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Global
Air Traffic Management
Operational Concept

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AMENDMENTS

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RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS		
No.	Date	Entered by

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No.	Date	Entered by

FOREWORD

The air transport industry plays a major role in world economic activity and remains one of the fastest growing sectors of the world economy. In every region of the world, States depend on the aviation industry to maintain or stimulate economic growth and to assist in the provision of essential services to local communities. In this light, civil aviation can be seen as a significant contributor to the overall well-being and economic vitality of individual nations as well as the world in general. Because of the continued growth in civil aviation, in many places, demand often exceeds the available capacity of the air navigation system to accommodate air traffic, resulting in significant negative consequences not only to the aviation industry, but also to general economic health. One of the keys to maintaining the vitality of civil aviation is to ensure that a safe, secure, efficient and environmentally sustainable air navigation system is available at the global, regional and national levels. This requires the implementation of an air traffic management system that allows maximum use to be made of enhanced capabilities provided by technical advances.

In the 1980s, the ICAO Council considered the steady growth of international civil aviation, taking into account emerging technologies, and determined that a thorough assessment and analysis of procedures and technologies serving civil aviation was in order. It was generally recognized at the time that the existing approach to the provision of air traffic services (ATS) and the air navigation system was limiting continued aviation growth and constraining improvements in safety, efficiency and regularity. In 1983, the ICAO Council established the Special Committee on Future Air Navigation Systems (FANS) to develop recommendations for the future development of air navigation for civil aviation over a period of the order of twenty-five years. In 1991, a second FANS Committee was established to monitor and coordinate transition planning for the future air navigation system. In September 1991, the Tenth Air Navigation Conference endorsed the FANS concept. After acceptance by the ICAO Council, it came to be known as "communications, navigation and surveillance/air traffic management (CNS/ATM) systems".

In order to progress implementation of CNS/ATM systems, a plan of action was needed. The first such effort was the *Global Coordinated Plan for Transition to ICAO CNS/ATM Systems* (Global Coordinated Plan). In 1996, the ICAO Council determined that CNS/ATM systems had matured and a more concrete plan was needed which would include all developments and possible technical solutions, while focussing on regional implementation. In light of this, ICAO revised the Global Coordinated Plan to make it a "dynamic" document, comprising technical, operational, economic, environmental, financial, legal and institutional elements, and also offering practical guidance and advice to regional planning groups and States on implementation and funding strategies. The revised document, now known as the *Global Air Navigation Plan for CNS/ATM Systems* (Global Plan, Doc 9750) was developed as a strategic document to guide the implementation of CNS/ATM systems.

In the intervening years, several States and all ICAO regions embarked on ATM implementation programmes intended to improve aviation operations by making use of CNS/ATM technologies. However, it was later recognized that technology was not an end in itself and that a comprehensive concept of an integrated and global ATM system, based on clearly established operational requirements, was needed. Such a concept, in turn, would form the basis for the coordinated implementation of CNS/ATM technologies based on clearly established requirements. To develop the concept, the ICAO Air Navigation Commission established the Air Traffic Management Operational Concept Panel (ATMCP).

The operational concept contained herein is intended to guide the implementation of CNS/ATM technology by providing a description of how the emerging and future ATM system should operate. This, in turn, will assist the aviation community to transition from the air traffic control environment of the twentieth century to the integrated and collaborative air traffic management system needed to meet aviation's needs in the twenty-first century. This effort should be seen as the next step in an evolutionary process that began with the FANS concept — the goal being an integrated, global ATM system. This document presents the operational concept that is intended to meet the needs of the ATM community into the foreseeable future. Appendix A provides a description of the ATM community, and a glossary of terms used specifically for describing the operational concept is contained in Appendix B.

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Chapter 1

GENERAL

1.1 ATM OPERATIONAL CONCEPT

1.1.1 The global air traffic management (ATM) operational concept presents the ICAO vision of an integrated, harmonized and globally interoperable ATM system. The planning horizon is up to and beyond 2025. The baseline against which the significance of the changes proposed in the operational concept may be measured is the global ATM environment in 2000.

Vision Statement

To achieve an interoperable global air traffic management system, for all users during all phases of flight, that meets agreed levels of safety, provides for optimum economic operations, is environmentally sustainable and meets national security requirements.

1.1.2 While the operational concept is visionary and even challenging, many of the current practices and processes will continue to exist through the planning horizon. In this sense, this operational concept document should be seen as evolutionary.

1.1.3 A key point to note is that the operational concept, to the greatest extent possible, is independent of technology; that is, it recognizes that within a planning horizon of more than twenty years, much of the technology that exists or is in development today may change or cease to exist. This operational concept has therefore been developed to stand the test of time.

Air Traffic Management

Air traffic management is the dynamic, integrated management of air traffic and airspace — safely, economically and efficiently — through the provision of facilities and seamless services in collaboration with all parties.

1.2 OPERATIONAL CONCEPT AND THE ATM SYSTEM

1.2.1 An operational concept is a statement of “what” is envisaged. It asks and answers the question of what outcomes are required in the case of the ATM system of the future. It is a vision statement. It is not a technical manual or blueprint nor does it detail “how” things will be enabled; that lies in a lower document in the hierarchy, which may include concepts of operation or use, technical standards and strategic plans.

1.2.2 The ATM system is a system that provides air traffic management through the collaborative integration of humans, information, technology, facilities and services, supported by air, ground and/or space-based communications, navigation and surveillance.

1.3 SCOPE OF THE CONCEPT

This operational concept describes the manner in which the ATM system will deliver services and benefits to airspace users by 2025. It also details how ATM will act directly on the flight trajectory of a manned or unmanned vehicle during all phases of flight, and the interaction of that flight trajectory with any hazard.

Scope

This air traffic management operational concept describes the services that will be required to operate the global air traffic system up to and beyond 2025. The operational concept addresses what is needed to increase user flexibility and maximize operating efficiencies in order to increase system capacity and improve safety levels in the future air traffic management system.

1.4 GUIDING PRINCIPLES

The ATM system is based on the provision of services. This service-based framework considers all resources, *inter alia,* airspace, aerodromes, aircraft and humans, to be part of the ATM system. The primary functions of the ATM system will enable flight from/to an aerodrome into airspace, safely separated from hazards, within capacity limits, making optimum use of all system resources. The description of the concept components is based on realistic expectations of human capabilities and the ATM infrastructure at any particular time in the evolution to the ATM system described by this operational concept and is independent of reference to any specific technology. Based on these considerations the elements are predicated on the guiding principles that follow.

1.5 DRIVERS FOR CHANGE

1.5.1 The ATM environment, like so many other environments today, is driven by safety and increasingly by commercial or personal outcome expectations. There are standards in place for global interoperability, and many States' systems have evolved within a standards framework to levels that are able to sustain their individual requirements. However, they now struggle or fail to meet the ever-growing user expectations of global harmonization and interoperability. There is no doubt that the ATM system of 2000 had many limitations, and these are outlined in Appendix C.

1.5.2 In 2000, a range of factors, including cost, efficiency, safety and national interest, drove change in the ATM system. Now, however, the driver for change must be ATM user expectations, within a framework of safety and business cases, and cost/benefit analysis. The operational concept identifies a range of user expectations; however, it is recognized that within the planning horizon, the set of solutions to provide expected benefits may change, and this will be identified and implemented through the safety and business case process.

Guiding Principles

Safety. The attainment of a safe system is the highest priority in air traffic management, and a comprehensive process for safety management is implemented that enables the ATM community to achieve efficient and effective outcomes.

Humans. Humans will play an essential and, where necessary, central role in the global ATM system. Humans are responsible for managing the system, monitoring its performance and intervening, when necessary, to ensure the desired system outcome. Due consideration to human factors must be given in all aspects of the system.

Technology. The ATM operational concept addresses the functions needed for ATM without reference to any specific technology and is open to new technology. Surveillance, navigation and communications systems, and advanced information management technology are used to functionally combine the ground-based and airborne system elements into a fully integrated, interoperable and robust ATM system. This allows flexibility across regions, homogeneous areas or major traffic flows to meet the requirements of the concept.

Information. The ATM community will depend extensively on the provision of timely, relevant, accurate, accredited and quality-assured information to collaborate and make informed decisions. Sharing information on a system-wide basis will allow the ATM community to conduct its business and operations in a safe and efficient manner.

Collaboration. The ATM system is characterized by strategic and tactical collaboration in which the appropriate members of the ATM community participate in the definition of the types and levels of service. Equally important, the ATM community collaborates to maximize system efficiency by sharing information, leading to dynamic and flexible decision making.

Continuity. The realization of the concept requires contingency measures to provide maximum continuity of service in the face of major outages, natural disasters, civil unrest, security threats or other unusual circumstances.

1.5.3 The ATM community's expectations should guide the development of the future ATM system. The ATM operational concept will guide the implementation of specific ATM technology solutions. It is crucial that the evolution to the global ATM system be driven by the need to meet the expectations of the ATM community and enabled by the appropriate technologies. These expectations are further described in Appendix D.

1.6 EXPECTED BENEFITS

1.6.1 This ATM operational concept seeks to derive benefits for all members of the ATM community.

1.6.2 From an airspace user perspective, greater equity in airspace access, greater access to timely and meaningful information for decision support, and more autonomy in decision making, including conflict management, will provide the opportunity to better deliver business and individual outcomes within an appropriate safety framework.

1.6.3 From a service provider perspective, including that of aerodrome operators, the ability to operate within an information-rich environment, with real-time data, as well as system trend and predictive data, fused with a range of automated decision-support or decision-making tools, will enable optimization of services to airspace users.

1.6.4 From a regulator perspective, safety systems will be robust and open, allowing safety not only to be more easily measured and monitored, but also compared and integrated on a global basis, not for its own sake, but as a platform for continuous improvement.

1.6.5 These expected benefits are described in Appendix E.

1.7 ATM SYSTEM PERFORMANCE

Members of the ATM community will have differing performance demands of the system. All will have either an explicit or implicit expectation of safety; although in 2000, this was difficult to measure and/or assure. Some will have explicit economic expectations, others efficiency and predictability. For optimum system performance, each of these sometimes competing expectations will need to be balanced. Furthermore, explicit safety outcomes will need to be met and demonstrated. The operational concept outlines a total system performance framework, including a system safety approach that will support both the "end-state" concept and the various evolutions to that "end-state". A more detailed description of ATM system performance is provided in Appendix F.

1.8 CONCEPT COMPONENTS

This operational concept defines seven interdependent concept components that will be integrated to form the future ATM system. They comprise airspace organization and management, aerodrome operations, demand and capacity balancing, traffic synchronization, conflict management, airspace user operations, and ATM service delivery management. The order of these components implies no priority. The management, utilization and transmission of data and information are vital to the proper functioning of these components. Detailed explanations of these concept components are provided in Chapter 2.

1.9 SIGNIFICANT CHANGES

1.9.1 This operational concept outlines a range of conceptual changes that will evolve over the planning horizon. Key to the philosophy adopted within the operational concept is the notion of global information utilization, management and interchange and with that an enabling, in an evolutionary way, of a significant change in the roles of all participants within the ATM system, thereby facilitating enhancements in safety, economy and efficiency across the system. This philosophy is supported in large part by evolution to a holistic, cooperative and collaborative decision-making environment, where the diverging expectations and interests of all members of the ATM community are balanced to achieve equity and access.

1.9.2 Air traffic management (ATM) considers the trajectory of a manned or unmanned vehicle during all phases of flight and manages the interaction of that trajectory with other trajectories or hazards to achieve the optimum system outcome, with minimal deviation from the user-requested flight trajectory, whenever possible.

1.10 EVOLUTION TO THE OPERATIONAL CONCEPT

The operational concept describes the components and, in general terms, their interdependencies, in a global sense. However, the concept also recognizes that reaching the “end-state” cannot be achieved by revolution; rather, it will be an evolutionary process, with an ultimate goal of global harmonization not later than the concept horizon of 2025. This will allow States, regions and homogeneous areas to plan the significant investments that will need to be made, and the time frame for those investments, in a collaborative decision-making environment within a framework of safety and business cases. The ATM operational concept also provides the basis from which the ATM operational requirements, objectives and benefits will be derived, thereby providing the foundation for the development of regional and national ATM implementation plans. This evolution is described in more detail in Appendix G, and the planning process is described in more detail in Appendix H.

1.11 SCALABILITY AND ADAPTABILITY

1.11.1 The operational concept is adaptable to the operational environment of all States and regions and is scalable to meet their specific needs. This recognizes the fact that while there are urgent requirements to implement ATM changes to meet a range of needs, *inter alia*, the growing traffic demands in certain areas or a lack of infrastructure in other areas, the appropriate solutions may differ.

1.11.2 In many areas, simple solutions based on regional harmonization or cooperation across homogeneous areas may provide satisfactory short- or medium-term responses to the requirements of this concept document, while in other areas, sophisticated ATM systems may be required.

1.12 DIFFERENT REGIONAL EXPECTATIONS

The expectations enunciated within any one particular region will be different to an adjacent or distant region, in the initial stages of evolution to the ATM system described in this operational concept. The concept allows for different emphasis to be placed on the various concept components to derive identified operational benefits. However, any such emphasis must still recognize that each component is a standard and uniformly understood “building block” that facilitates the movement of aircraft through regions with little or no change to equipment or procedures. Ultimately, the goal is to achieve global harmonization and interoperability.

1.13 REGIONAL COORDINATION

1.13.1 Recognizing that not all States or regions can move immediately to the ATM system described in this concept, the operational concept contains details on an expected planning and evolutionary process, within the ICAO framework.

1.13.2 The implementation of the concept is provided for by strategic plans, *inter alia,* the Global Air Navigation Plan for CNS/ATM Systems, regional plans and State implementation plans, which also describe the progressive intermediate steps toward that goal. The plans of all States need to be aligned to ensure, to the greatest extent possible, that solutions are internationally harmonized and integrated and do not unnecessarily impose multiple equipment carriage requirements in the air components of the ATM system, or multiple systems on the ground.

1.14 SCENARIO DEVELOPMENT

To better understand the interactions of the ATM components in the future, it is necessary to provide some illustrative examples of how the ATM components can be applied consistent with the concept. One particular interpretation has been developed and can be found in Appendix I.

Chapter 2

ATM OPERATIONAL CONCEPT COMPONENTS

2.1 INTRODUCTION

2.1.1 The ATM system will be based on the provision of integrated services. However, to better describe how these services will be delivered, seven concept components, together with their expected key conceptual changes, are first described in capsule form and then further elaborated upon in sections 2.2 to 2.8. In addition to the seven concept components, section 2.9 on information services describes the exchange and management of information used by the different processes and services. The ATM system needs to be disaggregated to understand the sometimes complex interrelationships between its components. The ATM system cannot, however, function without all of its components, which must be integrated. The separate components form one system. Figure 2-1 depicts the interrelationship of the system components and their convergence into a single system.

Airspace organization and management

2.1.2 Airspace organization will establish airspace structures in order to accommodate the different types of air activity, volume of traffic and differing levels of service. Airspace management is the process by which airspace options are selected and applied to meet the needs of the ATM community. Key conceptual changes include:

a) all airspace will be the concern of ATM and will be a usable resource;

b) airspace management will be dynamic and flexible;

c) any restriction on the use of any particular volume of airspace will be considered transitory; and

d) all airspace will be managed flexibly. Airspace boundaries will be adjusted to particular traffic flows and should not be constrained by national or facility boundaries.

Aerodrome operations

2.1.3 As an integral part of the ATM system, the aerodrome operator must provide the needed ground infrastructure including, *inter alia*, lighting, taxiways, runways, including exits, and precise surface guidance to improve safety and maximize aerodrome capacity in all weather conditions. The ATM system will enable the efficient use of the capacity of the aerodrome airside infrastructure. Key conceptual changes include:

a) runway occupancy time will be reduced;

b) the capability will exist to safely manoeuvre in all weather conditions while maintaining capacity;

c) precise surface guidance to and from a runway will be required in all conditions; and

d) the position (to an appropriate level of accuracy) and intent of all vehicles and aircraft operating on the movement area will be known and available to the appropriate ATM community members.

Demand and capacity balancing

2.1.4 Demand and capacity balancing will strategically evaluate system-wide traffic flows and aerodrome capacities to allow airspace users to determine when, where and how they operate, while mitigating conflicting needs for airspace and aerodrome capacity. This collaborative process will allow for the efficient management of the air traffic flow through the use of information on system-wide air traffic flows, weather and assets. Key conceptual changes include:

a) through collaborative decision making at the strategic stage, assets will be optimized in order to maximize throughput, thus providing a basis for predictable allocation and scheduling;

b) through collaborative decision making at the pre-tactical stage, when possible, adjustments will be made to assets, resource allocations, projected trajectories, airspace organization, and allocation of entry/exit times for aerodromes and airspace volumes to mitigate any imbalance; and

c) at the tactical stage, actions will include dynamic adjustments to the organization of airspace to balance capacity, dynamic changes to the entry/exit times for aerodromes and airspace volumes, and adjustments to the schedule by the users.

Traffic synchronization

2.1.5 Traffic synchronization refers to the tactical establishment and maintenance of a safe, orderly and efficient flow of air traffic. Key conceptual changes include:

a) there will be dynamic four-dimensional (4-D) trajectory control and negotiated conflict-free trajectories;

b) choke points will be eliminated; and

c) optimization of traffic sequencing will achieve maximization of runway throughput.

Airspace user operations

2.1.6 Airspace user operations refer to the ATM-related aspect of flight operations. Key conceptual changes include:

a) the accommodation of mixed capabilities and worldwide implementation needs will be addressed to enhance safety and efficiency;

b) relevant ATM data will be fused for an airspace user's general, tactical and strategic situational awareness and conflict management;

c) relevant airspace user operational information will be made available to the ATM system;

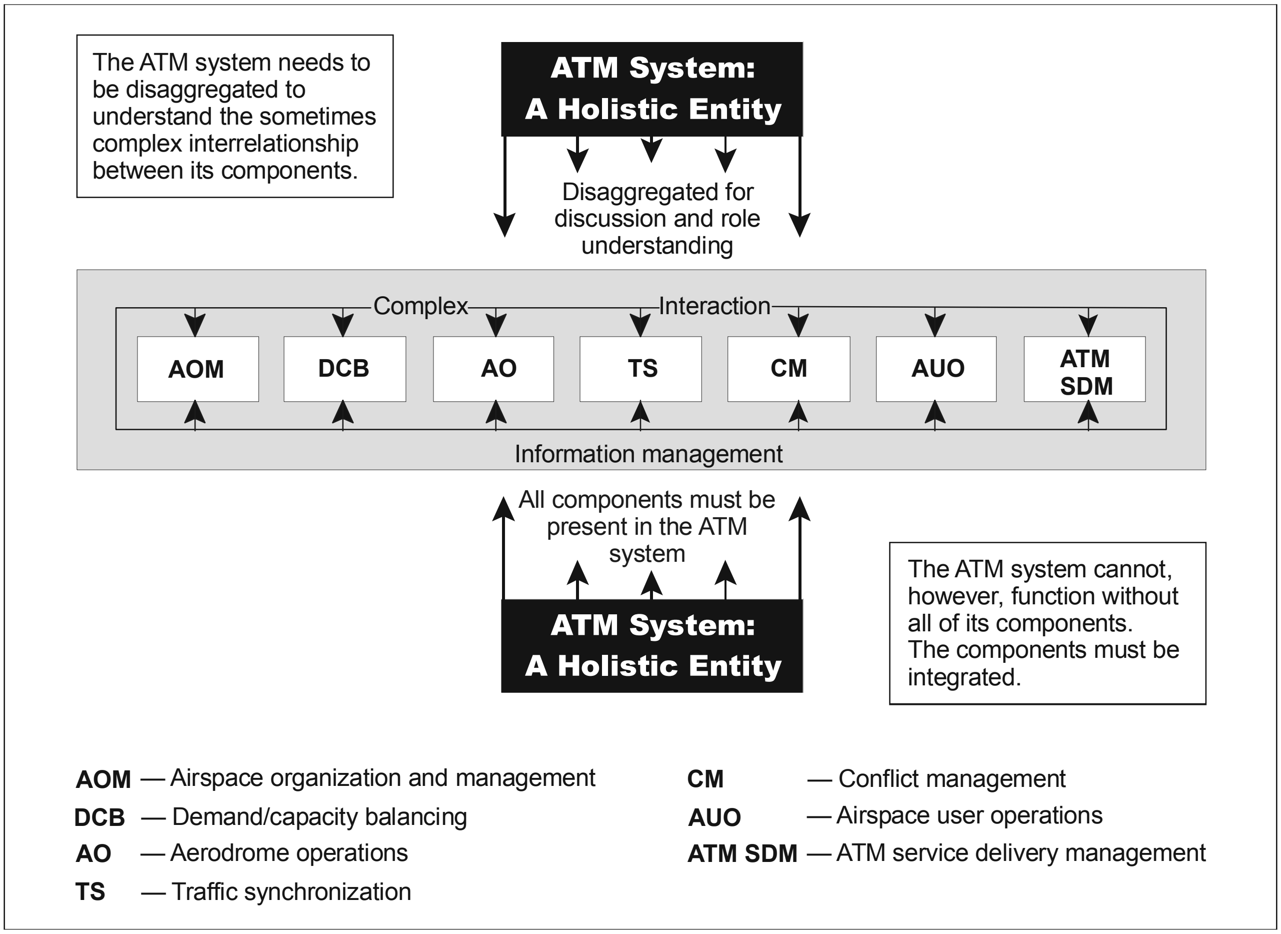

Figure 2-1. The seven ATM concept components

d) individual aircraft performance, flight conditions, and available ATM resources will allow dynamically-optimized 4-D trajectory planning;

e) collaborative decision making will ensure that aircraft and airspace user system design impacts on ATM are taken into account in a timely manner; and

f) aircraft should be designed with the ATM system as a key consideration.

Conflict management

2.1.7 Conflict management will consist of three layers: strategic conflict management through airspace organization and management, demand and capacity balancing, and traffic synchronization; separation provision; and collision avoidance.

2.1.8 Conflict management will limit, to an acceptable level, the risk of collision between aircraft and hazards. Hazards that an aircraft will be separated from are: other aircraft, terrain, weather, wake turbulence, incompatible airspace activity and, when the aircraft is on the ground, surface vehicles and other obstructions on the apron and manoeuvring area. Key conceptual changes include:

a) strategic conflict management will reduce the need for separation provision to a designated level;

b) the ATM system will minimize restrictions on user operations; therefore, the predetermined separator will be the airspace user, unless safety or ATM system design requires a separation provision service;

c) the role of separator may be delegated, but such delegations will be temporary;

d) in the development of separation modes, separation provision intervention capability must be considered;

e) the conflict horizon will be extended as far as procedures and information will permit; and

f) collision avoidance systems will be part of ATM safety management but will not be included in determining the calculated level of safety required for separation provision.

ATM service delivery management

2.1.9 ATM service delivery management will operate seamlessly from gate to gate for all phases of flight and across all service providers. The ATM service delivery management component will address the balance and consolidation of the decisions of the various other processes/services, as well as the time horizon at which, and the conditions under which, these decisions are made. Flight trajectories, intent and agreements will be important components to delivering a balance of decisions. Key conceptual changes include:

a) services to be delivered by the ATM service delivery management component will be established on an as-required basis subject to ATM system design. Once established, they will be provided on an on-request basis;

b) ATM system design will be determined by collaborative decision making and system-wide safety and business cases;

c) services delivered by the ATM service delivery management component will, through collaborative decision making, balance and optimize user-requested trajectories to achieve the ATM community's expectations; and

d) management by trajectory will involve the development of an agreement that extends through all the physical phases of the flight.

2.1.10 The seven ATM concept components introduced above are described in more detail in Figure 2-1.

2.2 AIRSPACE ORGANIZATION AND MANAGEMENT

2.2.1 All airspace will be the concern of ATM and will be a usable resource. The organization, flexible allocation and use of airspace will be based on the principles of access and equity. On this basis, any restriction on the use of any particular volume of airspace will be considered transitory. The airspace will be organized and managed in a manner that will accommodate all current and potential new uses of airspace, *inter alia*, unmanned aerial vehicles and transiting space-vehicles.

2.2.2 While acknowledging sovereignty, airspace will be organized globally. Homogeneous ATM areas and/or routing areas will be kept to a minimum, and consideration will be given to consolidating adjacent areas. The ATM community members concerned will undertake strategic planning for any defined area. The ATM service provider managing that airspace will effect tactical changes in specific airspace.

2.2.3 Coordinated planning among adjacent areas will be conducted with the objective of achieving a single airspace continuum. The airspace within that continuum will be free of operational discontinuities and inconsistencies. Airspace will be organized to accommodate the needs of the different types of users on a timely basis. Transition between areas will be transparent to users at all times.

2.2.4 Airspace organization and management will provide the first layer of conflict management. Effective airspace organization and management will enhance the ability of the ATM service provider and airspace users to accomplish conflict management and will also increase ATM system safety, capacity and efficiency.

Airspace organization

2.2.5 The airspace organization function will provide the strategies, rules and procedures by which the airspace will be structured to accommodate the different types of air activity, volume of traffic, and differing levels of service and rules of conduct. The principles of organization will be applicable from the most complex to the least complex airspace. The organizational principles underlying these strategies, rules and procedures include the following:

a) airspace management will be dynamic, flexible and based on services demanded. Airspace organizational boundaries, divisions and categories will be adapted to traffic patterns and changing situations and will support the efficient operation of the other ATM services identified in this chapter. Flexibility within airspace organization will include regular strategic planning processes and will allow actual operations to dictate a more optimum configuration;

b) airspace will be organized to facilitate the seamless handling of flights and the ability to conduct flights along optimum flight trajectories from gate to gate without undue restriction or delay;

c) airspace planning will be based on accommodating dynamic flight trajectories whenever practicable. Structured route systems will be established only in areas where the demand for dynamic trajectories cannot be accommodated; and

d) airspace will be organized to be easily learned, understood and used by the ATM community as appropriate.

2.2.6 Airspace organization will be based on the principle that all airspace is managed, and all related activity within airspace will be known to the ATM system in varying degrees. “Managed” means that a strategic or tactical decision as to the level of service to be provided will have been taken by the appropriate authority.

2.2.7 Although there will generally be no permanent/fixed constrained airspace, certain airspace will be subjected to service limitations, including access over an extended period, motivated by national interests or safety issues and appropriately considered in coordination with the ATM community.

2.2.8 There will always be airspace that is primarily used or organized for a specific purpose (e.g. trajectory-oriented airspace, high-density airspace, special-use airspace). However, aircraft neither operating in that particular mode, nor equipped accordingly for such airspace, will be accommodated by the system where deemed safe and appropriate. Accommodation will be made without constraining the primary use of that airspace.

2.2.9 Priority for the use of specific airspace will not be constrained by the primary usage or equipage on a routine basis. While it is recognized that airspace designation is useful, it should not be organized in a manner that permanently precludes the possibility of mixed usage/mixed equipage operations.

Airspace management

2.2.10 Airspace management is the process by which airspace organization options and other options in the provision of services will be selected and applied to best meet the needs of airspace users. Competing interests for the use of airspace will make airspace management a highly complex exercise, necessitating a process that equitably balances those interests.

2.2.11 The management of airspace will follow these guiding principles and strategies:

a) all airspace will be managed flexibly. Airspace boundaries will be adjusted to particular traffic flows and should not be constrained by national or facility boundaries;

b) airspace management processes will accommodate dynamic flight trajectories and provide optimum system solutions;

c) when conditions require that different types of traffic be segregated by airspace organization, the size, shape and time regulation of that airspace will be set to minimize the impact on operations;

d) airspace use will be coordinated and monitored in order to accommodate the conflicting legitimate requirements of all users and to minimize any constraints on operations;

e) airspace reservations will be planned in advance with changes made dynamically whenever possible. The system will also accommodate unplanned requirements;

f) structured route systems will be applied only where required to enhance capacity or to avoid areas where access has been limited or where hazardous conditions exist;

g) uniform airspace organization and management principles will be applicable to all regions. Global principles will be applicable at all levels of density and will affect total traffic volume. Complex operations may limit the degree of flexibility; and

h) areas that should strive for the earliest and shortest implementation are those where ATM community expectations are not being met.

2.3 AERODROME OPERATIONS

2.3.1 Aerodrome operations describe the aerodrome functionality within the ATM system in terms of such factors as information acquisition and delivery, facility access, demand on airspace, and limits on usability. There will be a dependency on landside operations where improvements will be needed to optimize aerodrome capacity.

2.3.2 Aerodrome operations will be considered from an en-route to en-route perspective in determining their role within the ATM system.

2.3.3 The principal challenge to aerodrome operators will be to provide sufficient aerodrome capacity, while the challenge to the ATM system will be to ensure that all available capacity is fully and efficiently utilized.

2.3.4 Aerodrome operation principles include the following:

a) runway occupancy time will be reduced;

b) the capability will exist to safely manoeuvre in all weather conditions while maintaining capacity; and

c) any activities that take place on the manoeuvring area or apron will be considered as having a direct influence on ATM.

2.3.5 Where required, runway geometry will permit runway entry and exit at any location along its length, minimizing runway occupancy time and reducing holding areas.

2.3.6 Precise surface guidance to and from a runway will be required in all conditions. The position (to an appropriate level of accuracy) and intent of all vehicles and aircraft operating on the movement area will be known and available to the appropriate ATM community members.

2.3.7 Landside activities not directly related to the ATM system will have an impact on aerodrome operations. These activities include, *inter alia*, customs, security, baggage handling and fuel supply, and will be optimized through the collaborative exchange of information.

2.3.8 Environmental issues such as noise, gaseous emissions and visual intrusions will be considered in the design, development and operation of aerodromes. Restrictions on airside operations may occur due to environmental constraints and public concern.

2.3.9 Flight parameters will be available to the ATM system, allowing for dynamic spacing and sequencing of departing aircraft, thereby minimizing wake vortex constraints on runway capacity.

2.4 DEMAND AND CAPACITY BALANCING

2.4.1 The function of demand and capacity balancing will be to minimize the effects of ATM system constraints. Demand and capacity balancing will be capable of evaluating system-wide traffic flows and capacities in order to implement necessary actions in a timely manner. A collaborative process will allow for the efficient management of the air traffic flow through the use of information on system-wide air traffic flows, weather and assets.

2.4.2 Demand and capacity balancing will allow airspace users to optimize their participation in the ATM system while mitigating conflicting needs for airspace and aerodrome capacity. Collaborative usage of decision-support tools will ensure the most efficient use of airspace resources, provide the greatest possible access to airspace resources, provide equitable access for all airspace users, accommodate user preferences and ensure that demand on an airspace resource will not exceed its capacity.

2.4.3 Demand and capacity balancing will be integrated within the ATM system. Demand and capacity balancing will be undertaken at the strategic, pre-tactical and tactical stages, defined as follows:

a) ***Strategic stage.*** At the strategic stage, demand and capacity balancing will respond to the fluctuations in schedules and demands, including the increasing globalization of traffic patterns, as well as the seasonal changes of weather and major weather phenomena. This stage will begin as soon as practicable. Through collaborative decision making, assets will be optimized in order to maximize throughput, thus providing a basis for predictable scheduling.

b) ***Pre-tactical stage.*** At the pre-tactical stage, demand and capacity balancing will evaluate the current allocation of ATM service provider, airspace user and aerodrome operator assets and resources against the projected demands. Through collaborative decision making, when possible, adjustments will be made to assets, resource allocations, projected trajectories, airspace organization, and allocation of entry/exit times for aerodromes and airspace volumes to mitigate any imbalance.

c) ***Tactical stage.*** At the tactical stage, demand and capacity balancing will focus more closely on demand management to adjust imbalances. It will consider weather conditions, infrastructure status, resource allocations, and disruptions in schedules that would cause an imbalance. Through collaborative decision making, these actions will include dynamic adjustments to the organization of airspace to balance capacity, dynamic changes to the entry/exit times for aerodromes and airspace volumes, and adjustments to the schedules by users.

2.4.4 Demand and capacity balancing principles include the following:

a) the difference between user-requested trajectories and actual trajectories will be optimized by the system to be as small as possible for individual flights;

b) recognition of deficiencies and optimization of assets will ensure maximum capacity through the balancing of operations against available assets;

c) balancing techniques will generally be based on system predictability; however, systems must be able to accommodate unplanned situations;

d) the balancing of demand and capacity will be performed from gate to gate;

e) system-wide balancing techniques will also be used to resolve local demand and capacity balancing problems;

f) strategic initiatives will require tactical flexibility to provide optimal airspace availability; and

g) demand and capacity balancing will take into account information about current and predicted airspace conditions, projected demand as well as past performance. Tools to strategically identify areas and times of higher density will also be available.

2.4.5 Advance demand and capacity balancing information will be made available to all airspace users and service providers, including aerodrome operators, to establish a common understanding of needs and capabilities. This will allow the development of collaborative strategies that will be more responsive to the situation.

2.4.6 In any ATM environment there will be intrinsic factors that will impact the decision-making processes with respect to demand and capacity balancing. These include, *inter alia*:

a) ***Limitation of real-time operational decision making.*** In trying to balance demand and capacity, decisions will be made based on available information that may be constantly changing, often as decisions are being made.

b) ***Limited window of opportunity.*** Decisions made in balancing demand with capacity will often be made quickly because the opportunity to achieve a solution is usually associated with a brief window of opportunity.

c) ***Inaccuracy of prediction.*** Decisions will be made regarding future states of the system, which can only be estimated based on current data. For example, weather, which often reduces the capacity of airspace resources, cannot be accurately predicted, nor can its precise impact on airspace resources be known in advance.

d) ***Stochastic nature of air traffic patterns.*** Air traffic patterns are highly complex. The effect of any one action on the overall flow of traffic cannot be modelled with certainty. Therefore, decision makers will have to take actions, the effects of which cannot always be precisely predicted.

2.5 TRAFFIC SYNCHRONIZATION

2.5.1 Traffic synchronization refers to the tactical establishment and maintenance of a safe, orderly and efficient flow of air traffic. Traffic synchronization, conflict management and demand and capacity balancing are interrelated and will become fully integrated, leading to a continuous and organized flow of traffic.

2.5.2 Traffic synchronization encompasses both the ground and airborne part of ATM and will constitute a flexible mechanism for capacity management by allowing reductions in traffic density and adjustments to capacity in response to variations in demand.

2.5.3 Traffic synchronization will make use of integrated and automated assistance to surface, departure, arrival and en-route management to ensure an optimum traffic flow. The objective will be to eliminate choke points and, ultimately, to optimize traffic sequencing to achieve maximization of runway throughput.

2.5.4 Traffic synchronization, together with the other ATM components, will contribute to the efficient handling of traffic from gate to gate. There will be dynamic 4-D trajectory control and negotiated conflict-free trajectories. These techniques will reduce the need for traditional path stretching in high traffic density areas and will reduce the adverse impact this has on economy and efficiency.

2.5.5 Traffic synchronization will be applicable and tailored to all airspace and aerodromes where the optimized ordering and sequencing of traffic are critical to accommodate demand.

2.5.6 Traffic synchronization principles include the following:

a) the ability to tactically and collaboratively modify sequences to optimize aerodrome operations, including gate management and/or airspace user operations;

b) evolution into 4-D control where a flight is given a time profile to follow to optimize throughput;

c) delegation of maintenance of spacing to the flight deck to increase traffic throughput while reducing ground system workload; and

d) wake vortex, which will continue to be a determinant of minimum spacing. Flight parameters will be available to the ATM system, allowing for dynamic spacing and sequencing of arriving and departing aircraft.

2.6 AIRSPACE USER OPERATIONS

2.6.1 Airspace user operations refer to the ATM-related aspect of flight operations.

2.6.2 The ATM system will accommodate diverse types of airspace user missions. These are expected to encompass, but are not limited to, air transport, military missions, business, aerial work and recreation. These missions will have differences in planning horizons, from those scheduled well in advance to just prior to flight.

2.6.3 The ATM system will accommodate diverse types of vehicle characteristics and capabilities.

2.6.4 Both manned and unmanned aerial vehicles will form part of the ATM system. The ATM system will accommodate the limited ability of some vehicles to dynamically change trajectory.

2.6.5 The evolution of ATM services will provide operational benefits and incentives commensurate with aircraft capabilities. It will have to be recognized, however, that the degree to which benefits and incentives can be realized may continue to differ with respect to the types of users. The development of the ATM system and aircraft capabilities, based on global standards, will ensure global interoperability of ATM systems and airspace user operations.

2.6.6 Aircraft design, including avionics, and operational characteristics have an influence on ATM performance (wake vortex, environmental considerations, aerodrome requirements, etc.). The interrelationship and interdependence of aircraft design and ATM performance are key considerations in aircraft and ATM system design.

2.6.7 Airspace user operations principles include the following:

a) relevant ATM data will be fused for an airspace user’s general, tactical and strategic situational awareness and conflict management;

b) relevant airspace user operational information will be made available to the ATM system; and

c) individual aircraft performance, flight conditions and available ATM resources will allow dynamically optimized 4-D trajectory management.

Mission planning

2.6.8 Mission planning is performed by airspace users as a collaborative exercise with airspace organization and management, aerodrome operations, and demand and capacity balancing, as appropriate, to ensure that the ATM system will be able to accommodate their mission.

Operational control

2.6.9 Operational control is a function exercised by airspace users with respect to an individual mission and means the exercise of authority over the initiation, conduct and termination of a mission.

2.6.10 Operational control is extended over the diverse types of airspace user missions and incorporates a number of elements including management of the mission, management of the individual flights, and collaboration with ATM.

Flight operations

2.6.11 Aircraft capabilities consistent with the applicable airspace management requirements will allow airspace users to fly user-preferred trajectories.

2.7 CONFLICT MANAGEMENT

Function

2.7.1 The function of conflict management will be to limit, to an acceptable level, the risk of collision between aircraft and hazards.

Relevant terms

2.7.2 Conflict is any situation involving aircraft and hazards in which the applicable separation minima may be compromised.

2.7.3 Conflict horizon is the extent to which hazards along the future trajectory of an aircraft are considered for separation provision.

2.7.4 Hazards that an aircraft will be separated from are: other aircraft, terrain, weather, wake turbulence, incompatible airspace activity and, when an aircraft is on the ground, surface vehicles and other obstructions on the apron and manoeuvring area.

2.7.5 Separation minima are the minimum displacements between an aircraft and a hazard that maintain the risk of collision at an acceptable level of safety.

2.7.6 Separation mode is an approved set of rules, procedures and conditions of application associated with separation minima.

2.7.7 Separation provision is the tactical process of keeping aircraft away from hazards by at least the appropriate separation minima.

Conflict management layers

2.7.8 Conflict management is applied in three layers, comprising:

a) strategic conflict management;

b) separation provision; and

c) collision avoidance.

2.7.9 The conflict management process can be applied at any point along the conflict horizon, from the flight formulation stage or schedule preparation well in advance of flight, to actual flight in real time.

Strategic conflict management

2.7.10 Strategic conflict management is the first layer of conflict management and is achieved through the airspace organization and management, demand and capacity balancing and traffic synchronization components.

2.7.11 The term "strategic" is used here to mean "in advance of tactical". This recognizes that a continuum exists from the earliest planning of the user activity through to the latest avoidance of the hazard. Strategic actions will normally occur prior to departure; however, they are not limited to pre-departure, particularly in the case of longer duration flights. Changes to the trajectory (whether at the request of the user or by the service provider) will result in the selection of the best means of conflict management, which may be strategic.

2.7.12 Strategic conflict management measures aim to reduce the need to apply the second layer — separation provision — to an appropriate level as determined by the ATM system design and operation.

Separation provision

2.7.13 Separation provision is the second layer of conflict management and is the tactical process of keeping aircraft away from hazards by at least the appropriate separation minima. Separation provision will only be used when strategic conflict management (i.e. airspace organization and management, demand and capacity balancing and traffic synchronization) cannot be used efficiently.

2.7.14 Separation provision is an iterative process, applied to the conflict horizon. It consists of:

a) the detection of conflict, which is based on the current position of the aircraft involved and their predicted trajectories in relation to known hazards;

b) the formulation of a solution, including selection of the separation modes, to maintain separation of aircraft from all known hazards within the appropriate conflict horizon;

c) the implementation of the solution by communicating the solution and initiating any required trajectory modification; and

d) the monitoring of the execution of the solution to ensure that the hazards are avoided by the appropriate separation minima.

2.7.15 New trajectories should be checked to ensure that they are free from conflicts within a considered conflict horizon. In order to minimize changes to aircraft trajectories, the conflict horizon will be extended as far as procedures and information permit. It is recognized that the conflict horizon may be reduced to solve near-term conflicts when required.

Separation mode

2.7.16 Separation mode is an approved set of rules, procedures and conditions of application associated with separation minima.

2.7.17 The separation mode will take in account, *inter alia*, the safety level required, the nature of the activity and hazard, the qualifications and roles of the actors, and other conditions of application, if applicable, such as weather conditions and traffic density.

Separator

2.7.18 The separator is the agent responsible for separation provision for a conflict and can be either the airspace user or a separation provision service provider.

2.7.19 The separator must be defined (that is predetermined) prior to the commencement of separation provision; however, the role of separator may be delegated.

Predetermined separator

2.7.20 Before the commencement of separation provision, it is essential that there is no ambiguity as to the agent responsible for keeping an aircraft separated from hazards. This agent will be called the predetermined separator because this role is determined prior to any need for separation provision. For any airspace user activity, the predetermined separator must be defined for all hazards; however, different predetermined separators may be defined for different hazards. For example, in some cases, the airspace user may be the predetermined separator in respect of weather and terrain, and the separation service provider will be the predetermined separator in respect of other hazards.

2.7.21 The role of separator may be delegated. When delegation occurs, the term separator applies to the agent currently responsible for separating aircraft from delegated hazards (the agent that has accepted the delegation). The term predetermined separator refers to the agent that the responsibility will ultimately transfer back to after the condition that terminates all delegations.

2.7.22 The ATM system will be designed to minimize restrictions on user operations and, in particular, will be designed to avoid, where possible, tactical changes to trajectories; therefore, the predetermined separator will be the airspace user, unless safety or ATM system design requires a separation provision service.

Self-separation

2.7.23 Self-separation is the situation where the airspace user is the separator for its activity in respect of one or more hazards.

2.7.24 Full self-separation is the situation where the airspace user is the separator for its activity in respect of all hazards. In this case, no separation provision service will be involved; however, other ATM services, including strategic conflict management services, may be used.

Distributed separation

2.7.25 Distributed separation occurs when, for an airspace user's activity, there are different separators for different hazards. This can be because different predetermined separators have been defined or because delegation of separation has occurred.

Cooperative separation

2.7.26 Cooperative separation occurs when the role of separator is delegated. This delegation is considered temporary, and the condition that will terminate the delegation is known. The delegation can be for types of hazards or from specified hazards. If the delegation is accepted, then the accepting agent is responsible for compliance with the delegation, using appropriate separation modes.

Note.— Participation in separation provision does not necessarily mean cooperative separation. Cooperative separation refers to the delegation of the role of separator, not simply compliance with instructions or suggestions.

Separation provision service

2.7.27 A separation provision service will be available when safety or ATM design requires.

2.7.28 Full separation provision service occurs when the service provider is the separator for an airspace user's activity from all hazards.

Separation provision intervention capability

2.7.29 In the development of separation modes (including determination of separators and minima), separation provision intervention capability must be considered. This capability is expected to have different values depending on whether intervention is from a separation provision service, a user or an automated system. This capability will take into consideration human factors principles. Humans may rationalize complex separation minima to a particular value for application.

2.7.30 Separation provision intervention capability refers to the quality of humans and/or systems to detect and solve a conflict and to implement and monitor the solution. The communications, navigation and surveillance systems' performance, as well as their situation assessment and problem-solving capabilities, are factors in determining the intervention capability.

Collision avoidance

2.7.31 Collision avoidance is the third layer of conflict management and must activate when the separation mode has been compromised. Collision avoidance is not part of separation provision, and collision avoidance systems are not included in determining the calculated level of safety required for separation provision. Collision avoidance systems will, however, be considered as part of ATM safety management. The collision avoidance functions and the applicable separation mode, although independent, must be compatible.

2.8 ATM SERVICE DELIVERY MANAGEMENT

Process

2.8.1 The ATM service delivery management function will manage the balance and consolidation of the decisions of the various other processes/services, as well as the time horizon at which, and the conditions under which, these decisions are made. Services to be delivered by the ATM service delivery system will be established on an on-request basis subject to ATM system design. ATM system design will be determined by collaborative decision making and system-wide safety and business cases.

2.8.2 When there is a request for ATM services, the process will consist of building an agreement on the flight trajectory based on user wishes and preferences, the constraints and opportunities related to the other services, and the information available on the operational situation. The agreement will then be the subject of monitoring. A significant deviation from the agreement, as observed or inferred from information available, will trigger a revision to the agreement or a warning to draw attention to the need to revert to the agreement.

2.8.3 ATM service delivery management will manage the distribution of the responsibilities for the various services and their seamless performance, including the designation of a predetermined separator for separation provision. This function will be important to ensure that the services delivered by the ATM service delivery system will, through collaborative decision making, balance and optimize user-requested trajectories to achieve the ATM community's expectations.

2.8.4 To maintain situational awareness, ATM service delivery management will monitor a wide range of non-flight-specific infrastructure and traffic demand information.

2.8.5 ATM service delivery management principles include:

a) trajectory, profile, and aircraft or flight intent;

b) management by trajectory; and

c) clearance.

Trajectory, profile, and aircraft or flight intent

2.8.6 The future ATM system, based on this concept, will rely on explicit and unambiguous information and on wide information exchange within the system. Key information relates to the future position of aircraft, and to the meaning and status of that information.

2.8.7 System-delivered trajectories will take into account aircraft performance characteristics.

2.8.8 The notification of intent will be a means for airspace users to specify their request for services and the nominal capabilities available during the flight.

2.8.9 The notification of intent will satisfy the gate-to-gate, collaborative decision-making and network management requirements.

Management by trajectory

2.8.10 Management by trajectory will involve the development of an agreement that extends through all the physical phases of flight. The trajectory will never be allowed to have an open-ended vector, which means every manoeuvre will be reflected as an update to the agreement. Management by trajectory does not mean that every aspect of a flight, including arrival profile, runway, taxi path and gate needs to be predetermined and captured in detail in the agreement at the time of departure. The agreement and the management of that agreement will have the detail required by the traffic management phases that the flight is subject to at the time the initial agreement and subsequent updates are made.

2.8.11 Clearances will allow the incremental delivery of the trajectory by the ATM system based on the assignment of traffic. Therefore, although the flight deck and the ATM system will have entered into a "gate-to-gate" agreement, that agreement will be actively affirmed by the delivery of each portion of the trajectory as a clearance.

2.9 INFORMATION SERVICES

2.9.1 The function of information services deals with the exchange and management of information used by the different processes and services. It will ensure the cohesion and linkage between the seven concept components described above.

Information management

2.9.2 Information management provides accredited, quality-assured and timely information used to support ATM operations. Information management will also monitor and control the quality of the shared information and provide information-sharing mechanisms that support the ATM community.

2.9.3 Information management will assemble the best possible integrated picture of the historical, real-time and planned or foreseen future state of the ATM situation. Information management will provide the basis for improved decision making by all ATM community members. Key to the concept will be the management of an information-rich environment.

2.9.4 Information management will contribute to meeting the expectations of the ATM community through all operational services. Its more direct contribution to improvements in the ATM system will be in the quality of the information that will, in turn, provide significant additional benefits. In particular, the wide availability of high-quality, relevant aeronautical data presented to all airspace users in a usable format will contribute to increased aviation safety.

2.9.5 The ATM community will depend on information management, shared on a system-wide basis, to make informed collaborative decisions for best business and operational outcomes. Within the ATM system, based on this operational concept, it will be the information itself that will be of significance and not the technology that supports it.

2.9.6 For the ATM system to operate at its full potential, pertinent information will be available when and where required.

2.9.7 ATM data has temporality and will change over time, but to varying degrees in terms of frequency or magnitude, varying from almost static to very dynamic. Information management will recognize and accommodate this temporality of data. This will impact the organization and issuance of data.

2.9.8 Information may be personalized, filtered and accessed as needed. The initial quality of the information provided will be the responsibility of the originator; subsequent handling will not compromise its quality.

2.9.9 The information management function will allow all participants to adjust information sharing to mitigate any proprietary concerns. Sensitivity with regard to some data will continue to exist and will be managed within the information management function. Once an ATM community member agrees to release information, the data will be available to the extent required and will be made accessible to specified parties.

2.9.10 Information management will achieve a seamless transfer of relevant information between parties in a flexible, adaptable and scalable information environment.

2.9.11 Information management will use globally harmonized information attributes.

Aeronautical information

2.9.12 The scope of information management includes all types of information, in particular, the aeronautical information. Since the architecture and organization of information services are implementation issues, this operational concept does not describe the traditional notion of aeronautical information services (AIS) as they were in 2000. Nevertheless, in addition to the intrinsic characteristics of information management, servicing information will incorporate the following basic concepts.

Temporality and issuance

2.9.13 The temporality of the information depends on its nature. Some data can be prepared in advance and are valid for a rather long period; other data change in real time and are obsolete immediately. As a principle, any valid and relevant information will be made available as soon as it becomes available.

2.9.14 In order to satisfy the requirements of all information users and to avoid waste of resources and the risk of information overload, information management will use a variety of information issuance concepts in relation to the application using it and the media used to carry it. Typically, the information relevant to a flight will be tailored and filtered, and accessible dynamically as the flight is planned and then progresses. Intelligent information management will be used to realize virtually "unlimited" access to information with "limited" bandwidth, and optimize the transfer of information.

Media

2.9.15 The reference medium for aeronautical data will be a fully electronic and networked environment, with printouts used only as needed for reference, temporary memorization and visualization support to human operators.

2.9.16 Information will use a variety of channels on the ground (and space-based segments). The best information routing will be selected for use on the basis of quality of service and economic criteria, possibly in real time.

Meteorological information

2.9.17 The provision of meteorological information will be an integrated function of the ATM system. The information will be tailored to meet ATM requirements in terms of content, format and timeliness.

2.9.18 The main benefits of meteorological information, for the ATM system, will be related to the following:

a) the improved accuracy and timeliness of meteorological information will be used to optimize flight trajectory planning and prediction, thus improving the safety and efficiency of the ATM system;

b) the increased availability of shared meteorological information on-board the aircraft will allow the preferred trajectory to be refined in real time;

c) better identification, prediction and presentation of adverse weather will allow the management of its effects more efficiently, thereby improving safety and flexibility, for example, by providing accurate and timely information on the need for diversion or re-routing;

d) improved aerodrome reports and forecasts will facilitate the optimum use of available aerodrome capacity;

e) increased availability of meteorological information (air-reports) from on-board meteorological sensors will contribute to improving forecast meteorological information and the display of real-time information; and

f) meteorological information will contribute to minimizing the environmental impact of air traffic.

2.9.19 Performance management will be an important part of the quality assurance of meteorological information.

Other essential services

2.9.20 There are other essential activities that the ATM system will provide information to, or may receive information from. These include the following:

a) ***Air defence systems and military control systems*** will need timely and accurate information on flights and ATM system intents. They will be involved in airspace reservations and notification of air activities and in enforcing measures related to security.

b) ***Search and rescue organizations*** will need timely and accurate search and rescue information on aircraft in distress and accidents because such information plays an important role in the quality of the search function.

c) ***Aviation accident/incident investigation authorities*** will need to exploit recordings of flight trajectory data and ATM actions.

d) ***Law enforcement (including customs and police authorities)*** will need flight identification and flight trajectory data, as well as information about traffic at aerodromes.

e) ***Regulatory authorities*** will need to implement the regulatory framework within the legal powers given to them and to monitor the safety status of the ATM system.

2.9.21 These entities have a defined relationship with the ATM system, and all will impose requirements on the system.

Appendix A

THE ATM COMMUNITY

This appendix lists and describes the various members comprising the ATM community. It is presented in alphabetical order rather than in any order of importance or priority.

Aerodrome community

The aerodrome community includes aerodromes, the aerodrome operator and other parties involved in the provision and operation of the physical infrastructure needed to support the take-off, landing and ground handling of aircraft.

Note.— The numerous aerodrome activities not directly related to aircraft flight operations (e.g. passenger processing, baggage handling, catering services, customs and immigration) were determined to be outside the scope of the ATMCP and were not considered in developing the ATM operational concept.

Airspace providers

The term airspace providers generally refers to Contracting States in their capacity as airspace owners with the legal authority to allow or deny access to their sovereign airspace. It may also apply to organizations of States that have been assigned responsibility for establishing the rules and guidelines for the use of airspace. The airspace provider is responsible for addressing and resolving issues such as airspace sovereignty, diplomatic clearance and national security (e.g. air defence) requirements. The airspace provider has an important role in achieving the benefits of collaborative ATM by ensuring that the airspace is organized and managed for both the safety and efficiency of service.

Airspace users

The term airspace users mainly refers to the organizations operating aircraft, and their pilots. In the ATM operational concept, three classifications of airspace users are considered:

a) ICAO-compliant manned flight operations (the largest segment by far);

b) ICAO non-compliant manned flight operations; and

c) flight operations of unmanned aerial vehicles (UAVs).

ICAO-compliant manned flight operations are those conducted in accordance with ICAO provisions (e.g. SARPs, PANS). ICAO-compliant airspace users include:

a) all civil aircraft operators (i.e. those engaged in commercial air transport (passenger, mail and cargo services)), aerial work, air taxi operators, business aviation, private air transport, sporting and recreational aviation, etc.; and

b) the portion of States' users operating State aircraft using civil air traffic rules.

ICAO non-compliant manned flight operations are those conducted by State aircraft which cannot comply for operational or technical reasons.

Flight operations of unmanned aerial vehicles (UAVs), a growing segment of airspace users, include both civil and military applications of UAV technology. In certain situations, UAV technology is seen as a more cost-effective solution than the use of conventional aeroplanes or helicopters.

In some circumstances, using UAVs is simply safer and it may also be the only possible way to get a particular job done. However, the emerging requirement for non-segregated operations of civil UAVs is totally new, and no regulatory framework for such operations currently exists.

ATM service providers

ATM service providers comprise all those organizations and personnel (e.g. controllers, engineers, technicians) that are engaged in the provision of ATM services to airspace users. ATM service provider responsibilities include CNS/ATM facility planning, investment and implementation; procedure development; training; and ongoing system operation and maintenance of seamless CNS/ATM services. ATM service provider organizations include:

a) State agencies;

b) State-owned self-financing corporations;

c) privatized ATM service providers;

d) regional ATM service providers; and

e) independent private sector ATM service providers of ground- and space-based CNS/ATM services.

ATM support industry

The ATM support industry comprises all those organizations that offer systems and services used by ATM service providers to provide CNS/ATM facilities and seamless services that achieve the ATM operational concept vision. In particular, the support industry includes:

a) information service providers;

b) equipment manufacturers;

c) research and development organizations; and

d) aviation standards development organizations.

Information service providers are government or private sector organizations that are not ATM service providers per se but that are engaged in the collection and dissemination of air navigation related information of an operational nature. This includes environmental information (e.g. maps, navigation databases); ground, airborne and space-based meteorological data; and aviation weather forecasting.

Equipment manufacturers are typically private sector corporations that are engaged in the development, production, implementation, testing and support of equipment used by ATM service providers, airspace users, aerodromes, and meteorological service providers, among others. This segment includes: airframe manufacturers, avionics manufacturers, CNS/ATM equipment manufacturers (e.g. computers and telecommunications equipment), engine manufacturers, satellite manufacturers and operators, systems integrators and industry associations.

Research and development organizations are engaged in the planning, funding and execution of programmes aimed at progressing the state-of-the-art in the field of aviation in general, and ATM in particular. Topics of interest directly related to the ATMCP operational concept include:

a) data link communications;

b) satellite navigation and augmentation;

c) enhanced surveillance using aircraft-provided information;

d) controller decision-support tools;

e) cockpit and controller shared situational awareness; and

f) human factors evaluations of new concepts of use for CNS/ATM technologies.

Aviation standards development organizations allow the ATM community to cooperate and reach consensus on the many technical and operational details needed to implement the global, interoperable ATM system defined by ICAO.

International Civil Aviation Organization (ICAO)

ICAO is the only international organization in a position to effectively coordinate global ATM implementation activities leading to the realization of a seamless global ATM system. The ATM operational concept vision has therefore been stated as follows:

> To achieve an interoperable global ATM system, for all users during all phases of flight, that meets agreed levels of safety, provides for optimum economic operations, is environmentally sustainable and meets national security requirements.

The aims and objectives of ICAO in accordance with Article 44 of the Convention on International Civil Aviation are to develop the principles and techniques of international air navigation and foster the planning and development of international air transport. ICAO ensures the safe and orderly growth of international civil aviation throughout the world. Recognizing the limitations of the present terrestrial-based system, ICAO, working with its Contracting States, international organizations and other community members, has developed the communications, navigation and surveillance/air traffic management (CNS/ATM) systems concept to serve the interests and the objectives of civil aviation throughout the world.

In accordance with its obligations under the Convention, ICAO continues to carry out its responsibility concerning the adoption and amendment of relevant international SARPs and procedures. These SARPs and procedures are continually being reviewed and updated while new ones are being developed to accommodate CNS/ATM system requirements. This continuing practice supports the principle of universal accessibility, without discrimination, by ensuring the highest possible degree of uniformity in all matters concerning the safety, regularity and efficiency of air navigation.

Finally, working with the CNS/ATM community, ICAO has developed this operational concept document in an attempt to establish a vision, with clearly stated objectives and benefits, of a seamless and global ATM system.

Regulatory authorities

Regulatory authorities are responsible for certain aspects of the overall performance of the aviation industry — most significantly, aviation safety — and other areas, including the environmental impact and international trade. Regulatory authorities plan the desired performance through safety standards; pilot, controller and system certification; and environmental regulations, to mention just a few. They then monitor the aviation system results; investigate accidents, incidents and other unexpected occurrences; and make recommendations and implement new regulations and standards to improve aviation system performance.

The aviation regulatory authorities include: aviation safety regulators, certification authorities (e.g. aircraft, systems, pilots, controllers, maintenance technicians), standardization organizations, environmental regulators and independent accident/incident investigation authorities, among others.

States

Global implementation of a seamless ATM system, through the provision of CNS/ATM facilities and seamless services, shall neither infringe nor impose restrictions upon States' sovereignty, authority or responsibility in the control of air navigation and the promulgation and enforcement of safety regulations. Furthermore, in pursuing the ATM operational concept vision, States should make optimum use of existing organizational structures, wherever possible, and ATM services should be delivered in accordance with existing institutional arrangements and regulations. Where modification becomes necessary, this will be accomplished through the international mechanisms already established.

Implementation should be sufficiently flexible to accommodate existing and future services in an evolutionary manner. It is recognized that a globally coordinated implementation, with the full involvement of ICAO, States and other community members — including the rationalization, integration and harmonization of CNS/ATM facilities, where appropriate — is the key to realization of the full benefits from collaborative ATM.

For over six decades after the founding of ICAO, Contracting States were generally responsible for acting as the regulatory authority, airspace provider and ATM service provider for aviation activities within their sovereign airspace and in the flight information regions for which they were responsible. Within the past ten to fifteen years many Contracting States have established innovative institutional arrangements (e.g. multi-national regulatory organizations, harmonized airspace planning and organization across several States, and autonomous ATM service providers) to meet their aviation responsibilities and needs. Therefore, while Contracting States remain members of the ATM community per se, the role of some members of the ATM community that complete activities or provide services that were traditionally the responsibility of Contracting States have evolved and are listed below:

a) regulatory authority;

b) airspace provider; and

c) ATM service provider.

Appendix B

GLOSSARY

The terms contained herein are used in the context of this ATM operational concept. Except where indicated, they have no official status within ICAO. Where a term is used differently from a formally recognized ICAO definition, this is noted.

Aircraft intent. Information on planned future aircraft behaviour, which can be obtained from the aircraft systems (avionics). It is associated with the commanded trajectory and will enhance airborne functions. The aircraft intent data correspond either to aircraft trajectory data that directly relate to the future aircraft trajectory as programmed inside the avionics, or the aircraft control parameters as managed by the automatic flight control system. These aircraft control parameters could either be entered by the flight crew or automatically derived by the flight management system.

Airside. The contiguous area within and extending to the aerodrome perimeter, prepared, intended and set aside for the movement, servicing and loading of aircraft, or where aircraft can otherwise be situated.

Airspace management. The process by which airspace options are selected and applied to meet the needs of the ATM community.

Air traffic management (ATM).* The dynamic, integrated management of air traffic and airspace — safely, economically and efficiently — through the provision of facilities and seamless services in collaboration with all parties.

Air traffic management system. A system that provides ATM through the collaborative integration of humans, information, technology, facilities and services, supported by air and ground- and/or space-based communications, navigation and surveillance.

ATM community. The aggregate of organizations, agencies or entities that may participate, collaborate and cooperate in the planning, development, use, regulation, operation and maintenance of the ATM system. (Appendix A refers.)

ATM operational concept. The ATM operational concept is a high-level description of the ATM services necessary to accommodate traffic at a given time horizon; a description of the anticipated level of performance required from, and the interaction between, the ATM services, as well as the objects they affect; and a description of the information to be provided to agents in the ATM system and how that information is to be used for operational purposes. The operational concept is neither a description of the air navigation infrastructure nor a technical system description nor a detailed description of how a particular functionality or technology could be used.

Availability. The ability of a system to perform its required function at the initiation of the intended operation. It is quantified as the proportion of the time the system is available to the time the system is planned to be available.

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* The ICAO definition contained in the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444) is different from the explanation given herein.

Benefit**.** Reduced cost to the user (to the ATM community as a whole) in the form of a saving in time and/or fuel; increased revenue; and/or an improvement to safety.

Capability**.** The ability of a system to provide a service or perform a function that, either on its own or with other services or functions, can deliver a definable level of performance. This level of performance is measurable within a framework of performance indicators and safety requirements.

Capacity**.** The maximum number of aircraft that can be accommodated in a given time period by the system or one of its components (throughput).

Conflict. Any situation involving an aircraft and a hazard in which the applicable separation minima may be compromised.

Conflict horizon. The extent to which hazards along the aircraft's future trajectory are considered for separation provision.

Constraint**.** Any limitation on the implementation of an "operational improvement".

Continuity**.** The probability of a system performing its required function without unscheduled interruptions during the intended period of operations.

Cooperative separation**.** Delegation of the role of "separator". The delegation can be for a particular type of hazard or from nominated hazards. If the delegation is accepted, then the accepting party is responsible for compliance with the delegation, using appropriate separation modes.

Delay**.** The difference between actual block time and ideal block time.

Demand**.** The number of aircraft requesting to use the ATM system in a given time period.

Efficiency**.** The ratio of the cost of ideal flight to the cost of procedurally constrained flight.

Enablers**.** Initiatives, such as (new) technologies, systems, operational procedures, and operational or socio-economic developments, which facilitate the implementation of operational improvements or of other enablers.

Equity**.** The first aircraft ready to use the ATM resources will receive priority, except where significant overall safety or system operational efficiency would accrue or national interests dictate that priority be provided on a different basis. Equity is ensured for all airspace users that have access to a given airspace or service by the global ATM system.

Flight deck**.** Term encompassing the flight crew and/or aircraft systems.

Flight intent. The future aircraft trajectory expressed as a 4-D profile until destination (taking account of aircraft performance, weather, terrain, and ATM service constraints), calculated and "owned" by the aircraft flight management system, and agreed by the pilot.

Gate to gate. A concept where the air traffic operations of ATM community members are such that the successive planning and operational phases of their processes are managed and can be achieved in a seamless and coherent way.

Hazards. The objects or elements that an aircraft can be separated from. These are: other aircraft, terrain, weather, wake turbulence, incompatible airspace activity and, when the aircraft is on the ground, surface vehicles and other obstructions on the apron and manoeuvring area. For any hazard (i.e. any condition, event or circumstance that could induce an accident), a risk can be identified as the combination of the overall probability or frequency of occurrence of a harmful effect induced by the hazard, and the severity of that effect. The terms accident and incident are defined in Annex 13 — *Aircraft Accident and Incident Investigation*.

Homogeneous ATM area.** An airspace with a common air traffic management interest, based on similar characteristics of traffic density, complexity, air navigation system infrastructure requirements or other specified considerations wherein a common detailed plan will foster the implementation of interoperable CNS/ATM systems.

Note.— Homogeneous ATM areas may extend over States, specific portions of States, or groupings of smaller States. They may also extend over large oceanic and continental en-route areas. They are considered as areas of shared interest and requirements.

***Landside*.** That portion of the aerodrome that is not considered airside. It consists primarily of passenger and cargo terminals, including appurtenances that may extend onto the airside, and those other facilities not located within the area defined by the term airside.

***Link*.** A direct connection between an operational improvement and an enabler, between operational improvements, between enablers or between lines of action. In “road-mapping”, a link defines a prerequisite for, or an enabler of, an operational improvement, another enabler or a line of action.

Major traffic flow.** A concentration of significant volumes of air traffic on the same or proximate flight trajectories.

Note.— Major traffic flows may cross several homogeneous ATM areas with different characteristics.

***Operational concept*.** For the purposes of this document, an operational concept is defined as:

a) a high-level description of the ATM services necessary to accommodate traffic at a given time horizon;

b) a description of the anticipated level of performance required from, and the interaction between, the ATM services, as well as the objects they affect; and

c) a description of the information to be provided to agents in the ATM system and how that information is to be used for operational purposes.

The global ATM operational concept differs from “architecture” and “concept of use”. “Architecture” includes the infrastructure and a technical system description that includes specific technologies and personnel functions. The operational concept describes how the air traffic management system will operate and identifies the services that will be required. Identification of what specific technologies are implemented to deliver these services is defined by “architecture”, to be developed by planning and implementation regional groups (PIRGs) and States. Thus, an operational concept drives the architecture. An ATM “concept of use” is a more detailed description of how a particular functionality or technology could be used. An operational concept portrays an ideal state in the future, to be reached progressively through a number of discrete change steps from the current situation. For the global ATM operational concept, 2025 was selected as the point in which the majority of expectations described could be realized. Descriptions of intermediate stages were done through scenarios, combining elements of the current global situations and target concepts.

** As used in the *Global Air Navigation Plan for CNS/ATM Systems* (Doc 9750).

Note.— The operational concept is neither a description of the air navigation infrastructure nor a technical system description nor a detailed description of how a particular functionality or technology could be used.

***Operational concept vision*.** To achieve an interoperable global ATM system, for all users during all phases of flight, that meets agreed levels of safety, provides for optimum economic operations, is environmentally sustainable and meets national security requirements.

Operational control.* A term used generically with respect to a flight, which means the exercise of authority over the initiation, conduct and termination of a mission. It will use sophisticated flight planning, flight following, and automation tools.

Operational requirement (OR). A statement of the operational attributes of a system needed for the effective and/or efficient provision of air traffic services to users.

***Option*.** When an operational concept (or a technical concept) can be realized through various solutions, each of these solutions is seen as an option. Selecting/retaining an option requires investigated cost-benefit and other analyses. In some cases, only one option can be retained. In other cases, several options can be left to the choice of implementers.

***Predictability*.** Is a measure of delay variance against a performance dependability target. As the variance of expected delay increases, it becomes a very serious concern for airlines when developing and operating their schedules. Conceptually, predictability metrics should be a comparison of the actual flight time to the scheduled flight time, since the scheduled time includes the amount of expected delay at a targeted dependability performance.

Required ATM performance (RASP). RASP is the set of criteria, expressed in the form of performance parameters and values of those parameters, that the ATM system needs to meet, with a given probability, in order to support the approved quality of service specified for a particular environment.

Note 1.— RASP does not mean that the system performance can be expressed by a single figure or that performance figures have to be unique globally. Lower performance bounds for the ATM system will be defined at the global level. RASP refers to a requirement; however, initiatives and choices will be left to implementers. Planning activities will respond to the difference between the current performance and the desired future targets. "Target" is understood to be the minimum that is required at a given point in time or at a given period and may also address the present.

Note 2.— Probability refers to the fact that whatever the performance parameter that must be met, it will always relate to certain traffic conditions or to infrequent possible events, the realization or non-realization of which does not constitute proof of meeting or failing the requirement.

Required total system performance (RTSP). RTSP is the aggregate of criteria, expressed in the form of performance parameters (operational and technical), that the ATM system needs to meet in order to deliver the approved quality of service and RASP specified for a particular environment.

Note 1.— The term RTSP is retained for internal performance with "total" to contrast with elements of the system addressed by specific required enabler performance parameters relating to their output (e.g. required communications performance for the communications systems).

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* The ICAO definition contained in the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444) is different from the explanation given herein.

Note 2.— "Required" implies something that is mandated or must be achieved, presumably to give some degree of assurance that something has or will be done. It gives no guidance as to the scope of application — only the sense of importance or urgency. In context, it may also imply a minimum level of action or service.

Risk management. The systematic application of management policies, procedures and practices to the tasks of establishing the context of, identifying, analysing, evaluating and treating risks; monitoring the implementation of treatments; and communicating about risk.

Routing area*.* A defined area encompassing one or more major traffic flows for the purpose of developing a detailed plan for the implementation of interoperable CNS/ATM systems.

Note.— A routing area may cross several homogeneous ATM areas with different characteristics. A routing area specifies common interests and requirements among underlying homogeneous areas, for which a detailed plan for the implementation of CNS/ATM systems and procedures either for the airspace or for the aircraft will be specified.

Safety case. Both the argument and the document that contend that the level of safety attained will satisfy the safety requirements. It intelligently and coherently argues the degree of safety achieved at any point of a system's life cycle by making rational and coherent reference to the documented results of the system safety approach defined below.

Separation minima. The minimum displacements between an aircraft and a hazard which maintain the risk of collision at an acceptable level of safety.

Separation mode. An approved set of rules, procedures and conditions of application associated with separation minima.

Separation provision. The tactical process of keeping aircraft away from hazards by at least the appropriate separation minima.

***Separation provision intervention capability*.** The quality of humans and/or systems to detect and solve a conflict and to implement and monitor the solution. The communications, navigation and surveillance systems' performance, as well as their situation assessment and problem-solving capabilities, are factors in determining the intervention capability.

***Separator*.** The agent responsible for separation provision for a conflict, being either the airspace user or a separation provision service provider.

Note.— The role of the separator may be delegated; however, a predetermined separator must be defined prior to the commencement of separation provision.

***Spacing*.** Any application of a distance or time between an aircraft and a hazard at or above separation minima in order to maintain a safe and orderly flow of traffic.

State aircraft. Aircraft used in military, customs and police services.

***Strategic action*.** Strategic action describes "action", i.e. initiatives of a general nature, which shall be launched in order to support one or several strategic objectives.

** As used in the *Global Air Navigation Plan for CNS/ATM Systems* (Doc 9750).

System safety approach. A systematic and explicit approach defining all activities and resources (people, organizations, policies, procedures, time spans, milestones, etc.) devoted to the management of safety. This approach starts before the fact, is documented, planned and explicitly supported by documented organizational policies and procedures endorsed by the highest executive levels. The system safety approach uses systems theory, systems engineering and management tools to manage risk formally, in an integrated manner, across all organizational levels, all disciplines and all system life-cycle phases.

Traffic synchronization**.** Traffic synchronization concerns the management of the flow of traffic through merging and crossing points, such as traffic around major aerodromes or airway crossings. It currently includes the management and provision of queues both on the ground and in the air. Traffic synchronization, as a function, is closely related to both demand/capacity balancing and separation provision and may in the future be indistinguishable from them. Traffic synchronization also concerns the aerodrome "service" part of the concept.

Trajectory or profile. This is a description of the movement of an aircraft, both in the air and on the ground, including position, time and, at least via calculation, speed and acceleration.

Unmanned aerial vehicle (UAV). An unmanned aerial vehicle is a pilotless aircraft, in the sense of Article 8 of the Convention on International Civil Aviation, which is flown without a pilot-in-command on-board and is either remotely and fully controlled from another place (ground, another aircraft, space) or programmed and fully autonomous.

Appendix C

LIMITATIONS ON THE PROVISION OF AIR TRAFFIC SERVICES IN 2000

1. The ATM system has limitations that may occur at different times and places. These limitations include but are not restricted to:

a) disparate services and procedures resulting from differing systems and limited system and decision-support tools;

b) a reliance on increasingly congested voice radio communications for air-ground exchanges;

c) rigid airspace divisions and route structures that do not allow the totality of ATM resources to be used to the best effect;

d) limited collaborative planning among ATM, aerodrome operators and aircraft operators;

e) less than optimum use of scarce resources such as airspace and aerodrome airside capacity;

f) limited facilities for real-time information exchange among ATM, aerodrome operators and aircraft operators, resulting in less than optimal responses to real-time events and changes in users' operational requirements;

g) the limited ability to maximize benefits for aircraft with advanced avionics; and

h) the long lead times involved in developing and deploying improved systems in aircraft fleets or in the ground infrastructure.

2. The limitations of the current ATM system result in inefficient aircraft operations. These inefficiencies include but are not limited to:

a) the requirement to fly circuitous departure and arrival procedures;

b) the exclusion of civil air traffic from airspace reserved for defence purposes;

c) indirect fixed routes between destinations;

d) excessive system-related ground and en-route delays;

e) the operation of aircraft at inefficient altitudes, speeds and in unfavourable winds; and

f) insufficient flexibility to permit optimum management of weather-related disruptions to airline operations.

Appendix D

EXPECTATIONS

Key to the operational concept is a clear statement of the expectations of the ATM community. The expectations for the global ATM system have been discussed among members of the ATM community in general terms for many years. These expectations stem from efforts to document ATM “user requirements”. The expectations hereafter are interrelated and cannot be considered in isolation. Furthermore, while safety is the highest priority, the expectations are shown in alphabetical order as they would appear in English.

Access and equity

A global ATM system should provide an operating environment that ensures that all airspace users have right of access to the ATM resources needed to meet their specific operational requirements and that the shared use of airspace by different users can be achieved safely. The global ATM system should ensure equity for all users that have access to a given airspace or service. Generally, the first aircraft ready to use the ATM resources will receive priority, except where significant overall safety or system operational efficiency would accrue or national defence considerations or interests dictate that priority be determined on a different basis.

Capacity

The global ATM system should exploit the inherent capacity to meet airspace user demands at peak times and locations while minimizing restrictions on traffic flow. To respond to future growth, capacity must increase, along with corresponding increases in efficiency, flexibility and predictability, while ensuring that there are no adverse impacts on safety and giving due consideration to the environment. The ATM system must be resilient to service disruption and the resulting temporary loss of capacity.

Cost-effectiveness

The ATM system should be cost-effective, while balancing the varied interests of the ATM community. The cost of service to airspace users should always be considered when evaluating any proposal to improve ATM service quality or performance. ICAO policies and principles regarding user charges should be followed.

Efficiency

Efficiency addresses the operational and economic cost-effectiveness of gate-to-gate flight operations from a single-flight perspective. In all phases of flight, airspace users want to depart and arrive at the times they select and fly the trajectory they determine to be optimum.

Environment

The ATM system should contribute to the protection of the environment by considering noise, gaseous emissions and other environmental issues in the implementation and operation of the global ATM system.

Flexibility

Flexibility addresses the ability of all airspace users to modify flight trajectories dynamically and adjust departure and arrival times, thereby permitting them to exploit operational opportunities as they occur.

Global interoperability

The ATM system should be based on global standards and uniform principles to ensure the technical and operational interoperability of ATM systems and facilitate homogeneous and non-discriminatory global and regional traffic flows.

Participation by the ATM community

The ATM community should have a continuous involvement in the planning, implementation and operation of the system to ensure that the evolution of the global ATM system meets the expectations of the community. The ATM community is more fully defined in Appendix A.

Predictability

Predictability refers to the ability of airspace users and ATM service providers to provide consistent and dependable levels of performance. Predictability is essential to airspace users as they develop and operate their schedules.

Safety

Safety is the highest priority in aviation, and ATM plays an important part in ensuring overall aviation safety. Uniform safety standards and risk and safety management practices should be applied systematically to the ATM system. In implementing elements of the global aviation system, safety needs to be assessed against appropriate criteria and in accordance with appropriate and globally standardized safety management processes and practices.

Security

Security refers to the protection against threats that stem from intentional acts (e.g. terrorism) or unintentional acts (e.g. human error, natural disaster) affecting aircraft, people or installations on the ground. Adequate security is a major expectation of the ATM community and of citizens. The ATM system should therefore contribute to security, and the ATM system, as well as ATM-related information, should be protected against security threats. Security risk management should balance the needs of the members of the ATM community that require access to the system, with the need to protect the ATM system. In the event of threats to aircraft or threats using aircraft, ATM shall provide the authorities responsible with appropriate assistance and information.

Appendix E

EXPECTED BENEFITS

1. The operational concept presupposes that the ATM community will work together to continually improve ATM performance, especially in relation to safety and achieving the expectations of the ATM community.

2. Improved safety management processes will ensure that safety performance remains the highest priority. Business cases will ensure efficient and cost-effective ATM developments and operations. Collaborative decision making and system-wide ATM information will enable airspace user participation in balancing the demands on the ATM system, thereby providing flexibility and predictability.

3. Specifically, these expected benefits include:

a) all airspace will be available as a usable resource, resulting in improved access, increased opportunity for user-preferred trajectories and, through community cooperation, increased capacity;

b) improved surface management of the aerodrome will provide predictable departure and gate-arrival times, thereby improving overall ATM system predictability and subsequent capacity. In particular, improved runway design, together with improved operational procedures, will increase capacity;

c) improved information exchange and cooperation within the ATM community will maximize system capacity;

d) improved all-weather operations will maintain maximum capacity;

e) the use of simulation, modelling and option evaluation tools will allow various management strategies to be considered and will provide flexibility in managing the overall ATM system while accommodating airspace user preferences;

f) improved information concerning demand and system capabilities will prevent system overloads, ensuring manageable workloads;

g) management by trajectory and the exchange of information between airspace users and the ATM system will improve conflict management and facilitate user-preferred trajectories;

h) using an extended conflict horizon and expanding the definition of hazards will enable more stable user trajectories;

i) new separation modes will improve ATM capacity;

j) the provision of accredited, quality-assured and timely information will allow an informed decision-making process; and

k) the ATM community will contribute to the protection of the environment by taking into consideration the consequences of airspace activities.

Appendix F

ATM SYSTEM PERFORMANCE

1. GENERAL

1.1 A key tenet of the operational concept is performance orientation. Appendix D sets out the expectations of the users of ATM services. Chapter 2 defines the components that will be required to satisfy these expectations. This appendix comprises two main parts:

a) it gives special emphasis to safety and safety management, which are the primary concern from concept inception and early design phases through to operations; and

b) it makes a first attempt to link the performance of the components to the expectations (including safety) through the concept of required total system performance (RTSP). However, it must be realized that the concept of RTSP is still in its infancy and requires much more work before reaching the level of maturity suitable to determine its viability.

1.2 The ATM system performance requirements should always be based on the key understanding that the ATM system is the collective integration of services, humans, information and technology.

2. MANAGEMENT OF SAFETY

2.1 Introduction

2.1.1 Safety will remain the highest priority in aviation, and the safety of air traffic will continue to be the most important consideration in all phases of the life cycle of the ATM system, from concept through to design, development, operation and maintenance.

2.1.2 The system safety approach outlined below is holistic, applying across the spectrum of the ATM system, where the system will be considered to include people, procedures and technologies performing specific tasks in a given environment.

2.1.3 The purpose of this section is not to define detailed ICAO requirements for safety management systems. It is to provide the minimum description required to ensure that the holistic approach will be an integral part of the concept and of the ensuing life-cycle activities. It will be subsequently refined as normative documents are produced. The acceptance of the ATM operational concept will be directly related to the evidence that can be provided on the ability of ATM to operate safely within the context of the operational concept.

2.1.4 The terms in this section may differ from those used elsewhere. It is emphasized that the characteristics listed below are essential to the concept and that only sufficient application of these characteristics can ensure that safety requirements are actually met.

2.2 System safety approach

2.2.1 Maximum effectiveness and efficiency of actions can be obtained by activities undertaken in the early phases of any system's life cycle since correcting problems during requirements definition and design is generally the most effective. Figure F-1 depicts this process for the ATM system as a whole. It describes how, starting from the conceptual level and even during operation, different players and disciplines make decisions against different criteria — including safety. These decisions will progressively define the ATM system (i.e. the way in which it is organized and the way in which people, procedures, technologies and information interact to perform a task).

2.2.2 This approach stems from the following notions that ATM shares with many other activities:

a) safety will not be the result of individual system components, but rather of the working together of those components as an integrated whole;

b) a number of important past accidents and incidents across several industries has demonstrated that organizations as a whole will need to adopt this systematic and traceable way of conducting safety business;

c) as accident rates diminish, the search for systemic causes will be increasingly difficult, and a common and systematic method will be necessary to build a robust framework for analysis;

d) as the pace and novelty of developments increase, it will be neither sufficient nor possible to rely solely on the application of codes built on past knowledge and experience; and

e) current regulatory trends will recommend strongly the application of system safety generally, including in the ATM domain, because it will be a cost-effective way to maintain effectual safety regulatory oversight, while facilitating the best exploitation of innovative developments.

2.2.3 This approach implies, *inter alia*, the following:

a) all safety practices and processes will be explicit and will comply with the safety requirements and standards of ICAO, State regulatory authorities and other appropriate parties;

b) each element of the ATM system, wherever implemented (aircraft, ground, space, etc.), will be subject to specific safety analysis, as an individual element and as a component of the larger integrated system. The implementation of any element of the system will be subject to appropriate safety assurance processes;

c) where a change to a system implies a departure from "currently approved operational boundaries", it will not be possible to determine a priori, without analysis, whether it will impact safety or not. Therefore, for any change, a clearly defined and explicit change management process will be used, supported by a safety case or equivalent, including the analysis of all the necessary routine and foreseeable emergency configurations;

d) clear accountability for all aspects of safety must be defined, and the roles and responsibilities for the management and integration of system elements must be explicitly stated. This includes a clear definition of the roles and responsibilities in the application of the elements of the ATM system such as allocation of separation responsibility, flow management, pilot responsibilities in various airspace, controller coordination responsibilities, system expectations, and failure mode management;

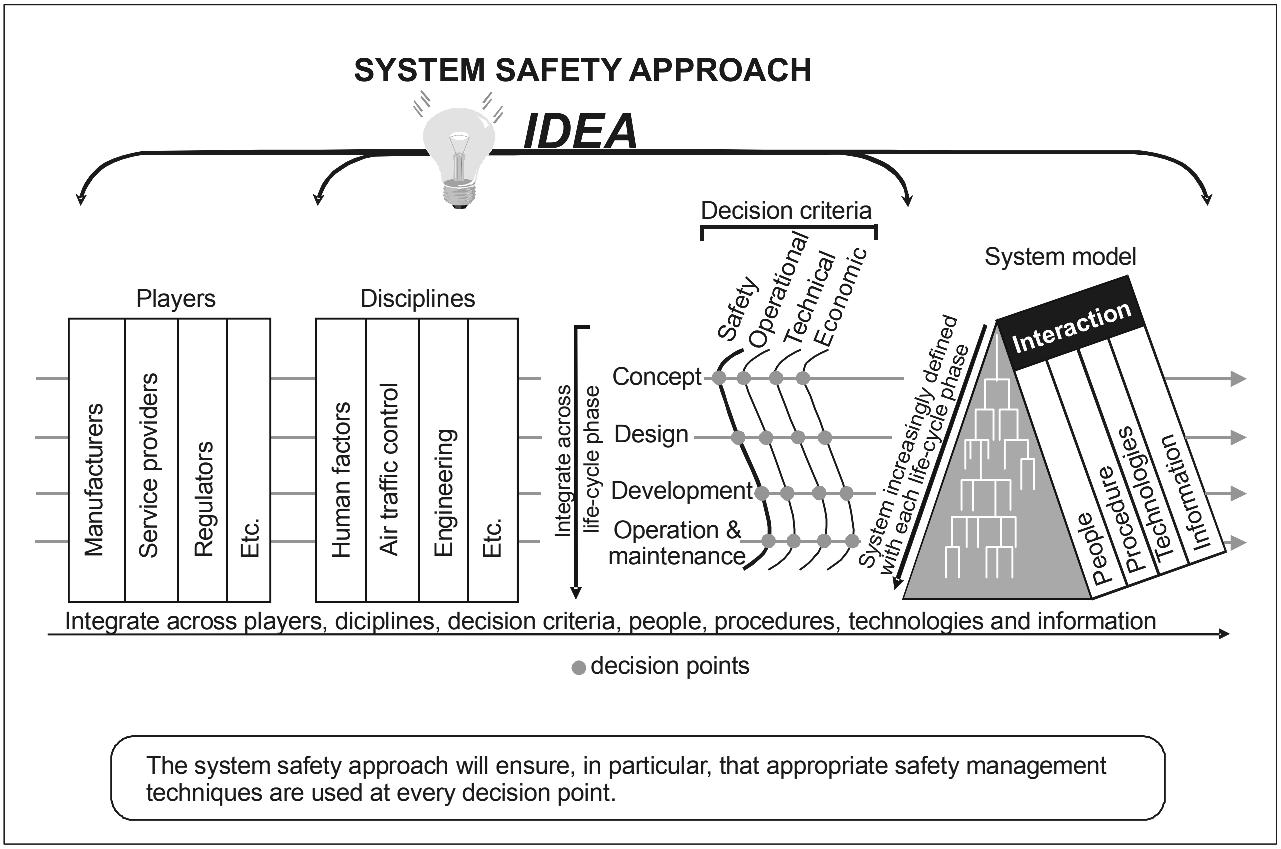

Figure F-1. System safety approach

e) where target levels of safety have been defined, they will form the basis for assessment of the risk tolerability within a system or component of the system. Where target levels of safety have not been defined, contemporary safety principles or comparative studies may be used, but will ensure global consistency;

f) the system safety approach will be applied across the entire ATM system. It will focus particularly on ATM processes in relation to human factors and human/machine interfaces; and

g) assessment and reviews will occur during the full life cycle, including during the planning and implementation phases.

2.3 Levels of safety

2.3.1 The acceptable or tolerable level of safety will be determined from the perception of safety needs by society and the international community. Acceptable safety will be related to the trust required from the ATM system.

2.3.2 The target level of safety will be the minimum level of safety to be achieved in any case. Possibly enforced by regulation, it will be equal to or better than the acceptable level of safety. The target level of safety will be based on risk assessment and acceptance criteria.

2.3.3 The observed level of safety is that which will be measurable. The observed level could produce results in a defined range without compromising acceptable and target levels of safety.

2.3.4 These levels of safety could be specified in qualitative and/or quantitative terms, often, but not exclusively, via indicators related to safety occurrences. Examples of the latter include:

a) a maximum probability of an undesirable event such as collision, loss of separation or runway incursion;

b) a maximum number of accidents per flight hour;

c) a maximum number of incidents per aircraft movement; and

d) a maximum number of valid short-term conflict alerts per aircraft movement.

Calculating risk versus accepting risk

2.3.5 In spite of all its complexity and limitations, calculating safety risk is a scientific activity that attempts to achieve a true measurement, but deciding on safety risk acceptability will involve a value judgement where consensus cannot always be reached easily because it calls on sociological perceptions, with decisions generally made in the political domain. While utilitarian approaches (i.e. cost-benefit) could contribute positively to the management of safety risk, they can cause legitimate disagreements on safety matters. It will therefore be important to address safety with a clear distinction between facts and values.

Expressing risk, measuring safety performance, consistency

2.3.6 The different ways of expressing risk and measuring safety performance, as well as the need for consistency, will be of paramount importance in ascertaining levels of safety and constructing safety cases.

Expressing risk

2.3.7 There are a number of ways of presenting risk and very significant conceptual differences between them (e.g. by flight hour, number of operations, time period; for a passenger, flight crew member or the average citizen). It will be desirable to express risk in a stable manner that provides a reference over a period of time in spite of system changes. The best way to express risk will depend on its acceptability by, and distribution among, the population; its cost, benefit and distribution; the way it is managed and communicated; and how it evolves with traffic volume.

Measuring safety performance

2.3.8 To satisfy specific requirements as part of the implementation of a safety management system, ICAO Contracting States have agreed to the collection, evaluation and review of safety-related data.

2.3.9 To maximize the benefits, such a major task should take into account that simply “measuring” safety will not be an effective way to identify whether safety is satisfactory because it provides insufficient evidence on the underlying causes and effects and thus will have little value as a means to prevent future accidents or serious incidents. A better approach would be to analyse the various causes. Their investigation across many accidents and, especially, recorded incidents, will allow the determination of:

a) the relative importance of the various causes;

b) the contribution by the various components of the ATM system;

c) the deficiencies to be corrected;

d) a more robust idea of the current and future safety situation; and

e) useful feedback, from experience, on the validity of risk mitigation measures.

2.3.10 Exchanging safety information across organizations and States will allow for effective collective learning, thus adding significant value to all parties.

Consistency

2.3.11 The goal will be to develop a consistent approach that can be applied over time and across segments of the industry for the purpose of making informative comparisons.

2.3.12 Since the goal will be to prevent future accidents, investigations must be carried out on multiple hierarchical levels including technical, human, organizational and regulatory. Since accident/incident models will influence what causes are ascribed and what countermeasures are taken, the model itself will affect very significantly the preventive capabilities. Thus, causation/prevention models should in particular:

a) be validated;

b) have good preventive value and link causes with ATM system components and actual preventive measures at multiple hierarchical levels including technical, human, organizational and regulatory (i.e. a set of meaningful safety indicators that warn of potentially deteriorating situations);

c) use sufficient objective, accredited and quality-assured data. This will be of utmost importance to ensure correct analysis conclusions; and

d) encourage the reporting of objective data.

2.3.13 Appropriate models (e.g. causation/prevention models) and acceptability criteria (e.g. safety risk (severity/frequency)) will be applied in a consistent manner and supported by quality assurance principles within the State's area of responsibility. Their consistent application, over the widest possible geographical area and period, will multiply dramatically the value of the information collected. Thus, as the new ATM concept is adopted globally, the regional sharing of models, criteria and data will become a prerequisite for further improvements in safety and will likely be supported by ICAO.

2.4 ICAO Universal Safety Oversight Audit Programme

2.4.1 The uniform application of ICAO Standards and Recommended Practices (SARPs) are recognized respectively as necessary and desirable for the safety and regularity of international air navigation. As signatories to the Convention, States have agreed to respectively comply and endeavour to comply with them.

2.4.2 Compliance with ICAO SARPs and PANS will be one element in the management of safety.

2.4.3 The ICAO Universal Safety Oversight Audit Programme incorporates as its core function safety oversight audits of States by ICAO, on a mandatory basis, with the objective of offering follow-up advice and technical assistance as necessary to enable States to implement ICAO SARPs and associated procedures (*Safety Oversight Audit Manual* (Doc 9735)). The programme also covers ATM.

2.4.4 The ICAO Universal Safety Oversight Audit Programme is consistent with the system safety approach in that it uses before-the-fact systematic management tools (i.e. audits) during the "operational" life of the SARPs to manage the exposure to risk presented by potential non-compliance. However, the ICAO Universal Safety Oversight Audit Programme is only part of system safety.

2.5 Measuring performance, and the concept of required total system performance (RTSP)

Background

2.5.1 In any system, it is necessary to set and measure performance outcomes in order to:

a) design, develop, operate and maintain a system that can meet the expectations of its users;

b) determine that the system is operating in accordance with its design; and

c) determine when and where action is to be taken to enhance performance levels when the system is not meeting, or is predicted not to meet, expectations.

2.5.2 This is also applicable to the ATM system, which is characterized by having to meet stringent minimum levels of performance and by the overriding consideration of safety.

From expectations to performance targets

2.5.3 At the highest level, expectations correspond to an external perception of air transport by the travelling public and society and, after proper analysis, can also be expressed as the external perception of ATM by the ATM community. These expectations apply to the entire ATM system.

2.5.4 A distinction should be made between the general description of a particular expectation, e.g. to have a safe system, and a more objective way of measuring its actual or forecast levels and comparing them to levels to be achieved. It is critically important to recognize that, even today, there is always a need to balance expectations against each other and against their likelihood, to be able to realize a system that can achieve them.

2.5.5 Performance measurements will need to be pragmatic and recognize contemporary practice. The definition of the most appropriate measures is a delicate issue. Nevertheless, this is a basic task in making user expectations clear and being able to verify that concepts and planned services can meet them.

2.5.6 It may well be that expectation levels will vary over time. At the level of this concept, which is primarily focussed on the situation to be achieved around 2025, expectations should be defined and considered for that time horizon and used to challenge concept statements and proposed features, and as a yardstick for a first validation. The expectation levels to be set by regions and States for actual implementation may differ from those used to prepare the global concept, while contributing to ensure global cohesion. These may also vary as a function of time depending on the volume of aviation activity and the enhancement of ATM services.

2.5.7 Expectations are not independent. For example, there will always be conflicts of interest among individual airspace users for access to the same airspace/runway at the same time, and the economic impact of meeting all needs may translate into unrealistic costs. Trade-offs will therefore be necessary. However, safety is always the highest priority in aviation. Therefore, once an acceptable level of safety has been established, it will not be subject to trade-offs.

Measuring performance

2.5.8 Care should be taken that the metrics faithfully reflect the nature of the expectations. Metrics should be measurable directly by the ATM community and should be SMART (specific, measurable, accurate, reliable and timely).

2.5.9 It is critical that the metrics be applied uniformly across the total system, i.e. that in a series of linked systems (regions, homogeneous areas, etc.) they will be the same, while the actual required level of performance may be variable.

Meeting performance requirements

2.5.10 The ATM system is complex and its behaviour is characterized by a collection of metrics with varying properties (statistical versus deterministic, range versus binary, lag versus lead, etc.).

2.5.11 Therefore, temporary aberrations in performance do not necessarily mean that the system is intrinsically unsafe, uneconomic, inefficient, etc. It can mean that the system is circumstantially not being operated correctly or that further improvement is required. As an example, accidents or incidents may occur, not directly as a result of a total misconception or inadequacy of the system, but as a result of operating a system element incorrectly. This is the source of a significant proportion of the recorded fatal accidents in aviation.

2.5.12 Regulators, service providers and service users may choose, for instance, to attack the safety problem at several layers and arrive at, or agree on, a set of values that should not be breached, either in isolation or simultaneously. It is this, among other things, which will determine the usefulness of the metrics. Without these preset limits, there may be a “self-justification mode” allowing limits to slide. Therefore any performance management system must set rules not only for performance measurement, but also for performance maintenance, performance management and performance enhancement. In relation to performance assessment, a distinction should be made between the levels to be achieved and the monitoring of their achievement, which may lead to specific actions in the case of observed non-compliance.

RASP and RTSP in perspective

2.5.13 A distinction will be made between the notion of external performance (outcome) to which corresponds the expectations, and the internal performance (output), which relates to the functionality of ATM components as they contribute and deliver collectively the required levels of external performance. The requirements for the former will be expressed as required ATM system performance (RASP) and, for the latter, as required total system performance (RTSP). By contrast with expectations, RTSP will address an internal perception: what functionality of which quality should ATM services, infrastructure, procedures, systems and resources have and/or aircraft and crews meet (i.e. impact on the required airborne equipment and crew qualification). If properly implemented and used, through the actions of all ATM community members, achieving RTSP will allow delivery of the RASP.

2.5.14 RTSP will incorporate all system capability aspects. Historically, it has been seen as a compound of required communications, surveillance or navigation performance, for these respective parts, but the proposed definition differs significantly from that view. The following aspects seem important (subject to confirmation by subsequent work): ATM services and information required in a given airspace, the interoperability of systems and procedures, and the interface with human operators and associated procedures.

2.5.15 Figure F-2 illustrates a potential hierarchy of performance requirements. It shows the transition from RASP to RTSP and then to individual enabling systems and, ultimately, technologies. It also shows that each transition from one layer to the next implies changing the nature of the discussion and the proposed solutions, and a change in representation and level of abstraction. One would migrate from expectations to services by defining the services that contribute to RASP. Individual enabling systems, like communications, will generally serve several services. Candidate technologies will be practical solutions to realize a particular enabling system.

2.5.16 The figure is a simple expression of a more complex reality of interactions that have to be considered when addressing ATM performance and trying to achieve requirements with actual systems.

2.5.17 The RTSP for a given airspace will be defined by considering the most demanding characteristics of the components of that airspace. This will be accomplished by taking into account the different flight phases, homogenous and routing areas, and traffic density and patterns, as well as the effects of particular environments or situations.

2.5.18 Nevertheless, the selection of a particular operational concept feature for the considered time horizon will not be totally independent from the availability of adequate technical solutions. In addition, it should not lead to radically different solutions for different traffic/geographical environments. In other words, the determination of RASP and RTSP is not a blind top-down process ignoring subjacent technologies, and there will be a need for interaction between designers of the overall ATM concept and of its more detailed components.

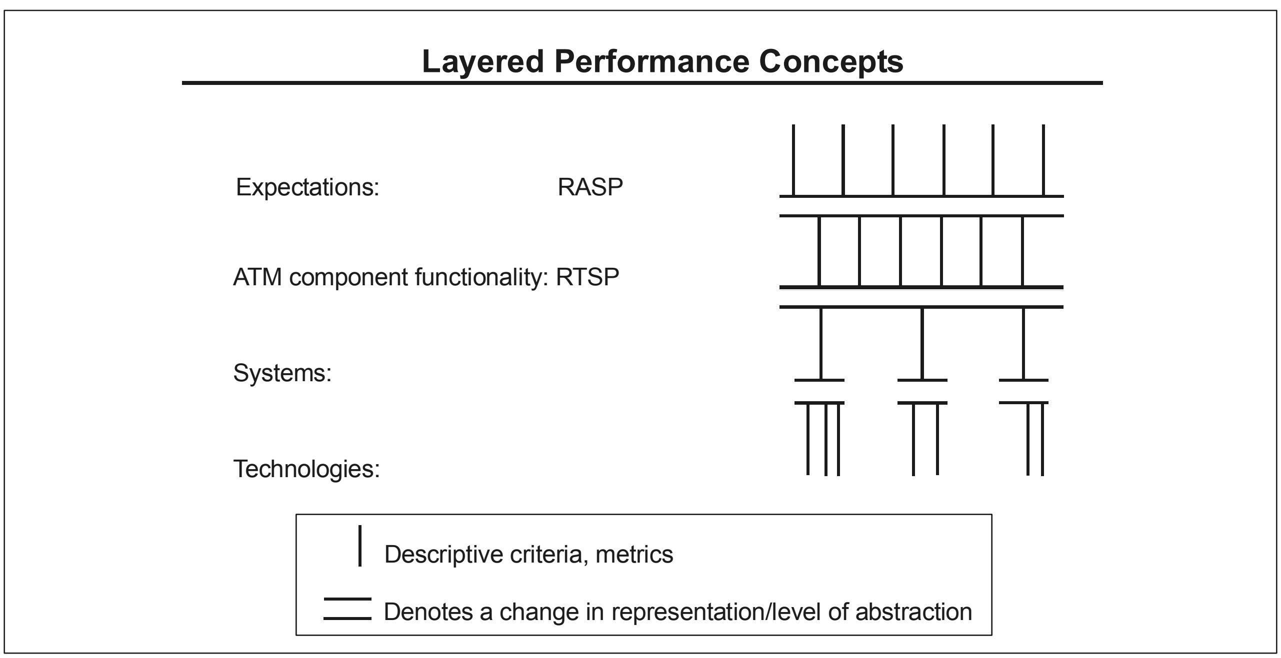

Figure F-2. Layered performance concepts

2.5.19 ATM can be viewed as a series of layers, from strategic planning to tactical real-time action, which involve various components applied as successive filters to ensure that traffic is safely managed. The layers progressively approach real-time decisions, requiring increasing accuracy and critical data. Conflict management, along with the tactical aspects of aircraft navigation and flight management, carry the most stringent requirements and will likely drive the RTSP.

2.5.20 RTSP will be expressed as a specific combination of component requirements that will be individually addressed and determined by input from relevant groups or panels whose collective ability to deliver the expectations should be validated by suitable means.

Elements of the RTSP

2.5.21 The exact services to be provided will remain a national/provider issue. The service level should be adapted to the needs of the users. A commercial passenger airline does not necessarily have the same requirements as a hang-glider pilot, so several levels of service could be defined (e.g. ranging from those for commercial airliner to those for uncontrolled air activity).

2.5.22 Although not all aspects of ATM will necessarily be subject to common requirements on a wide scale, there will nevertheless be a minimum set of characteristics that will have to be specified, in particular as they impact on the ability to satisfy the various expectations. For example, to ensure that continually changing flight and service provider crews will easily and routinely satisfy interoperability and safety expectations, common operational procedures will need to be implemented globally. To satisfy interoperability, systems will need to be standardized globally at a functional level; but to simultaneously maximize cost-effectiveness, they will need to be standardized also at a technological one.

2.5.23 Required performance could include, *inter alia*, the following potential aspects:

a) safe separation minima;

b) ATM service delivery time: the timeliness of its delivery and the effectiveness of what is provided gauge the performance of an ATM service;

c) strategies for demand and capacity balancing and traffic synchronization in a given airspace (level of service integration for demand and capacity balancing; strategies to handle network effects);

d) level of integration of information management service; it is probable that a required information performance could be defined;

e) quality of meteorological data;

f) airspace types; need to provide which ATM ground services;

g) data services/applications for air-ground exchanges;

h) flight notification conditions/processes: use of airspace, central or multiple addresses for flight notification filing, required advance notice, data quality;

i) flexibility of the system (e.g. reaction to weather);

j) coordination levels (ground-ground), with flight data to be exchanged and ground-ground communications;

k) possibility of using area navigation capabilities; possibility of utilizing user-preferred routing; rules for national interest airspace constraints;

l) procedures, e.g. speed stability or use of time (4-D) in ATM;

m) human performance: humans within the ATM system must demonstrate appropriate competence at all levels. Such competence should be continuously monitored and frequently tested, and competence regimes should be established sufficient to provide an assurance of human performance. Appropriate mechanisms may include licensing, certificates of competence, technical qualifications, training certificates or similar;

n) automation and human/machine interface: a minimum level of interoperability should be defined to ensure the smooth flow of traffic;

o) automated functions such as multi-radar tracking, correlation of radar track and flight plan, distribution of flight progress strips, automated coordination between sectors or between centres;

p) navigation service: navigation performance may specify certain horizontal navigation accuracies. There may be other aspects to specify, e.g. the definition of turns for accurate navigation, which take high importance in terminal airspace; the accuracy of height keeping; etc.;

q) compliance with environmental requirements.

Nominal versus degraded modes

2.5.24 This is another potential aspect of required performance. The operation of ATM when a part of its services is in a degraded mode will have to be considered carefully. Degraded modes should be identified and analysed to determine how the individual services possibly need to be adapted or reconfigured and how to mitigate the degradation. This will have an impact on the RTSP, for example, by addressing alternative concepts in case separation provision is degraded from its nominal mode. System architecture and system design will play a vital role here — to maximize the proportion of operation time where it is possible to meet nominal performance requirements, in particular through considerations such as system degradations, redundancy and system design features (e.g. defences against cascade and common mode failure).

Appendix G

EVOLUTION TO THE OPERATIONAL CONCEPT

1. INTRODUCTION

1.1 Within the planning horizon, it is expected that all States and regions will evolve their ATM systems to meet the balanced expectations of users within the framework of this operational concept. The migration to the concept objectives will be evolutionary and will involve different levels of emphasis on each of the concept components by States or regions to meet immediate or intermediate objectives, based on specific user requirements at the time. This section provides guidance on the migration process.

1.2 The operational concept is adaptable to the operational environment of all States or regions by being scalable to meet their specific needs. One State or region, or a specific area or location within a State, may have an immediate imperative to improve safety, while another State or region may have an immediate imperative to improve efficiency. Available ATM system components and services are detailed in Chapter 2, and the performance framework that encompasses particular ATM systems is defined in Appendix F.

1.3 States or regions cannot combine or implement the components in a non-standardized way. The concept components should be seen as fixed and standardized; each must be considered within a system design, but the weighting or desired “outcome contribution” of each may differ.

1.4 The ATM operational concept was developed recognizing that solutions may vary from State to State or region to region. Within a State, localized requirements, *inter alia,* mass rotary wing operations and space launch areas, may predicate changes in emphasis in the ATM system within that area. In all cases, however, the solutions must be interoperable.

1.5 The objective throughout the evolution to the concept objective is to constantly consider that target when planning each evolutionary change. This can be achieved through a strategic planning process that identifies the steps that are required in order to evolve to the concept.

1.6 The key issue is to eliminate, to the maximum extent possible, the need for duplication of ATM functionality within aircraft and/or ground systems. The solutions chosen by a State or region need not be technologically complex. Simple solutions, *inter alia,* changes to airspace organization and management, alignment of procedures, or strategic adjustment to flight schedules, may result in significant benefits for some States or regions. Others may require high levels of automation and technology.

2. USING THE CONCEPT COMPONENTS

2.1 The integration of the concept components can be balanced to achieve different expectation outcomes.

2.2 Figure G-1 provides a useful conceptual diagram based on the principle of scalable response. The diagram illustrates the framework within which the “outcome contribution” of each concept component is determined. It also illustrates that the range of responses, using the seven concept components, is variable over a wide range to achieve desired outcomes.

2.3 The size of the box in the diagram is determined by safety and business cases as well as by user expectations and required ATM system performance. It is reasonable that user expectations will remain somewhat constant, particularly when considering the concept objectives. Safety case and required ATM system performance analysis will present a range of potential solutions. Cross-ATM community cost/benefit analysis and business case — and the need for interoperability, will ultimately drive the chosen solution in any given State or region.

2.4 The “bubbles” in the diagram represent the standard concept components. Their relative sizes represent the degree of emphasis that is assigned to each component at a planning point in order to achieve a desired outcome.

2.5 All concept components must be present in each State’s or region’s ATM system to some degree. That is not to say that any particular component will be used as a major contributor to an outcome in a particular State or region, or that a great deal of automation or technology will be required to deliver against that component; however, they must be considered at each evolutionary stage.

2.6 There is a further constraint. Safety can never fall below minimum accepted levels. In fact, it should be argued that any change to the ATM system for an outcome not directly aimed at enhancing safety should, nonetheless, strive to achieve its net increase. This is illustrated in Figure G-2.

2.7 The safety balance model indicates that, on the whole, the system needs to retain a safety tension; that is, notwithstanding having achieved an acceptable level of safety, all members of the ATM community must continually explore ways to improve safety.

3. PLANNING APPLICATION

3.1 The functionality of the components cannot change; however, the degree of emphasis placed on the use of those components at any particular time during implementation in any given State or region can change. The “scalable response” approach provides a model that allows various States or regions to adjust and test the effectiveness of changing the degree of emphasis placed on any of the concept components.

3.2 The result will be the uniform application of concept components among States or regions, thus facilitating harmonization and interoperability.

3.3 Figure G-3 illustrates global implementation at some point in the evolution to 2025.

3.4 A key issue to be considered is the need to ensure that the outcome objective of a particular State or region does not impact on the overall objective of a seamless, globally interoperable ATM system. There are two keys to solving this potential issue. The first is ensuring that the “building blocks” (the concept components) are applied uniformly. The second is collaborative decision making within an information-rich environment.

3.5 During the evolution to the concept, aircraft will necessarily transit between States or regions where desired outcomes differ and, therefore, the emphasis on concept components differs. In order to ensure that they can operate seamlessly, the global ATM system needs to be networked into an information-rich environment, facilitating the uniform application of the concept components from region to region, and interoperability. This is illustrated in Figure G-4.

3.6 The benefit of this approach is that each State or region can assess its current state of development and which focus will achieve the best evolutionary outcome — i.e. it allows the mapping of a transition strategy.

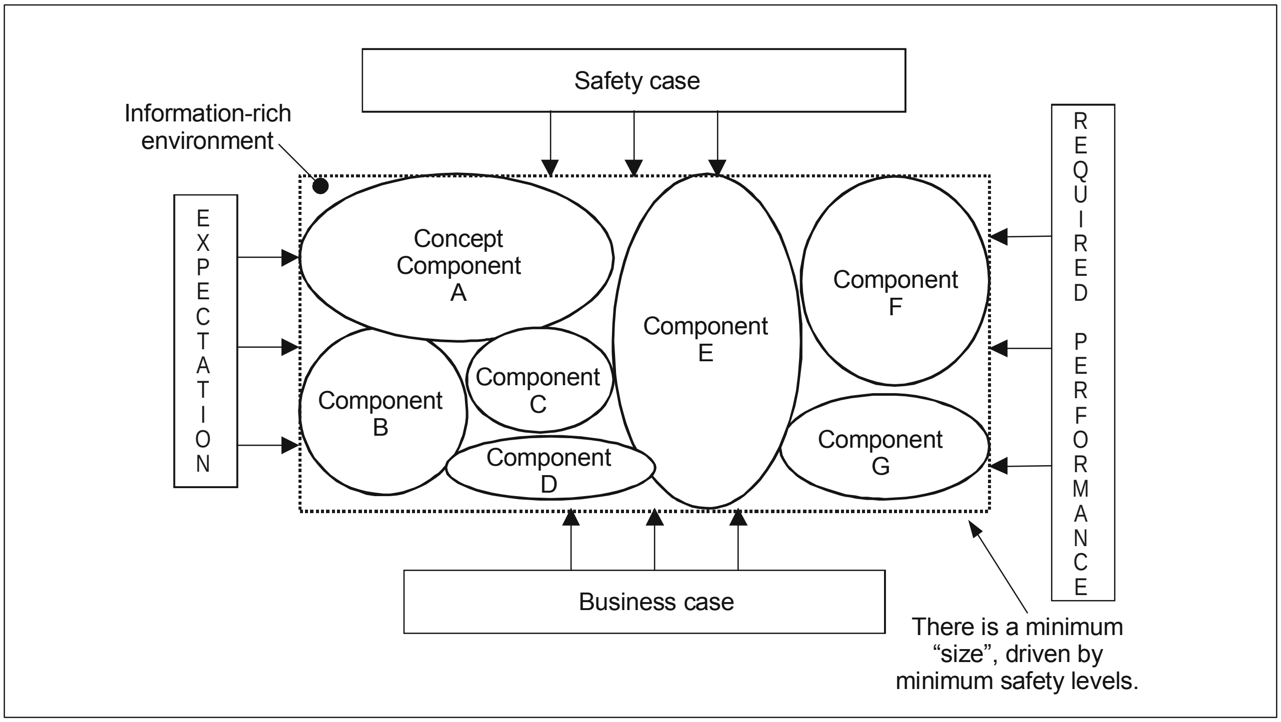

Figure G-1. "Scalable response"

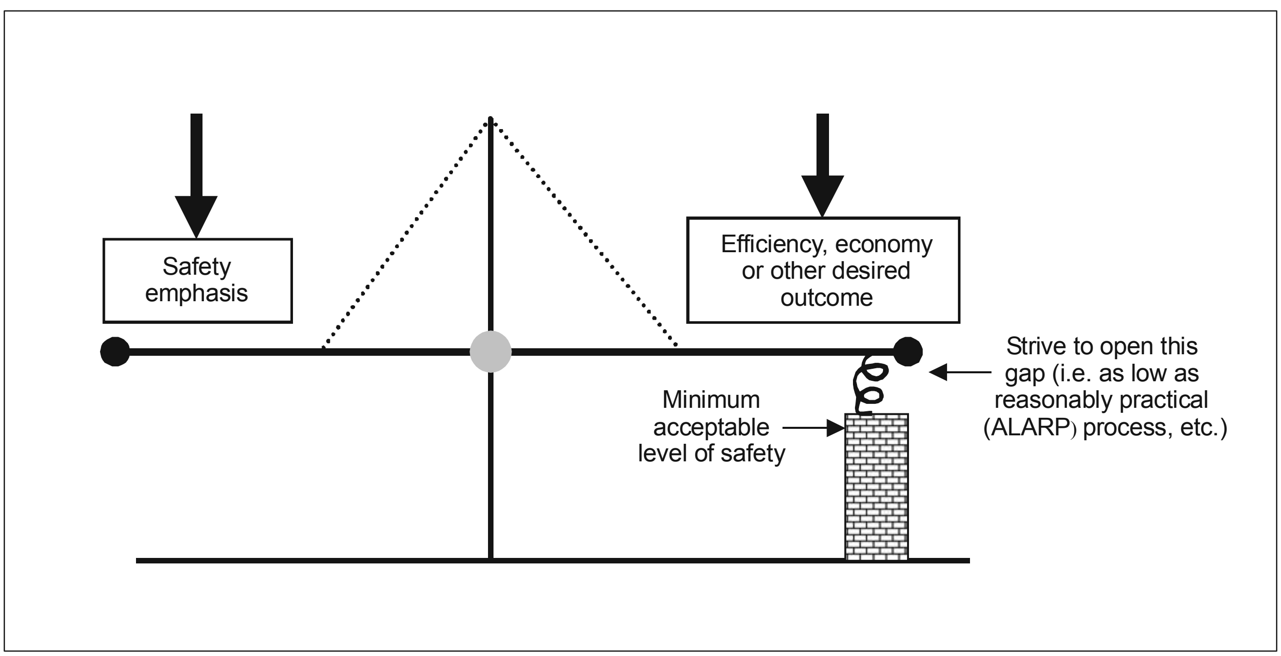

Figure G-2. Safety balance model

3.7 The planning framework to determine the required outcome for a particular State or region in moving towards the concept goal is more complex than current planning processes. It requires a level of strategic collaborative decision making by all of the partners in an open and collaborative environment. The cost/benefit analysis and business-case process will expose areas where resources may not currently be applied to the maximum benefit of the current ATM system.

3.8 The safety case process will expose points of weakness in the system that may require a change to the desired outcome and a change of emphasis, for instance, from economy to safety.

3.9 The current framework of planning and implementation regional groups (PIRGs) requires business-case and cost/benefit analysis processes to be applied. ICAO has developed appropriate guidance material in this regard. This must be complemented by a system safety approach.

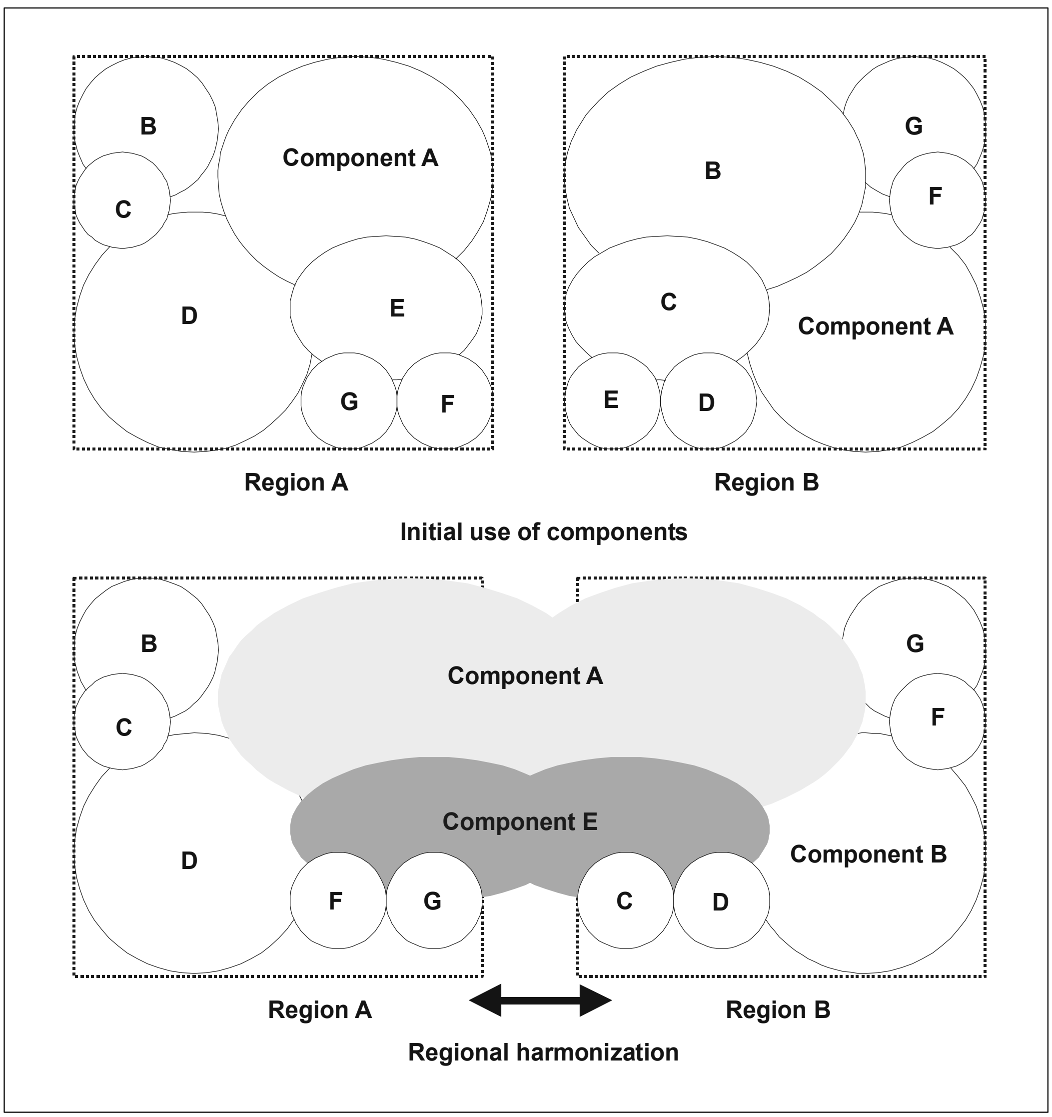

Figure G-3. Global integration

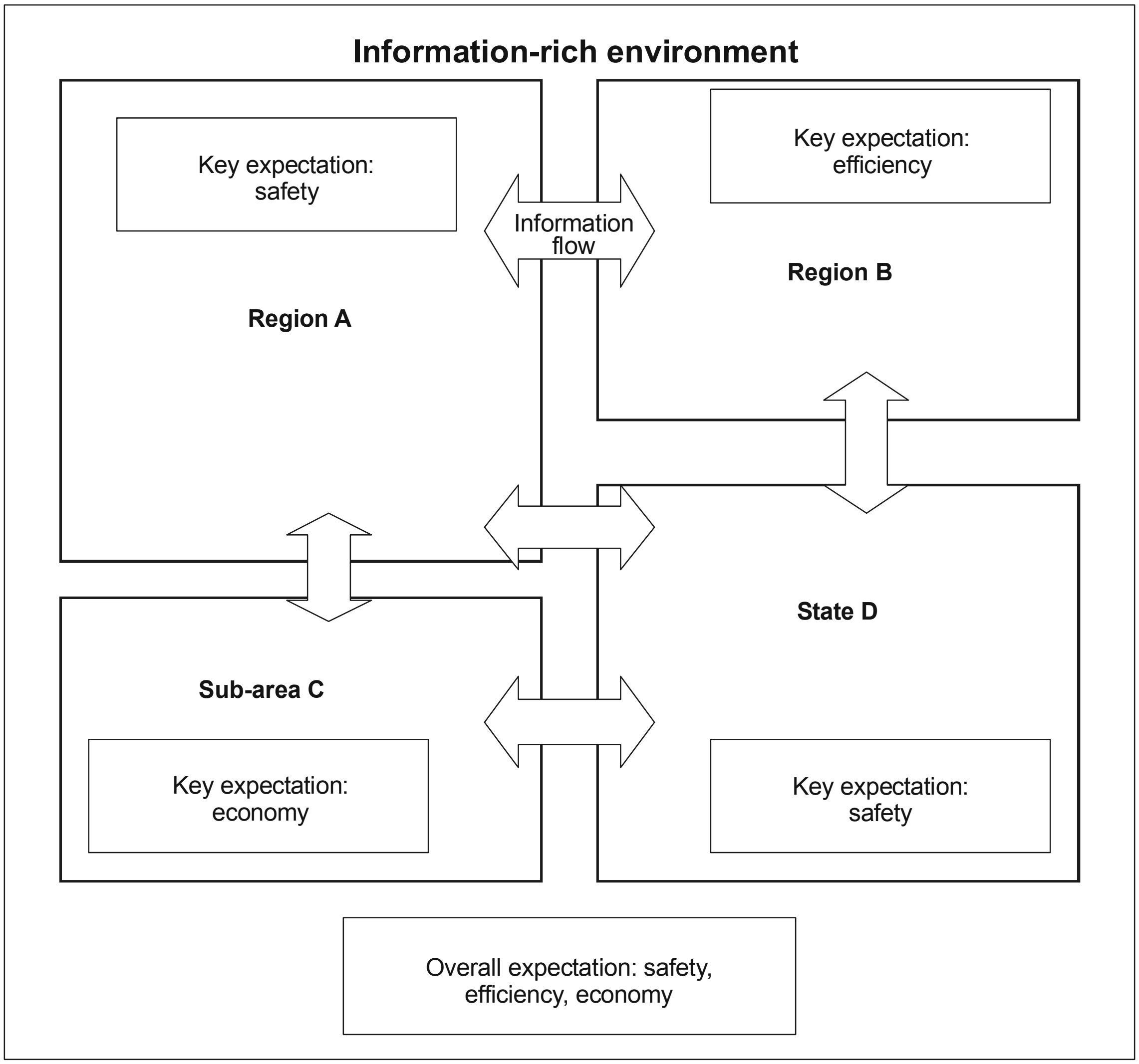

Figure G-4. Network

Appendix H

PLANNING

1. INTRODUCTION

1.1 This appendix describes the relationship between the operational concept and the planning process. The planning process at the global, regional and national levels should provide a well-understood, manageable and cost-effective sequence of improvements that keeps pace with user needs, culminating in a system meeting safety, capacity, efficiency and environmental demands.

1.2 The ATM operational concept provides the basis from which the ATM operational requirements, objectives and benefits will be derived, thereby providing the foundation for the development of regional and national ATM implementation plans. This appendix addresses all three levels of planning: global, regional and national, all of which must be adequately addressed and integrated in support of a seamless global ATM system.

2. FORECASTING

Planning for the implementation of ATM systems must begin with a thorough understanding of the requirements of the users of the system. Accurate forecasts of civil aviation activity must therefore be developed in order to support air navigation system planning activities. In addition to understanding user requirements, investment in new systems requires convincing data to sustain the validity of any proposals associated with that investment. Forecasting in support of ATM planning therefore involves assessment of future trends in aircraft movements and passenger and freight traffic.

3. PLANNING STRUCTURE

Planning takes place at global, regional and national levels. Planning is accomplished with the help of planning tools and methodologies that are used primarily at the regional and national levels, conditioned by guidance from the global level. The basis for effective planning is the ATM operational concept, which should support the development of regional and national implementation plans that will support system architectures.

4. GLOBAL PLANNING

4.1 The operational concept describes future ATM services that will be considered in the further development of the Global Plan which reflects the evolution of system requirements. The operational concept will also be used as a foundation for the further development of SARPs and ICAO guidance material in the technical and operational fields.

Regional planning

4.2 The regional air navigation plans set forth the requirements for facilities and services to support international air navigation. The operational concept will form the basis of regional air navigation planning. It is here that the top-down approach, comprising global guidance and regional harmonization measures, merges with the bottom-up approach, consisting of system architecture and implementation plans of States and aircraft operators.

National planning

4.3 While ICAO addresses the planning strategy at the global and regional levels, planning at the national level is the responsibility of States. National planning documents should be developed by each State. These may include national system architectures and ATM implementation plans. In addition to describing domestic requirements and implementation plans, national plans should also meet the international requirements as prescribed in the regional plans.

5. PLANNING FOR IMPLEMENTATION

It is considered that planning could best be achieved if it were organized based on ATM areas of common requirements and interest, taking into account traffic density and the level of sophistication required. As a prerequisite to developing an ATM plan, it is therefore necessary to identify specific planning areas on the basis of homogeneous ATM areas or major traffic flow/routing areas. This would be followed by an operational analysis and the identification of ATM objectives for those areas, using the operational concept as the basis. The results of this effort should lead to a logical set of infrastructure requirements to support the ATM objectives identified.

6. OPERATIONAL ANALYSIS

An operational analysis is a necessary part of ATM implementation planning and culminates in the identification of the operational requirements and, by establishing criteria to rate alternatives against, leads to the selection of a solution which should be the most effective in fulfilling the ATM objectives as defined in the operational concept. A method for conducting an operational analysis is described in the Global Plan. When evaluating potential improvements to the global ATM system, appropriate alternative analyses should be completed before selecting the optimum approach to improve the ATM system.

7. PLANNING PROCESS

A complete planning process begins with an operational analysis that identifies the weaknesses and/or opportunities in relation to the present system, followed by the development of a strategy containing the high-level objectives of the desired system. An operational concept would then provide the basis for the development of more specific objectives, and a system architecture would identify the technologies and modes of operation of the system to be built to meet the stated objectives. The architecture would form part of an ATM implementation plan.

8. GENERAL TRANSITION ISSUES

As stated above, the migration from the present system to the more advanced ATM systems is based on technologies that should be carefully planned. Assurance is needed at each step that continued levels of safety will be maintained — and improved upon where necessary. The demonstrated capabilities of new systems must be made clear to the members of the ATM community that must invest in new systems so that they will be encouraged to make the necessary investments to equip their fleets or to install the necessary infrastructure at the earliest opportunity.

Appendix I

THE CONCEPT — EXPLANATIONS AND EXAMPLES

1. INTRODUCTION

1.1 In order to assist in the understanding of the operational concept, some explanations and examples are provided in this appendix to illustrate what air traffic management may evolve to.

1.2 These examples are not meant to constrain the vision to one particular interpretation but rather to provide possible interpretations of the concept. Further examples are being prepared and will be distributed separately.

1.3 The concept requires integration of all concept components within the operating environment of each region, acknowledging that regions will apply different emphasis to concept components to achieve the desired outcomes. To assist in the understanding of each component, examples of individual components are provided. Additional examples, such as examples of collaborative decision making, are also provided.

1.4 The operational concept presents a vision of the future ATM system — a system that is not constrained by current technology. The transition to that concept is intended to be an evolutionary process.

2. AIRSPACE ORGANIZATION AND MANAGEMENT

2.1 Airspace organization and management will be dynamic, flexible and increasingly tactical in application.

2.2 Airspace organization and management will require close collaboration among airspace users, the airspace organization and management service provider and other ATM service providers to ensure, to the maximum extent possible, equity and access. Strategic airspace organization and management will rely on pragmatic identification by users of their specific requirements, so that constraints or requirements for the use of any particular airspace volume can be minimized. Restrictions on user operations will be imposed only when safety requires, or the ATM community agrees that certain procedures are appropriate for the efficiency of the ATM system, or a State identifies a particular national interest. Once the circumstances generating a requirement for constraints or requirements cease, the airspace restrictions will be released.

2.3 In order to ensure that the level of constraints on the ATM system imposed through airspace management are kept to a minimum, awareness of activities within all airspace will be required as part of ongoing monitoring, and adjustments to airspace organization and management will be made as required. In this sense, all airspace will be monitored, but to an appropriate level as determined by safety assessment within a safety management programme. Monitoring can take place in a number of ways. It can occur in advance of activity, *inter alia*, through assessment of flight schedules or statements of intent, discussions with potential airspace users, or notification by States of national interest requirements. It can occur dynamically, through co-monitoring (with other service providers) of tactical surveillance data. It can also occur post-activity, through assessment of the flight trajectories actually flown, with the intent of refining airspace organization and management techniques.

2.4 Airspace will ideally be organized and managed in such a way as to facilitate the use of full self-separation and autonomous flight, unless safety or efficiency assessment requires the provision of separation services. This must be achieved in conjunction with, or anticipation of, demand and capacity balancing techniques, to ensure that the potential for aircraft-to-hazard conflict is reduced to a level where such self-separation is expected to be able to be conducted to an accepted level of safety.

2.5 Techniques may include, *inter alia*, the promulgation of fixed or dynamic segregated departure and arrival tracks to aerodromes, the implementation of segregated fixed or dynamic route structures, the implementation of dynamic 4-D trajectory systems, and the coordination of hours of activity of national interest airspace constraints. It may also include the promulgation of certain user requirements — such as minimum capabilities, or hours of access — to mitigate risk. A primary tenet, however, must be that any such restriction or constraint, where possible or practicable, should be transient, and other users should be accommodated when the constraints are no longer required or the levels of risk allow.

2.6 The ATM system is subject to a number of uncontrollable or unpredictable events that can affect ATM. In particular, weather and natural phenomenon, including lines of thunderstorms, standing waves and clear air turbulence, snow on runways, volcanic ash, and so on, will continue to have significant consequences on user operations. Airspace organization and management service providers will react to these uncontrollable events by redistributing or reorganizing airspace to maintain maximum efficiency. This is an example of tactical airspace organization and management.

3. AERODROME OPERATIONS

3.1 In order to comprehensively consider the role of aerodrome operations within the ATM system, aerodrome operations will be considered from an en-route to en-route perspective.

3.2 Constraints on flights moving from the runway to the parking location and from the parking location to the runway will be minimized. System enhancements to minimize constraints will include:

a) Enhancement of the communication capabilities of airspace users at an increasing number of airports will improve information exchange and coordination activities, and increased collaboration and information sharing among airspace users and service providers will create a more realistic picture of aerodrome departure and arrival demand.

b) Automation aids for dynamic planning of surface movements will provide methods and incentives for collaborative problem solving by airspace users and service providers. This will improve the management of excess demand through balanced taxiway usage and improved sequencing of aircraft to the departure threshold. In addition, support tools will permit the optimization of take-off points along the runway, by accessing information on aircraft performance capabilities such as required take-off distance and climb-out capabilities. This will also apply in the case of arriving aircraft, allowing exit points from a runway to be accurately predicted or realistically assigned.

c) Integration of surface automation with departure and arrival automation will facilitate the coordination of all surface activities. Runway and taxiway assignments will be based on projected arrival/departure runway loading and surface congestion, airspace user runway preference, and parking location. Environmental considerations such as noise abatement or emission minimization will also be taken into account to the extent that safety is not compromised. Arrival runway and taxiway assignments will be planned early in the arrival phase of flight. Departure assignments will be made when the flight profile is filed, and updated accordingly until the time of push-back.

d) Surveillance and guidance systems will provide for greater situational awareness that will permit full capacity operations in all weather conditions.

3.3 The ATM environment will become increasingly integrated as surface-movement decision-support systems provide real-time data to the ATM environment-wide information system. When the aircraft starts moving, the flight's time-based trajectory will be updated in the ATM environment-wide information system, based on the estimated taxi time at the airport under prevailing traffic conditions. When the aircraft becomes airborne, this trajectory will again be updated. This continuous updating of the flight object will improve real-time planning for both the airspace user and the service provider. Real-time information will also improve the effectiveness of ongoing traffic management initiatives and the collaborative decision making involved with any proposed initiatives.

3.4 Surface-movement decision-support systems will also be an integral part of the total ATM environment automation system. This will ensure that surface initiatives and user preferences are not at cross-purposes with the information being generated by airspace automation systems. Thus, runway assignments in departure and arrival automation will be based not only on the location of the assigned parking location, but also on the surface automation's prediction of congestion and the related taxi plan. For departures, taxi time updates and the associated estimates included in the taxi plan will be coordinated automatically with airspace automation to efficiently sequence ground traffic to match projected traffic flows aloft. Conflict management on the airport surface will benefit from increased information which will improve situational awareness, support taxi planning and improve ramp management to match surface movement with the departure and arrival phases of flight.

3.5 Taxi planning will be significantly improved through the timely availability of traffic activity information. As the aircraft prepares to taxi, decision-support systems will be used to determine taxi sequencing and to perform conformance monitoring and conflict checking. Since this automated planning process will share information with the surface situation monitoring systems, the resulting taxi plan will balance the efficiency of the movement with the probability that it can be executed without change.

3.6 For departures, the decision-support system will incorporate departure times, aircraft type, wake turbulence criteria, and departure routes to safely and efficiently sequence aircraft to the departure threshold. For arrivals, the decision-support system will consider the intended parking location to minimize taxi time after landing. Additionally, improved information about aircraft intent will allow automatic monitoring of taxi plan execution and will provide alerts to the potential for runway incursion.

4. DEMAND AND CAPACITY BALANCING

4.1 Collaborative ATM system design and implementation will provide an agreed system capacity level. Available capacity will vary due to several factors including uncontrollable events, for example, weather-related turbulence.

4.2 Demand and capacity balancing actions aimed at ensuring safety, equity and access will be a collaborative decision-making process in which the collection, collation and analysis of data to produce an accurate picture of the demands and constraints that will affect any particular airspace volume will begin long before the day of operations. The degree of automation or sophistication required in the processes will reflect the performance requirements or expectations of a particular volume. A series of optimized airspace structures and forecast traffic models for the entire usable airspace volume may be required. In these plans, the allocation of airspace will be balanced between the needs of particular users, including, *inter alia*, commercial, general and military aviation.

4.3 In any particular environment, the planning processes may be divided into three major phases:

a) ***strategic planning:*** the long-term activities to produce a coordinated strategic plan of demand and capacity up to (or in some cases more than) one year in advance;

b) ***pre-tactical planning:*** modifications to the coordinated strategic plan; and

c) ***tactical planning:*** final modifications to the plan.

4.4 In some environments, the volume and complexity of data to be processed so as to produce the operations plans will require the support of advanced decision-support systems, aiding the development of plans at each level. Other environments may be assessed manually on the basis of operational experience or on the basis of historical analysis. In either case, the results will be available to all affected partners and will contribute to transparent negotiation and agreement. Data on planned flights, weather, and ATM capacities and capabilities will come from many sources in and beyond the affected airspace volume and will need to be collected, collated and analysed to provide the refined data needed to build up the analysis or simulation layers supporting each planning phase. That analysis will then be able to determine the effects of any proposed changes on the safety, capacity and efficiency of the system and then to assist the planners in modifying the plans to resolve any problems.

Strategic planning

4.5 The strategic planning phase can commence at any time in advance of a particular airspace activity. While full schedule information may not be known until some months or weeks before a particular flight, certain data will be available many years in advance and will aid in pre-planning. This can include, *inter alia*, historic demand from scheduled and non-scheduled flights, airspace availability or constraints, ATM resource availability (capabilities and capacity estimations) and the impact of operational changes (new procedures, new standards, availability of ATM and airport facilities, approximate estimates on the weather conditions for the season and estimations of likely business and other non-forecast airspace user demands). This data can be used to aid airspace organization and management processes. In this sense, airspace organization and management can be engaged as a strategic demand and capacity balancing tool by adjusting capacity.

4.6 The main benefit to be gained through a strategic planning phase is that processes will be improved, developing from a tactical or reactive system to one which will be strategic or proactive, and one in which predictability will be improved and which will allow the maximum possible flexibility and economy of operations for the user in normal conditions. Procedures will be established to best suit the traffic flows and to assist traffic separation by the creation of discrete system trajectories which can be reconfigured in line with the different demands on airspace at different times of the day and night. ATM may be required to establish airspace management regimes and route structures to maintain or improve safety levels, capacity and efficiency in the use of airspace and of runways.

Pre-tactical planning

4.7 During the pre-tactical phase, data received from all users and service providers, which could affect the plan, such as confirmations, modifications, cancellations and additions, will be received, analysed and incorporated. The plans developed in the strategic planning phase will be progressively refined and expanded, taking into account user preferences for flexibility, punctuality or service quality requirements. The plans will provide a framework that will give a good forecast of the traffic demand and the users' capabilities and will resolve conflicts of interest between those parties and user groups that plan their activities up to years in advance. At the same time, the plans will also estimate the reserve capacity and airspace needed for airspace users that, due to the tactical nature of their operations, cannot plan well in advance. In addition, the plans will set out the rules and parameters, which will broadly outline everyone's access to airspace, routes and airports, and will provide estimates on the reserve capacity that may be needed for each day's traffic situation.

4.8 In some environments, the plans may be published and further developed into regional, hour-by-hour plans that are finalized and promulgated at an agreed time before operation. The plans will contain, for example, statements of flight intent, airspace regimes and reservations plans, route configuration plans and service provider service limitations, capabilities and capacities. In other environments, plans will be developed on a less formal basis, but with the same intent of better matching capabilities with demand and capacity.

Tactical planning

4.9 At some stage prior to the flight, the user will have determined the flight trajectory that best addresses the user's operation and will submit the user-requested trajectory to the demand and capacity balancing service provider for assessment and agreement. The tactical planning phase will examine a flight request to see if it is acceptable or if there are any potential resource, capacity or congestion problems of which the user is unaware. If there are problems, demand and capacity balancing will identify user-preferred solutions, giving the user the freedom to choose the most optimum flight within the system constraints. If, however, safety levels or equity might be compromised, protocols will establish the demand and capacity balancing service as the final arbiter in the determination of a system-delivered trajectory.

4.10 Real-time information such as weather forecasts, traffic demand and airspace reservations will be used on a continuous basis to predict en-route and terminal capacity and traffic densities for the remainder of the day, update the hour-by-hour forecast of local capacity bottlenecks throughout the region(s), and assess the impact of individual flights on the complete flight trajectory (i.e. from gate to gate).

5. TRAFFIC SYNCHRONIZATION

5.1 Traffic synchronization is the establishment and maintenance of a safe, orderly and efficient flow of air traffic in all phases of flight.

5.2 In the departure phase of flight, traffic synchronization will involve the integration of departures into the airborne traffic environment. Improved departure flows will be achieved through tools that provide more efficient airport surface operations and improved real-time assessment of traffic activity in departure and en-route airspace.

5.3 In the en-route phase of flight, traffic synchronization will involve the sequencing, integration and spacing of en-route flows, to reduce reliance on tactical conflict management. Improved flow sequences will be achieved through tools that provide more efficient prediction of demand and capacity at crossing points, improved real-time assessment of traffic activity in departure/arrival airspace, the increased use of airborne equipage to maintain group spacing or station keeping, and the expanded use of dynamic routes based on enhanced navigation capabilities.

5.4 Arrival operations will also benefit from these tools; however, the primary task in this phase will be to plan and achieve optimum spacing and sequencing of the arrival flow. The runway assignment, which provides the basis for this activity, will be made as early as possible. The user's runway assignment preference will be available through the flight object within the ATM environment information system. Departure and arrival decision-support systems and the integrated surface management tools will be used to coordinate an optimal runway assignment.

5.5 In the final portion of the arrival phase, decision-support systems will facilitate the use of time-based metering to maximize airspace and airport capacity. Other tools will generate advisories to aid in the manoeuvring of flights onto the final approach in accordance with the planned traffic sequence.

5.6 In all phases, a service provider may give the pilot responsibility for station keeping, or a time to cross a point or points, to maintain the required sequence and traffic flow.

6. AIRSPACE USER OPERATIONS

6.1 The concept uses the term “airspace user” to recognize the diverse nature of missions and demands on the airspace resource, for example, military, airlines and general aviation.

6.2 This section illustrates the airspace user’s interaction with the ATM system. See also collaborative decision making.

ATM system design

6.3 The airspace resource is considered to be finite, and the capacity of the airspace resource depends on the procedures and tools employed. There will be conflicting demands among airspace users; therefore, resource management that can provide an acceptable level of safety, equity, access and efficiency is a major consideration.

6.4 There will be no ATM restrictions on user missions except where required due to safety or ATM system design. ATM system design will minimize restrictions, but will recognize that efficiencies can be achieved by some regulation and that some special needs, such as security requirements, must also be addressed.

6.5 All airspace users are members of the ATM community and are expected to participate or have representation in collaborative decision-making processes that affect their missions, including ATM system design processes. The ATM system design will give due consideration to, and be largely based on, user expectations. It should be noted that any changes to ATM system design will include ATM system-wide safety, business, environment and security cases. System-wide cases will contribute to increasing regional and global interoperability and harmonization.

6.6 The concept recognizes the mutual interrelationship between aircraft design and ATM performance. The ATM system will be designed to accommodate a wide variety of mission requirements, including a wide range of aircraft types and performance. Some efficiency in the ATM system can be best achieved through aircraft design, as indicated by system-wide safety and business cases.

6.7 In this illustration, airspace users prefer that no ATM requirements constrain their desired mission. All ATM services will be on an “on-request” basis; however, safety or ATM design requirements may require the use of a particular service. ATM system design will determine where and when services will be available.

6.8 Airspace users initially accept responsibility for all aspects of their mission, including conflict management, unless ATM system design requires services to be requested. Conflict management recognizes that conflicts are not just between aircraft but also between a mission and any hazard. In addition, the larger the conflict horizon, the increased likelihood that the user’s mission can be more efficiently conducted.

Cooperation

6.9 A spirit of cooperation is expected within the community, which will permit an acceptable level of information and airspace resource sharing. The airspace user will not necessarily be required to provide all the information requested by the ATM system because the user can determine different levels of participation; however, not sharing some information may result in increased ATM restrictions on particular missions.

6.10 All users should consider that the demand on the airspace resource for their particular mission is temporary. This will ensure the equitable use of the airspace resource among all airspace users.

Trajectory negotiation

6.11 When their mission is a flight, airspace users will communicate their specific mission requirements, using a 4-D flight trajectory, to the level of accuracy required by the ATM system. Advance notice of the flight, to a lesser level of detail, may have already been provided to aid ATM system design and configuration, including determining available ATM services and for demand and capacity balancing.

6.12 When an ATM service is used, users will always communicate their preferred 4-D trajectory. If users are aware of restrictions that will prevent the preferred trajectory, they may also propose a preferred alternative trajectory.

6.13 If the requested trajectories are not immediately available, the demand and capacity service provider will then negotiate with the user and, through collaborative decision making, work towards an agreed trajectory.

6.14 This trajectory will be approved with tolerances, which will constitute a “4-D trajectory contract” between the airspace user and the service provider. The airspace user can accept or reject the proposal, as part of the collaborative decision-making process.

6.15 The intent of these tolerances, which can vary over the trajectory, is to allow some freedom for changes within the trajectory to be made by the airspace user without further reference to the service provider. The tolerances are intended to provide as much flexibility as the ATM system can allow, while balancing the requirements of other airspace users.

6.16 After the trajectory has been agreed, if there are changes in ATM resources that will affect the aircraft’s trajectory, then collaborative decision making will consider alternative trajectories. If time permits, this may be the consideration of several options, but if time is limited, then this process may instead be based on pre-agreed procedures and preferences.

6.17 After the trajectory has been agreed, if the airspace user requests a trajectory change, then the requested 4-D trajectory will be communicated to the ATM service provider, and the collaborative decision-making trajectory negotiation cycle will commence again.

6.18 Effective information management and sharing will enable easy and rapid collaborative decision making among airspace users and ATM service providers since airspace users and service providers have access to the same information on the current and forecast status of the ATM system.

Performance incentive and assistance

6.19 When the airspace user is unable to meet ATM system requirements to operate a particular flight at a particular time because of lack of performance or equipment, the ATM service will, in many cases, be able to offer services to the airspace user that will mitigate the deficiency for that mission.

6.20 Procedures will be collaboratively developed that will provide an incentive for airspace users to improve ATM performance. These procedures should not prevent access to airspace by users suffering equipment failure or wishing occasional use of the airspace, if the ATM system is capable of safely handling the deficiency.

6.21 Note that the performance required to operate in a particular airspace will be dynamically managed, and the airspace user may also choose to operate at another time when performance requirements are less and so avoid the need for any additional service from the ATM system. An example may be the requirement for the user to broadcast position and intentions, which an equipment deficiency prevents. The ATM system may be able to broadcast this information on behalf of the airspace user using ATM surveillance capabilities to determine aircraft position, and intent information supplied to the ATM service provider by the airspace user and the service provider's broadcast equipment.

7. AIRLINE FLIGHT

7.1 The following examples relate to airspace users engaged in airline operations. They are not intended to be a complete description but apply to a particular interpretation. Other airspace users may follow similar ATM processes.

7.2 The airspace user may initially (as early as several months to a year before flight) provide, to the demand and capacity balancing service, information on intended operations, with accuracy appropriate to the planning stage, to facilitate strategic airspace organization and management.

7.3 When the availability of forecasts allows for meteorological flight planning, the airspace user will negotiate the user-preferred 4-D trajectory with the demand and capacity balancing service of the ATM provider. The 4-D system-proposed trajectory is defined in terms of the lateral, longitudinal and vertical components of the aircraft position, and the time of the position information. It includes route, altitudes, speeds and, where feasible with respect to the planning horizon, runway and arrival times, taking into account weather, airspace constraints, aircraft performance capability and user constraints such as schedules.

7.4 The system-offered trajectory, complete with departure time, weather data, waypoints with estimated time/altitude/speed, will be communicated to the flight deck for acceptance. The pre-departure system-delivered trajectory, i.e. the trajectory finally accepted, will be stored for access by all potential ATM service providers.

7.5 Based upon the flow of outbound traffic, the aerodrome operations service provider may amend the initial trajectory to define a safe and expeditious flight path through the departure phase of flight, where interaction with other departing or arriving aircraft may occur. The departure clearance will be communicated to the flight deck, as well as authorization to start the engines and, where applicable, to push back. The aircraft will taxi along designated routes to eliminate conflict between departing and arriving streams and to prevent potential queuing or congestion problems. Aircraft take-off performance itself (for example, a high rate of climb) may be used to discriminate departure traffic from arrival traffic and to mitigate environmental constraints.

7.6 The user-preferred trajectory is a route of flight most closely matching user expectations. The system-delivered trajectory will always attempt to match those expectations as closely as possible. Notwithstanding that the delivered trajectory may effectively release the aircraft to a self-separation mode, or to a free-routing mode, the delivered trajectory will also be taken into account within the ATM system in determining demand and capacity balancing, conflict management and aerodrome operations performance. Unforecast changes in trajectory can impact the operations of other aircraft. To that end, the current position of the aircraft and its predicted trajectory, as required by ATM system design, will be routinely communicated to other partners in the ATM system for strategic or tactical ATM purposes.

7.7 Any deviation from the initial system-delivered trajectory will be negotiated directly between the flight deck and the ATM service delivery management. Such deviations may be generated as a result of factors including, *inter alia*, unforecast weather, unpredicted activation of airspace constraints, destination arrival delays, the need for conflict management and resolution, changes in airspace capacity, changes to aircraft performance, or emergency situations. In a free-routing environment, a clearance or authorization to deviate or amend trajectory will not be required; however, any amended trajectory will be dynamically provided to the system to provide decision support to other ATM processes or partners.

7.8 When the ATM system is providing a flight-monitoring function or other function for an aircraft, the potential for flight optimization may be detected by the ATM system and offered to the airspace user. Any revised routing will be negotiated to be free from conflicts or, where self-separation has been invoked, any potential conflict identified within the trajectory parameters will be clearly enunciated to the flight deck in the trajectory offer. Where trajectories are being negotiated, the flight deck can assume that such negotiations are for the whole of the intended en-route phase of flight unless specifically stated.

7.9 The arrival phase of flight is characterized by flight transition from the en-route environment to the terminal and aerodrome environment using an arrival route or procedure; approach and landing; and taxiing to the parking location. The proposed arrival trajectory will have already been allocated on the basis of known departure and en-route trajectories, aircraft performance and known constraints within the terminal and aerodrome environment, minimizing the potential for delays and optimizing aerodrome capacity. Unforecast events may impact the arrival trajectory; however, any delays should have been absorbed within the en-route trajectory. Arrival trajectories will be segregated from departure trajectories, and such segregation may be based on aircraft performance characteristics. Aircraft performance characteristics (including wake vortex and slowing and stopping capabilities) and runway design characteristics (including high-speed exits and precision guidance capabilities) will have been taken into account in determining safe spacing for traffic synchronization to the runway and on the runway.

8. CONFLICT MANAGEMENT

8.1 In this example, the need for airspace users to achieve maximum efficiency for flights is a high priority, whether it is a required time of arrival or most economical operation. It is recognized that tactical changes to a flight trajectory in order to address separation from hazards or to wait for access to an ATM resource to become available will both have a significant impact on flight efficiency. The ATM system therefore has determined that negotiated 4-D trajectories that require no tactical intervention are the desired goal. It is recognized that certain inaccuracies in the information available, and unforeseen or uncontrollable changes will still require tactical modifications to flight profiles. In addition, there may remain in the ATM system design an element of tactical intervention as a cost-effective solution to some ATM issues. Trajectory management aims to achieve the desired time of arrival at the destination parking area.

Strategic conflict management

8.2 The purpose of conflict management is to limit, to an acceptable level, the risk of collision between an aircraft and a hazard. The airspace resource management activities of demand and capacity balancing and traffic synchronization obviously have a close connection to conflict management and are indeed considered to be the strategic components of conflict management. The use of strategic conflict management will reduce the need for tactical intervention to an agreed level. Note that the aim of demand and capacity balancing is efficient resource management and not simply preventing overload of tactical separation activities, which do not necessarily deliver maximum capacity because more aircraft can be handled in a smooth sequence than in a sequence that has to be tactically created.

8.3 In conflict management, the term "hazards" has been expanded to include all hazards to flights, and also to include hazards on the apron. Any solution to a conflict with a particular hazard must confine the solution trajectory to airspace (or an area) free from all hazards.

8.4 Because the trajectory is managed from gate to gate, it is necessary to consider hazards and resources on the apron. The trajectory from when the aircraft starts to move should aim to be conflict-free without delay. The trajectory includes transit from the landing runway to the arrival parking location, which should also aim to be conflict-free without delay.

8.5 To reflect the move towards more strategic conflict management, that is airspace resource management, the concept defines the term "conflict" as occurring whenever the applicable separation may be compromised. This definition was previously considered as "potential conflict" which reflected more tactical conflict management, that of keeping aircraft away from hazards. In strategic conflict management, a "conflict" occurs whenever there is a competing demand for the airspace resource.

Separation provision

8.6 Tactical conflict management, referred to in the concept as separation provision, is the next layer of conflict management. Separation provision has been defined in some detail in the concept and introduces the term separation mode. The concept does not address the development of separation modes, which requires considerable effort. Work on developing additional separation modes is still ongoing; however, the concept has been interpreted as having a defined minima for separation from all hazards, and a separator based on intervention capability.

8.7 Defined separation minima allows not only for a single value in all cases, but also dynamic values that are determined from defined parameters, for example, by using a separation minima formula. Defined minima are necessary for the development of decision-support tools, which require values by which hazards must be avoided.

8.8 In this example, intervention capability has produced different values for different separators, and for each separator the value varies depending on circumstances. A major reason for the different values is the total workload required from airspace users, service providers or the automated system. The choice of which separator is the best for a given situation is given due consideration in ATM system design. The airspace user as the predetermined separator is still the starting point of the design, meaning that there is no separation provision service unless safety or ATM system design requires such a service.

8.9 In this example, cooperative separation remains an option available within this particular ATM system, but not a requirement for the separator to use. Delegation occurs only when deemed appropriate by the current separator and after acceptance by the proposed delegated separator. The delegation is for a defined period under defined conditions. Because separation provision is tactical conflict management, this delegation and acceptance is in many cases well-defined. The procedures were developed from previously existing delegation procedures. An example is the phrase "cleared visual approach" which, according to pre-existing procedures, transferred the responsibility for aircraft separation from terrain, from the service provider to the airspace user (if the visual approach was accepted); however, separation from other traffic remained the responsibility of the service provider.

Collision avoidance

8.10 In this example, collision avoidance systems have continued to evolve; however, they have remained systems that avoid immediate proximity hazards, rather than systems that have evolved into some form of tactical separation provision. The role of collision avoidance systems is an important aspect of the safety design of the ATM system and is therefore considered as part of meeting the level of safety required by the ATM design. The importance of collision avoidance systems, which are the third level of conflict management, is the additional and independent level of conflict management to that provided by separation provision. Note that collision avoidance systems are not considered as an element of the separation modes of separation provision.

9. ATM SERVICE DELIVERY MANAGEMENT

9.1 The role of ATM service delivery management will be to coordinate the delivery of services from all service providers, including other ATM service delivery management providers, in response to an airspace user's request for a service. For example, it may be a single service delivery management that coordinates services from a number of different service providers located over several regions.

9.2 At the strategic level, ATM service delivery management will be responsible for conducting collaborative decision making within the ATM community to achieve the best outcomes for the ATM community. This includes balancing conflicting requests from different community members. The constraints on choices will be the global safety standards (and any additional requirements from States), which must be met. Within these constraints, the service delivery management service will provide the combination of ATM services that will best meet agreed levels of capacity and efficiency for the whole ATM community.

9.3 ATM service delivery management will normally be the first point of contact between a potential airspace user and the ATM services. This may occur directly, through a collaborative decision-making process about levels of service or, indirectly, through the determination by appropriate authorities, in the absence of an airspace user, of the need, or otherwise, for certain services or processes. The airspace user may also contact individual service providers directly for provision of a particular service, for example, for a short-term need.

9.4 Although ATM services will be available on request, it may not be efficient to supply all services in all airspace. Therefore it will be necessary for the community to agree when services will be available, subject to safety and business cases.

9.5 For example, as traffic levels increase in areas where no ATM conflict management services were previously required, there will be a number of options to maintain the required safety level. They include the requirement for a separation provision service (tactical conflict management) at peak times, demand capacity balancing (while self-separation continues) or particular procedures. It may be determined that the problem is localized with no consequences for international operators and that the most effective solution is a procedural one.

9.6 ATM service delivery management will assess the availability of other ATM service providers to effect a particular service. At a strategic level, this may entail accessing the capabilities of adjacent providers or conducting analysis work in support of safety and business cases for system enhancements.

9.7 Where required, appropriate automated decision-support tools will support ATM en-route services. Many of these systems will be aimed at conformance and safety monitoring.

Phases of flight

9.8 In the departure and arrival phases of flight, ATM service delivery management will be responsible for ensuring that flights can get to the runway in time for their take-off slot and, at the same time, for integrating them with all the other departing and arriving flights in order to ensure safety and to optimize the use of the parking locations, ramps, taxiways and runways. ATM service delivery management will ensure that service providers are given access to real-time data on projected arrivals and departures, runway loading, airport congestion, parking locations and environmental considerations, in order to reduce inefficiencies in aircraft and vehicle movements.

9.9 In the en-route phase of flight, ATM service delivery management will be involved in matching ATM service capabilities with demand, e.g. traffic flow characteristics, by a range of means, including, *inter alia*, dynamic re-sectorization in ATM service centres, changes to route structures or airspace organization, or changes to conflict management modes.

9.10 During the course of a flight — from its inception at the scheduling or planning stage, through its actual operation, to its completion at an arrival parking location — ATM service delivery will consider the objectives for any particular flight in the course of operations from gate to gate. The degree to which these objectives are evident during a flight and the interaction required is a function of both traffic volume and flight duration.

9.11 The phases of flight for ATM service delivery management might consist of:

a) ***planning:*** where the objective is integration into the ATM environment to achieve a close match between the user-preferred trajectory and the system-delivered trajectory;

b) ***ramp:*** where the objective is to move the flights in and out of the parking locations;

c) ***surface departures:*** where the objective is to move the aircraft from the ramp to the departure queue;

d) ***departure:*** where the departure queue and the runway are managed to launch aircraft from the queue into the airspace;

e) ***dispersion:*** where the objective is to get aircraft up and out of the terminal into the en-route structure;

f) ***cruise:*** in which aircraft are at altitude and moving towards their destination, but are not yet subject to actions related to the arrival phase;

g) ***collection:*** the state in which aircraft are sequenced and spaced to bring them into the terminal area for arrival;

h) ***approach:*** the phase in which aircraft are assigned to runways and onto the surface;

i) ***surface arrival:*** where aircraft are moved off runways and to the ramp and, once again;

j) ***ramp:*** where aircraft are manoeuvred into the parking location.

10. COLLABORATIVE DECISION MAKING

10.1 Collaborative decision making will allow all members of the ATM community, especially airspace users, to participate in the ATM decision making that affects them. The level of participation will reflect the level to which a decision will affect them.

10.2 Collaborative decision making will apply to all layers of decisions, from longer-term planning activities through to real-time operations. It will apply across all concept components of the ATM system and is an essential element of the operational concept.

10.3 Collaborative decision making means achieving an acceptable solution that takes into account the needs of those involved. All participants will therefore require a spirit of cooperation. A balance is required because collaborative decision making is primarily invoked to resolve competing demands for an ATM resource and to organize a safe sharing of that resource among airspace users.

10.4 The time available for achieving a collaborative decision decreases from the strategic to the tactical stages. In the most tactical of situations, there may be no time to consider options; however, wherever such situations can be foreseen, collaborative decision making will have been previously used to determine agreed procedures for such cases. For example, rules for determining priorities for accessing an ATM resource will have been collaboratively agreed in advance. Therefore collaborative decision making can be applied both actively and, through agreed procedures, passively.

10.5 Effective information management and sharing will enable each member of the ATM community to be aware, in a timely manner, of the needs, constraints and priorities of other members in relation to a decision-making issue.

10.6 Collaborative decision making can occur among airspace users directly, without any involvement of an ATM service provider.

Any member of the ATM community can propose a solution

10.7 Where a service provider is involved in collaborative decision making because of a requirement of the ATM system, it is often the ATM service provider that will propose a solution for consideration by the airspace user because the service provider will be aware of the requirements of other users and service providers and the collaboratively agreed rules for resolving competing requests for an ATM resource. However, because it is an information-rich environment where the airspace user may have access to the same information as the service provider, the airspace user will understand why a particular solution has been proposed.

10.8 If time permits, a user can propose an alternative solution that addresses a user's preference that is not known to the service provider. In the same way, the service provider can reject the user's proposed solution because of an ATM requirement that the user is not aware of. This illustrates how important full sharing of appropriate information is in order to have timely collaborative decision making.

11. INFORMATION MANAGEMENT

11.1 The ATM operational concept envisages the application of a system-wide information management concept, where information management solutions will be defined at the overall system level, rather than individually at each major subsystem (programme/project/process/function) and interface level, as has happened in the past.

11.2 System-wide information management, or simply information management, aims at integrating the ATM network in the information sense, not just in the system sense. This fundamental change of paradigm forms the basis for the migration from the one-to-one message exchange concept of the past to the many-to-many information distribution model of the future, that is, many geographically dispersed sources collaboratively updating the same piece of information, with many geographically dispersed destinations needing to maintain situational awareness with regard to changes in that piece of information.

11.3 Information management will ensure that the information needs of ATM stakeholders, both within as well as outside of the ATM network, will be satisfied in a much more flexible and cost-effective manner than previously.

11.4 This goal will be achieved by integrating the capabilities of all suppliers of ATM information in order to assemble and continuously maintain the best possible integrated picture of the past, present and future (planned) state of the ATM situation. This will be used as a common basis for improved decision making by all ATM stakeholders during their strategic, pre-tactical and tactical planning processes, including real-time operations and post-flight activities.

11.5 Successfully managing the quality, integrity and accessibility of this complex, growing web of distributed, fast-changing, shared ATM information, called the virtual ATM pool, can be considered as the main operational enabler for the operational concept.

11.6 Decision making is a normal operational process, but decisions will be of a better quality and engender greater confidence because accurate and validated information will be available in the right form, in the right place and at the right time. An open systems environment and better information management will allow information sharing on a much wider basis than hitherto and will support a permanent dialogue between the various partners, throughout all phases of flight.

11.7 The exchange of information will enable the various organizations to update each other continuously on events in real time. Thus, aircraft operators will have up-to-date and accurate information on which to base decisions about their flights, while ATM service providers, including aerodrome operators, will have a better knowledge of flight intentions for operational and planning purposes.

11.8 Other interested parties that need information to improve the service that they supply to or receive from ATM, including, *inter alia*, customs and immigration authorities, meteorology departments and baggage handlers, will benefit from more accurate arrival, departure or trajectory information. The combinations of partners involved in any particular decision-making process may be numerous. For example, some decisions will concern just the airport authority and aircraft operators (refuelling times, parking bays, etc.), whereas others will involve all parties (changes to departure times, etc.).

11.9 Information management may be conceptually subdivided into information ownership, licensing and pricing, information security management, ATM pool content management, the information acquisition process and the information dissemination process.

11.10 Information will be a commodity in the future information-rich ATM network, not just in the strategic planning phases, but also during real-time operations. However, there will be commercial sensitivity and national security considerations, as well as the interests of commercial information service providers.

11.11 Information ownership, licensing and pricing are issues that are related to, but distinct from, security and communication cost aspects. Certain ATM information provided by stakeholders within or outside of the ATM network will be available for sharing without restrictions. For other information, the suppliers may want to charge a fee, restrict dissemination and/or retain ownership and control after dissemination.

11.12 Arrangements will have been made to establish security levels; establish the willingness of stakeholders to provide certain information; gain access to information; play certain roles in collaborative decision making; and compensate or charge stakeholders accordingly in financial or other terms.

11.13 Protocols will have established the legal basis; for daily operational application they will be translated into appropriate “adaptation parameters” governing the continuous operation of the various information management subprocesses throughout the ATM network.

11.14 In a collaborative distribution environment, where technical, organizational and institutional barriers to the access of information have been drastically reduced, security will be of utmost importance. Consistent and compatible mechanisms will exist to handle the security aspects of information collection, content management, and dissemination throughout the ATM network. The principle of subsidiarity will be applied in data security matters, for example, physical storage and security management should be as close as practicable to the information owner.

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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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