert system for detecting immediate path conflicts, and the Minimum Safe Altitude Warning (MSAW) system for detecting potential flight into terrain. In addition, future automation functions may require inputs for path lateral and vertical conformance monitoring and for automated checking of path intent versus path clearances.

<u>Medium Term Separation Assurance</u>

The surveillance function currently provides state information for sector-based airspace planning and load management. In the future, additional automation functions such as Medium Term (~ 20 min. lookahead) Conflict Probe may be used to detect and resolve potential airspace conflicts, enhancing the productivity of ATC centers. These automation functions will probably require enhanced surveillance in order to provide accurate and reliable path predictions for medium term lookahead periods.

<u>Medium Term Airspace Planning</u>

In the future, the surveillance function must support medium term flow planning and airport arrival/departure management in congested hubs and other areas where traffic loads can lead to flow inefficiencies and saturation of airspace throughput. Automation tools such as the Center-TRACON Automation System (CTAS) arrival manager and proposed dynamic sectorization tools will require higher levels of surveillance performance if safety and capacity goals are to be achieved as traffic demand increases.

<u>Strategic/Long Term Planning and Flow Management</u>

One of the goals for the future flow management system is to transition from a departure managed system to an arrival managed system of flow management. One enabling technology for strategic management of airport arrival slots is accurate 4D prediction of flight paths from takeoff to arrival at airport metering fixes. The surveillance function supports strategic flow management by providing accurate state and intent information for long term path predictions.

Similarly, en route traffic flow control automation such as dynamic sectorization requires accurate path predictions for sector load analysis and flow management.

Current Radar-Based Surveillance System Performance

The current NAS uses a variety of radar systems to supply surveillance data for surface, terminal, and en route airspace management. On the airspace surface, current generation Airport Surface Detection Equipment (ASDE-3) primary radars are being installed at major hub airports to provide surface surveillance and incursion alerting. In the terminal airspace of most medium and large capacity airports, surveillance data is provided by an Airport Surveillance Radar (ASR) primary radar which provides position reporting on a periodic scan basis, supplemented by a co-located Secondary Surveillance Radar (SSR) which provides aircraft identification, altitude, and backup position reporting. Smaller airports may only have access to an SSR radar, or may have no surveillance capability other than that provided by voice reporting and tower controllers. En route airspace uses a networked system of Air Route Surveillance Radars (ARSR) which provide continuous monitoring of aircraft flying in domestic airspace above ~ 9,000 feet altitude. Each radar is networked to one or more Air Route Traffic Control Centers (ARTCC) to provide continuous monitoring of aircraft across NAS managed airspace. Considerable redundancy is built into the en route surveillance system in that ARSR sensors are positioned to achieve at least dual radar coverage throughout NAS managed airspace, and in addition a co-located SSR provides identification, altitude and position reporting along with that of the primary ARSR radars. Current terminal area surveillance is provided by a mix of ASR -7,8,9 primary radars and

Air Traffic Control Beacon Interrogator (ATCBI - 3,4,5) and Mode S secondary radars. The older generation analog ASR-7 radars are more than 30 years old and are being replaced by modern ASR-9 radars or the near term ASR-11 radar. The last-generation ASR-8 radars are also analog radars which are being upgraded to ASR-8D digital radars to perform surveillance equivalent to that of the current generation ASR-9 radars. The ATCBI-3,4,5 are older SSR radars which are being replaced by modern Mode S radars or the near term ATCBI-6 which is a monopulse SSR with limited Mode S functionality.

(The ASR-9s for major hub airports are paired with Mode S radars, and the ASR-11s will be paired with ATCBI-6 secondary radars.) These radars are designed to support ranges of at least 60 nm around each airport, and to scan at a rate of about one report per five second interval. The individual radars have a detection capability exceeding 98 percent, and a system availability exceeding 0.999 in low altitude terminal airspace. The modern radars have azimuth accuracies on the order of one milliradian rms, which means that the position reports of aircraft within terminal range are accurate to 0.1 nm or better. By contrast, the older radars have azimuth accuracies on the order of three milliradians which means that the cross-range components of position reports have much greater uncertainty and aircraft tracking is significantly less precise. Current en route surveillance is provided by a mix of ARSR-1,2,3,4 primary radars with co-located ATCBI and Mode S secondary radars. The ARSR-1,2 radars are very old analog radars and must be decommissioned in the near term as they are very expensive to maintain. The

ARSR-4 radars are the current generation systems which are being deployed paired with Mode S secondaries along the U.S. coast lines and international borders, and the ARSR-3 radars will be given service life extensions to maintain service over the next 20 years. These radars are designed to provide line-of-sight (~ 250 nm range) capability and to scan at a rate of about one report per 12 second interval. The detection probability and accuracies are similar to those of the terminal radars. This means that position reports at ranges on the order of 150 nm or more are considerably less accurate than those for terminal surveillance, and as a consequence of the report accuracy and lower data rate, en route tracking and data report quality are much lower for en route surveillance. This is one of the reasons that horizontal separation standards are much larger in en route airspace.

NAS Surveillance System Limitations and Deficiencies Surveillance system performance today is characterized by the radar sensors available, the tracking and data fusion software in the ATC centers, and the display automation used for tactical control. In the terminal area, the modern ASR and monopulse SSR sensors produce high quality position data for determining aircraft state and identity, and the older less capable sensors are in the process of being replaced. Similarly, most of the processing and display limitations of the current ARTS system may be overcome with the replacement STARS automation system. A primary architectural problem, however, is the low connectivity of radars in the terminal area. This leads to an expensive system, since every airport with ATC facilities needs a source of surveillance data. One of the goals of the future system is to reduce the number of radars in each urban area to provide dual surveillance coverage of all major airports (for functional redundancy in case of system failures), and at least single coverage of other airports by networked distribution of surveillance data to ATC fusion nodes. These goals are annunciated in the NAS Architecture V2.0 (U.S. FAA,1996).

By contrast, current NAS en route surveillance is characterized by a number of problem areas. The accuracy and usefulness of aircraft state data is greatly limited by the use of legacy tracking and display software. This results in fair to poor velocity estimates with considerable noise variations from scan to scan, and in large tracker lag errors (~ 30 to 60 second lag errors during turn maneuvers). Moreover, the use of the 'radar mosaic' concept for switching from one primary sensor source to another as the aircraft traverses across mosaic boundaries leads to track state 'jumping' as the tracker shifts from one sensor source to another. In addition to these implementation problems, the current surveillance system does not provide flight path intent data for path conformance monitoring, and provides only limited coverage at low altitudes and in mountainous terrain. The implementation problems of the current system can be largely overcome by use of modern multi-sensor tracking and data fusion software, which compensates for deterministic sensor errors such as azimuth bias errors, and enables dynamic blending of the most appropriate data for aircraft state estimation. (A surveillance 'server' concept is advocated in NAS Architecture Versions 2.0-3.0, which would network multiple terminal and en route sensors into common data fusion nodes, and distribute the global track data to appropriate ATM facilities, requesting users, and to external fusion nodes.)

Surveillance System Performance Metrics

Within the regions where surveillance coverage is available, the primary metrics for the surveillance function are accuracy, availability, integrity and latency. (Continuity of function and reception probability are also of interest, but are usually treated within the scope of the above metrics.) Although individual sensors or subsystems may have individual or characteristic performance, it is the end system performance metrics which are of significance for the users of surveillance data. For path prediction analysis, for example, both position and velocity performance is significant for determining the overall prediction errors for a given lookahead period. We summarize these metrics and future requirements in this section.

<u>Accuracy Metrics</u>

The accuracy metrics in the current system are most often driven by user requirements for separation assurance. In the terminal area, where this function involves vectoring and altitude level-off controls, the greatest need is for relative accuracy measures, i.e. monitoring the current aircraft states versus the currently active clearance. Typical relative position accuracy of modern radars in the terminal area is under 0.1 nm and is adequate for current means of separation assurance. The future use of RNP routings on the order of RNP-0.3 for SIDs, STARs, and non-precision approach, and the potential use of operational concepts to increase throughput may lead to requirements for substantially higher accuracy and dynamic reporting of path intent. Part of this requirement will be for absolute accuracy, since bias errors between the flight navigation system and the surveillance system may appear as path conformance violations to ground controllers, and part of this requirement will be for more precise velocity states for faster detection and resolution of route conformance and clearance errors. The accuracy metrics for surveillance performance in transition and en route airspace are driven by several needs including conflict detection, separation assurance and sector load planning. Operational concepts such as the use of medium term conflict probe will require much better tracking than is available with current legacy systems. Earlier studies (Warren, 1996) have shown the need for much reduced lags in tracking of maneuvering aircraft, and in achieving steady state velocity errors on the order of 5 knots rms. Similarly, the use of operational concepts to achieve reduced separation standards, and the future use of RNP-1 routings may lead to requirements for substantially better tracking accuracy than is achievable with currently fielded systems.

Availability Metrics Since active surveillance is essential for safely separating aircraft at the separation standards currently used in the NAS, the desired levels of system availability are on the order of 0.99999 or better (RTCA, 1997, MASPS on Automatic Dependent Surveillance63

Broadcast (ADS-B), V6.0). Individual radar sensors can support availability on the order of 0.999. However, to achieve the overall system level availability, dual surveillance coverage is usually required. This is currently not a problem at high altitudes since dual radar coverage or better is available throughout the NAS. At low altitudes, and in the terminal maneuvering areas this requirement is difficult to achieve and an availability of 0.999 is currently considered acceptable, except at the major hub airports. This level of availability is probably adequate for future systems, except that traffic growth may extend the need for higher availability in more terminal areas. Continuity of function is often included in the availability metrics and in future system planning considerations. Integrity Metrics Integrity is usually measured in terms of undetected errors in surveillance system outputs. Desired system level integrity is on the order of one undetected error in 10 7 scans/output reports. At the sensor level, clutter detections and fruit replies can lead to large spontaneous errors at much higher rates. The tracking and data fusion software typically provides the added integrity to achieve the desired system level performance. Future systems will probably require equivalent integrity, although the use of multi-sensor processing and integrity checking could yield higher integrity than current systems. Latency Metrics Latency is a measure of the acceptable delay between successive surveillance reports on

the average or at a specified probability level. (For example, with en route radars the probability of reception per scan is on the order of 98%, and the latency between successive scans is 12 seconds at the 98% probability level.) This metric is typically specified by a stressing application such as separation assurance at a typical range between the aircraft being tracked and the tracking sensor. For close range applications such as parallel approach monitoring and collision avoidance, a typical latency requirement is a one second report updating at a 95 to 99 percent probability of reception. For other applications latency requirements increase with separation range and size of minimum separation standards, e.g. latency may be 15 minutes with ~95% reception probability for an oceanic ADS system supporting horizontal separation standards on the order of 30 miles. This does not include transmission latency, which is a measure of the time delay in actually receiving the report at the data fusion center, or latency error, which is a measure of the time stamping error associated with a surveillance report. These metrics are also useful in quantifying system performance.

Aviation Weather Performance

Weather has a major impact on the safety, efficiency, and capacity of aviation operations. Accidents and incidents continue to be caused by adverse weather. Runway acceptance rates and other capacity metrics are reduced in IMC. According to some studies, 40-65 percent of delays that affect U.S. domestic airlines are caused by adverse weather, at annual direct costs ranging from $4-5B per year (Evans, 1995). In addition, passengers are inconvenienced by flight delays and cancellations or diversions due to weather, and are uncomfortable when turbulence is encountered during a flight. The expected future growth in air traffic will only exacerbate all these conditions, imposing constraints on the ability of the airlines to meet growing demand while improving safety and efficiency. Boeing has recently launched an Aviation Weather Study to collect and document information on the affect of aviation weather on the domestic and international ATM system (Lindsey, 1997). An important component of this effort is to develop an understanding of user requirements for aviation weather information, and then to assess how well the current and planned aviation weather system will meet those needs. Section 5.5 presents some of the preliminary findings from this project regarding the operational aspects of current and future aviation weather technologies. Recently, the National Research Council released a report describing the results of its review of the domestic aviation weather system (NRC, 1995). Some of the key findings and recommendations from that study related to the performance of weather technologies included:

- Some of the measurements provided by automated weather observing systems are not always reliable, especially observations of ceiling and visibility measurements. More human observers are needed at key facilities to ensure that erroneous data are not disseminated to pilots and controllers.
- Aircraft observations of winds and temperatures provided by the Meteorological Data Collection and Reporting System have improved forecast accuracy, and its use should be expanded and more carriers encouraged to participate.
- New weather technologies coming online now and in the near term are producing much larger data sets than previously available. New data management and analysis technologies, such as the Aviation Gridded Forecast System, are needed to manage and distribute this information.
- The accuracy and timeliness of short-term 'nowcasts' and longer term forecasts of weather conditions in the terminal area and en route environments need to be improved. Additional research is required to improve current weather forecasting tools and to develop new technologies. Many of the negative impacts of weather on the aviation system are regional rather than global problems. Regional solutions should be sought where they will be most effective (Alaska is a key area identified by the NRC where this recommendation should be followed).
- Interactive computer graphics workstations and graphical images depicting current and expected weather conditions are becoming the tools of choice for analyzing and disseminating weather information to users. Efforts are needed to standardize the information provided by these systems so that all users benefit from shared situational awareness. Controllers in particular should be given critical weather information in formats that improves their situational awareness without increasing their workload. Such information could significantly improve the efficiency of the air traffic control system while improving safety standards at the same time.
- The limited capabilities of current cockpit displays and communications links are the largest technical constraint on disseminating weather information to pilots. Research is needed to develop cockpit display systems and communications systems that will provide weather information to pilots in as an efficient and timely manner as possible.

Human factors issues and crew workload considerations must be addressed early in this process.

The NRC study addressed many areas of concern related to the aviation weather system, but it did not specifically investigate some of the near term and far term performance requirements for aviation weather technologies to support CNS/ATM systems. For example, accurate 3D meteorological information will be needed for CTAS and conflict probe trajectory calculations, and for the wake vortex separation prediction system being developed by NASA. The data sets needed for these tools will be generated from analyses of current surface and aloft conditions and forecasts of future conditions. The accuracy, precision, and completeness of the meteorological information must be quantified, and the sensitivity of CNS/ATM tools to errors in the data need to be determined. Information is also needed on the amounts and types of additional data, especially upper-air data, that will be required to ensure the success of these technologies. Most weather impacts on today's ATM system are associated with bad weather, especially in the terminal area when adverse weather creates inefficiencies that lead to capacity reductions at the busiest airports. Thus, most aviation weather technology deployments already made or planned for the near term focus on improving the quality and timeliness of weather information for instrument meteorological conditions. However, for the far term the focus will need to shift to improving the quality of aviation weather information under all weather conditions, including what would normally be considered fair weather, i.e., visual meteorological conditions. This is because the day-to-day success of Free Flight and new CNS/ATM technologies like CTAS will depend in part on the quality of the observed and predicted meteorological information that these technologies will need.

COMMUNICATION

Air/Ground Communication

Air/ground communication provides for the transfer of information between the aircraft and a ground entity. The ground entity may be an air traffic control facility, an airline operations center or another source of required information, such as an airport which prepares an Automated Terminal Information System (ATIS) message. Air/air communication is a special case of air/ground communication. The primary use of air/air communication is monitoring the party line of other air/ground communications. Certain operations, such as operations at uncontrolled airfields, require transmission-inthe- blind. That is, the pilot reports his position and intent to any and all aircraft near that airport without addressing a specific aircraft or expecting a reply. In addition, flight crews directly communicate between aircraft, such as in oceanic airspace.

Communication functionality may be described in three layers of service. The Application layer provides standard formats for efficient transfer of information. In voice communication, this consists of standard phrases and reporting procedures which have volved over time and are specified in documents such as FAA Order 7110.65, Air Traffic Control, and the Aeronautical Information Manual (U.S. FAA, 1997). The next layer is the Protocol layer, which provides the conventions or rules for communication. The third layer is the Media layer, which connects communicating nodes together by radio frequencies or wires.

Voice

Voice air/ground communication has evolved from early tube-type avionics transmitters and receivers to modern 760-channel very high frequency (VHF) transceivers and satellite communication (SATCOM). As shown in Figure 5.2, voice communication provides both air traffic services (ATS) and AOC services. Air traffic services includes ATC voice procedures, waypoint reports, and ATIS broadcast information. Although waypoint reports are actually a subset of ATC voice procedures, they are shown here as a placeholder for the ADS function which will be described in the data communication section. ATIS broadcast is shown here as a representative of a broader group broadcast services, including transcribed weather broadcast (TWEB), Automated Weather Observation System (AWOS), and Automated Surface Observation System (ASOS) on very high frequency omnidirectional range (VOR) and non-directional beacon (NDB) audio channels.

Two-way voice traffic on VHF or HF radio is performed as half-duplex; that is, one party transmits, then the other party responds using the same channel. The speaker presses a transmit button to gain access to the channel; hence the term push-to-talk (PTT). In theory, an ATC controller is the owner of any channel assigned to ATC but in fact channel access is equal for all users. Many operations, including oceanic VHF, the emergency channel (121.5 MHz), and Multicom, have no ATC participant who can be said to own the channel. Since there are many users potentially requiring access to the channel, a verbal Medium Access Control (MAC) protocol has evolved. The pilot or controller listens for a break in the communications, presses the transmit button, and speaks the message. If a response is not received in a timely manner, the sender assumes that a collision happened or some other problem prevented the person at the other end from responding and the transmission is repeated. This is essentially the same logic as the Collision Sense Multiple Access (CSMA) normally attributed to digital data protocols. The individual messages may be considered packets of information.

MODULE III:

GLOBAL AIR NAVIGATION & CNS/ATM SYSTEMS

CONCEPT AND DEVELOPMENT

Communications, navigation, and surveillance systems, employing digital technologies, including satellite systems together with various levels of automation, applied in support of a seamless global air traffic management system. The Objectives of the CNS/ATM Systems is to foster implementation of a seamless, global air traffic management system that will enable aircraft operators to meet their planned times of departure and arrival and adhere to their preferred flight profiles with minimum constraints and without compromising agreed levels of safety.

An effective CNS/ATM System looks at to develop a seamless, globally coordinated system of air navigation services that will cope with worldwide growth in air traffic demand while:

- improving upon the present levels of safety;
- improving upon the present levels of regularity
- improving upon the overall efficiency and capacity of airspace and airports
- improving operations allowing for capacity increase while minimizing fuel consumption and aircraft engine emissions;
- increasing the availability of user-preferred flight schedules and profiles; and
- minimizing differing equipment carriage requirements between regions.

HISTORICAL DEVELOPMENT

The air transport industry has grown more rapidly than most other industries through the 1980s and 1990s. Between 1985 and 1995, air passenger travel and air freight on scheduled services grew at average annual rates of 5.0 and 7.6 per cent, respectively. Over this same period, aircraft departures and aircraft-kilometers grew at average rates of 3.7 per cent and 5.8 per cent, respectively.

The FANS Committee:

Having considered the steady growth of international civil aviation preceding 1983 and taking into account forecasts of traffic growth and perceiving that new technologies were on the horizon, the Council of ICAO at the time, considered the future requirements of the civil aviation community. It determined that a thorough analysis and reassessment of the procedures and technologies that had so successfully served international civil aviation over the many years was needed. In further recognizing that the systems and procedures supporting civil aviation had reached their limits, the Council took an important decision at a pivotal juncture and established the Special Committee on Future Air Navigation Systems (FANS). The FANS Committee was tasked with studying, identifying and assessing new technologies, including the use of satellites, and making recommendations for the future development of air navigation for civil aviation over a period of the order of 25 years.

The FANS Committee determined that it would be necessary to develop new systems that would overcome limitations of conventional systems and allow ATM to develop on a global scale. The future systems would be expected to evolve and become more responsive to the needs of users whose economic health would be directly related to the efficiency of these systems. The FANS Committee concluded that satellite technology offered a viable solution to overcome the shortcomings of conventional ground-based systems and to meet the future needs of the international civil aviation community.*

The FANS Committee further recognized that the evolution of ATM on a global scale using new systems would require a multidisciplinary approach because of the close interrelationship and interdependence of its many elements. Understanding that coordination and institutional issues could eventually arise with new concepts, and realizing that planning would have to be carried out at the worldwide level, the FANS Committee recommended to the

ICAO Council in its final report that a new committee be established to advise on the overall monitoring, coordination of development and transition planning. This would ensure that implementation of future CNS/ATM systems would take place on a global basis in a cost-effective and balanced manner, while still taking into account air navigation systems and geographical areas.

In July 1989, the ICAO Council, acting on the recommendation of the FANS Committee, established the Special Committee for the Monitoring and Coordination of Development and Transition Planning for the Future Air Navigation System (FANS Phase II).

In October 1993, the FANS Phase II Committee completed its work. The FANS Phase II Committee recognized that implementation of related technologies and expected benefits would not arrive overnight, but would rather evolve over a period of time, depending upon the present aviation infrastructures in the different States and regions, and the overall requirements of the aviation community.

The FANS Phase II Committee also agreed that much of the technology they were considering was already becoming available and that work should begin by gathering information and, where possible, accruing early benefits using available technologies.

The Tenth Air Navigation Conference

In September 1991, 450 representatives from 85 States and 13 international organizations gathered at ICAO Headquarters in Montreal, Canada, at the Tenth Air Navigation Conference, to consider and endorse the concept for a future air navigation system as developed by the FANS Committees that would meet the needs of the civil aviation community well into the next century. The FANS concept, which became known as the communications, navigation, surveillance/air traffic management (CNS/ATM) systems, involves a complex and interrelated set of technologies, dependent largely on satellites. CNS/ATM is the vision developed by ICAO with the full cooperation of all sectors of the aviation community to accommodate the future needs of international air transport.

The result of the Conference encapsulated a set of universally agreed upon recommendations covering the full spectrum of CNS/ATM activities, which continue to offer guidance and direction to the international civil aviation community as they plan and implement the technical and operational aspects of CNS/ATM systems.

The endorsement of the CNS/ATM systems reached at the Tenth Air Navigation Conference signalled the beginning of a new era for international civil aviation and paved the way for the many activities related to the planning and implementation of new systems around the world.

During the follow-up of the Tenth Air Navigation Conference, the ICAO Council re-emphasized the important role of regions and States with regard to the planning, implementation and transition to CNS/ATM systems and reiterated the need for a high degree of participation of the ICAO regional offices in their respective planning and implementation roles.

Further to the work and recommendations of the ICAO Council on CNS/ATM systems, the 29th ICAO Assembly approved two resolutions, which were consolidated at the 31st ICAO Assembly (Appendix B to Chapter 2 refers). These resolutions further endorse and support speedy implementation of CNS/ATM systems.

Global planning

In order to progress implementation of CNS/ATM systems, a plan of action was needed. The first such effort towards developing a plan was the ICAO Global Coordinated Plan for Transition to ICAO CNS/ATM Systems, which was included as an appendix to the Report of the Fourth Meeting of the Special Committee for the Monitoring and Co-ordination of Development and Transition Planning for the Future Air Navigation System (FANS Phase II) (Doc 9623). In 1996, the ICAO Council recognized that this plan had served its purpose well and had made a significant contribution toward realizing the vision established by the FANS Committees, while educating the international community on CNS/ATM systems and associated implementation issues. The Council concluded, however, that the CNS/ATM systems had matured; therefore, a more concrete plan which would include all developments, while putting focus on regional implementation, was required.

In light of the above, the Council directed the ICAO Secretariat to revise the Global Plan as a “living document” comprising technical, operational, economic, financial, legal and institutional elements, offering practical guidance and advice to regional planning groups and States on implementation and funding strategies, which should include technical cooperation aspects. These aspects of CNS/ATM systems are addressed in this revised edition of the Global Plan.

SHORTCOMINGS OF CONVENTIONAL SYSTEMS

The FANS Committee, early in its work, recognized that for an ideal worldwide air navigation system, the ultimate objective should be to provide a cost effective and efficient system adaptable to all types of operations in as near four-dimensional freedom (space and time) as their capability would permit. With this ideal in mind, it was recognized that the existing overall air navigation system and its subsystems suffered from a number of shortcomings in terms of their technical, operational, procedural, economic and implementation nature. After close analyses, the FANS Committee ascertained that the shortcomings of current systems (FANS I conducted its work between 1983 and 1988) around the world amounted to essentially three factors:

a) the propagation limitations of current line-of-sight systems;

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

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

Although the effects of the limitations were not the same for every part of the world, the FANS Committee foresaw that one or more of these factors inhibited the desired development of ATM almost everywhere. As the limitations were inherent to the existing systems themselves, the FANS Committee realized that there was little likelihood that the global ATS system of the time could be substantially improved. New approaches were necessary by which the limitations could be surmounted and which would further permit ATS systems to evolve into an ATM system more responsive to the needs of the users. CNS/ATM systems therefore, would have to allow for a considerable improvement in safety, efficiency and flexibility on a global basis

COMMUNICATION, NAVIGATION AND SURVIELLIENCE SYSTEMS: AN OVERVIEW

OBJECTIVES OF THE CNS/ATM SYSTEMS

	Air Traffic Management	**Flight Operations**
General	• ensure that all necessary information, including information needed for dynamic flight planning, is available to all ground and airborne systems • enhance functional integration of ground systems with airborne systems and the ATM-related aspects of flight operations • enhance the accuracy of conflict prediction and resolution and the provision of real-time information to controllers and operators	• enhance the accuracy of information related to flight progress • enhance functional integration of airborne systems and flight operations with ground systems • ensure the provision of accurate information between airborne system elements and ground system elements necessary for dynamic flight planning
Safety	• ensure the provision of well-adapted and harmonized safe procedures on a global basis • ensure that separation between aircraft is maintained ensure that clearance between aircraft and obstacles is maintained • provide for enhanced contingency planning ensure that rapid alerting service is available • ensure that safety levels are maintained as the use of automation increases	• improve pilot situational awareness • ensure adequate clearance from terrain • enable aircraft to maintain their own separation under specific circumstances • ensure that safety levels are maintained as the use of automation increases • ensure integrity of database information

Regularity and efficiency	• provide for the application of global ATM under all operational conditions • improve the application of tactical airspace management through dynamic user involvement, leading to more efficient airspace utilization • improve strategic airspace management while increasing tactical airspace flexibility • ensure the provision of information necessary for tactical and strategic ATFM • enhance overall tactical and strategic ATFM so that demand does not exceed capacity • increase available capacity without increasing controller workload	• ensure that aircraft can operate under all types of weather conditions • provide for the application of use preferred flight profiles • ensure that the necessary infrastructure is available to support gate-to-gate operations • improve user capability to optimize flight planning • dynamically, in order to improve airspace capacity through more flexible operations • minimize aircraft operating cost penalties • minimize differing equipment carriage requirements • between regions

BRIEF LOOK AT THE EXISTING SYSTEM

The four main elements of CNS/ATM systems are summarized below and are dealt with in detail in later chapters of the Global Plan.

Communications

In CNS/ATM systems, the transmission of voice will, initially, continue to take place over existing very high frequency (VHF) channels; however, these same VHF channels will increasingly be used to transmit digital data. It aims to enhance coverage, accessibility, capability, integrity, security and performance of aeronautical communication systems in accordance with ATM requirements.

Satellite data and voice communications, capable of global coverage, are also being introduced along with data transmission over high frequency (HF) channels. The secondary surveillance radar (SSR) Mode S, which is increasingly being used for surveillance in high-density airspace, has the capability of transmitting digital data between air and ground. An aeronautical telecommunication network (ATN) will provide for the interchange of digital data between end-users over dissimilar air-ground and ground-ground communications subnetworks. The regular use of data transmission for ATM purposes will introduce many changes in the way that communications between air and ground takes place, and at the same time offer many new possibilities and opportunities.

The benefits expected from the future communications systems lie in the fact that they will allow more direct and efficient linkages between ground and airborne automated systems in conjunction with pilot/controller communications. In fact, digital data link can be seen as the key to the development of new ATM concepts leading to the achievement of real benefits.

Navigation

Improvements in navigation include the progressive introduction of area navigation (RNAV) capabilities along with the global navigation satellite system (GNSS). These systems provide for worldwide navigational coverage and are being used for worldwide en-route navigation and for non-precision approaches. With appropriate augmentation systems and related procedures, it is expected that these systems will also support most precision approaches. It aims to enhance coverage and allow for all weather navigation capability in all airspace, including approach and landing, while maintaining or improving integrity, accuracy and performance in accordance with ATM requirements. GNSS, as specified in Annex 10, will provide a high-integrity, high-accuracy and all-weather worldwide navigation service. The successful implementation of GNSS would enable aircraft to navigate in all types of airspace, in any part of the world, offering the possibility for many States to dismantle some or their entire existing ground-based navigation infrastructure. However, the removal of conventional radio navigation aids should be considered with caution and after a safety assessment has demonstrated that an acceptable level of safety can be met and after consultation with users through the regional air navigation planning process.

Surveillance

Traditional SSR modes will continue to be used, along with the gradual introduction of Mode S in both terminal areas and high-density continental airspace. The major breakthrough, however, is with the implementation of automatic dependent surveillance (ADS). ADS allows aircraft to automatically transmit their position, and other data, such as heading, speed and other useful information contained in the flight management system (FMS), via satellite or other communications links, to an air traffic control (ATC) unit where the position of the aircraft is displayed somewhat like that on a radar display. ADS can also be seen as an application that represents the true merging of communications and navigation technologies, and, along with ground system automation enhancements, will allow for the introduction of significant improvements for ATM, especially in oceanic airspace. Software is currently being developed that would allow this data to be used directly by ground computers to detect and resolve conflicts. Eventually, this could lead to clearances being negotiated between airborne and ground-based computers with little or no human intervention. It aims to enhance and extend effective surveillance to oceanic and remote areas while improving air traffic situational awareness in the cockpit in accordance with ATM requirements

Benefits would be derived quickly through ADS in oceanic and some continental areas that currently have no radar coverage.

ADS-broadcast (ADS-B)* is another concept for dissemination of aircraft position information. Using this method, aircraft periodically broadcast their position to other aircraft as well as to ground systems. Any user, whether airborne or on the ground, within range of the broadcast, receives and processes the information. All users of the system have real-time access to precisely the same data, via similar displays, allowing a vast improvement in traffic situational awareness.

Air traffic management

In considering implementation of new communications, navigation and surveillance systems and all of the expected improvements, it can be seen that the overall main beneficiary is likely to be ATM. More appropriately, the advancements in CNS technologies will serve to support ATM. When referring to ATM in the future concept, much more than just air traffic control is meant. In fact, ATM refers to a system's concept of management on a much broader scale, which includes ATS, air traffic flow management (ATFM), airspace management (ASM) and the ATM-related aspects of flight operations.

An integrated global ATM system should fully exploit the introduction of new CNS technologies through international harmonization of Standards and procedures. Ultimately, this would enable the aircraft operators to conduct their flights in accordance with their preferred trajectories, dynamically adjusted, in the most optimum and cost-efficient manner. Figure I-1-2 illustrates how the utilization of CNS technologies will result in ATM benefits.

AIR TRAFFIC MANAGEMENT

- ➔ Enhanced safety
- ➔ Increased system capacity; optimized use of airport capacity
- ➔ Reduced delays
- ➔ Reduced flight operating costs
- ➔ Reduced fuel consumption and emissions
- ➔ More efficient use of airspace; more flexibility; reduced separations
- ➔ More dynamic flight planning; better accommodation of optimum flight profiles
- ➔ Reduced controller workload/increased productivity

COMMUNICATION	NAVIGATION	SURVEILLANCE
➔ More direct and efficient air-ground linkages ➔ Improved data handling ➔ Reduced channel congestion ➔ Reduced communications errors ➔ Interoperability across ➔ applications ➔ Reduced workload	➔ High-integrity, high-reliability, all-weather navigation services worldwide ➔ Improved four-dimensional navigation accuracy ➔ Cost savings from reduction or non-implementation of ground based navigation aids ➔ Better airport & runway Utilization ➔ Provision of non-precision approach/precision approach (NPA/PA) capabilities at presently non-equipped airports ➔ Reduced pilot workload	➔ Reduced error in position reports ➔ Surveillance in non-radar Airspace ➔ Cost savings ➔ Higher degree of controller responsiveness to flight profile changes ➔ Conformance monitoring ➔ Improved emergency assistance

BENEFITS OF THE NEW SYSTEMS

CNS/ATM systems will improve the handling and transfer of information, extend surveillance using ADS and improve navigational accuracy. This will lead, among other things, to reductions in separation between aircraft, allowing for an increase in airspace capacity.

Advanced CNS/ATM systems will also see the implementation of ground-based computerized systems to support increases in traffic. These ground-based systems will exchange data directly with FMS aboard aircraft through a data link. This will benefit the ATM provider and airspace user by enabling improved conflict detection and resolution through intelligent processing, providing for the automatic generation and transmission of conflict-free clearances, as well as offering the means to adapt quickly to changing traffic requirements. As a result, the ATM system will be better able to accommodate an aircraft's preferred flight profile and help aircraft operators to achieve reduced flight operating costs and delays.

Benefits for the airlines

The benefits of CNS/ATM systems will ensue through the formation of a more close-knit relationship, allowing rapid and reliable transmission between ground and airborne system elements. More accurate and reliable navigation systems will also allow aircraft to navigate in all types of airspace and operate closer together.

In anticipation of the advantages of CNS/ATM systems, the airlines expect reduced separation standards over oceanic airspace; increased access to remote areas; the gradual introduction of 1 000 ft vertical separation above 29 000 ft; increased opportunities for more dynamic and direct routings; and an overall enhancement of safety.

Benefits for the States that provide the global air navigation infrastructure

For those States that provide and maintain extensive ground infrastructures, a reduction in the overall cost of operation and maintenance of facilities is expected as the traditional ground systems become obsolete and satellite technology is increasingly employed. They will also benefit from enhanced safety.

CNS/ATM provides a timely opportunity for developing States to enhance their infrastructures to handle additional traffic with minimal investment. Many of these States have large areas of available but unusable airspace, mainly because of the expense involved in purchasing, operating and maintaining the necessary ground infrastructures.

CNS/ATM systems will afford them opportunities to modernize inexpensively, which includes the provision of precision and non-precision approaches.

Environmental benefits

As the aviation industry grows more and more rapidly, the impact of air traffic operations on the global atmosphere becomes increasingly important in addition to the local effects of noise and air quality. Efforts to control or reduce the environmental impact of air traffic have identified a range of options that might reduce the impact of aircraft engine emissions. In particular, it is expected that improvements in ATM could help reduce aviation fuel burn, and thereby reduce the levels of aircraft engine emissions. ICAO's Committee on Aviation Environmental Protection (CAEP) has developed a methodology and tool for estimating global emissions and fuel usage and evaluating the impact of various CNS/ATM enhancements.

General aviation

General aviation and utility aircraft will find increasing access to avionics equipment that will allow them to operate in flight conditions, into and out of airports, that they would normally have been prohibited from using because of the operating cost and associated requirements.

Furthermore, as a result of implementing CNS/ATM systems, many remote areas that are currently inaccessible to most general aviation aircraft because of their inability to communicate or safely navigate over them, would become accessible.

Indirect benefits

In addition to the direct benefits listed above, there are also many indirect benefits, such as:

- lower fares and rates;
- passenger timesavings;
- transfer of high-technology skills;
- productivity improvements and industry restructuring;
- stimulation of related industries;
- enhanced trade opportunities; and
- increased employment.

ORGANIZATIONAL AND FINANCIAL ISSUES

A major challenge in the implementation process of CNS/ATM systems relates to organizational and financial aspects. A characteristic of many CNS/ATM systems\ elements is the multinational dimension; consequently, international cooperation will be required to a great extent throughout the implementation process and eventually in the future operational environment. In many cases, financing of basic system elements may need to be a joint venture amongst the States involved at the regional or global level. Financing at the national level would normally be approached in a manner similar to that applied to conventional air navigation systems. The establishment of financially-autonomous authorities to operate air navigation services (ANS) at the national level, and also at the international level, may facilitate solving the financing of CNS/ATM systems.

ASSISTANCE REQUIREMENTS AND TECHNICAL COOPERATION

While some States will be in a position to develop their national CNS/ATM plans and implement systems using their own resources, the majority of States will require some type of assistance in CNS/ATM planning and implementation. Surveys carried out by ICAO through questionnaires have identified States' requirements for assistance as follows:

- needs assessments and project development;
- familiarization and specialized seminars and workshops;
- transition planning, including cost-benefit and cost recovery analyses;
- donor mobilization and financing arrangements;
- systems planning, specification, procurement, installation and commissioning; and
- human resource planning and development.

The Statement of ICAO Policy on CNS/ATM System Implementation and Operation includes, inter alia, a stipulation that ICAO shall play its central role in coordinating technical cooperation arrangements for CNS/ATM systems implementation. The ICAO Objectives Implementation Mechanism was established by the 31st ICAO Assembly (Assembly Resolution A31-14 refers) to, inter alia, provide the technical assistance required by States in national CNS/ATM systems planning and implementation on a not-for-profit basis. Assistance in the establishment of cooperative arrangements among States, under the auspices of ICAO, e.g. to address common equipment or training requirements, could also be provided.

ICAO'S PLANNING STRUCTURE FOR CNS/ATM SYSTEM

INTRODUCTION

The increasing demands on the global air navigation system can be expressed in terms of aircraft movements at airports and in the airspace. Aircraft departures and arrivals at airports are expected to increase by nearly 30 per cent between 1995 and 2005. Aircraft-kilometers flown are expected to increase by 55 per cent over the same period. Further growth in these parameters is likely in the decade beyond.

As traffic volumes grow, the demands on the ATS provider in an airspace increase. For given separation standards, the number of flights unable to follow optimum flight paths increases. This creates pressure to upgrade the level of ATS.

In the past, this may have required expenditures on additional facilities such as VHF omnidirectional radio range (VOR) and radar and communications equipment. CNS/ATM systems, however, will provide for increased capacity to meet such demands and will also produce benefits in the way of more efficient flight profiles.

Although implementation of the new CNS/ATM systems is well under way, the major challenge for ICAO now is to guide the evolutionary development and implementation of a seamless, global ATM system that will enable aircraft operators to meet their planned times of departure and arrival and adhere to their preferred flight profiles with minimum constraints. The first version of the Global Coordinated Plan for Transition to ICAO CNS/ATM systems was an important milestone towards achieving this goal. Transition and implementation remains as the continuing challenge, which poses many difficult and complex issues for those involved in the overall planning and implementation process.

THE REGIONAL PLANNING PROCESS

The regional planning process is the principal engine of ICAO's planning and implementation work. It is here that the top-down approach, comprising global guidance and regional harmonization measures, converges with the bottom-up approach constituted by States and aircraft operators and their proposals for implementation options.

In its most basic form, the output from the regional planning process should be a listing of air navigation facilities and services, together with their achievable time frames, necessary for CNS/ATM systems implementation. These listings are already, or will be, included in the ANPs, which are produced by ICAO regional air navigation meetings and maintained by the ICAO PIRGs with the assistance of ICAO's regional offices.

Traffic forecasts have a special role in planning the implementation of CNS/ATM systems. The forecasts represent the demand for future ATM. The PIRGs must therefore base their work on well-developed traffic density forecasts. The plans developed from this work then specify the infrastructure and arrangements which will supply the required level of ATS. A uniform strategy has been adopted by ICAO for the purpose of preparing traffic forecasts in support of the regional planning process. This involves the establishment of a small group of forecasting experts in each of the ICAO regions. Each traffic forecasting group will provide the corresponding PIRG with forecasts of aircraft movements within homogeneous ATM areas and along major international traffic flows.

THE NATIONAL PLANNING PROCESS

ICAO has been addressing the planning strategy for CNS/ATM systems at the global and regional levels, leaving the responsibility for undertaking the task of structuring national plans to Contracting States. There is a need for integration and rationalization to ensure harmonization of national planning with planning at other levels. A national plan is required to improve the overall efficiency and capacity of the State airspace infrastructure and to address the requirements arising out of the growth in both international and domestic air traffic. National planning, which is formulated by each State, should be in accordance with regional requirements and implementation guidelines.

It requires ongoing interaction with adjacent States, the regional planning group, and sub-regional groups to ensure harmonization and interoperability. The national plan document, so structured, will direct the national work programme for a progressive, cooperative and cost-effective implementation of CNS/ATM systems.

CNS/ATM PARTNERS AND TOOLS

Planning for implementation of facilities and services associated with CNS/ATM systems involves the combined efforts of ICAO, States, users, service providers and industry. These entities are more commonly known as the CNS/ATM partners. The partners conduct their work at several levels with the aim of developing planning documentation which, either directly or indirectly, forms the foundation for development of the regional ANPs. ANPs then list the requirements for facilities and services necessary for the safe and efficient conduct of international civil aviation, and also depict time lines. ICAO provides guidance at the global level in order to ensure harmonization and standardization of regional ANPs.

RELEVANT ICAO POLICIES ON CNS/ATM

General

The ICAO Council, at the second meeting of its 141st Session, acting on recommendations contained in the Report of the Fourth Meeting of the Special Committee for the Monitoring and Co-ordination of Development and Transition Planning for the Future Air Navigation System (FANS Phase II) (Doc 9623), approved the Statement of ICAO Policy on CNS/ATM Systems Implementation and Operation (Appendix A to this chapter refers), which stipulates principles of universal accessibility, sovereignty authority and responsibility of Contracting States of ICAO.

This statement also sets out the precepts concerning technical cooperation, institutional arrangements, airspace organization and utilization, continuity and quality of service and cost-recovery.

Financial

As referred to in paragraph 9 of the Statement of ICAO Policy on CNS/ATM Systems Implementation and Operation, the basic policy established by ICAO in the area of airport and air navigation services charges is expressed in Article 15 — Airport and similar charges — of the Chicago Convention. Additional and more detailed policy guidance in the area of air navigation services charges is provided in ICAO's Policies on Charges for Airports and Air Navigation Services (Doc 9082). The basic philosophy and principles expressed in the Convention and the Statement on charges for air navigation services are fairness and equity in the determination and sharing of air navigation services costs.

The principles contained in the Council Statement address such subjects as the cost basis for air navigation services charges, allocation of air navigation services costs among aeronautical users, air navigation services charging systems, approach and aerodrome control charges, route air navigation services charges, charges for air navigation services used by aircraft when not over the Provider State, and consultation with users regarding charges and air navigation services planning. These principles, by applying to air navigation services in general, thereby also apply to CNS/ATM systems. Hence, no specific reference is made to particular cost-recovery principles that apply exclusively to these systems. CNS/ATM systems will, however, require special considerations insofar as organizational, managerial and cooperative aspects are concerned, as well as with regard to financing, cost and cost-recovery mechanisms.

Technical cooperation

The 31st ICAO Assembly (Assembly Resolution A32-21 refers) (see Appendix C to this chapter) established the ICAO Objectives Implementation Mechanism as part of the transition to a new policy on technical cooperation, recognizing that the advisory role of ICAO to its Contracting States should be complemented and strengthened at the State and regional levels for the effective implementation of SARPs and ANPs by the ICAO Technical Co-operation Programme. The Council also assigned ICAO a central role in coordinating technical cooperation arrangements for CNS/ATM systems implementation and invited States to provide funds and in-kind assistance where possible.

The Assembly encouraged States to make use of, and contribute to, the ICAO Objectives Implementation Mechanism, aimed at consolidating all other funding mechanisms. The ICAO Council directed this new mechanism to pay special attention to assistance requirements of States in CNS/ATM and other areas.

Institutional guidelines and guidelines for transition

Finally, in developing the original Global Plan for transition to CNS/ATM systems, the FANS Phase II Committee developed a set of institutional guidelines providing guidance for transition to and implementation of\ CNS/ATM systems. Since the writing of the original Global Plan, the original institutional guidelines have been duly considered by ICAO bodies, overtaken by events or have otherwise become obsolete. Many of these are embodied in the Statement of ICAO Policy on CNS/ATM Systems Implementation and Operation.

ICAO'S ROLE AND RESPONSIBILITY

ICAO is the focal point for developing the blueprint for CNS/ATM systems and is also the central coordinating body for its implementation. ICAO has fulfilled and continues to fulfil this role in the following ways:

a) In 1983, the ICAO Council gave the task of studying, inter alia, civil applications of satellite systems to the FANS Committee, which developed an air navigation concept for the future;

b) The ICAO Air Navigation Commission, with the support of its panels and the ICAO Secretariat, is carrying out much of the technical work necessary for international standardization, including the development of an ATM operational concept;

c) The international SARPs are continuously reviewed, updated and developed to take into account CNS/ATM systems requirements;

d) PIRGs are developing the regional requirements for facilities and services to be implemented by States;

e) Guidance material on economic and related organizational and managerial issues has been developed;

f) A legal framework for GNSS is being studied; and

g) ICAO's Technical Co-operation Programme is providing assistance to States with such requirements.

In accordance with its obligations under the Chicago Convention, ICAO continues to carry out its responsibility concerning the adoption and amendment of relevant international SARPs and procedures. These SARPs and procedures are continually being developed, reviewed and updated developed to accommodate CNS/ATM systems requirements. This continuing practice ensures the highest possible degree of uniformity in all matters concerning safety, regularity and efficiency of air navigation.

ICAO POLICY ON CNS/ATM SYSTEMS IMPLEMENTATION AND OPERATION

(Approved by Council (C 141/13) on 9 March 1994)

In continuing to fulfil its mandate under Article 44 of the Convention on International Aviation by, inter alia, developing the principles and techniques of international air navigation and fostering the planning and development of international air transport so as to ensure the safe and orderly growth of international civil aviation throughout the world, the International Civil Aviation Organization (ICAO), recognizing the limitations of the present terrestrial-based system, developed the ICAO communications, navigation and surveillance/air traffic management (CNS/ATM) systems concept, utilizing satellite technology. ICAO considers an early introduction of the new systems to be in the interest of healthy growth of international civil aviation.

The implementation and operation of the new CNS/ATM systems shall adhere to the following precepts:

1. Universal Accessibility

The principle of universal accessibility without discrimination shall govern the provision of all air navigation services provided by way of the CNS/ATM systems.

2. Sovereignty, Authority and Responsibility of Contracting States

Implementation and operation of CNS/ATM systems which States have undertaken to provide in accordance with Article 28 of the Convention shall neither infringe nor impose restrictions upon States' sovereignty, authority or responsibility in the control of air navigation and the promulgation and enforcement of safety regulations. States' authority shall be preserved in the coordination and control of communications and in the augmentation, as necessary, of satellite navigation services.

3. Responsibility and Role of ICAO

In accordance with Article 37 of the Convention, ICAO shall continue to discharge the responsibility for the adoption and amendment of Standards, Recommended Practices and Procedures governing the CNS/ATM systems.

In order to secure the highest practicable degree of uniformity in all matters concerned with the safety, regularity and efficiency of air navigation, ICAO shall coordinate and monitor the implementation of the CNS/ATM systems on a global basis, in accordance with ICAO's regional air navigation plans and global coordinated CNS/ATM systems plan. In addition, ICAO shall facilitate the provision of assistance to States with regard to the technical, financial, managerial, legal and cooperative aspects of implementation. ICAO's role in the coordination and use of frequency spectrum in respect of communications and navigation in support of international civil aviation shall continue to be recognized.

4. Technical Cooperation

In the interest of globally coordinated, harmonious implementation and early realization of benefits to States, users and providers, ICAO recognizes the need for technical cooperation in the implementation and efficient operation of CNS/ATM systems. Towards this end, ICAO shall play its central role in coordinating technical cooperation arrangements for CNS/ATM systems implementation.

ICAO also invites States in a position to do so to provide assistance with respect to technical, financial, managerial, legal and cooperative aspects of implementation.

5. Institutional Arrangements and Implementation

The CNS/ATM systems shall, as far as practicable, make optimum use of existing organizational structure, modified if necessary, and shall be operated in accordance with existing institutional arrangements and legal regulations. In the implementation of CNS/ATM systems, advantage shall be taken, where appropriate, of rationalization, integration and harmonization of systems. Implementation should be sufficiently flexible to accommodate existing and future services in an evolutionary manner. It is recognized that a globally coordinated implementation, with full involvement of States, users and service providers through, inter alia, regional air navigation planning and implementation groups, is the key to the realization of full benefits from the CNS/ATM systems. The associated institutional arrangements shall not inhibit competition among service providers complying with relevant ICAO Standards, Recommended Practices and Procedures.

6. Global Navigation Satellite System

The global navigation satellite system (GNSS) should be implemented as an evolutionary progression from existing global navigation satellite systems, including the United States' global positioning system (GPS) and the Russian Federation's global orbiting navigation satellite system (GLONASS), towards an integrated GNSS over which Contracting States exercise a sufficient level of control on aspects related to its use by civil aviation. ICAO shall continue to explore, in consultation with Contracting States, airspace users and service providers, the feasibility of achieving a civil internationally controlled GNSS.

7. Airspace Organization and Utilization

The airspace shall be organized so as to provide for efficiency of service. CNS/ATM systems shall be implemented so as to overcome the limitations of the current systems and to cater for evolving global air traffic demand and user requirements for efficiency and economy while maintaining or improving the existing levels of safety.

While no changes to the current flight information region organization are required for implementation of the CNS/ATM systems, States may achieve further efficiency and economy through consolidation of facilities and services.

8. Continuity and Quality Of Service

Continuous availability of service from the CNS/ATM systems, including effective arrangements to minimize the operational impact of unavoidable system malfunctions or failure and achieve expeditious service recovery, shall be assured. Quality of system service shall comply with ICAO Standards of system integrity and be accorded the required priority, security and protection from interference.

9. Cost-Recovery

In order to achieve a reasonable cost allocation between all users, any recovery of costs incurred in the provision of CNS/ATM services shall be in accordance with Article 15 of the Convention and shall be based on the principles set forth in ICAO's Policies on Charges for Airports and Air Navigation Services (Doc 9082), including the principle that it shall neither inhibit nor discourage the use of the satellite-based safety services. Cooperation amongst States in their cost-recovery efforts is strongly recommended.

GLOBAL PLANNING METHODOLOGY

INTRODUCTION

As traffic volumes grow worldwide, the demands on the ATS provider in a given airspace increase, as do the complexities of air traffic management. The number of flights unable to follow optimum flight paths also increases with an increase in traffic density. This creates pressure to upgrade the level of ATS by, inter alia, reducing separation minima.

Implementation of CNS/ATM systems will enhance capacity to meet the increasing demand, while producing additional benefits in the way of more efficient flight profiles and increased levels of safety. The potential for new technologies to significantly reduce service costs, however, will require new arrangements in the provision of services and changes in air traffic management procedures.

This chapter of the Global Plan provides instructions on how to begin the process of identifying ATM requirements, on the basis of identified homogeneous ATM areas and major traffic flows and routing areas, followed by the determination of regional and global CNS system elements needed to meet the ATM requirements.

HOMOGENEOUS ATM AREAS AND MAJOR TRAFFIC FLOWS

Homogeneous ATM area

Homogeneous ATM area means airspace with a common air traffic management interest, based on similar characteristics of traffic density, complexity, air navigation system infrastructure requirements or other specified considerations wherein a common detailed plan will foster the implementation of interoperable CNS/ATM systems.

Homogeneous ATM areas may extend over States, specific portions of States, or groupings of States. They may also extend over large oceanic and continental areas. They are considered areas of shared interest and requirements.

The method of identifying homogeneous ATM areas involves consideration of the varying degrees of complexity and diversity of the worldwide air navigation infrastructure. Based on these considerations, it is considered that planning could best be achieved, at the global level, if it were organized based on ATM areas of common requirements and interest, taking into account traffic density and the level of sophistication required

Major traffic flow means concentration of significant volumes of air traffic on the same or proximate flight trajectories.

Routing Area

An area encompassing one or more major traffic flows, defined for the purpose of developing a detailed plan for the implementation of CNS/ATM systems and procedures.

A routing area may cross several homogeneous ATM areas with different characteristics. A routing area specifies common interests and requirements among underlying homogeneous areas, for which a detailed plan for the implementation of CNS/ATM systems and procedures either for airspace or aircraft will be specified.

The basic planning parameter is the number of aircraft movements that must be provided with ATM services. Estimates and forecasts of annual aircraft movements over the planning period are required for high-level planning. Forecasts of aircraft movements in peak periods, such as during a particularly busy hour, are needed for detailed planning. Additionally, appropriate civil/military coordination and consideration of special use airspace (SUA) is required. This coordination should take place during the planning stage to ensure a realistic chance of implementation and in the tactical phase to allow for a flexible use of airspace through the dynamic design and activation of SUA. The principal data sources for current or historic aircraft movements are the official airline guides:

World Airways Guide, ICAO's Traffic by Flight Stage Statistics and En-route Facility Statistics, and specific statistical information for flight information regions, which can be obtained from relevant area control centres (ACCs).

The ICAO Secretariat, in cooperation with the International Air Transport Association (IATA), is progressively developing estimates of current traffic volumes for specific areas, which consist of major international route groups. This information is being designed to assist with planning at the global level. Additionally, traffic forecasting groups are being established by ICAO in order to provide the PIRGs with comprehensive databases and forecasts of traffic flows for groups of routes for the detailed planning process.

While the Global Plan provides the framework to be followed in the planning process, along with the latest information and planning criteria for development of emerging and future systems, the Statement of Basic Operational Requirements and Planning Criteria for Regional Air Navigation Planning (approved by the Air Navigation Commission on 17 June 1999) provides the necessary guidance on the preparation of the regional air navigation plan for air navigation facilities, services and procedures recommended for the area, to meet the requirements of all international civil aircraft operations during at least the next five-year period, taking due account of the long-term planning and implementation strategies regarding CNS/ATM systems and as portrayed in the Global Plan, and possible effects on adjacent regions.

PLANNING METHODOLOGY

The basis for developing a global, integrated ATM system will be an agreed-to structure of homogeneous ATM areas and major traffic flows/routing areas. These areas and flows tie together the various elements of the worldwide aviation infrastructure into a global system. The Global Plan lists several of these. Further identification and analyses of these areas and traffic flows are being carried out by PIRGs in collaboration with the aircraft operators, reflecting the latter's requirements.

The planning process for any particular region should begin with the identification of specific homogeneous ATM areas and major traffic flows, based on user needs, followed by the development of an ATM plan for the region and, eventually, for each State. Considering the communications, navigation and surveillance elements of the CNS/ATM systems infrastructure to support air traffic management, it is necessary for each region or State to first ascertain the ATM objectives for a given homogeneous ATM area or major traffic flow/routing area. The ATM operational concept, expected to be available by mid-2002, will describe how the global ATM system should operate and will help to determine the ATM objectives. An operational analysis should be performed in order to determine which CNS and other technical and automation elements are needed to fulfil the ATM objectives. The operational analysis and the ATM operational concept therefore complement each other.

Finally, an assessment should be made of the technical elements and implementation options that would most appropriately and cost-effectively meet the ATM objectives for that area or traffic flow/routing area.

Based on the above, PIRGs are responsible for the integration and harmonization of CNS/ATM systems plans for their various regions, while ICAO, through this Global Plan, ALLPIRG meetings, worldwide conferences, and an interregional coordination mechanism, carries out interregional coordination to ensure global compatibility, harmonization and seamlessness of the systems. At all stages of the planning process, coordination with aircraft operators must be carried out in order to fully address user requirements.

Each regional planning group will develop its own work structure for accomplishing the work associated with the step-by-step approach listed hereunder. In some cases, an already established working group or CNS/ATM subgroup may be in a suitable position to accomplish the work; in other cases, specific task forces or subgroups will need to be established.

The step-by-step approach for planning ATM requirements and CNS infrastructure is as follows:

- Step 1. Identify homogeneous ATM areas and/or major traffic flows.
- Step 2. List the ICAO region(s), flight information region(s) and State(s) involved in the homogeneous ATM areas and/or major international traffic flows.
- Step 3. Carry out air traffic forecasts and ascertain airspace user needs.
- Step 4. Perform an operational analysis of the current infrastructure for the areas identified in Step 2 in terms of, inter alia:
    - ATM limitations and shortcomings;
    - separation standards; and
    - CNS availability.
- Step 5. Determine the ATM objectives for the areas identified in Step 2 in terms of the required total systems performance (RTSP), using as the basis the guidance material contained in the operational concept document (operational analysis).
- Step 6. Establish CNS and other technical and automation requirements necessary to support the desired ATM objectives identified in Step 5 (operational analysis).
- Step 7. Analyse the benefits/improvements resulting from Steps 5 and 6 in order to establish (operational analysis):
  a) costs/benefits;
  b) relative priority;
  c) expected performance improvements; and
  d) implementation dates of the various ATM objectives and CNS facilities for each of the homogeneous ATM areas and major traffic flows/routing areas.
- Step 8. Considering the many technical solutions an implementation options available, repeat as necessary Steps 5, 6 and 7 to determine the most appropriate solution (operational analysis).
- Step 9. Develop an ATM implementation plan based on the outcome of steps 1 through 8 above using as the basis the guidance material contained in the operational concept document and the results of the operational analysis. A safety assessment should demonstrate that any new systems, or changes to the present systems, will achieve an acceptable level of safety.

- Step 10. Examine the possibilities of funding the implementation of the CNS/ATM systems infrastructure for States requiring financial assistance.
- Step 11. Determine the means and methods of cost-recovery.
- Step 12. Establish a framework to interface with all the CNS/ATM partners on a continuing basis to ensure the harmonious and integrated implementation of CNS/ATM systems in homogeneous areas and/or major international traffic flows.

The FASIDs of the regional ANPs should be developed with full consideration of the high-level guidance provided in Part I and the step-by-step approach described here and conceptualized in the tables in Part II of the Global Plan. As the ATM operational concept and the associated RCP*, required navigation performance (RNP), RSP* and RTSP* mature, they should be integrated into the planning process so that further development can take place. Planning and implementation should therefore be seen as a continuing, evolving and maturing process.

THE OPERATIONAL ANALYSIS

An operational analysis is a necessary part of ATM implementation planning which leads to the selection of solutions which will be the most effective in fulfilling the ATM objectives. The ICAO global ATM operational concept will describe how the global ATM system should operate and will also help to identify the facilities and services required to fulfil the global objectives. The operational analysis and the ATM operational concept complement each other.

Given the difficulty encountered in attempting to define long-term operational requirements for various large air navigation system projects, the development of operational requirements on the basis of an operational analysis is not an exact science. Looking too far into the future and attempting to incorporate definitive needs is difficult and prone to error in light of the evolving nature of ATM systems and the rapidly changing technological solutions. It is more appropriate, therefore, to address more immediate requirements and ensure that a mechanism is available to extend the implementation process into the future.

An analysis is appropriate when perceived symptoms indicate a deficiency in the air traffic services being provided; when additional demands from users require such services to be expanded; or when circumstances indicate that a need or opportunity exists to improve effectiveness, efficiency or economy within the ATM system.

It is generally accepted that with the introduction of CNS/ATM systems, new opportunities for improving ATM have emerged and will continue to emerge. Therefore, a thorough operational analysis should be carried out, followed by the development of ATM implementation plans, prior to implementing new ATM systems.

- Getting started. The operational analysis begins with the identification of a need, problem or opportunity by studying the existing set of circumstances.

- Definition of the ATM role and objectives. The role of ATM in the context of the systems or services being studied is defined, and the ATS policies, objectives or tasks that are pertinent to the analysis are specified.

- Description of the current system. By referring to air navigation system (ANS) documents for the system under study, the role that the system is intended to fulfil is outlined, along with the tasks it is intended to support. A list of objectives that the system should sustain by its currently specified performance capability is then compiled.

- The current system's performance is established in relation to its capability to satisfy the identified needs.

- The operational deficiencies that prevent the resolution of problems are identified.

- Performance limitations that constrain the current system's ability to take advantage of the existing opportunity are detailed.

- Interactions and interfaces between the system under study and others are examined.

- Evaluation: Current system against present requirements. A comparison is made of the existing system's capability against the present requirements. The following questions should be answered:
  a) Does the current system do the present job adequately?
  b) Does its capability enable the allocation of additional tasks to satisfy the identified needs?

- If the answers are "yes", longer-term analysis can be undertaken. However, if either answer is "no", it is clear that the current system is deficient and should be modified or replaced to remedy its shortcomings, if possible. Any modification must address the changes necessary to satisfy the needs, or to resolve the identified problems and their causes, and should not merely attempt to minimize or alleviate the associated symptoms.

- Listing of future objectives and system requirements. The future objectives and requirements that must be addressed are then listed, and the operational characteristics that a system must possess to support these are derived. Section 4 of the operational concept document describes future air traffic scenarios while Section 3 describes technical solutions which may be needed to fulfil future requirements.\

- Evaluation: Current system against future requirements. The capability of the existing system to support the identified future objectives and to satisfy their associated requirements is investigated, and the current system's capacity to perform the future job is determined.

- If the current system has already been shown to meet present requirements and has the ability to satisfy future requirements, the analysis stops because there is no need to satisfy, no problem to resolve, and no opportunity will be missed.

- Analysts must avoid the tendency to develop a solution and then invent a need, problem or opportunity to which the solution can be applied.

- If the current system cannot satisfy the present requirements and/or the future requirements, the exercise continues.

- Statement of operational requirements. From the previous steps it becomes possible to prepare a statement of operational requirements which describes, in broad terms, the need for a new or modified system and addresses the capability such a system must have.

- An operational requirement may be defined as a statement of the operational attributes of a system needed for the effective and/or efficient provision of air traffic services to users. An operational requirement is not a description of "how" a need is to be met. Furthermore, solutions to problems will not always be technical in nature. It may be that the requirement will be met by appropriate procedural, training or staffing actions. However, when technical solutions are required, close coordination between operational and technical experts is essential if the optimum solution is to be found.

- The described capability, which is expanded upon below, is that which is necessary to satisfy the need, to resolve the problem, or to take advantage of the opportunity which would support the objectives and ensure that the role of ATS is fulfilled.

- Establishing compliance criteria. Compliance criteria, which are high-level "musts" describing the basic operational characteristics of the system needed, are then generated. These criteria outline essential performance capabilities that proposed solutions must possess. Later, alternatives will be rated against these operational absolutes. For example, the communications systems performance requirement parameters specified for ICAO ATS data link applications state, ". . . the probability that a message will be misdirected will be equal to or less than 10-7 ."

- Listing and describing alternatives. Next, all reasonable alternatives are listed and described, including procedural change and the possibility of doing nothing. At this point descriptions need not be extremely detailed. For example, if a potential solution stems from the same equipment family as a primary radar system, it is necessary only to describe in general terms how a primary radar system operates and not how all the different types of primary radar function.

- This step will need to include a "market search" of potential solutions available as commercialI-3-6 Global Air Navigation Plan for CNS/ATM Systems off-the-shelf (COTS) products which have been developed in response to similar problems identified by other administrations. In the past, the "custom-built" solution has normally proven to be the better method; however, as the harmonization of ATC systems across international boundaries increases due to improved cooperation, this may no longer be the case.

- Selection of preferred option. Each alternative must be compared against each compliance criterion to determine the preferred option. On the initial assessment, any alternative must receive a "yes" [it satisfies each criterion], or a qualified "yes" [it satisfies each criterion with certain limitations], to be considered further.
    a. If any alternative receives a "no" [it does not satisfy a criterion], that choice is no longer considered unless every other alternative fails, i.e. gets at least one "no". If this happens, the options may be reviewed to select the option with the lowest "no" count. At this point the chosen option will, of necessity, be a compromise. Any alternative that does not satisfy all criteria cannot, by definition, fulfil the entire need, resolve the entire problem, or take full advantage of the opportunity. Some undesirable effects will continue. Therefore, the solution must be the option which most effectively responds to the operational issues being addressed.
    b. During the operational analysis, alternatives should not be evaluated based on costs. If the consideration of money enters the decision-making process too soon, it may cause a bias towards a less expensive solution which may not attain the desired operational results. Costs will be addressed during the cost-benefit analysis and during the efficiency analysis when the best technical solution will be found to address the operational concerns considering technical, financial and other issues. It may become evident that potential technical solutions need not be pursued as it becomes apparent that the cost of implementation cannot be supported.
    c. Where COTS products appear to provide possible solutions to the problems being addressed, the option of developing a new system will usually carry a lesser weight unless the cost of the COTS product is clearly exorbitant. This should rarely be the case. However, the costs of "modifying" COTS products to meet specific requirements may ultimately cost more than the build-from-scratch option.

- Conclusions, recommendations, preferred options. The conclusions and recommendations from all previous steps, ending with the preferred options based on operational effectiveness, are finally presented to the appropriate level of management for action. Senior management must agree that a problem or opportunity exists, and approve the resources to develop the detailed and accurate costing data needed.

- Development of operational performance requirements. The final step in the analysis process is the description of the complete operational capacity of the proposed solution. For example, the description of a data link system which will handle inter-facility messages must include clear performance requirements for the definitions of the types of messages to be exchanged, how many in a given time period, at what times of the day, between which agencies, internal and external, acceptable error rates, system availability and reliability, etc. Later, these operational performance requirements will be used to assist in evaluating the operational acceptability of technical alternative proposed as candidates for meeting the operational need.

- Prototyping and simulation. Prototyping and simulation can prove extremely valuable at this point in the analysis as a means of validating the operational concepts being defined, ensuring the operational acceptability of competing computer/human interfaces (CHI) operational procedures, and clarifying the requirement in concrete terms. This approach mitigates the possibility of technical misinterpretations of the operational need and thus prevents the final delivery of a system or component which does not reflect the operational intent.

COMMUNICATION SYSTEMS

MEANING

The communications element of CNS/ATM systems provides for the exchange of aeronautical data and messages between aeronautical users and/or automated systems. Communications systems are also used in support of specific navigation and surveillance functions.

There are basically two categories of aeronautical communications:

a) safety-related communications requiring high integrity and rapid response:

1) air traffic services communications (ATSC) carried out among ATS units or between an ATS unit and an aircraft for ATC, flight information, alerting, etc;

2) AOC communications carried out by aircraft operators on matters related to safety, regularity and efficiency of flights; and

b) non-safety related communications:

1) aeronautical administrative communications (AAC) carried out by aeronautical personnel and/or organizations on administrative and private matters; and

2) aeronautical passenger communications (APC).

In general, communication systems used in CNS/ATM systems are capable of carrying both of the above-mentioned categories. However, safety-related communications shall always have priority over non-safety related ones

Main Features of New Communications Systems

There are some fundamental differences between conventional aeronautical communications systems and those which form part of the new CNS/ATM systems. Some key features of the new systems, which significantly differ from conventional ones, are as follows:

a) most routine communications are done by data interchange;

b) voice communications are mainly used in non-routine and emergency situations; and

c) there is emphasis on global connectivity and operation.

Such features allow for better use of communication channels and enable facilities to be shared among many users.

AIR-GROUND COMMUNICATIONS

It is envisaged that most routine air-ground communications in the en-route phase of flight will be via digital data interchange. For this purpose, the user often selects a particular message from a pre-constructed set of messages using a screen menu, adds some specific parameters (or free text) and then sends it. Some data transfers take place between automated airborne and ground systems without the need for manual intervention.

Such data exchanges will greatly reduce the volume of voice communications and therefore reduce the workload of pilots and controllers. In busy terminal areas, however, the use of voice communications will likely still be preferred. For emergency or non-routine communications, voice will remain as the primary means of air-ground communications.

Transmission of air-ground messages is carried out over one of the following radio links:

a) AMSS — Geostationary communications satellites, designed specifically for mobile communications, offer wide/near global coverage and both voice and data communications channels. The use of AMSS is particularly suited to aircraft flying in oceanic and/or remote continental airspace;

b) VHF (Analog) — Existing VHF analog radios have excellent operational reliability and will continue to be used for voice communications in busy terminal areas as well as for general non-routine communications in their areas of coverage. Where the saturation of VHF frequency bands for aeronautical communications may occur, provisions have been made to reduce the channel spacing from 25 kHz to 8.33 kHz to increase the number of available channels in that area;

c) HF (Analog) — Radio communications using the HF band for long distance contacts have reliability limitations imposed mainly by the variability of propagation characteristics. It is envisaged that with increased use of AMSS in oceanic/remote areas, congestion on HF channels will be relieved. Until a new satellite constellation suitable for aeronautical use, covering the entire globe, is put in place for flights over polar regions, HF will remain as the only available means of communications in these areas (e.g. polar areas);

d) VDL Mode 2 — This mode provides an air-ground, ATN-compatible, data link and uses digital radio techniques. The nominal data rate of 31.5 kbps is compatible with the 25 kHz channel spacing used in analog VHF radio and for VDL Mode 3 (integrated voice and data). The modulation scheme used in Mode 2 is capable of supporting ATN protocol suites for different operational applications, thereby greatly increasing the efficient use of the VHF channel;

e) VDL Mode 3 — This mode uses a time division multiple access (TDMA) technique and is capable of integrating both voice and data communications systems. The improved utilization of the VHF spectrum is achieved through the provision of four separate radio channels over one carrier (25 kHz channel spacing);

f) VDL Mode 4 — This mode uses a self-organizing time division multiple access (STDMA) technique and is intended to be used for surveillance applications (e.g. ADS and ADS-B). This mode is being considered for use in other air-ground data link applications;

g) SSR Mode S data link — The SSR Mode S data link provides surveillance capability and an air-ground data link, which is specifically suitable for limited data messaging in high-density areas. It is capable of operating in an environment where different levels of Mode S data link capabilities exist; and

h) HF data link — The HF data link provides an air-ground data link which is ATN-compatible and is primarily considered to complement AMSS in oceanic/remote areas.

AMSS, VDL, SSR Mode S and HF data links use different data transmission techniques, but as individual networks, they all use the same network access protocol in accordance with the International Organization for Standardization (ISO) — Open Systems Interconnection (OSI) reference model. This provides for their interconnection to other ground-based networks so that the aircraft end of any of these data links can be connected to any ground-based system by adopting common interface services and protocols, also based on the ISO OSI reference model. The communications service, which allows ground, air-ground and avionics data subnetworks to interoperate for the specified aeronautical applications, is the ATN. The above-mentioned air-ground data links are ATN-compatible and can therefore constitute ATN subnetworks. In an ATN environment, subnetworks are connected to other subnetworks through ATN routers, which select the “best” route for transmission of each data message. As such, the choice of the air-ground data link is often transparent to the end-user.

Radio links used for communications with aircraft in flight are of extreme importance to the safety, regularity and economy of flights. As such, the necessary technical and institutional arrangements must be in place to:

a) ensure the availability of a sufficient radio frequency (RF) spectrum for aeronautical services, noting present and foreseen levels of traffic; and

b) prevent RF interference (RFI) into frequencies, bands, services and users of aeronautical radio systems; and

c) allow the provision of communications services by commercial service providers.

GROUND-GROUND COMMUNICATIONS

It is envisaged that most routine communications between ground-based aeronautical users and systems will be by data interchange. Such interchanges between entities such as meteorology offices, NOTAM offices, aeronautical data banks, ATS units, etc., may be in any of the following forms:

a) free-text messages;

b) pre-selected data messages (with some manually added parts); and

c) automated data interchange between computerized systems.

A variety of ground networks, implemented by States, a group of States or commercial service providers, will continue to provide data communications services to aeronautical users. However, only networks that use packet switching techniques and are compatible with the ISO OSI reference model will be able to use the internet working services of the ATN. With gradual implementation of the ATN, the use of the aeronautical fixed telecommunication network (AFTN) will diminish. During the transition period, however, interconnection of AFTN terminals to the ATN will be possible via special gateways.

Voice communications between ATS units will continue to be required for emergency or non-routine cases. Considering the relatively low usage of voice communications, dedicated direct-speech circuits will gradually be replaced with aeronautical switched networks capable of handling both voice and data. There is also a trend to use fully digital voice switching and signalling techniques as more flexible and less costly digital leased lines become widely available.

AERONAUTICAL TELECOMMUNICATION NETWORK (ATN)

The ATN and its associated application processes have been specifically designed to provide, in a manner transparent to the end-user, a reliable end-to-end communications service over dissimilar networks in support of air traffic services. ATN can also carry other communications service types, such as AOC communications, AAC and APC. Some other features of the ATN:

a) enhance data security;

b) are based on internationally recognized data communications Standards;

c) accommodate differing services (e.g. preferred air-ground subnetwork);

d) allow the integration of public/private networks; and

e) make efficient use of bandwidth, which is a limited resource in air-ground data links.

FUTURE TRENDS

As a result of advancing technology, new communications systems offer more, better and cheaper services. The use of such new systems for international civil aviation applications is being investigated. Some future communications systems that have the potential of providing the necessary level of service to the aviation community are:

a) non-geostationary satellite systems (using lower orbits), which cover the entire globe and have less power requirements; and

b) new network technologies providing integrated voice and data service.

The most important question to be asked when considering a new system is whether it meets existing or emerging operational and user requirements. Other factors to be considered are standardization, certification, harmonious deployment by various users, and cost-benefit considerations.

REQUIRED COMMUNICATION PERFORMANCE (RCP)*

The emergence of several types of data links for the conduct of air-ground data interchange, as well as for the support of specific navigation, surveillance and other functions, has raised the concern that the air navigation system is becoming too complex. Obviously, it would have been ideal to have a single air-ground communications system capable of handling all communications, navigation and surveillance requirements in all types of airspace and for all phases of flight in a cost-effective manner. However, as no such technological solution has yet been found to meet all operational requirements, the aviation community has to consider all available as well as emerging communications systems, though some may only perform a single function or only serve a limited area.

The availability of several communications systems does provide a degree of flexibility to planning and implementation in different types of airspace; however, the proliferation of subnetworks will add to the complexity of the operation and administration of the global ATN. For example, if a large continental airspace is already covered by VHF for aeronautical communications, perhaps VDL would be the best choice for an air-ground data link since most of the necessary infrastructure (buildings, towers, power supplies, etc.) would already be in place. Similarly, if an extensive network of SSR Mode S has already been implemented in an area, data link capability could be added with relatively small additional investment.

Although having the choice between several types of communications systems has some advantages from the implementation point of view, it does make the regional planning for air navigation systems more complex, especially when it comes to making contiguous FIRs harmonious and synchronous from the communications point of view. One solution to this problem is to do away with the specification of individual systems and instead, translate all relevant operational requirements in a certain airspace and scenario into a series of communications performance parameters. The term required communications performance (RCP)* therefore refers to a set of well-quantified communications performance requirements, such as capacity, availability, error rate, and transit delay. Once RCP* has been specified for an operational scenario in a given airspace, any single communications system, or combination of systems meeting the set parameters, can be considered as operationally acceptable.

GENERAL TRANSITION ISSUES

Guidelines for transition to the future systems encourage equipage by users for the earliest possible accrual of systems benefits. Although a transition period of dual equipage, both airborne and ground, is often necessary to ensure the reliability and availability of a new system, the guidelines are aimed at minimizing this period to the extent practicable. Appendix A to this chapter lists the guidelines that States, regions, users, service providers and manufacturers should consider when developing CNS/ATM systems or planning for implementation of such systems.

NAVIGATION SYSTEMS

The navigation element of CNS/ATM systems is meant to provide accurate, reliable and seamless position determination capability, worldwide, through introduction of satellite-based aeronautical navigation.

REQUIRED NAVIGATION PERFORMANCE (RNP)

Modern aircraft are increasingly equipped with RNAV, the use of which facilitates a flexible route system. Also, by using the concept of RNP, the need for selection between competing systems can be avoided. However, international standardization of navigation techniques, which are in wide use internationally, is still required.

The RNP concept for en-route operations has been approved by ICAO (Annex 11, Chapter 2) and has been extended to cover approach, landing and departure operations. RNP is a statement of navigation performance accuracy within a defined airspace based on the combination of the navigation sensor error, airborne receiver error, display error and flight technical error.

RNP types for en-route operations are identified by a single accuracy value defined as the minimum navigation performance accuracy required within a specified containment level. The en-route RNP types are described in Doc 9613.

The RNP types for approach, landing and departure operations are defined in terms of required accuracy, integrity, continuity and availability of navigation. While some RNP types contain accuracy specification of lateral performance only (i.e. similar to en-route), other types also include lateral and vertical performance specifications. The types similar to en-route specification are intended for operations such as non-precision approach or departure.

Most RNP types for approach and landing operations do require vertical containment based on navigation system information.

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

The GNSS is a worldwide position and time determination system, which includes one or more satellite constellations, aircraft receivers, and system integrity monitoring, augmented as necessary to support the RNP for the actual phase of operation.

The satellite navigation systems in operation are the global positioning system (GPS) of the United States and the global orbiting navigation satellite system (GLONASS) of the Russian Federation. Both systems were offered to ICAO as a means to support the evolutionary development of GNSS. In 1994, the ICAO Council accepted the United States' offer of the GPS, and in 1996 it accepted the Russian Federation's offer of GLONASS.

The GPS space segment is composed of twentyfour satellites in six orbital planes. The satellites operate near-circular 20 200 km (10 900 NM) orbits at an inclination angle of 55 degrees to the equator, and each satellite completes an orbit in approximately 12 hours.

The GLONASS space segment consists of twenty-four operational satellites and several spares. GLONASS satellites orbit at an altitude of 19 100 km with an orbital period of 11 hours and 15 minutes. Eight evenly spaced satellites are arranged in each of the three orbital planes, inclined 64.8 degrees and spaced 120 degrees apart. GNSS AUGMENTATIONS

To overcome inherent system limitations and to meet the performance requirements (accuracy, integrity, availability and continuity of service) for all phases of flight, GPS and GLONASS require varying degrees of augmentation. Augmentations are classified in three broad categories: aircraft-based, ground-based and satellite-based.

Aircraft-based augmentations

One type of aircraft-based augmentation (ABAS) is called receiver autonomous integrity monitoring (RAIM), which can be used if there are more than four satellites with suitable geometry in view. With five satellites in view, five independent positions can be computed. If these do not match, it can be deduced that one or more of the satellites are giving incorrect information. If there are six or more satellites in view, more independent positions can be calculated and a receiver may then be able to identify one faulty satellite and exclude it from the position determination calculations.

Other aircraft-based augmentations can also be implemented and are usually termed aircraft autonomous integrity monitoring (AAIM). An inertial navigation system, for example, can aid GNSS during short periods when the satellite navigation antennas are shadowed by the aircraft during manoeuvres or during periods when insufficient satellites are in view. Augmentation techniques particularly useful for improving availability of the navigation function also include altimetry-aiding, more accurate time sources or some combination of sensor inputs combined through filtering techniques.

Ground-based augmentations

For ground-based augmentation systems (GBAS), a monitor is located at or near the airport where precision operations are desired. Signals are sent directly to the aircraft in the vicinity (approximately 37 km (20 NM)). These signals provide corrections to increase the position accuracy locally along with satellite integrity information. This capability requires data link(s) between the ground and the aircraft.

Satellite-based augmentations

It is not practical to provide coverage with ground-based systems for all phases of flight. One way to provide augmentation coverage over large areas is to use satellites to transmit augmentation information. This is known as satellite-based augmentation (SBAS).

The provision of satellite-based augmentation by geostationary satellites has certain limitations and therefore cannot be expected to support all phases of flight, especially precision approach and landing of higher categories. Since these satellites orbit above the equator, their signals would not be available in polar regions and may be masked by aircraft structure or terrain. This suggests that other GNSS augmentation satellite orbits and/or ground-based augmentation might need to be considered to alleviate these shortcomings.

AVIONICS

Simple GPS or GLONASS receivers that do not include RAIM capability (or similar forms of integrity monitoring) generally cannot meet the requirements for all phases of flight.

Multi-sensor systems, using GNSS as one of the sensors, are expected to be in use for the foreseeable future. Such navigation systems generally exhibit better levels of performance than the individual sensor or stand-alone systems. Aircraft using multi-sensor navigation systems, such as integrated GNSS/IRS or GNSS/IRS/FMS, may be certified as meeting levels of RNP which could not be obtained by use of GPS or GLONASS alone.

WGS-84 COORDINATE SYSTEM AND AERONAUTICAL DATABASES

The successful global implementation of satellite navigation is predicated on the existence of a coordinate and procedures database of a very high quality. Accurate satellite navigation is only possible when the groundderived coordinates, calculated coordinates, and the satellite system-derived coordinates use the same geodetic reference system.

In support of evolving satellite-based technology, ICAO adopted WGS-84 as the common geodetic reference datum for civil aviation with an applicability date of 1 January 1998 (Annex 15). Implementation of WGS-84 involves, among other things, the transformation of existing coordinates and reference datums to WGS-84.

Aeronautical databases are built and updated through the use of surveys of existing navigation aids, position fixes and runway thresholds and through the design of new routes or approach procedures. Systems are to be in place to ensure the quality (accuracy, integrity and resolution) of position data from the time of the survey, to the submission of information to the next intended user.

Aeronautical databases must be updated on a regular basis.

EVOLUTIONARY INTRODUCTION

GNSS implementation will be carried out in an evolutionary manner, allowing gradual system improvements to be introduced. Near-term applications of GNSS are intended to enable the early introduction of satellite-based en-route navigation, using the existing satellite systems (GPS and GLONASS) and primarily aircraft-based augmentations.

Medium-term applications will make use of existing satellite navigation systems with any augmentation or combination of augmentations required for operation in a particular phase of flight. Longer-term applications will apply to future GNSS.

Three levels are generally accepted for the introduction of GNSS-based operations:

a) supplemental-means GNSS must meet accuracy and integrity requirements for a given operation or phase of flight; availability and continuity requirements may not be met. Other navigation systems supporting a given operation or phase of flight must be on board;

b) primary-means GNSS must meet accuracy and integrity requirements, but need not meet full availability and continuity of service requirements for a given operation or phase of flight. Safety is achieved by limiting operations to specific time periods and through appropriate procedural restrictions.

Other navigation systems can be retained on board to support the primary-means GNSS;

c) sole-means GNSS must allow the aircraft to meet, for a given operation or phase of flight, all four requirements: accuracy, integrity, availability and continuity of service.

SYSTEMS TO SUPPORT APPROACH, LANDING AND DEPARTURE OPERATIONS

The standard non-visual aids for precision approach and landing are defined in Annex 10, Volume I, Chapter 2. It is intended that the introduction and application of these non-visual aids will be in accordance with the global strategy set forth in Annex 10, Volume I, Attachment B. This strategy will:

a) continue ILS operations to the highest level of service as long as operationally acceptable and economically beneficial b) implement MLS where operationally required and economically beneficial;

c) promote the use of multi-mode receivers (MMR) or equivalent airborne capability to maintain aircraft interoperability;

d) validate the use of GNSS, with such augmentations as required, to support approach and departure operations, including Category I operations, and implement GNSS for such operations as appropriate;

e) complete feasibility studies for Category II and III operations, based on GNSS technology, with such augmentations as required. If feasible, implement

GNSS for Category II and III operations where operationally acceptable and economically beneficial; and

f) enable each region to develop an implementation strategy for future systems in line with the global strategy.

The terminology in 6.24 applies to the required state of avionics equipage and the ability of aircraft to meet RNP requirements with, in case of “sole means”, no other navigation equipment on board. It is also related to the intended operation (or phase of flight). Operational approvals for aircraft are therefore issued for particular operations and normally identify specific conditions or restrictions to be applied. To this end they may vary from State to State.

GNSS sole-means approval is therefore a necessary, but not sufficient, condition for termination of present radio navigation services. A number of aircraft may be approved for sole-means GNSS navigation for particular operations or phases of flight. However, the air traffic service provider must provide a navigation service to all users to support all phases of flight. It is therefore necessary to harmonize withdrawal of conventional navaids with the introduction of GNSS navigation service. These considerations are not applicable to airspace where present navaids are not available and GNSS alone can be introduced to benefit GNSS-equipped users.

When introducing GNSS-based services, each State shall identify the elements of GNSS that are provided (e.g. GPS, GLONASS, SBAS, GBAS) and develop an implementation plan. Where navigation services such as VOR, DME and ILS already exist, States could credit the economic savings associated with the decommissioning of ground-based navigational aids. The cost of implementing SBAS and GBAS should be tied to the provision of user benefits and increased airspace efficiency associated with area navigation and the potential to support lower decision altitude/height to more runways.

Advantages of GNSS services include the use of GPS/ABAS for en-route and non-precision approach operations where the coverage of ground-based navigation aids does not exist or is limited. In such an environment, GNSS would become the only navigation service as soon as it is introduced. SBAS-based precision approach capability to runways that currently only have a non-precision approach capability will provide further advantages in terms of increased safety and operational efficiency.

Several technical concerns have been raised with respect to the reliance on GNSS services. Principal among them is the possibility for intentional interference, or jamming, that has the potential to disrupt GNSS navigation services over relatively large areas. States and air navigation service providers should develop plans to reduce the likelihood of such occurrences, to detect and eliminate sources of interference and to ensure that aircraft can continue to operate safely during periods when GNSS signals are disrupted. Depending on the traffic density in a given airspace and the degree of integration and automation of the air navigation system, a safety assessment might demonstrate the need for navigational information derived from different independent sources to address certain threats such as intentional jamming.

Other risk areas are expected to be mitigated as GNSS continues to evolve to a more comprehensive service, such as the introduction of additional signals for aeronautical use on GPS and GLONASS satellites, augmentation system improvements, and the introduction of additional satellites and satellite systems. Each State will have to evaluate the effectiveness of the mitigation techniques applied in its airspace to determine if it is acceptable to rely on GNSS alone for the provision of navigation service.

GENERAL TRANSITION ISSUES

Guidelines for transition to the future systems encourage equipage by users for the earliest possible accrual of systems benefits. Provision and carriage of terrestrial and satellite-based navigation equipment are required during the transition period when the reliability and availability of a new system must be proven. Appendix A to this chapter lists the guidelines that States, regions, users, service providers and manufacturers should consider when developing GNSS or when planning for its implementation.

SURVEILLANCE SYSTEMS

CURRENT SURVEILLANCE SYSTEMS

The surveillance systems presently in use can be divided into two main types: dependent surveillance and independent surveillance. In dependent surveillance systems, the aircraft position is determined on board and then transmitted to ATC. The current voice position reporting is a dependent surveillance system in which the position of the aircraft is determined from on-board navigation equipment and then conveyed by the pilot to ATC by radiotelephony.

Independent surveillance is a system that measures aircraft position from the ground. Current surveillance is either based on voice position reporting or based on radar PSR or SSR, which measures range and azimuth of aircraft from the ground station.

FUNCTIONAL DESCRIPTION

Voice position reporting

Surveillance through voice position reporting is mainly used in oceanic airspace and aerodrome control service or area control service outside radar coverage. Pilots report their position using VHF and/or HF radios.

Primary surveillance radar (PSR)

The ground-based PSR system provides information on the bearing and distance of the aircraft. PSR does not require carriage of any equipment by aircraft and is capable of detecting almost any moving target. With increasing usage of more advanced surveillance systems, the use of PSR for international air traffic management will diminish. PSR will, however, continue to be used for national applications. Primary radars are currently used for surface movement detection as well as weather detection. Precision approach radars (PARs) are primary radars used for approach operations based on specific procedures for the pilot and the controller; however, use of PARs for civil applications is rapidly decreasing.

Secondary surveillance radar (SSR)

The SSR interrogates transponder equipment installed in the aircraft. In Mode “A”, the aircraft transponder provides identification information, aircraft bearing and distance and in Mode “C”, it provides pressure-altitude information. The current SSR is in wide use in many parts of the world where terrestrial line-of-sight surveillance systems are appropriate. The accuracy, resolution and overall performance of range and azimuth information are significantly improved by the application of monopulse (including large vertical aperture antennas) and other advanced processing techniques. The beneficial role of SSR for surveillance purposes can be enhanced through the use of Mode S, which is a technique that uses a unique address (the 24-bit address) for each aircraft. It permits the selective interrogation of Mode S transponder-equipped aircraft and therefore eliminates garbling. It also provides for a two-way data link capability between Mode S ground stations and Mode S transponders. SSR Mode S is the appropriate surveillance tool in high-density traffic areas. The interconnection of ground stations in clusters provides an enhanced surveillance and communications system.

Automatic dependent surveillance (ADS)

The introduction of air-ground data links, together with sufficiently accurate and reliable aircraft navigation systems, presents the opportunity to provide surveillance services in areas that lack such services in the present infrastructure, in particular, oceanic and other areas where the current systems prove difficult, uneconomic, or even impossible to implement. ADS is an application for use by ATS in which aircraft automatically transmit, via a data link, data derived from on-board navigation systems. As a minimum, the data include the four-dimensional position, but additional data may be provided as appropriate. The ADS data will be used by the automated ATC system to present information to the controller. In addition to providing traffic position information in non-radar areas, ADS will find beneficial applications in other areas, including high-density areas, where ADS may serve as an adjunct and/or back-up for SSR, thereby reducing the need for primary radar. In some circumstances, it may even substitute for secondary radar. As with current surveillance systems, the full benefit of ADS is obtained by supporting complementary two-way pilot/controller data and/or voice communications (voice for at least emergency and non-routine communications).

ADS–broadcast (ADS-B*)

ADS-B* is an expansion of the ADS technique that involves a broadcast of the position information to multiple aircraft or multiple ATM units. Each ADS-B*- equipped aircraft or ground vehicle periodically broadcasts its position and other relevant data derived from on-board equipment. Any user segment, either airborne or groundbased, within range of this broadcast, can process the information. ADS-B* is currently defined only for lineof-sight operations (e.g. broadcast over VHF digital link or by SSR Mode S extended squitter). ADS-B* is also envisaged to be applied for surface movement, thus being an alternative to surface radar such as airport surface detection equipment (ASDE).

TECHNICAL OPTIONS OVERVIEW

Implementation of ADS requires:

a) position data supplied by the on-board navigational equipment;

b) message time stamp within 1 second coordinated universal time (UTC);

c) air-ground data link;

d) a ground infrastructure providing the information to ATC; and

e) appropriate air traffic services procedures.

In the case of ADS, a two-way air-ground data link capability is required, whereas in the case of ADS-B*, one-way data links will suffice because the information is transmitted in a broadcast mode. In addition, synchronized time, such as GNSS time, is highly recommended for the

operation of ADS and ADS-B*.

ATM REQUIREMENTS FOR SURVEILLANCE

ATM requirements for surveillance will vary with the airspace concerned and the traffic density and complexity. The requirements can be defined as follows:

a) current surveillance systems shall provide updated aircraft position reports so as to assure safe separation;

1) for oceanic and low-density airspace including remote areas, an update rate of 12 seconds is adequate;

2) in high-density en-route/terminal environments, an update rate of 4 seconds is more appropriate;

b) the accuracy of the surveillance system should support the separation minima for the defined airspace;

c) the surveillance system should enable the ATM to provide the user with a choice of flight path en route and to fully accommodate emergency procedures; and

d) the surveillance system should assist search and rescue operations.

AIRBORNE COLLISION AVOIDANCE SYSTEM (ACAS)

The airborne collision avoidance system (ACAS) is an aircraft system based on SSR transponder signals, which operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders (Mode C or Mode S; ACAS cannot detect Mode A only transponders). ACAS I provides information as an aid to "see and avoid" action but does not include the capability for generating resolution advisories (RAs). ACAS II provides vertical resolution advisories (RA) to the pilot. In the case where both encountering aircraft are ACAS-equipped, the manoeuvres can be coordinated automatically (ACAS cross-link). ACAS II is presently being implemented in several States or among groups of States. ACAS II implementation must be considered in association with pressure altitude reporting transponder carriage.

REQUIRED SURVEILLANCE PERFORMANCE (RSP)*

The emergence of several types of surveillance systems or procedures, in addition to existing surveillance facilities to support ATM functions, has raised concern that the air navigation system is becoming too complex. Admittedly, it would have been ideal to have a single surveillance system capable of meeting the surveillance requirements for all phases of flights in all kinds of airspace. From a cost-effective standpoint, however, surveillance systems with different characteristics and capabilities are required to handle traffic conditions that vary significantly from lowdensity traffic areas to high-density terminal areas. Until such time as one surveillance system is able to meet all requirements, the aviation community has to consider all options. While the availability of surveillance alternatives provides flexibility during the planning process, it does complicate the harmonization of the surveillance functions.

To facilitate the planning, one solution would be to translate all relevant operational requirements into a series of surveillance performance parameters. The term “required surveillance performance (RSP)”* therefore refers to a set of well-quantified surveillance performance requirements such as capacity, availability, accuracy, and update rate.

Once RSP* has been specified for an operational scenario in a given airspace, any single system or combination of surveillance systems, meeting the set parameters, can be considered operationally acceptable.

FUTURE TRENDS

ADS-B* has the potential to complement SSR in terms of coverage (gap filler) and even to replace SSR for low- to medium-traffic density. If aircraft are adequately equipped, the ADS-B* information can also be used as a basis for a cockpit display of traffic information (CDTI)*.

The level of equipage is expected to increase in accordance with the global mandatory carriage of ACAS and pressure-altitude SSR transponders.

Airborne separation assurance systems are being developed that may enable the pilot to exercise responsibility in certain circumstances for separation from other aircraft. These systems may provide alert and protection zones around aircraft, together with information to help the pilot monitor and resolve potential conflicts. Other applications are being considered which may include traffic information service-broadcast (TIS-B), ADS-B*, CDTI* and conflict detection and resolution functionality.

Future surveillance may include an ACAS III* system, which will provide both horizontal and vertical resolution advisories.

GENERAL TRANSITION ISSUES

Guidelines for transition to the future systems encourage equipage by users for the earliest possible accrual of systems benefits. Although a transition period of dual equipage, both airborne and ground, is often necessary to ensure the reliability and availability of a new system, the guidelines are aimed at minimizing this period to the extent practicable. Appendix A to this chapter lists the guidelines that States, regions, users, service providers and manufacturers should consider when developing CNS/ATM systems or planning for implementation of such systems.

METEOROLOGY

This chapter describes how the provision of meteorological information supports air traffic management and the technological developments in meteorological systems, which will be required to facilitate the evolutionary transition to new global ATM systems. It also addresses the coordinated national, regional and global planning of meteorological systems needed to realize the potential benefits from improved meteorological information in the new CNS/ATM systems.

METEOROLOGICAL SUPPORT TO INTERNATIONAL CIVIL AVIATION

Traditionally, the provision of meteorological information to support international civil aviation was based primarily at the national level and organized hierarchically, with a specific meteorological office designated to be associated with each flight information centre (FIC)/area control centre (ACC), approach control unit and air traffic control tower. The associated meteorological offices supplied selected meteorological information necessary to enable each of the air traffic services units to meet its various obligations.

The meteorological information provided was related to an FIR and particular aerodromes required as destinations and alternates in that FIR and in immediately adjacent FIRs. Communication of this information beyond the FIRs concerned was tightly controlled so as not to overload the AFTN unnecessarily. The meteorological information was provided to pilots, inter alia, in face-to-face briefings in an airport meteorological office, using controller/pilot voice communications and through the automatic terminal information service (ATIS) and HF/VHF meteorological information for aircraft in flight (VOLMET) broadcasts.

It was inevitable, however, that the fundamental changes in international civil aviation in the 1980s, such as deregulation, increased air traffic and longer, direct flights, and the increased associated costs of the provision of facilities and services, which essentially prompted the creation of CNS/ATM systems, would also drive a parallel need for changes in the provision of meteorological services for international civil aviation.

These changes in the provision of meteorological services, which began in the early 1980s, comprised two main elements. The first was the development of the ICAO world area forecast system (WAFS) which, initially, centralized the production of global upper wind and temperature forecasts by two world area forecast centres (WAFCs), along with the production of significant weather (SIGWX) forecasts and the dissemination to States by fifteen regional area forecast centres (RAFCs) of WAFCand RAFC-produced charts. The second element concerned the gradual change in the content and format of the meteorological information provided to pilots and a relaxation of the rules governing the exchange of operational meteorological information (OPMET) messages to permit a wider distribution.

In the recent past, changes which had generally progressed steadily over the previous decade began to accelerate markedly. This was not due to any sudden change in the operational requirements — essentially these were still being driven by the explosive growth in global air traffic and the need for cost-effective means to satisfy the attendant requirements — but by the technological developments in computing and telecommunications. These developments made possible a complete rethinking of the facilities and services in a cost-effective manner, while at the same time improving safety. Taking advantage of these technological developments so that aviation meteorology contributes effectively to the smooth transition to global CNS/ATM systems is the challenge facing the international meteorological community today.

METEOROLOGICAL SYSTEMS TO SUPPORT GLOBAL CNS/ATM

The need for aviation meteorology to think increasingly in terms of global rather than regional or national concepts had already been foreshadowed in the development of the WAFS and in the changes made to the content, format and exchange pattern of OPMET messages.

In fact, the original concept of the WAFS, as approved by the ICAO Council, included a final phase in which all WAFS data and products would be produced by computer at the two WAFCs, with global dissemination of the information direct from the WAFCs to States by satellite broadcast. The rapid developments in computer technology and associated forecasting techniques, and satellite broadcasting technology have rendered it possible to plan for the final phase of the WAFS much earlier than had hitherto been anticipated. In parallel with these developments, the introduction of a data link has permitted, for the first time, the automated uplink of meteorological information direct to the cockpit, either at the initiation of the ATM system or in response to the pilot's request, and the automated downlink of data from the aircraft including wind and temperature, turbulence and humidity.

Two other components of the global meteorological system are the ICAO international airways volcano watch (IAVW) and the ICAO tropical cyclone warning system, both of which are of particular importance for international air navigation since volcanic ash and tropical cyclones are the only weather phenomena which would normally result in the cancellation of a flight at the pre-flight planning stage. The IAVW was initially introduced to be operated on a voluntary basis but has since been consolidated into a well-structured global system consisting of nine volcanic ash advisory centres (VAACs) which issue volcanic ash advisories both in alphanumeric and graphical formats to be used by MWOs for issuing SIGMET messages, by international NOTAM offices for the issuance of NOTAMs for volcanic ash and ASHTAMs, by ATM for re-routing and activation of contingency arrangements, and by operators for pre-flight and in-flight planning. The ICAO tropical cyclone warning system was established consisting of six tropical cyclone advisory centres (TCACs) which issue tropical cyclone advisories to be used by MWOs for issuing SIGMET messages, by ATM for re-routing and activation of contingency arrangements, and by operators for pre-flight and in-flight planning.

In a limited way, ATM is already employing additional and enhanced meteorological information made possible by the aforementioned technological advances in meteorological systems. The application of these systems to current operations is focused mainly on specific elements of ATM, where it can be demonstrated that the provision of enhanced or additional meteorological data and products is either critical to the operation concerned or provides a cost benefit. An example of this is the provision of additional and enhanced meteorological information to support the following:

- the provision of medium-level SIGWX forecasts and en-route diversion aerodrome reports and
- forecasts for one-engine inoperative drift-down procedures for extended range operations;
- the provision of the latest SIGMETs and upper wind/temperature data from meteorological watch offices (MWOs) and WAFCs respectively, direct to ATC computers, for updating flight plans for dynamic aircraft routing over the Pacific Ocean;
- the daily selection of the organized tracks over the North Atlantic based upon upper wind fields produced by the WAFCs; and
- the use of real-time information on hazardous enroute and destination weather and updated upper wind fields for air traffic flow control.

All of the examples provided in the previous paragraphs concern pre-flight planning and en-route operations. These depend upon the WAFS, direct satellite broadcasts, and the direct and preferably automated provision of updated meteorological forecasts or real-time data to ATC. But examples need not be restricted to en-route operations. In the terminal area, the advent of data link has already spurred the development of systems for the automated provision of meteorological information direct to aircraft, some examples of which are:

- uplink of reports from automatic weather observing stations;
- uplink of wind shear/microburst warnings from automated terminal Doppler weather radar (TDWR); and
- automatic downlink of wind/temperature data from aircraft on approach and during climb-out. ways and means of providing the required meteorological

METEOROLOGICAL SYSTEMS TO SUPPORT THE TRANSITION TO THE NEW GLOBAL CNS/ATM SYSTEMS

In order to support and facilitate the transition to CNS/ATM systems, the meteorological systems described in the foregoing paragraphs will have to be further developed and more focused on global requirements, in addition to national and regional requirements. These developments must meet aeronautical requirements to improve safety and provide an identifiable cost-benefit to users. The systems must converge, as much as possible to create a seamless and transparent global meteorological system for the provision of meteorological service to international civil aviation.

In many respects the WAFS and the ICAO direct satellite broadcasts have already made the transition to a seamless and transparent system, which, moreover, is also converging with systems for the exchange of OPMET messages. The global ATM system will require access to global meteorological information on a far shorter timescale than has been customary in the past. In many cases, virtual “instant” access, including real-time data, will be required.

Such stringent requirements will dictate that as many of the processes as possible, which the systems comprise, must be automated. The meteorologists’ input will be increasingly transferred to the beginning of the processes, even to the extent of transferring knowledge and experience through artificial intelligence to dedicated expert systems.

Development of the meteorological systems to support a global ATM system will be required specifically in the following areas:

a) rapid progress to the final phase of the WAFS with two WAFCs producing automated global upper winds/temperatures and SIGWX forecasts, which may be input directly into ATC and airline computers. The final phase is expected to be implemented by 2002;

b) continued extension of the three ICAO direct satellite broadcasts to exchange global OPMET messages and, as necessary, other non-MET aeronautical information;

c) availability at ATC centres and airline centralized operational control of background upper wind fields for display, both in the form of WAFS global upper wind forecasts and "real-time" wind fields derived from the wind information reported automatically from an aircraft in ADS messages; and reports and forecasts of hazardous weather, particularly volcanic ash, thunderstorms, clear-air turbulence and icing, to assist in tactical decision-making for aircraft surveillance, air traffic flow management, and updating flight plans for flexible/dynamic aircraft routing;

d) automatic uplink of aerodrome weather observations to aircraft on approach or departure, including D-ATIS and D-VOLMET to replace HF and VHF VOLMET; and dedicated systems to detect hazardous weather, such as automated terminal Doppler weather radar (TDWR);

e) automatic downlink of meteorological information derived from aircraft sensors (wind, temperature, turbulence and humidity) to ATC computers to provide background upper wind fields, as described above, and real-time descent wind profiles to assist in the automatic sequencing of aircraft on approach to maximize runway capacity; and relay of this information to the two WAFCs for assimilation in global numerical weather prediction models, thereby improving the overall quality of subsequent global forecasts;

f) use of meteorological sensors, including Doppler radar, possibly providing input to expert systems, which will provide automated runway wake vortex reports and forecasts to assist in optimizing aircraft separation, thereby maximizing runway capacity;

g) full implementation of the IAVW, which would result in a reduction in the time-delay for volcanic ash reports and advisories and associated SIGMETs from volcano observatories, volcanic ash advisory centres (VAACs) and meteorological watch offices to reach area control centres and aircraft in flight by employing more direct routing; and

h) harmonized common point of access to aeronautical information services (AIS) and meteorological services for air navigation meteorological information to support combined automated AIS/MET pre-flight briefing facilities.

PLANNING AND IMPLEMENTATION OF METEOROLOGICAL SYSTEMS

All of the foregoing elements are either currently in existence and being further developed or are the subject of research and development by States. The implementation of these elements to form a seamless global system will proceed step by step as aeronautical requirements for the service are stated and reflected, as appropriate, in the relevant ICAO SARPs. This is critical in order to indicate clearly that the service is required by international civil aviation to contribute to the maintenance or improvement in air safety and/or provide a demonstrated cost-benefit to users associated with global ATM. Once the requirements are firmly established, standardization of the relevant meteorological facilities and services will facilitate the planning of a seamless and transparent meteorological system to support the global ATM system.

In planning for the implementation of meteorological systems, account has to be taken of the existing national, regional and global meteorological and telecommunications infrastructures and a determination made as to which parts will be able to support the global ATM system and which will need to be upgraded or replaced.

Clarification will be needed concerning the optimum balance between the required meteorological information being "pushed" to the aircraft from the ground and being "pulled" to the aircraft by pilot request. How, in which form and where the global meteorological information will best be routed and concentrated will be very much dependent upon receiving this clarification as early as possible in the planning process. In general, it would seem that, in the future, increasing emphasis will be placed on "routine" meteorological information being accessible by the pilot automatically upon demand, with directed or broadcast transmissions being restricted mainly to safetyrelated information. Making information accessible to the pilot may be achieved in practice either by having it uplinked and stored in the aircraft computers or stored on the ground in OPMET databases and/or servers which can be interrogated by the pilot. The optimum balance between the meteorological information broadcast directed from the ground to the aircraft, and meteorological information obtained by pilots interrogating OPMET databases must emerge from the development of the operational requirements, which will then be reflected in the pattern of global OPMET exchange requirements.

AERONAUTICAL INFORMATION SERVICES

This chapter describes how aeronautical information services (AIS) and aeronautical charts (MAP) have traditionally been provided and the need for a new approach to support global air traffic management systems and their associated automation systems. This chapter also outlines the necessary developments in AIS and MAP as well as the ways and means of collecting, preparing, validating, organizing and distributing aeronautical information in support of air traffic management.

AIS AND MAP SUPPORT TO INTERNATIONAL CIVIL AVIATION

The major objective of AIS is to ensure the flow of information necessary for the safety, regularity and efficiency of international civil aviation. In that respect, each Contracting State is required to provide this service and is responsible for the information provided. Traditionally, aeronautical information has been provided as hardcopy documents in the form of the Integrated Aeronautical Information Package, which contains information for the entire territory and also areas outside the territory for which a State is responsible for the provision of air traffic services. The information must be provided in a suitable form and must be of high quality, be timely and include, as necessary, aeronautical information of other States. In addition, pre-flight and in-flight information services must be provided.

To satisfy the requirements of flight operations, aeronautical information/data necessary for the safety, regularity and efficiency of air navigation must be made available to personnel, including flight crews and those involved with flight planning, flight simulation and air traffic services and to units responsible for flight information services. The role and importance of aeronautical information/data has changed significantly with the implementation of RNAV, RNP and airborne computer-based navigation systems. These systems are all data-dependent, and in that respect aeronautical data have become the necessary critical components of the system. Consequently, corrupt or erroneous aeronautical information/data can potentially affect the safety of air navigation. In this respect, as of 1 January 1998, each Contracting State must take the necessary measures to introduce a properly organized quality system containing procedures, processes and resources necessary to implement quality management at each functional stage of the data process. Quality systems must provide users with the assurance and confidence that distributed aeronautical information/data satisfy established requirements for data quality (accuracy, resolution and integrity) and timeliness.

For the safe performance of air operations, it is essential that current, comprehensive and authoritative navigation data be available at all times, and that aeronautical charts supply that information in a manageable and condensed manner. Considering that all segments of aviation make reference to aeronautical charts for air traffic control, planning and navigation purposes, it is of prime importance to place current and accurate charts in the hands of users.

Current practices require Contracting States to ensure the availability of specific charts either by producing the charts themselves or arranging for their production by another State, or by an agency which would then be provided with the necessary data. International specifications are required in order to achieve the safety, regularity and efficiency of international air navigation by specifying the types of charts to be made available and by ensuring the adequate uniformity of the charts. The increased speed of aircraft, together with a greater range in operating altitudes and route stages, and increasing air traffic congestion impose requirements for rapid chart interpretation and some latitude for improvements in chart design to meet changing operational needs. In addition, the effective functioning of AIS pre-flight information units is partly dependent upon the availability of aeronautical charts for flight planning. Finally, the aeronautical information services are required to publish in their Aeronautical Information

Publications (AIPs) a description and list of available aeronautical charts series, together with an indication of their intended use.

The provision of aeronautical information and aeronautical charts services to support international civil aviation is primarily the responsibility of States. The aeronautical information provided is related to the FIR and aerodromes within a given region. This information is provided to pilots in face-to-face briefings at the aerodrome AIS unit or in flight, through air traffic control. Communication of the latest information to users is effected through the aeronautical fixed telecommunication network (AFTN) in the form of notices to airmen (NOTAM). So far, automation of the AIS has been basically oriented toward the NOTAM system, and planning has taken place at the regional level. With the adoption of CNS/ATM systems by international civil aviation, new requirements for aeronautical information and charts services have emerged. These new requirements are driven by the growth in global air traffic and the need for cost-effective solutions, as well as the technological developments in computing and telecommunications. It is therefore essential that in the interest of safety and efficiency of civil aviation, AIS and MAP services contribute effectively to the transition to global CNS/ATM systems by developing further specifications and conditions to satisfy these new operational requirements.

AIS AND MAP SERVICES TO SUPPORT GLOBAL CNS/ATM SYSTEMS

For CNS systems to operate and generate the full benefits of their use through enhanced ATM, the support of other services such as AIS and MAP is essential. In this respect, the enhanced ATM system, along with the requirement for precise navigation capability, will require quality aeronautical information so as to be able to provide guidance for gate-to-gate operations* between origin and destination. This will include the ability of aircraft to navigate on the ground and en route, using on-board navigation systems that can calculate desired tracks.

With the increased quantity of aeronautical information and with the clearly defined operational requirement for aeronautical data quality (accuracy, resolution and integrity), emerging aeronautical databases are improving, inter alia, the speed, efficiency and cost-effectiveness of aeronautical information. For these reasons, many States have begun or are planning to develop electronic aeronautical databases with the intent of using such data to prepare and update their AIPs and/or to exchange electronic aeronautical information. It is therefore necessary to develop new Annex 15 specifications related to the electronic storage, provision and interrogation of aeronautical information.

These new specifications should provide neutral international Standards on the basis of which an ICAO Conceptual Information Data Model will be developed. To satisfy the operational requirements for the exchange of aeronautical data while taking into account the compatibility of different systems and formats, a new data exchange model is also required. The 1990s witnessed a revolution in the way aeronautical information is processed, integrated and presented to pilots and other users. The technology is available today to display a viable electronic chart in the cockpit, thereby substantially reducing the need for paper charts. The real need, however, is for more than just an electronic page turner that replaces a paper chart book. The future electronic chart must be intuitive and designed to simplify the pilot's interpretation tasks, while minimizing information overload by reducing the amount of displayed data.

It must also provide pilots with the option of accessing only the specific data required for a particular phase of flight. As charted aeronautical information symbology is gradually transferred from paper to electronic form, a degree of standardization of the symbology to be used in electronic chart displays will be required. Some of these Standards have already been developed and included in Annex 4; however, further development is in progress. In order to provide worldwide standardization of the charting information necessary for aircraft to use GNSS, some new charting specifications have also been introduced into Annex 4, and the development of the complete specifications continues.

It is important that terrain and obstacle information be available and accurately presented on electronic aeronautical charts. Users' requirements for the quality and format of electronic terrain and obstacle data must be taken into account in addition to how this information can best be consolidated with aeronautical information and presented on electronic charts. Annex 4 specifications are being developed to ensure that they facilitate and standardize the provision of electronic terrain and obstacle information, which meets user requirements while taking into account quality assurance.

New Annex 15 specifications dealing with the exchange of electronic aeronautical data through the use of available and new technological means are under development as well. In addition, data link communications as specified for CNS/ATM systems will replace most voice communications of aeronautical information currently disseminated by ATS. Once a sufficient number of aircraft are capable of air-ground data link communications and aeronautical databases are made available, pilots will be able to access and interrogate those databases at various stages of flight. Worldwide standardization of the communication and display of these data is deemed necessary, which will include aspects of surface-to-surface as well as data link communications to facilitate interrogation of aeronautical information from aircraft. New Annex 15 Standards will also include procedures for aeronautical data transfer, taking into account data formats and data protection during the transfer. The ICAO Training Manual, Part E-3 — Aeronautical Information Services Personnel (Doc 7192) is being updated, and an ICAO training programme for AIS/MAP personnel is being developed. The programme will include training curricula for AIS/MAP technical officers and will establish uniform Standards for the qualifications and scope of knowledge that must be met by all AIS/MAP technical officers worldwide. The material will be based on the recently updated operational requirements for the provision of quality aeronautical information necessary for the safety, regularity and efficiency of international air navigation. As a result of the increased responsibility of AIS/MAP personnel to provide quality aeronautical information, there may eventually be a need to license certain AIS/MAP personnel.

AIS/MAP SYSTEMS TO SUPPORT THE TRANSITION TO THE NEW GLOBAL CNS/ATM SYSTEMS

In order to support and facilitate the transition to new global CNS/ATM systems, the aeronautical information and charts systems will be further developed and oriented more towards global requirements, in addition to national and regional requirements. This should be done in such a way that would safely increase efficiency and costeffectiveness to users. The goal, as far as possible, is the creation of a seamless and transparent global aeronautical information system.

It is envisaged that the global ATM system will require global aeronautical information of a required quality. The ultimate goal would be to provide on-line, in real-time, quality aeronautical information to any user, any time, anywhere. To achieve this high-level goal, aeronautical information must be provided and exchanged in electronic form based on a conceptually standardized data model. Strict quality principles must be in place to ensure that aeronautical data are available, verified and validated in order to give the end-user confidence in the correctness of the information.

Development of aeronautical information systems to support global ATM is specifically required in the following areas:

- completion by States of implementation of the World Geodetic System — 1984 (WGS-84) common geodetic datum adopted for international civil aviation;
- implementation by States of a quality system for the origination, production, maintenance and distribution of aeronautical information;
- development and introduction of an ICAO conceptual information data model for the storage, retrieval and exchange of aeronautical data;
- extension of the broadcast of aeronautical information through satellites to enable exchange of aeronautical data, in textual and graphical form, and messages associated with the status of ground-based databases;
- development of specifications for the direct uplink of aeronautical information (including charts) into aircraft, along with the possibility for interrogation, from the aircraft, of aeronautical databases on the ground; and

MODULE IV: ICAO AND AIR SPACE AND AIR TRAFFIC MANAGEMENT

ICAO INSTITUTIONAL AND REGULATORY FRAMEWORK

INSTITUTIONAL FRAMEWORK

The aims and objectives of ICAO in accordance with Article 44 of the Convention on International Civil Aviation (Doc 7300) are to develop the principles and techniques of international air navigation and foster the planning and development of international air transport to, inter alia, ensure safe and orderly growth.

The Convention establishes the privileges and restrictions of all ICAO Member States and provides for the adoption of International Standards and Recommended Practices (SARPs) regulating international air transport. The Convention recognizes and accepts the principle that every State has complete and exclusive sovereignty over the airspace above its territory.

The ICAO Assembly and Council and their subsidiary bodies set the continuing direction of the work of the Organization. One of the major duties of the Council is to adopt SARPs, which are designated as Annexes to the Convention on International Civil Aviation.

Although the Council is responsible for the adoption of SARPs and the approval of Procedures for Air Navigation Services (PANS), the principal body concerned with their development is the ICAO Air Navigation Commission. The Commission is composed of qualified and experienced individuals in the science and practice of aeronautics, nominated by ICAO Member States and appointed by the Council.

Due to increased dialogue and a changing culture, civil/military cooperation is becoming a global topic because of the enormous positive effects for both civil and military air traffic management (ATM) systems and related aviation operations.

ARTICLE 3 OF THE CONVENTION

Article 3 (a) of the Convention expressly excludes State aircraft from its scope of applicability. Articles 3 (b), (c) and (d) further clarify the definition and scope of application of the Articles of the Convention:

a) This Convention shall be applicable only to civil aircraft, and shall not be applicable to State aircraft.

b) Aircraft used in military, customs and police services shall be deemed to be State aircraft.

c) No State aircraft of a Contracting State shall fly over the territory of another State or land thereon without authorization by special agreement or otherwise, and in accordance with the terms thereof.

d) The ICAO Contracting States undertake, when issuing regulations for their State aircraft, that they will have due regard for the safety of navigation of civil aircraft.

The foregoing notwithstanding, further references to civil/military coordination and cooperation matters are included in the Convention, the Resolutions of ICAO General Assemblies, ICAO Annexes, PANS, and a variety of documents and manuals.

As a consequence of Article 3, in particular subparagraph 3 (d), States are required to safeguard navigation of civil aircraft when setting rules for their State aircraft. This leaves it up to the individual State to regulate these operations and services, generating a wide diversity of military regulations. However, especially in congested airspace, harmonized regulation is a precondition for a safe, efficient and ecologically sustainable aviation system.

At the same time, States are aware of the limitations of ICAO SARPs and designated Annexes to the Convention, including PANS and regional supplementary procedures (SUPPs), as they relate to State/military aircraft and their services. Indeed, as seen above, Article 3 of the Convention specifically exempts State aircraft from compliance with articles of the Convention.

Annex 11 — Air Traffic Services allows States to delegate responsibility for the provision of ATS to another State. However, States retain sovereignty over the airspace so delegated, as confirmed by their adherence to the Convention. This factor may require additional effort or coordination in relation to civil/military cooperation and appropriate consideration in bilateral or multilateral agreements.

More and more multinational military operations that cross international boundaries require complex coordination and planning processes to avoid unnecessary segregation or restrictions and to achieve the required level of safety. In light of Article 3 (d) it should be the role of ICAO to support States in harmonizing their State aircraft operations and the respective services in a regional and, ideally, a global context.

ASSEMBLY RESOLUTIONS

The topic of civil/military coordination has been discussed over the years in the ICAO Assembly, and many resolutions referring to civil/military coordination have been formulated. At the 37th Session of the Assembly, 28 September to 8 October 2010, Resolution A37-15, Appendix O, "Coordination and cooperation of civil and military air traffic" was further articulated.

It was recognized that airspace is a resource common to both civil and military aviation and that many air navigation facilities and services are provided for and used by both civil and military aviation. Further, the shared use of airspace and certain facilities and services by civil and military aviation shall be arranged so as to ensure the safety, regularity and efficiency of international civil aviation as well as the requirements of military air traffic. As a consequence, ICAO Member States may include, when appropriate, representatives of military authorities in their delegations to ICAO meetings.

The 37th Assembly also concluded that ICAO should serve as an international platform to facilitate improved civil/military cooperation, collaboration and the sharing of best practices.

EXISTING REGULATORY FRAMEWORK

Obligations of ICAO Member States under the Chicago Convention germane to civil/military issues include:

a) rule-making as regards aviation safety rules in compliance with ICAO SARPs contained in the Annexes to the Convention (Article 37); and

b) carrying out tasks which pertain to, for instance, ATM and which are laid down in the Annexes to the Convention, such as the classification of airspace and coordination between civil and military air traffic.

Annex 2 — Rules of the Air contains rules relating to the flight and manoeuvre of aircraft within the meaning of Article 12 of the Convention. It includes provisions on the coordination with military authorities for reason of a State's territorial integrity and sovereignty, namely for air defence reasons. To facilitate coordination with appropriate military units, a flight plan has to be submitted for any flight within or into designated areas or along designated routes. In those instances a flight plan is submitted to facilitate coordination and control of flights with transparent and real-time data exchange.

Annex 11 contains the SARPS that States use as reference for the provision of air traffic services (ATS). Currently, the Annex addresses only the need for coordination with military authorities or units, mainly the degree and level to which State aircraft activities may affect civilian operations or vice versa. Topics covered include activities that may directly affect flight safety, be potentially hazardous to civil aircraft, or require interception of civil aircraft or coordination due to unlawful interference of air traffic.

The Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444), together with the Standards in Annex 2 and the Regional SUPPS, govern the application of the rules of the air and ATS. The PANS-ATM contains procedures applicable to other in-flight contingencies, such as strayed or unidentified aircraft, that involve coordination with military authorities. Some miscellaneous procedures are detailed for the conduct of special military operations.

The Manual Concerning Safety Measures Relating to Military Activities Potentially Hazardous to Civil Aircraft Operations (Doc 9554) describes the coordination that should take place between military units and ATS units. It details the requirements to establish and maintain close cooperation with military authorities responsible for activities that may affect flights of civil aircraft. The Air Traffic Services Planning Manual (Doc 9426), published in 1984, was one of the first manuals to provide ICAO guidance material on civil/military coordination and cooperation. Most of that guidance material remains valid today.

The Global Air Navigation Plan (Doc 9750) has as a final goal the achievement of an integrated, harmonized and globally interoperable ATM system. A global system can be described as a worldwide system that, on a global basis, achieves interoperability and seamlessness across regions for all users during all phases of flight. The Global Plan includes technical, operational, economic, environmental, financial, legal and institutional elements and also offers States practical guidance on implementation and funding strategies. In accordance with the Plan, States and regions will choose objectives and draft their guidance in support of the particular needs of a homogenous ATM system.

Doc 9750 aims to provide initial guidance on, and facilitate implementation of, the civil/military coordination measures and cooperation concepts embedded in the Global Air Traffic Management Operational Concept (Doc 9854). Achievements in the integration of the specified Global Plan initiatives (GPI) require the implementation of collaborative airspace design and management, performance-based navigation (PBN), the integration of ground and airborne systems or data link or communications. It is significant to note that the first of the twenty-three detailed GPIs of the Global Air Navigation Plan is GPI-1, "Flexible Use of Airspace".

Doc 9854 is a relatively new document that describes the services that will be required to operate the global air traffic system in the near future and beyond. The Operational Concept highlights the elements needed to increase user flexibility, maximize efficiencies and increase system capacity while at the same time improving safety. Consideration of the interoperability and operations of military systems is an integral part of these elements.

CIVIL/MILITARY INTEROPERABILITY

INTRODUCTION

The ATM Operational Concept presents a vision of an integrated, harmonized and globally interoperable ATM system — a system that meets agreed levels of safety, provides for optimum economic operations, is environmentally sustainable and meets national security requirements for all users during all phases of flight. The vision does not discriminate or make any exceptions about the type of traffic it is designed to serve.

Communications, navigation and surveillance (CNS) systems, and advanced information management technology are to be used to functionally combine the ground-based and airborne system elements into a fully integrated, interoperable ATM system open to all users.

Interoperability can be considered as the ability of "systems" (not exclusively technical systems) to provide information and services to, and accept information and services from, other systems and to use the information and services so exchanged. Interoperability constitutes the driver of standardization, integration and cooperation.

Global standards, uniform principles and agreements are needed to ensure the technical and operational interoperability of the ATM system. However, ATM system interoperability needs to be considered in the broader context of governance, not just technology and procedures, while bearing in mind the requirements users place on the system. After all, ATM aims to enable all airspace users, including the military, to operate their preferred flight/mission profiles, cost-efficiently and effectively, without compromising flight safety or national security.

Interoperability specifics, however, are not always well-defined when considered in relation to the CNS/ATM field. They are often situation-dependent, come in various forms and degrees and can occur at various levels, i.e. strategic, operational and technical.

From the aforementioned, it can be concluded that civil/military coordination and interoperability are very similar. Interoperability can be identified as strategic/political or operational/technical as described in 2.2 and 2.3.

STRATEGIC AND/OR POLITICAL INTEROPERABILITY

At the strategic/political level, the concept of interoperability can be considered as an enabler for coalition building. It facilitates meaningful contributions by aviation coalition partners, both civil and military. At the highest level, interoperability of aviation issues centres on harmonizing global (e.g. ICAO) or regional (e.g. European Union) views, doctrines and, foremost, a regulatory framework. One main element at this level is the political willingness to cooperate and coordinate over the long term, to achieve and maintain shared interests in aviation safety, environment, efficiency and capacity. The price of strategic and/or political interoperability at national as well as international levels can be high and finding a common ground can be difficult to achieve. National considerations and culture are potential disablers of affordable interoperability. Nevertheless one can assume that the aviation chain is as strong as its weakest link and that it is therefore in everyone's interest to cooperate and invest in order to achieve the highest level of interoperability.

OPERATIONAL AND TECHNICAL INTEROPERABILITY

Interoperability at the operational level occurs when strategic, political and technical interoperability come together, not only to help all aviation partners to shape the environment and manage crisis, but also to support any anticipated aviation growth and its associated impact on aviation safety, environment, efficiency and capacity.

The benefits of interoperability at the operational and technical level generally derive from the inter-changeability of system elements or operational procedures. An example is the system-wide information management (SWIM) concept which is or will be used in a civil (SESAR/NextGen) as well as in a military (Network Centric Warfare) environment. These concepts enable users to randomly use that portion of information viable for their respective operation and can be achieved only through the interoperable technical feeders of the network. For this reason States and military organizations should endeavour to define mutually interoperable systems early in their design phase.

Another benefit of interoperability is modularity, which allows for the possibility of collecting only those technical facilitators that are necessary to conduct one's operation. An example of this is the all-purpose structured Eurocontrol surveillance information, known as the ASTERIX protocol, used for radar data exchange. This exchange protocol, in combination with a multi-radar tracker, can enable a civil air navigation service provider (ANSP) to use externally provided radar data, without necessarily procuring its own radar system, by using radar data provided by military sensors. States and military organizations should ensure a level of modularity in their respective systems to allow those systems access to a free exchange of information as required.

Costs associated with interoperability at the operational and tactical level very often derive from inefficiencies caused by a number of factors outside the direct control of the involved parties, such as strategic objectives, system impossibilities and institutional or governmental changes. States and military organizations should consider interoperability from the early stages of system design to ensure that costs are kept low and to ensure system compatibility.

REGULATION AND STANDARDIZATION

CNS/ATM regulations in any form can have an impact on the military either when military ground systems are integrated into a CNS/ATM network, when military units provide air navigation services to civil aviation or when carriage requirements are imposed on airspace users. Therefore, States and service providers implementing regulations or designing procedures should consider and minimize the impact of such actions on military users and systems (ground or airborne).

Existing civil standards and specifications are adequate to support technical compliance of civil CNS/ATM systems but tend to overlook the specific characteristics of available military CNS/ATM systems. To enable solutions that would promote civil/military interoperability, States should ensure that such specifications respond to the fulfilment of defined performance levels, using multiple means of compliance, rather than mandating particular equipage fits.

Historically, the supporting technical infrastructure enabling military operations, comprising multiple ground-based and airborne CNS/ATM systems, has been procured with the primary objective of satisfying the very demanding wartime requirements of military command and control.

The resulting lack of interoperability between the underlying civil ATM infrastructure and many military ground systems and tactical aircraft avionics is difficult to overcome due to:

a. lengthy military procurement cycles;
b. public budget constraints;
c. lack of space in the cockpit for extra avionics;
d. absence of supporting military requirements;
e. lack of recognized certification processes;
f. security and institutional aspects; and
g. difficulty monitoring civil CNS/ATM developments.

One of the most significant consequences of this situation is evidenced whenever a military aircraft that intends to use civil route structures has to be accommodated using special handling or by applying exemption policies or derogations for the airborne equipage. It needs to be realized that the need for an exemption for State aircraft should be based on compelling technical or military reasons and used only as a measure of last resort.

With the future predominance of strategic ATM capabilities, reduction of tactical interventions and consequent automation of the associated ATC tools and information flows in a network-centric environment (SESAR/NextGen), military platforms may face serious difficulties when attempting to freely access the airspace designated for civil aviation if they lack the required levels of connectivity with the underlying civil ATM system.

This possible situation entails the urgent need to identify valid solutions for interoperability between civil and military CNS/ATM systems at an early stage in their development and to define a migration path towards long-term avionics convergence and integration. States and service providers should establish a formal process of consultation with military users at an early stage of future avionics development with the aim of achieving maximum system interoperability between civil systems and military units.

AIRSPACE ORGANIZATION AND MANAGEMENT

GENERAL PRINCIPLES

With reference to the ATM Operational Concept, airspace management (ASM) is the process by which airspace options are selected and applied to meet the needs of airspace users. Competing interests for the use of airspace make ASM a highly complex exercise, necessitating a process that equitably balances those interests. The ultimate goal of ASM is to achieve the most efficient use of the airspace based on actual needs and, when possible, avoid permanent airspace segregation.

The management of airspace should follow these guiding principles and strategies:

a) all available airspace should be managed flexibly;

b) airspace management processes should accommodate dynamic flight trajectories and provide optimum operational solutions;

c) when conditions require different types of traffic to be segregated by airspace organization, the size, shape, and time regulation of that airspace should be set so as to minimize the impact on operations;

d) airspace use should be coordinated and monitored in order to accommodate the conflicting requirements of all users and to minimize any constraints on operations;

e) airspace reservations should be planned in advance with changes made dynamically whenever possible. The system also needs to accommodate short-notice unplanned requirements; and

f) complexity of operations may limit the degree of flexibility.

The effective implementation of an ASM process demands commitment from all stakeholders involved. A first step towards an effective implementation of the flexible use of airspace (FUA) concept would be to allow civilian users temporary access to military restricted and reserved airspace for optimum use of the airspace. Another step would be to allow military users temporary access to civilian restricted and reserved airspace.

THE FLEXIBLE USE OF AIRSPACE CONCEPT

Flexible use of airspace (FUA) is an airspace management concept based on the principle that airspace should not be designated as purely civil or military, but rather as a continuum in which all user requirements are accommodated to the greatest possible extent. The FUA concept includes consideration of effective communication, cooperation and coordination necessary to ensure a safe, efficient and predictable use of airspace. The establishment of joint civil/military coordination entities for airspace organization and management is essential to the realization of current and future CNS/ATM initiatives. Meeting future air traffic requirements for increased safety, security, capacity, efficiency, environmental sustainability, and sovereignty depends on effective civil/military coordination.

The civil aviation authorities of some States are already working with military authorities, using coordinated processes to manage civilian use of active military airspace. Jointly, civil and military authorities have put in place procedures to apply airspace reservations or restrictions only during limited periods of time, based on actual use. On completion of the activation requiring segregation, capacity is made available again to civil traffic. Examples of the coordination process in several States between civil and military sectors are contained in Appendices A, B and C.

Even when States have agreements such as the one in Appendix A, there continues to be numerous occasions when restricted or reserved airspace, with no planned military missions, has gone unused. Temporarily segregating airspace based on actual military requirements, through an effective collaborative civil/military process, should be pursued to recapture this unused capacity and release it for effective use by civil aviation. In order to enable effective flexible use of airspace, some basic prerequisites should be observed by States:

a) establishment of a national, high-level civil/military coordination body;

b) development of a consistent, collaborative national airspace planning process taking into consideration the needs of all airspace users and national security, defence and law enforcement requirements;

c) establishment of communication, negotiation and priority rules and procedures for civil/military coordination;

d) establishment and publication of procedures for activities which require airspace reservation or restriction. Airspace reservations or restrictions should be applied only for limited periods of time and based on actual use;

e) development of framework agreements between civil and military authorities to facilitate coordination;

f) establishment of a system to periodically review airspace needs, organization and management; and

g) predictive and timely access to restricted or reserved airspace whenever possible in order to maximize benefits and flexibility for all users.

Today aircraft are more capable of accurate navigation than in the past. Using global navigation satellite systems (GNSS) and performance-based navigation (PBN), aircraft can fly between terminals and en-route phases of flight with negligible deviations. However, lack of civil/military coordination of airspace management has resulted in inefficient airspace use and limited use of aircraft capabilities. The safe and efficient joint use of airspace by civil and military operations rests on understanding and accommodating the airspace requirements of all users on a fair and equitable basis, while respecting State sovereignty and national/international security, defence and law enforcement obligations.

FUA PRINCIPLES

An FUA concept should embrace the following principles:

a) Coordination between civil and military authorities should be carried out at the strategic, pre-tactical and tactical levels (see Figure 3-1) in order to increase safety and airspace capacity and to improve the efficiency of aircraft operations.

b) Consistency between ASM, air traffic flow management (ATFM) and ATS should be established and maintained at the three levels of ASM.

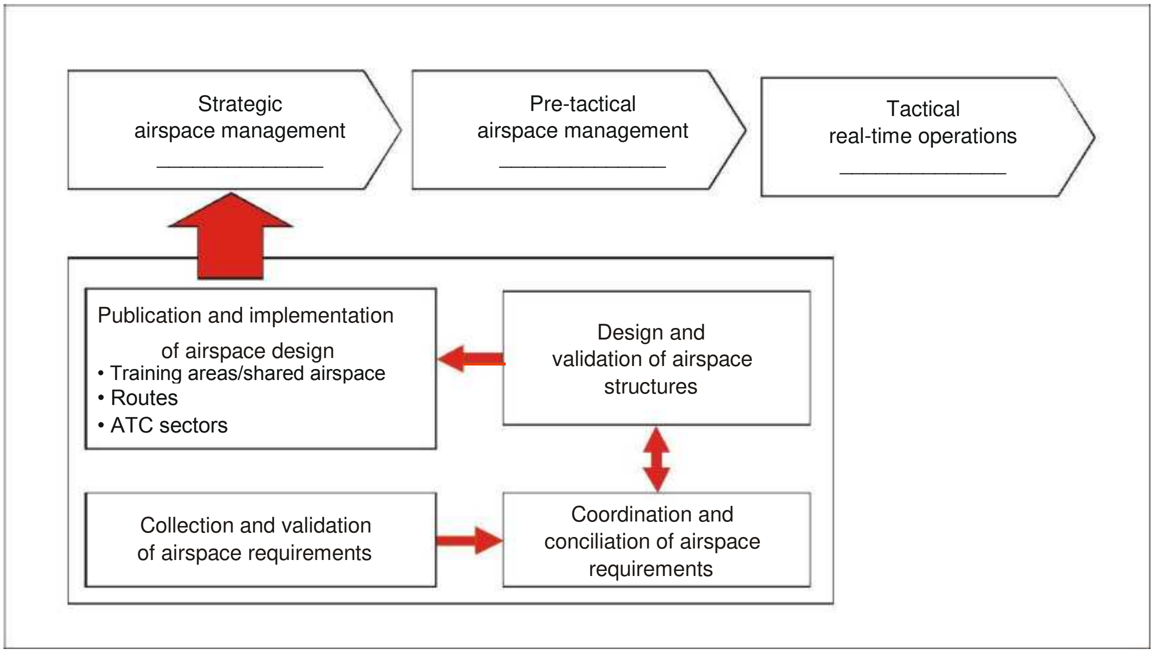

Figure 3-1. Coordination between civil and military authorities carried out at the strategic, pre-tactical and tactical levels

c) Airspace reservations should be of a temporary nature, applied only for limited periods of time and based on actual use of airspace.

d) The FUA concept should, whenever possible, be applied across national borders and/or the boundaries of flight information regions (FIRs).

Strategic airspace management

At the strategic ASM level, the following tasks need to be performed in order to ensure the overall application of the FUA concept:

a) establish airspace structures;

b) develop coordination procedures and airspace management procedures; and

c) develop cross-border coordination and separation standards between civil and military flights.

Pre-tactical airspace management

States should establish an ASM entity to allocate airspace in accordance with the conditions and procedures agreed upon at the strategic level.

The ASM entity should take the form of a joint civil-military cell, if both civil and military authorities are responsible for airspace management in a given State. It can also be a joint cell of two or more States. States should provide to the ASM entities adequate supporting systems to ensure a timely and efficient ASM process.

Tactical airspace management

Tactical ASM should be carried out at the level of ATS units and controlling military units. Dedicated coordination procedures and communication facilities should enable mutual provision of airspace data in a timely manner to allow effective real-time activation, deactivation or reallocation of the airspace allocated at the pre-tactical level. All affected users should be notified of the current status of the airspace. Direct communication between civil and military ATS units should be available with a high degree of reliability to permit the resolution of specific traffic situations if and where civil and military controllers are providing services in the same airspace. If required to meet minimum safety levels, exchange of flight data, including the position and flight intention of the aircraft, should be available between civil ATC units and controlling military units.

FLEXIBLE AND ADAPTABLE AIRSPACE STRUCTURES AND PROCEDURES

An FUA concept can be based on the potential offered by flexible and adaptable airspace structures and procedures that are especially suited to temporary allocation and utilization like conditional routes, temporary reserved area (TRA), temporary segregated airspace (TSA) and cross-border area (CBA).

Conditional route: A conditional route (Figure 3-2) is a non-permanent ATS route or portion thereof which can be planned and used under specified conditions. According to its foreseen availability, flight planning possibilities and the expected level of activity of the possible associated TSA, a conditional route can be divided into the following categories:

- Category one: permanently plannable;
- Category two: non-permanently plannable; and
- Category three: not plannable.

Temporary reserved area (TRA): A TRA (Figure 3-2) is airspace temporarily reserved and allocated for the specific use of a particular user for a determined period of time and through which other traffic may be allowed to transit under ATC clearance.

Temporary segregated airspace (TSA): A TSA is airspace temporarily segregated and allocated for the exclusive use of a particular user during a determined period of time and through which other traffic will not be allowed to transit.

Cross-border areas (CBA): A CBA is an airspace reservation/segregation established for specific operational requirements over international boundaries. CBAs are established to allow military training and other operational flights on both sides of a border. CBAs, not being constrained by national boundaries, can be located so as to benefit both civil and military aviation. CBAs, combined with the potential use of conditional routes through them, permit the improvement of the airspace structure in border areas and assist in the improvement of the ATS route network. Political, legal, technical and operational agreements between the States concerned are required prior to the establishment of CBAs. Formal agreements for the establishment and use of CBAs have to address issues of sovereignty, defence, legality, operations, the environment and search and rescue.

COLLABORATIVE DECISION-MAKING

Collaborative decision-making (CDM) is the process whereby all ATM decisions, except tactical ATC decisions, are based on sharing all information relevant to air traffic operations among all civil and military partners. The principles of CDM should be adopted by States and service providers, with the participation of military planners, as a tool to support ASM. CDM brings together airlines, civil and military aviation authorities and airports in an effort to improve ATM through information exchange, data sharing and improved automated decision support tools. The philosophy of collaboration promises to become the standard in aviation. CDM enables information-sharing and facilitates decision-making processes by ensuring that stakeholders are provided with timely and accurate information essential for the planning of their operations be they civil or military. For example, accurate estimates of arrival and departure times improve aircraft handling, apron services, stand and gate management, ATC and ATFM. Involvement of military airspace users and military airspace planners in national or regional airspace planning ensures adequate planning both in time and dimension, which serves military aviation but also de-conflicts with civil traffic flows to the maximum extent possible. By enabling decision-making based on accurate shared information, CDM increases predictability in case of unforeseen events or disruption. Properly carried out, CDM also leads to optimum airspace utilization with benefits to all participants in the system.

ATM SECURITY AND ATM IN CRISIS SITUATIONS

ATM SECURITY

ATM security is a growing concern for all involved in aviation. The implementation of the new security SARPs for ATS providers, adopted as Amendment 12 to Annex 17 — Security — Safeguarding International Civil Aviation Against Acts of Unlawful Interference, requires a more comprehensive approach to the security of the civil aviation system through the contribution of ATS providers in the ATM system, thereby driving the need to formalize and reinforce guiding principles for ATM security in the ATM system. Although aviation security remains essentially a national responsibility, the increased international threat of terrorism makes it necessary to improve cooperation between all stakeholders, civil and military, so that a collaborative, cooperative ATM security framework focusing on security policy, legislation and procedures to counter unlawful interference, terrorism and disruption can be achieved.

More specifically, Amendment 12 to Annex 17 states, inter alia, that "each Contracting State shall require air traffic services providers operating in that State to establish and implement appropriate security provisions to meet the requirements of the national civil aviation security programme of that State". A review of the ICAO definitions in the PANS-ATM (Doc 4444) and a review of expectations for security in the ATM Operational Concept provide the foundation for understanding the meaning of ATM security.

Security references in the ATM Operational Concept (Doc 9854)

Vision statement. To achieve an interoperable global air traffic management system, for all users during all phases of flight, that meets agreed levels of safety, provides for optimum economic operations, is environmentally sustainable and meets national security requirements.

Guiding principle — Continuity. The realization of the concept requires contingency measures to provide maximum continuity of service in the face of major outages, natural disasters, civil unrest, security threats or other unusual circumstances.

Air defence and military control systems will need timely and accurate information on flights and ATM system intentions. They will be involved in airspace reservations, notification of air activities and enforcing measures related to security.

Law enforcement (including customs and police authorities) will need flight identification and flight trajectory data, as well as information about traffic at aerodromes.

The airspace provider is responsible for addressing and resolving issues such as airspace sovereignty, diplomatic clearance and national security (e.g. air defence) requirements.

Security. Security refers to the protection against threats that stem from intentional acts (e.g. terrorism) or unintentional acts (e.g. human error, natural disaster) affecting aircraft, people or installations on the ground. Adequate security is a major expectation of the ATM community. The ATM system should therefore contribute to security, and the ATM system, as well as ATM-related information, should be protected against security threats. Security risk management should balance the needs of the members of the ATM community that require access to the system, with the need to protect the ATM system. In the event of threats to aircraft or threats using aircraft, ATM should provide the authorities responsible with appropriate assistance and information.

ATM security should be considered as the safeguarding of the ATM system from security threats and vulnerabilities and the contribution of the ATM system to civil aviation security, national security and defence, and law enforcement.

To elaborate, ATM security should provide collaborative support to the security of the airspace and ATC assistance to airlines, the military, and law enforcement in responding to non-compliant aircraft and disruptive passengers on board aircraft. At the same time, ATM security should protect the ATM system assets from service degradation; physical attack (e.g.

terrorist/criminals); insider ill-doing; cyber attack on information or data processing (e.g. by a hacker or computer malware); electromagnetic attack (e.g. causing interference with communications, navigation and surveillance equipment).

Overall, ATM security should enable effective response to security incidents affecting the ATM infrastructure or airspace and should enable planning for service/business continuity and recovery. Service continuity and recovery refers to the provision of ATS. Business continuity and recovery refers to the integrity of continued business operations.

ATM security management for protection of the ATM system

Ideally, ATM security management for protection of the ATM system should provide a comprehensive framework for the ATM service provider to manage security of the organization. Security management should enable an organization to develop and implement a security policy and programme that takes into account various regulatory requirements and other goals and objectives to which the organization subscribes. It applies to the security aspects that the organization identifies as those which it can control or influence and provides a mechanism to assure itself of meeting the stated security objectives.

ATM security management should consist of five key activities:

a) Policy-making. An organization's commitment to meeting customers' and stakeholders' expectations through active participation and leadership from senior management. This commitment and leadership should manifest itself in the organization's security policy and provide the resources for the security management programmes. An essential foundation of cooperation is a collaborative regulatory framework to ensure that compatible standards and security management practices are systematically applied and the legal framework is adapted to the requirements of ATM security.

b) Security risk assessment and planning. A systematic assessment of the organization's security risks against potential threats. This action should collect and analyse data to identify the organization's risk posture. The results of these analyses should identify gaps and priorities which would form the basis for the development of an implementation plan to manage security risk.

c) Implementation and operation. The security management plan becomes a reality only with a formal organizational structure, the building of competence, and a clear, consistent communication of the operational requirements. The measures that are introduced to enhance ATM security must be a reasonable response to the threats that are posed and affordable by the various stakeholders. Synergies with other security initiatives, in relation to the response of ATM to security threats, should be maximized to ensure cost-effectiveness.

d) Auditing and corrective action. A quality assurance programme of checks and balances to provide the objective review and feedback needed for continuing improvements.

e) Management review. The overall security management system and programme should be periodically reviewed by senior management to ensure continuing relevance, adequacy and effectiveness of the system and programme.

Security management should provide a structure allowing the organization and others to objectively evaluate performance against security objectives. A consistent and continuing use of security management should lead to continuous improvement of the organization's security performance, resulting in progressive improvement of protection for the ATM system.

Further guidance material on the protection of air navigation facilities and systems can be found in the Aviation Security Manual.

ATM security — The contribution of the ATM system to national security, aviation security and law enforcement

The general objective of ATM security is to determine effective mechanisms and procedures to enhance the response of ATM to security threats that affect flights (aircraft, passengers and crew) or the ATM system itself. Within this context, the purpose of airspace security is the safeguarding of the airspace from unauthorized use, intrusion, illegal activities or any other violation. This safeguarding of the airspace and protection of the ATM system itself requires that ATSPs provide ATM security services which enable military, law enforcement and aviation security authorities to carry out their roles and responsibilities within the ATM system.

The national governments and the public should have confidence that the airspace and all other aspects of the ATM system (people, infrastructure and data) are secure and well-protected from any unlawful activities that could potentially cause disruption to civil air transport.

Therefore, to adequately provide for national security and defence, aviation security and law enforcement, the following three levels of security objectives should be considered:

a) tactical operations security should provide daily ATM security oversight and coordination that maximizes awareness of security situations within the ATM system via layered security processes;

b) strategic operations security should ensure continuity of the ATM system via long-range planning, crisis management, analysis and support functions; and

c) special interoperations security should feature enhanced ATM security cooperation and use of liaisons for civil/military/law enforcement operations.

The combination of organization, means and doctrines (regulations, procedures) established to protect the ATM system must be able to assist the responsible authorities by providing protective measures as early as possible against threats, attacks and acts of unlawful interference, whenever and wherever necessary and possible.

Enhancing the security measures of the ATM system will have a positive effect both on the prevention of incidents and on the ability to respond to acts of unlawful interference. This includes security measures adopted by all parts of the ATM system, both technical and operational. In particular, this includes fostering of security awareness, improving the dissemination of information, developing ATM security standards and coordination procedures, and addressing all security requirements in the communications, navigation and surveillance domains and for the ATM infrastructure.

A more effective cooperation between civil and military authorities should be achieved by the enhancement of coordination and communications procedures and by the application of improved communications technology.

ATM IN CRISIS SITUATIONS

During any crisis situation, there will be a requirement for increased coordination between civil and military ATM authorities in order to allow civil air traffic to continue to operate to the maximum extent possible, while facilitating operational freedom for military air operations. The extent of any changes to the normal peacetime ATM system will depend upon decisions made at the time in light of the prevailing situation. These ATM changes would be introduced progressively, but may, under certain circumstances, be effected immediately depending on the nature of the crisis. A crisis may cause unusual military traffic flows in the airspace of nations whether or not they are directly involved in the crisis. Regional variations may also be applicable depending on which part of the globe the crisis situation is centred.

Whatever the circumstances, the requirement for increased civil/military coordination would be greatly enhanced by the development of contingency plans. Such plans should address the requirements for the expeditious handling of increased air traffic in support of any future crisis within their flight information regions (FIRs)/upper flight information regions (UIRs) and through any cross-border area shared with neighbouring nations. Procedures covering the requirements for diplomatic clearances for overflying aircraft should also be included.

Initially, there could be a need for augmentation of tactical air units and airlifts by military and civil transport aircraft which, together with associated air-to-air refuelling operations, would have to be accommodated within the routine air traffic environment. The initial phase could also comprise a number of repatriation flights or VIP flights which would require a high degree of priority. In addition to the increase in military air activity, civil humanitarian aid operations must also be taken into account. Although normal peacetime ATM measures would be applied initially to deal with changes in the pattern and density of air traffic, it is expected that these measures may prove to be insufficient. Consequently, national contingency plans should be able to respond to the increased complexity of airspace requirements and any subsequent changes. They should consider the establishment and manning of a national ATS crisis entity which would be responsible for maintaining close coordination between national authorities and the relevant international aviation organizations.

It is of paramount importance from the early stage of a crisis that, immediately following a political decision to take action during a crisis situation, civil and/or military aircraft employed in support of the military operations be afforded maximum priority in the use of the airspace and the ATM resources of participating nations.

The interrelationship and a safe and balanced coexistence of civil and military activities are crucial. Military operational requirements and consequent planning will need to be considered at the earliest possible opportunity against an assessment of the impact that any planned action may have on civil operations in the airspace, and priorities allocated accordingly. Continual reassessment of the impact will be necessary as the situation and military requirements develop.

Guidance material on the contribution of air traffic control to national security during a crisis can be found in the Aviation Security Manual.

STATE AIRCRAFT OPERATIONS

INTRODUCTION

In accordance with the Chicago Convention, Article 3 (b), "Aircraft used in military, customs and police services shall be deemed to be State aircraft". In broad terms, the right to access all airspace, within the limits of the operational needs, is a crucial requirement to enable the military, customs and police to perform the security, defence and law enforcement missions mandated by their States and by international agreements. It is, therefore, a fundamental requirement that each State be able to train and operate its State aircraft effectively. In this manner, it is vital for State aircraft to be provided access to sufficient space, enabling adequate opportunities for the training and execution of security, defence and law enforcement elements.

In pursuit of their tasks, operators of State aircraft should, where practicable, respect international, regional and State civil aviation legislation and aim for compliancy. However, it is recognized that the nature of the defence and security tasks can create unique situations that need special handling and considerations. In this regard, this chapter will first explain what roles are performed by military and non-military flights under the title of "State aircraft". It will then highlight circumstances when State aircraft can be fully compliant or partially compliant with international civil aviation rules and procedures, as provided for in ICAO SARPs, and the general expectations for handling such aircraft by an air navigation service provider (ANSP).

STATE AIRCRAFT ROLES

Without restating the definition from the Convention, it is nevertheless crucial to re-emphasize that State aircraft can consist of military and non-military air assets, given that it is the nature of their actual tasks that frame the character of the definition (i.e. in support of the State or the State's interests or obligations). Furthermore, the provision of Article 3 (b) does not preclude ICAO Member States from defining what constitutes a State aircraft. Consequently, the diversity of aircraft types that can be considered as State aircraft vary considerably, ranging from a highly-agile military air defence fighter aircraft to a fisheries protection twin-engined turboprop. A more detailed description of the roles that should be considered under the title of "State aircraft" follows.

Airlift. Airlift aircraft enable the movement and sustainment of forces anywhere in the world and across the entire range of operations. They provide rapid and flexible mobility options to military, national and international government agencies to quickly respond to various crisis situations worldwide. Such operations include airlift support to military crisis operations and also humanitarian relief operations. Airlift flights can be either military or civilian registered, but under the terms of State aircraft, the aircraft are operated on behalf of the State. The aircraft are predominantly multi-engined transport aircraft, engaged in passenger and freight carriage.

Counter-air. Exclusively a military task, the purpose of counter-air operations is to achieve a desired or necessary level of control of the air, through the destruction, degradation or disruption of enemy aircraft and missiles, in order to allow friendly forces greater freedom of action, while minimizing their vulnerability to detection and attack. Furthermore, air policing and patrol missions to safeguard nations against threats are practised and conducted with high priority. During crisis situations, control of the air is achieved through counter-air operations, which use a variety of integrated weapons systems and sensors to counter threats. These systems consist of manned and unmanned aircraft, ballistic missiles and air/land and sea-launched cruise missiles.

Space operations. Air and space power contribute to space operations through offensive or defensive operations conducted to help attain and maintain a desired degree of space superiority to allow friendly forces to exploit space capabilities.

Air power contribution to land and maritime operations. Predominantly military, but also including some non-military air platforms, air power provides the advantage of finding, fixing and engaging targets of interest without many of the physical, spatial and environmental limitations imposed on surface forces. However, integration between air and surface forces creates greater synergy of action and can be a more overwhelming force than in cases where a single component cannot be as effective. Such activities include air interdiction, close air support, electronic warfare, anti-surface warfare, anti-submarine warfare and aerial mining. Air assets involved in these roles are numerous and wide-ranging, including helicopters, combat fighter/bomber jet aircraft, unmanned air systems and multi-engined widebodied aircraft.

Airborne operations. Airborne operations provide air-delivered combat power to seize ground or installations through the airdrop or air-landing of land forces directly onto an objective. This is predominantly a military activity and generally involves helicopters and/or multi-engined wide-bodied aircraft.

Aeromedical evacuation. Aeromedical evacuation is a specialized form of airlift for transporting ill or injured personnel under medical supervision to appropriate medical treatment facilities. Although predominantly a military task in hostile environments, aeromedical evacuation can be conducted by military or non-military aircraft, ranging from helicopters to multi-engined widebodied aircraft.

Intelligence, surveillance and reconnaissance. Intelligence, surveillance and reconnaissance (ISR) integrates, where appropriate, capabilities from all military components and some non-military platforms, in order to provide awareness essential to successful planning and conduct of operations, through collection, processing, exploitation and dissemination of accurate and timely information. Air assets involve various manned and unmanned systems, which can require dedicated volumes of airspace.

Special air operations. Special operations forces are specifically organized military units manned by carefully selected people using modified equipment and trained in unconventional applications of tactics against strategic and operational objectives. Special air operations are a key enabler for Special Forces to conduct their missions. The nature of their tasks requires surprise and covert handling. The types of aircraft involved include helicopters and multi-engined widebodied aircraft.

Air-to-air refuelling. Air-to-air refuelling (AAR) is predominantly a military task but can be conducted by non-military registered aircraft. AAR is an essential capability that increases the range, endurance, payload and flexibility of all capable receiving aircraft. AAR is predominantly delivered from multi-engined widebodied aircraft to smaller combat jet aircraft; however, combinations of air assets ranging from helicopters, through combat jet aircraft to multi-engined widebodied aircraft can be involved. AAR requires dedicated airspace, either in the form of a statutory routine area or a temporary, mobile airspace block that enables aircraft to refuel in transit.

Search and rescue. The provision of search and rescue (SAR) services by ICAO Member States is a fundamental obligation under the Convention on International Civil Aviation. SAR is essentially a humanitarian activity with the primary aim of saving lives. In many countries, the military is responsible for SAR operations. However, non-military air assets can have either a shared or leading role in this vital capability. The aircraft types involved include helicopters and multi-engined aircraft which, during actual SAR emergencies, will require priority handling and unrestricted access to appropriate airspace.

Police/customs. Air operations in support of police operations and customs and border protection (CBP) services are predominantly undertaken by non-military law enforcement air assets. Police aerial units are often tasked to assist in surface vehicle pursuits and surveillance, which allows surface police/law enforcement units to disengage and follow from a discreet distance, making the pursuit less dangerous but still allowing for surface police/law enforcement units to be directed to apprehend suspects, as necessary. Air operations by police services are generally conducted through the use of helicopters; however, multi-engined fixed-wing aircraft are also used, which allow higher and quieter surveillance, making it less likely suspects will become aware that they are being watched. In a similar manner, CBP services utilize helicopters for some surveillance operations. However, given the larger scale and distances involved with CBP operations, multi-engined aircraft and unmanned air systems can have a more enhanced capability and role.

Meteorological support. Military and non-military aircraft are employed by some nations in support of collection, research and modification of weather systems. Due to the nature of the tasks, multi-engined fixed-wing aircraft fitted with unique on-board meteorological equipment are predominantly utilized, although unmanned air systems offer increasing utility.

Geographic and hydrographic support. The measurement and description of the physical features and conditions of terrain, navigable waters and adjoining coastal areas, including oceans, rivers and lakes, involve land, maritime, space and air assets. Military and non-military manned and unmanned aircraft take a key role in complementing the other environments in this work.

Aerial fire fighting. Aerial fire fighting is the use of aircraft and other aerial resources to combat wildfires. The types of aircraft used include helicopters and multi-engined fixed-wing aircraft, from military and non-military sources, which deliver fire suppressants and/or “smokejumpers”.

Experimental/trial aircraft. Experimental/trial aircraft activity includes acceptance testing for new aircraft, aerodynamics and systems research on military and non-military aircraft. The activities range in variety and ATM requirements; however, each will most likely require temporary dedicated airspace to ensure safety.

VIP aircraft. Some nations maintain one or more dedicated aircraft to transport their heads of State and government. These aircraft can consist of a mix of helicopters and multi-engined fixed-wing aircraft.

Unmanned aircraft systems. Unmanned aircraft system (UAS) operations can take place both by night and day, in all weather conditions. They are an increasingly important air asset that offers flexibility and utility within military and non-military services. Generally, UAS operate in segregated airspace; however, UAS may need to operate with greater flexibility on certain missions. Individual States may therefore approve UAS operations outside of segregated airspace on a case-by-case basis.

STATE NON-AVIATION AIRSPACE REQUIREMENTS

State non-aviation operations in some circumstances require access to national airspace. Often these operations will not be compatible with other concurrent aviation activity and will render airspace non-compliant with FUA principles. Operations including surface/naval weapons firing, research, development and exercising of non-kinetic weaponry, jamming, and weapons storage will normally require the use of segregated airspace in order to ensure the safety of non-participants.

STATE AIRCRAFT CONSTRAINTS

Having highlighted the variety of typical roles that State aircraft undertake, it is necessary to also set the context within which these aircraft operate and the associated constraints that State aircraft have. These constraints cover three broad areas.

Institutional constraints. State aircraft operations are not profit-making but are more attuned to serving a function or carrying out a requirement. Mandated to meet security and defence interests as demanded by governments, State aircraft operations require cost-effective access to training areas that need to be economically viable from home bases while also operationally achievable. Furthermore, aging fleets and constraints on defence budget spending, create the financial challenge of fitting State aircraft with new equipment to satisfy global developments in new ATM programmes.

Operational constraints. Defence and security threats set operational imperatives that State aircraft operations must be prepared for and able to conduct effectively. These demands give rise to unique situations that need special handling and considerations, placing operational constraints that must be considered in terms of ATM measures. For example, activities such as SAR, air policing/patrol, aerial fire fighting and special air operations create mission-critical criteria that demand utmost priority for the safety of the public for which they serve. ATM delays or denied access to relevant airspace should not occur during these types of missions.

Technical constraints. Equipage of State aircraft is predominantly focused on the output and nature of the task that the aircraft is expected to deliver. Consequently, the provision of ATM and CNS equipment on board State aircraft may have certain constraints due to limited space, together with the potential areas of operation expected of particular State aircraft to fulfil the nature of their assigned tasks.

FULLY-COMPLIANT OPERATIONS

Despite the institutional, operational and technical constraints highlighted in 5.4, State aircraft operations will, where possible, aim for compliance with civilian requirements. Specific roles that can reasonably be expected to conform and be fully compliant are as follows.

Airlift. Airlift transport and freight aircraft are normally equipped to the same standard as commercial transport aircraft, either through actual equipment or performance, and can be fully compliant with international civil aviation rules and procedures. However, there are circumstances in which airlift operations of State aircraft require the execution of a-typical manoeuvres or self-separation which can differ, sometimes significantly, from the SARPs.

VIP aircraft. Fixed-wing aircraft operating in the VIP role can be expected to be fully compliant with ICAO SARPS; however, the associated VIP status may require additional handling and prioritization, consistent with the ATM capacity and flow management at the time.

PARTIALLY-COMPLIANT OPERATIONS

The following State aircraft roles are unlikely to be fully compliant with ICAO SARPs for the duration of their activity but may, where required, offer partial compliancy.

Counter-air missions. Counter-air missions including quick reaction alert, air policing/patrol and interceptions of suspected hijacked aircraft can offer partial compliancy during training missions, where practicable. However, it is most likely, due to the flexibility that is critical to achieving their missions, that their operations will largely differ from civil aviation rules and procedures. Further, the aircraft may require short-notice penetration of airspace, heavily congested by civil air traffic, and expeditious handling.

Aeromedical evacuation. When the aircraft being used for aeromedical evacuation is a multi-engined widebodied aircraft, it may be feasible for the aircraft to offer compliancy during the en-route phase of flight. Nevertheless, certain medical situations may require slower rates of climb and/or descent than might otherwise be expected of this type of aircraft.

ISR. Some ISR platforms can offer compliancy during the en-route, take-off and landing phases of flight; however, it is most likely that dedicated volumes of airspace will be required for surveillance operating areas. Such operating areas can be enduring and/or require short-notice relocation depending on mission tasking.

Unmanned aircraft systems. Whether an unmanned aircraft is State or civil, if it is to be integrated into the civil ATM system, it must be remotely-piloted. Autonomous unmanned aircraft will not, in the foreseeable future, be integrated; however they may be accommodated in segregated airspace or by using special ATC provisions in non-segregated airspace. The provision of ATS should be one and the same whether the aircraft is State or civil or is piloted from on board or remotely. The introduction of UAS must not increase the risk to other aircraft or third parties and should not prevent or restrict access to airspace. ATM procedures for handling UAS should mirror those for manned aircraft whenever possible. There will be some instances where the remote pilot cannot respond in the same manner as an on-board pilot (e.g. to follow the blue C172, report flight conditions, meteorological reports). ATM procedures will need to take account of these differences. The Unmanned Aircraft Systems (UAS) circular (Cir 328) contains expanded information on each of the topics above. ICAO is in the early stages of developing the international regulatory framework for UAS that will facilitate their integration into non-segregated airspace. However, it will be many years before a comprehensive set of SARPs, procedures and guidance material will be completed.

SAR. SAR flights, whether civil or military, must be given high priority and handled as expeditiously as possible. Although SAR activities are normally performed at lower altitudes, aircraft are sometimes used at medium altitudes as airborne relay units or as an on-scene SAR coordinator/commander. Larger multi-engined fixed-wing aircraft may offer partial compliancy as long as their contribution to the actual SAR mission remains uncompromised.

Large-scale exercises. Large-scale exercises predominantly require access to large volumes of airspace and, if carried out within controlled airspace, considerable ATC capacity en route. Such exercises require appropriate planning and coordination, which enable timely reservation and promulgation of suitable airspace for the activity. Large-scale exercises often require segregation of large segments of airspace, and for this reason all efforts must be made to closely monitor airspace usage in order to release segregated airspace for public use as quickly as feasible.

Police/customs. State aircraft operations involving police forces and customs services will generally be conducted at lower altitudes but medium-level surveillance, both by manned and unmanned air vehicles. These operations may be achievable with partial compliancy on a case-by-case basis. Nevertheless, short-notice access to controlled airspace and expeditious handling may be required.

CIVIL/MILITARY COLLABORATION — A NEW GLOBAL CHALLENGE

Historically, State agreements between military aviation units and ANSP have focused on the needs of State defence, security and emergency procedures as well as military readiness and response requirements. There is now a clearly defined need to establish procedures that support the efficient integration of military and civil aviation in day-to-day operations.

Collaboration begins with good communication. ATM stakeholders should meet regularly to better understand the needs, desires, constraints and challenges that each operator and service provider faces in operating within State airspace. Good communication and mutual understanding enable building collaboration upon a solid foundation. Good civil/military communication and collaboration are the key to success for ATM around the world.

ATM stakeholders should approach and decide on each change-process on a collaborative basis. Optimized decision-making is the result when the interests of all ATM stakeholders are represented and the impact of the required changes is weighed and balanced against the needs and issues of military, civil and State aviation.

Aviation operations of all types contribute significantly to the economy of a State, and, as such, their growth needs to be protected and encouraged. In this regard, each State will benefit from a strong commitment to civil/military collaboration. Collaboration on the design and management of State airspace, technical requirements, and data and information collection and dissemination will allow civil aviation to flourish and military aviation to perform their required missions.

Further, aviation is a global business with an economic impact that crosses State borders. Strong State commitments to civil/military collaboration will be conducive to international harmonized approaches to aviation and the building of national and international agreements that benefit State and international civil aviation stakeholders alike.

This circular provides several examples of successful State civil/military collaboration resulting in benefits to airspace management and ATM system operations. These examples demonstrate that collaboration:

a. attains higher levels of safety;
b. increases airspace capacity;
c. enhances national security; and
d. increases operational efficiencies through:
    - interoperability of civil and military aircraft;
    - reduction in distances flown;
    - establishment of optimal flight profiles; and
    - reduction in fuel consumption and carbon emissions.

Not only does collaboration have a positive impact on day-to-day airspace management but it also allows for improved planning and execution of future technical and operational concepts. Collaborative assessments of costs and benefits will allow States to meet the future demands of civil and military aviation with much greater certainty. As a result of collaboration, States will likely be encouraged to consider common requirements for technology, capabilities, performance and procedures to meet future ATM demands.

This guidance should be considered as the first attempt to show a path forward. It not only indicates the strategic direction of ICAO, but also attests to the readiness of numerous global and regional partners in the aviation industry, military entities, ATM, and aviation service provision to engage in a mutually rewarding collaborative effort.

LEGAL ISSUES CONCERNING COMMUNICATION/NAVIGATION AND SURVEILLANCE SYSTEMS

INTRODUCTION

It has been generally agreed that there is no legal obstacle to the implementation of CNS/ATM systems and that there is nothing inherent in CNS/ATM systems that is inconsistent with the Chicago Convention. There is also a consensus that GNSS shall be compatible with the Chicago Convention, its Annexes and other principles of international law.

Presently, the legal aspects of CNS/ATM systems address issues mainly related to GNSS, which is a key element of ICAO CNS/ATM systems.

The Council has been considering the question of a legal framework for GNSS, in the form of a new legal instrument, or several instruments of different types, for some time, with the assistance of the Legal Committee, a Panel of Legal and Technical Experts and a Secretariat Study Group. Even though there is no consensus on the form of any new instrument, there has been much discussion on what features it might contain. The primary legal issue considered to require new law is how to secure accessibility and continuity of GNSS services. Corresponding to this issue, the institutional aspects mainly relate to the future operating structures for GNSS. Attention has been devoted to both the legal considerations in respect of the existing systems and to the elaboration of a more complete and lasting legal framework for the long-term future.

The transitional arrangements with respect to the existing satellite navigation systems are governed by the Chicago Convention and relevant SARPs. In addition, aspects relating to the provision of the GNSS signal-inspace were the subject of the exchange of letters between ICAO and the United States, dated 14 and 27 October 1994, and ICAO and the Russian Federation, dated 4 June and 29 July 1996.

The Panel of Legal and Technical Experts on the Establishment of a Legal Framework with Regard to GNSS (LTEP), which was established by the ICAO Council on 6 December 1995, has been given the mandate, inter alia, to consider the different types and forms of the long-term legal framework for GNSS and to elaborate the legal framework that would respond to certain fundamental principles. The consideration of the legal framework has resulted in consensus on the text of a draft Charter on the Rights and Obligations of States Relating to GNSS Services, which was adopted by the 32nd Session of the Assembly (22 September to 2 October 1998) in the form of Resolution A32-19. (the "Charter", Appendix A to this chapter refers).

Consideration of other legal issues has led to 16 Recommendations (Appendix B to this chapter refers). The material in this chapter is intended to assist States in identifying relevant legal issues, which they may encounter in the planning and implementation of CNS/ATM systems.

FUNDAMENTAL PRINCIPLES OF THE GNSS LEGAL FRAMEWORK

The Charter embodies certain fundamental principles applicable to the implementation and operation of GNSS. Some of these principles were derived from the Statement of Policy on CNS/ATM Systems Implementation and Operation, adopted by the Council on 9 March 1994 ("Council Statement of 1994"), as well as from the exchange of letters between ICAO and the United States and ICAO and the Russian Federation, respectively. Certain other principles are essentially restatements and elaborations of provisions of the Chicago Convention.

The safety of international civil aviation

The safety of international civil aviation is a paramount principle embodied in the Preamble and Article 44 (h) of the Chicago Convention. The Charter, described above, provides for a specific reference to this principle in its paragraph 1:

"States recognize that in the provision and use of GNSS services, the safety of international civil aviation shall be the paramount principle."

Accordingly, the safety of international civil aviation should be fully safeguarded at all times in the operation of GNSS, including during modification to the system.

Universal accessibility without discrimination

The principle of universal accessibility without discrimination, which is also embodied in the Chicago Convention and ICAO practice, is of particular importance with respect to navigation satellites as compared to communication satellites. In the case of the latter, the existence of multiple providers and commercial competition will provide a natural basis for guaranteed accessibility. In the event of the lack of access to the services of one provider, the users will simply switch to another provider. Furthermore, the major commercial providers of satellite communications services (e.g. Inmarsat) provide in their constitutional instruments the legal guarantees for accessibility to the services without discrimination.

The case of navigation satellites is somewhat different. In certain cases, aircraft operators and providers of air traffic services have, in the past, relied on navigational signals generated by navigation aids outside their territory and not under their direct control (e.g. Loran, Omega, or shorter range navigation aids). GNSS will intensify such reliance on foreign systems. For the majority of user States, the existing GNSS facilities are controlled and operated by one or several States. For the time being, multiplicity of system providers and commercial competition do not exist in this field. While some consider that the existing systems do not require a separate legal framework, there has been concern among some potential civil users of GNSS and States with respect to the guaranteed access to, and continuity of, such services. Accordingly, the

Council Statement of 1994 affirmed explicitly that the principle of universal accessibility without discrimination shall govern the provision of all air navigation services by way of CNS/ATM systems. The principle, which restates and elaborates principles already enshrined in the Chicago Convention, has also been incorporated into the exchange of letters between ICAO and the United States and ICAO and the Russian Federation concerning the provision of GPS and GLONASS.

The Charter mentioned above provides that every State and aircraft of all States shall have access, on a non-discriminatory basis and under uniform conditions, to the use of GNSS services, including regional augmentation systems within the area of coverage of such systems. The term "aircraft" is included in order to ensure that the aircraft of all States will have such access.

It may be concluded that the principle of universal accessibility without discrimination is now well accepted. The remaining issue is how to render it generally applicable. States in the process of planning and implementation of CNS/ATM systems could, if necessary, provide additional assurances through bilateral agreements or other arrangements to safeguard their accessibility.

Continuity of services

Closely related to the issue of nondiscriminatory access is the issue of the continuity of services. When GNSS becomes the primary means of air navigation and the traditional terrestrial facilities for air navigation will have become obsolete, the discontinuation of GNSS services, if decided unilaterally by the provider State, could theoretically force users to rely on redundant and back-up systems that might not be convenient or economical for an extended period. The provision of GNSS services will always follow the principle of redundancy. GNSS will consist of a menu of options. The options range from an automatic switch to a back-up system on "standby", which will be part of the institutional arrangements, to an institutional guarantee by an international organization which may make alternative services available. In the exchange of letters with ICAO, the United States and the Russian Federation have respectively committed to take all necessary measures to maintain the integrity and reliability of the services and each of them expects that it will be able to provide at least six years' notice prior to termination of its services.

The Charter states that every State providing GNSS services shall ensure the continuity, availability, integrity, accuracy and reliability of its services, including effective arrangements to minimize the operational impact of system malfunctions or failure, and to achieve expeditious service recovery. States providing services shall ensure that the services are in accordance with ICAO Standards. States shall provide, in due time, aeronautical information on any modification of the GNSS services that may affect the provision of the services.

The concept of continuity may be understood in either a technical or a legal sense. In the narrower technical sense, continuity may refer to effective arrangements to minimize the operational impact of unavoidable system malfunctions or failure and achieve expeditious service recovery. In a wider legal sense, continuity may also mean the principle that the services are not to be interrupted, modified, altered or terminated for military, budgetary or other non-technical reasons. It is recommended that States provide adequate safeguards to the principle of continuity in both the technical and legal meaning in the implementation and operation of CNS/ATM systems.

The Chicago Convention and its Annexes already provide Standards for the integrity and reliability of air traffic services, including navigation aids, and additional SARPs for GNSS are being developed.

Respect of State sovereignty

The principle of complete and exclusive sovereignty of States over the airspace above their territory is a cornerstone of customary international air law, which has been recognized by the

Chicago Convention, 1944. The Council Statement of 1994 affirmed that implementation and operation of CNS/ATM systems, which States have undertaken to provide in accordance with Article 28 of the Chicago Convention, shall neither infringe nor impose restrictions upon State sovereignty, authority or responsibility in the control of air navigation and the promulgation and enforcement of safety regulations. The same principle has also been reiterated in the exchange of letters between ICAO and the United States and ICAO and the Russian Federation, respectively. In providing the GPS and GLONASS signals to other States and their operators, the United States and the Russian Federation will not be performing functions under Article 28 of the Chicago Convention, but will only provide navigation aid signals for use in aircraft positioning.

The implementation of CNS/ATM systems will favour the concept of "seamless airspace" as opposed to airspace divided by FIRs or territorial State boundaries. For example, one ATM facility may cover an entire region, replacing the work of many existing facilities. From a pragmatic point of view, the implementation of GNSS requires that a balance be struck between the need to respect State sovereignty and the need to promote the use of advanced air navigation and ATM technology. A necessary compromise may involve a certain flexibility in the exercise of certain sovereign rights, in particular by entrusting tasks of signal provision and augmentation to foreign States and/or joint agencies or operating structures, in exchange for additional benefits flowing from the public utility services of GNSS. Regional air traffic management arrangements are already functioning, or are under development, in a number of places, and functioning well.

Compatibility of regional arrangements with the global planning and implementation

The planning and implementation of CNS/ATM systems is a complex, multifaceted, progressive process, which must be carefully monitored and coordinated at the international level. Such a planning and implementation process could not be successful without global coordination.

Paragraph 5, subparagraph 2 of the Charter provides that States shall ensure that regional or subregional arrangements are compatible with the principles and rules set out in the Charter and with the global planning and implementation process for GNSS. Since the implementation of CNS/ATM systems is a complex and far-reaching project, it will require that two primary conditions be met:

the first is to devise and implement the systems according to a very well-prepared plan; and the second is for all members of the global community to cooperate fully in its realization.

Financial resources are limited and should ideally be used to achieve optimum results. Duplication of efforts should be minimized and mutual interference prevented. Regional or sub-regional arrangements should therefore promote the global integration of the system.

Cooperation and mutual assistance

Paragraph 7 of the Charter provides that with a view to facilitating global planning and implementation of GNSS, States shall be guided by the principle of cooperation and mutual assistance. Paragraph 8 provides that every State shall conduct its GNSS activities with due regard for the interests of other States.I-11-4 Global Air Navigation Plan for CNS/ATM Systems

These proposed broad principles appear necessary in view of ICAO's objective to achieve a single, integrated, global CNS/ATM system. Since the global system will be a seamless one, with airspace boundaries transparent to users, it will require an unprecedented degree of cooperation among international organizations, States, service providers and users at all levels; local, national, regional and global.

In the event that the space segments of GNSS encounter technical failure or malfunction, it might be necessary for the owner or controlling entity of the segments to receive cooperation and assistance from other States. ICAO has repeatedly emphasized that States should be guided by the principle of cooperation and mutual assistance.

For the above reasons, cooperation and mutual assistance are essential in the planning, implementation and operation of CNS/ATM systems. The forms of cooperation may vary, depending upon the situation in particular States or regions.

OTHER LEGAL ISSUES

In addition to the fundamental principles incorporated into the Charter, there are other legal issues under consideration, such as:

a) certification;

b) liability;

c) administration, financing and cost-recovery; and

d) future operating structures.

In considering these issues, LTEP put forward 16 Recommendations (Appendix B to this chapter refers) which, along with the report on the work of the Panel, were submitted to the 32nd Session of the Assembly of ICAO, through the Legal Commission, for further guidance. In this respect, the 32nd Session of the Assembly adopted Resolution A32-20 (Appendix C to this chapter refers).

Certification

GNSS, like other air navigation facilities, requires certification by the relevant authorities in order to ensure that it complies with Standards related to the safety of international civil aviation. Recommendations 1 to 8 adopted by LTEP address the issues related to certification (see Appendix B to this chapter).

Liability

Similar to terrestrial air navigation facilities, GNSS may, due to technical failure, inaccuracy or other reasons, become a cause of damage to aircraft, persons or goods on the ground or in flight. Issues relating to liability have been the subject of detailed discussions in LTEP and are reflected in Recommendations 9 to 11 (see Appendix B to this chapter). Administration, financing and cost-recovery

Recommendations 12 to 14 put forward by LTEP are related to the legal aspects of administration, financing and cost-recovery of GNSS services. These recommendations refer, inter alia, to GNSS services as an international service for public use, identify the possible options for administrative mechanisms for GNSS, and consider the possible methods of financing GNSS (see Appendix B to this chapter).

Future operating structures for GNSS

The term "future operating structure" is related to long-term GNSS, rather than the existing systems. It is ICAO's established policy that GNSS should be implemented as an evolutionary progression from existing global navigation satellite systems, including the United States' GPS and the Russian Federation's GLONASS, toward an integrated GNSS over which Contracting States exercise a sufficient level of control on aspects related to its use by civil aviation. Recommendations 15 to 16 put forward by LTEP address the related issues and identify certain possible fields of international action (see Appendix B to this chapter).

MODULE V:

AIR SPACE AND AIR TRAFFIC MANAGEMENT IN INDIA

INTRODUCTION AND HISTORICAL EVOLUTION

Aviation has come a long way since 17 December 1903. The globe is now enveloped by a network of air routes and airspace has become busy airways for world commerce. Air transport sector changed at remarkable pace and moved rather fast from the piston – engine to turbo-props and to all jets–wide body in quick succession.

While the air traffic growth has his been greater than growth in the national economy,
the demand for air transport is primarily determined by economic development, and there is a strong correlation between the two.
Development in personal income has a direct bearing to the level of purchasing power and the propensity to undertake leisure travel in general and air travel in particular. International trade - in goods and other commercial activities have a direct impact on the demand for air travel and freight movements. Demand for international air travel is also fueled by the expansion of international tourism. World Tourism Organization (WTO) estimated a world total of 1.56billion international arrivals in 2020 as against 657 million international tourist arrivals in 1999. Asia-Pacific is the fastest growing region. According to a forecast by the Air Transport Action Group (ATAG), Geneva, the region's share of scheduled international passenger traffic will reach 49.8 percent by 2010 (a marginal reduction may be possible due to current economic down turn).

The aviation industry has therefore become a major economic activity. Economic activity means competition. Competition between airlines, between airports is increasing in many parts of the world. Underlying this challenge is the steady growth in demand for air transport services, which most credible forecasts indicate will continue. International Civil Aviation Organization (ICAO), International Air Transport Association (IATA) and major aircraft manufacturers all predict that the worldwide demand for air transport will grow at an average annual rate of 5 percent to 6 percent over the next 20 years. While this growth is welcome, it presents challenges to every sector of the industry. Airlines and manufacturers are working closely to accommodate the growth with new aircraft that are larger, more economical and more environment- friendly than in the past. While it is relatively easier for the airlines to buy these new hi-tech aircraft and modernise their fleet, it is much more difficult and time consuming for the airports to build up the compatible ground environment to accommodate the airline fleet change. Several airports have experienced such a mismatch when their national carriers inducted wide-bodied, fly-by-wire modern aircraft in the past. Therefore, induction of these new large aircraft like A380 poses greater challenges to airport management. Airport and airspace congestion is already a burning problem in many parts of the world – Middle East and Indian sub continent are no exception and with the global increase in air traffic the scenario that exists today over Europe and other western countries will shift to this part of the world. Satellite based high tech Communication, Navigation Surveillance and Air Traffic Management (CNS/ATM) is in the process of being introduced. Predictably, it may help to achieve a 'seamless travel' irrespective of national borders.

Changing faces of airlines and airports are therefore, pausing new challenges and air transport management is becoming increasingly complex. Aviation industry has thus accepted that the air transport sectors-airline,airport and aerospace can no longer be managed without the professional sector- specific management qualifications.

Aviation/Air Transport infrastructure of a nation includes airports, aircraft (airlines), and aerospace industry and air traffic control / air navigation services. These are mutually depended on each other however airport plays a dominant role as it is the runway that triggers the aviation activities in a country. Airports are key attraction for foreign investments and are also output generators and job creators. It is predicted that the worldwide demand for air transport will grow at an average annual rate of 5 percent to 6 percent over the next 20 years. While this growth is welcome it presents challenges to every sector of industry. Therefore, with the growth of airport industry greater will be the challenges for its management. Airport and airspace congestion is already a burning problem in many parts of the world. Big aircrafts and their acquisition and maintenance throw much more difficulty in their management. Modernization of aviation industry in terms of hi-tech communication, navigation, surveillance and air traffic management (CNS/ATM) calls for professional approach in their management. Environment concerns also calls for better land use plans and greater challenge to maintain a delicate balance the economic activities and the environment protections. Thereby, making air transport management must to be performed exceptionally well so that it becomes a 'world class' environment for the aviation industry.

AN OVER VIEW ON AIR TRANSPORT MANAGEMENT IN INDIA

Aviation came to India almost the same time it took roots in Europe. The first air display as an event was organized at Tolliganj club in Calcutta on 28th December, 1910. First long distance air service from Cairo to Calcutta took place on 29th November – 12 December, 1918. On 24th Jan, 1920, the Indian postal department announced a weekly Bombay - Karachi airmail service. With independence of India, Bombay witnessed the first air India landing with the constellation aircraft on 16th march 1948. In the international sector Air India launched an all tourist class flight to Nairobi from 01st December, 1952. On 01st august, 1953, the government of India nationalized all the aviation services. International air services were to be provided by Air India international ltd and all the domestic flights including Air India were integrated into a single national domestic carrier – Indian airlines Ltd by way of air corporation act, 1953.

Ministry of civil aviation is the apex body for policy making and the overall coordination body for directorate general of civil aviation and all other aviation related authorities. DGCA is the body appointed by the central government to discharge regulatory functions in respect of civil aviation in India, under the provisions of Rule 134 of the Aircraft Rules, 1937, grants permission to persons to operate an air transport service to, with in and from India. There existed four international airfields in India, Bombay, Calcutta, Delhi and madras which were governed by international airport of India since 1st April 1972. Trivandrum international airport was added to IAAI on 1st April 1991. National airport authority was formed by transferring all the function/provision of air traffic control and air navigation services from the DGCA on 1st June 1986.

With the liberalization of the national economy, government of India took the first step towards liberalization in 1986 and deregulated scheduled air operations by the issue of AIC24/1990, which formulated detailed guidelines for air taxi operations and made them eligible to operate to all airports in the country including airports which were hitherto open to scheduled operations. These private airlines were allowed operating charter and non-scheduled services to all authorized airports under the Air Taxi Scheme and were also permitted to decide their fares and flight schedules. Another major move towards liberalization was in the early 1990s when India implemented an open sky policy for cargo which allowed international airlines to operate cargo flights without restrictions and to charge rate without reference to Director General of Civil Aviation (DGCA). Under this policy, any foreign domestic airline or association of exporters or private operator's could bring freight carriers to India for lifting cargo from any airport. However, there still remain restrictions as international airlines are not allowed to carry domestic cargo on their flights within the country. The next major step was the termination of the state monopoly over scheduled air transport services with the enactment of the Air Corporation (Transfer of Undertaking and Repeal) Act, 1994. The main reasons for the deregulation were the decline in profitability of Air India and Indian Airlines owing to organizational and managerial inefficiencies and that the capacity of the national carriers was not enough to meet growing passenger demand. With the enactment of the 1994 Act, private operators were allowed to operate both scheduled and non-scheduled services in the domestic sector and there were no major restrictions on aircraft size and type. However, in order to ensure safety, security and orderly growth of air transport services lead to establishment of National Airports Authority of India (NAAI) for management of airports, civil enclaves, air transport services and all navigation and communication stations connected therewith. The formation of NAA helped to provide a facelift to domestic airport and modernized air space management. NAA and IAAI were merged in 1994 and came into being Airports authority of India. The constitution of Airport Authority of India (AAI) and transfer and vesting of the undertakings of the IAAI and NAAI were for better administration and co-ordinate management of airports and civil enclaves. Due to infrastructural constraints at a number of airports, the government permitted the addition to capacity based on traffic projections. To support the growth of the airline industry the Government in 1994-95 permitted direct import of aviation turbine fuel (ATF) under the special import license scheme. In 1997-98, the privatization policy was further liberalized and foreign equity participation of up to 40 per cent (100 percent in case of non-resident Indians) was allowed in the domestic airline sector. Foreign airlines are, however, not allowed to pick up the equity, directly or indirectly.

Many operators rushed in as air taxi operators and in 1997, there were 21 air taxi operators. There overall share was nearly 30% of the total traffic. The mushrooming of the air taxi operators witnessed in the early 1990s in India almost vanished one by one leaving only very few private airlines operational. Following stiff competition some of them further consolidated their position by mergers and acquisitions. Jet acquired, Sahara; Kingfisher acquired Deccan and air India and Indian airlines merged as Air India.

Thus liberalization of aviation industry in India has precipitated the boom for domestic and international passenger carriers. The domestic passenger and cargo traffic recorded a growth rate of 44.6% and 8.7%, and the international passenger and cargo traffic recorded growth rates of 15.8% and 13.8% respectively during 2006-07. Till recent times AAI manages total 122 airports in the country, which include 11 international airports, 94 domestic airports and 28 civil enclaves. Top 5 airports in the country handle 70% of the passenger traffic of which Delhi and Mumbai together account for more than 50%. The latest data compiled by Airports Authority of India (AAI) shows that all the airports handled 90.44 million passengers during the calendar year 2006 compared with 67.95 million handled during the same period in the previous year. The substantial growth of Indian aviation industry is mostly due to low fares offered by Low Cost Carriers (LCC) like Deccan, Spice jet, Go Air etc; and scheduled domestic air services are now available from 75 airports as against just 50 earlier. Changes thus witnessed during the past few years, once again reestablishes the fact that healthy competitions and effective management are essential for the balanced growth of air transport, both in quality and quantity.

Country's aviation industry got the fillip with the opening up of sky by the Government in 90s. Everyone talked about India's high-paced economy and subsequent growth for the aviation industry. All major worldwide studies predict India and China to be driving forces behind the aviation growth in coming decades. India is a signatory to several international conventions governing air transportation. To increase connectivity between India and other countries and facilitate travel for passengers, India has entered into Air Service Agreements (ASA) with 100 countries till date. These bilateral Agreements provide the basic legal framework for operation of air services between the two contracting parties. The number of flights each country can operate and the destinations that could be served are also specified in these Agreements. The traffic rights available under an ASA could be utilized by the airlines designated by respective Governments. The 'Open Sky Policy'

Air Growth and GDP. It is well established that the growth of air travel is a direct reflection of the national income levels, cost of air travel and the target population. Airline/airport contributions by way of passenger and freight movements, and the increasing number of aircraft movement are vital input to national economy. For the past 35 years on average, the global Passenger- Kilometer Performed (PKP) recorded 1.6 times the GDP. Hence it is closely linked with growth rate of a country. Adequacy of air transport both in quality and reliability therefore, is a big factor in the ability of the countries to compete at global level.

AIRPORT AS GROWTH ENGINE.

Airports are the basic mode on which air transport industry thrives. Airports are vital catalyst in creating new employment opportunities and business ground for foreign investment. Airport have also been diversifying their business- direct operation in ground handling, management contract at other airports, providing training or consulting services, airline partnership and diversification into non-aviation activities. The direct economic impact is obtained by measuring by values of the activities of airlines, airports and business generated at airport. Other benefits of airport are time saving and cost avoided by air travelers with higher level of safety, comfort and convenience of air travel. The spin off effects of airport is numerous. It’s much like the ripple effect, on the total economy. It will provide direct and indirect employment opportunities to manifold number of people.

AIRPORT AS REVNUE GENERATOR.

Apart from generating revenue from passenger and freight travel, airport generates a host of other non aeronautical revenues. Air transport stimulates tourism and it has a catalytic impact on other services like in flight catering, development of new business unit in locations with good air service link. It provides the fastest distribution service throughout the world. Most airports arrange for non aeronautical activities by outside parties such as automobile parking, hotel/guesthouses etc. In Asia ratio of aeronautical to non aeronautical revenue is around 67:33. It is a fact that air transport drives economic and social progress and it remains one of the largest and fastest growing industries in the world contributing to every sector of economy either directly or indirectly.

The question today arises weather the Indian aviation industry which is still in a nascent stage can survive the heat. Most, if not all airlines in the country has reported losses not just for the third and fourth quarters, but the whole of 2007-08. And this is not any different for other airlines worldwide. So, how should the industry respond to the situation? For the time being, most airlines have resorted to cutting routes, issuing e-tickets and charging for items such as snacks and checked-in luggage to cut their losses. Some, however, have also hiked fuel surcharges to offset high ATF rates. There are a few who are even considering selling their stake. But is this the solution when the ATF prices have doubled over the last year and now form almost 80 per cent of overall operating costs and almost three-fourths of a budget airline's ticket fare? The industry has tough challenges ahead and there is urgent requirement for world class management programmers to not only survive the current turbulence but also it has to maintain the growth to keep the momentum going.

IDENTIFIED CHALLENGES

The growths in the aviation sector and capacity expansion by carriers have posed challenges to aviation industry on several fronts. These include ever growing cost of an aircraft, fuel prices and traffic constraints. Environment around modern airport, safety concerns, declining returns, well trained professionals, the lack of accompanying capacity and infrastructure. Moreover, stiff competition and rising fuel costs are also negatively impacting the industry. The day-to-day problems faced by the air traffic control system are primarily related to the volume of air traffic demand placed on the system and weather. Several factors dictate the amount of traffic that can land at an airport in a given amount of time. Beyond runway capacity issues, weather is a major factor in traffic capacity. Fog, rain, ice or snow on the runway cause landing aircraft to take longer to slow and exit, thus reducing the safe arrival rate and requiring more space between landing aircraft. Various other challenges which can be identified as major ones are;

a) **Airport and Airspace congestion :** Capacity constraint at airports as well as in airspace is causing immense slowdown resulting in waste of time as well as fuel. It calls for immense close coordination between the airport slots and air traffic slots.

b) **Aircraft pricing and running cost as a challenges :** Introduction cost of new large aircraft are prohibitively high. Some of the reasons for high input costs are due to withholding tax on interest repayments on foreign currency loans for aircraft acquisition, increasing manpower costs due to shortage of technical personnel and construction cost of world class airport and maintenance of same.

c) **Rising fuel prices:** Turbulence in aviation industry due to unrelenting increase in oil price is a matter of deep concern for all airlines. Indian carriers which were until recently in a robust mood are now feeling the heat. As fuel prices have climbed, the inverse relationship between fuel prices and airline stock prices has been demonstrated. Moreover, the rising fuel prices have led to increase in the air fares.

d) **Gaps in Airport infrastructure and leadership:** Airport and air traffic control (ATC) infrastructure is inadequate to support growth. While a start has been made to upgrade the infrastructure, the results will be visible only after 2 - 3 years. The regulatory bodies should be able to review the airport management to maintain the delicate balance between the commercial exploitation and the economic regulatory control.

e) **Safety and Insurance:** The recent air crash at Mangalore airport shows low degree of safety concern in few sectors/areas in India. The famous Dadari mid air crash between two aircrafts was again due to laxity in procuring the advanced radar system. All such accidents called for immense weight age on insurance which an air line or airport authority has to bear. There is a need to make air travel safe in India so that minimum liability is incurred on insurance. The whole range of aviation industry are all meant to achieve a 'Safe and efficient Air Travel'. However in India a concern towards safety and advancement required for safety is shown concerned only after a disaster. It's a big challenge to understand and keep safety as first which will cost escalating effect on cost of operation.

f) **Regional connectivity:** One of the biggest challenges facing the aviation sector in India is to be able to provide regional connectivity. What is hampering the growth of regional connectivity is the lack of airports. Also **Trunk routes** are a matter of concern that the trunk routes, at present, are not fully exploited. One of the reasons for inability to realize the full potential of the trunk routes is the lack of genuine competition. The entry of new players would ensure that air fares are brought to realistic levels, as it will lead to better cost and revenue management, increased productivity and better services. This in turn would stimulate demand and lead to growth.

g) **Employee shortage:** There is clearly a shortage of trained and skilled manpower in the aviation sector as a consequence of which there is cut-throat competition for employees which, in turn, is driving wages to unsustainable levels. Moreover, the industry is unable to retain talented employees and airlines are growing alliances leading to merger and acquisition of aircrafts and trained manpower.

H) **LCC :** The challenges facing LCC are crippling oil shock, absence of Institutional Funding, acute shortage of trained Pilots, severely limiting growth prospects, unplanned location of Airports, competition amongst the LCC's, image plagued by frequent breakdowns and freak accidents, LCC's already reached the threshold of cost efficiency, limited advertising. The aviation industry loses approximately Rs 2000 corers annually due to under pricing of tickets and increasing fuel costs

i) **Declining yields:** LCCs and other entrants together now command a market share of around 46%. Legacy carriers are being forced to match LCC fares, during a time of escalating costs. Increasing growth prospects have attracted & are likely to attract more players, which will lead to more competition. All this has resulted in lower returns for all operators.

j) **Environment:** Another challenge would be to counter green house gas emission by aircraft. Environment studies warn that emissions from aircraft are rising dramatically, with the prediction saying it will be more than double over the next 20 years. It says China and India are behind the global boom in aviation and suggests Governments should step in to tax aviation.

k) **Advancement:** The implementation and maintenance of advancement in industry such as CNS/ATM system for a seamless air traffic flow. Procurement and maintenance of advanced secondary radar system through the country. However these sophisticated air traffic management system do fail as at Indira Gandhi International Airport, the new radar system which was operational in March 2010, crashed on 29th July 2010, disrupting flight movements for almost 20 minutes.

COMPACTING STRATIGIES

Challenges that the airlines faced and the aviation industry as a whole over the last few years, has forced the industry to rethink how they do business on both a financial and operational level. Most airlines have faced up to these challenges, and as a result have been remarkably successful at turning around ailing companies, in many cases completely reinventing themselves. Although high fuel prices are affecting profitability, airlines are now in a much stronger position then 2000, due to unprecedented demand for air travel. **The notion of restructuring and cost cutting has been embraced wholeheartedly by all airlines as the only viable way to secure their long-term security**. Many airlines have been slower to face up these challenges, and face major cost cutting exercises in order to reach necessary levels of efficiency. There is no doubt that the aviation industry has come through one of the toughest periods in over 30 years. The industry is now in an excellent position to face the challenges ahead.

The Director General of Civil Aviation **must unveiled plans to drive the development and growth of the aviation industry** in India. Apart from regulating the industry and providing air navigation services, DGCA should focusing on building a vibrant and sustainable aviation industry that will continue to make a key contribution to India's economy. They should be also working with industry partners on programmes that better profile careers in the industry and facilitate individuals acquire new skills and raise their competencies, thereby growing the talent and manpower base for aviation companies and organizations and developing India as an Aviation Hub of Excellence. Various incentive programmes should be introduced to support the development of capabilities in the Indian aviation industry and ensure its continued competitiveness and dynamism. Built around the three thrusts of **enabling enterprise, ideas and people**. These programmes will also support broader industry-level initiatives to raise effectiveness and competitiveness through government industry partnerships. Work with multiple agencies and trade associations to improve operational efficiency and end-to-end supply chain visibility, with the aim of promoting India as a leading global air cargo and logistics hub.

Aircraft manufacturing major Airbus and Boeing must work alongside engine original equipment manufacturers (OEMs) and airlines to pursue development of sustainable bio-fuels.

They should constantly redesigning and re-engineering aircraft, develop lighter composite materials, more aerodynamic designs and more efficient engines. Every new generation of aircraft is more efficient, with a greater reduction in fuel-burn and emissions. Industry's more emphasis should be on improving the efficiency of engines in order to reduce fuel burn. It should invest more on new technology and exploration of alternative fuel sources. It needs to come up with some sort of solutions in that area. But it's still very much early stages. Within the next few years, commercial use of alternative fuel sources is a possibility. It's not a dream. It's a necessity. It's something that the industry, and all those associated with the industry, will have to come to grip with.

The LCC boom in India started with Low Price Tags, Apex Fares, Internet Auctions, Bulk Purchases and Last Day Fares. The factors that contributed to enormous growth of LCCs are low entry barrier; attraction of Foreign Shores; increased permitted Foreign Equity; and rising income levels and demographic profile, have contributed significantly to the unprecedented growth of LCC's in India. Within 3 years of operations in India, LCC's have taken the domestic market share of 49% and the factors contributing for such unprecedented market capitalization are highest load efficiency; flies to destinations in the hinterland; a Lean-and-Mean approach to staffing; expansion of operations to Sri Lanka; successfully targeted the increasing middle class population of India.

New management strategies like load management planning, marketing your airport and code sharing are needed to be used to optimize the entire system's operation. FAA and other stakeholders have recently initiated an effort to better understand and quantify these interrelationships in an environmental design space." Eventually this will lead to guidelines for setting long term goals and standards that optimize overall environmental performance and avoid unintended consequences. Analysts have long called for the **liberalization of the aviation industry** and its policies to realize its true potential. "As a result of the intense competition between tourism destinations worldwide, easy access - and, therefore, efficient air transport - has become increasingly important to tourists deciding which destination to choose, a World Tourism and Travel Council (WTTC) report about aviation. The report suggested that liberating the aviation industry and ending the monopoly of only national carrier, could help increase international arrivals by 2 million annually. The WTTC called for immediate changes, such as allowing flag carriers to operate more flights and allow more international charter flights and ending restrictions on privately owned airlines.

Conclusion

Economic recovery coupled with the steadying of world markets, has resulted in the return of business confidence and corporate investment in the aviation industry. The political environment has also begun to slowly stabilize; this has resulted in high level growth in the demand for worldwide leisure travel. This resulted in much stronger levels of air traffic in 2004 than had been forecast. Over the 2004 – 2023 period world passenger levels is forecast to increase by 5.3% year on year. Companies such as Boeing and Airbus will reap the benefits of this growth. Traffic growth coupled with fleet renewal, will require the delivery of approximately 16,600 new passenger aircraft. Freight traffic is also expected to grow at 5.9% per year, throughout the 2004 – 2023 periods. Traffic growth and fleet demand will result in the demand 3,100 freighter deliveries of which 23% will be purpose built freighters.

Civil aviation by itself is a creative activity and it plays a major role in the world economic development. Some of the immediate challenges for air transport are airport and airspace congestion, implementation of CNS/ATM system, introduction of new fuel efficient, less noisy large aircraft, increased security concerns, environmental pressure and changing faces of airport leadership. All these challenges requires new demand on aviation/airport management. Management of airport is required to be done on commercial philosophy and performed exceptionally well to be a 'World Class" despite facing tremendous constraints. Namely three key areas 'Access, commercialization and environment. Management must approach to excellence and bring out techniques that can give safe aircrafts, equipments, and air travel to world class and beyond.

INSTITUTIONAL AND ORGANIZATIONAL FRAMEWORK TO REGULATE AIR TRAFFIC AND AIR SPACE MANAGEMENT IN INDIA

STAKEHOLDERS INVOLVED IN AIR SPACE AND AIR TRAFFIC MANAGEMENT IN INDIA

Aviation as an activity encompasses a wide variety of stakeholders ranging from passengers to vendors of high and strategic technologies. The most important stake holder in the sector is the common passenger whose aspiration and need to travel is to deepen with time. He needs affordable, comfortable and safe travel with a decent quality of customer services.

Pilots, crew members and technicians constitute the backbone of civil aviation. Individually and collectively they are the essential stake holders of the industry. We need to ensure continued training and adoption of high standards of safety in operations in order to support this group.

Airline Operators, both SOP as well as NSOP, are the basic service providers and hence the growth and performance of the sector is substantially dependent upon them. Their expectation is to operate in a liberal laissez-faire environment where fair competition is allowed to thrive with minimal Govt. Controls.

Airport operators and managers of aviation infrastructure are critical in the growth of the sector. As such the Airport Authority of India which manages most of the aerodromes in the country and the emerging class of private entrepreneurs associated with creation of airport infrastructure are important partners in the performance of the sector. Their interest is in ensuring the safety, security and commercial viability of the airports that they operate.

Defence Ministry in an important stake holder as it manages a large number of airports in the country which are also used for civilian operations. The Ministry also shares a large part of the Indian air space and hence determines the scale of civil operations. We are required to maintain the primacy and priority of military needs in terms of use of airspace, infrastructure and operating procedures followed.

Ministry of Environment is an important player because Civil Aviation has a significant effect on environment through noise and effluents. The policies and pollution norms prescribed by the ministry significantly impact aviation activities. NGOs and Social Activists too form a part of this ecosystem and often influence policy direction.

Regulators like the Director General Civil Aviation (DGCA), Bureau of Civil Aviation Security (BCAS) and Airport Economic Regulation Authority (AERA) are a major component of the aviation system. International regulators like EU, FAA and ICAO regulate international operations and prescribe standards that significantly determine Indian aviation as well.

Regulatory Service Providers like the CISF are important stake holders of the system. They contribute to making the aviation environment secure for the passengers and operators. They also provide critical security to civil aviation installations.

The Ministry of Home has a vital role to play in civil aviation due to security reasons. They also provide vital intelligence inputs to handle security issues. They also require the Ministry of Civil Aviation to be a partner in disaster management, rescue operations and policing activities.

As **MRO** is likely to assume a greater importance in the civil aviation picture with the passage of time agencies related to this activity are likely to emerge as an important ingredient of the system. Their needs relate to **R&D**, easy import of technology and availability of trained human resource.

Training Schools both for pilots as well as engineering technicians have a major contribution to make in the growth of civil aviation sector. To compete with international flying schools who operate in a comparatively different environment, these institution require similar global environment to perform optimally. They expect a dynamic regulatory regime which responds rapidly to changing training and technology needs of the industry.

Civil aviation operations depend heavily on efficient ground handling. The ground handling agencies thus are a significant player in the system.

Oil Marketing Companies provide the basic input of civil aviation through supply of fuel. They are an important link in the operations supply chain of the industry.

Ministries of Finance and revenue decide the tax regime and financial dispensations in which the industry operates hence they too contribute heavily to the growth and expansion of civil aviation.

Ministry of Urban Development and Municipal Agencies provide the approach infrastructure to airports. They control the access to the services and hence are a major contributory factor in the growth of the sector. They also control the growth of habitations near airports and the implementation of building regulations which effect air movements.

The **Air Traffic Controllers** who manage the air traffic are important both for optimal utilisation of air space as well as safety of operations. They constitute the life blood of the entire civil aviation sector. They have ongoing training requirements caused by the constant change in technology and procedures.

The **Ministry of Science and Technology** is in the process of developing a 70-90 seater civilian aircraft capable of 1000-2000 km flying. This is going to change the entire shape of Indian civil aviation sector once the proposed aircraft materialises and goes into commercial production. They presently also provide meteorological inputs to air controllers which are critical for safe operations.

Ministry of Communication who conduct wireless examinations for Indian pilots are an important stake holder, they also provide wireless connectivity which is critical to air traffic management.

Manufacturers of Aircrafts and engines provide the basic hardware of the industry. They provide direction and pace through their marketing strategies and development of technology. They are impacted by taxation issues prevalent at the time.

DIRECTORATE GENERAL OF CIVIL AVIATION

The Directorate General of Civil Aviation (DGCA) is responsible for ensuring that CNS/ATM services provided by the Airports Authority of India are in accordance with the requirements specified in the Civil Aviation Requirements issued under section 4 in the specific area of CNS/ATM. In order to ensure this, DGCA is required to carry out surveillance/ audit etc. However, these functions are being performed in a limited manner in the form of proficiency checks of ATCOs and commissioning of the CNS equipment, etc.

The Aerodrome Standards Directorate in DGCA, which is presently assigned this responsibility, is not adequately staffed to carry out the desired level of oversight functions. In order to augment the specialized manpower, it has been decided, as an interim measure, to utilize the services of the trained manpower available with the Airports Authority of India for the purpose of carrying out the oversight functions in an effective manner and also assist

DGCA in the preparation of guidelines, checklists and other associated work.

This Civil Aviation Requirement is issued under the provisions of Rule 133A of Aircraft Rules, 1937 for information, guidance and compliance by all concerned.

This CAR is issued in supersession of CAR Section 4 Series A Part II, Issue I dated 11th March 2009.

Applicability

This Civil Aviation Requirement shall be applicable to Airports Authority of India.

Functions

The Seconded CNS/ ATM Inspectors shall carry out the following oversight functions in their respective field:-

Communication, Navigation and Surveillance (CNS):

(a) Commissioning of the CNS equipment;

(b) Periodic inspections and surveillance of the Aeronautical Telecommunication stations to ensure that the performance and maintenance of the CNS equipment is in accordance with the stipulated guidelines;

(c) Scrutiny and processing of Manuals of Aeronautical

Telecommunication Stations submitted by AAI for the purpose of approval and Safety Management Manuals in respect of such stations;

(d) Provide assistance in the establishment of Directorate of Airspace and Air Traffic Management in DGCA for certification and formulation of related regulation and guidance material; and

(e) Any other duty assigned by DGCA from time to time particularly Surveillance/ oversight functions.

Air Traffic Management ;

(a) All matters related with the licensing of ATCOs;

(b) Deal with the matters relating to airspace management like notification of the airspace, temporary closure of airspace, implementation of flexi use of airspace;

(c) Process the cases relating to the promulgation of the navigation procedures for en-route (ATS route), PBN procedure and terminal IAL procedures etc.;

(d) Approval of maps and charts in accordance with CAR on the subject of Aeronautical charts;

(e) Certification of ATM facilities and systems;

(f) Provide assistance in the establishment of Directorate of Airspace and Air Traffic Management in DGCA and formulation of related regulations and guidance material; and

(g) Any other duty assigned by DGCA from time to time particularly surveillance/ oversight functions.

Criteria for nomination of Air Traffic Management & CNS Inspectors

The Airports Authority of India shall nominate at least four CNS Inspectors and eight ATM Inspectors to DGCA for performing above functions.

The nominated Air Traffic Management and CNS Inspectors shall meet the following criteria:-

(a) Qualification: He shall be conversant with the Indian regulations/ requirements and ICAO SARPS and related guidance material. Preference will be given to those who have undergone training in the field of ATCO licensing and certification of CNS and ATM facilities.

(b) Knowledge : The CNS/ ATM Inspector shall have a basic knowledge and expertise in the field of commissioning and maintenance of Communication, Navigation & Surveillance equipment, Air Traffic

Services, Aeronautical Information Services, Aeronautical charts, designing of IAL procedures etc. enabling him/her to administer the regulatory regime pertaining to the Airspace /ATM matters and certification of CNS facilities.

(c) Experience: He shall have worked in the relevant field for at least 5 years.

Selection Process

The selection of the Seconded Air Traffic Management and CNS Inspectors shall be made by a committee to be constituted by the Director General, on the basis of qualifications, experience and past performance of the nominated inspectors.

Terms and Conditions of Secondment

The CNS/ ATM Inspector shall be on deputation to DGCA for a period not exceeding two years initially, which may be renewable.

He shall have no management responsibilities in his parent orgnisation nor in any way associated with associations/unions, etc. during his secondment tenure, to avoid clash of interests.

The pay, allowances, progression in service, perks etc. of Seconded CNS/ ATM Inspector during their secondment to DGCA shall be protected and paid by their parent organisation as per the existing terms and condition of the service.

The Seconded CNS/ ATM Inspectors shall report to DGCA for assignment of duties both for inspections and office work.

The CNS/ ATM Inspectors shall carry out inspections/ surveillance duties only on behalf of the DGCA and shall perform their duties in a manner befitting to a Government servant.

The Seconded CNS/ ATM Inspector shall be accountable to DGCA for all the inspection/surveillance etc. functions performed by him.

Before assigning the inspection/ surveillance duties, the Seconded CNS/ ATM Inspectors shall undergo orientation training and standardization course to be conducted in DGCA, including on-the-job training under the supervision of DGCA officers.

General Requirements

DGCA may cancel the secondment of any Seconded Inspector for reasons to be recorded in writing. In such a case, the Airports Authority of India may be asked to nominate additional inspector as replacement.

DGCA may grant dispensation from any of the requirement specified above in any case where he is satisfied that it is expedient so to do.

DGCA shall have the discretion to review the above mentioned requirements.

ROLE OF AIRPORTS AUTHORITY OF INDIA IN AIR SPACE AND AIR TRAFFIC MANAGEMENT

Airports Authority of India (AAI) was constituted on 1st April, 1995 by merging erstwhile National Airports Authority (NAA) and International Airports Authority of India (IAAI). The integration of NAA and IAAI was aimed to derive the synergy of merger and build a new organization to take up upcoming challenges in competitive environment. Civil aviation, world over, has gone a sea change and the Airports Authority of India (AAI) is ready to meet these challenges both at national and international levels. The Eleventh Five Year plan has been prepared and growth targets set for various economic parameters contributing to growth, of civil aviation are encouraging.

AAI maintains and operates 127 airports including civil enclave at Defence airfields for commercial Airlines operations. The International Airports at Delhi and Mumbai have been leased to Joint Venture Companies on 03.05.2006 for modernization etc. as part of the Restructuring being undertaken by the Government for these two International Airports. Greenfield airport developed at Shamshabad near Hyderabad has become operational with effect from 23.3.2008. Similarly, the Greenfield airport developed at Devanahalli near Bangaluru has become operational with effect from 24.5. 2008. AAI provides CNS/ATM services at all the airports in the country which include Indian airspace measuring over 2.8 million square nautical miles.

During the year 2008-09, AAI handled 13.06 lakh aircraft movements (10.40 lakhs domestic and 2.70 lakh international); 108.88 million passengers (77.30 million domestic and 31.58 million international) and 16.97 lakh metric tonnes of air cargo (5.48 lakh metric tonnes domestic and 11.49 lakh metric tonnes international).

Training

AAI imparts training at its own Civil Aviation Training College, Allahabad on various operational areas like Air Traffic Control, Radars, Communication, etc. It maintains the National Institute of Aviation Management and Research (NIAMAR) at Delhi for imparting various aviation management training programmes and refresher courses. In addition there is a Fire Service Training School at Narayanpur near Kolkata and the Fire Training Centre at New Delhi for imparting training and conducting refresher courses on fire fighting rescue services.

Gagan Project

GPS Aided Geo Augmented Navigation "Gagan" is an augmentation system to enhance the accuracy and integrity of GPS signals to meet precision approach requirements in Civil Aviation and is being implemented jointly by AAI and ISRO in three phases. Technology Demonstration System will be upgraded to a full operational capability system in the second and third phase. GSAT IV being fabricated by ISRO will carry GAGAN payload. The footprint of this satellite will cover a vast geographical area from Africa to Australia and hence would facilitate expansion of the service area of "Gagan" far beyond Indian airspace. When implemented this would replace most of the ground-based navigational aids and it would be possible to provide precision approach and landing guidance up to category I to aircraft hitherto not available due to terrain conditions precluding the provision of Instrument Landing System.

The Technology Demonstration System Phase of the Project has been successfully completed and action has been initiated for Final Operation Phase (FOP).

Development of Non-Metro Airports by AAI

In order to meet the growing demand for infrastructure at the airports, AAI has decided to modernize and develop 35 non-metro Airports by providing world class infrastructure facilities at these airports. The 35 non-Metro airports identified are Ahmedabad, Amritsar, Guwahati, Jaipur, Udaipur, Trivandrum, Lucknow, Goa, Madurai, Mangalore, Agatti, Aurangabad, Khajuraho, Rajkot, Vadodara, Bhopal, Indore, Nagpur, Visakhapatanam, Trichy, Bhubaneswar, Coimbatore, Patna, Port Blair, Varanasi, Agartala, Dehradun, Imphal, Ranchi, Rajpur, Agra, Chandigarh, Dimapur, Jammu and Pune. These non-Metro Airports are being developed to world class standards which include features such as modular design, structured steel and toughened glass glazing, modern flooring, high ceiling with vertical air conditioning system, modern passenger boarding bridges with glass wall, walk ways, conveyor belts, escalators, elevators, improved signages, intelligent terminals was Integrated building management system and Common User Terminal Equipment (CUTE).

The development works for Terminal Buildings and Airside have already been undertaken / in the process of award except in cases where land issues are involved. These works will be completed in phases by March, 2010.

As regards City Side Development at selected non-Metro Airports, this is being done with private sector participation. The process is under finalization for Amritsar and Udaipur airport and thereafter will be extended to other airports.

ROLE OF AIR TRAFFIC CONTROLLERS IN INDIA

MEANING OF AIR TRAFFIC CONTROL

Air traffic control (ATC) is a service provided by ground-based controllers who direct aircraft on the ground and through controlled airspace, and can provide advisory services to aircraft in non-controlled airspace. The primary purpose of ATC worldwide is to prevent collisions, organize and expedite the flow of traffic, and provide information and other support for pilots. In some countries, ATC plays a security or defensive role, or is operated by the military.

To prevent collisions, ATC enforces traffic separation rules, which ensure each aircraft maintains a minimum amount of empty space around it at all times. Many aircraft also have collision avoidance systems, which provide additional safety by warning pilots when other aircraft get too close.

In many countries, ATC provides services to all private, military, and commercial aircraft operating within its airspace. Depending on the type of flight and the class of airspace, ATC may issue instructions that pilots are required to obey, or advisories (known as flight information in some countries) that pilots may, at their discretion, disregard. Generally the pilot in command is the final authority for the safe operation of the aircraft and may, in an emergency, deviate from ATC instructions to the extent required to maintain safe operation of their aircraft. Pursuant to requirements of the International Civil Aviation Organization (ICAO), ATC operations are conducted either in the English language or the language used by the station on the ground. In practice, the native language for a region is normally used; however, the English language must be used upon request.

In 1921, Croydon Airport, London was the first airport in the world to introduce air traffic control.

ROLES AND RESPONSIBILITIES OF AIR TRAFFIC CONTROLLERS

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Airport control

The primary method of controlling the immediate airport environment is visual observation from the airport control tower the aerodrome control tower (TWR). The tower is a tall, windowed structure located on the airport grounds. **Aerodrome** or **Tower** controllers are responsible for the separation and efficient movement of aircraft and vehicles operating on the taxiways and runways of the airport itself, and aircraft in the air near the airport, generally 5 to 10 nautical miles (9 to 18 km) depending on the airport procedures.

Surveillance displays are also available to controllers at larger airports to assist with controlling air traffic. Controllers may use a radar system called Secondary Surveillance Radar for airborne traffic approaching and departing. These displays include a map of the area, the position of various aircraft, and data tags that include aircraft identification, speed, altitude, and other information described in local procedures. In adverse weather conditions the tower controllers may also use Surface Movement Radar (SMR), Surface Movement Guidance and Control Systems (SMGCS) or Advanced SMGCS to control traffic on the manoeuvring area (taxiways and runway).

The areas of responsibility for TWR controllers fall into three general operational disciplines; Local Control or Air Control, Ground Control, and Flight Data/Clearance Delivery—other categories, such as Apron Control or Ground Movement Planner, may exist at extremely busy airports. While each TWR may have unique airport-specific procedures, such as multiple teams of controllers ('crews') at major or complex airports with multiple runways, the following provides a general concept of the delegation of responsibilities within the TWR environment.

Remote and Virtual Tower (RVT) is a system based on Air Traffic Controllers being located somewhere other than at the local airport tower and still able to provide Air Traffic Control services. Displays for the Air Traffic Controllers may be either optical live video and/or synthetic images based on surveillance sensor data.

Ground control

Ground Control (sometimes known as Ground Movement Control) is responsible for the airport "movement" areas, as well as areas not released to the airlines or other users. This generally includes all taxiways, inactive runways, holding areas, and some transitional aprons or intersections where aircraft arrive, having vacated the runway or departure gate. Exact areas and control responsibilities are clearly defined in local documents and agreements at each airport. Any aircraft, vehicle, or person walking or working in these areas is required to have clearance from Ground Control. This is normally done via VHF/UHF radio, but there may be special cases where other procedures are used. Aircraft or vehicles without radios must respond to ATC instructions via aviation light signals or else be led by vehicles with radios. People working on the airport surface normally have a communications link through which they can communicate with Ground Control, commonly either by handheld radio or even cell phone. Ground Control is vital to the smooth operation of the airport, because this position impacts the sequencing of departure aircraft, affecting the safety and efficiency of the airport's operation.

Some busier airports have Surface Movement Radar (SMR), such as, ASDE-3, AMASS or ASDE-X, designed to display aircraft and vehicles on the ground. These are used by Ground Control as an additional tool to control ground traffic, particularly at night or in poor visibility. There are a wide range of capabilities on these systems as they are being modernized. Older systems will display a map of the airport and the target. Newer systems include the capability to display higher quality mapping, radar target, data blocks, and safety alerts, and to interface with other systems such as digital flight strips.

Local control or air control

Local Control (known to pilots as "Tower" or "Tower Control") is responsible for the active runway surfaces. Local Control clears aircraft for takeoff or landing, ensuring that prescribed runway separation will exist at all times. If Local Control detects any unsafe condition, a landing aircraft may be told to "go-around" and be re-sequenced into the landing pattern by the approach or terminal area controller.

Within the TWR, a highly disciplined communications process between Local Control and Ground Control is an absolute necessity. Ground Control must request and gain approval from Local Control to cross any active runway with any aircraft or vehicle. Likewise, Local Control must ensure that Ground Control is aware of any operations that will impact the taxiways, and work with the approach radar controllers to create "holes" or "gaps" in the arrival traffic to allow taxiing traffic to cross runways and to allow departing aircraft to take off. Crew Resource Management (CRM) procedures are often used to ensure this communication process is efficient and clear, although this is not as prevalent as CRM for pilots.

Flight data / clearance delivery

Clearance Delivery is the position that issues route clearances to aircraft, typically before they commence taxiing. These contain details of the route that the aircraft is expected to fly after departure. Clearance Delivery or, at busy airports, the Traffic Management Coordinator (TMC) will, if necessary, coordinate with the en route center and national command center or flow control to obtain releases for aircraft. Often, however, such releases are given automatically or are controlled by local agreements allowing "free-flow" departures. When weather or extremely high demand for a certain airport or airspace becomes a factor, there may be ground "stops" (or "slot delays") or re-routes may be necessary to ensure the system does not get overloaded. The primary responsibility of Clearance Delivery is to ensure that the aircraft have the proper route and slot time. This information is also coordinated with the en route center and Ground Control in order to ensure that the aircraft reaches the runway in time to meet the slot time provided by the command center. At some airports, Clearance Delivery also plans aircraft push-backs and engine starts, in which case it is known as the Ground Movement Planner (GMP): this position is particularly important at heavily congested airports to prevent taxiway and apron gridlock.

Flight Data (which is routinely combined with Clearance Delivery) is the position that is responsible for ensuring that both controllers and pilots have the most current information: pertinent weather changes, outages, airport ground delays/ground stops, runway closures, etc. Flight Data may inform the pilots using a recorded continuous loop on a specific frequency known as the Automatic Terminal Information Service (ATIS).

Approach and terminal control

Many airports have a radar control facility that is associated with the airport. In most countries, this is referred to as *Terminal Control*; in the U.S., it is referred to as a TRACON (Terminal Radar Approach Control). While every airport varies, terminal controllers usually handle traffic in a 30-to-50-nautical-mile (56 to 93 km) radius from the airport. Where there are many busy airports close together, one consolidated Terminal Control Center may service all the airports. The airspace boundaries and altitudes assigned to a Terminal Control Center, which vary widely from airport to airport, are based on factors such as traffic flows, neighboring airports and terrain. A large and complex example is the London Terminal Control Centre which controls traffic for five main London airports up to 20,000 feet (6,100 m) and out to 100 nautical miles (190 km).

Terminal controllers are responsible for providing all ATC services within their airspace. Traffic flow is broadly divided into departures, arrivals, and overflights. As aircraft move in and out of the terminal airspace, they are handed off to the next appropriate control facility (a control tower, an en-route control facility, or a bordering terminal or approach control). Terminal control is responsible for ensuring that aircraft are at an appropriate altitude when they are handed off, and that aircraft arrive at a suitable rate for landing.

Not all airports have a radar approach or terminal control available. In this case, the en-route center or a neighboring terminal or approach control may co-ordinate directly with the tower on the airport and vector inbound aircraft to a position from where they can land visually. At some of these airports, the tower may provide a non-radar procedural approach service to arriving aircraft handed over from a radar unit before they are visual to land. Some units also have a dedicated approach unit which can provide the procedural approach service either all the time or for any periods of radar outage for any reason.

In the U.S., TRACONs are additionally designated by a three-letter alphanumeric code. For example, the Chicago TRACON is designated C90.

ATC provides services to aircraft in flight between airports as well. Pilots fly under one of two sets of rules for separation: Visual Flight Rules (VFR) or Instrument Flight Rules(IFR). Air traffic controllers have different responsibilities to aircraft operating under the different sets of rules. While IFR flights are under positive control, in the US VFR pilots can request flight following, which provides traffic advisory services on a time permitting basis and may also provide assistance in avoiding areas of weather and flight restrictions. Across Europe, pilots may request for a "Flight Information Service", which is similar to flight following. In the UK it is known as a "Traffic Service".

En-route air traffic controllers issue clearances and instructions for airborne aircraft, and pilots are required to comply with these instructions. En-route controllers also provide air traffic control services to many smaller airports around the country, including clearance off of the ground and clearance for approach to an airport. Controllers adhere to a set of separation standards that define the minimum distance allowed between aircraft. These distances vary depending on the equipment and procedures used in providing ATC services.

General characteristics

En-route air traffic controllers work in facilities called Air Traffic Control Centers, each of which is commonly referred to as a "Center". The United States uses the equivalent term Air Route Traffic Control Center (ARTCC). Each center is responsible for many thousands of square miles of airspace (known as a Flight Information Region) and for the airports within that airspace. Centers control IFR aircraft from the time they depart from an airport or terminal area's airspace to the time they arrive at another airport or terminal area's airspace. Centers may also "pick up" VFR aircraft that are already airborne and integrate them into the IFR system. These aircraft must, however, remain VFR until the Center provides a clearance.

Center controllers are responsible for climbing the aircraft to their requested altitude while, at the same time, ensuring that the aircraft is properly separated from all other aircraft in the immediate area. Additionally, the aircraft must be placed in a flow consistent with the aircraft's route of flight. This effort is complicated by crossing traffic, severe weather, special missions that require large airspace allocations, and traffic density. When the aircraft approaches its destination, the center is responsible for meeting altitude restrictions by specific points, as well as providing many destination airports with a traffic flow, which prohibits all of the arrivals being "bunched together". These "flow restrictions" often begin in the middle of the route, as controllers will position aircraft landing in the same destination so that when the aircraft are close to their destination they are sequenced.

As an aircraft reaches the boundary of a Center's control area it is "handed off" or "handed over" to the next Area Control Center. In some cases this "hand-off" process involves a transfer of identification and details between controllers so that air traffic control services can be provided in a seamless manner; in other cases local agreements may allow "silent handovers" such that the receiving center does not require any co-ordination if traffic is presented in an agreed manner. After the hand-off, the aircraft is given a frequency change and begins talking to the next controller. This process continues until the aircraft is handed off to a terminal controller ("approach").

Radar coverage

Since centers control a large airspace area, they will typically use long range radar that has the capability, at higher altitudes, to see aircraft within 200 nautical miles (370 km) of the radar antenna. They may also use TRACON radar data to control when it provides a better "picture" of the traffic or when it can fill in a portion of the area not covered by the long range radar.

In the U.S. system, at higher altitudes, over 90% of the U.S. airspace is covered by radar and often by multiple radar systems; however, coverage may be inconsistent at lower altitudes used by unpressurized aircraft due to high terrain or distance from radar facilities. A center may require numerous radar systems to cover the airspace assigned to them, and may also rely on pilot position reports from aircraft flying below the floor of radar coverage. This results in a large amount of data being available to the controller. To address this, automation systems have been designed that consolidate the radar data for the controller. This consolidation includes eliminating duplicate radar returns, ensuring the best radar for each geographical area is providing the data, and displaying the data in an effective format.

Centers also exercise control over traffic travelling over the world's ocean areas. These areas are also FIRs. Because there are no radar systems available for oceanic control, oceanic controllers provide ATC services using procedural control. These procedures use aircraft position reports, time, altitude, distance, and speed to ensure separation. Controllers record information on flight progress strips and in specially developed oceanic computer systems as aircraft report positions. This process requires that aircraft be separated by greater distances, which reduces the overall capacity for any given route. See for example theNorth Atlantic Track system.

Some Air Navigation Service Providers (e.g. Airservices Australia, The Federal Aviation Administration, NAV CANADA, etc.) have implemented Automatic Dependent Surveillance – Broadcast (ADS-B) as part of their surveillance capability. This new technology reverses the radar concept. Instead of radar "finding" a target by interrogating the transponder, the ADS-equipped aircraft sends a position report as determined by the navigation equipment on board the aircraft. Normally, ADS operates in the "contract" mode where the aircraft reports a position, automatically or initiated by the pilot, based on a predetermined time interval. It is also possible for controllers to request more frequent reports to more quickly establish aircraft position for specific reasons. However, since the cost for each report is charged by the ADS service providers to the company operating the aircraft, more frequent reports are not commonly requested except in emergency situations. ADS is significant because it can be used where it is not possible to locate the infrastructure for a radar system (e.g. over water). Computerized radar displays are now being designed to accept ADS inputs as part of the display. This technology is currently used in portions of the North Atlantic and the Pacific by a variety of states who share responsibility for the control of this airspace.

Precision approach radars are commonly used by military controllers of airforces of several countries, to assist the Pilot in final phases of landing in places where Instrument Landing System and other sophisticated air borne equipment are unavailable to assist the pilots in marginal or *near zero visibility* conditions. This procedure is also called **Talkdowns**.

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Flight traffic mapping

The mapping of flights in real-time is based on the air traffic control system. In 1991, data on the location of aircraft was made available by the Federal Aviation Administration to the airline industry. The National Business Aviation Association (NBAA), the General Aviation Manufacturers Association, the Aircraft Owners & Pilots Association, the Helicopter Association International, and the National Air Transportation Association petitioned the FAA to make ASDI information available on a "need-to-know" basis. Subsequently, NBAA advocated the broad-scale dissemination of air traffic data. The Aircraft Situational Display to Industry (ASDI) system now conveys up-to-date flight information to the airline industry and the public. Some companies that distribute ASDI information are FlightExplorer, FlightView, and FlyteComm. Each company maintains a website that provides free updated information to the public on flight status. Stand-alone programs are also available for displaying the geographic location of airborne IFR (Instrument Flight Rules) air traffic anywhere in the FAA air traffic system. Positions are reported for both commercial and general aviation traffic. The programs can overlay air traffic with a wide selection of maps such as, geo-political boundaries, air traffic control center boundaries, high altitude jet routes, satellite cloud and radar imagery.

Airport control

Inside the São Paulo-Guarulhos International Airport's tower, Latin America's busiest airport.

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Potomac TRACON, Warrenton, Virginia, United States.

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The FAA's air traffic controllers ensure the safe and efficient flight for about two million aviation passengers per day - or almost one billion people per year. Air traffic controllers safely manage more than 60 million aircraft annually to their destinations.

The U.S. air traffic controller workforce consists of approximately 15,000 dedicated and well-trained men and women working in air traffic control towers, terminal radar approach control centers, and en route control centers managing 30.2 million square miles of airspace.

Air Traffic Control Tower Controllers…

…work in the glassed-in towers you see at airports. They manage traffic from the airport to a radius of 3 to 30 miles out. They give pilots taxiing and take off instructions, air traffic clearance, and advice based on their own observations and experience. They provide separation between landing and departing aircraft, transfer control of aircraft to the en route center controllers when the aircraft leave their airspace, and receive control of aircraft on flights coming into their airspace.

CATEGORIES OF AIR TRAFFIC CONTROLLERS

Terminal Radar Approach Controllers…work in radar rooms, using terminal radar sensors to assist the aircraft until it reaches the edge of the facility's airspace, usually about 20 to 50 miles from the airport and up to about 17,000 feet, before handing it off to the En Route Center Controllers.

En Route Center Controller…work in 21 centers across the country, in a location away from the airport. You will never see them during the course of your flight, but they will normally direct your aircraft for the bulk of your ride. Controlling traffic usually at or above 17,000 feet, the typical center has responsibility for more than 100,000 square miles of airspace generally extending over a number of states. These controllers give aircraft instructions, air traffic clearances and advice using radar or manual procedures they keep track of the thousands of planes in the sky at any one time. Due to the radar equipment, they work in semi-darkness and guide aircraft on the scope.

Roles and Responsibilities of Air Traffic Control Facilities

The FAA's air traffic controllers ensure the safe and efficient flight for about two million aviation passengers per day - or almost one billion people per year. Air traffic controllers safely manage more than 60 million aircraft annually to their destinations.

The U.S. air traffic controller workforce consists of approximately 15,000 dedicated and well-trained men and women working in air traffic control towers, terminal radar approach control centers, and en route control centers managing 30.2 million square miles of airspace.

Air Traffic Control Tower Controllers…

Hartsfield-Jackson Atlanta International Airport

…work in the glassed-in towers you see at airports. They manage traffic from the airport to a radius of 3 to 30 miles out. They give pilots taxiing and take off instructions, air traffic clearance, and advice based on their own observations and experience. They provide separation between landing and departing aircraft, transfer control of aircraft to the en route center controllers when the aircraft leave their airspace, and receive control of aircraft on flights coming into their airspace.

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En Route Center Controllers…

Miami Air Route Traffic Control Center

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THE FUTURE OF AIR SPACE AND AIR TRAFFIC MANAGEMENT IN INDIA

Transformational change in governance, technology, processes and people is about to occur in India's ATM system.

With air traffic in India more than tripling in volume over the last decade, much of the focus in terms of capacity building has been on airport modernisation and construction. However, equally if not more critical, is the issue of airspace and air traffic management infrastructure.

With Indian aviation expected to enter a new growth phase, this critical component of the aviation value chain requires a strong focus. The following short extracts from the CAPA India ATM Report 2014 touch on some of the key issues covered. The full report is to be released on 30-Jun-2014.

Over the past 10 years the number of passengers handled by Indian airports has grown from 49 million in FY2004 to 169 million in FY2014. Total aircraft movements in India over this 10 year period increased at a compound annual growth rate of 9.1% to reach just over 1.5 million arriving and departing services in the 12 months ended 31-Mar-2014.

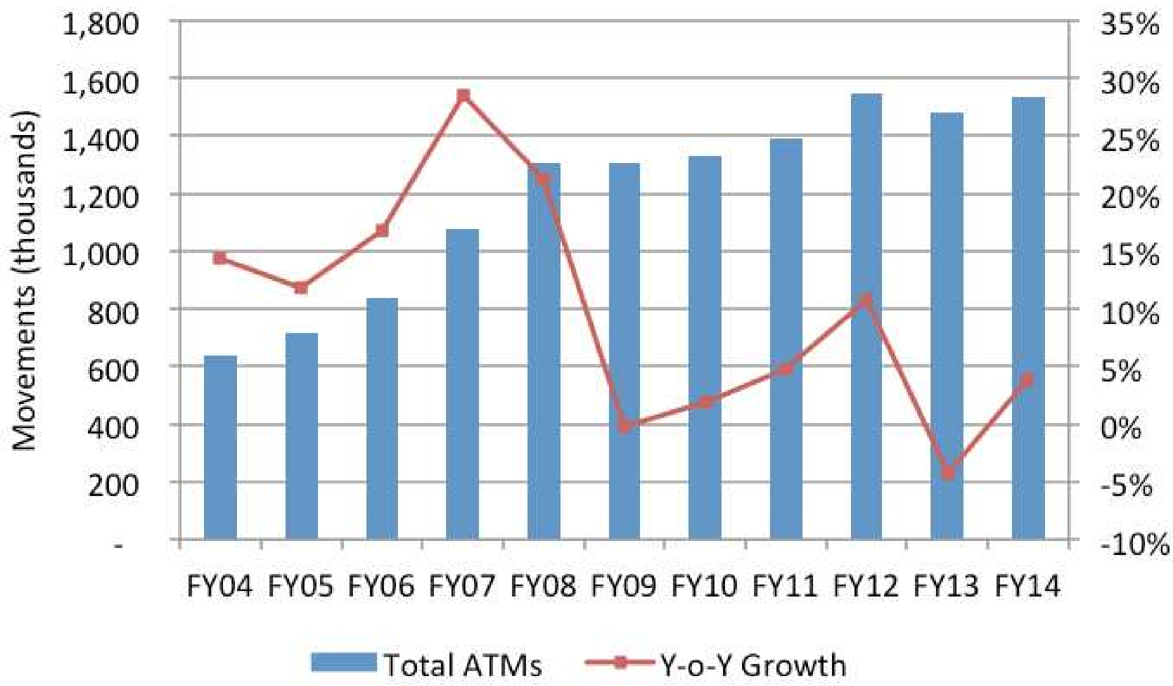
The CAPA India ATM Report 2014, to be released on 30-Jun-2014, is the most in-depth study ever conducted on the current status and outlook for air traffic management in India. This comprehensive report covers traffic movements and forecasts to FY2023; infrastructure status and requirements; inventory of equipment; manpower and training issues; benchmarking against international standards; implementation of new procedures including flexible use of airspace; impact of the GAGAN satellite based navigation system; and prospects for corporatisation of the Indian ANSP.

An early bird discount of almost 25% is available for orders and payments received by 15-Jun-2014. For more information contact capa@centreforaviation.com

This rapid growth will place significant pressure on air traffic management

Today, in addition to this local growth, Indian airspace handles approximately 400,000 annual over-flight movements.

Total Aircraft Movements at Indian Airports FY2004 to FY2014



Source: CAPA India, Airports Authority of India

CAPA projects that by FY2023 arriving and departing movements will have more than doubled again to 3.8 million. And in terms of over-flight movements, given India's geographic location between two of the fastest growing aviation markets in the world, namely Asia and the Middle East, the upper level corridors through Indian airspace are also expected to become increasingly crowded.

In addition to the rapid growth being experienced at an all-India level for which system-wide responses are required, there are also challenges at individual airports related to runway capacity which require local solutions. Mumbai is a prime example of an airport where increasing the maximum number of runway movements per hour has been critical to prevent the airport from reaching saturation.

The magnitude of growth that is expected will create significant pressures on air traffic management in India to which ad hoc responses will not suffice. Long term solutions will require a new way of thinking with a fresh approach and an organisation that is focused not only on technology and equipment, but also people and training.

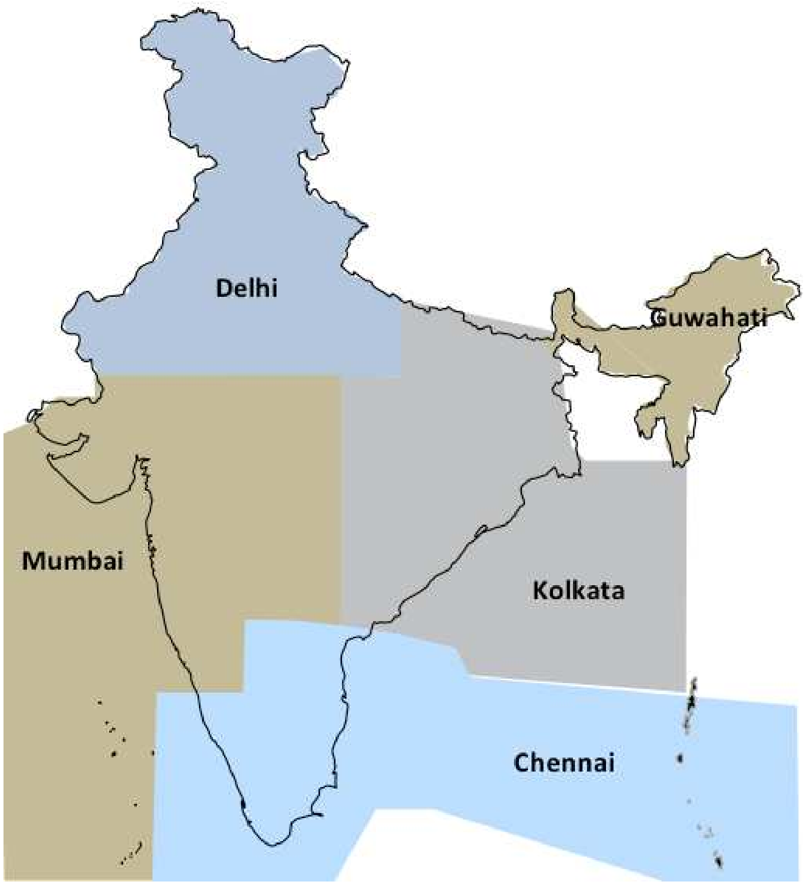
CAPA India ATM Report 2014 will include an in-depth traffic and operational review of ATM in India over the last 10 years, and present movements and traffic forecasts for the top 10 airports through to FY2023.

India’s air navigation services provider has commenced a major upgrade programme

India’s airspace covers 9.5 million square kilometres, of which just over 60% is oceanic, comprising regions over the Arabian Sea, the Bay of Bengal and the Indian Ocean. Approximately 35% of the airspace in India is reserved for military use which does create challenges for commercial operations.

The airspace is divided into four primary Flight Information Regions (FIR) at Delhi, Mumbai, Chennai and Kolkata, with a sub-FIR atGuwahati.

Indian Airspace Flight Information Regions



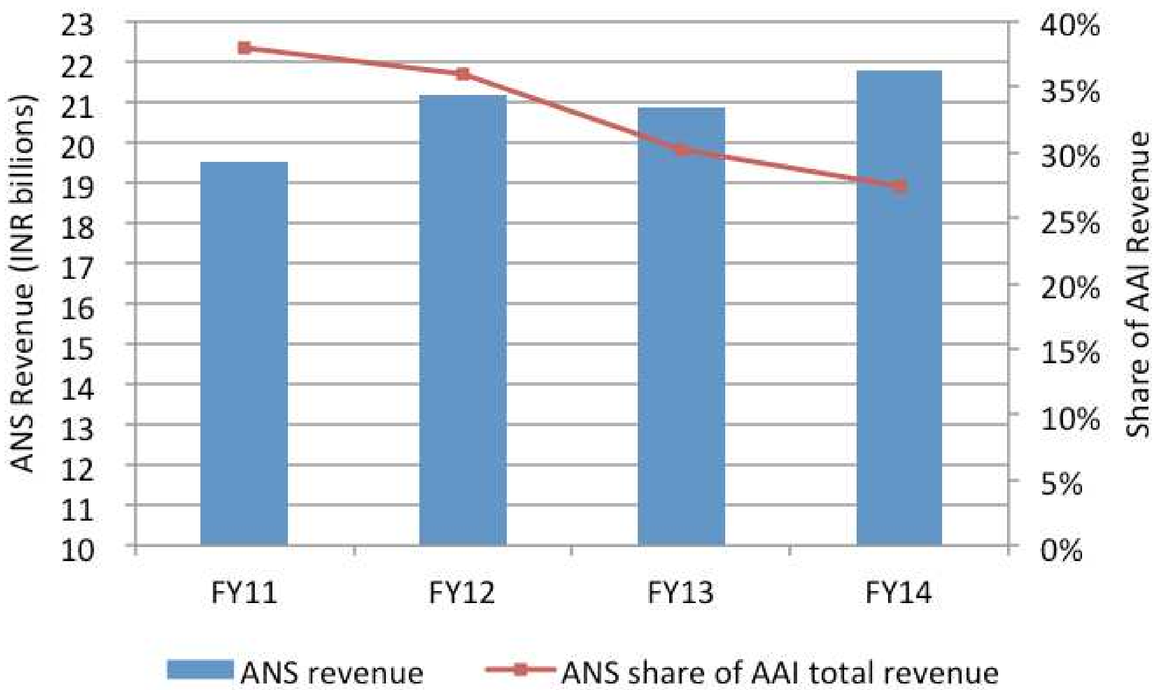
Source: CAPA India

Air navigation services (ANS) for civilian operations are provided by the state-owned Airports Authority of India (AAI). The AAI has a dual role, as both the air navigation services provider and as the operator of 125 airports across India, although around 50 of these are idle. A further five airports accounting for more than 50% of total traffic are managed by private operators, however the AAI providesair traffic control (ATC) services at these airport.

India has 26 civil enclaves, which are managed by the AAI. These are areas with a defence airfield which are designated for civilian use. At such airports the ATC services are provided by the Indian Air Force.

In FY14 the AAI generated INR21.8 billion (USD369 million) from ANS activities (route navigation facility charges, and terminal navigation and landing charges), up 12% in the three years since FY11. However, as a result of sharp growth in income from the lease of airports to PPP operators, particularly at Delhi and Mumbai, the ANS share of total revenue declined from 38.0% to 27.4% over the same period.

AAI Revenue from ANS Activities FY11 to FY14



Source: CAPA India

The AAI has made important strides towards addressing the management of recent and projected growth. Key initiatives underway or completed include:

- Restructuring of Indian airspace which commenced with upper level harmonisation of the Chennai FIR (and being rolled out across the other FIRs) and the integration of radars into the ATC automation system which has increased handling capacity;
- Extended provision of VHD Data Link; DATIS, PDC, AIDC;
- Automatic Dependence Surveillance – Broadcast (ADS-B) has been extended from 14 to 21 locations providing enhanced surveillance and redundancy for radar coverage;
- Improved DVOR/DME and ILS navigation equipment;
- Extension of Performance Based Navigation: Standard Instrument Departures (SIDs) and Standard Terminal Arrival Procedures (STARs) have been implemented at ten

international airports and are in the process of being introduced at seven additional airports;

- Introduction of Airport Collaborative Decision-Making (A-CDM) has improved on-time performance significantly. At Delhi Airport on-time departures have increased from 79.4% to 86.4%, and arrivals improved from 73.0% to 79.2%. A-CDM will be implemented at the six metro airports and eight non-metro airports by the end of 2015;
- Radar separation within the terminal airspace of Delhi, Mumbai, Bengaluru and Hyderabad airports has been reduced from five to three nautical miles;
- Issuance of pre-departure clearance to aircraft via a dedicated channel on a data link has been implemented at the six metro airports;
- Continuous descent procedures have been implemented at Delhi, Mumbai, Ahmedabad and Hyderabad;
- Construction of rapid-exit taxiways at several busy airports has reduced runway occupancy time which has enhanced traffic handling capacity;
- Implementation of Advanced Surface Movement Guidance and Control Systems (A-SMGCS) at the largest international airports;
- Three runway operations at Delhi Airport (increasing capacity from 60 to 75 hourly movements);
- Advanced ATM automation systems have been introduced at 38 non metro airports as well as the 6 metros, providing tools that enhance safety and efficiency;
- Continued progress towards the implementation of ground based and satellite based augmentation system, GAGAN.

CAPA India ATM Report 2014 will include comprehensive information on capacity planning for thenext 10 years; equipment introduced over the last 10 years; plans for equipment modernisation; capex plans for the next 5-10 years; review of technology strategy; status of skills availability and training capacity.

SATELLITE-BASED NAVIGATION SYSTEM IS THE FLAGSHIP PROJECT

The Airports Authority of India (AAI) along with Indian Space Research Organization (ISRO) has been jointly developing an Indian Satellite Based Augmentation System (SBAS) - GPS Aided Geo Augmented Navigation (GAGAN) - to provide seamless air traffic management over Indian Air Space in line with ICAO's Future Air Navigation System requirement.

GAGAN is intended to provide improved accuracy, availability and integrity necessary to enable users to rely on GPS for all phases of flight, from en route through to approach for all airports within the GAGAN coverage area.

The Cabinet Committee on Economic Affairs had approved a budget for the development and implementation of GAGAN of INR7.74 billion of which the AAI was to contribute almost 80%, with the balance to come from ISRO. Approximately INR5 billion has been spent to date.

Benefits from the implementation of GAGAN are expected to include:

- Ability to operate more direct routes and reduce fuel burn;
- Enhanced safety due to increased precision approaches;
- Potential cost savings due to the elimination of ground equipment;
- Improved navigation coverage in remote and oceanic airspace;
- Reduced workload for flight crew and air traffic controllers;
- Optimised airspace utilisation due to the reduced separation.

The Directorate General of Civil Aviation (DGCA), India provisionally certified GAGAN to Required Navigation Performance, 0.1 i.e. accuracy to 0.1 nautical miles in Dec-2013. The objective is to attain APV1/1.5 certification which will allow the system to offer precision approaches in India.

Aircraft, crews, runways, approach procedures and separation procedures and systems must be certified by the national regulatory authority before the system can be used operationally. GAGAN is expected to become operational from 2015.

CAPA India ATM Report 2014 will include the latest updates on the operation of GAGAN, including costs and benefits for key stakeholders.

FLEXIBLE USE OF INDIA'S AIRSPACE WILL DELIVER SIGNIFICANT EFFICIENCIES

India has pursued a number of initiatives to optimise airspace capacity including enhanced radar surveillance, supplemented by ADS-B; the introduction of air traffic flow management procedures and collaborative decision making at the six metro airports; and the implementation of systems that enhance route trajectories such as flexible use of airspace (FUA).

Approximately 35% of India’s airspace is not available for use by civilian operators. In the case of the Delhi FIR this increases to 70%. This restriction imposes the need to operate more circuitous routings, increasing fuel burn, costs and emissions.

However in 2012 the Ministries of Civil Aviation and Defence reached an agreement to progressively introduce FUA. This approach is “subject to ensuring adequate safeguards in the system to prevent inadvertent leaks of military information and dissemination of any information on military aviation activities.”

Since FUA was introduced this has led to better availability of seven routes for dynamic flight planning through military controlled airspace.

Four entry-exit way points at common FIR boundaries have been set up to support independent traffic flows. Other than this, conditional arrival/departure routes have been set up through Special Use Airspace (SUA) at Delhi, Chennai and Cochin. This initiative has led to radar information sharing between the AAI and the Indian Air Force at Delhi, Tambaram, Bangalore and Kolkata, while AAI provides navigation aids at these defence airfields.

A NATIONAL HIGH LEVEL AIRSPACE POLICY BOARD

In order to expand the level of cooperation, plans call for a National High Level Airspace Policy Board to establish procedures for allocation of airspace. The board is to consist of multiple stakeholders including the Ministry of Civil Aviation; Ministry of Defence; Indian Air Force; Airports Authority of India; Directorate General of Civil Aviation; and the Indian Space Research Organisation.

CAPA India ATM Report 2014 will include analysis of the status of status of flexible use of airspace, including challenges with implementation, benefits achieved, likelihood of further expansion, impact on routings; key objectives of Military Liaison Units; planned operational model for the future Joint Control Analysis Centre; information on the AAI's Aircraft Operations Control Centre; trends in over-flight routings; roll-out plans for PBN/RNAV; analysis of Q routes processes and procedures and cost-benefit analysis; integration of collaborative decision making and air traffic flow management systems.

AAI priorities range from designing national airspace systems down to addressing local capacity issues

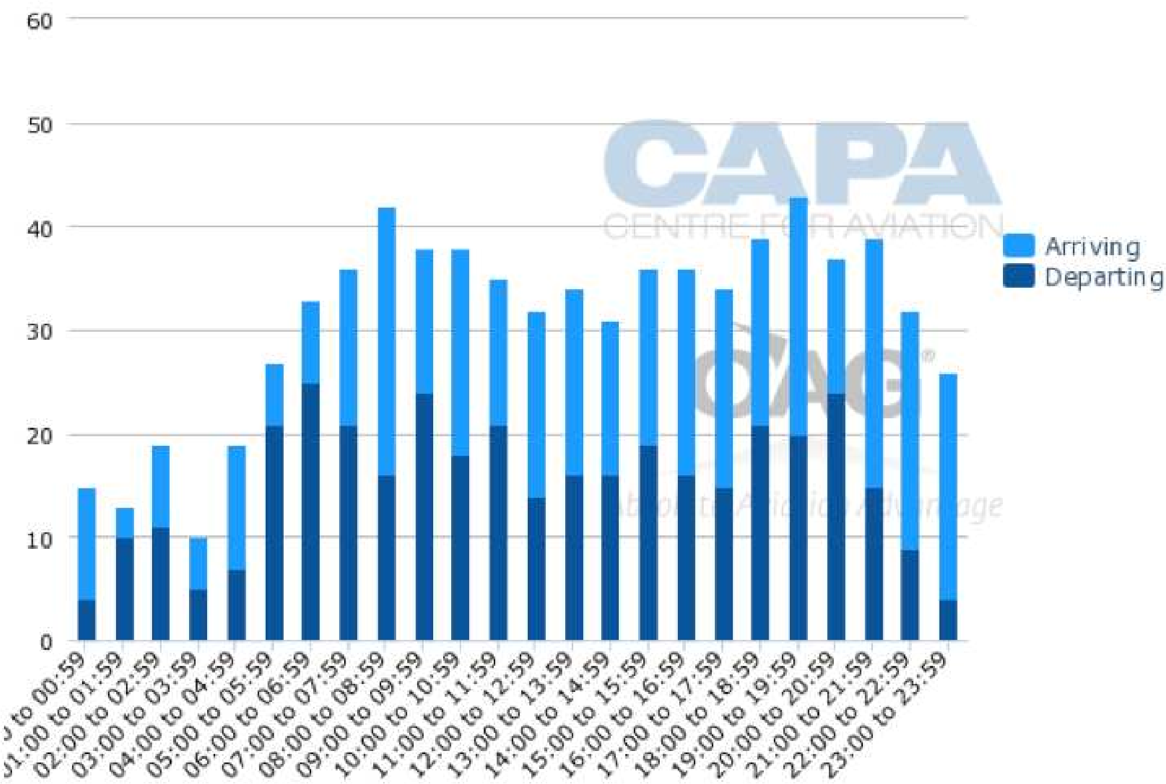
The AAI's responsibilities require it to maintain both a holistic perspective of the entire Indian airspace as well as airport-specific issues. Mumbai is a prime example of how airside capacity can have a major impact not just at a local level but nationally.

Until 2010 Mumbai was the busiest airport in India. However its airside configuration limited it to a maximum of around 32 aircraft movements per hour. By 2010/11 Mumbai was operating at close to this level for almost 19 hours a day, leaving it severely slot constrained except between midnight and 5am. Traffic growth was curtailed and the airport was overtaken by Delhi, as both Air India and Jet Airways announced plans to shift their hubs to India's capital.

The airport's new T2 will expand the airport's terminal capacity to 40 million passengers once fully commissioned. But at 32 runway movements an hour the airport would have struggled to support enough airline activity to generate 40 million passengers.

NATS UK was engaged as a consultant to help decongest the airside, which included the construction of rapid exist procedures, and to assist with the implementation of new flight paths and procedures. As a result the airport is now able to handle peaks of just over 40 aircraft movements per hour and is targeting to increase this further to 46-48 movements.

Pattern of Scheduled Hourly Aircraft Movements at Mumbai Airport 27-May-2014



Source: CAPA – Centre for Aviation, OAG

A detailed analysis of the structural runway and airside capacity of at least the 40 largest airports in the country is required to assist with forward planning for infrastructure requirements. At a national level it is necessary to identify as early as possible where and when capacity constraints are likely to emerge at a given airport and to determine whether these can be addressed through upgrading of the existing infrastructure or the deployment of new technology, or if in fact a new airport will be required.

AVAILABILITY OF SKILLED MANPOWER

In order to be keep pace with growth requirements the AAI will need to ensure that it has appropriate systems in place to recruit, train and retain controllers and engineers. The ANS division currently employs 2,144 air traffic controllers. Despite the recruitment of 800 controllers between 2010 and 2012 the AAI remains 10-20% below its sanctioned strength.

AIR TRAFFIC CONTROLLERS EMPLOYED BY REGION

ATC Zone	Air Traffic Controllers
Northern Region	652
Southern Region	628
Western Region	513
Eastern Region	259
North Eastern Region	92
Total	2,144

Source: CAPA India

Detailed estimates for the future requirements for controllers are critical. This analysis should take into account the projected growth in traffic, the impact of new technology, and the expected attrition of manpower as a result of controllers retiring or moving to other geographies or industries. The DGCA has been planning to introduce licensing of air traffic controllers, the implications of which need to be considered. It has been suggested that this could increase the mobility of controllers and make them more susceptible to being recruited by foreign ANSPs, particularly in the Gulf.

And the next generation of employees is not as wedded to the concept of picking and sticking with an industry for life. Switching between sectors will become increasingly common and this in itself will increase the demand for training as staff turnover is likely to be higher than in the past.

The difference in salaries paid to controllers in India compared with overseas markets is significant, particularly in terms of the base remuneration. Amongst the 23 ANSPs participating in the CANSO Global Air Navigation Service Performance Report 2013, the AAI had by far the lowest average air traffic controller salaries at USD20,000 compared with an average for the sample of USD130,000. Although the differential is narrowed once non-cash components are included. For example, Indian controllers receive attractive housing and health insurance benefits.

The salary gap for air traffic controllers is notable in contrast to the labour market situation for another skilled aviation role, namely pilots, with Indian carriers paying close to the same levels offered by European or North American airlines.

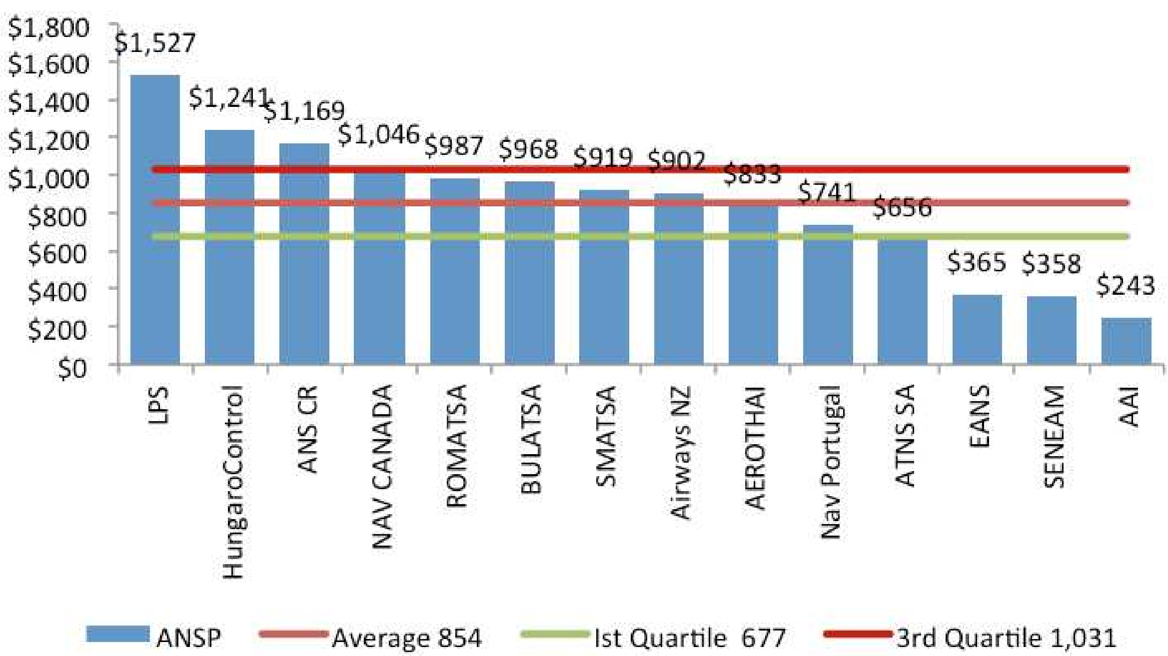
Although low by international standards, the remuneration for air traffic controllers is considered competitive for public sector positions in India. However, if the AAI wants to continue to recruit high quality candidates it will increasingly need to compete with private sector employers for the brightest science and engineering graduates and this may result in increased labour costs going forward. It will also require an outreach programme to engage more actively with school leavers and university students to promote the attraction of a career in air traffic control.

The capacity of the available training infrastructure to support the development of the requisite skills from ab initio through to upgrading the capabilities of existing controllers on new technologies and procedures must also be determined. The Airports Authority of India (AAI) has a dedicated college at Allahabad and an additional facility at Hyderabad, but significant investment is required in order to update equipment and install the latest simulation technology.

GROWTH CHALLENGES CALL FOR A NEW GOVERNANCE STRUCTURE FOR THE ANSP

The AAI has performed its ANS responsibilities with great care and commitment. And by global standards it is a relatively efficient, low cost provider of services to airlines, due in large part to the impact of salary costs. As a result of this labour cost advantage, the AAI's consolidated charges for an A320 aircraft travelling a distance of 1000 km between two airports is USD243 compares to an average of USD854 for the ANSPs under consideration.

Example Consolidated Price (USD) per 1000 km Flight for A320 by ANSP



Source: CAPA, CANSO

The competitive rates however mean that the AAI has less revenue available for investment in equipment, people and training in order to meet its responsibilities against the backdrop of fast growth and rapidly evolving technology. Similarly, give the dual role of the AAI as an ANSP and an airport operator and developer means that that there are competing claims on that capital.

Given the expected future direction of the sector, and in line with international trends, the time is now approaching to develop a new model rather than ad hoc revisions to the existing structure.

The Ministry of Civil Aviation (MoCA) has indicated that it will accept the recommendation of a consultant to corporatise the ANS division of the AAI. This would involve hiving-off the division as an independent autonomous body with separate financials. The new ANS entity would be subject to stringent performance parameters and monitoring mechanisms. However, execution of this plan has been delayed due to concerns about the impact on the AAI's revenue.

As and when it proceeds, the corporatised entity should be headed by a domain expert and not a bureaucrat. In addition there is a need to implement a new culture focused on performance, cost efficiency, service and environmental sustainability whilst maintaining safety as the primary objective. This will require greater engagement and collaboration with airline customers.

The AAI may need to appoint a global technical advisor for a period of 3-5 years during the transition from its current insular environment to a more customer-focused, service-driven and accountable organisation.