*International Civil Aviation Organization*

**Eight Meeting of the Communications/Navigation/Surveillance and Meteorology Sub-Group (CNS/MET SG/8) of APANPIRG**

Bangkok, Thailand, 12-16 July 2004

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**Agenda Item 5: Radio navigation Aids**

**1) review strategies for Precision Approach and Landing Guidance Systems and GNSS Implementations**

# REVIEW OF STRATEGIES FOR IMPLEMENTATION OF GNSS AIR NAVIGATION CAPABILITY AND THE PROVISION OF PRECISION APPROACH AND LANDING GUIDANCE SYSTEMS

(Presented by the Secretariat)

**SUMMARY**

This paper presents the Regional Strategies for the implementation of GNSS navigation capability and for the provision of precision approach and landing guidance systems for review.

## 1. INTRODUCTION

1.1 The regional strategies for implementation of GNSS air navigation capability and the provision of precision approach and landing guidance systems were reviewed and updated by the Seventh Meeting of CNS/MET Sub-Group of APANPIRG in July 2003.

1.2 The updated strategies were adopted by APANPIRG/14 in its Conclusions 14/19. The Regional Strategy for the Provision of Precision Approach and Landing Guidance Systems is provided in the Attachment 1 and the Strategy for Implementation of GNSS Navigation Capability in the ASIA/PAC Region is provided in the Attachment 2 to this paper.

## 2. DISCUSSION

2.1 The 14th meeting of APANPIRG reviewed both strategies in light of available information presented to the meeting. The strategies with the amendments proposed by the Sub-Group were adopted without any change.

2.2 It should be noted that GNSS is identified as a standard navigation systems and relevant SARPs including augmentations systems serving flight operations up to Category I precision approach have been included in the Amendment No.76 to Annex 10 which became applicable on 1 November 2001.

2.3 As the Regional Strategies are considered as living documents, the Sub-group is expected to continue to review both Strategies on a periodic basis and propose appropriate amendments, as required, taking into account technological developments in GNSS.

2.4 The Eleventh Air Navigation Conference noted the Strategies adopted by APANPIRG/14. The AN Conf/11 also reviewed and updated the following documents:

a) ICAO Strategy for the introduction and application of non-visual aids to approach and landing in Annex 10, Volume 1, Attachment B (Attachment 3 to this paper); and

b) Global Air Navigation Plan for CNS/ATM systems (Doc. 9750), particularly those dealing with GNSS (Attachment 4 to this paper).

2.5 The AN Conf/11 emphasized the need for ICAO, States, airspace users and other parties concerned to continue work towards the safe and efficient global navigation system for all phases of flight.

## 3. ACTION BY THE MEETING

3.1 The meeting is expected to:

a) review the Regional Strategy for Precision Approach and Landing Guidance Systems and the Strategy for the Implementation of GNSS Navigation Capability in the ASIA/PAC region, in light of developments of aeronautical navigation systems; and

b) propose necessary updates, as required.

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## UPDATED STRATEGY FOR THE PROVISION OF PRECISION APPROACH AND LANDING GUIDANCE SYSTEMS

**Considering**:

a) in the ASIA/PAC Region, ILS is capable of meeting the majority of requirements for precision approach and landing;

b) requirements for provision of terrestrial-based navigation facilities, non-precision and precision approach and landing have been implemented in most cases;

c) the availability of ICAO SARPs and guidance material for GNSS with augmentation to support Cat I precision approach;

d) the knowledge that GNSS without augmentation can support non-precision approaches and that augmented GNSS- based systems is expected to be available to support Category I operations by year 2006;

e) GNSS with augmentation to support category II and III operations is expected to be available in 2010 – 2015 time frame;

f) MLS Cat I is operational and ground and airborne Cat III B certification is in progress;

g) a multi-modal airborne approach and landing capability is necessary and expected to be available;

h) the definition of Required Navigation Performance for approach, landing and departure operations;

i) the need to maintain aircraft interoperability both within the region and between the ASIA/PAC Region and other ICAO regions and to provide flexibility for future aircraft equipage.

**The strategy for ASIA/PAC Region in the provision of precision approach and landing guidance is:**

a) Retain ILS as an ICAO standard system for as long as it is operationally acceptable and economically beneficial;

b) Implement GNSS with augmentation to support Category I operations where operationally required and economically beneficial;

c) Conduct studies for the implementation of GNSS ground- based augmentation systems and GNSS avionics equipment for Category II and III operations;

d) Introduce applicable Required Navigation Performance (RNP) for approach, landing and departure operations in accordance with ICAO provisions.

e) Conduct necessary on-going GNSS and RNP education and training for operational personnel to ensure safe operations.

f) Implement MLS where operational requirements cannot be satisfied by implementation of ILS or GNSS.

g) Protect radio frequency spectrum of ILS, MLS and GNSS since the transition from ILS to GNSS and /or MLS will be evolutionary and will take some time.

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**UPDATED STRATEGY FOR THE IMPLEMENTATION OF GNSS NAVIGATION CAPABILITY IN THE ASIA/PAC REGION**

**Considering that:**

1) Safety is the highest priority;

2) Elements of Global Air Navigation Plan for CNS/ATM system on GNSS and requirements for the GNSS implementation have been incorporated into the CNS part of FASID;

3) GNSS SARPs, PANS and guidance material for GNSS implementation are available;

4) The availability of avionics including limitations of some receiver designs; the ability of aircraft to achieve RNP requirements and the level of user equipage;

5) Development of GNSS systems including satellite constellations and improvement in system performance;

6) Airworthiness and operational approvals allowing the current GNSS to be used for en-route and non precision approach phases of flight without the need for augmentation services external to the aircraft;

7) Development status of aircraft-based augmentation systems;

8) Regional augmentation systems include both satellite-based (SBAS) and ground-based systems (GBAS);

9) Human, environmental and economic factors will affect the implementation of GNSS.

10) The regional navigation requirements are:

   (a) RNP10/RNP4 for en-route;
   (b) RNP4 for *transition to* terminal phase of flight;
   (c) *RNP1 for terminal phase of flight*;
   (d) NPA/APV for approaches and departures; and
   (e) Precision approaches at selected airports.

**The general strategy for the implementation of GNSS in the ASIA/PAC Region is detailed below**:

1) There should be an examination of the extent to which the GNSS system accessible in the Region can meet the navigational requirements of ATM service providers and aircraft operators in the Region;

2) Evolutionary introduction of GNSS Navigation Capability should be consistent with the Global Air Navigation Plan for CNS/ATM Systems;

3) During transition to GNSS, sufficient ground infrastructure for current navigation systems must remain available. Before existing ground infrastructure is considered

for removal, users should be given reasonable transition time to allow them to equip with GNSS to attain equivalent navigation service;

4) Implementation shall be in full compliance with ICAO SARPs and PANS;

5) Introduce the use of GNSS for en-route, terminal and approach navigation;

6) States are encouraged to implement future GNSS approvals based on TSO C145/146 receiver standards or equivalents;

7) To the extent possible, States should work co-operatively on a multinational basis to implement GNSS augmentation systems in order to facilitate seamless and inter-operable systems;

8) States consider segregating traffic according to navigation capability and granting preferred routes to aircraft with better navigation performance**,** taking due consideration of the need of State aircraft.

9) States undertake a co-coordinated R & D programme on GNSS implementation and operation;

10) ICAO and States should undertake education and training to provide necessary knowledge in GNSS theory and operational application, including RNP, and

11) States establish multidisciplinary GNSS implementation teams, using section 6.10.2 of ICAO Circular 267, Guidelines for the Introduction and Operational Approval of the GNSS , as a guide.

*Note1: Identified SBAS systems are EGNOS, MSAS and WAAS. The MSAS is expected to be available for providing augmentation for the ASIA/PAC region.*

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**AERONAUTICAL TELECOMMUNICATIONS**
**ANNEX 10**
**TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION**

**VOLUME I — RADIO NAVIGATION AIDS**

# ATTACHMENT B. STRATEGY FOR INTRODUCTION AND APPLICATION OF NON-VISUAL AIDS TO APPROACH AND LANDING

*(see Chapter 2, 2.1)*

## 1. Introduction

1.1 Various elements have an influence on all weather operations in terms of safety, efficiency and flexibility. The evolution of new techniques requires a flexible approach to the concept of all weather operations to obtain full benefits of technical development. To create this flexibility a strategy enables, through identification of its objectives and thoughts behind the strategy, incorporation of new technical developments or ideas into this strategy. The strategy does not assume a rapid transition to a single globally established system or selection of systems to support approach and landing operations.

1.2 The strategy addresses the application of non-visual aids to approach and landing with vertical guidance (APV) and precision approach and landing operations.

## 2. Objectives of strategy

The strategy must:

a) maintain at least the current safety level of all weather operations;

b) retain at least the existing level or planned improved level of service;

c) maintain global interoperability;

d) provide regional flexibility based on co-ordinated regional planning;

e) be applicable until at least the year 2020; and

f) take account of economic, operational and technical issues.

## 3. Considerations

### 3.1 General

The following considerations are based on the assumption that the operational requirement and the required commitment are available and the required effort is applied.

### 3.2 ILS-related considerations

a) There is a risk that ILS Category II or III operations cannot be safely sustained at specific locations;

b) operators, as required, are equipped with ILS receivers which meet the interference immunity performance standards (Annex 10, Volume I, Chapter 3, 3.1.4);

c) expansion of ILS is limited by channel availability (40 channels);

d) many aging ILS ground installations will need to be replaced; and

e) in most areas of the world, ILS can be maintained in the foreseeable future.

### 3.3 MLS-related considerations

a) MLS Category I is operational;

b) ground and airborne Category IIIB certification is in progress and is scheduled to be completed by early 2004; and

c) MLS implementation is planned at specific locations to improve runway utilisation in low visibility conditions.

### 3.4 GNSS-related considerations

a) Standards and Recommended Practices (SARPs) are in place for GNSS with augmentation to support APV and Category I precision approach;

b) SARPs for ground-based regional augmentation system (GRAS) for APV operations are under development;

c) GNSS with satellite-based augmentation system (SBAS) for APV operations is operational;

d) GNSS with ground-based augmentation system (GBAS) for Category I precision approach operations is expected to be operational by 2006;

e) it is not expected that an internationally accepted GNSS with augmentation as required may be available for Category II and III operations before the 2010-2015 time frame;

f) technical and operational issues associated with GNSS approach, landing and departure operations must be solved in a timely manner; and

g) institutional issues associated with GNSS approach, landing and departure operations must be solved in a timely manner.

### 3.5 Multi-modal airborne approach and landing capability considerations

To enable this strategy, a multi-modal airborne approach and landing capability is necessary and is expected to be available.

### 3.6 Other considerations

a) There is an increasing demand for Category II and III operations;

b) GNSS can potentially offer unique operational benefits for low-visibility operations, including new procedures, flexible siting requirements and provision of airport surface guidance;

c) only the three standard systems (ILS, MLS and GNSS with augmentation as required) are considered to play a major role in supporting all weather operations. The use of head-up displays in conjunction with enhanced and/or synthetic vision systems may provide operational benefits;

d) a consequence of the global strategy is that there will not be a rapid transition from ILS to new systems such as GNSS or MLS. It is therefore essential for the implementation of the strategy that the radio frequency spectrum used by all of these systems is adequately protected;

e) to the extent practical a transition directly from ILS to GNSS is preferable. In some States, however, it may not be possible to make this transition without losing the current level of Category II or III operations;

f) as long as some users of a given runway continue to rely on ILS, the potential operational benefits resulting from the introduction of new landing systems may be limited by the constraints of mixed-system operations;

g) APV operations may be conducted using GNSS with augmentation as required or barometric vertical guidance and GNSS with ABAS or DME/DME RNAV lateral guidance; and

h) APV operations provide enhanced safety and generally lower operational minima as compared to non-precision approaches.

## 4. Strategy

Based on the considerations above, need to consult aircraft operators and international organizations and, to ensure safety, efficiency and cost-effectiveness of the proposed solutions the global strategy is to:

a) continue ILS operations to the highest level of service as long as operationally acceptable and economically beneficial;

b) implement MLS where operationally required and economically beneficial while making every effort to ensure airport access is not denied to ILS-equipped aircraft;

c) implement GNSS with augmentation as required for APV and Category I operations where operationally required and economically beneficial;

d) promote the development and use of a multi-modal airborne landing capability;

e) promote the use of APV operations, particularly those using GNSS vertical guidance, to enhance safety and accessibility;

f) identify and resolve operational and technical feasibility issues for GNSS with ground-based augmentation system (GBAS) to support Category II and III operations. Implement GNSS for Category II and III operations where operationally required and economically beneficial; and

g) enable each region to develop an implementation strategy for these systems in line with the global strategy.

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**GLOBAL AIR NAVIGATION PLAN FOR CNS/ATM SYSTEMS**



## Chapter 1

## INTRODUCTION TO CNS/ATM

### A BRIEF LOOK AT CNS/ATM

### Navigation

1.20 Improvements in navigation include the progressive introduction of area navigation (RNAV), supported by an appropriate combination of global navigation satellite system (GNSS), self-contained navigation systems (IRU/IRS) and conventional ground-based navigation aids. The ultimate

goal is a transition to GNSS that would eliminate the requirement for ground-based aids, although the vulnerability of GNSS to interference may require the retention of some ground aids in specific areas.

1.21 GNSS provides for global navigational coverage and is being used for oceanic, en-route and terminal navigation and for non-precision approaches. With appropriate augmentation systems and related procedures, GNSS supports approaches with vertical guidance and precision approaches. Core satellite constellation(s) with proper augmentation as specified in Annex 10,provide a high-integrity, high-accuracy and all-weather global navigation service. The full implementation of GNSS will enable aircraft to navigate in all types of airspace, in any part of the world, using on-board avionics to receive and interpret satellite signals.

1.22 The introduction of GNSS offers the possibility for many States to dismantle some or all of their existing ground-based navigation infrastructure. However, the removal of conventional radio navigation aids should be considered with caution and after a safety assessment has demonstrated that an acceptable level of safety can be met and after consultation with users through the regional air navigation planning process.

1.23 The major benefits from the introduction of these navigation elements are summarized in Figure I-1-2.

*Editorial Note.— Renumber* subsequent paragraphs accordingly.

*Amend* Navigation section of Figure I-1-2 as follows:

| **Navigation** |
|---|
| ➢ High-integrity, high-reliability, all-weather global navigation service<br>➢ Improved four-dimensional navigation position determination accuracy<br>➢ Potential cost savings from the reduction or non-implementation of ground-based navigation aids<br>➢ More efficient airspace and airport utilization<br>➢ Provision of improved approach capabilities<br>➢ Potential to reduce pilot workload<br>➢ Ability to reduce the environmental impact through flexible routing |

## Chapter 2

## ICAO'S PLANNING STRUCTURE FOR CNS/ATM
## APPENDIX A TO CHAPTER 2

## STATEMENT OF ICAO POLICY ON CNS/ATM SYSTEMS IMPLEMENTATION AND OPERATIONS
### 6. GLOBAL NAVIGATION SATELLITE SYSTEM

The global navigation satellite system (GNSS) is being implemented as an evolutionary progression from existing global navigation satellite systems, including the United States' global positioning system (GPS), and the Russian Federation's global orbiting navigation satellite system (GLONASS). States may obtain better control over the use of GNSS through the deployment of independent, interoperable systems or the implementation of augmentation systems, e.g. satellite-based augmentation systems or ground-based augmentation systems.

The future GNSS will consist of multiple constellations and multiple frequency signals from the core constellations GPS, GLONASS and GALILEO which is being developed by the European Union member States. GPS will be enhanced by the addition of a second civil signal on L2 and, more importantly for aviation, a third civil signal on L5 which is in a protected aeronautical radio-navigation service (ARNS) frequency band. GLONASS is also evolving to add multiple frequencies available to civil users with the advent of the GLONASS-M and GLONASS-K satellites with second civil signal on L3 in the ARNS band. The GALILEO system will offer another constellation of navigation satellites with multiple frequency signals available to civil aviation. ICAO continues to explore, in consultation with Contracting States, airspace users and service providers, the feasibility of the use of multiple, interoperable GNSS elements.

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## Chapter 6
## NAVIGATION SYSTEMS

**REFERENCES .....**

### OBJECTIVES

6.1 The navigation element of CNS/ATM systems is intended to provide an accurate, reliable and seamless global navigation (positioning) capability. Positioning is established using an appropriate mix of capabilities provided by satellite-based, self-contained navigation systems and/or ground-based navigation facilities.

### REQUIRED NAVIGATION PERFORMANCE (RNP) AND AREA NAVIGATION (RNAV)

6.2 Modern aircraft are increasingly equipped with RNAV systems, the use of which facilitates a flexible route system. The application of RNAV in various parts of the world has already been shown to provide a number of advantages over conventional station-referenced navigation and benefits such as more direct routing.

6.3 The RNP concept applies to navigation performance within an airspace and therefore affects both the airspace and the aircraft. RNP is intended to characterize an airspace through a statement of the navigation performance (RNP type) to be achieved by aircraft within this airspace. The RNP concept for en-route operations has been approved by ICAO (Annex 11, Chapter 2) and RNP types are described in the *Manual on Required Navigation Performance (RNP)* (Doc 9613).

6.4 RNP alone cannot be used in the selection of separation minima, and a decision to establish route spacing and aircraft separation minima should also take into account the level of communications, surveillance and air traffic services in the airspace concerned.

## GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

6.5 The GNSS is a global position and time determination system, which includes core satellite constellations, aircraft receivers, system integrity monitoring, and augmentation systems that enhance performance of the core constellations.

6.6 The satellite navigation systems in operation are the global positioning system (GPS) of the United States and the GLObal Navigation Satellite System (GLONASS) of the Russian Federation. Both systems were offered to ICAO as a means to support the evolutionary development of GNSS. In 1994, the ICAO Council accepted the United States' offer of the GPS, and in 1996 it accepted the Russian Federation's offer of GLONASS.

6.7 The nominal GPS space segment is composed of twenty-four satellites in six orbital planes. The satellites operate near-circular 20 200 km (10 900 NM) orbits at an incli-nation angle of 55 degrees to the equator, and each satellite completes an orbit in approximately 12 hours.

6.8 The nominal GLONASS space segment consists of twenty-four operational satellites and several spares. GLONASS satellites orbit at an altitude of 19 100 km with an orbital period of 11 hours and 15 minutes. Eight evenly spaced satellites are arranged in each of the three orbital planes, inclined 64.8 degrees and spaced 120 degrees apart.

## GNSS AUGMENTATIONS

6.9 To satisfy aviation performance requirements (accuracy, integrity, availability and continuity of service) for all phases of flight and to enable a degree of independent monitoring, GPS and GLONASS require varying levels of augmentation. Augmentations are classified in three broad categories: aircraft-based, ground-based and satellite-based (see Table I-6-1).

### Aircraft-based augmentations

6.10 Aircraft-based augmentation system (ABAS) integrates the information obtained from GNSS with other information available on board the aircraft. One form of ABAS is receiver autonomous integrity monitoring (RAIM), which uses only characteristics inherent in the core GNSS constellation. If signals of more than four satellites with suitable geometry are received, RAIM makes use of the redundant information to provide an integrity check.

6.11 Other aircraft-based augmentations can also be implemented and are usually termed aircraft autonomous integrity monitoring (AAIM). An inertial navigation system, for example, can aid GNSS during short periods when the satellite navigation antennas are shadowed by the aircraft during manoeuvres or during periods when insufficient satellites are in view. Augmentation techniques particularly useful for improving availability of the navigation function also include altimetry-aiding, more accurate time sources or some combination of sensor inputs combined through filtering techniques.

### Ground-based augmentations

6.12 Ground-based augmentation system (GBAS), located at or near the airport, supports precision approach operations, and can also support area navigation in the terminal area as necessary. It includes two or more reference receivers that monitor satellite signals. GBAS broadcast signals are sent directly to the aircraft in the vicinity (approximately 37 km (20 NM)). These signals provide corrections to locally increase the position accuracy and provide satellite integrity information. This capability requires a VHF ground-to-air data broadcast channel. Standards for a ground-based system which can provide an area

navigation service in a larger area are under development (ground-based regional augmentation system (GRAS).

**Satellite-based augmentations**

6.13 Satellite-based augmentation system (SBAS) provides augmentation coverage over large areas. SBAS uses a network of monitoring stations to collect information about the signals from each of the navigation satellites and broadcasts differential corrections and integrity data over a wide area using goestationary satellites. The provision of satellite-based augmentation by geostationary satellites has certain limitations and in many cases cannot be expected to support all phases of flight, especially precision approach and landing. Since these satellites orbit above the equator, their signals would not be available in polar regions and may be masked by aircraft structure or terrain. This suggests that other GNSS augmentation satellite orbits and/or ground-based augmentation might need to be considered to alleviate these shortcomings for certain regions or operations.

## FUTURE GNSS SIGNALS AND THEIR COMBINED USE

6.14 GPS and GLONASS are being enhanced to provide additional signals on protected frequencies. GALILEO is being developed to provide an additional constellation of navigation satellites also providing multiple signals on several frequencies. The increasing number of GNSS signals and constellations has the potential to offer significant benefits to civil aviation including improved performance and robustness, GNSS ground architecture simplification and alleviation of institutional concerns. The introduction of these new elements also raises some technical and institutional issues. As these future signals and system elements are developed, ICAO will provide guidance to States as to how to best make use of these additional signals and elements in combination and to maximize the opportunities from the capabilities being offered.

## AVIONICS

6.15 GNSS receivers that do not include ABAS, SBAS or GBAS capability (or future forms of integrity monitoring) generally cannot meet aviation navigation requirements.

6.16 Multi-sensor systems, using GNSS as one of the sensors, are expected to be in use operation for the foreseeable future. Such navigation systems exhibit more reliable performance than the individual sensor or stand-alone systems. Aircraft using multi-sensor navigation systems, such as integrated combinations of GNSS, IRS and DME, may provide higher service availabiity which could not be obtained by use of GPS or GLONASS alone.

## COORDINATE DATA

6.17 The successful global implementation of satellite navigation is predicated on the existence of a coordinate and procedures database of a very high accuracy and integrity. Reliable satellite navigation is only possible when the coordinates, derived from the navigation database of waypoints are of the required quality.

6.18 In support of evolving navigation techniques, ICAO adopted WGS-84 as the common geodetic reference datum for civil aviation with an applicability date of 1 January 1998 (Annex 15). Implementation of WGS-84 involves, among other things, the possibility of coordinate conversion for non-critical points (e.g. obstacles en-route) and preferred resurveying of all critical points needed to high quality (e.g. runway threshold) to WGS-84.

6.19 Aeronautical databases are built and updated through the use of surveys of existing navigation aids, position fixes and runway thresholds and through the design of new routes or approach procedures. Systems are to be in place to ensure the accuracy, integrity and resolution of position data from the time of the survey, to the submission of information to the next intended user. Aeronautical databases must be updated on a regular basis.

**EVOLUTIONARY INTRODUCTION**

6.20 GNSS implementation will be carried out in an evolutionary manner, allowing gradual system improvements to be introduced. Near-term applications of GNSS are intended to enable the early introduction of satellite-based area navigation without any infrastructure investment, using the core satellite constellations and integrated multisensor airborne systems. The use of these systems already allows for increased reliability of non-precision approach operations at some airports.

6.21 Other applications will make use of existing satellite navigation systems with some type of augmentation, or combination of augmentations required for operation in a particular phase of flight. Longer-term applications will apply to future GNSS.

6.22 GNSS-based operations can be approved with a variety of operational procedures, depending on the GNSS level of service and the operational requirements. These procedures can be very specific, either to particular types of aircraft (based on equipage), the type of operation (e.g. non-precision approach), any unique characteristics of the operation (e.g. ability to conduct approaches along curved path segments), or a specific location (e.g. airspace with low traffic density). Periods of system unavailability must be operationally managed through NOTAMs or an equivalent notification to the users. Some States have approved the use of GNSS where the user is responsible for deciding if there is an operationally significant outage.

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| *Editorial Note.*— | Original paragraph 6.25 has been moved and modified. It is now paragraph 6.28. |

6.23 Operational approvals for aircraft are issued for particular operations and normally identify specific conditions or restrictions to be applied. To this end they may vary from State to State, and from operation to operation.

6.24 GNSS approval may facilitate the withdrawal of specific conventional ground-based radio navigation services. The withdrawal of ground-based navigation services should, however, be undertaken with due consideration to the need for and methods of mitigating GNSS vulnerabilities (see 6.27). The air navigation service provider must then provide a navigation service to all users concerned to support all relevant phases of flight without reliance on any conventional ground-based means of navigation. It is therefore necessary to harmonize any withdrawal of conventional navaids with the introduction of GNSS navigation service. These considerations are not applicable to airspace where conventional ground-based navigation aids are currently not available and GNSS alone can be introduced to benefit GNSS-equipped users.

6.25 When introducing GNSS-based services, each State shall identify the elements of GNSS that are to be approved (e.g. GPS, GLONASS, and augmentation systems) and develop an implementation plan. The cost of implementing SBAS and GBAS should be tied to the provision of user benefits and increased airspace efficiency associated with area navigation and the potential to support lower decision altitude/height to more runways. Where navigation services such as VOR, DME and ILS already exist, States could credit the economic savings associated with the decommissioning of ground-

based navigational aids although the costs associated with the transition need to be fully understood and taken into account.

6.26 Advantages of GNSS include the provision of navigation service for en-route through non-precision approach operations where the coverage of ground-based navigation aids does not exist or is limited. In such an environment, GNSS becomes the only navigation service as soon as it is introduced. Approaches with GNSS-based vertical guidance to runways that currently only have a non-precision approach capability will provide further advantages in terms of increased safety and operational efficiency.

## MITIGATION OF GNSS VULNERABILITIES

6.27 A number of GNSS vulnerabilities have been identified, in particular the risk of intentional interference or jamming. Adequate mitigations have been identified, including use of inertial navigation systems, procedures, and terrestrial aids. Additional mitigations will be available with the provision of new GNSS signals and constellations. States should assess the vulnerability for their airspace and select mitigations depending on the nature of the air traffic in the airspace in question and the operations that must be supported. The appropriate mitigations will ensure safe operations in the transition to GNSS and enable States to reduce existing terrestrial navigation aids, avoid the provision of new terrestrial navigation aids, and discontinue them in certain regions. To date, no vulnerabilities have been identified that could not be addressed by appropriate mitigation methods thus confirming the ultimate goal of transition to GNSS as a global system for all phases of flight.

## SYSTEMS TO SUPPORT APPROACH, LANDING AND DEPARTURE OPERATIONS

6.28 The standard non-visual aids for precision approach and landing are defined in Annex 10, Volume I, Chapter 2. It is intended that the introduction and application of these non-visual aids will be in accordance with the global strategy set forth in Annex 10, Volume I, Attachment B. Based on all relevant considerations, this strategy is to:

a) continue ILS operations to the highest level of service as long as operationally acceptable and economically beneficial while making every effort to ensure airport access is not denied to ILS equipment aircraft;

b) implement MLS where operationally required and economically beneficial while making every effort to ensure airport access is not denied to ILS-equipped aircraft;

c) implement GNSS with augmentation as required for APV and Category I operations where operationally required and economically beneficial;

d) promote the development and use of a multi-modal airborne landing capability;

e) promote the use of APV operations, particularly those using GNSS vertical guidance, to enhance safety and accessibility;

f) identify and resolve operational and technical feasibility issues for GNSS with ground-based augmentation system (GBAS) to support Category II and III operations. Implement GNSS for Category II and III operations where operationally required and economically beneficial; and

g) enable each region to develop an implementation strategy for these systems in line with the global strategy.

## GENERAL TRANSITION ISSUES

6.29 Guidelines for transition to the future systems encourage equipage by users for the earliest possible accrual of systems benefits. Provision and carriage of terrestrial and satellite-based navigation equipment are required during the transition period when the reliability and availability of a new system must be proven. Appendix A to this chapter lists the guidelines that States, regions, users, service providers and manufacturers should consider when developing GNSS or when planning for its implementation.

## APPENDIX A TO CHAPTER 6
## GUIDELINES FOR TRANSITION TO NAVIGATION SYSTEMS

- GNSS should be introduced in an evolutionary manner, with improvements in GNSS capability generating increasing benefits, and culminating in GNSS supporting all phases of flight. As GNSS evolves, the planning for the removal of ground-based navigation aids should take account of the issues described below:

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

- States/regions can consider segregating traffic according to navigation capability and granting preferred routes to aircraft with better navigation performance where this can be done without reducing airspace capacity.

- Before any existing ground infrastructure is considered for removal, users shall be given reasonable transition time to allow them to equip with GNSS to attain equivalent navigation service.

- As GNSS is introduced for enroute operation, States/regions should coordinate to ensure that harmonized separation standards and procedures are developed and introduced concurrently in all flight information regions along major traffic flows to allow for a seamless transition to GNSS-based navigation.

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

  a) maintaining or improving the current level of safety;

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

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

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

e) appropriate level of user equipage with GNSS capability;

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

g) density of traffic/frequency of operations;

h) mitigation of risks associated with radio frequency interference failures and ionospheric issues.;

i) design and implementation of procedures; and

j) over-all economics and lead times to introduce aircraft avionics requirements.

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## Chapter 12 ORGANIZATIONAL AND INTERNATIONAL COOPERATIVE ASPECTS

12.11 The GNSS will initially be composed of a satellite systems that provide standard positioning service and system augmentations, which may have wide area or local area coverage. System augmentation is required for meeting certain performance requirements. Positioning signals are being offered free of charge by the two provider States concerned: at least up to the year 2010 by the Russian Federation (the GLONASS system) and, for the foreseeable future, with six years' advance notice of any change to that policy, by the United States ( GPS). Both these systems are originally military systems, which are being made available for civilian use. Unless these systems are replaced by (civilian) systems requiring financial commitments from the civil establishment worldwide, the provision, as opposed to the use, of the standard positioning service does not appear to be dependent on organizational issues needing to be addressed by States other than the provider States. The GALILEO core satellite constellation, being developed by the European Union member States, is intended to be a civil controlled and operated system designed to fulfil the requirements of a variety of users including civil aviation. Similar to GPS and GLONASS, GALILEO Open Service will provide a positioning service to aviation free of direct user charges.

12.12 System augmentation gives rise to somewhat different considerations. For example, SBAS could be provided by the same State(s) or entity that operates a core satellite constellation providing global standard positioning service. However, a group of States or a regional organization might also undertake to operate the augmentation satellite service required, either by themselves or by contracting with a commercial or government organization to do so on their behalf. Thus, the same type of options as outlined in 12.8 above apply. In each instance, costs would be incurred that would presumably need to be recovered. From an organizational point of view, such augmentation would in fact be a multinational facility or service to which the guidance material on the provision and operation of multinational facilities and services, which is addressed later in this chapter, could apply, as long as the augmentation is primarily to serve civil aviation. On the other hand, if civil aviation is only going to be a minority user of the augmentation services provided, and the entity will provide augmentation services worldwide, a joint concerted approach through, for example, ICAO, a regional air navigation services providers association, or an international aviation user association, for dealing with the service provider, may be the most appropriate.

12.13 Augmentation with local coverage would most likely not require international involvement provided that the facility meets the specifications and Standards required for it to be listed as an international civil aviation facility. The facility itself could be provided by the national or local government or under contract by a commercial entity.

12.14 To capture the benefits associated with GNSS, the implementation of RNAV is essential. This will require a harmonized approach to the implementation of RNP and RNAV.

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