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NATIONAL PLAN FOR CNS/ATM SYSTEMS

GUIDANCE MATERIAL

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FOREWORD

Following comprehensive studies over several years, the communications, navigation and surveillance/air traffic management (CNS/ATM) systems concept was endorsed by the Tenth Air Navigation Conference in 1991 and by the 29th Session of the ICAO Assembly in 1992.

Planning for successful implementation of CNS/ATM systems is necessitated by the large and complex nature of the undertaking and the multidisciplinary roles of the partners involved. Planning takes place mainly at three levels: global, regional and national.

To progress with the planning, ICAO first determined the requirements for facilities and services to serve the international civil aviation community at the global level in the form of a global plan. The *Global Co-ordinated Plan for Transition to the ICAO CNS/ATM Systems* was initially developed by 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) in 1993. The Global Plan has now been revised and published as the *Global Air Navigation Plan for CNS/ATM Systems* and was presented to the World-wide CNS/ATM Systems Implementation Conference (Rio de Janeiro, 11–15 May 1998). Regional planning is the principal engine of ICAO 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.

While ICAO addresses planning strategy at the global and regional levels, planning at the national level is the responsibility of each State. However, in response to a request by a number of States for more information concerning the planning and implementation of CNS/ATM systems, this guidance material in the form of a *Model National CNS/ATM Systems Plan* has been developed. This circular is intended to assist States in structuring, formulating, amending and enhancing their individual plans for the transition to CNS/ATM systems. At the same time, those States that have completed their respective national CNS/ATM systems plans can validate their findings by adopting the approach. This guidance material, in addressing shortcomings of the current systems, identifies functional requirements in the short term (suggesting enhancements to current systems) as well as in the long term (suggesting implementation of the new systems). National planning guidance as contained in this circular, while being useful to States for planning for both domestic and international operations, requires coordination and harmonization with planning in adjacent States so that the implementation of facilities and services can be accomplished in line with the regional plan.

While describing the techniques and requirements of various systems configurations that can be implemented at the national level, this guidance material is not intended to indicate preference for any particular system configuration. The choice of a system configuration will depend on a variety of circumstances and requirements, such as type of airspace, density of air traffic and cost-effectiveness. The planning decision will therefore require the study of operational requirements, technical suitability and economic analyses.

The guidance material presented in this circular is consistent with, and complementary to, the *Global Air Navigation Plan for CNS/ATM Systems* (Doc 9750). For guidance on the application of CNS/ATM systems in relation to meteorology, aeronautical information services, organizational and international cooperative aspects, financial aspects, legal issues, training and technical cooperation — which are not specifically addressed in this circular — the reader is referred to the *Global Air Navigation Plan for CNS/ATM Systems*.

The cost/benefit guidance material in this circular is based on the *Economics of Satellite-based Air Navigation Services — Guidelines for cost/benefit analysis of communications, navigation and surveillance/air traffic management (CNS/ATM) systems* (Circular 257).

Formatted spreadsheets using WordPerfect and Excel software to apply the approach used in this Circular 278 covering technical analysis and cost/benefit analysis are available on diskette from the ICAO Secretariat on request. It should be noted that, in order to make the software as user-friendly as possible, several simplifications in assumptions and input of data have been made. The software developed for this Circular is intended to give States/providers and users a quick view of the economic potential of the CNS/ATM systems, as well as to allow ready comparisons of different implementation options. Wherever there is a need for a more comprehensive analysis, the software referred to in the foreword to Circular 257 should be applied. That software is also available from the ICAO Secretariat.

The guidance material includes a glossary that provides brief explanations of the common technical terms and acronyms. These explanations should be viewed as an aid to the general understanding of the reader and are not necessarily officially endorsed by ICAO.

Users are invited to express their views and offer comments and suggestions for improvements or additions based on their practical experience when using this guidance material for national planning for CNS/ATM systems. These should be directed to the Secretary General of ICAO.

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GLOSSARY

Note.— The explanations of the acronyms and technical terms provided here should be viewed as an aid to the general understanding of the reader and are not necessarily officially endorsed by ICAO. The reader should also recognize that there are ongoing developments in some of the technology and institutions.

A-SMGCS	advanced surface movement guidance and control system
AAC	aeronautical administrative communication
AAGDI	automated air-ground data interchange
AAIM	aircraft autonomous integrity monitoring
ABAS	aircraft-based augmentation system
ACARS	aircraft communications addressing and reporting system
ACAS	airborne collision avoidance system
ADS	automatic dependent surveillance
ADS-A	automatic dependent surveillance-addressed
ADS-B	automatic dependent surveillance-broadcast
ADS-C	automatic dependent surveillance-contract
ADSP	Automatic Dependent Surveillance Panel
AFTN	aeronautical fixed telecommunication network
A/G	air-ground
AIDC	air traffic services interfacility data communication
AMS(R)S	aeronautical mobile-satellite (route) service
AMSS	aeronautical mobile-satellite service
ANP	air navigation plan
AOC	aeronautical operational control
APANPIRG	Asia/Pacific Air Navigation Planning and Implementation Regional Group
APC	aeronautical passenger communication
APIRG	AFI Planning and Implementation Regional Group
ARABSAT	Arab Satellite Organization
ASDE	airport surface detection equipment
ASECNA	Agency for Air Navigation Safety in Africa and Madagascar
ASM	airspace management
ATC	air traffic control
ATFM	air traffic flow management
ATIS	automatic terminal information service
ATM	air traffic management

ATN	aeronautical telecommunication network
ATS	air traffic service
ATSC	air traffic services communications
BORPC	basic operational requirements and planning criteria
CBA	cost/benefit analysis
CDTI	cockpit display of traffic information
CFIT	controlled flight into terrain
CIDIN	common ICAO data interchange network
CNS	communications, navigation and surveillance
CNS/ATM	communications, navigation and surveillance/air traffic management
COCESNA	Central American Corporation for Air Navigation Services
COSPAS-SARSAT	space system for search of vessels in distress — search and rescue satellite-aided tracking
COTS	commercial off-the-shelf
CPDLC	controller-pilot data link communications
CSMA	carrier sense multiple access
DME	distance measuring equipment
EANPG	European Air Navigation Planning Group
EUROCONTROL	European Organisation for the Safety of Air Navigation
FANS	Future Air Navigation Systems
FANS Phase II	Special Committee for the Monitoring and Co-ordination of Development and Transition Planning for the Future Air Navigation System
FASID	Facilities and Services Implementation Document
FDPS	flight data processing system
FIR	flight information region
FIS	flight information service
FMS	flight management system
GBAS	ground-based augmentation systems
G/G	ground-ground
GLONASS	global orbiting navigation satellite system
GMS	ground monitoring station
GNSS	global navigation satellite system
GPS	global positioning system
GREPECAS	Caribbean/South American Regional Planning and Implementation Group
HF	high frequency
HFDL	HF data link
HMI	human-machine interface
IAS	indicated airspeed
ICAO	International Civil Aviation Organization
ICMHS	integrated communications message handling system

ILS	instrument landing system
IMC	instrument meteorological conditions
INTELSAT	International Telecommunications Satellite Organization
ISO	International Organization for Standardization
MCS	master control station
MIDANPIRG	Middle East Air Navigation Planning and Implementation Regional Group
MMR	multi-mode receiver
MNPS	minimum navigation performance specifications
MNT	Mach number technique
MSAW	minimum safe altitude warning system
MTCA	medium-term conflict alert
MTSAT	multifunctional transport satellite
MWARA	major world air routes area
NAMPG	North American Planning Group
NAT SPG	North Atlantic Systems Planning Group
NAV	navigation
NAVAID	aid to air navigation
NDB	non-directional radio beacon
NM	nautical mile
NOTAM	notice to airmen
NPA	non-precision approach
NPV	net present value
OSI	open systems interconnection
PANS	Procedures for Air Navigation Services
PANS-RAC	*Procedures for Air Navigation Services — Rules of the Air and Air Traffic Services* (Doc 4444)
PAR	precision approach radar
PIRG	planning and implementation regional group
PRM	precision runway monitor
PSR	primary surveillance radar
RA	resolution advisory
RAIM	receiver autonomous integrity monitoring
RCAG	remote controlled air-ground communication
RCP*	required communication performance
RDARA	regional and domestic air routes area
RF	radio frequency

* Emerging concept or technology — consensus still to be reached.

RFI	radio frequency interference
RNAV	area navigation
RNP	required navigation performance
RSP*	required surveillance performance
R/T	radiotelephony
RTSP*	required total system performance
RVSM	reduced vertical separation minimum
SARPs	Standards and Recommended Practices
SATCOM	satellite communication
SBAS	satellite-based augmentation system
SITA	Société internationale de télécommunications aéronautiques
SMGCS	surface movement guidance and control system
SRP	slot reference point
SSR	secondary surveillance radar
STCA	short term conflict alert
STDMA	self-organizing time-division multiple access
TDMA	time division multiple access
TMA	terminal control area
UTC	coordinated universal time
VCCS	voice communications control system
VDL	VHF digital link
VHF	very high frequency
VMC	visual meteorological conditions
VOLMET	meteorological information for aircraft in flight
VOR	VHF omnidirectional radio range

* Emerging concept or technology — consensus still to be reached.

Chapter 1
INTRODUCTION

1.1 The *National Plan for CNS/ATM Systems* guidance material outlines a model framework for States to formulate their national plans for CNS/ATM systems in a progressive, cost-effective and cooperative manner.

WHY DEVELOP A NATIONAL CNS/ATM SYSTEMS PLAN?

1.2 A national CNS/ATM systems plan is required to:

a) improve the overall efficiency and capacity of the State airspace infrastructure; and

b) address the requirements arising out of growth in both international and domestic air traffic.

HOW WILL THE PLANNING DOCUMENT FOR CNS/ATM SYSTEMS BENEFIT THE STATE?

1.3 The planning document, as structured by the State, will:

a) provide a basis for consultation with aircraft operators, the air defence organization and the regulatory agency;

b) ensure that required coordination is effected with adjacent States and international organizations;

c) recommend transition priorities;

d) serve to manage the national plan, which identifies tasks and timetables with associated milestones;

e) identify allocation of resources;

f) serve as a basis for project cost estimation and the obtaining of funding;

g) show the cost-effectiveness of various options for CNS/ATM systems elements considered in national planning; and

h) direct the work programme for a coordinated approach in the transition to CNS/ATM systems.

HOW IS THIS CIRCULAR STRUCTURED?

1.4 This circular is broken down into the following chapters:

Chapter 2 focuses on the CNS/ATM systems concept and global transition strategy as contained in the Global Plan, Part I — *Operational Concept and General Planning Principles.*

Chapter 3 identifies the basis for listing of available infrastructure and those in the planning stage in terms of airports, airspace, air routes, communications, navigation and surveillance elements.

Chapter 4 deals with the evaluation of current systems in terms of air traffic management (ATM) operations, CNS equipage and support systems.

Chapter 5 presents the need for assessing current traffic density and projecting air traffic forecasts up to the year 2010 for passengers, freight and aircraft movements, with emphasis on aircraft movements and regional flows of traffic.

Chapter 6 develops functional requirements or improvements in the short term, as well as in the long term, taking into account airspace users' needs.

Chapter 7 provides details and a methodology to select a range of operational, technical and institutional options that are available to build the CNS/ATM systems concept.

Chapter 8 explains the strategy for determining the timescale for the implementation of new systems and at the same time for the phasing out of current equipage/service not required under CNS/ATM systems.

Chapter 9 describes the role of cost/benefit analysis in the planning process.

Chapter 10 assists in carrying out the harmonization of national plans with regional plans in order to provide interoperability and to ensure seamlessness in ATM.

Chapter 11 discusses the global planning methodology based on homogeneous ATM areas and major international traffic flows.

1.5 The chapters are organized in an easy-to-follow manner, incorporating the major components of CNS/ATM systems. After the *National Plan for CNS/ATM Systems* is finalized and published, it is necessary that it be updated periodically in order to accommodate changing needs.

HIGHLIGHTS OF THE GUIDANCE MATERIAL

1.6 This guidance material:

a) is consistent with and complementary to the Global Plan;

b) is a high-level document;

c) requires reference to related ICAO manuals and circulars for more detailed guidance;

d) focuses on practical aspects, using a quantitative approach, such as checklists, templates, decision trees, flowcharts and implementation tables;

e) contains some material from the Global Plan and other ICAO documents, reproduced here to make it a comprehensive document;

f) in addressing the shortcomings of current systems, identifies functional requirements in the short term (suggesting enhancements in current systems) as well as in the long term (suggesting implementation of new systems);

g) focuses on the technical, operational and cost/benefit aspects of national planning;

h) assists in the harmonization of the national plan with the regional plan;

i) is accompanied by a user-friendly software package developed (based on Circular 257) to carry out cost/benefit analyses;

j) takes into account comments from States and industry;

k) addresses international and domestic air traffic needs;

l) takes into account regional requirements in terms of ATM objectives and supporting CNS elements; and

m) harmonizes with global implementation guidelines.

APPROACH TO NATIONAL PLANNING

1.7 When preparing the national plan for transition to CNS/ATM systems, a methodology based on the following steps is recommended. This approach envelops the gate-to-gate philosophy:

a) Establish a national CNS/ATM systems planning group.

b) Study CNS/ATM systems technology and the Global Plan.

c) Review the regional air navigation plan and take into account regional ATM objectives and regional ATM requirements in terms of communication, navigation and surveillance elements.

d) Initiate coordination with adjacent States.

e) Consistent with ICAO's regional air navigation plan, identify the principal objectives of the State for implementation of CNS/ATM systems.

f) List the current and planned infrastructures in terms of airports, airspace, air routes, communication, navigation and surveillance elements.

g) Assess the current traffic density and carry out air traffic forecasts for the years 2003, 2008 and 2013 with emphasis on aircraft movements and regional flows of traffic.

h) Evaluate the current ATM system, focussing on route structure, separation standards, equipage, maintenance, operations and procedures in order to identify any weaknesses.

i) As a result of gap analyses, develop functional requirements that would result in improvements/benefits both in the short term and the long term, keeping in view users' requirements.

j) Analyse various operational/technical options, as well as institutional options, and determine the ATM objectives and supporting CNS elements that are most suitable for the scenario, taking into account the planning situation in adjacent States, the development status of Standards and Recommended Practices (SARPs) and the regional approach to air navigation planning.

k) Determine implementation time lines for new systems and decommissioning time lines for current ground systems that are not required as a result of the transition to CNS/ATM systems.

l) Carry out cost/benefit analyses to determine the most appropriate plan, using the iteration process.

m) Harmonize with the regional plan.

n) Formalize the planning document and initiate actions for the implementation of CNS/ATM systems.

1.8 The flow chart describing the sequence of activities to be carried out at the national level for planning for transition to CNS/ATM systems is shown in Figure 1-1.

WHAT ARE THE WORKING LEVELS REQUIRED TO PLAN FOR NATIONAL CNS/ATM?

1.9 The national CNS/ATM planning group needs to be constituted with the responsibility of structuring the National Plan in order to facilitate the transition to CNS/ATM systems. The group will identify a series of stepped changes in concepts and associated systems, starting from the baseline. The changes must be demonstrated to bring about a progressive capacity gain, in line with rising traffic demand, in a safe and cost-effective manner. The suggested composition of the planning group includes members from participating organizations, such as:

a) the national administration;

b) the regulating agency;

c) ATM service provider;

d) airspace users;

e) the airport authority;

f) research and development organizations;

g) military authorities, including air defence; and

h) other relevant bodies.

In setting up the working arrangements, as shown in Figure 1-2, a close alignment must be maintained.

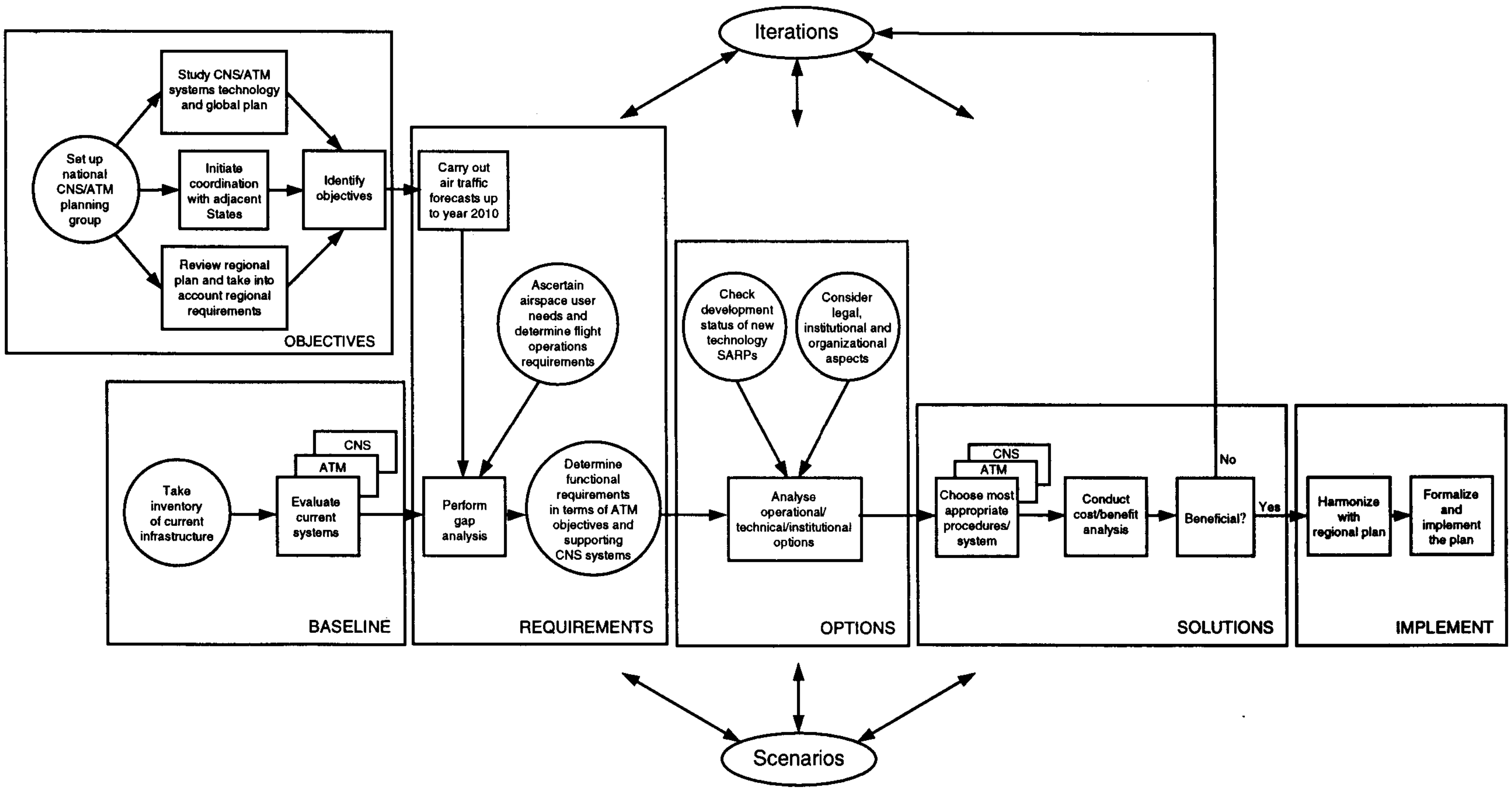

Figure 1-1. The overall approach to national planning and implementation for CNS/ATM systems

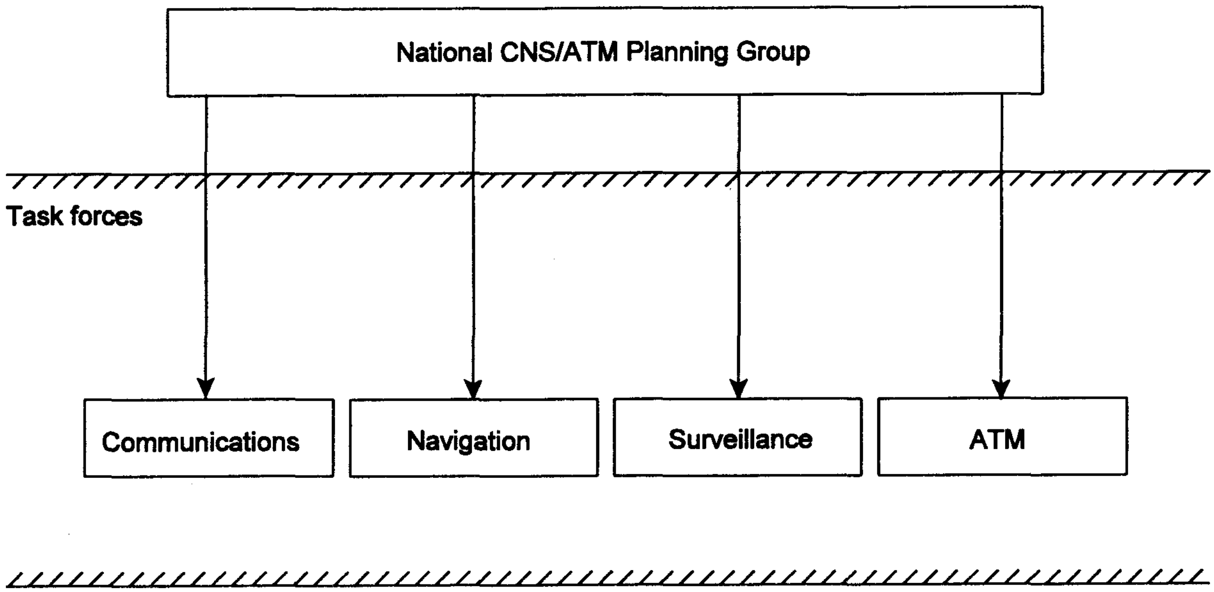

Figure 1-2. Planning group working arrangements

1.10 Task forces may be created when the scope or depth of work required is more specialized in nature and cannot be undertaken by the planning group. Task forces are normally restricted to a single task; they have clearly identified deliverables and target dates, and are dissolved once the task is completed.

COORDINATION WITH ADJACENT STATES

1.11 States, when embarking on planning for CNS/ATM systems, should at the beginning initiate coordination with adjacent States to understand their planning strategy. This process will ensure interoperability and harmonization with adjacent airspaces. Coordination is perhaps best achieved through:

a) a cooperative approach, by inviting the adjacent States to join the national planning team and taking into account relevant input to harmonize the national plan with the plans of adjacent States; or

b) the establishment of a subregional group for CNS/ATM planning based on homogeneous ATM areas and major international traffic flows.

WHAT ARE THE OBJECTIVES AND HOW ARE THEY TO BE SEEN BY THE PLANNING GROUP?

1.12 It is necessary to first define the mission statement — what the planning group is working towards. The mission identifies, communicates and establishes a stable framework of objectives. These objectives need to be measurable statements against which the proposed system will be tested for acceptance.

1.13 The objectives of the State for the implementation of CNS/ATM systems (Table 1-1) may evolve from the following areas:

a) safety;

b) capacity;

c) regularity and efficiency;

d) cost-effectiveness; and

e) uniformity.

ICAO'S PLANNING STRUCTURE FOR CNS/ATM SYSTEMS

1.14 Planning for the successful implementation of CNS/ATM systems worldwide:

a) is necessitated by the large and complex nature of the undertaking and the multiplicity of partners involved (Table 1-2);

b) takes place mainly at global, regional and national levels;

c) requires a top-down approach for the development of the global system, in contrast to implementation itself which is essentially a bottom-up process; and

d) is done with the help of planning tools and methodologies whose use at the regional and national levels is conditioned by guidance from a higher level or levels.

Table 1-1. Objectives of a State in structuring CNS/ATM systems planning

1.	To maintain and enhance safety levels in the face of higher traffic densities.
2.	To provide air traffic control (ATC) capacity to handle air traffic to meet the forecast of demand without significant delays.
3.	To enable all airspace users to operate efficiently while accommodating both civil and military operators' needs.
4.	To provide the required ATM service in a cost-effective manner.
5.	To provide interoperability with adjacent airspaces.
6.	To adopt common standards, specifications and functionalities that will standardize the ATM environment.

Table 1-2. Planning for CNS/ATM systems by the partners

CNS/ATM Partners	Planning levels	Deliverables	Guidance
ICAO	Global	Global plan	ICAO policy
Regional planning groups	Regional	Regional plan	Global plan
States	National	National plan	Regional plan
Airspace users	Regional, national	User-driven plan	Regional, national plans
Service providers	Global, regional, national	Service-provider plan	Global, regional, national plans
Industry	Global, regional, national	Manufacturer plan	Global, regional and national plans

Global plan

1.15 Global planning:

a) is done by ICAO, applying relevant ICAO policies, SARPs and procedures; and

b) is embodied in a relatively stable global plan (Doc 9750, Part I) and in a flexible document (Part II) that has regional data and requires frequent updating (Figure 1-3).

1.16 The main, stable Part I offers high-level vision, describes the ATM operational concept and guides further revisions of the basic operational requirements and planning criteria (BORPC) of regional plans.

1.17 The flexible Part II offers more detailed information on CNS/ATM planning and guides the development of the Facilities and Services Implementation Document (FASID) as applicable to the regions.

Regional plan

1.18 Regional planning:

a) is the principal engine of planning and implementation;

b) is done by the planning and implementation regional groups (PIRGs) for each ICAO Region;

c) converges the top-down approach with bottom-up implementation;

d) involves in its process the application of planning tools and guidance materials as well as inputs from national, subregional and user-driven plans (Figure 1-4);

e) is embodied in a main part [basic air navigation plan (ANP)] and a flexible part (FASID);

f) needs continuous interface between each PIRG and States to ensure harmonization of planning; and

g) requires interaction between PIRGs at ALLPIRG* meetings to ensure interregional harmonization across regional boundaries (Figure 1-5).

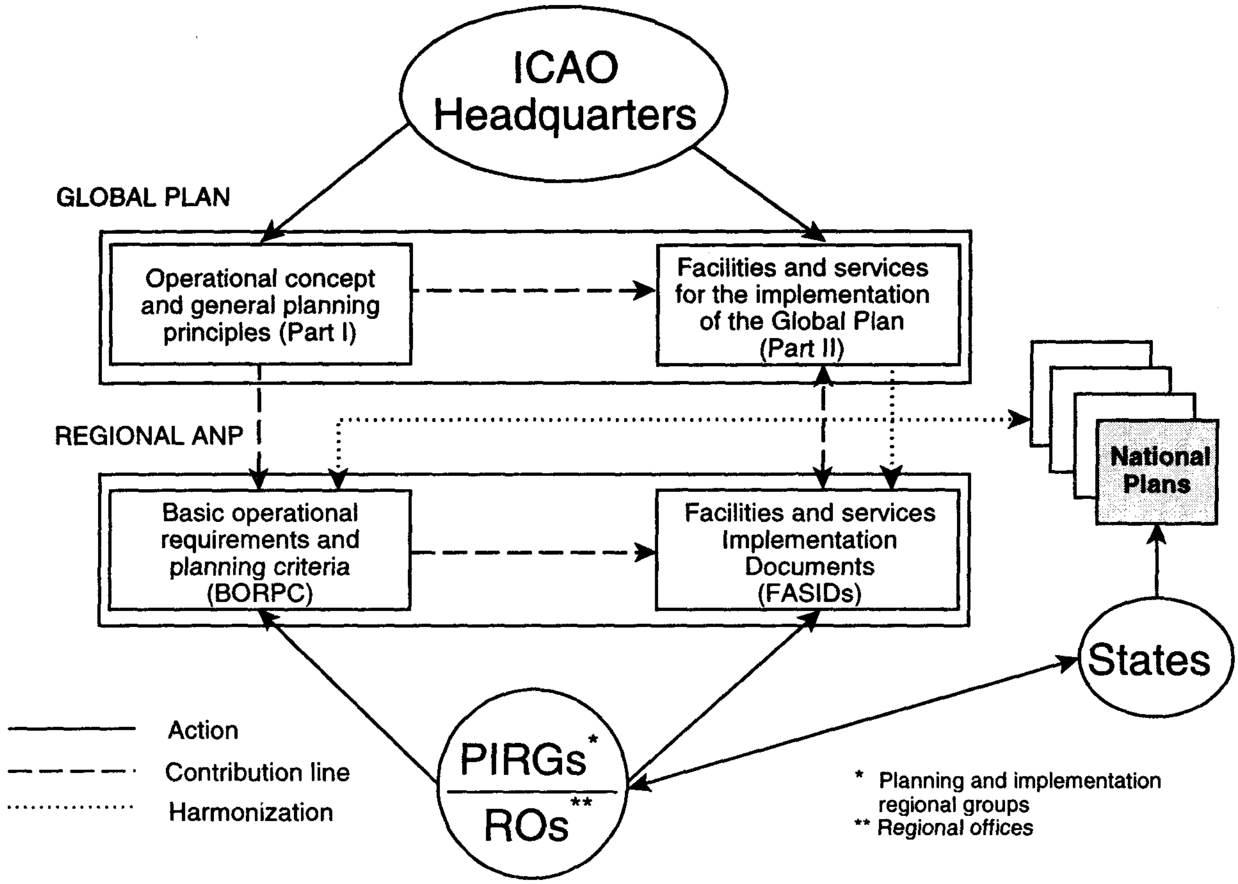

Figure 1-3. Relationship among the Global Plan, regional ANPs and national plans

* The ALLPIRG/Advisory Group was established by the Council of ICAO in 1996 to facilitate the global coordination of new technologies and develop a very close link between the ICAO implementation mechanism and other partners.

1.19 There are seven regional planning groups, namely:

a) the Asia/Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG);

b) the Africa-Indian Ocean Planning and Implementation Regional Group (APIRG);

c) the European Air Navigation Planning Group (EANPG);

d) the Caribbean and South American Regional Planning and Implementation Group (GREPECAS);

e) the Middle East Air Navigation Planning and Implementation Regional Group (MIDANPIRG);

f) the North Atlantic Systems Planning Group (NAT SPG); and

g) the North American Planning Group (NAMPG).

1.20 The review of the regional plan in order to understand regional requirements is the primary step before initiating formulation of the national plan.

National plan

1.21 National planning:

a) is done by each State;

b) should be in accordance with regional requirements and implementation guidelines;

c) addresses both domestic and international air traffic needs; and

d) requires ongoing interaction with adjacent States, the regional planning group and the subregional group to ensure harmonization and interoperability.

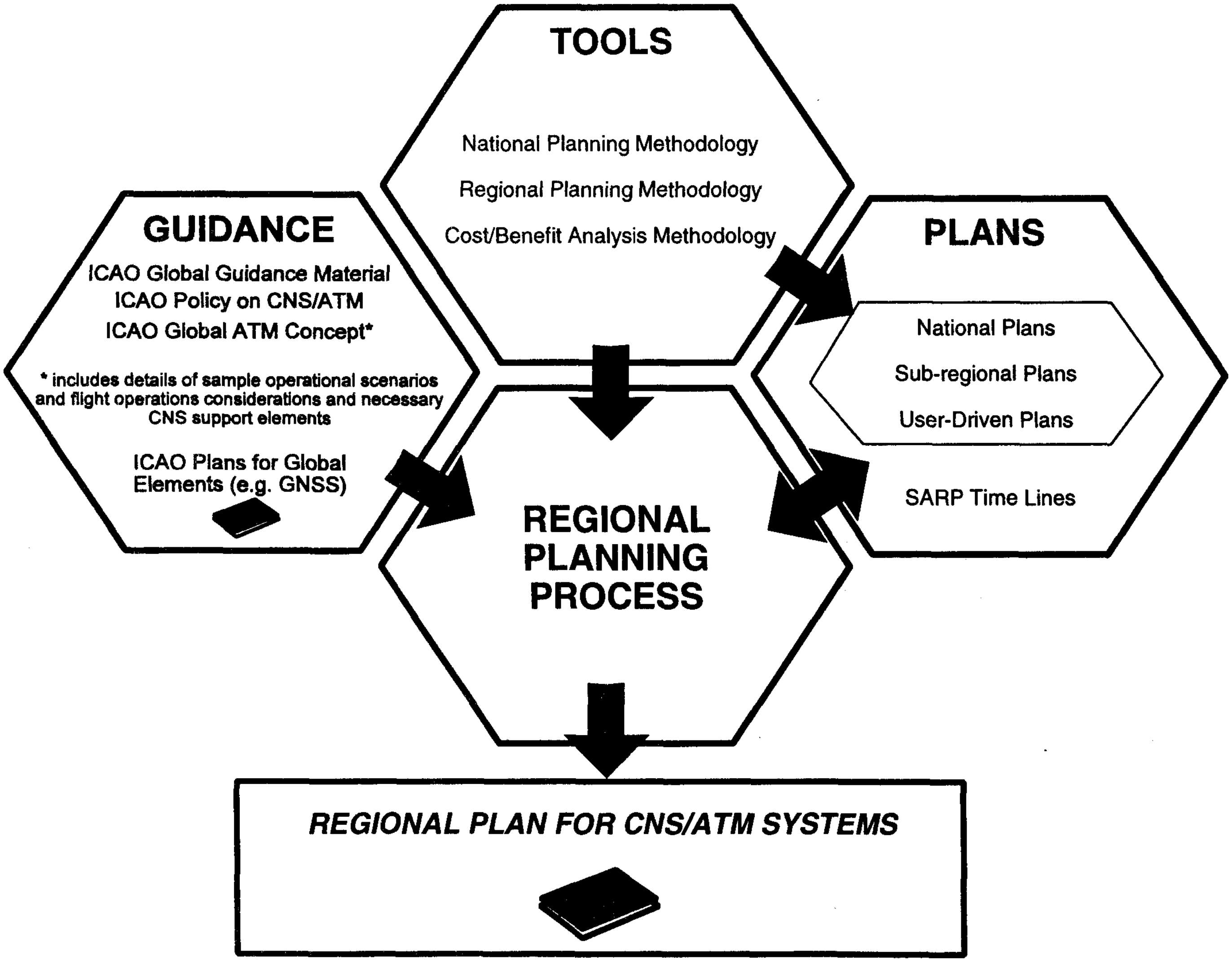

Figure 1-4. Planning process for CNS/ATM systems at the regional level

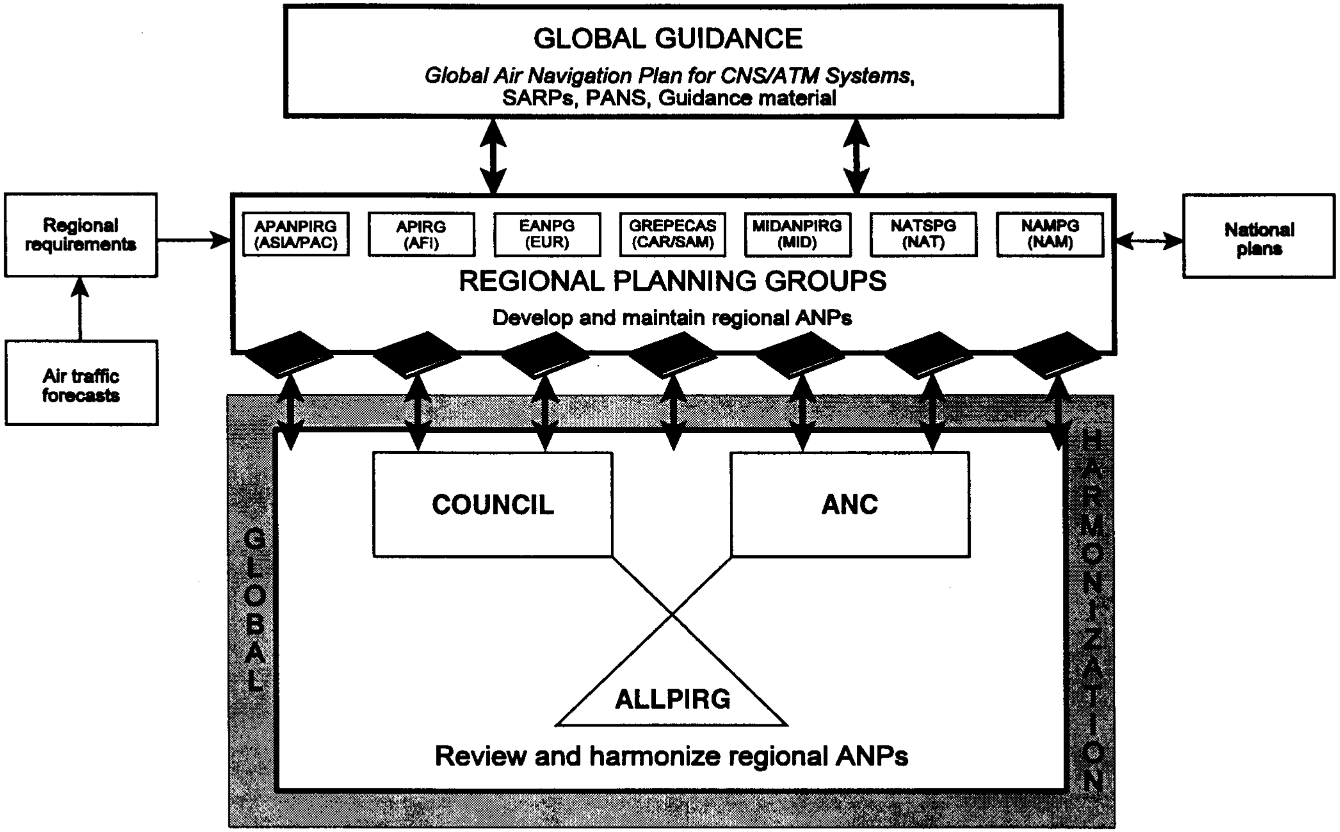

Figure 1-5. Interregional coordination

Chapter 2

CNS/ATM SYSTEMS OVERVIEW AND THE GLOBAL PLAN

BACKGROUND

2.1 The process of getting an aircraft safely and efficiently from its origin to destination requires effective air traffic management systems supported by three key functions: communications, navigation and surveillance. Communications is the exchange of voice and data information between the pilot and air traffic controllers or flight information centres. Navigation pinpoints the location of the aircraft for the air crew. Surveillance pinpoints the location of the aircraft for air traffic controllers; it includes communication of navigation information from aircraft to air traffic control centres that facilitates the continuous mapping of the relative positions of aircraft. ICAO calls the three functions the CNS systems and regards them as forming the basic support services of air traffic management (ATM) systems. While the functions are not new in aviation, both aircraft and their avionics have become more sophisticated.

2.2 In the early 1980s, ICAO recognized the increasing limitations of the then current air navigation systems and the need for improvements to take civil aviation into the 21st century. In 1983, ICAO established the Special Committee on Future Air Navigation Systems (FANS) with the task of studying, identifying and assessing new concepts and new technology and making recommendations for the coordinated evolutionary development of air navigation for the next twenty-five years.

THE FANS SYSTEMS CONCEPT

2.3 The FANS Committee, while critically examining the then current systems for their capabilities and possible modification to meet future needs, had concluded that the shortcomings of these systems were due essentially to three factors:

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

b) the difficulty, for a variety of reasons, of implementing CNS systems and of operating 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.

2.4 The committee concluded that the limitations of the then current systems were intrinsic to the systems themselves, and thus the problems could not be overcome on a global scale, except by new concepts and new CNS systems that would in turn support future ATM systems. The exploitation of satellite technology was the only viable solution. The committee, however, recognized that some line-of-sight systems would continue to be operable where appropriate, such as very high frequency (VHF) communications and SSR Mode S in terminal areas. Thus the FANS concept, now called *CNS/ATM systems*, is a mix of satellite technology and the best of the line-of-sight systems designed to achieve overall optimum performance. The FANS Committee submitted its report in May 1988.

2.5 The transition to the new CNS/ATM systems will not happen at the same time in every part of the world; the level of sophistication of the systems will be adapted to the needs of the different regions/States. Nevertheless, the planning and implementation will need to take into consideration the requirements of the airspace users as well as those of adjacent flight information regions (FIRs) to ensure that the resulting regional/national systems are well coordinated, rationalized and harmonized in such a way as to produce a timely, cost-efficient global system.

GLOBAL PLANNING

2.6 In order to progress toward implementation of CNS/ATM systems, a plan of action was needed. The first such effort towards developing a plan was the ICAO Global Co-ordinated 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 focussing on regional implementation, was required.

2.7 In light of the above, the Council directed the ICAO Secretariat to revise the Global Plan as a "living document" that comprises technical, operational, economic, financial, legal and institutional elements, and which offers 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 the revised edition of the Global Plan, known as the *Global Air Navigation Plan for CNS/ATM Systems*. The Global Plan is divided into two parts; Part I offers a high-level vision and Part II details more information on the status of regional planning. The following paragraphs are extracted from Part I of the Global Plan.

AIR TRAFFIC MANAGEMENT

ATM operational concept

2.8 Attaining the goal of an integrated, global ATM system requires harmonization and standardization of regional and national system elements and procedures. ICAO is developing new SARPs as part of its work on global ATM. States and industry then use this material as a guide toward the development and implementation of ATM systems leading toward global harmonization (see Figure 2-1 for an overview of a structured approach to the work on global ATM).

2.9 The basis for developing the Standards necessary for harmonization and integration is an ATM operational concept for the future ATM system (see Figure 2-2 for an overview of the operational concept and its subsections), which will be developed by ICAO with the assistance of a panel established for this purpose. The ATM concept will clarify the benefits and give States and industry a clear objective for designing and implementing ATM systems. Work on the ATM concept will be aimed at obtaining consensus on several issues (i.e. autonomy of flight*, separation assurance*, situational awareness, etc.). These issues, when agreed upon through ICAO, will become a part of the operational concept leading to Standards and procedures (see Figure 2-2).

2.10 The ATM operational concept will complement the Global Plan and guide CNS/ATM partners and, more specifically, PIRGs and States in the further development of ATM systems. As part of the overall CNS/ATM systems planning process, it will be necessary to consider how the elements of the operational concept could be applied in a particular airspace. In this light, the complete ATM operational concept will consist of the concept developed, taking into consideration the outcome of the step-by-step planning methodology.

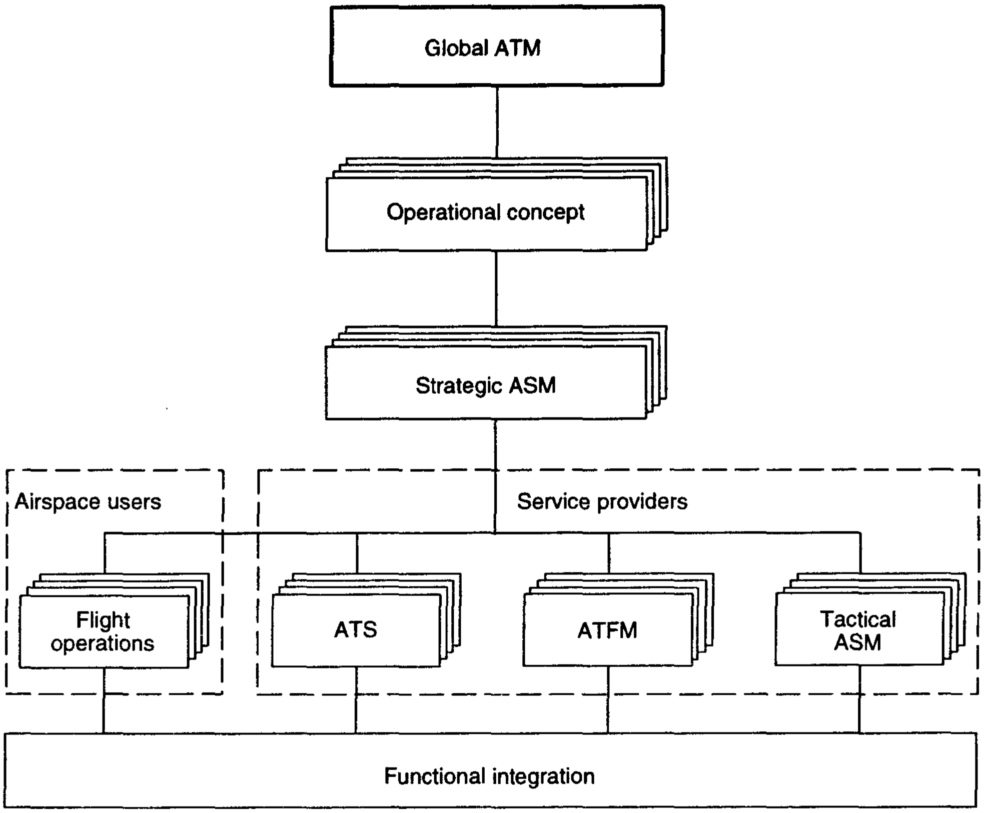

Figure 2-1. A structured approach to the work on global ATM

* Emerging concept or technology — consensus still to be reached.

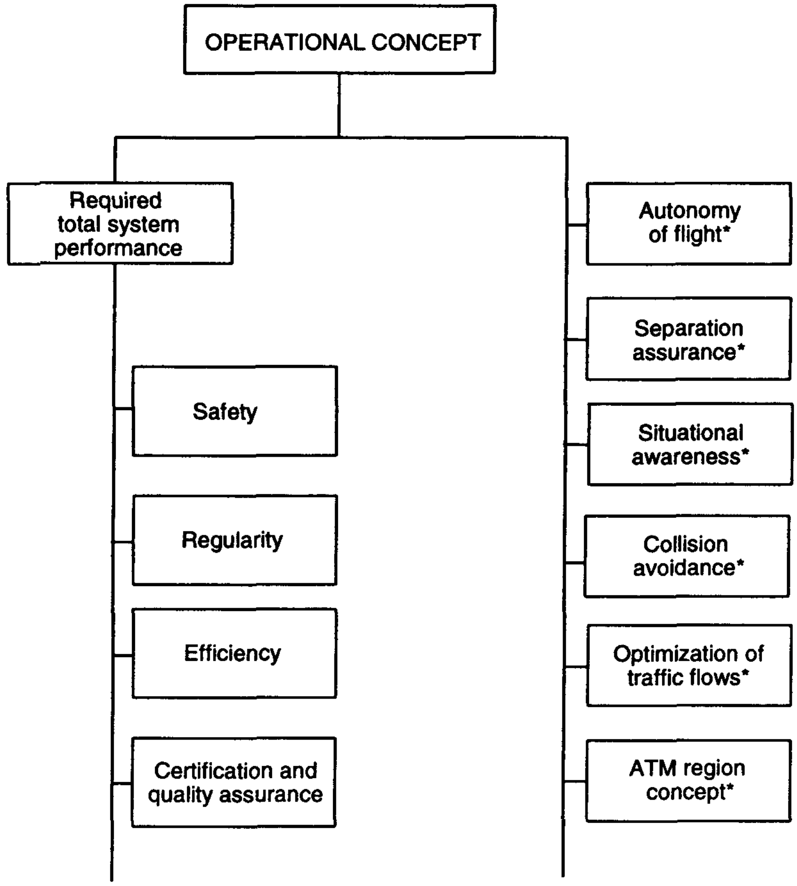

Figure 2-2. Overview of the operational concept and its subsections

Required total system performance (RTSP)*

2.11 ICAO has developed worldwide Standards for many aspects of civil aviation, however, the current ATS system has evolved without the establishment of globally agreed criteria for safety, regularity and efficiency of international civil aviation. A target level of safety has been defined only for some airspaces, but not on a global level. In the absence of agreed criteria for airspace/airport capacity and for flexible use of airspace*, there is no common basis for regularity and efficiency worldwide. As a result, there is no assurance that the future traffic demand and airspace users' needs can be met.

2.12 In light of the above, the future system must be viewed in its totality. The total system can be seen as the totality of airspace, the ATM-related aspects of flight operations, and the facilities and services provided. RTSP will specify criteria that should be met by the entire ATM system in the areas of safety, regularity, efficiency, human factors and sharing of airspace.

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* Emerging concept or technology — consensus still to be reached.

2.13 RTSP will allow the ATM provider and users of a given airspace to determine the optimum usage level of an airspace. For example, lower performance standards could be acceptable in a particular airspace, for some or all system elements, if the users were prepared to accept larger separation standards.

2.14 RTSP will offer guidance to the ICAO PIRGs who will carry out the actual planning of the infrastructure that serves international civil aviation.

Elements of the ATM system

2.15 The envisaged ATM system will consist of several sub-elements, which are: airspace management (ASM), the ATM-related aspects of flight operations, ATS and air traffic flow management (ATFM). These sub-elements will evolve and take on different roles, mainly because they will integrate into a total system. Rather than viewing ground and air as separate functions, the ATM-related aspects of flight operations will be fully integrated as a functional part of the ATM system. Ultimately, this interoperability and functional integration into a total system will yield a synergy of operations that does not currently exist. Through the use of a data link for data interchange between the elements of the ATM system, the functional integration can be accomplished.

Airspace management (ASM)

2.16 ASM has traditionally been recognized as a dynamic sharing of airspace by civil and military users. In a seamless, global ATM system, however, ASM will not be limited only to tactical aspects of airspace use. Its main scope will be toward a strategic planning function of airspace infrastructure and flexibility of airspace use.

2.17 In relation to ATM, strategic ASM is seen to consist of two main elements:

a) the determination, for any given airspace, of the ATM requirements for communications, navigation and surveillance; and

b) infrastructure planning.

Figure 2-3 depicts the approach to the work on strategic ASM.

2.18 *ATM operational requirements for communication.* ICAO is developing the ATM requirements for air-ground and ground-ground communications in support of a global ATM system. This work will include a statement of required communication performance (RCP)*, which will parallel and complement the work already accomplished concerning required navigation performance (RNP) and work being carried out regarding required surveillance performance (RSP)*. These emerging ATM requirements are expected to govern the development of SARPs, procedures and guidance material for the supporting communications systems.

2.19 *ATM operational requirements for navigation.* The ATM navigation requirements will specify area navigation (RNAV) capability of aircraft. While initially this RNAV capability may continue to be provided

* Emerging concept or technology — consensus still to be reached.

by airborne systems that rely on ground-based navigation aids, there will be an increasing trend towards global navigation satellite (GNSS)-based systems. This will lead to one of the main economic benefits of CNS/ATM systems, which is the eventual withdrawal of a portion of the current ground-based navigation system. ICAO is developing the ATM requirements for navigation capability and performance for en-route and terminal area operations as part of its work associated with RNP.

2.20 *ATM operational requirements for surveillance.* Without additional radar and/or automatic dependent surveillance (ADS), airspace capacity will be insufficient to accommodate future air traffic demand. The ATM surveillance requirements under development will specify criteria for radar and ADS coverage. This work will also include a statement of RSP to parallel the work already accomplished concerning RNP and to complement the work being carried out on RCP. It will also lead toward the sharing of surveillance data from ADS, SSR and integrated ADS/SSR systems.

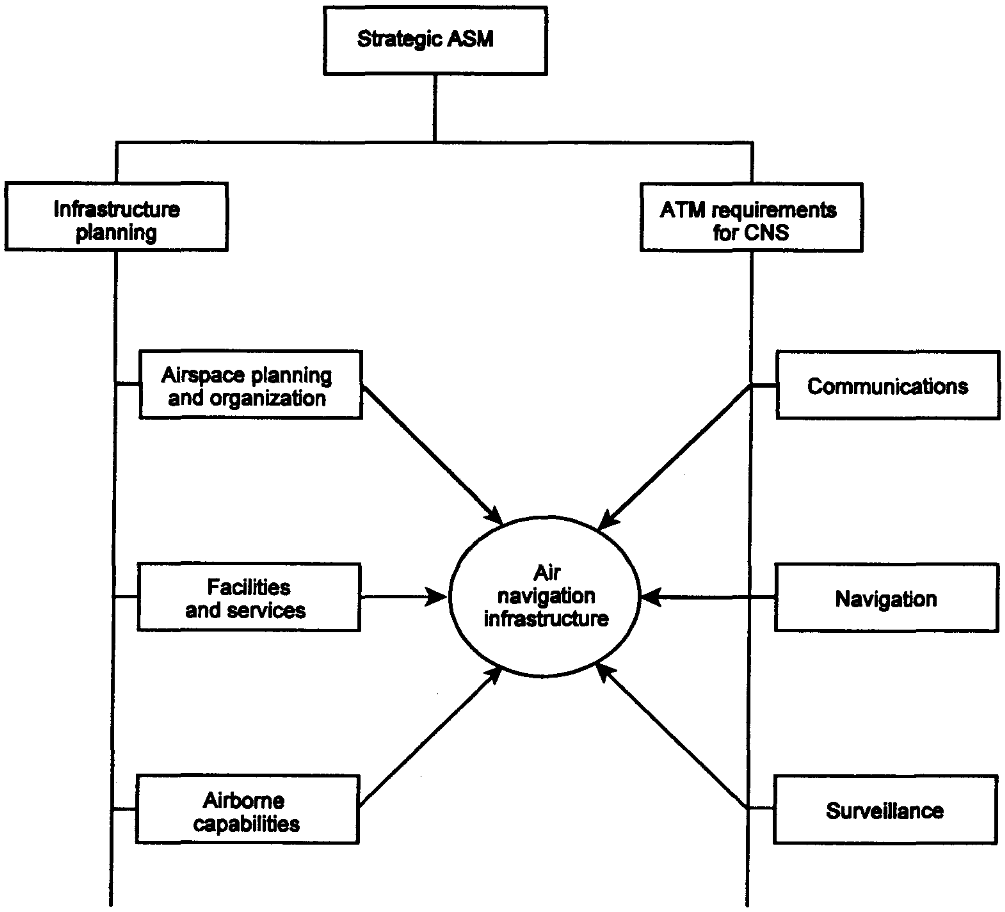

Figure 2-3. Strategic airspace management (ASM)

2.21 *Infrastructure planning.* ICAO continues to develop the operational requirements and planning criteria for airspace organization, services and facilities to support global ATM, on the basis of an airspace planning methodology. The objective of this methodology is to facilitate the optimal use of airspace, organized so as to provide for efficiency of service, while improving the existing levels of safety. The *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689) provides guidancc on the implementation of RNP and RNAV techniques to assist in the CNS/ATM systems implementation planning. This manual was designed to be used as a tool, using risk assessment modelling to derive safe separation minima for use in a given airspace on the basis of the volume of traffic, facilities and services, as well as on airborne capabilities. It provides implementation options for ground-based facilities and airborne systems to achieve required functionality, on the basis of stated objectives in terms of aircraft movements and operationally desirable separation minima. Based on the above, infrastructure planning will derive from clearly identified ATM requirements for CNS (Figure 2-3 refers).

Flight operations

2.22 The ATM-related aspects of flight operations are an integral part of ATM in CNS/ATM systems. Enhanced functional integration of the ATM-related aspects of flight operations and other components of ATM, i.e. ATS, ASM and ATFM, will be a key factor in the implementation of CNS/ATM systems. For example, automated systems on the ground will assist the controller with conflict detection and resolution, based on information derived from aircraft flight management systems and, at some point, will negotiate ATC clearances with these airborne systems. Additionally, other information that is now transmitted by voice will increasingly be carried out using automatic transmission of data.

2.23 The airborne part of ATM comprises three areas:

a) ATM-related functional capabilities of aircraft systems;

b) pilot procedures; and

c) integration of the ATM-related aspects of flight operations into the ATM process.

Recognizing the significance of the airborne component to ATM, the requirements for the ATM functional capabilities of systems such as airborne collision avoidance systems (ACAS), flight management systems (FMS) and airborne databases, are being developed.

2.24 The interface of ADS and ATS data link and other human-machine interface (HMI) issues is also being addressed. Integration work will eventually encompass electronic means to assist aircraft in maintaining an ATC-specified separation*, after such a requirement has been identified as further work on ATM continues.

2.25 *Gate-to-gate operations**. Efficiency of flight operations should be measured collectively for all flight phases, from gate-to-gate, as opposed to measuring efficiency from take-off to landing. The provision of ATM services should therefore support the gate-to-gate concept including flight scheduling and planning, and apron and manoeuvring area management.

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* Emerging concept or technology — consensus still to be reached.

2.26 Aircraft operators require a particularly high degree of regularity and punctuality in order to maintain the efficiency of commercial transport network operations. The ATM system must therefore be flexible enough to cater to short-term changes of departure times, as determined by the operators, in order, for example, to allow the connectivity of flights in cases of delayed arrivals. CNS/ATM systems should support the users in making flexible choices between departure punctuality and departure flexibility as part of an integrated gate-to-gate concept.

2.27 *Flexible use of airspace**. All airspace users should be given access to necessary airspace based on a flexible use of airspace concept, rather than on an ATM system based on the strict segregation of airspace.

2.28 Operators of State aircraft are also airspace users, and their airspace requirements (e.g. for the training of military operational traffic) should be respected. They should, however, not hinder a flexible, optimized use of airspace by other users. For example, a requirement of individual airspace users to "block" airspace of a certain dimension should be catered to on a temporary basis only (i.e. to be activated only when actually required).

2.29 Close coordination among all airspace users, particularly between civil and military, is a fundamental requisite for a flexible use of airspace. CNS/ATM systems should support this function by enhancing the capability of information exchange and real-time monitoring of airspace status.

2.30 *Flight planning.* The accuracy of the flight plan data used for the ground ATC system will be improved by incorporating data calculated in the flight management computer for the three- or four-dimensional flight profiles. The calculation and maintenance of the flight profiles will be shared between FMSs and ground ATC systems through the use of interactive automated aids, which allow a more collaborative role for users based on shared information, such as: current and future status of special-use airspace, traffic density forecasts, current traffic flow requirements and weather information. FMSs should have, *inter alia*, the following capabilities:

a) to calculate the flight profile for the intended flight, based on the flight plan delivered by the airline;

b) to adhere to the flight profile as accepted from the ground ATC system as far as it is within the aircraft flight performance capability; and

c) to automatically notify the ground ATC system as soon as deviations from the agreed flight profile exceed the agreed limits.

2.31 The limits within which an aircraft profile can be changed should be determined by the traffic situation and the aircraft's capability. These limits can be cooperatively negotiated. Such a cooperative process between ground systems and FMSs can only take place when a robust data link system is available; if not, default values will apply.

Air traffic services (ATS)

2.32 ATS will continue to be the primary element of ATM. ATS itself is composed of several sub-elements. These are the alerting service, flight information service (FIS) and ATC. The main objective of

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* Emerging concept or technology — consensus still to be reached.

ATC services is to prevent collisions between aircraft and between aircraft and obstructions on the manoeuvring area and to expedite and maintain an orderly flow of air traffic. The objective of FIS is to provide advice and information useful for the safe and efficient conduct of flights. The objective of the alerting service is to notify appropriate organizations regarding aircraft in need of search and rescue aid and assist such organizations as required.

2.33 Significant progress has been made on the development of provisions related to ATS in CNS/ATM systems. Standardization and implementation planning will ensure that ATS systems supporting ATM are developed so as to provide harmonization and integration into a regional and global network of continuous service. This requires harmonization of radar data and flight data processing systems (FDPS), among others. Eventually, the functional capabilities of ATS support systems such as conflict prediction, detection, advisory and resolution may need to be standardized.

Air traffic flow management (ATFM)

2.34 The objective of ATFM is to ensure an optimum flow of air traffic to or through areas during times when demand exceeds or is expected to exceed the available capacity of the ATC system. An ATFM system should therefore reduce delays to aircraft both in flight and on the ground and prevent system overload. The ATFM system assists ATC in meeting its objectives and achieving the most efficient utilization of available airspace and airport capacity. ATFM should also ensure that safety is not compromised by the development of unacceptable levels of traffic congestion and, at the same time, to assure that traffic is managed efficiently without unnecessary flow restrictions being applied.

2.35 In an integrated ATM system, real-time flow management tools will be required to assimilate the mass of information and offer flow strategies that take full advantage of changing conditions. Many aircraft have sophisticated FMSs that can adapt to changing situations and will communicate automatically with ground systems; therefore, they will be valuable partners in the flow strategy decision-making process. Comprehensive databases will describe current and projected levels of demand and capacity. Sophisticated models that accurately predict congestion and delay will be used to formulate effective real-time strategies for coping with excess demand. Users will interface with the flow management process in-flight planning to negotiate trajectories that best satisfy their needs while meeting ATM capacity constraints.

2.36 The tactical flow management process that monitors the progress of individual aircraft and intervenes in their flight paths when required to meet ATM constraints (e.g. separation standards) will also make extensive use of automation. When a user determines that a flight plan amendment or update is required, a negotiation process will be established between the aircraft's flight management computer system and the ground-based tactical management process to define a new trajectory that best meets the user's objective and satisfies ATM constraints. Similarly, when the ground-based tactical management process recognizes a need to intervene in the cleared flight path of an aircraft, the ATM computer will negotiate with the flight management computer to determine a modification meeting ATM constraints with a minimum deviation from the user's preferred trajectory. These negotiation processes will be a dialogue involving both the pilot and air traffic controller to the extent required to permit them to exercise their management and control responsibilities. In essence, ATS and ATFM will merge into a single, seamless system.

2.37 To ensure global compatibility of regional ATFM systems as part of an integrated ATM system, standardization of functionality is required on a worldwide basis. Such standardization is being undertaken as part of the technical work programme of ICAO through the development of functional specifications and procedures for the worldwide integration of ATFM systems which would facilitate an optimal flow of air traffic

Functional integration

2.38 ATM consists of a ground part and an air part, where both are needed to ensure a safe and efficient movement of aircraft during all phases of operations. The airborne and ground components of the system must have the functional capability of interfacing with one another in order to attain the general objectives of ATM. The ground part includes ATS, ATFM and ASM, where ATS is considered to be the primary component of ATM. Functional compatibility of the data exchanged between the airborne and the ground elements is essential to ensure the efficiency of the system. Furthermore, the various elements of the overall ATM system must be designed to work together effectively to ensure homogeneous, continuous and efficient service to the user from pre-flight to post-flight. International harmonization and, ultimately, integration into a seamless system, are needed to provide for consistency in operations across national boundaries.

2.39 Increasing numbers of aircraft are being equipped with new technology CNS systems that would enable an aircraft to proceed along any desired flight path. Current supporting ATS systems with varying capabilities do not permit optimum flight trajectories in most airspaces. The capabilities of airborne and ground-based systems cannot be fully exploited in the absence of functional integration of these systems.

COMMUNICATIONS

Function

2.40 The communication element of CNS/ATM systems provides for the exchange of aeronautical data and messages between aeronautical users and/or automated systems. Communication systems are also used in support of specific navigation and surveillance functions.

Communication services envisaged

2.41 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.; and

   2) aeronautical operational control (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).

2.42 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 ones.

Main features of new communication systems

2.43 There are some fundamental differences between conventional aeronautical communication systems and those which form parts of the new CNS/ATM systems. Some key features of the new systems that significantly differ from those of conventional ones are:

a) most routine communications are done by data interchange;

b) voice communication is mainly used in non-routine and emergency situations; and

c) there is emphasis on global connectivity and operation.

Such features allow for better usage of communication channels and enable facilities to be shared among many users.

Air-ground communications

2.44 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 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.

2.45 Transmission of air-ground messages is carried out over one of the following radio links:

a) Aeronautical mobile-satellite service (AMSS) — Geostationary communication satellites, designed specifically for mobile communications, offer wide/near global coverage and excellent voice and data communication 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. In near/medium terms, the saturation of VHF frequency bands for aeronautical communications may occur in some parts of the world. To this effect, provisions have been made to reduce, where needed, channel spacing from 25 kHz to 8.33 kHz, increasing the number of available channels in that area. Standards are also being developed for a time-division multiple-access digital radio as the medium-term solution (after 2002) to spectrum congestion and enhanced air-ground services.

c) High frequency ((HF) analog) — Radio communications using the HF band for over-the-horizon 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 and, eventually, the use of HF for routine communications will diminish. 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.

d) VHF digital link (VDL) Mode 1 — The use of analog VHF radio for data interchange was first initiated by aircraft operating agencies in the late 1970s. Existing airborne VHF radios have been used to transmit AOC and AAC data between aircraft and their operating agencies through special ground stations and interconnecting networks. The system, which is called the aircraft communication addressing and reporting system (ACARS), has evolved and grown considerably and, currently, many major carriers use it for AOC, AAC and limited, non-time critical ATSC purposes. ACARS has not been subject to any ICAO standardization process, but the VDL Mode 1 has been specifically designed to permit the use of its radio and data modulation scheme and equipment. Data rate in VDL Mode 1 is 2400 baud. Mode 1 can be seen as a stepping stone towards Mode 2.

e) VDL Mode 2 — This mode, which has already been standardized by ICAO, uses digital radio techniques. The nominal data rate of 31.5 kbps is compatible with the 25 kHz channel spacing and VDL Mode 3 (integrated voice and data). The modulation scheme used in Mode 2 is capable of supporting different protocol suites for different operational applications, thereby greatly increasing the efficient use of the VHF channel.

f) VDL Mode 3* — This mode uses a time division multiple access (TDMA) technique and is also being standardized by ICAO. TDMA uses digital radio techniques capable of integrating both voice and data communication 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).

g) VDL Mode 4* — This mode uses a self-organizing time division multiple access (STDMA) technique which, in addition to providing the data communication functions, is also intended to make available navigation and surveillance data link capabilities.

h) SSR Mode S data link — The SSR Mode S data link provides surveillance capability and an air-ground data link that is specifically suitable for limited data messaging in high-density areas. It is also capable of operating in a mixed environment where different levels of data link capability exist among aircraft transponders.

i) HF data link — Studies have shown that the use of HF data link for ATSC would be feasible. As propagation anomalies seldom affect the entire HF frequency band at all locations, a carefully placed system of well-connected ground stations and availability of a suitable pool of frequencies would make it possible to find a "best" frequency for transmission of data packets at any place and time. The HF data link could complement AMSS in oceanic/remote areas and provide primary capability in polar areas.

2.46 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 ISO 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 communication service, which allows ground, air-ground and avionics data subnetworks to interoperate for the specified aeronautical applications, is the aeronautical telecommunication network (ATN). The above-mentioned air-ground data links are

* Emerging concept or technology — consensus still to be reached.

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.

2.47 Radio links used for communication 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;

b) prevent RF interference (RFI) into frequencies, bands, services and users of aeronautical radio systems; and

c) allow the provision of communication services by commercial service providers.

Ground-ground communications

2.48 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.

2.49 A variety of ground networks, implemented by States, a group of States or commercial service providers, will continue to provide data communication services to aeronautical users. However, only networks that use packet switching techniques and are compatible with ISO OSI reference model will be able to use the internetworking 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.

2.50 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 towards using fully digital voice switching and signalling techniques as more flexible and less costly digital leased lines become widely available.

Aeronautical telecommunication network (ATN)

2.51 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 communication 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 communication Standards;

c) accommodate differing services (e.g. preferred air-ground subnetworks);

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

2.52 As a result of advancing technology, new communication systems offer more, better and cheaper services. The use of such new systems for international civil aviation applications is being investigated. Some future communication systems that have the potential to provide 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.

2.53 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)*

2.54 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 communication system capable of handling all communication, 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 must consider all available as well as emerging communication systems, though some may only perform a single function or only serve a limited area.

2.55 The availability of several communication 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 with VHF for aeronautical communication, perhaps VDL could be the best choice for an air-ground data link as most of the necessary infrastructure (e.g. buildings, towers, power supplies) is already in place. Similarly, if an extensive network of SSR Mode S has already been implemented in an area, data link capability can be added with relatively little additional investment.

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* Emerging concept or technology — consensus still to be reached.

2.56 Although having the choice between several types of communication 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 communication performance parameters. The term RCP therefore refers to a set of well-quantified communication performance requirements, such as capacity, availability, error rate, transit delay and so on. Once RCP has been specified for an operational scenario in a given airspace, any single communication system or combination of systems meeting the set parameters can be considered as operationally acceptable.

NAVIGATION

Objectives

2.57 The navigation element of CNS/ATM systems is meant to provide accurate, reliable and seamless position determination capability worldwide, through the introduction of satellite-based aeronautical navigation.

Required navigation performance (RNP)

2.58 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.

2.59 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.

2.60 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.

2.61 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 the *Manual on Required Navigation Performance* (Doc 9613).

2.62 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)

2.63 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.

2.64 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.

2.65 The GPS space segment is composed of twenty-four 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.

2.66 The GLONASS space segment consists of twenty-four operational satellites and several spares. GLONASS satellites orbit at an altitude of 19 100 kilometres 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

2.67 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

2.68 One type of aircraft-based augmentation system (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.

2.69 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 the combination of sensor inputs through filtering techniques.

Ground-based augmentations

2.70 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 aircraft in the vicinity (approximately 37 km (20 NM)). These signals provide corrections that increase the position accuracy locally as well as satellite integrity information. This capability requires data link(s) between the ground and the aircraft.

Satellite-based augmentations

2.71 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 a satellite-based augmentation system (SBAS).

2.72 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

2.73 Simple GPS or GLONASS receivers that do not include RAIM capability (or similar forms of integrity monitoring) generally cannot meet requirements for all phases of flight.

2.74 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 that could not be obtained by use of GPS or GLONASS alone.

WGS-84 coordinate system and aeronautical databases

2.75 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 ground-derived coordinates, calculated coordinates and the satellite system-derived coordinates use the same geodetic reference system.

2.76 In support of evolving satellite-based technology, ICAO adopted WGS-84 as the common geodetic reference datum for civil aviation with an effective 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.

2.77 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

2.78 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.

2.79 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.

2.80 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 performance requirements: accuracy, integrity, availability and continuity of service.

2.81 GNSS performance requirements are given in Annex 10, Volume I. These requirements support GNSS operations in airspace with various levels of traffic and complexity through the definition of ranges of availability and continuity requirements.

2.82 The terminology in 2.80 applies to the required state of avionics equipage and the ability of aircraft to meet RNP requirements with, in the 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 by State.

2.83 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 as necessary to support all phases of flight. It is therefore necessary to harmonize the withdrawal of conventional navigational aids with the introduction of GNSS navigation service. These considerations are not applicable to airspaces where present navigational aids are not available and GNSS-alone service can be introduced to benefit GNSS-equipped users.

2.84 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 VHF omnidirectional radio range (VOR), distance measuring equipment (DME) and instrument landing system (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 approach minima to more runways.

2.85 Advantages of GNSS services include the use of GPS/ABAS for en-route and non-precision approach operations where there are no existing ground-based navigation aids. 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.

2.86 Several technical concerns have been raised with respect to the reliance on GNSS services. Principal among them is the potential for intentional interference, or jamming, that could 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.

2.87 Other risk areas are expected to be mitigated as GNSS continues to evolve to a more comprehensive service that will include 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 when it is acceptable to rely on GNSS alone for the provision of navigation service.

Systems to support approach, landing and departure operations

2.88 The standard non-visual aids to precision approach and landing are defined in Annex 10, Volume I, Chapter 2. It is intended that 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 is to:

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 receiver (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.

SURVEILLANCE

Current surveillance systems

2.89 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 (primary surveillance radar [PSR] or secondary surveillance radar [SSR]) which measures range and azimuth of aircraft from the ground station.

Functional description

Voice position reporting

2.90 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)

2.91 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 the 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)

2.92 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 is 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 communication system.

Automatic dependent surveillance (ADS)

2.93 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 would 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 communication (voice for at least emergency and non-routine communication).

ADS-broadcast (ADS-B)*

2.94 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 ground-based, within range of this broadcast, can process the information. ADS-B is currently defined only for line-of-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 radars such as airport surface detection equipment (ASDE).

Technical options overview

2.95 Implementation of ADS requires:

a) position data supplied by the on-board navigational equipment;

b) a message time stamp within 1 second Coordinated Universal Time (UTC);

c) an air-ground data link;

d) a ground infrastructure providing the information to ATC; and

e) appropriate air traffic services procedures.

2.96 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 as 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

2.97 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;

* Emerging concept or technology — consensus still to be reached.

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 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)

2.98 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 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. ACAS III, which will provide both horizontal and vertical resolution advisories, is under development.

Required surveillance performance (RSP)*

2.99 The emergence of several types of surveillance systems or procedures, in addition to existing surveillance facilities to support ATM functions, has raised concerns 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 low-density traffic areas to high-density terminal areas. Until such time as one surveillance system is able to meet all requirements, the aviation community must 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 RSP therefore refers to a set of well-quantified surveillance performance requirements such as capacity, availability, accuracy, update rate and so on. 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.

* Emerging concept or technology — consensus still to be reached.

Future trends

2.100 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)* and is envisaged to be part of ACAS III*.

2.101 ACAS provides for airborne surveillance and collision avoidance*. Airborne surveillance systems have the potential to provide, in addition to the avoidance of collisions, other functionalities such as situational awareness* and separation assurance*. This potential of airborne surveillance is being investigated whilst ensuring that the collision avoidance functionality is not adversely affected.

2.102 As of 31 December 1996, some 20 000 aircraft were equipped with Mode S transponders, and 10 000 of these were also ACAS-equipped. The level of equipage is expected to increase in accordance with the global mandatory carriage of ACAS and pressure altitude SSR transponders.

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* Emerging concept or technology — consensus still to be reached.

Chapter 3

CURRENT INFRASTRUCTURE

3.1 The first activity in the preparation of a national CNS/ATM systems plan is to conduct, at the national level, a review of the present availability of systems and services. In the execution of this review, a status report is prepared for each of the facilities. Such an inventory of systems in terms of airports, airspace and equipage, besides being a starting point for the development of the plan, can eventually have a technical, operational and financial impact on the final product. The matrices presented in Tables 3-1 to 3-7 will assist in the process of this stock-taking task.

AIRPORTS

3.2 The listing of airports, in indicating the type of traffic each airport handles (international or domestic), leads to an input for deciding the location of terminal facilities. The runway configuration, weather conditions, current traffic levels and aerodrome layout form the basis for determining the type of surface movement control systems required.

AIRSPACE

3.3 Efficient airspace management is fundamental to increasing the capacity of the air traffic management system. The various components of the airspace structure, i.e. ATS routes and reserved/restricted areas, within a State have evolved in a manner that has preserved the distinction between civil airspace and military airspace. To determine the extent of airspace available for civil aircraft usage, it is necessary to identify the restricted area in each FIR. Any airspace not available for civil operations makes it necessary to operate along a fixed route structure, which often requires following a circuitous route. Consequently, there is a need to coordinate with the military in the flexible use of airspace. The route structure and traffic density on each route may necessitate a review of current practices in airspace management.

COMMUNICATIONS

3.4 While dealing with the systems meant for voice communications, the matrix refers to equipment of both older and current generations. Main and standby equipment together constitute one system in operation. Any new systems planned or under installation are also to be listed.

NAVIGATION

3.5 The matrix for navigation covers NDB/VOR/DME as en-route aids, and ILS/MLS as precision approach aids. In listing each system, the assessment of its life cycle is important. The parameters to be considered in evaluating the useful life of equipment include the number of failures per year, mean time to repair, and availability of spares. The navigation equipment under installation or planned are also to be included.

SURVEILLANCE

3.6 The surveillance system, in the present scenario, includes PSR (terminal)/or ASR, PSR (en-route)/or ARSR and SSR. While describing the equipage, it is necessary to bring out whether SSR in operation is monopulse and can be upgradable to Mode S. This information would facilitate in deciding the most cost-effective solution for the surveillance element. While doing this exercise, radars under installation or planned are also to be taken into account.

Table 3-1. Current infrastructure — airports (sample matrix)

SNo	Name	International and/or domestic	Aerodrome layout	No. of runways/ configuration
1.	XXX	International and domestic	Complex	Twp/parallel

QUALIFICATIONS

a) New airports, if planned, may also be listed separately.

b) Aerodrome layout may be classified as basic, simple or complex:
Basic — An aerodrome with one runway with one taxiway to one apron area;
Simple — An aerodrome with one runway having more than one taxiway to one or more apron areas;
Complex — An aerodrome with more than one runway, having many taxiways to one or more apron areas.

c) Runway configuration may be converging, intersecting, parallel or near-parallel.

Table 3-2. Current infrastructure — airspace (sample matrix)

SNo	Flight Information Region	Oceanic			Continental		
		Total Area NM^2	Restricted NM^2	Restricted as %	Total area NM^2	Restricted NM^2	Restricted as %
1.	XXX	1 000 000	300 000	30	300 000	210 000	70
	Total						

Table 3-3. Current infrastructure — route structure (sample matrix)

ATS route designation	Bidirectional or unidirectional	Crossing routes *1	Traffic volume (per week)	ICAO airspace classifications *2	ATC service provided *3	Separation minima applied *4			Traffic characteristics *5	Remarks *6
						Long	Lat	Vertical		

*1. e.g. "several crossing routes", "none", etc.
*2. classes A to G (Annex 11, Appendix 4, refers).
*3. e.g. "Area radar control", etc.
*4. if applicable.
*5. e.g. "frequent altitude change", "numerous VFR activities", etc.
*6. e.g. "frequent convective weather (CB)", etc.

Table 3-4. Current infrastructure — voice communications: (VHF RT, HF RT, ATIS and VOLMET) (sample matrix)

SNo	System	Location(s)	Qty	Date of installation	Date until which existing system is expected to provide satisfactory service
1	VHF R/T	XXX		5.10.90	5.10.2005
		YYY	1510	⊗ 20.07.2000	20.07.2015
2	HF R/T	XXX	5	10.09.80	10.09.95
3	ATIS	XXX	3	△ 31.03.99	31.03.2014

QUALIFICATIONS

a) VHF R/T refers to all phases of flight.
b) HF R/T includes both MWARA and RDARA frequencies.
c) ATIS is automatic terminal information service operating in VHF band.
d) VOLMET (meteorological information for aircraft in flight) is a voice broadcast on HF about meteorological information.
e) The equipment planned or under installation may also be shown.
f) Assume 15 years of life.
g) △ Indicates facility under installation.
h) ⊗ Indicates facility planned.
i) Main and standby equipment together constitute one system in operation.

Table 3-5. Current infrastructure — navigation: NDB, VOR (CVOR/DVOR) and DME (sample matrix)

SNo	System	Location(s)	Qty	Date of installation	Date until which existing system is expected to provide satisfactory service
1	NDB	XXX	1	30.06.80	30.06.95
2	VOR (DVOR)	XXX	1	△31.03.99	31.03.2014
	VOR (CVOR)	YYY	1	8.09.90	8.09.2005
3	DME	XXX	1	⊗15.02.2000	15.02.2015

QUALIFICATIONS

a) Assume 15 years of life.
b) △ Indicates facility under installation.
c) ⊗ Indicates facility planned.

Table 3-6. Current infrastructure — navigation: ILS/MLS (including DME) (sample matrix)

SNo	System	Location(s)	Qty	Date of installation	Date until which existing system is expected to provide satisfactory service
1	ILS (CAT. I)	XXX	1	28.11.95	28.11.2010
2	ILS (CAT. II)	YYY	1	24.05.82	24.05.97
3	ILS (CAT II)	YYY	1	△31.05.99	31.05.2014
4	MLS (CAT. I)	ZZZ	1	⊗01.02.2000	01.02.2015

QUALIFICATIONS

a) Assume 15 years of life.
b) △ Indicates facility under installation.
c) ⊗ Indicates facility planned.
d) ILS/MLS system includes markers, locators and DME, as the case may be.

Table 3-7. Current infrastructure — surveillance: all primary (ARSR, ASR, ASDE) and secondary radars (Mode A/C, Mode S) (sample matrix)

SNo	System	Location(s)	Qty	Date of installation	Date until which existing system is expected to provide satisfactory service
1	PSR (Terminal)	XXX	1	△20.03.99	20.03.2014
2	PSR (En-route)	YYY	1	03.09.86	03.09.2001
3	SSR (Mode A/C)	ZZZ	1	⊗20.05.2000	20.05.2015
4	SSR (Mode S)	XXX	1	⊗30.06.2000	30.06.2015
5	ASDE	YYY	1	10.09.95	10.09.2010

QUALIFICATIONS

a) Assume 15 years of life.
b) SSR Mode A/C and SSR Mode S may be indicated separately.
c) △ Indicates facility under installation.
d) ⊗ Indicates facility planned.
e) PSR (terminal) is also known as ASR.
f) PSR (en-route) is also known as ARSR.
g) ASDE is airport surface detection equipment.

Chapter 4
EVALUATION OF CURRENT SYSTEMS

A comprehensive evaluation and analysis of the characteristics and the capabilities of the current system in terms of equipage and operations is required. The flow chart at Figure 4-1 is an approach for the evaluation of the current systems and the determination of their shortcomings. The analysis will result in the identification of short-term improvements for immediate deficiencies and the development of functional requirements with regard to long-term improvements for long-term problems. The checklists at Tables 4-1 and 4-2 can assist the State in determining the areas of limitations and shortcomings. While the lists are not exhaustive, they are, nevertheless, an attempt to identify the general characteristics of the systems.

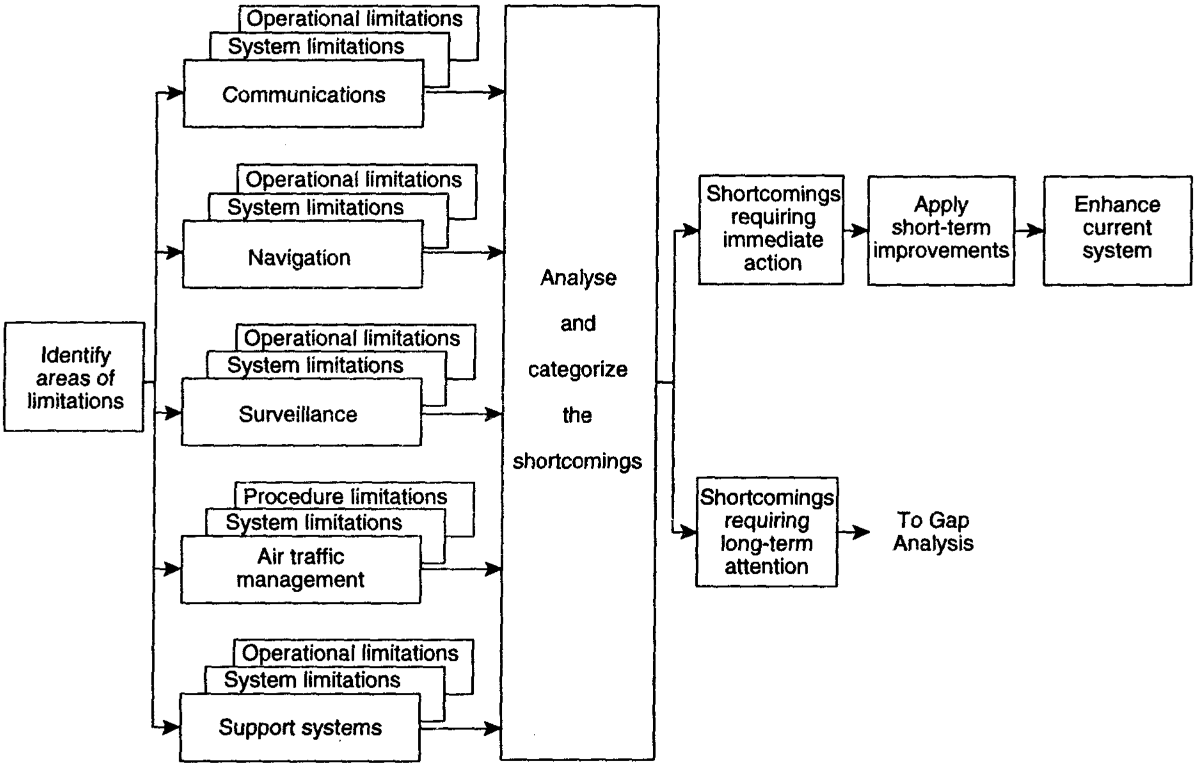


Figure 4-1. Evaluation of current systems

Table 4-1. Shortcomings of current systems (sample matrix)

Communications	Navigation	Surveillance
1. Voice communications control system (VCCS) not available	1. Limited coverage and accuracy of VOR/DME/NDB	1. Limited surveillance both in remote areas and continental airspace
2. VHF radiotelephony coverage poor	2. Difficult to site VOR/DME/NDB in remote areas and hilly regions, therefore lack of navigation guidance in these regions	2. Difficult to site a radar in certain parts of the State
3. VHF radiotelephony has interference problems	3. Precision approaches Cat. I not available	3. Non-monopulse SSRs are not operationally suitable
4. VHF frequency and channel congestion	4. FM interference and channel capacity problem in ILS	4. No surveillance available for airport surface area; low visibility causing problems
5. The ground-to-ground voice/ data network is not available	5. At some airports, difficult to site an ILS	5. No surveillance possible in oceanic airspace
6. The terrestrial-based, ground-to-ground, voice/data network is performing poorly	6. Navigation equipment (NDB/ VOR/DME/ILS) is old and performance poor	6. Adequate numbers of primary/ secondary radars are not available to cover entire airspace
7. HF/RT noisy, uncertain and inefficient	7. Remote monitoring/ maintenance facility not available for VOR/DME/ILS	7. Radar (primary/secondary) equipment in operation is outdated and no spares available
8. Some circuits of AFTN are of low speed/not compatible	8. Siting decisions of NDB/ VOR/ILS are not appropriate	8. Siting decisions of primary/ secondary are not appropriate
9. VHF/HF/AFTN equipage old, causing maintenance problems	9. Lack of navigation guidance (NDB/VOR/DME) in en-route continental airspace	9. Radar networking does not exist
10. Lack of air-ground data links	10. CVOR is experiencing scalloping due to nearby structures/obstructions	10. No surveillance available in en-route continental/ terminal areas

Table 4-2. Shortcomings of current systems (sample matrix)

Air traffic management	Support systems
Airspace management (ASM)	1. Maintenance facilities for CNS equipage is poor/ outdated
1. Airspace segregation between military and civil operations	2. Flight calibration facilities are inadequate/not available
2. The use of fixed routes	3. Manpower skills are low
3. Airspace sectorization is not optimal, particularly between upper/lower airspaces	4. Lack of adequate training infrastructure
4. Lack of parallel route structure to relieve route congestion	
Air traffic services (ATS)	
5. Need for reduced horizontal/vertical separation minima to increase airspace capacity	
6. Poor coordination between ATS centres	
7. Manual separation calculations	
8. Manual conflict detection	
9. Lack of ATS automation tools	
Air traffic flow management (ATFM)	
10. Inefficient use of airspace and ATC system capacity	
11. Lack of optimum flow of air traffic when demand exceeds available ATC system capacity	
12. ATFM procedures not established	

Chapter 5
AIR TRAFFIC FORECASTS

ICAO'S FORECAST

5.1 ICAO's current forecast of the future growth in air transport is depicted in Figure 5-1 below. 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-kilometres 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 VORs, radars 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.

DEMAND FOR CNS/ATM SERVICES

5.2 The major influences that are expected to have an impact on the demand for CNS/ATM services are:

a) national/international tourism;

b) gross domestic product;

c) regional and sectoral economic development;

d) content and nature of competition in domestic and international aviation; and

e) overflying aircraft movements.

5.3 As aircraft movements — rather than passengers — are the fundamental part of demand for CNS/ATM services, it is necessary to forecast aircraft movements at major airports and on major air routes. However, to arrive at this figure, we need to develop a structured approach by first assessing passenger forecast, followed by freight forecast. If freighter aircraft represent a small portion of movements in an airspace, they can be included with the passenger aircraft movements. Due to any reason, if passenger forecasts or freight forecasts are not available or require a long time-frame to undertake the task, it would be appropriate to focus on aircraft movements, as most of the benefits and some of the costs associated with CNS/ATM depend on the quantity of traffic served by the system. Overflying aircraft movements represent the traffic which uses upper airspace of the State but does not originate/terminate within the State. Figure 5-2 is a graphical representation of elements involved in capacity assessment of ATM. Tables 5-1 and 5-2 are the sample matrices for compiling the relevant data. The information provided in these two tables will be the input for cost/benefit analyses.

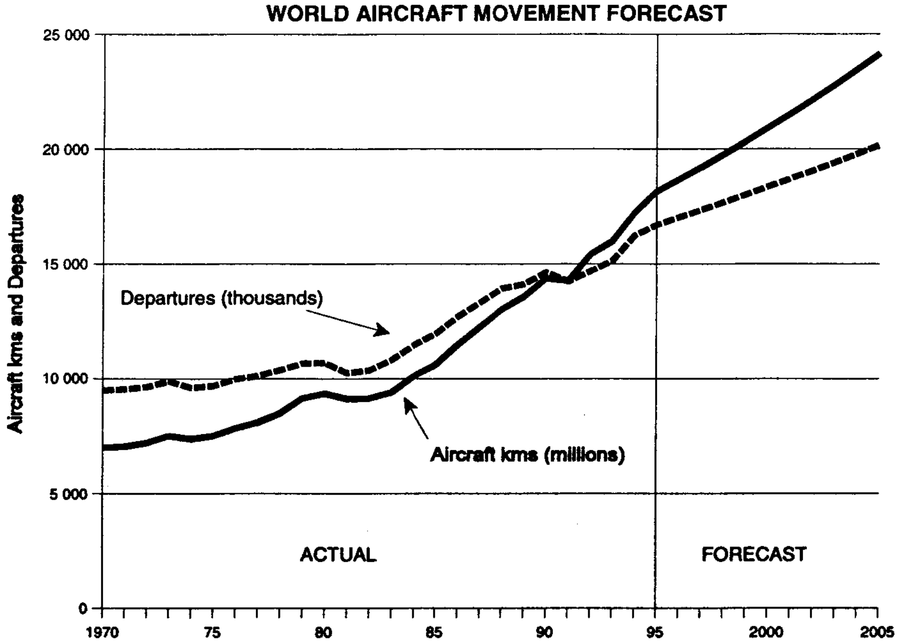


Figure 5-1. Outlook for world aircraft movements

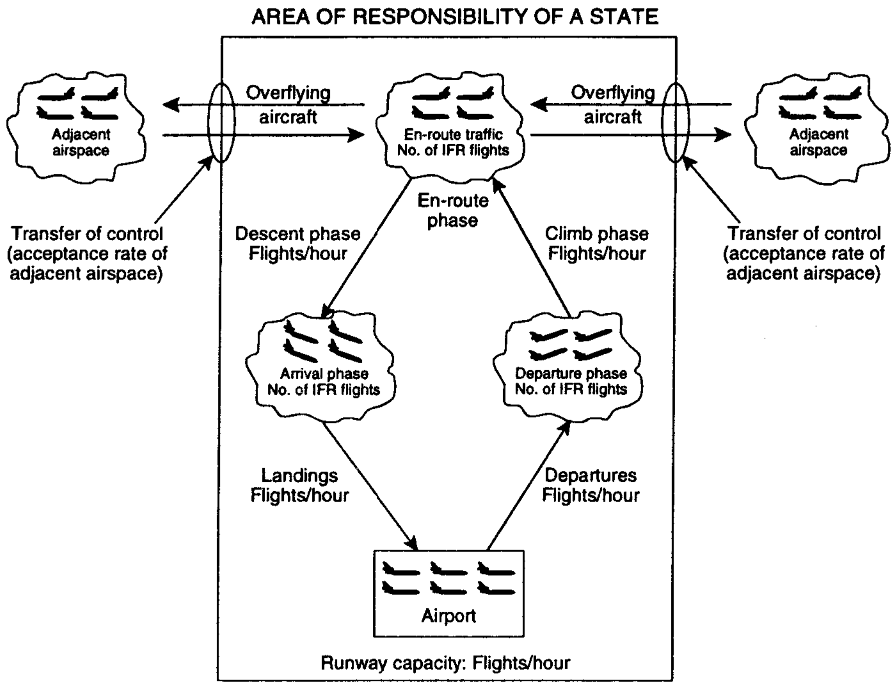


Figure 5-2. Capacity assessment for ATM

Table 5-1. Summary of air traffic forecasts for the years 2003/2008/2013 (sample matrix)

	Actual	Estimate	Forecast			Average annual growth rate (per cent)		
	1998	1999	2003	2008	2013	1999 - 2003	2004 - 2008	2009 - 2013
Passengers (millions) Domestic International Total								
Freight (thousand metric tonnes) Domestic International Total								
Aircraft movements (thousands) Domestic International Total								
Over-flying aircraft (thousands) Total								

QUALIFICATION

If passenger and freight forecasts are not available, the State is to focus on aircraft movements/over-flying aircraft.

Table 5-2. Aircraft hours in national airspace

Movement	Average traffic duration in national airspace in hours
International	
Domestic	
Overflight	

Chapter 6

AIRSPACE USERS' NEEDS AND FUNCTIONAL REQUIREMENTS

AIRSPACE USERS' NEEDS

6.1 Users' needs are expressed in terms of requirements and expectations regarding the future ATM system. Four major categories of airspace users are identified as:

a) commercial air transport;

b) military aviation;

c) general aviation; and

d) aerial work.

They can be further subdivided into special interest groups, i.e. groups of users who are expected to have at least some requirements that are different from those of the average user (see Table 6-1).

6.2 Complementary to the objectives of ATM, users generally emphasize the need for:

a) continuous involvement of users in the planning process;

b) basing the development and implementation planning on rigorous applications of cost/benefit analysis;

c) ensured interoperability of systems with adjacent areas;

d) delivery of various levels of service as requested by individual users;

e) supporting flexible, dynamic adjustment of aircraft trajectories;

f) continuous, uninterrupted operation of CNS facilities;

g) improved availability and increased accuracy of meteorological data required for flight; and

h) coordination with the military for flexible use of airspace.

6.3 Though airspace users generally underline the need for the development of an integrated ATM system taking advantage of future technologies and more efficient procedures for ATM services, for more specific requirements, the planning group, in the course of its planning activities, may need to involve State airspace users' groups.

GAP ANALYSIS LEADING TO FUNCTIONAL REQUIREMENTS

6.4 Gap analysis involves the study of various inputs for the process and listing of the parameters/services which need to be addressed in order to meet the defined service level. In other words, gap analysis is used to investigate the difference between what is available now and what is required to be done in order to achieve the desired target/service level.

6.5 The approach, shown graphically in Figure 6-1, will provide more visibility in the planning process, facilitate the solution of the most appropriate technical or operational means of resolving the issues, and highlight critical areas. In the execution of this task, close cooperation with aircraft operators will be necessary in order to ensure that the proposed technical solutions produce benefits at an acceptable cost.

6.6 The functional requirements, which stem from gap analysis, will offer solutions for performance shortfalls and thus achieve the desired service level. The matrix at Table 6-2, detailing improvements needed both for the short term and the long term and covering all elements of CNS/ATM, will serve as a checklist, while identifying the functional requirements.

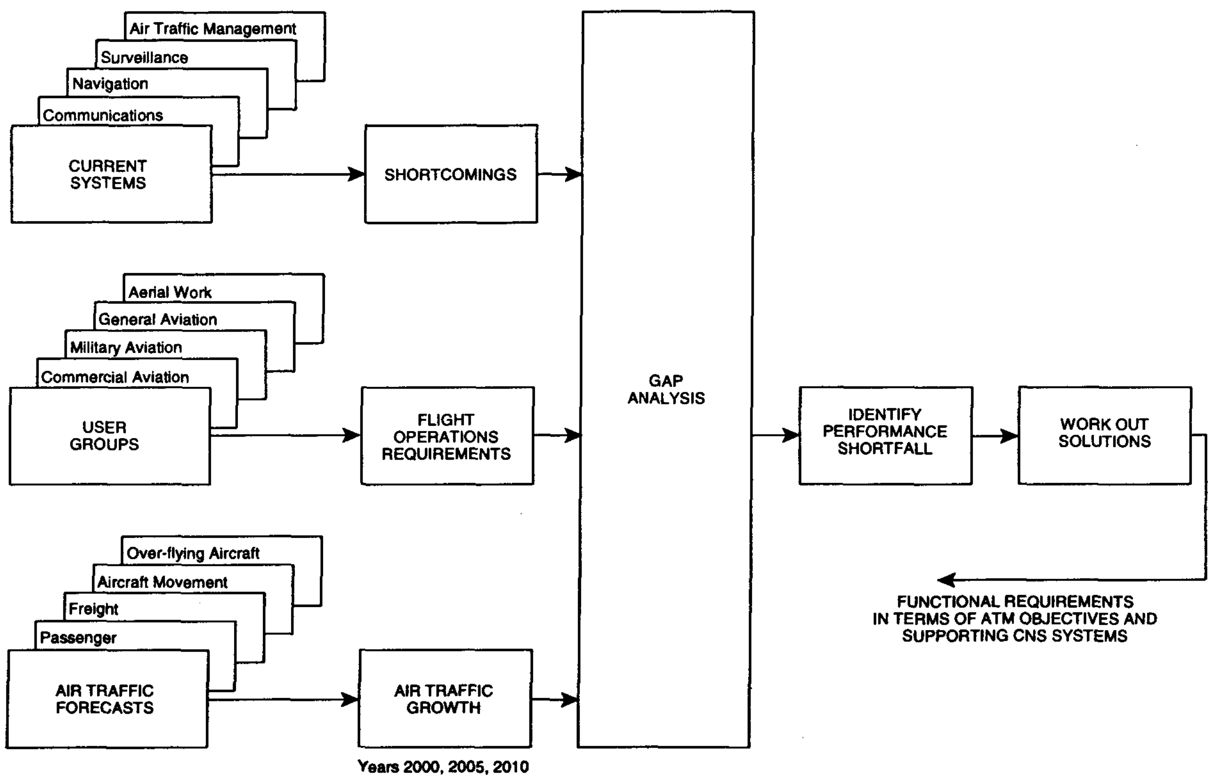


Figure 6-1. Developing functional requirements

Table 6-1. Different categories of airspace users

Commercial aviation	Military aviation	General aviation	Aerial work
1. Scheduled airlines (international carriers) 2. Scheduled airlines (regional carriers) 3. Non-scheduled airlines (charters) 4. Air taxis	1. Military aircraft not flying under civil control 2. Military aircraft planned to have frequent access to regulated airspace 3. Military search and rescue aircraft	1. Executive/corporate 2. Private air travel 3. Sporting and recreation aviation	1. Surveying 2. Agriculture 3. Search and rescue 4. Flying clubs 5. Police/customs

Table 6-2. Functional requirements — Short-term/long-term (Sample matrix)

Air traffic management	Communications
Airspace management (ASM)	*Data communications*
1. Optimize sectorization. 2. Improve current route network and airspace structure. 3. Introduce fixed and random RNAV routes. 4. Develop flexible use of airspace concept. 5. Enhance civil/military coordination. 6. Apply RNP in designated airspace.	1. Establish ground-ground data network, either satellite-based, land-based (microwave/copper/fibre) or mixed. 2. Upgrade AFTN to the required functionality. 3. Plan for AFTN upgrading to become an end-system of ATN. 4. Plan for appropriate air-ground data link (VHF data/HF data/AMSS data/Mode S data), depending on type of airspace /air traffic density.
Air traffic services (ATS)	*Voice communications*
7. Provide/enhance ATS decision support tools for high-density areas. 8. Reduce vertical separation minima. 9. Reduce horizontal separation minima. 10. Provide/enhance SMGCS. 11. Improve inter-centre (ATS) coordination procedures and techniques by introducing AIDC. 12. Apply data link for pre-departure clearance.	5. Establish ground-ground voice network, either satellite-based, land-based or mixed. 6. Plan for VCCS to improve controllers' communication. 7. Increase coverage of VHF radiotelephony (VHF R/T) to cover all air traffic flows in the State. 8. Improve VHF frequency assignment. 9. Take measures to alleviate interference to VHF R/T. 10. Find medium-term solution to reduce VHF channel congestion.

Air traffic management	Communications
Air traffic flow management (ATFM)	11. Develop implementation programme for VHF digital system for combined air-ground voice and data communications to replace current VHF analog systems.
13. Establish centralized ATFM centre.	12. Optimize utilization of present 25 kHz channel VHF spectrum.
14. Optimize and provide balance between air traffic demand and ATC system capacity by introducing ATFM measures and procedures.	13. Reduce VHF channel spacing to 8.33 kHz for increasing the channel capacity as a medium-term solution.
	14. Introduce SATCOM (AMSS) voice in oceanic airspace.
	15. Provide SATCOM (AMSS) voice for remote continental airspace
	16. Replace HFRT in continental airspace by VHF R/T.
Navigation	**Surveillance**
1. Install VOR/DME to meet near-term requirements.	1. Provide secondary radar coverage (Mode A/C or Mode S) for continental en-route surveillance.
2. Install ILS Cat. I as a near-term approach to meet low visibility conditions.	2. Consider the networking of radars for efficient usage by transporting radar tracks on G/G data network.
3. Implement common geodetic reference system (WGS-84).	3. Consider the possibility of using military radars.
4. Introduce GNSS for oceanic airspace.	4. Introduce ADS-B for A-SMGCS.
5. Implement GNSS for en-route continental airspace and NPA.	5. Consider upgrading monopulse SSR Mode A/C to Mode S capability.
6. Install MLS to overcome current ILS-related problems, such as FM interference, channel capacity and siting.	6. Plan for ADS in continental/terminal areas.
	7. Provide primary/secondary radar coverage for major TMAs.
7. Introduce GNSS-based Cat. I precision approaches.	8. Establish SMGCS using ASDE for near-term solution.
8. Consider the requirements for Cat. II/Cat. III precision approaches.	9. Usage of ADS to provide surveillance coverage for areas beyond radar coverage, such as oceanic airspace/remote continental airspace.

Chapter 7
TRANSITION METHODOLOGY

TRANSITION STRATEGY

7.1 As it may not be possible to implement CNS/ATM functionality in the entire State simultaneously, there is a need for geographical phasing. The necessary approach must be evolutionary in order to utilize the systems already in place. The following elements need to be considered in the evolution from the baseline to the CNS/ATM functionality:

a) the status of current systems, their life cycles and degrees of operational efficiency;

b) the pace of change will depend upon the rate at which the required technological and operational requirements are developed at the national and international levels;

c) system improvements, when introduced, should begin to offset their cost as early as possible;

d) operational concepts may drive the need for the mechanism to address legal matters, sovereignty of airspace and international agreements;

e) the airspace users' needs and the requirements of other concerned entities will dictate in the decision-making process for CNS/ATM elements; and

f) the period of implementation will vary according to the needs of the State, keeping in view the above factors.

7.2 In developing guidelines for transition, it is useful to consider the type of system and the specific problem or issues affecting its transition to full operational use in a particular airspace type or phase of flight. Pertinent areas where such issues might arise can be grouped into several categories: human, equipment, operational, management and cost. The type of relevant questions for each category are shown in Table 7-1.

7.3 The need for coordination with adjacent States must be considered throughout the planning process.

TRANSITION METHODOLOGY

7.4 The approach used in the transition to CNS/ATM is based on:

a) the functional requirements;

b) airspace users' needs;

c) a cost-effective solution; and

d) any trends, assumptions and uncertainties.

Table 7-1. General transition issues

Human
■ Procedures and training for use of parallel systems ■ Human-machine interface issues for parallel systems ■ Operator/user confidence in the new system ■ Selection criteria for operators/users of the new system ■ Procedures in case of new or old system failure ■ Automation issues ■ Operator knowledge of the system mix
Equipment/Facilities/Infrastructure
■ Use of different systems in different flight phases ■ Different aircraft capabilities or user classes in the same airspace ■ National or other boundaries with different infrastructures ■ Non-equipped "intruders" ■ Disruption of operations to change the system ■ Supplementary versus sole-means use ■ Aircraft/facilities out of service to re-equip ■ Initial benefits of the new system during the transition
Management
■ Standards and regulations ■ Phased transition; intermediate steps ■ Organizational restructuring during the transition ■ Pre-operational trials ■ Research and development and applications development ■ Need and incentives to minimize the duration of the transition period ■ Communication among States on implementation plans
Cost
■ New system cost and investment in the old system; amortization ■ Cost of maintaining parallel systems

7.5 An overview of the methodology adopted for the transition to the CNS/ATM concept is shown in Figure 7-1. This incorporates separate — but complementary — development stages involving parallel bottom-up and top-down approaches to ensure that all of the available options are identified. It is necessary to break down each of the components into its constituent elements (e.g. the airspace management component could be broken down into elements such as airspace usage, route network, etc.). There is no single, ideal method of breaking down an operational concept into its individual parts. The types and groups of components and elements used are, to a large degree, dependent on both the concept itself and the viewpoint from which it is being examined. A list of components and elements generally applicable in deriving the CNS/ATM options is given in Table 7-2.

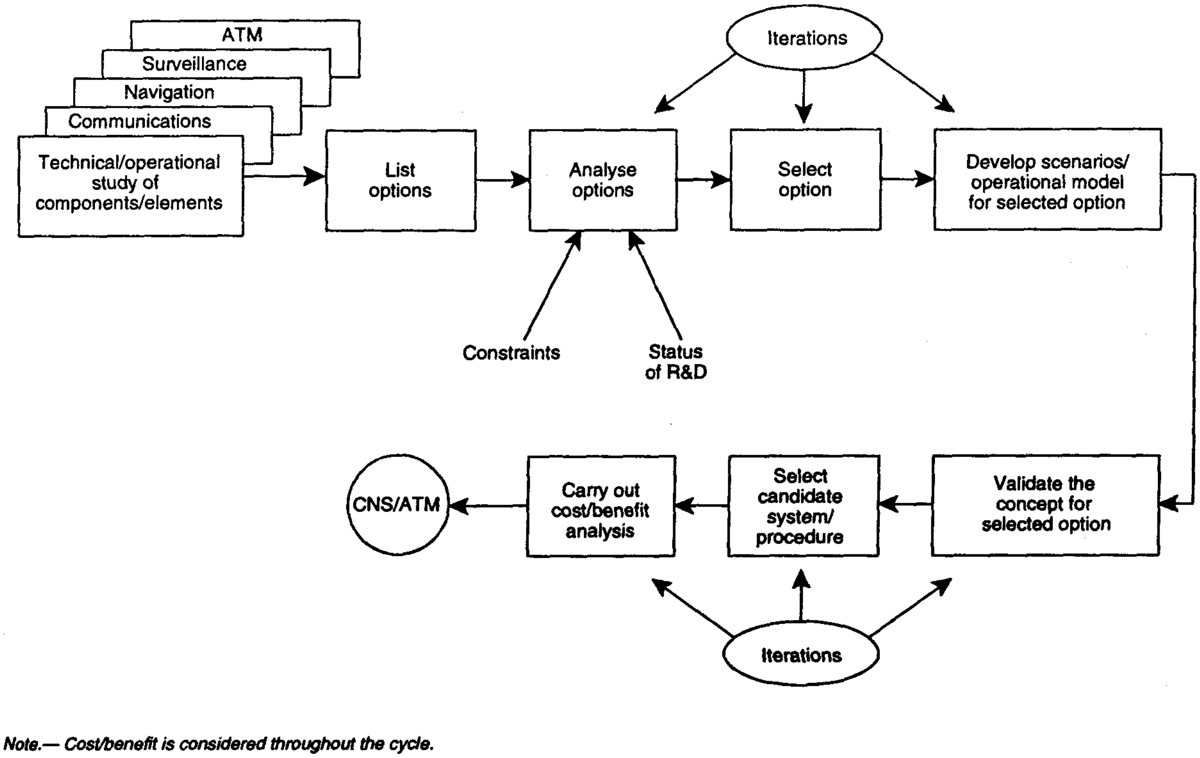


Figure 7-1. Transition methodology

Table 7-2. CNS/ATM system elements

Communication	Navigation	Surveillance	Air Traffic Management
Data • VHF • HF • Mode S • Satellite • ATN Voice • VHF • Satellite	GNSS • GPS • GLONASS Augmentation • ABAS • GBAS • SBAS	SSR • Modes A/C • Mode S ADS • VHF • HF • Satellite ADS-B	ASM • RNP • RNAV • Airspace utilization ATS • Separation Standards • Automation systems ATFM • Planning • Coordination

7.6 The resultant list represents the composite range of options which may be supplemented by new and missing options at a later date, as more concept-related information becomes available.

7.7 The analysis of options may be pitched initially at the macro level, using the following characteristics:

a) current endorsed policies (ICAO, State, regional strategy);

b) current and future development plans;

c) time constraints; and

d) overall feasibility.

7.8 The analysis information needs to be updated periodically during the life of the planning document, as more details become available over a period of time, particularly from research and development activities. While doing the analysis of options, it is recognized that there is a great deal of interdependency between the options and choices made about options in one group and those of another group. For instance, the type of data link chosen would influence the decision for the surveillance component. In consequence, the analysis results need to be viewed as a whole across the complete range, rather than as isolated comments.

7.9 For selected options, there is a requirement to develop operational scenarios which will be validated further. This will eventually result in the selection of a particular technical/operational element. This overall process will necessarily follow an iterative path, as more information becomes available from validation and research and development activities.

What are the main features of CNS/ATM systems?

The distinct features of CNS/ATM are:
- mix of satellite- and ground-based systems
- global coverage
- seamlessness
- interoperable systems
- use of air-ground data link
- use of digital technologies
- various levels of automation

COMMUNICATIONS

7.10 Communications is an enabling technology that is essential to the operation of ATM. Within the context of ATM, the subject can be considered under two broad headings — voice communications and data communications, each of which can be further subdivided into air-ground (A/G) and ground-ground (G/G) segments. Improvements in both voice and data communications will be necessary to handle near-term as well as long-term needs of air traffic services. The following approach will meet the needs for improvements in existing systems, as well as for the development of future communication systems.

Data communications (ground-ground)

Control/monitoring data transfer of communications, navigation and surveillance systems from the technical site to operational units

7.11 Different media are employed connecting communications equipment, navigational aids and radars from the technical site to operational units, thus permitting the transfer of control/monitoring data. The medium of transfer can be: a) copper; b) fibre; c) radio; or d) satellite, depending upon technical and cost factors.

What is the first step for planning for the transition to ICAO CNS/ATM systems?

It is essential to have G/G networking for transporting textual data, radar data, graphics and voice. The selected network platform can be either terrestrial or satellite, or a mix of terrestrial/satellite, depending on economic and technical factors.

Internetworking of ground data networks

7.12 The establishment of ground data networks is a first essential step in improving the efficiency and integrity of ground-ground ATS data communications. The network system could be based on:

a) satellite systems (such as VSAT technology) — easy to install and expand, high up-front investment;

b) terrestrial systems (microwave links, UHF links/PTT lines, fibre optics) — high maintenance cost, requires good infrastructure, not possible in remote areas; or

c) a mix of satellite and terrestrial systems.

When establishing G/G networking, the following systems (current and future), as possible inputs to the networking, need to be considered to ensure connectivity:

Data: AFTN, FDPS, FAX, RDPS, e-mail, ADS, SBAS, VHF, HF, ATN, AIDC
Voice: VHF, PABX, VCCS, DSC
Remote operations: NAVAIDs monitoring and maintenance
Graphics: Weather maps

Aeronautical fixed telecommunication network (AFTN)

7.13 AFTN is a low- to medium-speed, store-and-forward network, implemented on dedicated lines, and used for the transfer of aeronautical messages. The present system uses old technology and has low capacity, and it will be increasingly unable to handle future data requirements. Improvements for the near term fall within a number of categories, including:

a) upgrading of present manual to automatic messaging;

b) development of high-speed links (high modulation rates);

c) conversion of land line circuits into satellite links, if and where necessary;

d) introduction of X-25 protocols between centres; and

e) use of the common ICAO data interchange network (CIDIN).

These near-term tasks will reduce AFTN transit times and improve the integrity of the data transmitted. The long-term improvement involves transition from AFTN to ATN.

Why implement ATN?

- Need for high volume data exchange
- Need for low transit times
- Policy decision to move to ISO protocols
- Need for interactive data where multiple messages are exchanged between applications
- Need to communicate with other organizations that are using the ATN
- Need to integrate air-ground and ground-ground data networks

7.14 Aeronautical fixed services migration planning alternatives

7.14.1 Migration to the end-state of ATN can occur in a minimum of three steps. Each phase should be fully backward-compatible for AFTN, as each State will migrate at its own pace.

7.14.2 *Step 1 — Current AFTN operations and planning for the future.* This step involves examining current AFTN operations, taking into account the current and planned interregional network configuration, reliability of AFTN circuits, and responsibilities for the routing and distribution of information. Output from Step 1 includes:

a) complete awareness of current operations and network configuration;

b) coordinated transition and implementation plans of network configuration; and

c) agreements with neighbouring States/regions.

What does an AFTN/ATN gateway do?

- Provides basic interoperability
- Envelops or converts AFTN messages
- Allows message transfer capability between two dissimilar systems
- Is a tool for migration strategy

7.14.3 *Step 2 — Transition to AFTN/ATN gateway.* This step is comprised of the implementation of the AFTN/ATN gateway and its integration with the AFTN. This step begins with the formal conformance tests of the gateway and its interoperability with the AFTN environment. There should not be any procedural impact on the existing AFTN procedures. The ATN backbone service is to be inserted transparently from the AFTN perspective. During Step 2, planning should continue for further migration from AFTN/ATN gateways/AFTN configuration to the open systems interconnection (OSI) CNS/ATM environment. Output from Step 2 includes:

a) implementation of AFTN/ATN gateways;

b) post-implementation network performance reviews; and

c) development of OSI CNS/ATM products.

7.14.4 *Step 3 — Implementation of the OSI CNS/ATM environment.* This step provides the ability for the data exchange between OSI-compliant ATM hosts. The major difference is the additional protocol architecture needed for data transfer between ATM hosts operating within the OSI environment. Conformance testing is required for all host systems having common data or message exchange requirements. Full implementation of services requires interoperability testing, which could include validation of performance requirements. Output from Step 3 includes:

a) an ICAO-standardized, OSI upper-layer protocol architecture operating over the ATN;

b) an ATN environment that supports a network configuration; and

c) a post-implementation review of performance and support.

Conventional AFTN support

7.15 The AFTN/ATN gateway provides a message transfer capability to and from the ATN configuration and the AFTN configuration. The implementation of the gateway has an impact on AFTN routing, particularly between regions and between States connected via medium-speed trunk circuits. Hence there is a need for a more timely exchange of routing information between administrations operating gateways and adjacent AFTN centres.

ATN end-system

7.16 ATN end-systems are capable of communicating with other ATN end-systems to provide end-to-end communication services to ATN applications. For this purpose, the ATN end-systems include a full 7-layer protocol stack to host the appropriate communication services in support of one or more ATN applications. ATN end-systems are also the interface to the ATM and the aircraft automation, as well as the controllers' and pilots' human-machine interface. Figure 7-2 illustrates the ATN end-to-end relationship over an OSI 7-layer reference model.

Implementation of an AFTN/ATN gateway

7.17 There are a number of different physical configurations in which an AFTN/ATN gateway could be implemented, as shown in Figure 7-3. The configurations can be either stand-alone, part of the AFTN host or part of the ATS message server host.

Routing considerations — AFTN/ATN environment

- AFTN address is used to globally identify the user, regardless of attachment to AFTN or ATN
- Users do not need to know if their communicating entities are attached to AFTN or ATN
- Store-and-forward message transfer service is available on end-to-end basis
- AFTN routing is by switching centres, whereas gateway routing is via ATN connectivity
- Routing in AFTN is static; ATN routing is dynamic

AFTN/ATN transition paths

7.18 When a State wishes to make the transition to the ATN, it can do so unilaterally, bilaterally or multilaterally. While doing so, the AFTN circuits of adjacent States must not be effected.

7.19 The strength of the ATN lies in the ability to interconnect heterogeneous subnetworks in different States and provide end-to-end connectivity between end-users. In current AFTN practices, the States are connected as shown in Figure 7-4. Each AFTN (non-OSI network) is connected directly to its counterpart in an adjacent State. Once a State has made its internal transition to the ATN, it then has the ability for end-to-end data transfer within its State borders. Further, it may still communicate with the network in an adjacent State via a gateway (see Figure 7-5). When the network in the adjacent State is also OSI-compliant, then a gateway is no longer needed; a router can then be used to connect the two ATN subnetworks (see Figure 7-6). The composite network formed by the connection of the OSI networks in every State would eventually form the worldwide ATN (the case where these States are interconnected is shown in Figure 7-7). It is envisaged that the networks interconnected by a gateway will eventually either cease to exist or be upgraded to an OSI environment. The time period required to phase out some networks could be quite long. For this reason, any proposed network configuration should accommodate old applications for a considerable period of time.

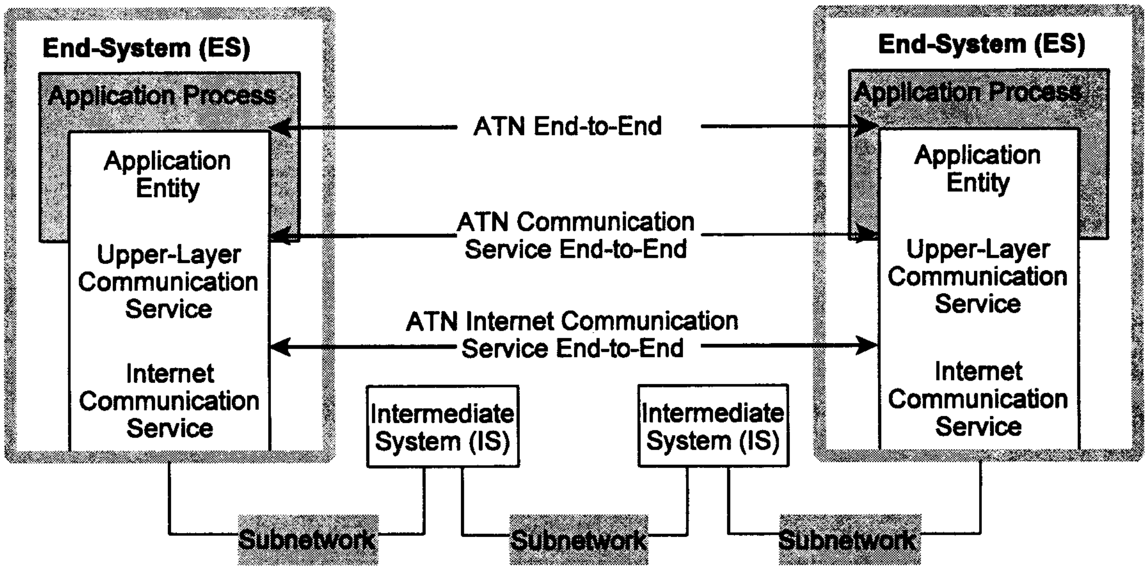


Figure 7-2. ATN end-to-end relationship

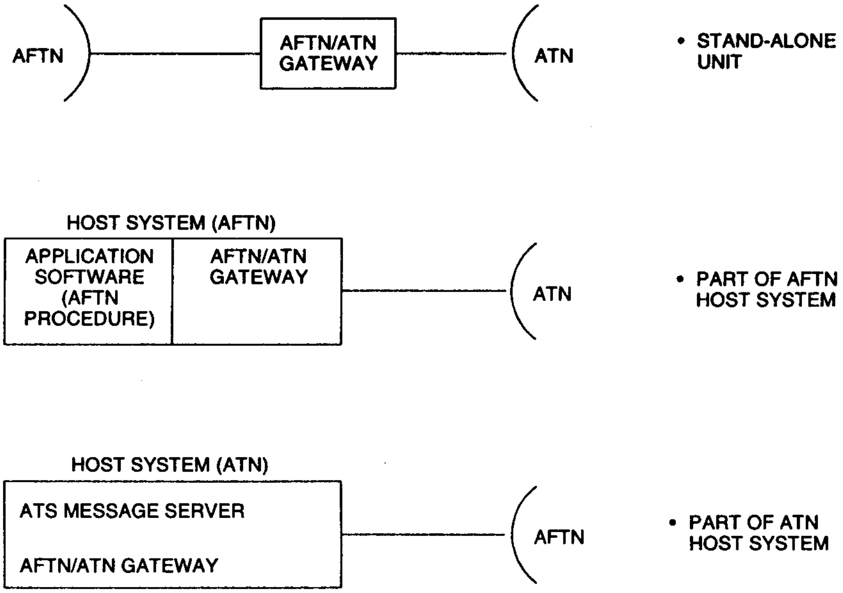


Figure 7-3. Configuration of an AFTN/ATN gateway

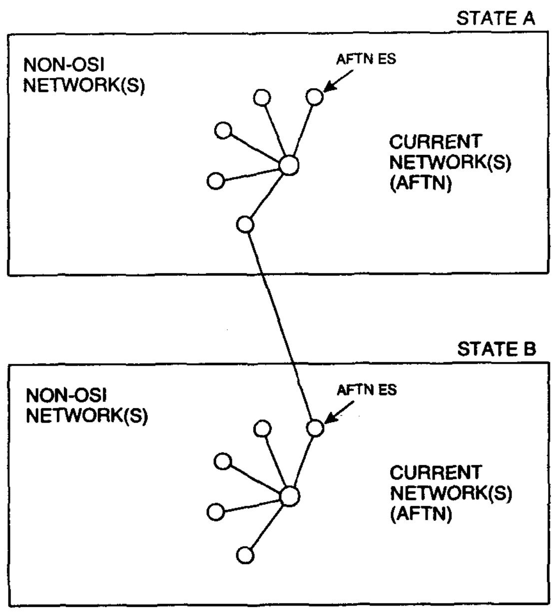


Figure 7-4. Interconnection of the AFTN between two States

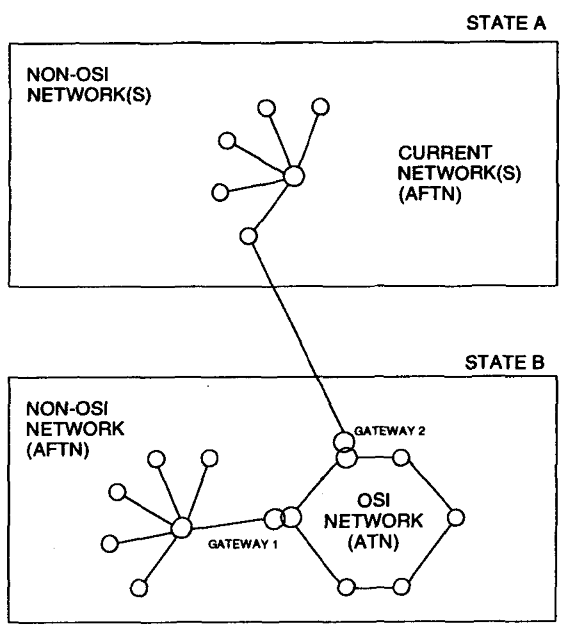


Figure 7-5. Interconnection between two States, one having an AFTN (non-OSI) network and the other having an ATN OSI network

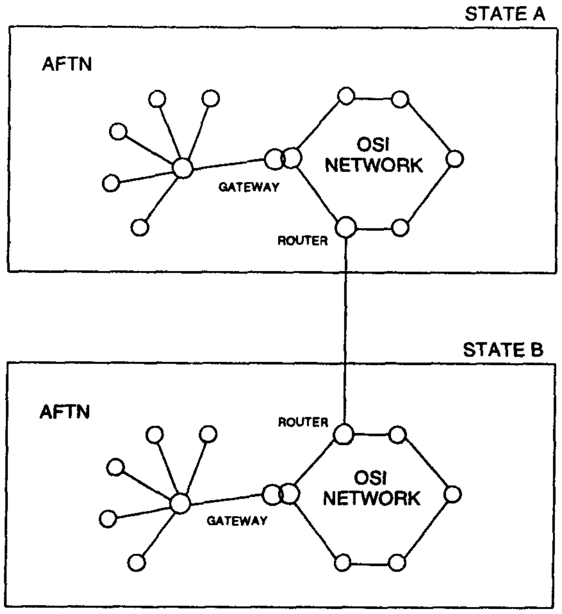


Figure 7-6. Interconnection of OSI networks of two States

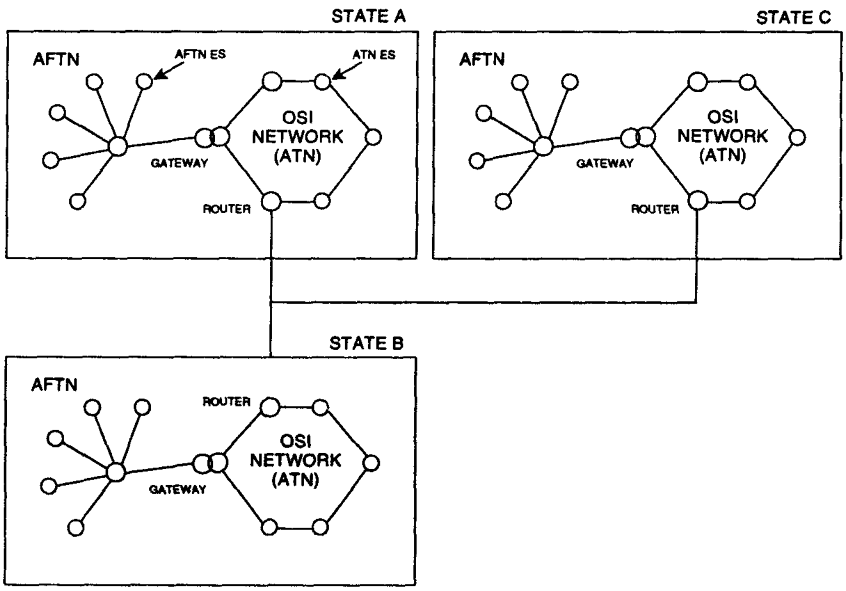


Figure 7-7. Worldwide interconnection of OSI networks

ATS inter-facility data communications (AIDC)

7.20 AIDC is an ATN data link application which can be employed by two ATS units to exchange ATC information. This information includes advanced flight notification, clearances, transfer of control, surveillance data and free-text data. In addition, acknowledgement messages and application status monitoring capabilities are provided. To achieve this objective, common formats and protocols have been established. This is initially applicable to high-complexity ATC areas but could be gradually extended to medium-complexity ATC areas.

Summary

7.21 Table 7-3 is a summary of tasks involved in the ground-to-ground data communications segment. While States take action to enhance current systems (first column) to bring about short-term improvements, there is a need to plan for new systems (second column) to address long-term improvements. Accordingly, with reference to the second column, determine which new systems are to be implemented by the State and indicate the time lines for corresponding systems in Table 8-2 regarding communication systems implementation (Chapter 8). Subsequently, plan for phasing out of current systems (third column), if any, by ensuring some reasonable period of parallel operation of current and new systems and indicate the time lines for the corresponding systems in Table 8-2 regarding communications systems implementation (in Chapter 8).

Data communications (air-ground)

7.22 The congestion of radiotelephony (R/T) is becoming one of the limiting factors in high-density areas to further growth in ATC capacity. More aircraft could be controlled within a given sector — and probably more safely — if a significant part of R/T communication was replaced by data link. Reduction of controller/pilot R/T workload per flight will improve ATM efficiency.

What are the basic principles of data link functions?
- They will supplement and support voice communications, not replace them
- Initial service is for routine events
- Messaging should be simple
- Procedures should be consistent with current voice systems
- En-route, terminal and tower ATC facilities require different data link capabilities

Air-ground data communications is comprised of two main parts

7.23 *Controller-pilot data link communications (CPDLC)* will provide direct communication between the controller and the pilot, and is to be used in conjunction with, or instead of, voice. CPDLC functions will be introduced through a phased implementation programme based on experience with initial routine, non-critical functions. Critical functions requiring a minimum reaction time may be implemented in the medium and long term, although there is a potential to use CPDLC as a back-up in cases of R/T blockage or outage.

Table 7-3. Summary — Ground-ground data communications transition (sample matrix)

Short-term improvements — enhance current systems	Long-term improvements — implement new systems	Phase-out of current systems not required consequent to transition to new systems
1. Upgrade AFTN for near-term improvements such as increasing modulation rates, conversion of land lines into satellite lines (only if necessary), introduction of X-25 protocol	1. Establish satellite-based ground-ground networking if terrestrial-based system is not satisfactory or implement a mix of terrestrial and satellite links 2. Implement ATN	1. AFTN 2. Terrestrial-based ground-ground networking

7.24 *Automated air-ground data interchange (AAGDI).* Data from on-board systems, such as FMS, flight directions/autopilots, will be down linked to provide ground systems with actual flight data, such as speed, heading, profile, route, weight, weather data, etc. This will allow the updating of ground systems with actual flight data, thus further diminishing the requirement of R/T transmissions, while providing essential data to controllers. Data from ground systems (e.g. weather) will be uplinked to aircraft. This will facilitate the functional integration of airborne and ground systems.

Air-ground data exchange medium

7.25 Air-ground data exchange medium is comprised of four systems. It includes VHF, HF, Mode S and satellite. Choices between the technologies used to pass data link messages will be governed largely by operational, technical and cost considerations.

Selection of medium options

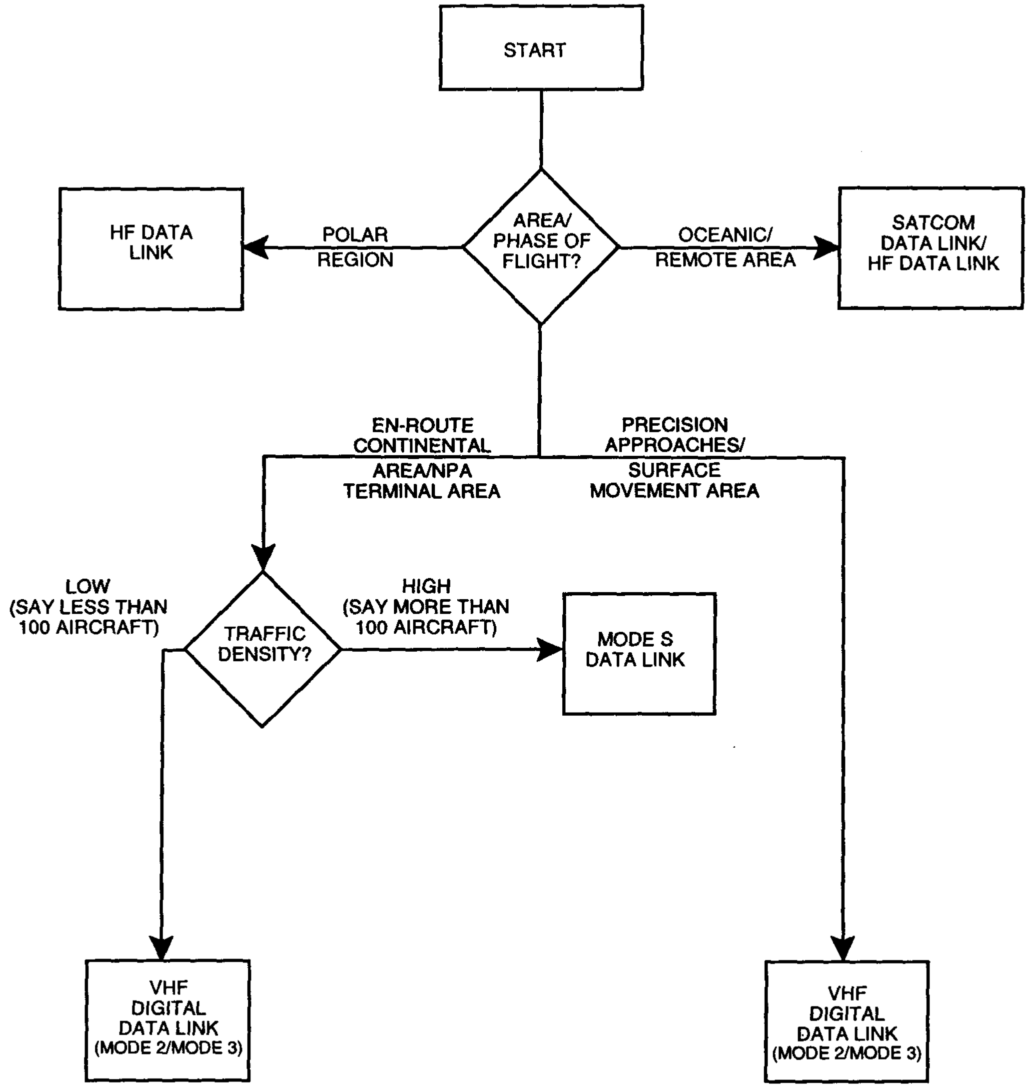
7.26 The decision tree in Figure 7-8 is an approach to choosing the medium based on phase of flight, geographical area and air traffic density. However, a final decision, after meeting technical and operational requirements, will be based on economic considerations. It is necessary that, at every stage of medium selection, the cost/benefit ratio be evaluated. *VHF AM* data link refers to current VHF using the aircraft communications addressing and reporting system (ACARS), whereas *VHF digital* implies VDL Mode 2 (data only) and VDL Mode 3 (data and voice).

7.27 Realistically, data link services will not become available everywhere at one time, but will grow from areas of greatest need, such as oceanic environments, into domestic airspace. It is expected that the prime data media over continental airspace will be Mode S and VHF links, with satellite and HF links being used over oceanic and remote areas.

7.28 VHF digital link (VDL)

7.28.1 A number of ATN-compliant VHF data links have been defined. There are currently two existing, one planned and one proposed VDL modes with differing capabilities:

a) VDL Mode 1 is a low-speed bit-oriented data transfer system. It uses a carrier sense multiple access (CSMA) methodology. The physical layer conforms with the existing ACARS system (and at the same data rate). VDL Mode 1 has been superseded by VDL Mode 2;



Implementation options: VHF data/HF data/SATCOM data/Mode S data

Qualifications:

1. The division between high and low density (100 aircraft) indicates the break-even region, and not the break-even point.
2. It is assumed that, on average, the message length is 300 bits.
3. *Traffic density* refers to the number of aircraft at a time in a circle having a radius of 250 NM.
4. It is necessary to conduct cost/benefit analyses at each stage for determining the cost-effectiveness of the system.

Figure 7-8. Decision tree — Air-ground data communication

b) VDL Mode 2 is similar to the VDL Mode 1. Mode 2 uses a much more efficient modulation system to support a greatly improved data rate;

c) VDL Mode 3 is the future ICAO VHF air-ground communications system. It provides integrated voice and data link technology on time division multiple access (TDMA); and

d) VDL Mode 4 is a proposed use of the VHF data link based on a self-organizing time division multiple access principle. The current proposal is to support applications such as ADS, TIS and full data link communications.

7.29 HF data link (HFDL)

7.29.1 HFDL incorporates the following features to achieve the performance required by ATM:

a) several HFDL ground stations within each region provide the aircraft with multiple air-ground paths;

b) automatic frequency selection and management (without human intervention) ensure that the best propagating frequency is used;

c) digital signal processing minimizes the effects of noise, fading and multipath on HFDL performance;

d) the actual performance has indicated that HFDL can achieve performance characteristics exceeding HF voice and approaching SATCOM (AMSS) data link; and

e) it uses bands in the 2.85 – 22 MHz range.

7.29.2 HFDL is envisioned to be used in three ways:

a) as a complement to SATCOM;

b) as a sole long-range data link; and

c) as the data link covering remote regions and polar regions.

7.29.3 When combined with SATCOM, a higher level of system availability is achievable than with dual redundant SATCOM installations. Data link availability of dual SATCOM systems is limited by SATCOM propagation anomalies such as ionosphere scintillation rather than equipment malfunctions. Thus, an aircraft equipped with both HFDL and SATCOM data links is capable of achieving very high performance.

7.29.4 The major benefit HFDL provides is its ability to provide data link coverage over remote land and polar regions. In regions where VHF data link coverage may be difficult to establish because of terrain, for example, HFDL can provide data link coverage. In addition, HFDL will provide coverage in polar regions where there is currently no SATCOM coverage. The State can purchase HFDL service from a service provider without incurring any capital costs.

7.30 Aeronautical mobile satellite service (AMSS)

7.30.1 A number of types of satellite communications are in existence or proposed for implementation to support air-ground data link communications as one of their functions (satellite systems can support a very wide range of communications requirements). Most of these systems are proposed to operate on one of three main principles:

a) GEOS — geostationary orbit satellite;

b) MEOS — medium earth orbit satellite; or

c) LEOS — low earth orbit satellite.

7.30.2 The common principle of communication for each of these systems is the same but the configuration principles are quite different.

7.30.3 This guidance material concentrates on the use of GEOS, especially those services offered by INMARSAT-2 and -3. These satellites are in geostationary orbit and require only three satellites to provide non-polar worldwide coverage.

7.30.4 The AMS(R)S is a special subset of the AMSS and, as such, is considered a separate service. The AMSS is a mobile-satellite service in which mobile earth stations are located on board aircraft. The AMS(R)S is reserved for communications relating to safety and regularity of flights, primarily along national or international civil air routes.

7.30.5 The AMS(R)S currently uses a geostationary satellite system to provide worldwide (non-polar) voice and data services, giving more reliable and extensive coverage than provided by the current HF analog voice service. AMS(R)S applications include ADS-C, in which aircraft periodically report their locations via data link and two-way voice communications.

7.31 Mode S data link

7.31.1 Mode S SSR is the new-generation ground-based radar surveillance system. In addition to its SSR Mode A/C and Mode S cooperative independent surveillance capability, Mode S supports enhanced surveillance functionality as well as full data link transactions and is defined as a fully ATN-compliant subnetwork.

7.31.2 Mode S uses the concept of selective interrogation to communicate with aircraft, thereby eliminating several problems found with the existing Mode A/C surveillance. However, Mode S is fully compatible with Mode A/C and supports existing ACAS which occupies the same frequencies (1 030 MHz and 1 090 MHz).

Aeronautical telecommunication network (ATN)

7.32 The ATN will provide for the interchange of digital data between a wide variety of end-systems supporting end-users, such as aircraft operators, air traffic controllers and airline offices. The ATN, based on the ISO OSI reference model, allows for the interoperation of dissimilar air-ground (VHF, Mode S, AMSS and HF) and ground-ground (ATS message server) subnetworks as a single internet environment. End-systems attached to ATN subnetworks communicate with end-systems on other subnetworks by using ATN routers. ATN routers can be either mobile (aircraft-based) or fixed (ground-based). The ATN routers select the logical path across a set of ATN subnetworks that can exist between any two end-systems. This path selection process uses the network level addressing, quality of service and security parameters provided by the initiating end-system. Thus, the initiating end-system does not need to know the particular topology or availability of specific subnetworks.

7.33 The architecture of ATN is shown in Figure 7-9. The step-by-step approach to the implementation of ATN is shown in Figure 7-10.

7.34 Guidelines for ATN implementation

7.34.1 *General.* The ATN implementation is expected to progress on a region-by-region basis. Even within the regions, it is likely that individual States will make the transition to ATN at different times and possibly in different ways, while maintaining interoperabilty and continuity of ATM services.

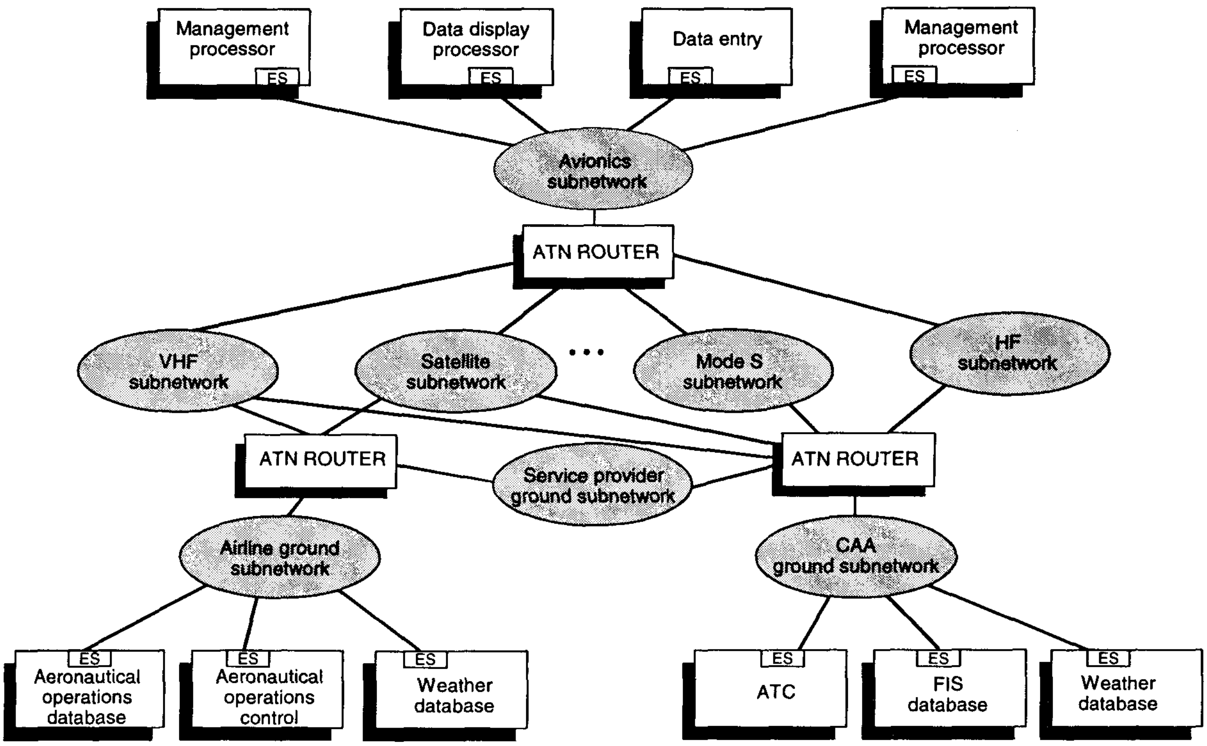


Figure 7-9. ATN architecture

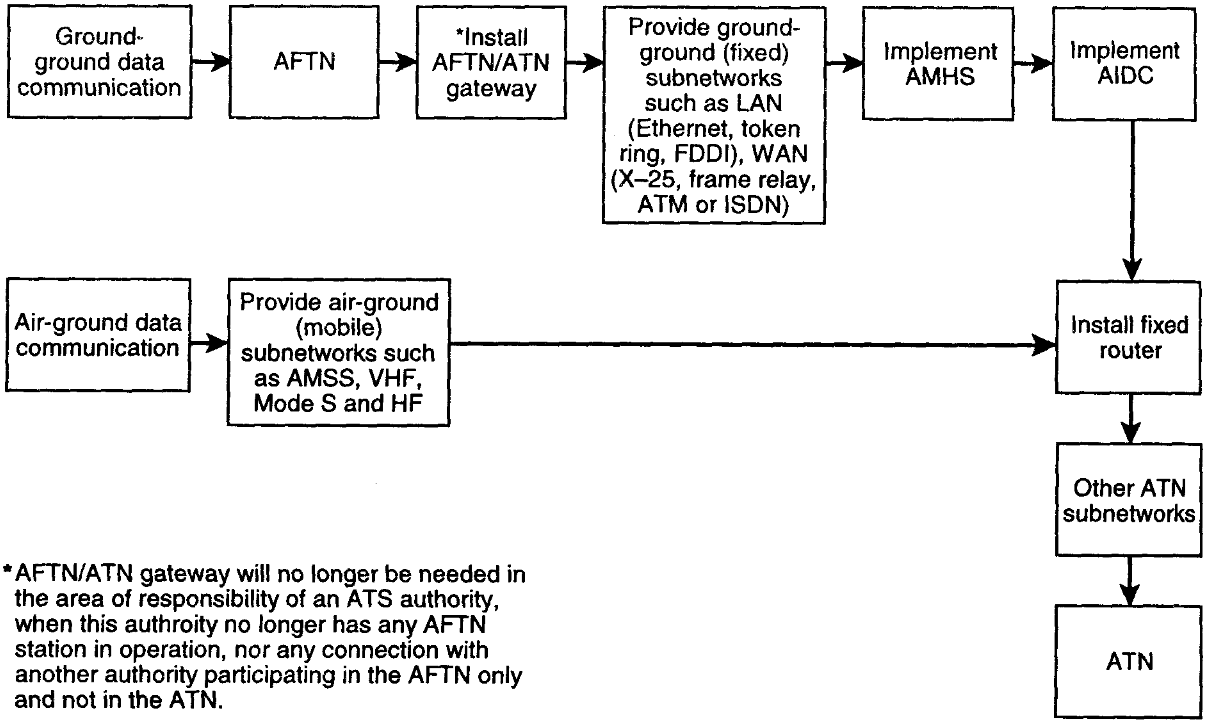


Figure 7-10. Approach to implementation of ATN

7.34.2 *Key milestones.* The objective of this section is not to specify what States must do to implement the components of ATN, but rather to define a number of tasks or milestones that must be completed, each of which contributes towards the successful implementation of the ATN. The key milestones for the implementation of ATN are:

a) the establishment of an ATM operational concept;

b) the identification of a network operating system to meet ATM requirements;

c) the conducting of the cost/benefit analysis, taking into account users' requirements;

d) planning for the transition, considering interoperability and HMI;

e) the establishment of ATN hardware, software and procedures;

f) the carrying out of an operational evaluation;

g) the issuance of certification; and

h) the commissioning of ATN.

Interim data communication system using ARINC 622

7.35 In response to significant user demand, an interim data communication capability, using the ARINC 622 protocol (FANS 1/A), has been developed. The system, though having certain limitations, does meet near-term ATS requirements. ARINC 622 provides the capability to operate bit-oriented applications over existing data communication networks. This strategy, while offering limited functionality, is not upward-compatible for ATN.

ATIS and VOLMET service

7.36 Currently, an aircraft in flight is informed of the meteorological (MET) information and notice of facilities or services that are not available by means of VHF voice radio (automatic terminal information service [ATIS]) and HF voice radio (meteorological information for aircraft in flight [VOLMET]). With the introduction of data link services for transporting MET and outages data, the voice-based ATIS and VOLMET service is no longer required. The State, after gaining experience in data link, may phase out the ATIS voice and VOLMET voice services.

Summary

7.37 Table 7-4 is a summary of the tasks involved in the air-to-ground data communications segment. While States take action to enhance current systems (first column) to bring about short-term improvements, there is a need to plan for new systems (second column) to address long-term improvements. Accordingly, with reference to the second column, determine which new systems are to be implemented by the State and indicate the time lines for corresponding systems in Table 8-2 regarding communication systems implementation (Chapter 8). Subsequently, plan for phasing out of current systems (third column) by ensuring some reasonable period of parallel operation of current and new systems and indicate the time lines for the corresponding systems in Table 8-2 regarding communication systems implementation (in Chapter 8).

Table 7-4. Summary — Air-ground data communications transition (sample matrix)

Short-term improvements — enhance current systems	Long-term improvements — implement new systems	Phase-out of current systems not required consequent to transition to new systems
1. Use of ARINC 622 protocol for VHF and satellite ACARS data communication	1. VHF data link 2. Mode S data link 3. AMSS data link 4. HF data link 5. ATN	1. ATIS (VHF voice radio) 2. VOLMET (HF voice radio)

Voice communications (ground-ground)

7.38 Voice links via telephone (known as *direct-speech circuits*) remain the principle means of coordination between controllers, both inter- and intracentre. It is envisaged that most routine information will be passed by data networks (AIDC) in the future, although voice telephone will continue to provide the means of passing non-routine information.

Voice communication control systems (VCCS)

7.39 VCCS allow controllers to call other controllers, interface with public telephone networks and connect to required radio systems to communicate with aircraft via a single, common keypad. The new digital voice switching systems are expected to bring in more extensive integration and improved controller interface. These include cordless headsets and a screen-based interface. VCCS with required functionality need to be introduced or upgraded, based on the State's operational requirements.

Internetworking of voice circuits

7.40 Networking of ground-ground voice communication systems of different functionality will provide major improvements in ATS communications. As part of CNS/ATM implementation, the State may need to plan for either a terrestrial network or a satellite network, or a mix of both networks, depending on the local infrastructure and terrain. ICAO is currently developing updated material on this subject.

Summary

7.41 Table 7-5 is a summary of the tasks involved in the ground-to-ground voice communications segment. While States take action to enhance current systems (first column) to bring about short-term improvements, there is a need to plan for new systems (second column) to address long-term improvements. Accordingly, with reference to the second column, determine which new systems are to be implemented by the State and indicate the time lines for corresponding systems in Table 8-2 regarding communication systems implementation (Chapter 8). Subsequently, plan for phasing out of current systems (third column), if any, by ensuring some reasonable period of parallel operation of current and new systems and indicate the time lines for the corresponding systems in Table 8-2 regarding communication systems implementation (in Chapter 8).

Voice communications (air-ground)

7.42 At present, voice provides the primary method of contact between air and ground, using VHF R/T and HF R/T links. However, R/T suffers from various coverage and propagation problems and, in the case of VHF, frequency congestion. As a medium, it will become increasingly inadequate for handling growth. Nevertheless, R/T voice will be retained as a medium for the foreseeable future, with data link taking over most routine air-ground exchanges. The flowchart at Figure 7-11 identifies problem areas and solutions for current VHF R/T systems.

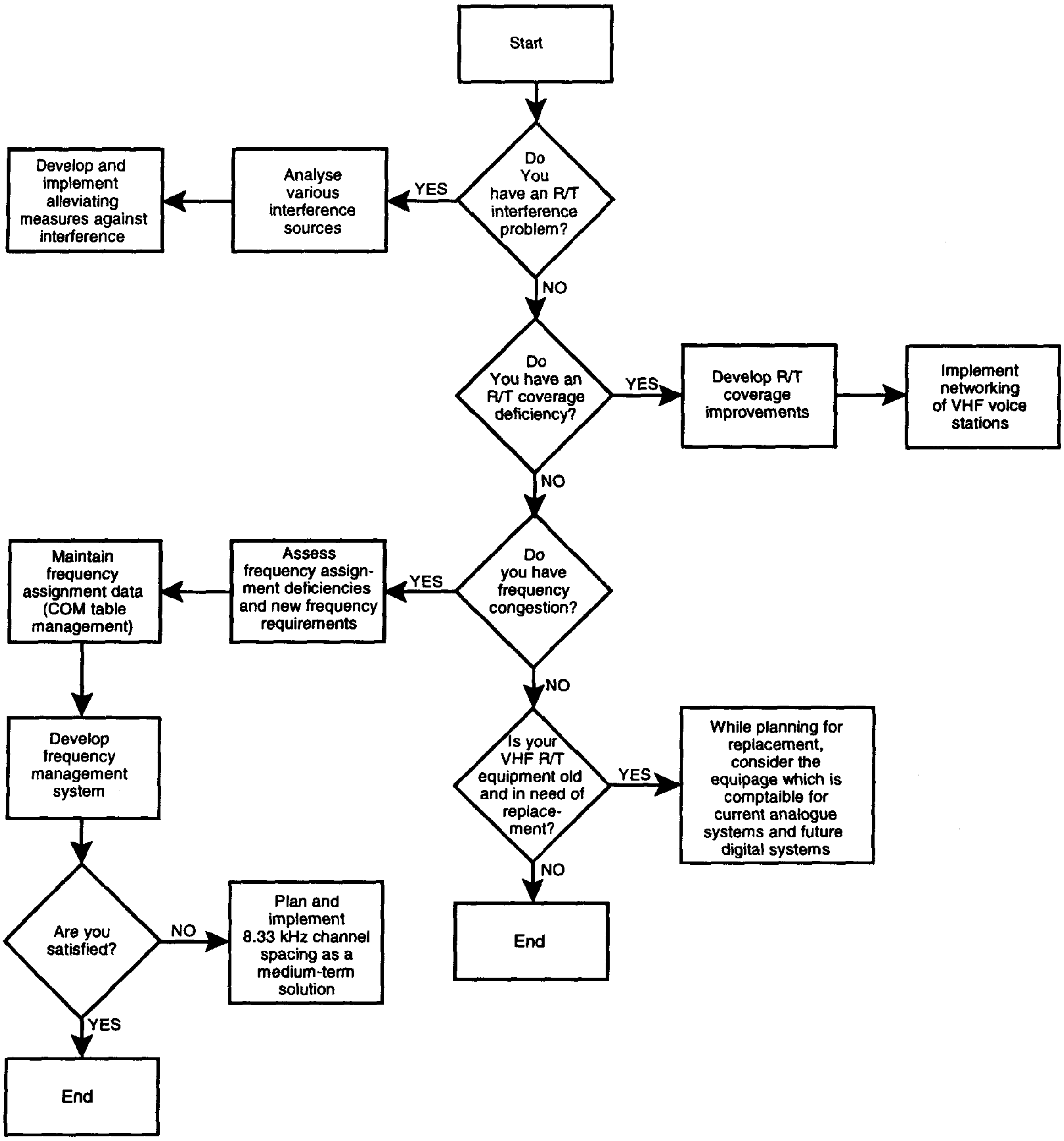


Figure 7-11. VHF voice communications — Problem areas and possible solutions for current systems

Explanatory notes for Figure 7-11

1. *The interfering sources could be:*

   For transmitter: Intermodulation, broadband noise and spurious outputs;

   For receiver: Intermodulation, cross-modulation, spurious response, local oscillation radiation and blocking of receiver.

2. *Alleviating measures include:*

   a) appropriate separation (approximately 300 m) between horizontal antennae;

   b) reduction of this separation to 65 m by including a cavity filter in the receiver antenna; and

   c) use of a multicoupler (a system which enables usage of four transmitters or four receivers to one antenna), thereby reducing the population of antennae.

3. *Install an adequate number of VHF R/T systems to ensure no coverage gaps exist on ATS routes.*

4. *The remote-controlled air-ground system (RCAG) of VHF may be networked for seamless availability of VHF R/T on ATS routes over entire continental airspace.*

Table 7-5. Ground-ground voice communications transition (sample matrix)

Short-term improvements — enhance current systems	Long-term improvements — implement new systems	Phase-out of current systems not required consequent to transition to new systems
1. Upgrade land line voice circuits to satellite links, if performance not satisfactory 2. VCCS to be upgraded or newly established, based on needs	1. Networking of voice communication system either terrestrial-based, satellite-based or mix of both systems	1. Terrestrial-based ground-ground networking

> ***How to ensure seamless VHF operations over entire continental airspace?***
> Establish G/G networking, either terrestrial-based, via satellite links or mix of both systems, and interface remote operated VHF R/T through the system.

Medium-term systems

7.43 In the areas where there is acute VHF frequency congestion, reducing the channel spacing to 8.33 kHz would help to relieve the problem. This situation is particularly relevant in the European Region. This solution may be implemented in discrete steps to different parts of the airspace. It must provide sufficient capacity to enable the transition and to meet future requirements.

Long-term systems

7.44 Digital VHF radio

7.44.1 At present, the VHF frequency band (118 – 137 MHz) is divided into channels separated by 25 kHz. It provides approximately 760 voice channels for national and international requirements, which can be reassigned repeatedly with sufficient regional separation. These channels are not sufficient to satisfy requirements for the long term and will produce VHF frequency congestion.

7.44.2 In accordance with the ICAO-envisaged plan, VHF radio systems will make the transition to digital modulation to improve security, increase immunity to radio frequency interference and support increased channel capacity. The new system, VDL Mode 3, in addition to using digital technology, shall offer combined voice and data transmission. While planning for the introduction of the digital VHF system VDL Mode 3, capable of allowing a mix of voice and data, amplitude-modulated voice will continue to be supported for aircraft and areas that have not converted to the VDL Mode 3 system.

7.44.3 The State considering replacing the current 25 kHz AM VHF voice may consider planning for equipment which is compatible with current analog voice systems, as well as with future digital data and voice systems.

7.45 AMSS

7.45.1 Satellite will provide the primary medium for voice and data communications in the oceanic and remote regions. The majority of ATC communications via satellite will consist of data, with voice reserved for emergency and non-routine communications. *Inmarsat*, the current AMSS service provider, is offering three different types of Aero products:

a) **Aero-H** for long-/medium-haul commercial aircraft and heavy corporate jets;

b) **Aero-I** for short-/medium-haul commercial aircraft, light corporate jets and turboprops; and

c) **Aero-L** for commercial aircraft and corporate jets that do not need voice or high speed data communications.

7.45.2 The Aero-H (high-gain) AES provides aircraft with simultaneous, two-way, digital voice, fax and real-time data communications capabilities. This service has been developed to meet the needs of aircraft operators requiring telephony, fax and data communications capabilities for their flight and cabin crews as well as for passengers. Aero-H has global coverage and is compliant with the ICAO AMSS SARPs.

7.45.3 The Aero-I (intermediate gain) has been designed to provide aircraft with simultaneous, two-way, digital voice and fax capabilities for regional applications. This service has been developed to meet the needs of short-/medium-haul aircraft operators requiring telephony and fax capabilities for their passengers. Aero-I voice services will be provided in spot beams only and are not primarily intended to be used for safety services, although such use is not precluded.

7.45.4 The Aero-L (low-gain) AES provides aircraft with a real-time, low speed, two-way data communication capability. This service has been developed to meet the needs of aircraft operators requiring a highly reliable data communications capability for their flight crew, cabin crew and passengers. Aero-L is fully compliant with the ICAO AMSS SARPs.

7.45.5 The SATCOM service can be taken on lease from a service provider by the State; no capital costs are involved in establishing this facility.

7.45.6 Some future communication systems, which have the potential to provide AMSS in addition to the current GEO system, are non-geostationary satellite systems using medium earth orbits and low earth orbits.

Phase-out of current systems

7.46 As VHF R/T coverage is made available in the continental airspace of the State along the entire route, the HF R/T used for regional and domestic air route areas (RDARA) may be phased out. Similarly, as experience is gained in the utilization of satellite data/voice communications, HF R/T on oceanic/remote regions may be considered for withdrawal. The current analog VHF R/T may be gradually withdrawn from service as and when maturity is gained in the utilization of digital VHF data/voice radio or when 8.33 kHz spacing is introduced (applicable in parts of Europe) as a medium-term strategy.

Summary

7.47 Table 7-6 is a summary of tasks involved in the air-to-ground voice communications segment. While States take action to enhance current systems (first column) to bring about short-term improvements, there is a need to plan for new systems (second column) to address long-term improvements. Accordingly, with reference to the second column, determine which new systems are to be implemented by the State and indicate time lines for corresponding systems in Table 8-2 regarding communication systems implementation (Chapter 8). Subsequently, plan for phasing out of current systems (third column) by ensuring some reasonable period of parallel operation of current and new systems and indicate the time lines for the corresponding systems in Table 8-2 regarding communication systems implementation (in Chapter 8).

General transition issues

7.48 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. Following are the guidelines that States, regions, users, service providers and manufacturers should consider when developing CNS/ATM systems or planning for implementation of such systems.

Guidelines for transition to communication systems

a) States should begin to use data link systems as soon as possible after they become available.

b) Transition to AMSS should initially be in oceanic airspace and in continental en-route airspace with low-density traffic.

c) States/regions should coordinate to ensure that where ATC applications supported by AMSS are to be introduced, they should be introduced simultaneously in adjacent FIRs through which there are major traffic flows.

d) During the transition period after AMSS is introduced, the current levels of integrity, reliability and availability of existing HF communications systems must be maintained.

e) Communications networks between ATC facilities within a State and ATC facilities in adjacent States should be established if they do not already exist.

f) The ATN should be implemented in phases.

g) If new application message processors and data link systems are implemented, they should support code- and byte-independent data transmission protocols in order to facilitate transition to the ATN.

h) States should establish procedures to ensure that both security and interoperability aspects of the ATN are not compromised.

Table 7-6. Summary — Air-ground voice communications transition (Sample matrix)

Short-term improvements — enhance current systems	Long-term improvements — implement new systems	Phase-out of current systems not required consequent to transition to new systems
1. Improve VHF R/T coverage 2. Implement measures to solve R/T interference problems 3. Develop frequency management system as a near-term solution for alleviating frequency congestion problem	1. Implement 8.33 kHz channel spacing as a medium-term solution for solving VHF frequency congestion problem 2. Plan and implement digital VHF radio, combining voice and radio 3. AMSS (voice) communications for oceanic/remote areas	1. Continental HF R/T 2. Oceanic HF R/T 3. 25 kHz analog VHF R/T 4. 8.33 kHz analog VHF R/T

NAVIGATION

7.49 New technology to support better methods of navigation is necessary to improve the accuracy of position determination and to provide better predictions of future positions to enable aircraft to fly more accurate and well-defined profiles. Improvements in position accuracy are also a prerequisite for the introduction of reduced separation minima.

Current systems

7.50 Fixed ground-based aids, such as VOR and NDB for en-route navigation and ILS and MLS for precision approaches, are currently in use for navigation of the aircraft. DME, providing distance information to the aircraft, is linked to VOR for the en-route phase and ILS/MLS for precision approaches. These aids are subject to problems such as line-of-sight propagation, FM interference on ILS and capacity limitations of ILS.

New systems

7.51 Satellite navigation systems are evolving. GNSS, providing independent navigation where the user performs on-board position determination from information received from broadcast transmission by a number of satellites, will provide highly reliable and more accurate global coverage independently. GNSS at present is comprised of two constellations: GPS, owned and maintained by the United States, and GLONASS, owned and managed by the Russian Federation.

Geodetic reference

7.52 The maps used across various States in the world to determine the position of runways, obstacles, airports, navigation aids and ATS routes are based on a wide variety of geodetic reference systems. Consequently, it is necessary to convert data originating in one reference system before it can be used in a different reference system. With the introduction of satellite navigation, the problem is more evident and has clearly shown the need for a universal map reference system. ICAO, to address this issue, decided to adopt the world geodetic system – 1984 (WGS-84) as a universal reference system for air navigation with an applicability date of 1 January 1998. Such adoption of WGS-84 by the State as a geodetic reference is a prerequisite for — and the first step in — the transition to satellite navigation.

Implementation GNSS

7.53 ICAO has endorsed satellite navigation as the primary future system. GNSS, along with augmentation such as ABAS, SBAS and GBAS, will enable user aircraft to perform on-board position determination for en-route, terminal, non-precision and precision approaches.

7.54 All electronic systems used for navigation and approach guidance must meet fundamental requirements in terms of accuracy, integrity, availability and continuity. The Standards related to these requirements, known as RNP, are more stringent for the more demanding operations. For example, the integrity warning (time to alert) during a non-precision approach must come within ten seconds of failure, while the warning for a Category III approach must come within one second.

7.55 The basic GNSS constellation cannot meet RNP Standards for any phase of flight. It must be augmented to varying degrees through:

a) aircraft-based augmentation system (ABAS):

1) receiver autonomous integrity monitoring (RAIM); or

2) aircraft autonomous integrity monitoring (AAIM);

b) the satellite-based augmentation system (SBAS); and

c) the ground-based augmentation system (GBAS).

Table 7-7 defines augmentation requirements to meet RNP parameters for various phases of flight in GNSS architecture scenarios.

Transition to GNSS

7.56 Figure 7-12 details an approach for the transition to GNSS covering all phases of flight, including augmentation requirements.

Table 7-7. GNSS architecture scenarios

RNP values	RNP = 1	RNP = 0.3	RNP = 0.03/50 or 0.02/40
Scenarios	Oceanic/ remote areas	En-route continental/NPA	PA Cat. I (DH to be defined)
Scenario 1	GPS + ABAS	GPS + ABAS + SBAS	GPS + ABAS + SBAS
Scenario 2	GPS + GLONASS + ABAS	GPS + GLONASS + ABAS	GPS + GLONASS + ABAS + GBAS
Scenario 3	Initially GPS + ABAS and use GLONASS subsequently	• Initially GPS + ABAS + SBAS/GBAS • Subsequently decom-mission SBAS with usage of GLONASS	• Initially GPS + ABAS + SBAS/GBAS • Subsequently decom-mission SBAS and provide additional GBAS with usage of GLONASS

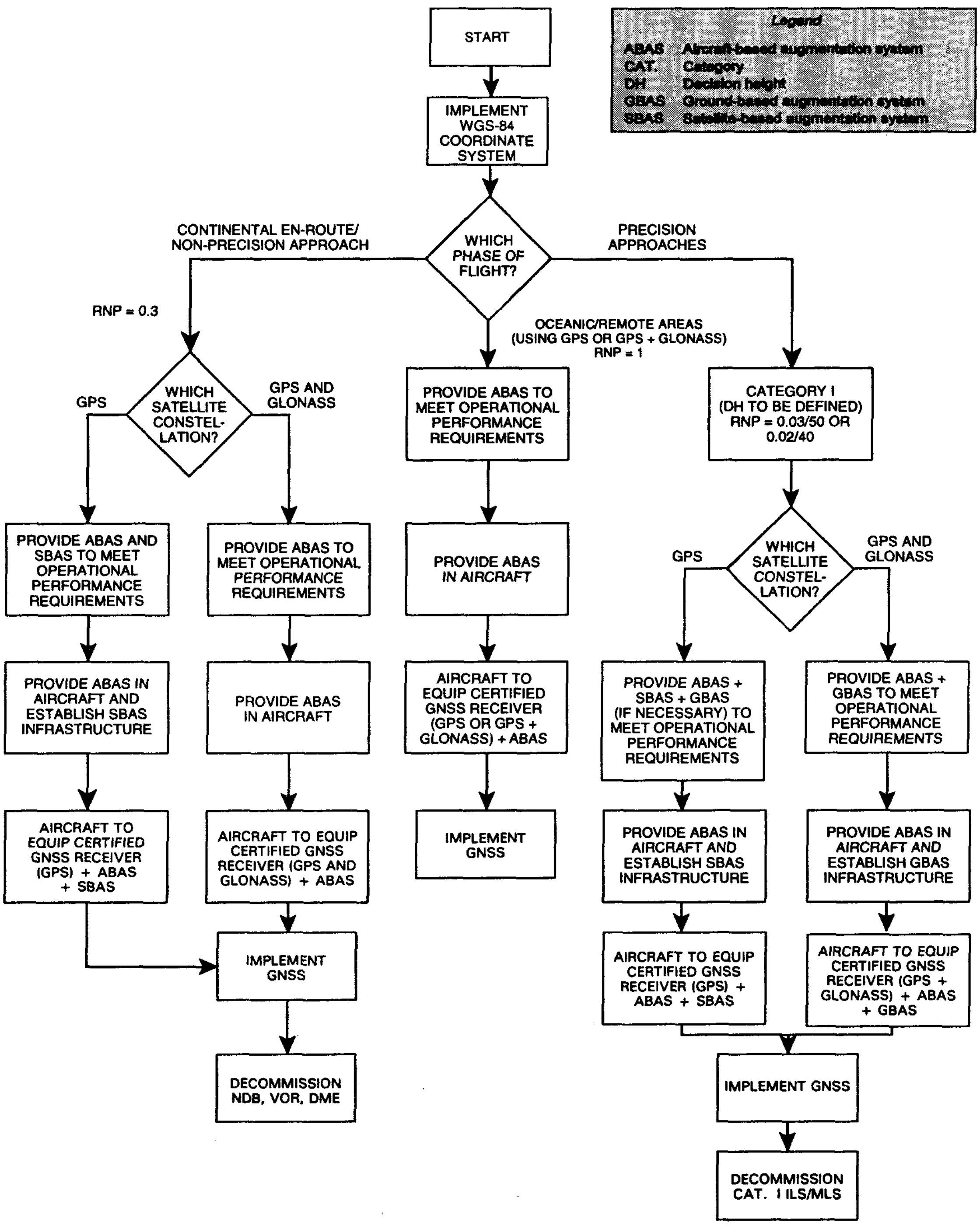


Figure 7-12. Decision tree — navigation

7.57 Oceanic

7.57.1 The improved accuracy afforded by the use of GNSS for oceanic airspace, in conjunction with ADS, will allow reduced separation between aircraft, nearer to optimal flight to take advantage of favourable winds, and dynamic flight re-routing to adapt to changing meteorological conditions. The transition to satellite navigation involves:

a) the conversion of coordinates to WGS-84;

b) the equipage of aircraft with a suitable GNSS receiver which has the capability for ABAS;

c) the promulgation of procedures;

d) the implementation of GNSS initially on supplemental/primary means; and later

e) the implementation of GNSS on sole means.

7.58 Continental en-route/Non-precision approaches (NPA)

7.58.1 Navigation component options involve adopting RNAV and GNSS as the basic building blocks for the provision of future en-route and approach navigational services. The principal benefits to the aircraft operation resulting from GNSS are the availability of many more and safer non-precision approaches and an advanced, highly accurate area navigation capability.

With reference to implementation of GNSS on supplemental means, what is an overlay?

An overlay is a customized flight path, developed with sequencing way-points, that emulates an existing, published instrument approach procedure.

7.58.2 For continental en-route, initially, GNSS (GPS) can be used to fly existing NPA on supplemental means, based on traditional aids to air navigation, such as VOR and NDB. These "overlay" approaches will provide pilots with experience using GNSS while improving guidance accuracy. In order to gain early operational benefits from GNSS, the State may consider implementing GPS for NPA on primary means. Finally, with the provision of necessary augmentation as outlined in Figure 7-12, sole-means approvals for the use of GNSS for NPA can be issued. The step-by-step approach to the implementation of GNSS for NPA using overlay methodology is depicted in Figure 7-13.

7.58.3 SBAS is essential for meeting integrity requirements to support NPA if only GPS constellation is used. However, SBAS could be further enhanced to include accuracy elements to support all phases of flight through Cat. I precision approaches. Figure 7-14 details the various steps involved in establishing SBAS initially to meet integrity requirements, followed by enhancements to meet accuracy requirements. However, it is neither necessary nor advisable for every State to establish SBAS independently. A subregional or regional approach is recommended in the implementation of SBAS, so as to gain operational and economic benefits. Table 7-8 suggests different levels of international SBAS participation, which is required for ensuring seamless navigation through interoperable systems.

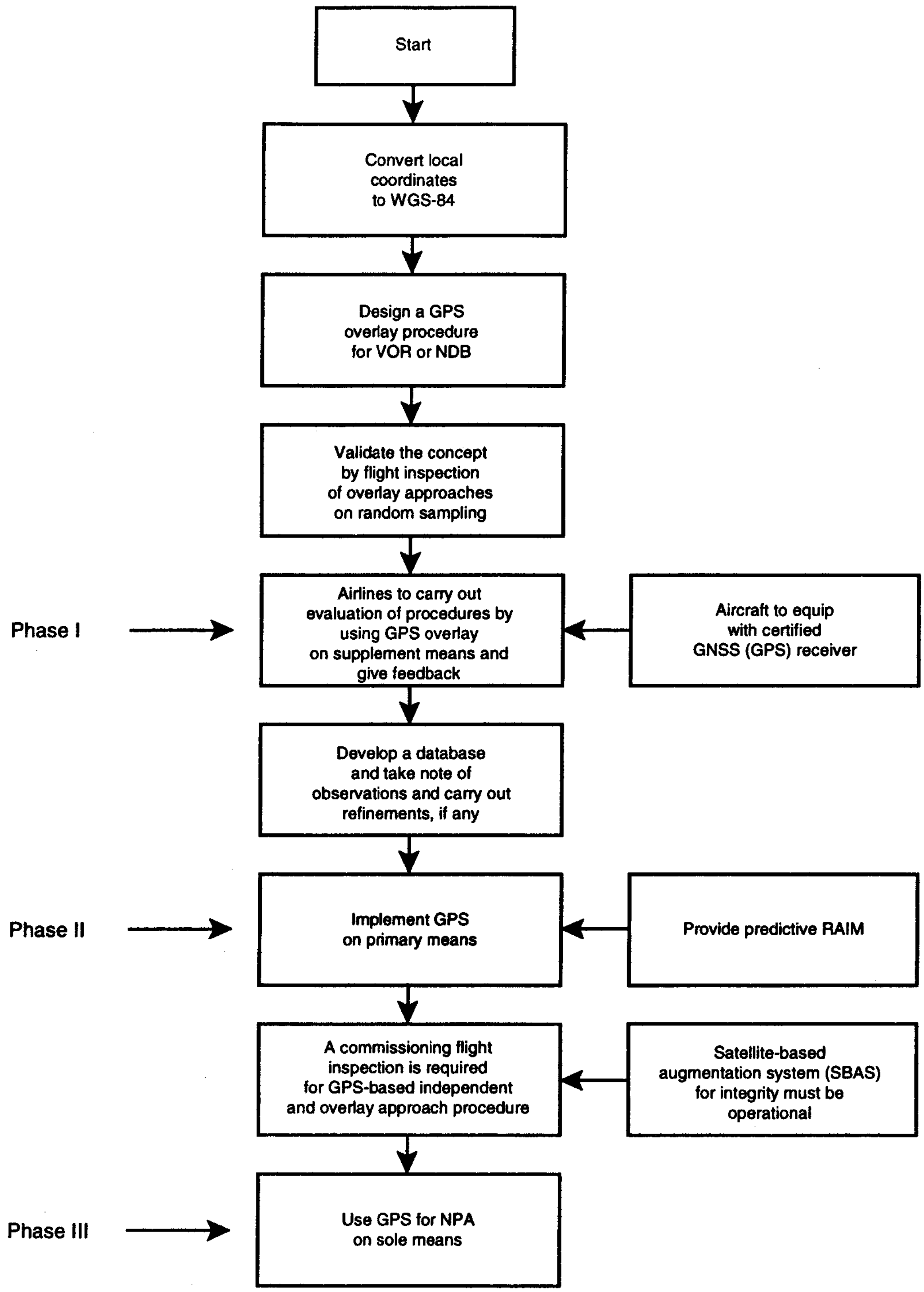
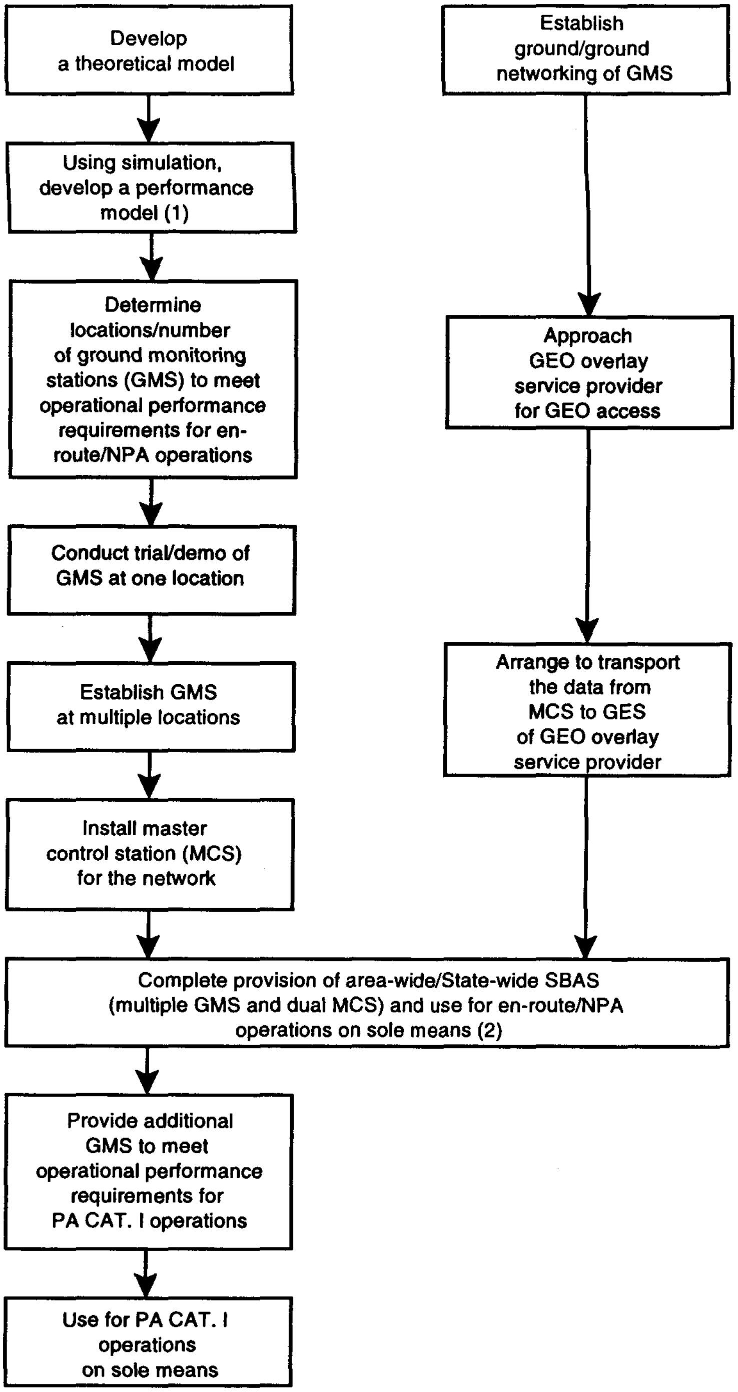


Figure 7-13. Implementation of GNSS (GPS) for non-precision approaches (using overlay methodology)



Notes:

1. Performance model to be included initially for integrity and subsequently for accuracy enhancement.
2. Regional/subregional approach to the establishment of SBAS is recommended.

Figure 7-14. Approach to establishing SBAS

Table 7-8. SBAS participation levels

Level 1	Use neighbouring system's downlink of GEO satellite
Level 2	Install one ground monitoring station (GMS) and connect to neighbouring system of SBAS
Level 3	Install multiple GMS connecting to neighbouring system
Level 4	Install multiple GMS and dual master control stations (MCS) connecting to neighbouring system; no GEO
Level 5	Independent SBAS system with GMS and MCS • GEO uplinking through overlay service provider • The different SBAS systems need to be interconnected via MCS for SBAS integration

7.59 Receiver database

7.59.1 With the implementation of satellite navigation, receiver databases are becoming increasingly important. Work to develop Standards and procedures is currently underway to ensure a consistent and accurate means of updating receiver databases.

7.60 Precision approaches

7.60.1 Currently, ICAO designates both ILS and MLS as standard precision approach systems. ICAO's Special Communications/Operations Divisional Meeting, held in Montreal in March/April 1995, reassessed the ILS/MLS transition plan in light of new developments and developed a new strategy for precision approaches. This includes the use of ILS/MLS for Cat. I, II and III — as long as it is operationally feasible and economically viable — while encouraging the use of GNSS, depending upon operational capabilities and institutional considerations. Figure 7-12 suggested an approach to choosing the candidate technology for precision approaches. It is emphasized that, though ILS/MLS meets near-term and middle-term navigation requirements, planning should be initiated for the transition to satellite navigation, as GNSS is the cornerstone of the CNS/ATM systems concept and is expected eventually to provide a sole means of navigation.

How to decide location of GNSS integrity monitoring stations, part of SBAS?

Integrity monitoring stations can be chosen to provide monitoring coverage with different "depths" of redundancy. A "depth one" international network has enough monitors to guarantee that every GPS and GLONASS satellite is always seen by at least one monitor. Depth two and three networks — required by regional augmentation systems — have enough monitors that every GPS and GLONASS satellite is seen by at least two or three monitors, respectively.

7.60.2 The accuracy provided by the SBAS is adequate to support precision approaches to Cat. I minima (decision height to be defined), but not to Cat. II/Cat. III minima. Meeting the more stringent requirements of the latter (Cat. II/Cat. III) will require GBAS. Under this concept, the corrections to the basic GNSS signals are broadcast within line-of-sight of the ground reference station. The range of this service is typically 25–30 NM. In addition to providing Cat. II/Cat. III capability, GBAS will be used at busy airports to increase the service availability of Cat. I. GBAS may also be required to support Cat. I approaches at airports whose specific locations make it difficult to use SBAS, such as those at latitudes greater than 55 degrees, due to inadequate visibility of Inmarsat GEO satellites.

Phase-out of current en-route and precision approach systems

7.61 As a result of the transition to satellite navigation, major economic benefits will accrue to both service providers and aircraft operators through the possible elimination of the majority of ground-based navigation systems. However, two factors mitigate against early replacement: GPS and GLONASS must be augmented and proven to have the reliability and robustness required to fully meet aviation needs, and aircraft operators must be able to recoup their investments in the avionics for conventional systems.

7.62 The principle milestones in the transition process occur when:

a) GNSS is approved for supplemental use;

b) GNSS is approved for primary use; and

c) a conventional system is withdrawn from service.

As soon as GNSS is declared for primary use, there will be strong economic pressure to decommission conventional systems. The use of facilities must be monitored and those having the least impact on users should be the first to be withdrawn from service.

Summary

7.63 Table 7-9 is a summary of tasks involved in the navigation segment. While States take action to enhance current systems (first column) to bring about short-term improvements, there is a need to plan for new systems (second column) to address long-term improvements. Accordingly, with reference to the second column, determine which new systems are to be implemented by the State and indicate the time lines for corresponding systems in Table 8-3 regarding navigation systems implementation (Chapter 8). Subsequently, plan for phasing out of current systems (third column) by ensuring some reasonable period of parallel operation of current and new systems and indicate the time lines for the corresponding systems in Table 8-3 regarding navigation systems implementation (in Chapter 8).

General transition issues

7.64 Guidelines for transition to the future systems encourage equipage by users for the earliest possible accrual of systems benefits. Although a transition period of equipage, both airborne and ground, is necessary to ensure the reliability and availability of a new system, this period should be limited to the extent practicable. Following are the guidelines that States, regions, users, service providers and manufacturers should consider when developing GNSS or when planning for its implementation.

Table 7-9. Summary — navigation transition (sample matrix)

Short-term improvements — enhance current systems	Long-term improvements — implement new systems	Phase-out of current systems not required consequent to transition to new systems
1. Extend navigation coverage for en-route traffic; install additional VOR/DME to meet near-term requirements	1. Implement WGS-84 coordinate system	1. NDB
	2. GNSS for oceanic airspace	2. VOR
		3. DME
2. Install ILS/MLS, as the case may be, to meet precision approach requirements as a near-term/middle-term strategy	3. GNSS for continental en-route airspace/NPA	4. ILS
	4. GNSS for precision approaches	5. MLS

Guidelines for transition to navigation systems

a) GNSS should be introduced in an evolutionary manner, with increasing benefits commensurate with improvements in navigation service. These benefits should culminate in GNSS sole-means operations.

b) The ground infrastructure for current navigation systems must remain available during the transition period.

c) States/regions should consider segregating traffic according to navigation capability and granting preferred routes to aircraft with better navigation performance.

d) States/regions should coordinate to ensure that separation standards and procedures for appropriately equipped aircraft are introduced simultaneously in each FIR through which major traffic passes.

7.65 In planning the transition to GNSS, the following issues must be considered:

a) schedule for provision and/or adoption of a GNSS service, including aircraft and operator approval processes;

b) extent of existing ground-based radio navigation services;

c) strategy for transition schedule to GNSS capability (i.e. benefits-driven or mandatory);

d) appropriate level of user equipage with GNSS capability;

e) provision of other air traffic services (i.e. surveillance and communication);

f) density of traffic/frequency of operations; and

g) mitigation of risks associated with radio frequency interference.

SURVEILLANCE

7.66 Traditionally, surveillance has been synonymous with radar, whether primary or secondary radar. However, radar suffers from a number of technical constraints. The effectiveness of radar systems is affected by coverage and siting problems, a reduction in accuracy when the range is increased, and relatively slow update rates; conversely, radar is the only tool currently available which will detect non-cooperative targets. Surveillance can be effected by four systems:

a) manual dependent — position reports conveyed by the pilot via VHF R/T or relayed via HF R/T;

b) independent — primary surveillance radar (PSR) and airport surface detection equipment (ASDE);

c) cooperative independent — secondary surveillance radar (SSR); and

d) automatic dependent — automatic position reporting from aircraft navigation system known as automatic dependent surveillance (ADS).

Current systems	*New systems*
PSR (Terminal)	SSR Mode S
PSR (En-route)	ADS
SSR Modes A/C	ADS-B
ASDE	

Figure 7-15 identifies problem areas and possible solutions for the current and medium-term surveillance functions.

New systems

Automatic dependent surveillance (ADS)

7.67 ADS will permit the surveillance of aircraft through automatic position reporting from the aircraft navigation system (such as GNSS) with a high degree of accuracy. The information so received on the ground, through an air-ground data link (e.g. VHF, HF, satellite), will be presented to ATC on a situation display terminal, similar to radar information. This ADS is also known as *ADS-C* (contract) or *ADS-A* (addressed). Implementation of the ADS function requires:

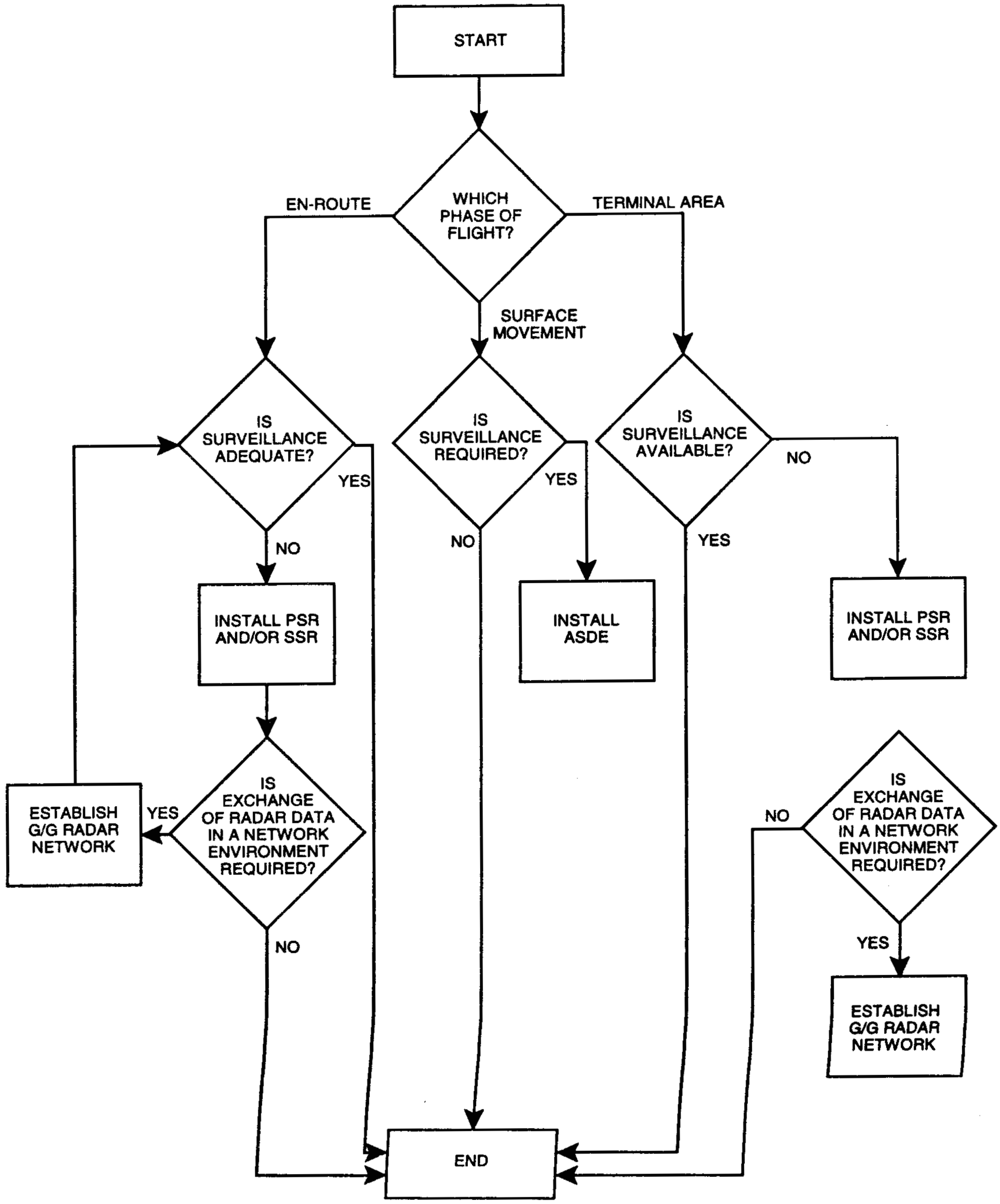
a) accurate position data supplied by the on-board navigation equipment;

b) message time-stamp provided to the ADS function, which varies no more than one second from Coordinated Universal Time (UTC);

c) CPDLC, an A/G data link (VHF/HF/satellite);

d) situation display systems for ATC; and

e) adequate procedures in place.



Note.— SSR to be installed should be monopulse and capable of upgrading to Mode S eventually.

Figure 7-15. Short-/medium-term improvements in surveillance

SSR Mode S

7.68 SSR requires cooperative transponders in aircraft in order to provide operability and has evolved into Mode A (4 096 4-digit codes) and Mode C (altitude) capabilities for the identification and height determination of the aircraft. The current monopulse SSR can be upgraded to provide the additional Mode S (selective address) capability. This has the distinct advantage of interrogating the aircraft selectively, thereby increasing the accuracy of azimuth information, reducing garbling and offering a data-linking capability. ICAO SARPs for the use of SSR Mode S are already in existence, as are certification and operational approval Standards for airborne SSR equipment.

Automatic dependent surveillance – broadcast (ADS-B)

7.69 In automatic dependent surveillance – broadcast (ADS-B), GNSS is used to determine the aircraft's position and the Mode S squitter — VHF digital link — relays position information to a ground station. ICAO SARPs for ADS-B-supporting technologies are underway. Research activities in the area of ADS-B systems are currently in progress and are expected to be available for operational use in the time frame of 2003 to 2005.

Selection of surveillance options

7.70 Figure 7-16 depicts the decision tree for surveillance and suggests an approach to selecting the technology candidate based on operational requirements, air traffic density, phase of flight and geographical area.

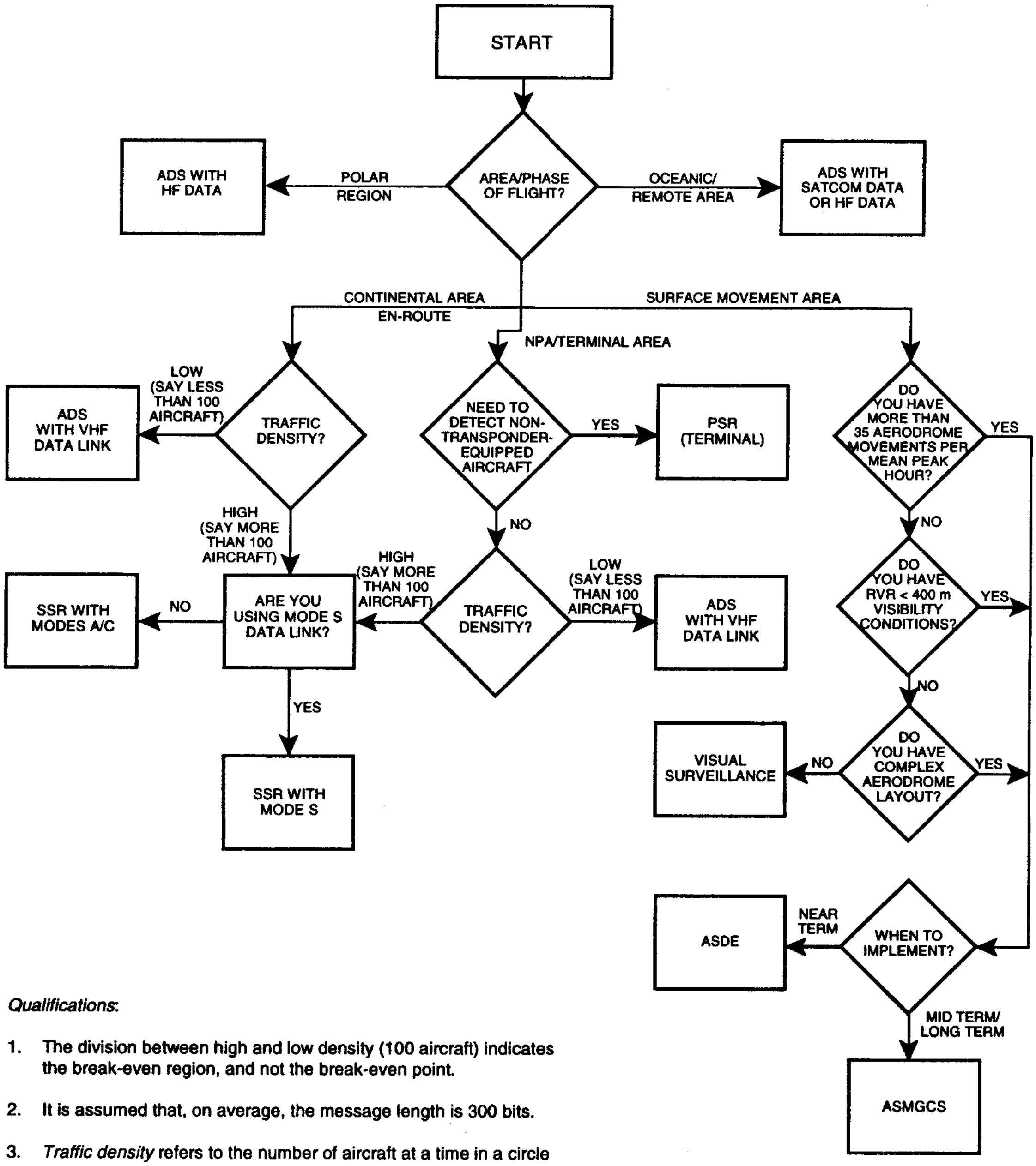
Oceanic airspace/remote areas

7.71 In oceanic airspace, the surveillance function is currently manual, based on pilot position reports received through HF communication relay. ADS supported by AMSS data/HF data is appropriate for use in oceanic airspace. Oceanic ADS is dependent upon the GNSS/airborne receivers to determine aircraft position and to use satellite communication (SATCOM) data link or HF data link to relay the aircraft's position to the ATC.

7.72 In response to user demand, an interim ADS system (FANS 1/A) is being introduced by States in order to gain early benefits and to meet near-term requirements. The system involves position-fixing by GNSS and employs the ARINC 622 protocol on character-oriented data link (satellite/VHF). While recognizing that the early use of ADS using ARINC Specification 622 ACARS satellite/VHF data link may serve as a valuable interim step towards the introduction of oceanic ATM applications, States choosing to implement this interim system should review the specification in order to determine the minimum functionality required for support of those ATM applications.

En-route continental area

7.73 The present PSR systems for en-route (also known as *air route surveillance radar*) air traffic surveillance, in addition to being costly, are difficult to install and maintain in inaccessible locations. These are gradually being replaced by SSR Modes A/C, and hence the use of PSR for en-route traffic surveillance will diminish further and will eventually be phased out. SSR Modes A/C can be upgraded to Mode S as and



Qualifications:

1. The division between high and low density (100 aircraft) indicates the break-even region, and not the break-even point.
2. It is assumed that, on average, the message length is 300 bits.
3. *Traffic density* refers to the number of aircraft at a time in a circle having a radius of 250 NM.
4. It is necessary to conduct cost/benefit analyses at each stage for determining the cost-effectiveness of the system.

Implementation options: ASR / SSR Modes A/C / ASDE / SSR MODE S / ADS / A-SMGCS

Figure 7-16. Decision tree — surveillance

when the need for a data link is projected based on operational requirements. ADS based on VHF data link is another option to replace PSR for en-route traffic. The decision tree in Figure 7-16 indicates the methodology for selecting the surveillance candidate.

Terminal area

7.74 The PSR systems currently used for the surveillance of terminal control areas (TMAs) are likely to be retained, at least for the short term to medium term, where the detection of non-transponder-equipped aircraft remains a safety issue. The alternative solutions, such as SSR Modes A/C, SSR Mode S and ADS using VHF data link, are the candidate technologies for surveillance for TMA operations. The flow chart in Figure 7-16 will assist in deciding on the option for TMA surveillance.

Surface movement area

7.75 Visual surveillance and ASDE have been the main sources of surveillance on the airport surface. Depending on the aerodrome layout, traffic density and visibility conditions, surveillance in future can be based on ADS or ADS-B. Based on operational requirements, in the long term, the advanced surface movement guidance and control system (A-SMGCS) using the ADS-B system may be employed. A suggested approach for decision-making is depicted in Figure 7-16.

Summary

7.76 Table 7-10 is a summary of tasks involved in the surveillance segment. While States take action to enhance current systems (first column) to bring about short-term improvements, there is a need to plan for new systems (second column) to address long-term improvements. Accordingly, with reference to the second column, determine which new systems are to be implemented by the State and indicate the time lines for corresponding systems in Table 8-4 regarding surveillance systems implementation (Chapter 8). Subsequently, plan for phasing out of current systems (third column) by ensuring some reasonable period of parallel operation of current and new systems and indicate the time lines for the corresponding systems in Table 8-4 regarding surveillance systems implementation (in Chapter 8).

General transition issues

7.77 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. Following are the guidelines that States, regions, users, service providers and manufacturers should consider when developing CNS/ATM systems or planning for implementation of such systems.

Guidelines for transition to surveillance systems

a) States should, as necessary, develop operational procedures in accordance with ICAO SARPs, procedures and guidelines, for the implementation of ADS within airspace under their control.

b) Transition to ADS should initially begin in oceanic airspace and in continental en-route airspace with low-density traffic.

c) States and/or regions should ensure that ADS is introduced in a coordinated fashion in adjacent FIRs traversed by major traffic flows.

d) Where different surveillance methods are employed in adjacent FIRs, commonality or compatibility of the systems should be ensured to enable a service that is transparent to the user.

e) During the transition period in which ADS position reporting is introduced, the current levels of integrity, reliability and availability of existing position reporting systems must be maintained.

f) States and/or regions should take action within the ICAO framework to ensure that implementation of changes due to ADS and other systems result in more efficient use of airspace.

g) During the transition to ADS, suitably equipped aircraft should be able to derive benefits from the use of preferred routes without penalizing non-ADS-equipped aircraft.

h) ADS should be introduced in incremental phases.

i) ADS equipment should be implemented in accordance with Standards and procedures in such a way as to permit the use of ADS as a back-up for other surveillance methods.

Table 7-10. Summary — surveillance transition (sample matrix)

Short-term improvements — enhance current systems	Long-term improvements — implement new systems	Phase-out of current systems not required consequent to transition to new systems
1. Install PSR (terminal)	1. SSR Mode S	1. PSR (en-route)
2. Establish ground-ground networking for radar systems	2. Oceanic ADS	2. PSR (terminal)
3. Install SSR Modes A/C	3. Continental ADS	3. ASDE
4. Install ASDE	4. A-SMGCS	
	5. Interim ADS - as a near-term/ mid-term solution	

AIR TRAFFIC MANAGEMENT

7.78 Air traffic management should enable aircraft operators to meet their planned times of departure and arrival and adhere to their proposed flight profiles with minimum constraints, without compromising agreed levels of safety.

7.79 The overall objectives of the ATM component of CNS/ATM systems are identified in Table 7-11. The objectives for a specific ATM system would be determined from a consideration of these ATM objectives, current and forecast traffic levels and available resources including human and financial resources (more information on the design of ATM systems may be found in the *Manual on Airspace Planning Methodology for the Determination of Separation Minima* [Doc 9689]). The ATM operational concept should assist in ATM design, with the goal of providing for the safe and efficient operations of aircraft for each phase of flight.

7.80 After determining the ATM requirements of a given area, based on air traffic forecasts and the requirements of aircraft operators, a strategy should be developed to guide the implementation of the CNS/ATM systems infrastructure, taking into account the performance capabilities of the CNS elements and the ATM objectives. These performance capabilities are used to determine airspace design (separation minima, route spacing, sectorization, instrument procedures required and the capability requirements for ATC intervention). Table 7-12 depicts the types and kinds of functions and services required to obtain ATM operational enhancements through, *inter alia*, reduced separation minima.

Airspace scenarios and associated benefits to ATM

7.81 A large number of technologically-related opportunities and benefits are now available for implementation on worldwide ATM systems that will improve ATM services to better meet user requirements, which are increasingly aimed at more dynamic and autonomous operations. Tables 7-13 to 7-17 depict the relationship between ATM and CNS elements, along with the benefits. These are defined in the context of scenarios reflecting typical airspace and traffic level combinations. It should be noted that the contents of the tables are by no means all-encompassing, nor are they considered to be absolute requirements.

Global ATM

7.82 Planning for the implementation of CNS/ATM systems is well under way to varying degrees in the ICAO Regions. It is necessary that the transition be clearly focussed on how to integrate those elements into a coherent and seamless global ATM system. One of the guiding principles for the transition to and implementation of CNS/ATM systems is that safety levels must be improved. However, while safety is a primary objective, it cannot be considered in isolation of the need to provide for an orderly and efficient flow of air traffic. ATM systems must be developed and organized to overcome shortcomings and to accommodate future growth in order to offer the best possible service to all airspace users, as well as to provide adequate economic benefits to the civil aviation community.

Table 7-11. Objectives of air traffic management

	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 with 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 user-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

* Emerging concept or technology — consensus still to be reached.

Table 7-12. ATM operational requirements in an RNP/RNAV environment

Code	ATM operational enhancements*	Required functions — air	Required services — ground	Notes
AIR TRAFFIC SERVICES				
1. Routings and required conventional functionalities				
1A	• fixed routes	• RNAV capability	• NAVAID infrastructure	
1B	• flexible routes	• RNAV capability	• NAVAID infrastructure	
2. Routings and required CNS/ATM functionalities				
2A	• fixed routes	• DCPC (voice/data) • RNP/X approval/ certification • FMS	• DCPC (voice/data)	• see Notes 1, 2 and 3
2B	• flexible routes	• DCPC (voice/data) • RNP/X approval/ certification • FMS	• DCPC (voice/data)	• see Notes 1, 2 and 3
2C	• dynamic user-preferred re-route (e.g. DARPs)	• DCPC (voice/data) • RNP/X approval/ certification • Aeronautical operational control (AOC) data link • Direct flight plan uploads • FMS	• DCPC (voice/data) • AOC data link • flight plan generation • AOC/ATS data communication	• utilization dependent on airspace complexity • see Notes 1, 2 and 3
2D	• autonomy of flight** concept	• to be developed	• to be developed	• concept still undergoing definition by ICAO
3. En-route vertical separation reductions				
3A	• 300 m (1 000 ft) vertical separation between FL 290 and FL 410	• RVSM certification/ operational approval • voice/data communication	• height monitoring sampling • voice/data communication	• see ICAO *Regional Supplementary Procedures* (Doc 7030), NAT/RAC • sampling to verify that aircraft population height-keeping accuracy is in conformance with appropriate Standards
4. En-route longitudinal separation reductions				
4A	• 80 NM (non-radar environment)	• RNAV • MNPS approval • voice/data communication	• Mach number technique (MNT) • 60-minute position reporting • voice/data communication	• MNT may be required • MNPS is used in a generic sense and may not be required in all cases • see Note 1
4B	• 50 NM (non-radar environment)	• RNP 10 approval/certification • FMS • DCPC (voice/data)	• 30-minute position reporting • MNT • DCPC/voice/data	• final requirements to be developed • MNT may be required • see Notes 1, 2 and 3
4C	• 30 NM (non-radar environment)	• FMS • DCPC (voice/data) • RNP 4 approval/certification • ADS	• DCPC (voice/data) • ADS	• final requirements to be developed • see Notes 1, 2, 3 and 4
4D	• less than 30 NM (non-radar environment)	• FMS • DCPC (voice/data) • RNP/X approval/certification • ADS	• DCPC (voice/data) • ADS	• final requirements to be developed • see Notes 1, 2, 3 and 4

Code	ATM operational enhancements*	Required functions — air	Required services — ground	Notes
4E	• 10 minutes (non-radar environment)	• RNAV • voice/data communication	• MNT where prescribed • voice/data communication	• RNAV capability may not be required in all situations • accurate time requirement/ common time reference • see Note 1
4F	• 7 minutes (non-radar environment)	• FMS • DCPC (voice/data) • RNP 10 approval/certification	• DCPC (voice/data)	• final requirements to be developed • accurate time requirement/ common time reference • see Notes 1, 2 and 3
5. En-route lateral separation				
5A	• 60 NM (non-radar environment)	• RNP 12.6 approval/ certification • voice/data communication	• voice/data communication • pilot position reports	• presently implemented as MNPS and AUSEP in the NAT and Asia/Pacific Regions respectively • performance monitoring may be required • see Notes 1, 3 and 5
5B	• 50 NM (non-radar environment)	• RNP 10 approval/certification • voice/data communication	• voice/data communication • pilot position reports	• performance monitoring may be required • see Notes 1, 3 and 5
5C	• 30 NM (non-radar environment)	• RNP 4 approval/certification • DCPC (voice/data)	• DCPC (voice/data)	• final requirements to be developed • performance monitoring may be required • see Notes 1, 2, 3 and 5
5D	• less than 30 NM (non-radar environment)	• DCPC (voice/data) • RNP/X approval/certification • ADS	• DCPC (voice/data) • ADS	• final requirements to be developed • performance monitoring may be required • see Notes 1, 2, 3, 4 and 5
5E	• 16.5 NM (uni-directional) (non-radar environment)	• RNP 5 approval/certification • DCPC voice	• DCPC voice	• relates to VOR reference system • see Notes 3, 5, 6 and 7
5F	• 18 NM (bi-directional) (non-radar environment)	• RNP 5 approval/certification • DCPC voice	• DCPC voice	• relates to VOR reference system • see Notes 3, 5, 6 and 7
5G	• 10 to 15 NM (radar environment)	• RNP 5 approval/certification • DCPC voice	• radar • DCPC voice	• system safety evaluation required • see Notes 3, 5, 6 and 7
5H	• 8 to 12 NM (radar environment)	• RNP 4 approval/certification • DCPC voice	• radar • DCPC voice	• system safety evaluation required • see Notes 3 and 5

Code	ATM operational enhancements*	Required functions — air	Required services — ground	Notes
AIRSPACE MANAGEMENT				
6A	• airspace integration and flexible use of airspace**	• to be provided to all aircraft	• separate databases for: - aircraft - AOC - military reserved airspace - national security - environmental - aeronautical information - airports - weather - traffic - SAR - rules of the air	• this provides the information that is necessary to create flexible use of airspace**
AIR TRAFFIC FLOW MANAGEMENT				
7A	• integrated air traffic flow management	• to be provided to all aircraft	• separate databases for: - aircraft - AOC - airspace requirements - environmental - aeronautical information - airports - weather - traffic forecast • integrated automation of database management • AOC interface • ATC/ASM/ATFM interface	• purpose is to ensure an optimum flow of air traffic by balancing traffic demand and ATC capacity

* For each particular operational enhancement, there will be a need for the airlines and the ATS providers to review existing procedures to identify what new requirements are required prior to operational implementation

** Emerging concept or technology — consensus still to be reached.

NOTES

1) *When a data link is used for communication, voice communications must be available. Depending upon the separation requirement, the voice requirement may be for direct voice.*

2) *Performance requirements of a data link depend upon the application for which it is being used.*

3) *The approval for RNP operations is specific for each RNP type.*

4) *ADS requirement is associated with and related to the overall communication performance requirements for position reporting.*

5) *Lateral route systems require regional safety assessments and agreement.*

6) *In some cases, the RNP requirement may be met without the use of RNAV; however, in future CNS/ATM systems, all aircraft are expected to be RNAV-equipped.*

7) *RNP/5 relates to a VOR reference system up to the year 2000, at which time safety assessments are required against a new target level of safety.*

Table 7-13. ATM — Oceanic/continental airspace with low-density traffic

Functions	Technical elements		Procedural aspects		ATM benefits
	Ground	Air	Structure	Procedures	
COM					
• AMSS voice and data • HF voice and data	• ATN connectivity to AMSS, HF • ATN end-systems (HMI) • Voice AMSS, HF	• ATN connectivity to AMSS and HF avionics • Voice AMSS, HF	• RCP*	• Data link handling procedures • Message format	• Improved tactical control • Improved pilot/controller communications • Facilitated ATC/FMS dialogue
NAV					
• GNSS	NIL	• GNSS receiver • FMS	• RNP • Airspace organization • RNP certification/ approval	• Navigation procedures	• Improved airspace utilization
SUR					
• ADS • ADS-B*	• ATN connectivity to AMSS and HF • Situation display for ADS and ADS-B*	• ATN connectivity with ADS and ADS-B* function and situation display • ADS, ADS-B* avionics	• Airspace organization • RSP*	• Surveillance procedures • Message format	• Reduction of R/T workload • Improved situational awareness*
AUTOMATION					
• Decision support systems	• Automated flight data processing • Conflict alert advisory prediction-resolution software	• FMS	• Airspace organization	• Automation procedures and algorithm development • Message format	• Increased direct routings • Improved conflict prediction and resolution

* Emerging concept or technology — consensus still to be reached.

Table 7-14. ATM — Oceanic/airspace with high-density traffic

Functions	Technical elements		Procedural aspects		ATM benefits
	Ground	Air	Structure	Procedures	
COM					
• AMSS voice and data • HF voice and data • Extended VHF voice and data	• ATN connectivity to AMSS, HF, extended VHF • ATN end-systems (HMI) • Voice AMSS, HF, extended VHF	• ATN connectivity to AMSS, HF, extended VHF avionics • Voice AMSS, HF, extended VHF	• RCP*	• Separation criteria • Data link handling procedures • Message format	• Improved tactical control • Improved pilot/controller communications • Facilitated ATC/FMS dialogue
NAV					
• GNSS		• GNSS receiver • FMS	• RNP • Airspace organization including separation criteria • RNP certification/ approval	• Navigation procedures	• Increased airspace capacity by reduction in separation minima due to increased positional accuracy • Improved airspace utilization
SUR					
• ADS • ADS-B*	• ATN connectivity to AMSS, HF and extended VHF • Situation display for ADS and ADS-B*	• ATN connectivity with ADS and ADS-B* function and situation display • ADS and ADS-B* avionics	• Airspace organization including separation criteria • RSP*	• Surveillance procedures • Message format	• Increased airspace capacity by reduction in separation minima due to improved conformance monitoring • Improved airspace utilization • Reduction of R/T workload • Improved situational awareness*
AUTOMATION					
• Decision support systems	• Automated flight data processing • Conflict alert advisory prediction-resolution software	• FMS	• Airspace organization	• Automation procedures and algorithm development • Message format	• Increase in direct routings • Increase in user-preferred flight profiles • Increased capacity • Improved traffic planning • Improved conflict prediction and resolution • Improved trajectory planning

* Emerging concept or technology — consensus still to be reached.

Table 7–15. ATM — Continental airspace with high-density traffic

Functions	Technical elements		Procedural aspects		ATM benefits
	Ground	Air	Structure	Procedures	
COM					
• AMSS voice and data • VHF voice and data • SSR Mode S data link	• ATN connectivity to SSR Mode S and VHF • ATN end-systems (HMI) • Voice VHF	• ATN connectivity to VHF and SSR Mode S avionics • Voice VHF	• RCP*	• Separation criteria • Data link handling • Message format	• Improved pilot/controller communications • Facilitated ATC/FMS dialogue • Complement VHF coverage • Reduction of R/T workload
NAV					
• GNSS	• Augmentation	• GNSS receiver • FMS	• Application of RNP • Airspace organization including separation criteria • RNP certification/ approval	• Navigation procedures	• Increased airspace capacity by reduction in separation minima due to increased positional accuracy • Improved airspace utilization
SUR					
• ADS • ADS-B* • SSR	• ATN connectivity to VHF, SSR Mode S • Situation display for ADS and ADS-B*	• ATN connectivity with ADS and ADS-B* function and situation display • SSR Mode S transponder • ADS and ADS-B* avionics	• Airspace organization including separation criteria • Application of RSP*	• Surveillance procedures	• Increased airspace capacity by reduction in separation minima due to improved conformance monitoring • Improved airspace utilization • Reduction of R/T workload • Improved situational awareness* • (ADS, ADS-B*) complement to and possible back-up for SSR • Reduced need for PSR

* Emerging concept or technology — consensus still to be reached.

Functions	Technical elements		Procedural aspects		ATM benefits
	Ground	Air	Structure	Procedures	
AUTOMATION					
• Decision support systems	• Automated flight data processing • Conflict alert advisory prediction-resolution software	• FMS	• Airspace organization	• Automation procedures and algorithm development • Message format	• Improved traffic planning • Improved conflict prediction and resolution • Improved trajectory planning • Increase in direct routings • Increase in user-preferred flight profiles

Table 7-16. ATM — terminal areas with high-density traffic

Functions	Technical elements		Procedural aspects		ATM benefits
	Ground	Air	Structure	Procedures	
COM					
• VHF voice and data • SSR Mode S data link	• ATN connectivity to VHF and SSR Mode S • ATN end-systems (HMI) • Voice VHF	• ATN connectivity to VHF, SSR Mode S avionics • Voice VHF	• Airspace organization • Application of RCP*	• Separation criteria • Message format • Data link procedures	• Improved pilot/controller communi-cations • Facilitate ATC/FMS dialogue • Complement VHF coverage • Reduction of R/T workload
NAV					
• GNSS • ILS • MLS	• ILS • MLS • Augmentation systems	• GNSS receiver • ILS • MLS • MMR • FMS	• Application of RNP • Airspace organization including separation criteria • RNP certification/ approval	• Approach procedures	• Increased airspace capacity by reduction in separation minima due to increased positional accuracy • Improved airspace utilization

* Emerging concept or technology — consensus still to be reached.

Functions	Technical elements		Procedural aspects		ATM benefits
	Ground	Air	Structure	Procedures	
SUR					
• ADS • ADS-B* • SSR	• ATN connectivity to VHF and SSR Mode S • Situation display for ADS and ADS-B*	• ATN connectivity with ADS and ADS-B* function and situation display • SSR Mode S transponder • ADS and ADS-B* avionics	• Airspace organization including separation criteria • Application of RSP*	• Surveillance procedures development	• Increased airspace capacity by reduction in separation minima due to improved conformance monitoring • Improved airspace utilization • Reduction of R/T workload • Improved situational awareness* • (ADS, ADS-B*) complement to and possible back-up for SSR • Reduced need for PSR
AUTOMATION					
• Decision support systems	• Automated flight data processing • Conflict alert advisory prediction-resolution software • Metering software	• FMS	• Airspace organization	• Automation procedures and algorithm development • Message format	• Increase in direct routings • Improved sequencing and flight profiles • Improved trajectory planning • Improved traffic planning • Improved conflict prediction and resolution

* Emerging concept or technology — consensus still to be reached.

Table 7–17. ATM — terminal areas with low-density traffic

Functions	Technical elements		Procedural aspects		ATM benefits
	Ground	Air	Structure	Procedures	
COM					
• VHF voice and data	• ATN connectivity for VHF • ATN end-systems • Voice VHF	• ATN connectivity to VHF avionics • Voice VHF	• RCP*	• Data link procedures • Message format	• Improved pilot/controller communi-cations • Facilitated ATC/FMS dialogue • Complement VHF coverage
NAV					
• GNSS	• Augmentation systems	• GNSS receiver	• RNP certification approval	• Approach procedures	• Improved airspace utilization
SUR					
• ADS • ADS-B* • SSR	• ATN connectivity for VHF • Situation display for ADS and ADS-B*	• ATN connectivity with ADS and ADS-B* function and situation display • ADS, ADS-B* avionics	• RSP*	• Surveillance procedures	• Improved airspace utilization • Improved situational awareness* • Reduced need for PSR
AUTOMATION					
• Decision support systems	• Situation display • Automated flight data processing	• FMS		• Automation procedures and algorithm development • Message format	• Increase in user-preferred flight profiles • Improved traffic planning • Improved conflict prediction and resolution

* Emerging concept or technology — consensus still to be reached.

ATM functions

7.83 The functions of air traffic management include:

a) airspace management (ASM);

b) air traffic services (ATS); and

c) air traffic flow management (ATFM).

Airspace management

7.84 Airspace is a finite resource, and the way it is organized and the route structure that it contains have a major impact on its capacity potential. Current airspace divisions and route systems have evolved in line with a fixed-route structure, based on ground-based CNS systems. In contrast, advances in avionics and on-board position determination mean that aircraft are becoming less dependent on fixed navigational aids and routes, and can fly more flexible, economic and accurate random profiles. This process offers the potential for airspace capacity gains, if accompanied by greater flexibility in the way the traffic flows and how the airspace is organized and managed.

Route structure

7.85 In general, route structure options fall into three main categories:

a) *fixed routes*, which can be — but are not necessarily — associated with a fixed navigation aid structure;

b) *RNAV fixed routes*, which are fixed, published routes but are not associated with a fixed, ground NAVAIDs structure;

c) *RNAV random routes*, where the route is not published but rather is defined on a flight-by-flight basis by the users; and

d) *mixed routes*, which combine both fixed routes and random routing.

Each of these categories also combines a number of integral variations. For example, fixed routes include dynamic, published structures.

7.86 Current airspace management centres around a fixed-route structure and is mostly delineated by ground-based navigation aids. These fixed route structures usually take account of the general flow pattern experienced within national airspace boundaries; however, they are neither particularly economical in terms of fuel costs nor dynamically responsive to the large variations in traffic density that routinely occur both inside and across national boundaries. A possible extension of a fixed-route concept is to introduce a dynamically changing, fixed-route structure based on predicted traffic flows for given future time periods, e.g. different configurations each day on the forecasted traffic flow for that period. However, by their very nature, fixed routes inhibit the potential increases in airspace capacity to be gained from the route flexibility offered by improved navigational systems.

7.87 Advances in on-board navigation systems offer the possibility of a greater use of random routings, rather than fixed routes, thereby allowing users to operate more flexibly and efficiently. By definition, random routes are unpublished routes. In practice, random routing operations contain at least some predictable elements (i.e. departure/arrival points) and may follow a planned flight path or be changed dynamically in flight to suit the prevailing conditions. Their use is combined with the on-board carriage and use of RNAV capabilities.

7.88 The area navigation (RNAV) operation is a method of navigation which permits aircraft operation on any desired flight path. Owing to the development of avionics, aircraft have become capable of flying "off-track" and proceeding directly between two points, without flying over navigation aids. RNAV is not a navigational aid with its own discrete sensors but rather is a computerized navigation management system which accepts data from all available sources. Such sources may typically include DME/DME, VOR/DME, INS/IRS, Doppler and air data from aircraft instruments, with DME/DME normally being the preferred mode. The data received from these sensors is then compared with a comprehensive database to provide the pilot with longitudinal and latitudinal positional information. The database can typically store up to 5 000 way-points and 300 discrete routes. Distance to the next way-point of the flight, together with the estimated time of arrival, may be displayed, and should it be desired to arrive by a given time, the RNAV equipment will indicate the necessary indicated airspeed (IAS) or Mach number to achieve this.

7.89 The State, based on local requirements and traffic densities, may enforce the carriage of RNAV equipment mandatory in the area, thus providing the opportunity to extend the use of area navigation operations. To a certain extent, random (in terms of more direct) routings are already offered by controllers when traffic conditions allow (e.g. in low-density areas or during quieter periods), but their use is on an *ad hoc* basis, not pre-planned. Possible future options for the random routings include the unrestricted use of more direct and fuel-efficient routings; routings flown within designated and published random routing RNAV areas; or a mix of both. Regardless of the option chosen, the change from a fixed (deterministic) route structure to a random (non-deterministic) routing environment will need to be supported by changes in the current divisions of responsibility for separation assurances and enhancement of ATM support devices (such as flight data processing systems, data communication facilities and controller tools).

7.90 In reality, and until more advanced air traffic management tools become available, random routing operations based on RNAV capabilities may be more suited to the en-route phase of flight, or to medium- and low-density areas or time periods, with fixed-route structures being used in high-density areas of TMAs where traffic flows need to be more orderly and predictable. Any changes in route structure will need to be accompanied by changes in the associated control sector boundaries. Where routes are changed dynamically to reflect traffic conditions, it will be necessary to employ an integrated, multi-sector planning environment, with dynamic sectors which are functionally identical. Conversely, it is equally possible that there may be a need to make adjustments to the route network to match a particular sector configuration (e.g. to avoid a large concentration of traffic at or around a particular location).

Airspace organization

7.91 The present airspace organization is founded on fixed — and largely static — airspace divisions and boundaries. It is general practice to set aside portions of the airspace on a permanent or semi-permanent basis for military activities. Overall, the airspace organization is inflexible and leads to an inefficient use of the available airspace resources. Having recognized the deficiencies of the present airspace organization, a new concept, *airspace desegregation*, encompassing the dynamic and flexible use of airspace within a State, needs to be considered for implementation. Within the flexible airspace concept, the airspace will be viewed as a continuum, and that airspace set aside for the exclusive use of one category of user (e.g. defence) will be kept to the absolute minimum. This, in turn, will mean that airspace routes can be created in areas where this was not previously possible, even if these routes are not available at all times.

Flexible use of airspace

7.92 The concept of flexible use of airspace is based on the following principles:

a) airspace should no longer be designated as either purely civil or military airspace;

b) airspace should be considered as one continuum and allocated according to user requirements; and

c) any necessary airspace segregation will be temporary, based on real-time usage.

Airspace management — Civil/military coordination

7.93 Three levels correspond to civil/military coordination:

a) *strategic level*:

1) establishment of predetermined airspace structure; and

b) agreement on priorities and negotiation procedures;

b) *pre-tactical level*:

1) day-to-day allocation of airspace, according to user requirements; and

2) communication of airspace allocation data to all concerned; and

c) *tactical level*:

1) real-time use of airspace; and

2) activation/de-activation of re-allocation.

Flexible airspace structure

7.94 The concept of a flexible airspace structure is based on the potential offered by new, adaptable airspace structures and procedures:

a) *a basic ATS routes network*;

b) *conditional routes* — non-permanent ATS routes or route portions which will be available for specific regular times or made available daily;

c) *temporarily segregated areas* — those areas which are temporarily reserved for the exclusive use of specific users (e.g. danger or restricted areas for military use); and

d) *cross-border areas* — these are temporarily segregated areas which are established over international boundaries by States.

7.95 The implementation approach for flexible use of airspace is shown in Figure 7–17.

Optimized sectorization

7.96 The conventional approach to increasing capacity is to subdivide and reorganize the present structure of fixed airspace control sectors. However, the limiting factor in the ATM system at present is the workload of the air traffic controller. The potential gains from employing smaller sectors are usually offset, at least to some degree, by an increase in the intersector coordination workload. Additionally, it is possible that the extent to which airspace can be further subdivided is limited.

7.97 Alternate options include more flexible and dynamic sectorization methods, where boundaries are adjusted to take into account traffic plans and densities. While doing so, consideration would need to be given to the way that airspace responsibilities are allocated to the various ATS units and between the sector control teams.

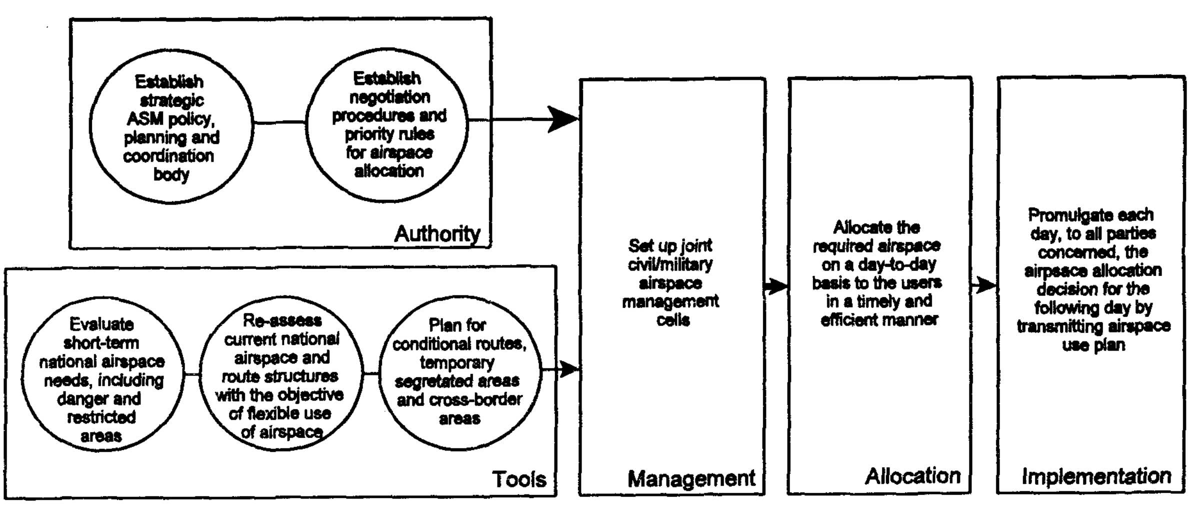


Figure 7-17. Flexible use of airspace — Approach to implementation

Application of RNP

7.98 With the adoption of the RNP concept, it can be ensured that aircraft in clearly defined airspace can establish their position to a required accuracy. As a product of improved accuracy and integrity of positioning, this in turn will enable current separation standards to be safely reduced to improve airspace efficiency. The RNP concept specifies the navigational requirement and accuracy needed for aircraft to operate in defined airspace. RNP is an air navigation planning tool with an initial focus on horizontal applications. The various RNP values specified are RNP 20, RNP 12.6, RNP 10, RNP 4 and RNP 1. Based on a number of considerations, as explained in the *Manual on Required Navigation Performance (RNP)* (Doc 9613), a State may plan for the implementation of RNP, which would facilitate the reduction of separation standards. Table 7-18 specifies RNP types for general application to en-route operations.

Introducing RNP into an airspace

7.99 In order that RNP may be introduced by States on an evolutionary basis, the following aspects should be considered:

a) availability of ground infrastructure and aircraft equipage;

b) lead time for installation of airborne systems;

c) development and implementation of regional transition plans;

d) existence of Standards and procedures;

e) airspace demand requirements;

f) availability of airworthiness and operational approval procedures;

g) airspace/sectorization design requirements;

h) lead time for training and publication; and

i) cost/benefit considerations.

Table 7-18. RNP types

	RNP type				
	1	4	10	12.6	20
Accuracy 95 per cent position accuracy in the designated airspace	±1.85 km (±1.0 NM)	±7.4 km (±4.0 NM)	±18.5 km (±10.0 NM)	±23.3 km (±12.6 NM)	±37 km (±20.0 NM)

7.100 Aircraft with appropriate RNP certification will be able to fly with reduced separation. The adoption of the RNP concept will provide the following benefits:

a) improved on-time performance through the use of more direct and optimal routings;

b) increased number of routes available, resulting in increased airspace capacity; and

c) enhanced flight safety, along with a requirement for accurate navigation by all aircraft concerned.

Air traffic services (ATS)

7.101 ATS is a generic term for flight information service, alerting service and air traffic control service. The main objectives of air traffic services are to prevent aircraft collisions, both with other aircraft and with obstructions, and to expedite and maintain an orderly flow of air traffic. Air traffic flow management and airspace management complement ATC in the attainment of these objectives by maximizing the use of available airspace capacity.

7.102 The level of sophistication of the present ATC equipment varies considerably from State to State. Most ATC systems are based on synthetic radar displays, which show limited track label information, and paper flight progress strips, which are annotated by hand. Some States employ electronic flight strips and automated internal coordination procedures, but their use is not widespread. The networking and sharing of data, both within and across national boundaries, is limited. While computer-assisted monitoring tools are becoming more commonplace, coordination between the en-route, arrival and airfield segments of flight is mostly procedural or is accomplished by manually operated voice links.

7.103 The principles of automation in ATM could be extended to many areas. Choices and options on which information should be processed and distributed, and how these processes should be automated and interfaced with other systems, are almost infinite. However, there is little point in ATC automation for its own sake; the decisions made must reflect specific operational needs and complement the overall support strategy adopted.

7.104 The main development in the area of air traffic control strategies is the ICAO principle, embodied in the CNS/ATM systems strategy, that the human and ground elements will remain an essential part of future ATM operations. While the retention of the human in the control loop dictates the main thrust of future developments, the degree and level of ATM automation will be decided by the availability and robustness of particular technologies and by cost/benefit analyses.

7.105 Air traffic controllers must know where all of the aircraft under their responsibility are, and must determine how and when to take action to ensure that the aircraft remain separated from each other, while also seeing to their requests and needs for descent, climb, take-off, departure, etc.

7.106 Although it is well accepted that the human controller in the system has performed these tasks more than adequately over the years, it is also accepted that improvements could be made by using decision support software tools. These tools are expected to assist the controller to some degree with conflict prediction, detection, advisory and resolution.

7.107 The degree and level of implementation of ATM decision support systems/tools by a State should be based on operational needs and cost/benefit analyses. The automatic tools include:

a) conformance monitoring to monitor conformance of the actual flight path with that of the flight plan;

b) conflict prediction, alert and resolution (short-term conflict alert [STCA]/medium-term conflict alert [MTCA]); and

c) minimum safe altitude warning (MSAW) in order to assist in the prevention of controlled flight into terrain (CFIT).

7.108 For the purpose of cost/benefit analysis, States may consider following three levels of basic automation tools:

a) low-level — conformance monitoring and MSAW;

b) medium-level — low level and conflict prediction and MTCA; and

c) high-level — medium level and STCA and resolution.

7.109 Functional integration of the ground system with the airborne system is essential in order to attain the general objectives of ATM. Functional compatibility of data exchanged between the airborne and the ground elements will ensure efficiency of the system.

7.110 An increased ability to accommodate user-preferred flight profiles in support of the concept of autonomous flight will be gained through improved decision support tools.

7.111 Independent IFR approaches to closely spaced runways (760 m/2 500 ft or less) will be based on precision runway monitor (PRM), which is an SSR with an update rate of 1 per sec, and improved monitor controller displays. This will provide capacity increases in instrument meteorological conditions (IMC) at locations with such runway configurations.

7.112 The use of curved and segmented approaches using MLS or GNSS may eliminate some constraints imposed by centre line approach procedures dictated by the limitations of instrument landing systems (ILS). In certain situations, this will be essential to eliminate conflicts among approach operators involving adjacent airports and will allow each airport to operate independently. These techniques will also lead to added flexibility in controlling the noise footprint of airport traffic operators.

7.113 The arrival metering and sequencing system is a computerized, multi-runway decision-making tool for airports and en-route ATC centres. The system provides an economical and efficient solution to overcome existing bottlenecks in air traffic by minimizing aircraft delays within the terminal control area through optimized sequencing of traffic flows. Improved metering (spacing between aircraft) and sequencing (ordering of landing) using automated devices, while assisting air traffic controllers in establishing efficient flows of approaching aircraft for parallel and converging runway configurations, will increase runway capacities in IMC to a level approaching present runway capacities in visual meteorological conditions (VMC).

7.114 Advanced SMGCS (A-SMGCS) — which is a fusion of radar and airfield lighting technologies — will be used for routing, guidance, surveillance and control of aircraft and vehicles on the ground in order to maintain acceptable movement rates under all weather conditions, while improving the required level of safety. ADS-B is envisaged to be the tool for A-SMGCS, thus being an alternative to surface radars such as airport surface detection equipment. A-SMGCS is to be provided where the traffic density and/or local conditions so warrant.

7.115 The AIDC application exchanges information between ATS units for support of critical ATC functions, such as notification of flights approaching an FIR boundary, coordination of handoffs and transfer control. The AIDC utilizes the services of the ATN to provide efficient digital data communications among ATS facilities.

7.116 Application of data link (such as pre-departure clearance and ATIS) should aim for a reduction of voice communication load and also for an improvement in the provision of critical data to the user.

Coordination

7.117 The present methods of coordination, based largely on voice communication, will not be adequate to handle future traffic growth. There is also likely to be a shift in the current coordination parameters, which are based on current position and intended routes, towards coordination covering full route trajectories. The advent of ATN, together with improvements to the methods of data transfer, offers the scope to automate a variety of coordination functions. Choices involving changes to coordination functions are expected to revolve largely around the extent to which particular methods should be employed and automated; a balance is to be struck between voice, data and silent coordination procedures.

Separation standards

7.118 The required separation between aircraft is generally expressed in terms of minima, that is to say, standards which should not be infringed. Minima are specified in a measurement of distance, horizontally in nautical miles (NM) or degrees of angular displacement, and vertically in feet. Minima may also be specified as a measurement of time intervals. Horizontal separation (longitudinally) can be established and maintained by using either aircraft DME or radar, or by the application of a speed differential (Mach number technique).

7.119 Separation by time is another method used in air traffic control. The application of separation to aircraft, based solely on position information received from pilots via air-ground communication, is generally referred to as *procedural control* and is applied in oceanic airspace as well as in domestic airspace where radar coverage is not available. Radar separation, on the other hand, is based on radar-displayed position information and is currently applied in continental airspace.

7.120 The Mach number technique (MNT) involves the assigning of Mach numbers to two (or more) aircraft flying in trail at the same altitude. Where the longitudinal separation standard is 15 minutes, ATC may reduce this standard to 10 minutes by assigning the same Mach number to each of the aircraft flying in trail. Where the lead aircraft is faster than the trailing one, initial separation at the oceanic entry point may be reduced below 10 minutes. Maintaining a fixed Mach number on long-haul flights may result in less-than-optimum fuel consumption. However, reduction of the non-radar longitudinal separation minima by an application of the Mach number technique is an effective method of increasing airspace capacity.

Determining separation minima — Influencing factors

7.121 In determining appropriate separation minima, it is necessary to have detailed information on existing airspace, the CNS/ATM capabilities and the airspace characteristics which may influence the safe separation minima. There are a number of factors which may influence the separation minima, as listed in Table 7-19.

Table 7-19. Determining separation minima — influencing factors

I. Airspace structure
• Route structure, i.e. the use of parallel or non-parallel ATS routes and whether they are bidirectional or unidirectional
• Existing separation minima and how often values close to the separation minima are used in practice
• Complexity of the airspace, including *inter alia*: a) traffic demand pattern; b) numbers and locations of crossing tracks; c) amount of traffic operating on opposite direction tracks; d) amount of traffic which is either climbing or descending; e) nature of the aircraft population, i.e. the diversity of traffic with respect to aircraft performance and equipage (e.g. mix of various speeds, climb performance, desired optimal flight levels); f) peak and average traffic demands versus system capacity; g) runway capacities and the limitations of associated ground services; h) any adjoining special use airspace, airspace usage and types of activities including the civil/military mix; and i) regional meteorological conditions (e.g. the prevalence of convective storms, etc.)
• Designated airspace classifications
II. Communication capability
• Direct controller-pilot voice communication (VHF/SATCOM)
• Indirect controller-pilot voice communication (HF)
• Controller-pilot data link communication (CPDLC)
• Controller-controller voice and automated data link communication, both inter- and intra-ATS unit(s)
• Data link between ground ATC automation systems and aircraft flight management computers
• System availability, reliability and capacity
III. Surveillance capability
• Procedural dependent surveillance: a) content of pilot position reports; and b) reporting intervals

- Automatic dependent surveillance (ADS):
  - a) basic update rate;
  - b) display accuracy;
  - c) ADS contracts (e.g. increased reporting rate by triggering events);
  - d) sensor accuracy;
  - e) system reliability; and
  - f) end-to-end communications time capabilities
- Independent surveillance (radar):
  - a) type of sensor (primary or secondary);
  - b) coverage area;
  - c) processing and associated delays;
  - d) update rate;
  - e) display accuracy; and
  - f) system reliability

IV. Aircraft navigation performance

- Required navigation performance (RNP)
- Typical and non-typical performance (e.g. MASPS/MOPS); (RTCA SC181 documents refer)
- Time-keeping accuracy

V. Flow management capability (ability to control traffic input to ATC)

- Strategic air traffic flow management
- Tactical air traffic flow management
- Ad hoc ATC "in trail" restrictions or enhancements
- Procedural restrictions (e.g. by local operating procedures)

VI. Air traffic management tools to reduce controller workload or improve controller intervention capability

- Automated controller planning tools including conflict prediction and resolution
- Controller displays
- Out-of-conformance alerts (3-D) (i.e. automatic systems which alert ATC to any deviation of an aircraft from its nominal path)

Approach to determining separation standards

7.122 Because separation standards have a significant impact on the capacity and functioning of an integrated ATM system, it is necessary to develop comprehensive, reliable methods for determining separation standards applicable to new technologies and procedures.

7.123 The ATM operational concept is based on the requirements that planning of ATM systems ensure that reductions in separation minima are applied on a subregional basis in accordance with relevant ICAO SARPs, while meeting the requirements of regional air navigation agreements. Any separation minima applied should be selected from those found in the ICAO *Procedures for Air Navigation Services — Rules of the Air and Air Traffic Services* (PANS-RAC, Doc 4444) and the *Regional Supplementary Procedures* (Doc 7030). These documents should also be revised to meet changing requirements, based on technological and procedural opportunities.

7.124 A prerequisite to the implementation of any reduction in separation minima is the maintenance of a level of safety equal to or better than the present level. This safety requirement must be taken into account in the development of automated systems. Such systems should, to the extent possible, be flexible with regard to separation minima parameters. For example, a separation minimum of seven minutes in oceanic airspace may not meet the target level of safety at a given point in time whereas eight minutes may do so. Furthermore, flexibility must also be considered in the context of the progression of planned reductions in separation minima.

7.125 The approach leading to the implementation of airspace enhancements and reduced separation initiatives can be seen as involving a generic three-step process:

1) assessment of requirements;

2) planning and preparation; and

3) operational implementation.

7.126 Once the need to enhance operational efficiency in a particular area has been identified, the potential benefits to be gained, the costs to the user community and the impact on air traffic operations must be investigated. Part of this analysis will establish the capabilities necessary in the ATM ground system, given the performance and capabilities of the existing aircraft population, leading to an agreed safety level for the operations desired. Within the context of the agreed safety measure, a thorough analysis of operational safety, including consideration of contingencies and environmental conditions, should be conducted to establish the aircraft requirements and to validate the ground system requirements. Once these requirements are understood, the need for rule-making and a cost/benefit analysis must be determined. Any operational procedures necessary to support the safety constraints and contingencies or regulatory changes must be identified and coordinated with the user community.

7.127 Planning and preparation for the changes should be initiated using the results of a requirements assessment. The effort can be divided into a number of activities, which would be initiated by the development and coordination of any necessary amendments to regional supplementary procedures, and which would contain criteria to implement operational enhancements and/or reduced separation minima. The result will lead to efforts to establish the State approval process for aircraft and operators as well as to a means for investigating and tracking significant operational errors and incidents. There will also be a need to establish an ongoing process to assess operational safety once the change takes effect. A verification trial plan that will determine the technical and operational data necessary to gain confidence that the requirements and methods for implementing new Standards are effective, should be conducted in parallel with updates of documentation.

7.128 With the analysis and planning complete, it will be possible to begin operational implementation. During the operational phase of implementation, it will be necessary to ensure that appropriate organizations and States initiate ongoing safety and performance monitoring programmes and improvement processes. This analysis will involve tracking errors; reviewing incidents that affect operational safety and taking steps to mitigate against reoccurrence; and assessing feedback from the user community on the safe and effective use of operational procedures. The feedback process may generate further initiatives.

Reduced vertical separation minima (RVSM)

7.129 Improved altimetry standards and height-keeping monitoring facilities will allow for a reduced vertical separation from the current 2 000 ft to 1 000 ft between flight level (FL) 290 and FL 410, inclusive, for subsonic aircraft in minimum navigation performance specification (MNPS) airspace. In addition to providing for flight at more fuel-efficient altitudes and increased track capacity, this will free up intervening altitudes for crossing traffic. For more guidance on planning for RVSM, refer to the *Manual on Implementation of a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 420 Inclusive* (Doc 9574). Experience gained in implementing RVSM in the North Atlantic Region should also be taken into account.

Air traffic flow management (ATFM)

7.130 Although the future ATS systems should be designed to accommodate normal peak traffic demand with the capability of expanding to meet forecasted future growth, it may not be practicable to provide for the systems which are capable at all times of accommodating excessive peak levels of air traffic demand. ATFM is a service complementary to ATS; its objective is to ensure an optimum flow of air traffic through areas during times when demand exceeds or is expected to exceed the available ATC capacity.

Application of ATFM procedures

7.131 ATFM measures shall be applied only for the period when it is expected that the air traffic demand will exceed the ATC capacity in the areas concerned. The two main measures applied are:

a) re-routing; and

b) allocation of slots.

Re-routing shall be the first option to be examined.

7.132 ATFM measures shall be established and coordinated in such a way that they do not cumulatively interact with each other. Whenever ATFM measures must be applied in the form of delays, they shall be applied to aircraft on the ground rather than to aircraft in flight. Whenever the application of ATFM measures in the form of delays to airborne aircraft becomes unavoidable, the flights concerned shall be informed of that fact as soon as possible. Whenever en-route holding becomes necessary, the aircraft concerned shall be held as close as practicable to the entry point of the area causing the restriction. Aircraft operators shall be informed as soon as possible if unforeseen ATFM measures become necessary and shall be provided with advice on available alternatives.

7.133 Re-routing

7.133.1 Re-routing of flights to avoid or reduce delay shall always be coordinated between the aircraft operator and the ATFM unit concerned in accordance with established procedures. Options to be considered will depend on whether or not the flight is subject to a strategic routing scheme (see below). They include:

a) alternate routes as published in the routing scheme;

b) off-load routes as published in the routing scheme (which should be opened whenever capacity is available); and

c) any other route where capacity is available (even if not in the routing scheme) after coordination with the ATFM units concerned.

7.134 Slot allocation

7.134.1 When the demand in a given area exceeds the available capacity, efforts shall be made to resolve the problems by offering re-routes. If this is not possible, slot allocation shall be applied. Slot allocation is an ATFM measure established to reduce demand to the level of the ATC capacity and to smooth out traffic flows, thus making full use of the available ATC capacity. All traffic may be subject to slot allocation, except that which is excluded or exempt. Delays will not normally be applied to aircraft in flight. However, if this becomes unavoidable, the flights concerned will be informed as soon as possible and, if necessary, will be held as close as practicable to the entry point of the area causing the restriction. Where a flight is subject to more than one restriction, the ATFM unit concerned shall issue a single slot which takes into account all restrictions along the route of the flight.

7.134.2 An en-route slot is related to a slot reference point (SRP, a geographical point or reference location for a restriction used to calculate slots). The slot is defined by a time and a tolerance during which period the flight is expected to cross the SRP. A departure slot (approved departure time [ADT]) is defined by a time and a tolerance during which period the flight is expected to take off. Departure slots are based on the aerodrome of departure and are calculated using the estimated flying time from the aerodrome of departure to the SRP. Whenever possible, slots will be passed to the aircraft operator and ATC at the airfield of departure as a departure slot. Slot tolerance is decided by the ATFM authorities following appropriate consultation and is published. ATC is responsible for departure slot monitoring at departure aerodromes. The exact procedures to be followed will depend on the way the ATS is organized at each aerodrome.

Phases of ATFM activity

7.135 ATFM is carried out in three phases:

a) The *strategic* phase. Strategic activities are research, planning and coordination activities carried out in the period from two days to several months in advance of the day of operation;

b) The *pre-tactical* phase. Pre-tactical activities are planning and coordination activities carried out within the two days prior to the day of operation; and

c) The *tactical* phase. Tactical activities are those ATFM activities carried out on the day of operation.

7.136 Strategic phase

7.136.1 Strategic activities are to be directed towards early identification of major demand/capacity problems within the ATC system and in conjunction with interested parties (ATC, military, user organizations, etc.) and comprise:

a) resolving or alleviating such problems in advance by the application of measures other than ATFM measures (i.e. ATC organizational); or

b) where action under a) is not possible, providing procedures and information to allow such problems to be dealt with effectively and efficiently during the ATFM pre-tactical and tactical phases; or

c) where action under a) and b) is not possible, devising strategic ATFM measures.

7.136.2 Strategic ATFM planning normally takes the form of a continuous process involving the routine collection, collation and interpretation of data and the regular review of procedures and measures.

7.136.3 The strategic planning phase at both national and international levels shall be used to provide ATC planning authorities with advice and information to enable them to introduce changes or make adjustments to:

a) airspace organization;

b) ATC procedures; or

c) staffing arrangements

so that effective use is made of available capacity, and additional capacity is provided where it is likely to be needed. Strategic ATFM measures are not appropriate where alternative ATC solutions are possible.

7.136.4 ATFM measures agreed during the strategic planning phase are to be designed to provide the structure for enabling the application of effective, flexible flow management measures during the pre-tactical and tactical phases. Procedures or agreements that limit or inhibit tactical flexibility are, where possible, to be avoided.

7.136.5 Special events such as air shows, major sporting fixtures, commercial exhibitions, military exercises, etc., likely to generate additional demand or cause a temporary reduction in capacity (due to airspace reservations or temporary changes in procedures), should be evaluated as part of the strategic planning task. Coordination with the organizers in conjunction with the appropriate ATC authorities (civil and military) and aircraft operator organizations will be required to:

a) determine the extent of any disruption and the need for strategic or tactical ATFM measures; and

b) investigate the possibility of re-arranging the times of the event or extent of airspace reservations to limit disruption.

7.137 Pre-tactical phase

7.137.1 Pre-tactical planning involves examining the updated demand for up to two days in advance, comparing it with ATC capacity expected to be available and, where necessary, either adjusting the strategic plan or deciding tactical measures to overcome cases of excess demand.

7.137.2 Wherever possible, pre-tactical planning shall include an analysis of the results of previous pre-tactical and tactical activity in order to continuously improve the way in which these activities are carried out and to refine the way in which ATFM measures are planned and executed.

7.138 The tactical phase

7.138.1 Tactical ATFM activities shall be directed towards:

a) ensuring that adequate measures are in place to resolve demand/capacity problems;

b) executing the agreed tactical measures;

c) ensuring that the measures imposed are the minimum required, that unnecessary restrictions are lifted and that unavoidable delays are distributed as evenly as possible; and

d) ensuring that ATC resources are deployed to take account of the actual demand situation and make maximum use of available capacity.

7.138.2 To achieve the above, real-time supervision of the ATFM operation shall be implemented involving the following:

a) close contact with the live ATC operation to maintain an updated picture of the actual traffic situation and the resources available;

b) access to the latest actual and forecast demand data; and

c) constant monitoring of flow measures and regular coordination with aircraft operators and ACCs to identify imbalances and aberrations in the delay pattern.

ATFM and airborne flights

7.139 ATFM shall take action on individual flights before their departure and shall not normally intervene in the progress of airborne flights which are the responsibility of the appropriate ATC unit. However, airborne flights may be subjected to additional tactical ATFM measures:

a) in case of emergency;

b) where appropriate procedures and agreements exist; and

c) with the agreement of all concerned.

7.140 Such ATFM measures may include coordinating the re-routing of aircraft in flight to relieve a particular demand/capacity problem and make effective use of available capacity.

Data requirements

7.141 The efficient operation of the ATFM service depends on the timely receipt of reliable information on planned flight operations and revisions thereto, as well as data on *ad hoc* flight operations. It also depends on the availability of information on the air navigation infrastructure (ATS route network, ATC sectorization, etc.) as well as on ATC system capacity figures. Those data need then to be processed in order to allow an overall assessment of demand/capacity by the ATFM service. Operators and ATC authorities should, therefore, ensure they are familiar with the data requirements of the ATFM service and make arrangements for provision of the required data.

Summary

7.142 Table 7-20 is a summary of tasks involved in the air traffic management segment. States may decide upon the implementation of appropriate systems/procedures, taking into account the ATM objectives. Accordingly, the timescales for the corresponding systems/procedures of ATM should be indicated in Table 8-1 regarding air traffic management systems implementation (Chapter 8).

Table 7-20. Summary — air traffic management transition (sample matrix)
List indicating implementation of systems/procedures for enhancing/improving ATM

Airspace management	Air traffic services	Air traffic flow management
1. Optimized sectorization 2. Route network restructuring (fixed RNAV, contingency RNAV and random RNAV) 3. Airspace desegregation (flexible use of airspace, civil/military coordination, single continuum of airspace) 4. Application of RNP/RCP/RSP	1. ATS decision support tools (conformance monitoring, conflict alert/detection/ resolution, MSAW, arrival metering, etc.) 2. Reduced separation minima (vertical, horizontal) 3. A-SMGCS 4. ATS inter-facility data communication 5. Application of data link (PDC, gate link)	1. Capacity assessment 2. Centralized ATFM facility 3. Strategic planning (acceptance rates, departure slots, procedures) 4. Tactical planning (real-time input, aircraft positions and constraints)

Guidelines for transition to global air traffic management systems

7.143 *General*

a) The ATM system should ensure the provision of safe, uniform procedures on a global basis.

b) The ATM system must improve upon the present, agreed levels of safety.

c) The ATM system should offer to the users maximum flexibility and efficiency in airspace utilization, taking into account their operational and economic needs, as well as the ground system capabilities.

d) The ATM system should facilitate a dynamic airspace environment that allows aircraft operators to follow preferred and flexible flight profiles with minimum constraints.

e) The ATM system must be capable of presenting the functional compatibility of the data exchanged between the airborne and the ground elements, in order to ensure global efficiency.

f) The ATM system should allow for the sharing of airspace between different categories of users, and the airspace should be organized as flexibly as possible, considering different levels of aircraft equipage.

g) The various elements for the overall ATM system should be designed to work together effectively to ensure homogeneous, continuous and efficient service to the user from pre-flight to post-flight.

h) Pilots and air traffic controllers should be kept involved in the ATC process, and automated systems should be human-centred.

i) The ATM system should be capable of working with a wide variety of traffic densities, aircraft types, avionics sophistication, etc.

j) The ATM system should not be overly sensitive to random disturbances, such as outages, emergencies, errors in forecasting, etc.

7.144 *Transition and implementation*

a) The development and implementation of the ATM system should be evolutionary.

b) The design of the ATM system should provide a well-understood, manageable, cost-effective sequence of improvements that keeps pace with user needs and culminates in a system that meets safety, capacity, efficiency and environmental demands.

c) The ATM system design should allow for its implementation at various levels of sophistication to provide services tailored to specific applications and regions.

d) Future ATM systems should be implemented in a way that allows adjacent systems to interface so that boundaries are transparent to airspace users.

e) During the transition period to future ATM systems, present levels of integrity, reliability and availability of existing systems must be maintained.

7.145 *Airspace organization and management*

a) In the design of the future airspace structure, airspace boundaries and divisions should prevent neither the efficient use of automated conflict detection and resolution techniques nor the exploitation of the advanced avionics of modern aircraft.

b) The aim of airspace sectorization should be to develop an optimum airspace configuration, in combination with the use of other suitable methods for increasing ATM system capacity.

c) Airspace use should be carefully coordinated and monitored in order to cater for the conflicting legitimate requirements of all users and to minimize any constraints on operations.

d) When it is unavoidable to segregate different categories of traffic, the size, shape and regulation category of airspace should be tailored to the minimum required to protect the operations concerned.

e) The permanent segregation of airspace should be avoided in favour of flexible use of airspace*; however, where it is necessary to cater for specific flight operations, e.g. military, reservation of airspace for such events should be limited in time and space to the minimum required.

f) Efficient communications should be provided between the entities providing services to air traffic, in order to enhance civil-military coordination in real-time.

g) Consideration should be given to combining flight information services with available surveillance services outside controlled airspace.

h) To facilitate airspace design, planning should be based on an area control concept rather than on a fixed route network whenever practicable/feasible.

i) Random RNAV areas should be introduced whenever practicable/feasible in order to enable aircraft to fly their preferred routes.

j) Fixed-route systems based on RNAV should only, if necessary, be applied in high traffic density airspace. Such route systems shall be published and shall be designed to enable air traffic to be separated systematically, while seeking to permit economical flight paths.

k) Areas that should strive for the earliest and shortest implementation of ATM systems are those where there are known constraints in today's system; that is, where user needs are not met, or where user benefits cannot be fully realized.

* Emerging concept or technology — consensus still to be reached.

7.146 *Air traffic services*

a) The implementation and application of automation and other advanced technologies, while necessary to increase efficiency and regularity, should maintain and, where possible, improve the controller's work environment.

b) The implementation of an improved air navigation system should be supported by improvements in the communication, navigation and surveillance systems and by advanced automation functions.

c) Airspace capacity increases should not cause a concurrent increase in controller workload.

d) Automation aids such as conflict prediction and resolution advisory functions should be introduced to assist the controller where practicable. The accuracy of these systems must be assured.

e) Safety levels must be improved as the use of automation increases.

f) Automation aids, which improve planning data accuracy and reduce the necessity for controller interventions to resolve conflicting situations, must contain provisions which allow for required controller awareness in relation to the traffic situation.

g) The ATM system will allow for a transfer of responsibility of some separation functions from ground to airborne systems under specific circumstances. The trend may continue based on advancements in cockpit situational awareness, however, the ground system should remain as the overriding authority in all cases where arbitration is required.

h) Data link application should take place during an early stage of the transition phase, based on the availability of any of the foreseen data link systems.

i) Application of the data link should aim for a reduction of voice communication load and also for an improvement in the provision of flight data (short-term intent and four-dimensional profile data for the entire flight route) by providing FMS data to the ground ATC system.

j) Communications networks between ATM facilities within a State and ATM facilities in adjacent States should be established if they do not already exist.

k) States and/or regions should coordinate to ensure that where ATC applications supported by AMSS, such as ADS, are to be introduced, they should be introduced simultaneously in adjacent FIRs through which there are major traffic flows.

l) In collaboration with neighbouring FIRs, States should develop operational procedures for the implementation of new systems such as ADS within airspace under their control, where such application would be advantageous.

m) Rules and procedures should facilitate the operation of aircraft with different equipment in the same ATM environment.

n) States and/or regions may consider segregating traffic according to CNS capability and granting preferred routes/flight levels to aircraft with improved capabilities.

o) States and/or regions should coordinate to ensure that separation standards and procedures for appropriately equipped aircraft are introduced simultaneously in each FIR through which major traffic passes.

p) Systems or other provisions must allow the controller to ensure safe separation in the event of system failures.

q) Implementation of new functions should improve existing or basic functions rather than just replace them and should relieve rather than worsen controller functions.

r) Rules and procedures should be developed to facilitate the transfer of aircraft between adjacent systems that provide different levels of services.

s) Rules and procedures for the sharing of responsibility between the ground ATC system and the flight management system for calculating and maintaining flight profiles should be clearly defined prior to implementation.

t) All the future automation specifications for ATC systems should provide for functional coherence between air traffic flow management and air traffic control systems.

7.147 *Air traffic flow management (ATFM)*

a) Data on likely future demand should be collated from historical information, planned development by airports and airlines, aircraft manufacturers' order books, and the macro-economic forecasts of trends in the home State and other State economies.

b) A recognized and common methodology for the assessment of the capacity of the current and planned ATM system should be developed to include sector capacities and, in particular, "choke" points.

c) Regions should consider the introduction of a centralized flow management unit.

d) Where more than one flow management unit exists, plans to harmonize procedures and practices with adjacent units should be developed.

7.148 *Human Factors*

a) Planning and implementation of improved ATM capabilities should include consideration of Human Factors impacts and requirements. The goals listed for the future ATM system should be qualified in relation to Human Factors, at least in terms of the following considerations:

1) The level of safety targeted for the future system should be defined not only with reference to various system statistics, but also with reference to error-inducing mechanisms related to human capabilities and limitations as well as important individual cases.

2) The definition of system and resource capacity should include reference to the responsibilities, capabilities and limitations of ATS personnel and air crews who must retain situational awareness and understanding in order to carry out all of their responsibilities.

3) Dynamic accommodation of three- and four-dimensional flight trajectories to provide user-preferred routings, while an ultimate goal for users, may initially be restricted by human capabilities and the need to organize the flow of air traffic in an orderly manner in order to provide separation. The transition period will need careful research and evaluation on Human Factors aspects.

4) The provision of large volumes of potentially relevant information to users and ATS personnel should be limited to that which is absolutely necessary and be mediated by methods that effectively package and manage such information to prevent information overload, while providing information pertinent to particular operational needs.

5) A single airspace continuum should be free of operational discontinuities and inconsistencies between kinds of airspace and kinds of facilities that affect responsibilities and activities of air crews or ATS personnel at functional boundaries.

6) The organization of airspace in accordance with ATM procedures should also be readily learnable, recallable and, to the maximum practical extent, intuitively understandable by air crews and ATS personnel.

7) The responsibilities of pilots, air traffic controllers and system designers should be clearly defined prior to the implementation of new automated systems and tools (e.g. conflict resolution advisories, data link, ADS, etc.).

7.149 *Aerodrome operations*

a) Metering, sequencing and spacing aids should be introduced in areas where there are frequent delays for aircraft arriving in all weather conditions.

b) Simultaneous approaches to closely spaced parallel runways should be implemented at locations where technology and procedures have been developed that permit such use.

c) Alternative approach capabilities should be considered for terminal applications where there are closely spaced airports, closely spaced parallel runways, noise footprint requirements, terrain/obstacle clearance requirements or limited real estate available for new runway construction.

d) Data link communications should be considered at airports to relieve air-ground voice communications congestion, and thereby reduce errors or confusion arising from voice communications.

e) Automated surface movement guidance and control systems, in conjunction with surface detection radar or differential GNSS equipment, which associate call signs with displayed surface locations and contain controller alerting capabilities, should be provided where the traffic density and/or local conditions warrant this.

f) Lighting systems, positional display systems and other devices that assist pilots and controllers in preventing runway incursions should be introduced according to local needs.

INSTITUTIONAL OPTIONS

Introduction

7.150 In accordance with Article 28 of the Convention on International Civil Aviation, States are responsible for the provision of facilities and services required for international civil aviation. A State may delegate the provision of service to another entity, including a commercial or private operator, but the State nevertheless remains responsible for setting and maintaining the standard of services provided. However, the CNS/ATM system elements, due to their global coverage capabilities, have an impact on implementation options which, in turn, would call for institutional arrangements which may be somewhat different from those in practice for the current air navigation system.

Implementation approach

7.151 There are three basic approaches to establishing and managing CNS/ATM systems. These can be grouped as national systems, regional systems and global systems. It is possible to adopt a mix of these approaches, depending on differing environments. However, it should be noted that, in order to ensure interoperability and seamlessness, which are the essence of CNS/ATM systems, the proliferation of system elements which are already available at the global and regional levels should be discouraged.

7.152 In each approach to the implementation of CNS/ATM systems, the function may be met by either public or private providers. For each category and each sector, there is a basic requirement that the service provided comply with ICAO SARPs and other applicable provisions of international law; in addition, its operation must be coordinated with other categories and sectors. With regard to the provision of aeronautical safety services, the Tenth Air Navigation Conference (1991) noted that at least four implementation options were available to States:

a) contract with certified service providers;

b) commission existing multilateral government organizations such as the Agency for the Safety of Aerial Navigation in Africa and Madagascar (ASECNA), the Central American Corporation for Air Navigation Services (COCESNA), the European Organisation for the Safety of Air Navigation (EUROCONTROL), etc., to act on their behalf in dealing with service providers;

c) join other States to form an *ad hoc* group of States or a new international organization that would negotiate for service; and/or

d) use a mechanism within ICAO to act on behalf of States in dealing with service providers.

National systems

7.153 National systems offer appropriate solutions for systems and equipment of a very limited range, even if they partly operate beyond national boundaries.

7.154 The providers may be public or private, with all kinds of intermediate variations between purely public and purely private solutions. One intermediate solution could consist of a separate entity which is given the status and the flexibility of a private provider and in which public and private interests may participate on a minority or majority basis, respectively. Whatever the solution, it is up to the respective States to determine the choice and the details.

7.155 The CNS/ATM systems elements, which are appropriate for establishment and management at the national level, can be grouped as:

a) communications:

   1) VHF voice/data communications;

   2) Mode S data communications;

   3) ground-to-ground data/voice communications*; and

   4) ATN (ATM end-systems/gateway*/router*);

b) navigation:

   1) ground-based augmentation system for GNSS;

c) surveillance:

   1) SSR Mode S;

   2) ADS; and

   3) ADS-B; and

d) air traffic management:

   1) ASM*;

   2) ATS*; and

   3) decision support systems.

Regional systems

7.156 Regional systems of one kind or another are necessary where the functions of equipment and systems transcend national boundaries.

7.157 Here again, public as well as private providers are possible. The following alternatives may serve as an illustration of different scenarios:

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* These systems could also be implemented and managed on a regional basis.

a) service provided by one government:

   1) unilateral provision (e.g. Japan's multi-function transport satellite [MTSAT]); or

   2) regional coordination and co-financing (e.g. DEN/ICE);

b) services provided by a group of governments (e.g. COSPAS-SARSAT*); and

c) organizations with their own legal responsibility:

   1) intergovernmental organizations (e.g. ASECNA, COCESNA, EUROCONTROL, the Arab Satellite Organization [ARABSAT]);

   2) mixed economic organizations (or intergovernmental/commercial organizations, such as Inmarsat and the International Telecommunications Satellite Organization [INTELSAT]); and

   3) private economic organizations (e.g. the Société internationale de télécommunications aéronautiques [SITA], Aeronautical Radio, Inc. [ARINC]).

7.158 The CNS/ATM systems elements which lend themselves to establishment and management at the subregional, regional and multinational levels can be grouped as:

a) communications:

   1) ground-to-ground data/voice communications; and

   2) ATN (gateway/router);

b) navigation:

   1) satellite-based augmentation system for GNSS;

c) surveillance:

   1) dissemination of radar/ADS data; and

d) air traffic management:

   1) airspace management;

   2) air traffic services; and

   3) air traffic flow management.

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* Space system for search of vessels in distress (COSPAS) — search and rescue satellite-aided tracking (SARSAT).

Global systems

7.159 As the name implies, these systems provide global coverage. The service providers of global systems are responsible for creating and maintaining the necessary infrastructure for provision of services to States and airspace users. Consequently, there will be no requirement for capital investment by the States to establish the infrastructure. These services could be purchased from a service provider.

7.160 With regard to the categories of providers and all other aspects, the information provided regarding regional systems (7.157 refers) also holds true for global systems.

7.161 The CNS/ATM systems elements that provide global coverage include:

a) communications:

   1) HF data (e.g. ARINC); and

   2) AMSS voice/data (e.g. Inmarsat); and

b) navigation:

   1) GNSS/GPS/GLONASS; and

   2) GNSS overlay (e.g. Inmarsat).

7.162 In conclusion, States, in planning for the implementation of CNS/ATM systems, may:

a) consider the various institutional arrangements covering regulatory aspects and service provisions that are available for the establishment and management of CNS/ATM systems at the national, regional and global levels;

b) adopt a cooperative, multinational approach in order to ensure seamlessness and interoperable systems at the regional and global levels; and

c) avoid a proliferation of system elements in order to reduce costs, enhance safety and increase operational efficiency.

DEVELOPMENT OF SARPS

7.163 ICAO recognizes the need for timely completion of the necessary SARPs, PANS and guidance material in order to provide a sound basis for implementation of CNS/ATM systems. Through its panels and study groups, ICAO has progressed in the development of SARPs for new technologies and systems. A list of the panels of ICAO's Air Navigation Commission and study groups involved in CNS/ATM-related activities is provided in Table 7-21. The decision by a State to implement any element of CNS/ATM systems should take into account the availability of SARPs.

Table 7-21. Panels and study groups directly involved in CNS/ATM-related activities

Panels of the ANC	AMCP	Aeronautical Mobile Communications Panel
	ATMCP	Air Traffic Management Operational Concept Panel
	ATNP	Aeronautical Telecommunication Network Panel
	AWOP	All Weather Operations Panel
	GNSSP	Global Navigation Satellite System Panel
	OCP	Obstacle Clearance Panel
	OPLINKP	Operational Data Link Panel
	RGCSP	Review of the General Concept of Separation Panel
	SICASP	Secondary Surveillance Radar Improvements and Collision Avoidance Systems Panel
Study groups	ADMSG	Aeronautical Data Modelling Study Group
	AISMAPSG	Aeronautical Information and Charts Study Group
	AVSSSG	ATS Voice Switching/Signalling Systems Study Group
	HFSG	Flight Safety and Human Factors Study Group
	HRPTSG	Human Resource Planning and Training Study Group
	METLINKSG	Meteorological Information Data Link Study Group
	TRNSG	Testing of Radio Navaids Study Group
	WAFSSG	World Area Forecast System Study Group

Chapter 8

IMPLEMENTATION STRATEGY

8.1 In order to promote a smooth evolution and to minimize the risks associated with the modification of the State ATM infrastructure, it is essential that the CNS/ATM transition be developed in a multiple sequence of stepped changes over a 10- to 15-year period.

8.2 The implementation strategy involves the following principles:

a) it is a collective commitment of all participating/concerned entities in the State;

b) CNS/ATM systems are to be introduced in evolutionary stages, with a progressive development of technology and procedures;

c) the high-risk approach associated with a "big bang" implementation is to be prevented;

d) the framework must include an integrated approach, encompassing all elements of CNS/ATM, such as technical, operational, economic and institutional issues;

e) current ATM operations should not be affected;

f) during the transition and implementation stages, there shall be no degradation in the level of safety; and

g) there must be a continuous interface with adjacent areas/cross-border States/ States within the region to ensure a coordinated implementation and consistency of ATM services.

WORK PROGRAMME OF CNS/ATM IMPLEMENTATION

8.3 Based on the transition and implementation strategy, a work programme must be developed by the State, indicating tasks, time periods and the need for relevant consideration at each point in time. While doing so, it is necessary to identify the organization or group responsible for each task. The work programme, so developed, would assist the State in managing the transition to CNS/ATM.

DEVELOPMENT OF MILESTONES

8.4 There is a need to establish a priority structure of the CNS/ATM system elements and areas of applicability with regard to implementation. The priorities, in terms of realistic timescales, will need to be established in response to identified constraints and the perceived view of the State. The establishment of milestones should take into account certain key events, as indicated in the flowchart in Figure 8-1.

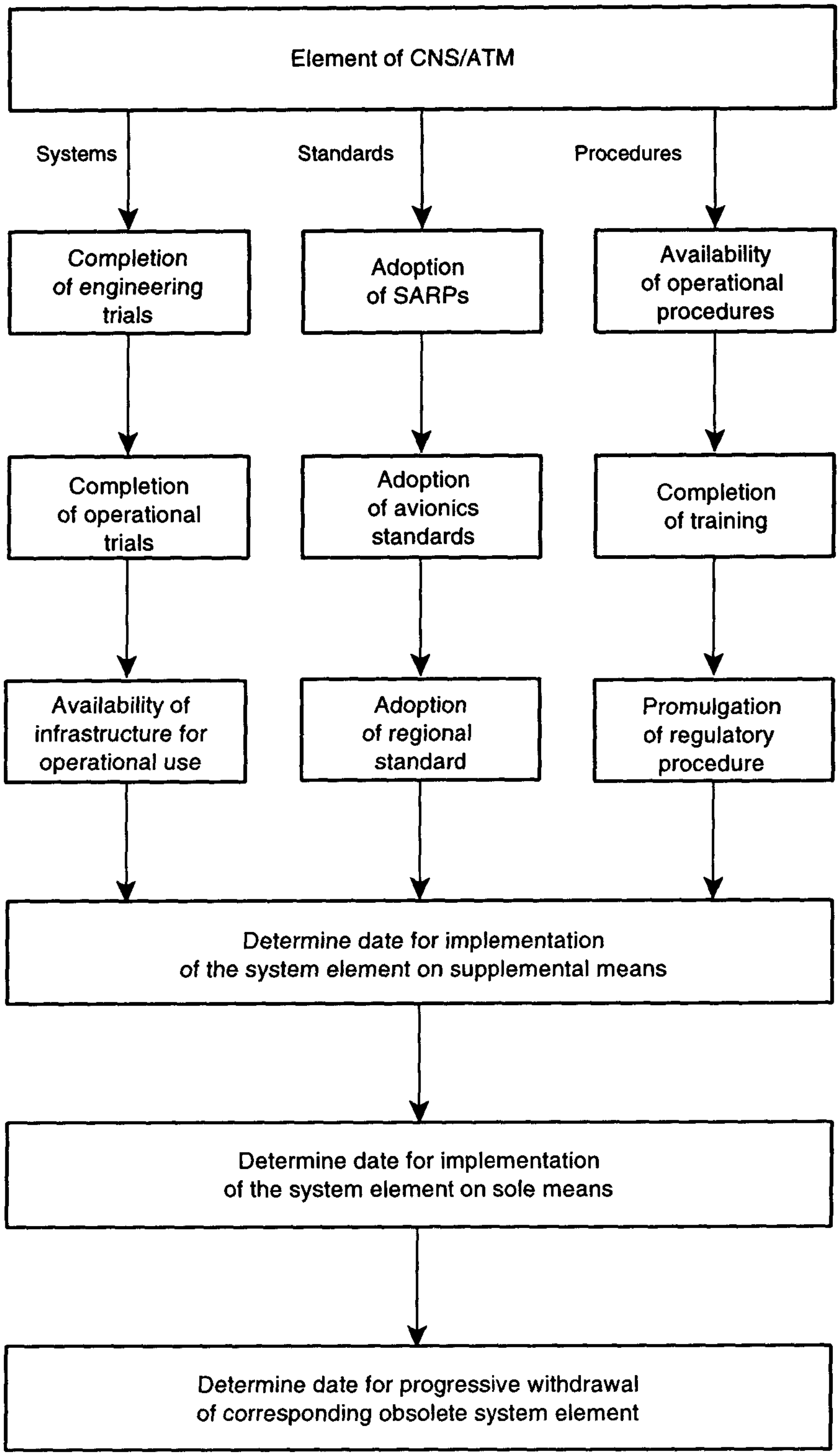

Figure 8-1. Milestone determination

IMPLEMENTATION TIMESCALE

8.5 The main tasks for the commissioning of new system elements under CNS/ATM and the decommissioning of current system elements (not required consequent to the transition to the new systems) are shown in the attached Gantt charts, Tables 8-1 to 8-4. The Gantt chart is an attempt to present graphically the relative timescales of various CNS/ATM systems project tasks. It is based on collective output of the transition strategy, implementation strategy and milestone determination. This programming is subject to modification at any time on the basis of available information. The timescales, which indicate sole means of implementation of different elements of CNS/ATM systems, are grouped as:

a) air traffic management — ASM, ATS and ATFM;

b) communications — data/voice;

c) navigation — oceanic/continental en-route/precision approaches; and

d) surveillance — oceanic/continental en-route/terminal/surface movement.

The timescale graphs facilitate close monitoring of the progress of CNS/ATM systems implementation.

8.6 The format of the implementation tables (Tables 8-1 to 8-4) is identical to that used in the Global Plan and regional plans. However, the implementation tables for States are more detailed and, in addition, contain timescales for the decommissioning of current systems. Such a standardization of the format of the implementation tables will facilitate the integration and harmonization of CNS/ATM system elements with those of adjacent States, as well as at the level of regional planning. In order to gain experience and maturity in the use of the new systems, States may consider operational use of both old and new systems elements for a considerable overlapping period.

8.7 In the event that the State is not required to implement a particular CNS/ATM systems element, the same may be indicated in the Gantt chart (Tables 8-1 to 8-4) as "NA" (not applicable) against that particular element. If the State decides to defer the decision of implementation of a certain CNS/ATM systems element, it would be appropriate to indicate the same as "TBD" (to be decided) against that particular element.

ARCHITECTURAL PHILOSOPHY

8.8 The architectural philosophy for CNS/ATM systems implementation will involve the following basic principles:

a) it will be "open" to allow different makes and types of equipment to be employed;

b) it will accommodate legacy systems and components to provide the baseline for a stepped evolutionary upgrade path;

c) it will be "distributed" to accommodate multiple centres of activities;

d) these centres will inter-operate based on appropriate common standards;

e) the distributed nature of the underlying systems will appear seamless to its users;

f) it will be flexible and scalable; and

g) it will provide improved levels of security, integrity and reliability to enhance the quality of service and overall safety of operation.

Table 8-1

AIR TRAFFIC MANAGEMENT SYSTEM IMPLEMENTATION			1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Development of SARPs	RTSP	Global ATM					■	■	■	■	■	■	■	■					
		Functional integration of flight OPS/ATM					■	■	■	■	■	■	■	■					
		ATM requirements for CNS				■	■	■	■	■	■								
		Separation between aircraft					■	■	■	■	■	■	■	■	■	■	■	■	■
		AIDC						■	■	■	■								
		ATFM procedures and systems								■	■	■	■	■					
Aircraft equipage / Flight operations		RNP certification/approval					■	■	■	■	■	■	■	■	■	■	■	■	■
		Functional integration of airborne systems with ground systems													■	■	■	■	■
Implementation and operational use																			
Airspace management																			
		Optimized sectorization																	
		Fixed RNAV ATS routes																	
		Contingency RNAV ATS routes																	
		Random RNAV routes																	
		Airspace desegregation/flexible use of airspace																	
		Application of RNP																	
		Application of RCP																	
		Application of RSP																	
Air traffic services																			
		Trajectory conformance monitoring																	
		Minimum safe altitude warning																	
		Conflict prediction																	
		Conflict alert																	
		Conflict resolution advice																	
		Functional integration of ground systems with airborne systems																	

AIR TRAFFIC MANAGEMENT SYSTEM IMPLEMENTATION	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Dynamic accommodation of user-preferred flight profiles																	
Reduced vertical separation																	
Reduced longitudinal separation																	
Reduced lateral separation																	
Independent IFR approaches to closely spaced runway																	
RNAV SIDs and STARs																	
Curved and segmented approaches																	
Arrival metering, sequencing and spacing																	
A-SMGCS																	
ATS inter-facility data communications (AIDC)																	
Applications of data link																	
Air traffic flow management																	
Capacity assessment																	
Centralized ATFM																	
Establishment of ATFM databases																	
Application of strategic ATFM																	
Application of pre-tactical ATFM																	
Application of tactical ATFM																	

Table 8-2

COMMUNICATION SYSTEM IMPLEMENTATION			1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Development of SARPs	RCP	AMSS	■	■															
		HF data	■	■	■	■	■												
		VHF data	■	■	■	■	■	■	■										
		SSR Mode S	■	■															
		ATN	■	■	■	■	■	■	■										
Aircraft equipage		AMSS		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
		HF data						■	■	■	■	■	■	■	■	■	■	■	■
		VHF data								■	■	■	■	■	■	■	■	■	■
		SSR Mode S			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
		ATN								■	■	■	■	■	■	■	■	■	■
		FANS 1 (or equivalent)			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Implementation and operational use of new systems and subsequent decommissioning of current systems																			
Data communications																			
		AMSS																	
		HF																	
		VHF digital																	
		SSR Mode S																	
		G/G network (satellite-based)																	
		G/G network (terrestrial-based)																	
		AFTN/ATN gateway																	
		ATN (ATN ES/router)																	
		AFTN																	
		FANS 1 (or equivalent)																	
Voice communications																			
		AMSS																	
		HF oceanic																	

COMMUNICATION SYSTEM IMPLEMENTATION																	
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
VHF digital																	
VHF analog (8.33 kHz spacing)																	
VHF analog (25 kHz spacing)																	
G/G network (satellite-based)																	
G/G network (terrestrial-based)																	
HF continental																	
VOLMET																	
ATIS																	

Table 8-3

NAVIGATION SYSTEM IMPLEMENTATION

			1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Development of SARPs	RNP	En-route	■	■	■	■	■												
		Terminal/NPA	■	■	■	■	■												
		Precision approach	■	■	■	■	■												
Development of SARPs	GNSS	GNSS performance criteria to support operational requirements	■	■	■	■	■	■	■										
		Development of GNSS NPA procedures	■	■	■	■	■												
		Use of GNSS with augmented systems	■	■	■	■	■	■	■	■									
		Long-term satellite navigation systeme	■	■	■	■	■	■	■										
		Data link for navigation (Mode 4)	■	■	■	■	■	■	■										
Availability		GPS	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
		GLONASS			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
		Inmarsat overlay					■	■	■	■	■	■	■	■	■	■	■	■	■
		SBAS									■	■	■	■	■	■	■	■	■
		GBAS									■	■	■	■	■	■	■	■	■
Aircraft equipage		GNSS + ABAS			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
		GNSS + ABAS/SBAS/GBAS									■	■	■	■	■	■	■	■	■
Implementation and operational use of new systems and subsequent decommissioning of current systems																			
		WGS-84																	
		GNSS for oceanic																	
		GNSS for continental en-route/terminal/NPA																	
		NDB																	
		VOR/DME																	
		GNSS for PA Cat. I																	
		ILS/MLS Cat. I																	

NAVIGATION SYSTEM IMPLEMENTATION

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
GNSS for PA Cat. II																	
ILS/MLS Cat. II																	
GNSS for PA Cat. III																	
ILS/MLS Cat. III																	

Table 8-4

SURVEILLANCE SYSTEM IMPLEMENTATION																			
			1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Development of SARPs	RSP	ADS	■	■	■	■	■	■	■	■									
		ADS-B			■	■	■	■	■	■									
		SSR Mode S	■	■															
Aircraft equipage		ADS									■	■	■	■	■	■	■	■	■
		ADS-B									■	■	■	■	■	■	■	■	■
		SSR Mode S			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Implementation of new systems and subsequent decommissioning of current systems																			
Interim ADS (ARINC 622)																			
ADS (oceanic)																			
ADS (continental)																			
PSR (en-route)																			
PSR (terminal)																			
VHF DF																			
ADS-B																			
SSR Mode A/C																			
SSR Mode S																			
A-SMGCS																			
ASDE																			

Chapter 9

COST/BENEFIT ANALYSIS (CBA)

INTRODUCTION

9.1 Financial and economic analyses are relevant at three different stages of the planning process. Before making any financial commitment, the economic viability of the CNS/ATM systems for civil aviation in the provider State should be demonstrated with support of a cost/benefit analysis. Measures of the viability of the *new* CNS/ATM investment package (the project case) should be based on a comparison with the *existing* systems (the base case). The existing systems are defined to include possible development over the planning period and their normal and expected maintenance. The new facilities will replace the existing facilities and, as the latter are phased out, their costs can be regarded as benefits from installing the new systems.

9.2 Secondly, cost/benefit analysis should be applied as an integrated part of the actual planning process in order to select the most cost-efficient implementation option from a menu of options. These options can be of an operational and/or technical nature, as well as of an institutional nature. For example, a State might independently supply services within its airspace or join forces with other States.

9.3 Once a system configuration has been selected, a business case study may be performed in order to facilitate coordination with all stakeholders concerned and to support the negotiations with financial institutions. The development of a business case for the implementation of CNS/ATM systems by a service provider or a user involves taking cost/benefit analysis a step further. In particular, changes in revenues resulting from changes in the price of the product or service sold by the organization must be taken into account. The results from an economic impact study may serve as support in the discussions with governmental authorities and financial institutions. Economic impact studies demonstrate how payments for transportation and construction activity stimulate an economy.

9.4 Chapters 1 to 8 of this document set out a methodology that analysts can use to develop and plan appropriate CNS/ATM systems configurations for the State. The methodology involves the use of cost/benefit analysis primarily to guide in the choices between different implementation options on the basis of their economic viability. This chapter provides an approach to cost/benefit analysis. Once the future system performance requirements and the candidate CNS/ATM systems configurations have been established, the economic viability of the various implementation options may be estimated. The approach described below is based on the guidance material in the *Economics of Satellite-based Air Navigation Services — Guidelines for cost/benefit analysis of communications, navigation and surveillance/air traffic management (CNS/ATM) systems* (ICAO Circular 257). It is recommended that the circular itself be used in those cases where this condensed material is considered insufficient. Reference is also made to Chapter 13 — Cost/benefit and Economic Impacts — of the *Global Air Navigation Plan for CNS/ATM Systems.*

NET PRESENT VALUE APPROACH

9.5 There are several ways to measure economic viability. A comprehensive economic evaluation using a net present value (NPV) analysis requires predictions of the future annual flows of costs and benefits associated with the implementation of CNS/ATM systems. Once all the year-by-year expenditures and benefits are established, the net benefit (benefit minus cost) for each year can be calculated and discounted back to the base year in accordance with standard accounting practices on the basis of an assumed rate of interest. The NPV of all the costs and benefits associated with the new system can then be established.

9.6 Another more simplified approach is the so-called *snapshot* method which focusses on one year in the future. Under this approach, the capital costs of the project are represented by the annual depreciation and interest associated with the new investment. The depreciation and interest saved by withdrawing the equipment of the existing system can be recorded as benefits, along with estimates of other annual benefits associated with the project. The annualized benefits and costs can be aggregated and the benefit/cost ratio calculated.

9.7 The guidance material in this chapter focusses primarily on the comprehensive model, i.e. the net present value analysis, as illustrated in Figure 9-1. From the NPV standpoint, the prospective economic viability of an investment project, such as CNS/ATM, depends on the extent to which the total benefit from the investment exceeds its total cost over the life cycle of the project.

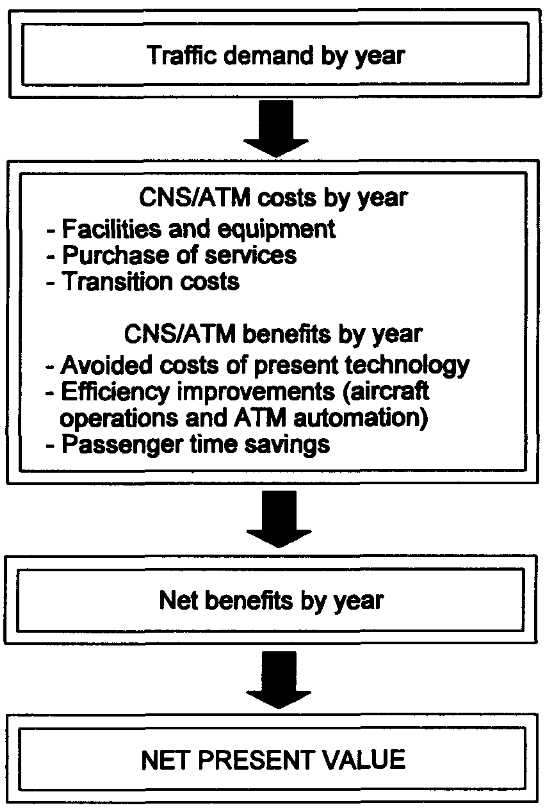

Figure 9-1. Net present value

MAIN FACTORS AFFECTING COSTS AND BENEFITS

9.8 The costs and benefits of implementing CNS/ATM systems will be affected by the volume of traffic and the rate of transition. Future volumes of traffic will have a bearing on the CNS/ATM hardware configurations required; the volume of "soft" elements (such as AMSS signals) required; and the benefits that will be derived from increased efficiency in aircraft operations. The latter include reductions in flight-hours and fuel consumption, and consequently all costs associated with flying time, including time-savings for passengers.

9.9 The rate of transition to the CNS/ATM systems will set the calendar for the acquisition of new-technology system elements; the volume of flights which can take advantage of the new systems; the phasing out of elements based on conventional technology and the length of the period with duplicated systems (when both conventional and new systems are in operation). In addition to avoided costs from the phasing out of conventional system elements, air navigation service providers will benefit from new systems which are easier to use and maintain and from access to a complete range of satellite services.

CBA SOFTWARE WITH SELF-CALCULATING SPREADSHEETS

9.10 To facilitate the calculation of costs and benefits associated with the implementation of CNS/ATM systems, ICAO has developed a CBA software (applicable to this Circular 278), with standard spreadsheet applications (in Excel and Quattro Pro), which is available on diskette from the ICAO Secretariat on request. (This software has been elaborated on the basis of the software referred to in the foreword to Circular 257 with the intent of making it more user-friendly.) Several simplifications have been made with regard to assumptions and input of data. The software provided can be used in an iterative fashion and thus can evaluate practically any mix of system parameters. CBA results may be calculated for any system configuration and implementation option.

DATA REQUIRED FOR THE CBA SPREADSHEETS

9.11 The following data will be required as input to the spreadsheets of the CBA software (Circular 278) which can be requested from the ICAO Secretariat:

a) areas of existing *FIRs* in square-kilometres;

b) elements of the conventional air navigation system — *Inventory* of how much equipment and its investment years:

VHF; HF; VOR; DME; ILS; ASDE; PSR; and SSR.

Note.— Additional future investments of conventional equipment, which would be required in the base case due to traffic growth, should be indicated as if that equipment had already been installed 15 years earlier. (Example: VOR equipment that would be required for 2005 should be indicated for 1990.)

c) *new SSR* — indicate all SSR equipment contained in the CNS/ATM systems, including both replacement investments for elements of the conventional system and new investments;

d) *automation* level of the ATC component of ATM — low, medium or high;

e) *database* for the implementation and transition to the CNS/ATM systems — indicate "Start-year" when CNS/ATM elements are planned to be in operation and "End-year" when elements of the conventional air navigation system are being phased out;

f) *CNS and ATM time lines*. These spreadsheets will show time lines for the various elements as a result of input data under the previous step "database";

g) *traffic* forecasts — number of flight hours. The number of flight hours may be calculated in two ways:

   1) input of figures on aircraft movements *and* traffic duration (forecast figures for 2003/1998, 2008/2003 and 2013/2008 relate to the total change during each five-year period); or

   2) use of the standard traffic growth figures (zero growth in domestic traffic and 5 per cent growth in international traffic and overflights) *and* indication of traffic duration for the various traffic categories;

h) *CBA results*. Change the values of the assumptions where necessary. See also *Comments on the application of the software* below;

i) *transition costs*. Try to put values to as many posts as possible;

   Note.— The posts in this spreadsheet are not linked to the automatic calculations in the present software and will have to be added manually to the results indicated on the CBA sheet (discounted to net present values with the anticipated interest rate); and

j) *cost data* — assumed values for equipment. The data already indicated on the spreadsheet are default values that need to be confirmed by manufacturers or other sources and which may vary widely depending on location, infrastructure available, etc. Change the default values accordingly as the indicated values will be used in the calculations.

9.12 More detailed instructions are given on each spreadsheet of the software. Note that the basic rule is to insert data only in the yellow fields of the spreadsheets.

COMMENTS ON THE APPLICATION OF THE SOFTWARE

9.13 The time profile of expected annual costs and benefits should extend over a long period such as 20 years. However, as the assumed lifetime of equipment has been set to 15 years, and in several cases investments may occur early in the project (calculation) period, in order to avoid the impact that replacement investments consequently might have on the calculation results, the length of the calculation period in the simplified approach described above should be adjusted accordingly. Although costs and benefits are often transacted in different currencies, it is recommended that they all be valued in a single currency at constant base-year exchange rates and product prices. By adopting this approach, it is assumed that future trends in exchange rates and general inflation would affect costs and benefits equally, with no net impact on the economic viability of CNS/ATM.

9.14 In order to take into account the fact that one dollar now is more valuable than one dollar in the future, even if prices are stable (as evidenced by the existence of real interest rates), it is necessary to express the net benefit for each future year in terms of its equivalent in the base year (i.e. usually the most recent past year). As mentioned above, this is achieved by a discounting process and puts all the net benefits generated in each year on a comparable basis, allowing them to be aggregated into a single NPV.

9.15 The discount rate to be used in the evaluation is the minimum rate of return required from investment in the project. It is related to the cost of the funds needed to support the project, which in turn is related to the long-term interest rate. Because the future cash flows have all been expressed in real terms (i.e. in constant base-year prices), the discount rate should be a real rate. The real discount rate is equal to the nominal rate minus the expected annual rate of inflation. If a commercial approach to the analysis is adopted, the real discount rate selected for the analysis would probably be based on the real long-term government bond rate in the country, plus a premium representing the degree of risk associated with the project. The government authorities may have an agreed discount rate normally used in evaluations of public sector projects or major transportation or civil aviation projects.

9.16 If the existing system were to be maintained, additional future investments in conventional equipment would be required in many cases to accommodate expanding traffic volumes. Together with replacement investments for existing equipment, these would constitute avoided costs, after the implementation of the CNS/ATM systems, to be included in the base case scenario.

9.17 Costs for operation and maintenance have not been included, as the main purpose of the analysis is to calculate such posts where there are net differences between the conventional and new CNS/ATM systems. However, the conventional systems are likely to be more expensive to operate and maintain than the new systems, and this could be considered as an additional avoided cost for the new systems for the years that remain of the analysis period after the conventional systems have been decommissioned.

9.18 It has not been practical to include transition costs for operation and maintenance of duplicated systems, training, staff redeployment and decommissioning of conventional facilities (see the transition costs spreadsheet) in the simplified user-friendly software developed for the purpose of the national plan. These costs can only be established by the actual provider of the air navigation services and will have to be considered as an addition to the results shown on the CBA spreadsheet, discounted to net present values with the anticipated interest rate.

9.19 Separate measurements of flight hours would normally be made for domestic and international traffic, arriving/departing international traffic and overflights, air carrier traffic, business aviation and general aviation. Business aviation and general aviation have been assumed to be of little value to the calculation results and are therefore not included in the present simplified software.

9.20 The cost of equipping aircraft with CNS/ATM avionics is an important parameter which should be established in consultation with aircraft operators and equipment manufacturers.

9.21 Forecasts of avionics investment will depend on forecasts of the number of aircraft using the relevant airspace which are, in turn, related to forecasts of aircraft flight hours. ICAO's global statistics on aircraft numbers and hours flown indicate that each aircraft of a commercial airline flies about 2 700 hours per annum (7.4 hours per day), on average. Adjustments to these figures could be made to reflect national and regional utilization of aircraft (hours flown per annum per aircraft) rather than the global average. As an indication, medium/long-haul aircraft are normally used 7 to 10 hours per day, while aircraft used solely in long-haul traffic may be used 10 to 15 hours per day.

9.22 A significant part of the investment costs of the set of antennas required for AMSS may be assumed to be met from passenger communications revenues; only the costs corresponding to the share of safety communications should be included in the evaluation of CNS/ATM systems.

9.23 The proportion of flight hours for which aircraft equipped with AMSS (and/or HF data link) will actually use AMSS (HF) depends on the availability of the alternative VHF or Mode S data links. Aircraft that use AMSS (HF) in oceanic and remote areas will probably switch to VHF (or Mode S) as soon as they are in range of these facilities. The proportion of flight hours when AMSS (HF) is used might eventually decline if VHF or SSR Mode S data link were to be installed or expanded at some future date.

9.24 The amount of savings to aircraft operators will primarily depend on the reduction in the number of aircraft-hours flown and on aircraft operating costs per hour. Because different aircraft types have different operating costs per hour, it would normally be advisable to categorize aircraft according to aircraft operating costs and to calculate savings for each aircraft category. As the improved aircraft efficiency is a key parameter, it should be assessed by aircraft operators and air traffic management specialists.

9.25 The value of passenger time is, in practice, extremely difficult to quantify and will depend on passenger perceptions and trip purpose (in particular, whether the travel is for leisure or for business purposes).

9.26 The average passenger load depends on the average aircraft size and load factor.

9.27 Wherever there is a need for more comprehensive analyses and calculations, the software referred to in Circular 257 and available from the ICAO Secretariat should be used.

SENSITIVITY ANALYSIS

9.28 As a cost/benefit analysis is based to a great extent on a number of assumptions, it is essential to determine the impact of alternative assumptions on some of the key parameters. Examples of some of the parameters to consider are efficiency improvements for the users, forecasts of flight hours, costs of equipment (ground equipment and avionics), price for satellite services and value per hour of passenger time saved. Sensitivity testing is facilitated through the use of computer spreadsheets.

CONCLUDING REMARK

9.29 As the CNS/ATM systems are global by nature, it is crucial — in addition to the costs and benefits for the different partners involved, such as States, service providers and users — to look at the effects on a wider community from a regional or subregional level. Cost/benefit studies for regional State groupings have an important role in the regional planning of CNS/ATM systems. The net economic impact may be more accurately measured at the regional and/or subregional level, since it is at these levels, rather than at the State level, that some of the costs will be incurred and the benefits received. International cooperation will provide for an acceptable distribution of benefits and for reducing the financial risks faced by individual States.

Chapter 10

INTEGRATION, HARMONIZATION AND INTEROPERABILITY

HARMONIZATION OF NATIONAL PLANS AND REGIONAL PLANS

10.1 Air traffic systems worldwide must be made interoperable and harmonized so that aircraft can operate safely and efficiently across national borders. This must be accomplished, however, in a global environment in which national needs vary from the most basic capability to sophisticated systems applicable to complex, congested operating environments. In this chapter, the factors which impede global harmonization and interoperability will be identified, and techniques and policies to advance that objective will be suggested. Practical measures that advance interoperability are also suggested, such as regional or global system architecture, commercial off-the-shelf (COTS) rather than customized products, technology re-use, and modularity and open-system designs.

10.2 The need for harmonization and interoperability arises from:

a) the diversity in ATC infrastructure;

b) a lack of similar functionality;

c) differing national requirements;

d) multiple technical options; and

e) divergent media and protocols.

With the gradual and phased implementation of CNS/ATM systems, it becomes necessary for the State to reconcile these differences within the State and with neighbouring States (through regional plans) by adopting an approach of cooperation and consensus building and utilizing harmonization tools and techniques. The ultimate objective of integration and harmonization in the CNS/ATM systems environment is to provide transparent ATS with seamless systems so that users can fly globally with uniform equipage and controllers can effectively handle mixed aircraft equipage on the same situation display.

MECHANISM

10.3 The mechanism for harmonization differs depending on the geographic level under consideration. Table 10-1 lists the availability of mechanisms at different levels of harmonization.

METHODS

10.4 The harmonization of CNS/ATM systems can be undertaken by using either a systems approach or a traffic flow approach. These two approaches are explained in Table 10-2.

HARMONIZATION TOOLS

10.5 Evolution in technology, along with greater demands for airspace resources, has precipitated a shift from ATC to ATM. One of the major technologies allowing this change is data link communications, which is altering the nature of the CNS systems. The three major technology transformations occurring in ATM are:

a) the change in communications from solely analog voice to digital data and voice;

b) the shift in navigation from ground-based navigational aids to GNSS; and

c) the evolution of surveillance from radar to ADS.

While these transformations occur in a progressive manner, there will be a need to provide and make use of harmonization tools to ensure interoperability and a seamless environment.

Table 10-1. Mechanism for harmonization

Level	Mechanism
National	National Committee for CNS/ATM Systems Planning
Subregional	Subregional group for CNS/ATM systems planning
Regional	CNS/ATM SG of the region
Global	ALLPIRG

Table 10-2. Methods of harmonization

Systems approach	• Communications • Navigation • Surveillance • ATM
Traffic flow approach	• ATM objectives • ATM requirements for communications, navigation and surveillance

GATEWAY FOR DATA COMMUNICATIONS FOR INTEROPERABILITY

10.6 The integrated communications message handling system (ICMHS) is a message processor that will support the entire range of aeronautical applications and provide a specific, generic interface for both radar and air/ground message data. Currently, each data link medium uses a different protocol to transfer information between air and ground. The message processor in ICMHS interfaces with the various media and protocols and translates these protocols into a standard protocol. The display system only needs to implement this single protocol. Figure 10-1 illustrates the interface between the data communications media, the message processor and display functions.

TOOLS FOR CNS HARMONIZATION

10.7 Tables 10-3, 4 and 5 identify different tools available both on the ground and on aircraft for the harmonization of CNS elements.

BENEFITS OF HARMONIZATION

10.8 The harmonization process involving systems, procedures and tools combines present and future ATM functions into a single package and results in a number of advantages, such as interoperability, seamlessness, cost-effectiveness, easy migration path and enhanced safety. As such, States are encouraged, while planning for CNS/ATM systems, to harmonize with the regional plan, the subregional plan and the plans of adjacent States.

Table 10-3. Tools — communications

Oceanic/ remote areas	Continental en-route	TMA	Approach and landing	Harmonization tool	
				Ground	Aircraft
AMSS Data/ HF data	VHF data/ SSR Mode S data	VHF data/ SSR Mode S data	VHF data/ SSR Mode S data	ATN	ATN
—	VHF data (analog/digital)	VHF data (analog/digital)	VHF data (analog/digital)	Message processor/ dual stack	VDL A/G protocol (TBD)
—	VHF data digital (Mode 1/Mode 2/ Mode 3)	VHF data digital (Mode 1/Mode 2/ Mode 3)	VHF data digital (Mode 1/Mode 2/ Mode 3)	Multi-mode radio	VDR
—	VHF voice (analog/digital)	VHF voice (analog/digital)	VHF voice (analog/digital)	Multi-mode radio	VDR
—	VHF voice analog (25 kHz/8.33 kHz spacing)	—	—	Multi-mode radio	VDR

Key: VDR — VHF digital radio
TBD — To be decided

Table 10-4. Tools — navigation

Oceanic/ remote areas	Continental en-route	TMA	Approach and landing	Harmonization tool	
				Ground	Aircraft
INS/GNSS	–	–	–	–	FMS
–	VOR-DME/ GNSS	VOR-DME/ GNSS	–	–	FMS
–	–	–	ILS/MLS/GNSS	–	MMR
GNSS (GPS/GLONASS)	GNSS (GPS/GLONASS)	GNSS (GPS/GLONASS)	GNSS (GPS/GLONASS)	–	Integrated GNSS receiver
–	–	GNSS augmentation (SBAS/GBAS)	GNSS augmentation (SBAS/GBAS)	SBAS/GBAS combined monitoring station, wherever required	Integrated GNSS receiver with SBAS and GBAS capability

Key: MMR — Multi-mode receiver
SBAS — Satellite-based augmentation system
GBAS — Ground-based augmentation system

Table 10-5. Tools — surveillance

Oceanic/ remote areas	Continental en-route	TMA	Approach and landing	Harmonization tool	
				Ground	Aircraft
ADS	–	–	–	–	–
	PSR/SSR Mode S/ADS	PSR/SSR Mode S/ADS	–	Integrated work station for radar/ADS inputs	

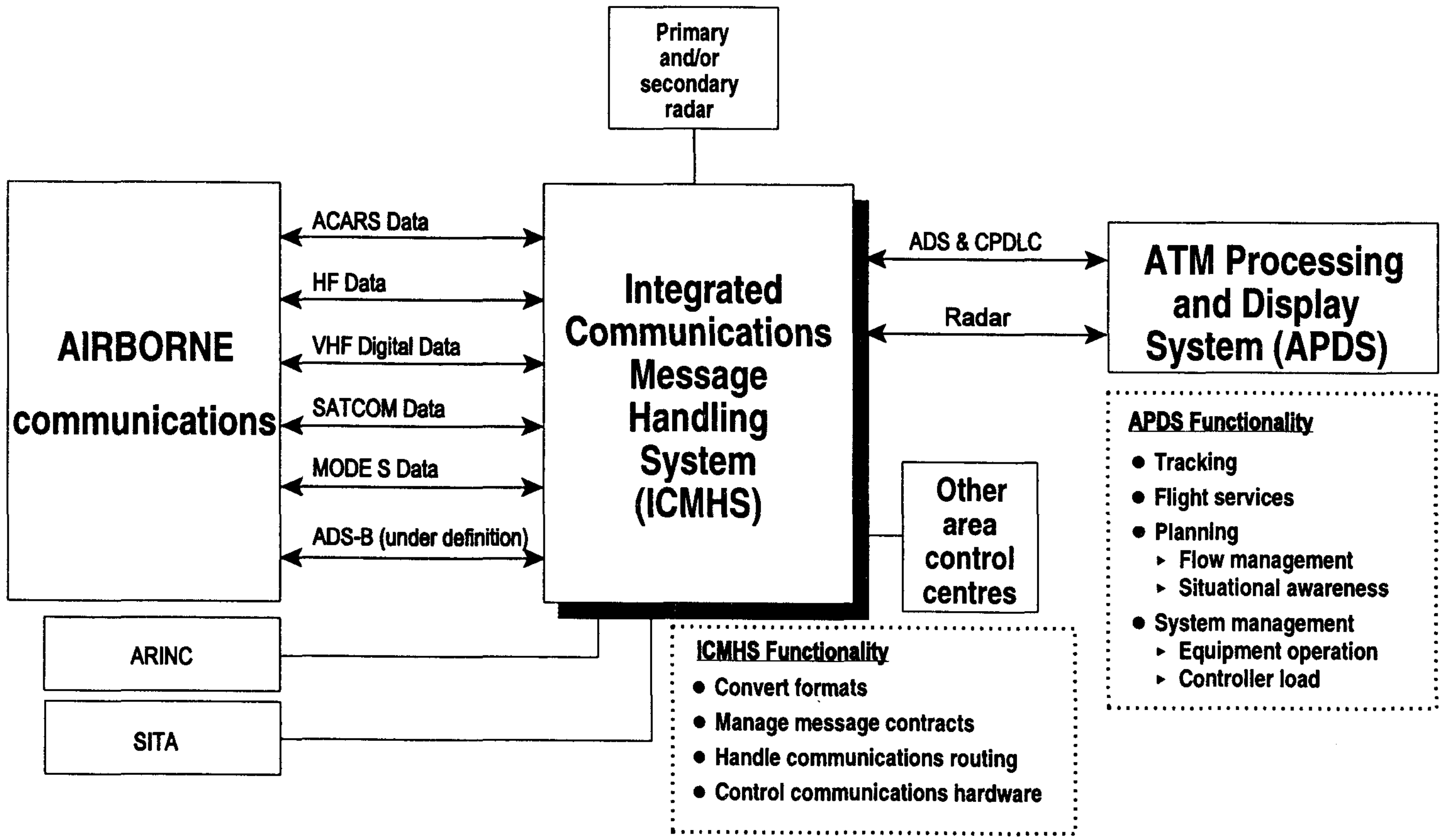

Figure 10-1. Interface between the data communications media and display functions

Chapter 11
GLOBAL PLANNING METHODOLOGY

INTRODUCTION

11.1 The primary goal of an integrated global air traffic management (ATM) system is to enable aircraft operators to meet their planned times of departure and arrival and adhere to their preferred flight profiles with minimum constraints and no compromise to safety. To accomplish this goal, the technologies afforded through the communications, navigation and surveillance (CNS) system will have to be fully exploited through international harmonization of ATM standards and procedures. From the aircraft operator's point of view, it is desirable to equip aircraft operating internationally with a minimum set of avionics which would be usable everywhere.

PLANNING PROCESS

11.2 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 planning by States and aircraft operators. However, a State's plans may be driven by local operational requirements, are likely to have different implementation timescales, will require unique facilities and functions and may pose problems in interfacing with other States. This could result in patchwork, particularly for international traffic. Consequently, a better approach to planning on a large yet integrated scale, based on homogeneous ATM areas and major international traffic flows, has been adopted in many regions. It should eventually lead to the creation of a global ATM system.

HOMOGENEOUS ATM AREAS AND MAJOR INTERNATIONAL TRAFFIC FLOWS

Homogeneous ATM areas

11.3 Homogeneous ATM areas can be understood as the areas which, among other considerations, have similar traffic density and complexity and similar air navigation infrastructure requirements.

Major international traffic flows

11.4 Major international traffic flows can be understood as geographical bands defined by origin and destination. (*Note.— Major international traffic flows may cross several homogeneous ATM areas with different characteristics.*)

CHARACTERISTICS OF THE APPROACH TO IMPLEMENTATION OF CNS/ATM SYSTEMS BASED ON HOMOGENEOUS ATM AREAS AND MAJOR INTERNATIONAL TRAFFIC FLOWS

11.5 The main features of this approach are, *inter alia*:

a) it envelops multiple regions/multiple States;

b) it may include various types of airspace: oceanic, continental en-route and terminal areas;

c) it involves consideration of the air navigation infrastructure, traffic density and airspace users' needs;

d) it has common ATM objectives;

e) it has interoperable CNS systems;

f) it absorbs the gate-to-gate concept;

g) the infrastructure could be established by a multinational group, service providers or States;

h) operational management rests with the multinational group, service providers or States;

i) ICAO is providing leadership for overall coordination and institutional arrangements;

j) there are early benefits to airspace users/States;

k) as it lends itself to a business case, it is easier to approach financial institutions for funding the project;

l) user charges are one of the means of cost recovery;

m) there may be merit in the establishment of joint charges collection agencies; and

n) user charges will serve as a source of repayment for the funding of ATM system projects by financial institutions.

STEP-BY-STEP APPROACH

11.6 The step-by-step approach to planning for implementation of CNS/ATM systems on the basis of homogeneous ATM areas and major international traffic flows is as follows:

Step 1) Identify homogeneous ATM areas and major international traffic flows.

Step 2) List the ICAO Region(s), flight information region(s) and State(s) involved in the homogeneous ATM areas and major international traffic flows.

Step 3) Carry out air traffic forecasts and ascertain airspace user needs.

Step 4) Evaluate the current infrastructure of the areas identified in Step 1 in terms of:

a) ATM limitations and shortcomings;

b) separation Standards; and

c) CNS availability.

Step 5) Determine ATM objectives for the areas identified in Step 1.

Step 6) Establish CNS requirements necessary to support the desired ATM objectives as determined in Step 5.

Step 7) Analyse the benefits/improvements as a result of Steps 5 and 6 in order to establish:

a) costs/benefits;

b) relative priority; and

c) implementation dates for the various ATM objectives and CNS facilities for each of the homogeneous ATM areas and major international traffic flows.

Step 8) Considering the many technical solutions and implementation options available, repeat as necessary Steps 5, 6 and 7 to determine the most appropriate solution.

Step 9) Examine the possibilities of funding implementation of the CNS/ATM systems infrastructure for States requiring financial assistance.

Step 10) Determine means and methods of cost recovery.

Step 11) 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 ATM areas and along major international traffic flows.

11.7 The overall approach to planning ATM objectives and CNS infrastructure, based on homogeneous ATM areas and major international traffic flows, is illustrated in Figure 11-1.

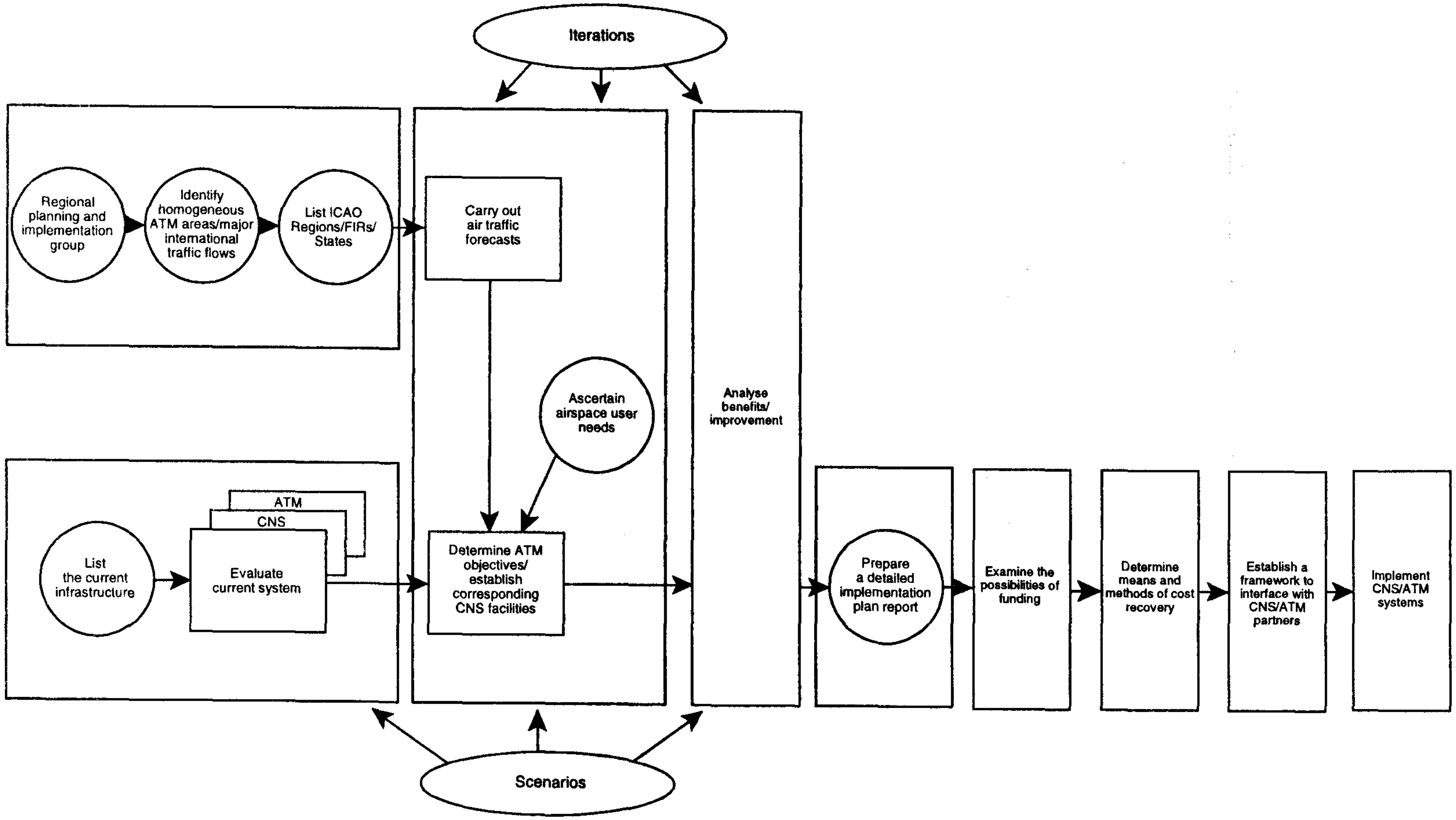

Figure 11-1. Approach to planning for CNS/ATM systems on the basis of homogeneous ATM areas and major international traffic flows

Appendix

BIBLIOGRAPHY

The following related studies and documents were referred to when structuring the guidance material.

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2. *Economics of Satellite-based Air Navigation Services — Guidelines for cost/benefit analysis of communications, navigation and surveillance/air traffic management (CNS/ATM) systems* (Circ. 257).

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— END —

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the Aeronautical Chart Catalogue *or the* Meteorological Tables for International Air Navigation.

International Standards and Recommended Practices are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications contained in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

Procedures for Air Navigation Services (PANS) are approved by the Council for worldwide application. They contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

Regional Supplementary Procedures (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

Technical Manuals provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

ICAO Circulars make available specialized information of interest to Contracting States. This includes studies on technical subjects.

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