Doc 8071

Manual on Testing of Radio Navigation Aids

Volume II
Testing of Satellite-based Radio Navigation Systems

Approved by the Secretary General
and published under his authority

Fifth Edition — 2007

International Civil Aviation Organization

Published in separate English, French, Russian and Spanish editions by the International Civil Aviation Organization. All correspondence, except orders and subscriptions, should be addressed to the Secretary General.

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11/06

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AMENDMENTS

Amendments are announced in the supplements to the *Catalogue of ICAO Publications;* the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS		
No.	Date	Entered by

CORRIGENDA		
No.	Date	Entered by
1	30/4/08	ICAO

FOREWORD

The need for uniform navigational guidance signals and consistent system performance for radio navigation aids used in the international aeronautical services has been recognized as an important adjunct to safety and regularity in civil aviation. ICAO continuing air navigation policies, and associated practices of the Organization in their part concerning ground and flight testing of radio navigation aids, call attention to this need and encourage improvements in radio navigation ground equipment, including associated testing and monitoring facilities, with the view to minimizing, to the extent practicable, the more demanding requirements of flight testing. Annex 10, Volume I, 2.7, provides an international Standard on the ground and flight testing of radio navigation aids.

This new edition of Volume II of Doc 8071 was developed by the Testing of Radio Navigation Study Group (TRNSG) to provide guidance on testing of satellite-based radio navigation systems. This edition of Volume II contains guidance on testing of non-precision approach (NPA) procedures using an aircraft-based augmentation system (ABAS), guidance on testing of a satellite-based augmentation system (SBAS) and a ground-based augmentation system (GBAS), as well as on the flight validation of instrument flight procedures.

The purpose of this document is to provide general guidance on the extent of testing and inspection of GNSS-based procedures. The guidance is representative of practices existing in a number of States.

Comments on this volume would be appreciated from States and other parties outside ICAO concerned with satellite radio navigation systems development and provision of services. Comments, if any, should be addressed to:

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Montréal, Quebec
Canada H3C 5H7

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LIST OF ACRONYMS

ABAS	Aircraft-based augmentation system
AIP	Aeronautical Information Publication
ANS	Air navigation services
APV	Approach with vertical guidance
ARNS	Aeronautical radio navigation service
ATC	Air traffic control
ATS	Air traffic services
CMC	Code minus character
COP	Change-over point
CRC	Cyclic redundancy check
CSA	Channel of standard accuracy
CW	Continuous wave
DF	Direction finding
DME	Distance measuring equipment
DOP	Dilution of precision
DSP	Digital signal processing
FAS	Final approach segment
FDE	Fault detection and exclusion
FDMA	Frequency division multiple access
FM	Frequency modulation
FTP	Fictitious threshold point
GAD	Ground accuracy designator
GBAS	Ground-based augmentation system
GCID	Ground continuity and integrity designator
GLONASS	GLObal NAvigation Satellite System
GNSS	Global navigation satellite system
GPS	Global Positioning System
HAT	Height above threshold
HDOP	Horizontal dilution of precision
HFOM	Horizontal figure of merit
IAP	Instrument approach procedure
IFR	Instrument flight rules
IGP	Ionospheric grid points
ILS	Instrument landing system
IMP	Intermodulation products
INS	Inertial navigation system
ITU	International Telecommunication Union
LTP	Landing threshold point
MAPt	Missed approach way-point
MEA	Minimum en-route altitude
MHA	Minimum holding altitude
MOC	Minimum obstacle clearance
MOCA	Minimum obstacle clearance altitude
MRA	Minimum reception altitude
MTBO	Mean time between outages
NOTAM	Notice to airmen

NPA	Non-precision approach
NSE	Navigation system error
PDOP	Position dilution of precision
RAIM	Receiver autonomous integrity monitoring
RF	Radio frequency
RFI	Radio frequency interference
RNAV	Area navigation
RNSS	Radio navigation satellite service
ROC	Required obstacle clearance
RPDS	Reference path data selector
RSDS	Reference station data selector
SA	Selective availability
SARPs	Standards and recommended practices
SBAS	Satellite-based augmentation system
SPS	Standard positioning service
TDMA	Time division multiple access
TV	Television
UHF	Ultra-high frequency
UTC	Coordinated universal time
VDB	VHF data broadcast
VHF	Very high frequency
VMC	Visual meteorological conditions
VOR	VHF omnidirectional radio range

Chapter 1

GENERAL

1.1 INTRODUCTION

1.1.1 Annex 10, Volume I, Chapter 2, 2.7 states, “Radio navigation aids of the types covered by the specifications in Chapter 3 [of Annex 10, Volume I] and available for use by aircraft engaged in international air navigation shall be the subject of periodic ground and flight tests”.

1.1.2 This volume of the *Manual on Testing of Radio Navigation Aids* addresses the Global Navigation Satellite System (GNSS). A general description of GNSS elements is contained in Attachment 1 to Chapter 1. This document contains guidance material only. The tests and procedures outlined do not have the status of Standards or Recommended Practices (SARPs) except for identified quotations from Annex 10.

1.2 PURPOSE OF THE DOCUMENT

This document is intended to provide general guidance on the testing and inspection to be carried out to ensure that GNSS procedures, using the SARPs specified in Annex 10, Volume I, Chapter 3, 3.7, are appropriate for aviation use.

1.3 SCOPE OF THE DOCUMENT

1.3.1 This document describes the ground and flight testing to be accomplished for a specific radio navigation aid. This volume addresses GNSS systems, and while maintaining the same format as Volume I, it adopts a change in philosophy to focus on total system performance rather than concentrating on detailed measurement of individual parameters.

1.3.2 Information is provided on measurement practices and special test equipment; however, it is not intended to recommend certain models of equipment, but rather to provide general information relative to the systems under consideration.

1.3.3 System testing is addressed in this document in general terms. System testing is normally done as part of design and development activities, prior to volume production and individual site installations. System testing includes design qualification testing, operational test and evaluation, and “shakedown” tests.

1.3.4 In this document, the terms “testing” and “inspection” have the following meanings:

— *Testing: A specific measurement or check of facility performance that may form a part of an inspection when integrated with other tests.*

— *Inspection: A series of tests carried out by a State authority or an organization as authorized by the State to establish the operational classification of the facility.*

1.3.5 GNSS navigation relies on real-time calculation of satellite and augmentation system information to determine position relative to the World Geodetic System — 1984 (WGS-84) geodetic reference datum. Testing is accomplished by dividing the GNSS architecture into the space-to-earth signals, from core satellite constellation(s), augmentation information and signals and procedure definition, including the integrity of the navigation database.

1.3.6 Operation of the core satellite constellation elements, such as the Global Positioning System (GPS) or the GLObal NAvigation Satellite System (GLONASS), is the responsibility of States or the designated authority providing the service. In general these elements are not tested as part of the ground or flight testing of a particular procedure. The exception is the confirmation that the spectrum used is free from harmful interference. Throughout the tests described, accuracy of the space-to-earth signals is not measured.

1.3.7 Augmentation systems external to the aircraft, such as the satellite-based augmentation system (SBAS) and the ground-based augmentation system (GBAS), are evaluated in accordance with this manual. Where particular performance is required by SARPs, appropriate ground and flight tests are described. The aircraft-based augmentation system (ABAS) is considered to be the subject of airworthiness certification and this volume provides for testing of ABAS-based procedures rather than this system testing.

1.3.8 The design of procedures requires the coding of geodetic information in a form usable by the on-board navigation system. Tests are described for the assessment of procedures for their data accuracy and operational suitability. Verification of data is limited to point of publication in the State's Aeronautical Information Publication (AIP) and **does not** take account of errors introduced by data packaging and distribution organizations. Data verification **does** include systems which transmit the data set as part of an augmentation system.

1.4 GROUND VERSUS FLIGHT TESTING/INSPECTION

General

1.4.1 The considerations for ground and flight testing/inspection as given in Doc 8071, Volume I, Chapter 1, 1.4, are also relevant for all applications of GNSS.

Testing objective

1.4.2 Ground and flight testing/inspection should serve to assess the consistency of the flight procedure as well as any influences which may lead to a local degradation in GNSS availability at the location of the inspection (e.g. interference). Ground and flight testing/inspection also assesses the performance of any local/regional GNSS augmentations.

GNSS analysis

1.4.3 When a State begins the introduction of GNSS flight procedures, an analysis should be performed of the capability of the particular GNSS architecture to provide the required performance to support the intended procedures (Annex 10, Volume I, Chapter 3, 3.7.2.4 refers). It is widely accepted that the GPS constellation of 24 satellites delivers availability of more than 99 per cent for the en-route operations and of more than 97 per cent for non-precision approach (NPA) procedures, in most parts of the world. However, this may not be true for the particular State and different GNSS core constellations. As an outcome of such analysis, the State may decide whether the safe use of GNSS requires any type of GNSS performance prediction as part of the flight preparation.

Importance of geodetic survey

1.4.4 The position information provided by GNSS is expressed in terms of the World Geodetic System — 1984 (WGS-84) geodetic reference datum. By contrast with conventional navigation systems, GNSS navigation delivers an aircraft to a point in space defined in a database and not to a terrestrial fixed point such as an antenna location. This change in concept places a high demand on the integrity of all survey data used in preparation of the flight procedure and in the on-board navigation system. It is mandatory that a State authorizing GNSS flight procedures maintain an appropriate quality assurance system covering all domains of data collection (survey), processing and publication. SARPs applicable to WGS-84 and aeronautical data are provided in Annexes 4, 11, 14 and 15.

GNSS monitoring

1.4.5 A State providing GNSS services for aviation should continuously perform a suitable monitoring and assessment of the GNSS signal-in-space (Annex 10, Volume I, Chapter 2, 2.4.3 refers). Such activity can detect any long-term trends which may affect GNSS performance within the airspace where GNSS-based operations are authorized by this State. There is no requirement to perform such a determination for any location in particular. The activities may be performed in the following domains:

Coordinate survey stability

1.4.5.1 While some parts of the world may experience a very stable relationship between their local WGS-84 coordinates and the core GNSS constellations, other parts may experience a physical movement relative to an earth-centred, earth-fixed reference system. The magnitude of such effects should be assessed prior to commencing GNSS operations. Appropriate mitigation schemes (e.g. periodic measurement campaigns, extrapolation computations) may be considered to limit the influence of such effects. It should be noted that the possibly small annual magnitude of coordinate shifts may build up to produce larger effects over longer periods of time.

GNSS availability

1.4.5.2 Subsequent to establishing the overall availability of GNSS in a particular State (as outlined in 1.4.3), proper means should be in place to assess the long-term evolution of a satellite system's availability to support GNSS operations. The purpose of this analysis is to determine whether any change has occurred to the conditions that were considered acceptable when the use of GNSS was originally authorized by this State, and to provide an indication whenever GNSS does not perform within the limits specified in the SARPs.

Interference

1.4.5.3 A traceability record should be maintained of all incidents involving interference from both in-band and out-of-band sources with the GNSS frequencies in use in a particular State. This record may be derived in several ways, including incident reports from local ground and/or flight inspections, use of special receivers for long-term monitoring of any frequency interference, or by incident reports from the airspace users.

Record keeping

1.4.6 The data derived from ground and flight test/inspection should be kept for a period of time as described in Attachment 2 of Chapter 1, Volume I of Doc 8071. The data derived from monitoring (see 1.4.5) should be kept for a time period appropriate to assess the influence of long-term effects. Data pertinent to accident and incident investigations should be retained until they are no longer required.

Availability prediction software

1.4.7 Software with an almanac applicable to the time of the flight test should be used to verify that minimum satellite geometry requirements are met for the full duration of the flight test. This will prevent unnecessary flight test attempts when the geometry does not support accuracy requirements. Such a prediction will also allow a clearer distinction between availability alarms triggered by insufficient satellite coverage and those caused by interference.

GPS selective availability

1.4.8 GNSS (GPS) specifications in Annex 10, Volume I, take into account the termination, as of 1 May 2000, of the selective availability (SA) feature of GPS. It should be noted that basic GPS receivers employing receiver autonomous integrity monitoring (RAIM), designed to operate with “SA-on” cannot take advantage of improved GPS availability resulting from the SA termination.

1.5 CATEGORIES AND PRIORITIES OF TESTS AND INSPECTIONS

1.5.1 It is difficult to define requirements for intervals between various types of tests/inspections due to many associated factors specific to different States. Factors such as stability of equipment, extent of monitoring, geographical area, weather, quality of maintenance crews, standby equipment, etc., are all related. The period between tests/inspections of a new facility should be short during the early months of operation and may be extended as satisfactory experience is gained.

1.5.2 This document contains suggested schedules for each augmentation system type. The schedules should be considered (and modified, if necessary) based on the conditions relevant to each State and each site. The manufacturer’s instruction manual will usually contain recommendations that may be useful in this regard. Facility testing can be considered in the following general categories:

Ground testing/inspection

1.5.3 *Site proving:* Tests carried out at proposed sites for the ground facility to prove suitability. Portable ground installations are used for this purpose.

1.5.4 *Initial proof of performance:* A complete inspection of the facility after installation and prior to commissioning to determine that the equipment meets the Standards and manufacturer's specifications.

1.5.5 *Periodic:* Regular or routine inspections carried out on a facility to determine that the equipment continues to meet the Standards and manufacturer's specifications.

1.5.6 *Special:* Tests after a failure of the facility or other circumstances that indicate special testing is required. Special tests will often result in appropriate maintenance work to restore the facility and a special flight inspection, if required.

Flight testing/inspection

1.5.7 *Site proving:* A flight test conducted at the option of the responsible authority to determine the effects of the ground environment at the proposed location on the performance of the planned facility or procedure.

1.5.8 *Commissioning:* An extensive flight inspection to establish the validity of the procedure and augmentation signals.

1.5.9 *Periodic:* Flight inspection to confirm the validity of the procedure and augmentation signals on a regular basis.

1.5.10 *Special:* Flight inspection required to investigate suspected malfunctions, aircraft accidents, etc. It is ordinarily only necessary to test those parameters which have or might have an effect on performance during special flight inspections. It may be economically advantageous in many cases to complete the requirements for a periodic or annual inspection.

Priority of inspections

1.5.11 Flight inspections should be scheduled and conducted using a priority system. Each State's aeronautical authority should define a priority for procedures based on GNSS information, until a general experience exists about the behaviour and use of GNSS navigation. The following is a suggested grouping of priorities, which is similar to that for ground-based systems:

a) *Priority 1:* Accident investigation, restoration of established facilities after unscheduled outages, and investigation of reported malfunctions.

b) *Priority 2:* Periodic inspections, commissioning of newly installed facilities, associated instrument flight procedures, and evaluations of proposed sites for new installations.

1.6 OPERATIONAL STATUS

Facility and/or procedure status can be identified as follows:

a) *Usable:* Available for operational use.

   i) *Unrestricted:* Providing safe and suitable conditions conforming to established Standards within the required airspace.

ii) *Limited or restricted:* Providing guidance not conforming to established Standards in all respects or in all sectors of the coverage area, but safe for use within the restrictions defined. It is extremely important that no procedure or facility which could be unsafe be classified as limited.

b) *Unusable:* Not available for operational use, or providing unsafe or erroneous guidance, or providing signals of an unknown quality.

1.7 AUTHORITY FOR STATUS DETERMINATION

The responsibility for determining procedure and facility status rests with the appropriate State authority or the organization authorized by the State.

1.8 NOTIFICATION OF CHANGE OF STATUS

1.8.1 Notification of a change of procedure or facility status is to be done through appropriate AIPs; differences from Standards are to be notified to ICAO and through NOTAMs.

1.8.2 Day-to-day changes in the status of procedures and facilities are to be promptly and efficiently advertised. A change in the status of a procedure or commissioned facility as a direct result of ground or flight inspection procedures, and resulting in a “usable” (“unrestricted”, “limited” or “restricted”) or “unusable” designation, should be advertised immediately by air traffic control (ATC) personnel and promptly by a NOTAM.

1.8.3 A facility having an “unusable” status is normally removed from service and can operate only for test or troubleshooting purposes.

1.9 AIRBORNE AND GROUND TEST EQUIPMENT REQUIREMENTS

The selection and utilization of special ground or flight inspection equipment used to determine the validity of navigation information and approach procedures should minimize the uncertainty of the measurement being performed. This equipment should be periodically calibrated to ensure traceability of measurements to appropriate standards.

1.10 COORDINATION BETWEEN GROUND AND FLIGHT TEST/INSPECTION

1.10.1 Comparison of the results obtained during successive ground and flight tests/inspections can determine the extent of the degradation of the performance of the procedure or facility. These results can also be used to determine the choice of the periodicity of the flight test/inspection.

1.10.2 Flight test/inspection may involve a coordinated effort with ground specialists making adjustments or participating in the flight test/inspection. Efficient two-way communications should be established between ground and air. An additional very high frequency (VHF) transceiver is often installed in the aircraft and a portable unit employed at the facility to provide this without interfering with the normal aircraft communications with air traffic control.

1.10.3 After comparing the results obtained during successive ground and flight tests/inspections, the flight inspector may incorporate some of the results in the flight inspection report, with the purpose of providing a more detailed and controlled record of the history of the facility/procedure.

1.11 FLIGHT INSPECTION UNIT

General

1.11.1 This section should be read in conjunction with Section 1.11 of Chapter 1, Volume I. Further information specific to GNSS is given in this section.

1.11.2 GNSS flight inspection differs from conventional radio navigation aid inspection in that it does not attempt to verify the accuracy of the raw signals transmitted from the satellites. It is more concerned with verification of the associated procedures and of the radio environment in which the navigation signals are received. The only exception is GBAS where the coverage of the augmentation signal is verified using similar procedures to those used for terrestrial navigation aids.

Position-fixing systems

1.11.3 For inspection of NPA procedures, an independent position-fixing system is not necessary. The pilot will assess the position guidance throughout the approach and confirm that obstacle clearance is sufficient and that the guidance delivers the aircraft to a suitable position from which to complete the landing.

1.11.4 For inspection of Category I GBAS procedures, a positioning system is not required, but may be used, depending upon regulatory requirements of individual States. Although no accuracy tolerances are defined, if a GNSS-based positioning system is used its independence should be demonstrated, i.e. there must be no common-mode errors between the GBAS and positioning system. For example, for code-based GBAS, a carrier-based position-fixing system may be used. Alternatively, a non-GNSS based position-fixing system may be used.

Flight inspection aircraft

1.11.5 The inspection aircraft should be fitted with certified GNSS aerials having known polar diagrams and gain. Consideration should be given to fitting an additional aerial on the underside of the aircraft for interference investigations.

1.11.6 For NPA inspection, a much simplified flight inspection aircraft may be used. The aircraft should be fitted with a Basic GNSS receiver (see Chapter 2, 2.1.1), or an acceptable equivalent, and a properly installed external aerial. Temporary internal aerials may not be suitable since there is no traceability of their polar diagram or gain. No other specialized equipment need be carried. In the event of this simplified inspection aircraft detecting any problems, further inspection should be made using a fully-equipped aircraft.

1.11.7 More information regarding flight inspection aircraft is provided in Attachment 2 to this chapter.

Flight inspection crew

1.11.8 For flight inspection of GNSS precision approach procedures, the crew should be trained in all aspects of GNSS inspection. This training should include the use of appropriate position-fixing systems where these are required for the inspection.

1.11.9 For NPA inspection, an inspection pilot should at least be familiar with approach procedure inspection and should be sufficiently trained to recognize any anomalous output from the receiver which would signify the need for more detailed inspection with a fully-equipped aircraft and crew.

1.11.10 A specialized navigation aid inspector who is qualified to commission instrument approach procedures is required for NPA procedure inspection.

1.12 ORGANIZATION AND QUALITY

Information on this topic is contained in Chapter 1 of Doc 8071, Volume I.

1.13 ELECTROMAGNETIC INTERFERENCE

1.13.1 Attachment 3 to this chapter provides guidance on this subject specifically for GNSS, including types of interference, possible sources, methods of detection and mitigations which can be used to eliminate or reduce the interference effects.

1.13.2 Additional guidance is available in RTCA document DO-235A, Assessment of Radio Frequency Interference Relevant to the GNSS.

1.14 SPECTRUM ANALYSIS

Information on this topic is contained in Attachment 3 to this chapter.

1.15 GROUND AND FLIGHT INSPECTION PERIODICITY

General

1.15.1 The determination of periodicity for ground and flight inspection should be based on a risk assessment of out-of-tolerance performance, which is not detected by the implemented monitoring system. Events which should be considered in determining the requirement for inspection include:

a) change in procedure and/or data set;

b) equipment failure and instability; and/or

c) environmental changes, particularly those that may cause RF interference.

Ground testing/inspection

1.15.2 Ground-based augmentation should be inspected at commissioning, configuration change (including software changes), and at periodic intervals based on equipment reliability. In considering equipment reliability it is appropriate to take into account the influence of a sub-assembly on the integrity of the guidance information provided by the total system. For example, the failure of a monitor may leave equipment in a state that will provide out-of-tolerance information in the case of a subsequent failure of the processing or transmission system. Other assembly failures may result in a reduced service volume; however, the information provided within the reduced volume is unaffected and within tolerance. For precision approach facilities, assemblies with significant influence on the integrity of provided information should be checked on a semi-annual or manufacturer's recommendation basis, whichever is more frequent.

Flight testing/inspection

1.15.3 Flight tests should be completed prior to commissioning, at the implementation of system configuration changes including procedure changes, and on a periodic basis based on environment changes. Flight tests are to ensure the system performance in the airborne operating environment is satisfactory. The requirement for and the extent of a flight test required by a configuration change should be assessed based on the influence the change has on airborne performance and the validity of ground testing in characterizing the airborne performance. Periodic flight tests should be scheduled based on the rate of change in the environment at the procedure's location. For precision approach facilities a nominal interval of 12 months is suggested.

1.16 FLIGHT INSPECTION AT NIGHT

1.16.1 Information on this topic is contained in Chapter 1 of Doc 8071, Volume I. It is recommended that each State develop procedures according to the aircraft and flight inspection system used, as well as the characteristics of the terrain.

1.16.2 GNSS signals are susceptible to the effects of increased solar activity on the ionosphere. This may cause differences between night and day flight tests.

1.17 USE OF GNSS TO SUPPORT MULTI-SENSOR AREA NAVIGATION (RNAV) PROCEDURES

GNSS may also be used to support multi-sensor RNAV approach procedures. In this case, GNSS is being used in the same way as in the stand-alone procedures covered in Chapter 2 and the relevant sections of these procedures are applicable.

1.18 GNSS DESIGN QUALIFICATION

1.18.1 A new equipment design of any navigation system is subject to design qualification or type approval. For GNSS equipment, greater emphasis on design qualification testing reduces the need for the more extensive ground and flight testing typical of other navigation systems. For example, in the case of GBAS, this is possible in part because GBAS broadcast antennas are less complex than those of ground-based navigation systems, and because the accuracy and integrity of the VDB signal is robust against propagation effects. Moreover, GNSS design involves complex algorithms and statistical parameters that can only be demonstrated through analyses, simulations, and long-term measurements at design qualification.

1.18.2 Design qualification is outside the scope of this document; the following brief information is provided to make States aware of the type of design qualification activities that are assumed to have been completed before carrying out the site-specific procedures given in this document. Design qualification should include general GBAS standards, design standards, manufacture, quality and support procedures and documentation requirements. These procedures would normally be carried out on only the first equipment as part of the design qualification process. The design qualification also includes tests in an operational environment. If no serious problems are encountered at typical sites, assessments and tests performed during design qualification may not be repeated for future production units. Items to be addressed during design qualification include:

a) *Safety assessment:* A system safety assessment should be conducted by the manufacturer of a GNSS element to provide evidence that the system meets the safety requirements as part of the overall design qualification requirements. The safety assessment process includes specific assessments conducted and updated during system design and development and interacts with the system development supporting processes. The requirements for conducting safety assessments may vary on a national or regional basis.

b) *Hardware/software design assurance:* The roles of hardware and software in implementing the functional requirements of a system must be clearly specified and justified. The partitioning of functions between hardware and software should take into account safety criticality, testability, reliability, verification and validation, maintainability, and life cycle costs. System development assurance level (defined in RTCA and EUROCAE documents) will be based upon the contribution of hardware/software to potential failure conditions as determined by the System Safety Assessment Process. The hardware/software level of development implies that the level of effort required to show compliance with the safety requirements varies with the failure condition category.

c) *Environmental performance:* These tests show that the equipment meets the performance requirements under the range of environmental conditions specified by the purchaser or manufacturer.

ATTACHMENT 1 TO CHAPTER 1

GNSS SYSTEM DESCRIPTIONS

1. CORE SATELLITE CONSTELLATIONS

The core satellite constellations, GPS and GLONASS, are currently defined in Annex 10, Volume I, Chapter 3, 3.7 and Appendix B.

2. GLOBAL POSITIONING SYSTEM (GPS)

2.1 GPS is a satellite-based radio navigation system which utilizes range measurements from the GPS satellites to determine precise position and time anywhere in the world. The system is managed for the Government of the United States by the United States Air Force, the system operator.

2.2 The Standard Positioning Service (SPS) provides a coarse acquisition code (C/A-code) centred at the L1 frequency (1 575.42 MHz).

2.3 Selective Availability (SA) is a set of techniques for denying the full accuracy and selecting the level of positioning, velocity and time accuracy of GPS available to users of the SPS signal. GPS SA was discontinued as of 1 May 2000.

2.4 The GPS has three major segments: space, control and user.

2.5 The GPS space segment is composed of 24 satellites in six orbital planes. The satellites operate in near-circular 20 200 km (10 900 NM) orbits at an inclination angle of 55 degrees to the equator, and each satellite completes an orbit in approximately 12 hours. The satellite orbits are arranged so that a minimum of four satellites, with a position dilution of precision (PDOP) of 6 and a 5-degree mask angle, are in view to users with a global average availability of 99.75 per cent with 24 operational satellites. The satellites broadcast a pseudo-random code-based timing signal and a data message that the airborne equipment processes to obtain satellite position and status. Every satellite's exact measured orbital parameters (ephemeris data) are broadcast as part of a data message sent in the GPS signal.

2.6 The GPS control segment has five monitor stations and three ground antennas with up-link capabilities. The monitor stations use a GPS receiver to passively track all satellites in view and accumulate ranging data from the satellite signals. The information from the monitor stations is processed at the master control station to determine satellite clock and orbit states and to update the navigation message of each satellite. This information is transmitted to the satellites via the ground antennas, which are also used for transmitting and receiving health and control information.

2.7 The GPS user segment consists of an antenna and receiver-processor to receive and compute navigation solutions to provide positioning and precise timing to the user. By knowing the precise location of each satellite and precisely matching timing with the atomic clocks on the satellites, the receiver can solve four simultaneous equations for time offset and the three components of position.

2.8 Measurements from a minimum of four satellites are required to establish a three-dimensional position and time. Three satellite measurements are required to determine a two-dimensional position and time, if altitude is known. Accuracy is dependent on the precision of the measurements from the satellites and the geometry of the satellites used.

3. GLOBAL NAVIGATION SATELLITE SYSTEM (GLONASS)

3.1 The GLONASS provides signals from space for accurate determination of position, velocity and time for properly equipped users. Navigation coverage is continuous, worldwide and all weather. Three-dimensional position and velocity determinations are based upon the measurement of transit time and Doppler shift of RF signals transmitted by GLONASS satellites. The system is managed for the Government of the Russian Federation by its Ministry of Defence.

3.2 The nominal GLONASS space segment consists of 24 operational satellites and several spares. GLONASS satellites orbit at an altitude of 19 100 km (10 325 NM).

3.3 A navigation message transmitted from each satellite consists of satellite coordinates, velocity vector components, corrections to GLONASS system time and satellite health information. To obtain a system fix, a user's receiver tracks at least four satellite signals, either simultaneously or sequentially, and solves four simultaneous equations for the three components of position and time.

3.4 The Channel of Standard Accuracy (CSA) has a frequency division multiple access (FDMA). Each channel is centred on the frequency L1 = 1 602 MHz + n * 0.5625 MHz, where "n" is the frequency channel number (n = 0,1.2...). Each satellite transmits signals on its own frequency. However, those satellites placed in antipodal slots of orbit planes and not appearing at the same time in a user's view have the same frequency. After 1998, the GLONASS channels began to shift down in frequency until the spectrum range reached from 1 598 to 1 604.25 MHz.

3.5 A GLONASS navigation data message provides information regarding the status of the individual transmitting satellite along with information on the remainder of the satellite constellation. From a user's perspective, the primary elements of information in a GLONASS satellite transmission are the clock correction parameters and the satellite position (ephemeris). GLONASS clock corrections provide data detailing the difference between the individual satellite's time and the GLONASS system time, which is related to coordinated universal time (UTC).

4. AUGMENTATION SYSTEMS

4.1 Three augmentation systems — aircraft-based augmentation system (ABAS), satellite-based augmentation system (SBAS) and ground-based augmentation system (GBAS) — are currently defined in GNSS SARPs in Annex 10, Volume I, Chapter 3, 3.7 and Appendix B.

4.2 Guidance material on augmentation systems is provided in Attachment D to Annex 10, Volume I.

ATTACHMENT 2 TO CHAPTER 1

FLIGHT INSPECTION AIRCRAFT

1. GENERAL CHARACTERISTICS

Information on this topic is contained in Chapter 1 of Doc 8071, Volume I. It includes: general characteristics; aircraft instrumentation; selection of antennas; flight inspection receivers and radio communication equipment; data processing, display and recording; and regulatory aspects.

2. GNSS-UNIQUE CHARACTERISTICS

Recorded parameters

Recording of GNSS parameters during the flight test is not required for NPA. However, the parameters in Tables II-1-2-1, II-1-2-2 and II-1-2-3 can support analysis of GNSS signal anomalies or interference encountered.

GNSS antenna location

The location of the GNSS antenna is critical. Masking by aircraft surfaces (e.g. wings or winglets) should be minimized. The antenna should be on the fuselage centreline, but if this is not possible, the antenna should be shimmed to a horizontal orientation. If interference investigation is required, adequate measurement equipment (e.g. low-noise amplifier (LNA), filters, and spectrum analyser) may be necessary.

Table II-1-2-1. GNSS parameters

Parameter	*Definition*	*Purpose*
Cross track distance	The across track distance computed by the GNSS receiver or FMS with GNSS sensor.	Provides a continuous record of the total system error component perpendicular to the desired track segments.
Active way-point	The active way-point identifier.	Gives a continuous indication of the active way-point.
Distance to active way-point	Distance to the active way-point in nautical miles.	Provides a continuous record of the GNSS receiver computed distance to the active way-point.
Bearing to active way-point	Bearing to the active way-point.	Provides a continuous record of the GNSS receiver computed true bearing to the active way-point.
No. of satellites visible	The number of space vehicles visible to the GNSS sensor.	Continuous indication of the satellites in view.
No. of satellites tracked	The number of space vehicles being tracked by the GNSS sensor.	Continuous indication of those satellites for which a range solution is being tracked.

Carrier-to-noise density ratio	The carrier-to-noise density for each satellite visible to the GNSS sensor.	Continuous indication of received C/N_0 from each satellite. Useful for investigating interference problems.
HDOP	Horizontal dilution of precision.	Continuous indication of the geometric dilution of the GNSS position accuracy in the horizontal plane.
RAIM alarm	Indicator of lost GNSS signal integrity as computed by the GNSS receiver/sensor RAIM algorithm.	Continuous indication of RAIM alarm status. Can be used to investigate loss of RAIM occurrences along with other inputs such as HDOP, HFOM, aircraft attitude (roll, pitch and heading) and satellite carrier-to-noise.
Date and time	GNSS UTC date and time.	Provides an accurate time for each GNSS position solution to be compared to a reference system.
GNSS position	Present position latitude and longitude.	Provides a continuous indication of the GNSS position.

Table II-1-2-2. Flight test system parameters

Parameter	*Definition*	*Purpose*
XTKER	The across track error. Derived by calculating the position difference between the GNSS and the positioning system, and then extracting the vector component that is 90 degrees from the track heading.	Provides a continuous record of the NSE (Navigation System Error) component perpendicular to the desired track.
ATKER	The along track error. Derived by calculating the position difference between the GNSS and the positioning system, and then extracting the vector that is in the direction of the track heading.	Provides a continuous record of the NSE component in the direction of the desired track.
WPDE	Way-point displacement error is the vector sum of the XTKER + ATKER.	Can be calculated for the point at which the position reference system indicates the aircraft is abeam the way-point being checked. Includes known errors inherent in the measurement system used.
Positioning system position data	Precise position of the GNSS antenna relative to the position system reference frame.	Provides a continuous record of the GNSS antenna position.
Positioning system time	Position system time tag. Preferably in UTC or GNSS time.	Provides a continuous record position reference time for correlation with GNSS position data.
Positioning system status	Operational status of the positioning system.	Provides continuous indication of the operational status of the position reference system.

Table II-1-2-3. Interference parameters

Parameter	*Definition*	*Purpose*
RAIM warning flag	Receiver Autonomous Integrity Monitoring is able to detect excessive pseudorange errors.	Cannot discriminate between interference, shading, multipath and other anomalies.
Receiver interference flag	Some GNSS receivers are equipped with an interference detection capability.	Detects interference by monitoring of the amplitude distribution (e.g. signal is buried in the noise, therefore amplitude has Gaussian distribution, amplitude distribution is distorted by interference signal).
C/N or C/N_0	Signal-to-noise or signal-to-noise density ratio, indicates quality of signal.	C/N or C/N_0 will be degraded during reception of an interference signal. To detect degradation value, C/N or C/N_0 has to be compared with undisturbed value of satellite with same elevation angle. Attitude of aircraft has to be taken into account.
Spectrum analyser measurements	Spectrum analyser equipment can be used to monitor the input to the GNSS receiver for signal levels which exceed the receiver interference protection criteria as specified in GNSS SARPs.	This measurement is dependent on achieving a measurement noise threshold in the area of −153.5dBW for GPS non-precision approach, −150.5dBW for GPS precision approach. Assessment of CW interference signals can be achieved by comparison with interference threshold mask. Assessment of broadband and pulsed interference signals requires high effort. It is desirable to calibrate the level into the spectrum analyser relative to an isotropic antenna output.

ATTACHMENT 3 TO CHAPTER 1

INTERFERENCE ISSUES

1. GENERAL INFORMATION

Additional information on interference issues is contained in Doc 8071, Volume I, Chapter 1, Attachment 3.

2. INTERFERENCE

Potential for interference

2.1 The potential for interference exists to various extents in all radio navigation bands. As with any navigation system, the users of GNSS signals must be protected from harmful interference that results in the degradation of achieved navigation performance.

2.2 Current satellite navigation systems provide weak received signal power — meaning that an interference signal can cause loss of service at a lower receiver power level than with current terrestrial navigation systems. Potential for interference exists wherever the GNSS signal is authorized for use. GNSS is, however, more resistant to misleading navigation errors from interference signals than current terrestrial radio navigation systems.

Spectrum allocations

2.3 Both current core satellite constellations, GPS and GLONASS, operate using the radio frequency (RF) spectrum allocated by the International Telecommunication Union (ITU). States authorizing GPS- or GLONASS-based operations have an obligation to ensure that their national frequency allocations and assignments in the 1 559–1 610 MHz band do not cause interference to GPS or GLONASS aviation users. Similarly, services operating in the adjacent bands should not generate harmful interference to GPS or GLONASS.

2.4 GPS and GLONASS operate using spectrum allocated to the aeronautical radio navigation service (ARNS) and radio navigation satellite service (RNSS). GPS, GLONASS and SBAS operate in segments of the 1 559–1 610 MHz frequency band. GBAS operates in the 108–117.975 MHz band allocated to ARNS.

3. SOURCES OF INTERFERENCE

In-band sources

3.1 A potential source of in-band harmful interference is that of fixed-service operation in certain States. There are primary or secondary allocations to the fixed-service for point-to-point microwave links in certain States in the frequency band used by GPS and GLONASS.

3.2 It is expected that States authorizing GNSS operations endeavour to ensure that existing and future frequency assignments in the 1 559–1 610 MHz band with the potential to interfere with the GNSS operations be moved to other frequency bands.

Out-of-band sources

3.3 Potential sources of interference from services operating in bands outside the 1 559–1 610 MHz band include harmonics and spurious emissions of aeronautical VHF transmitters, VHF and ultra-high frequency (UHF) television (TV) broadcast stations, and other high-power sources. Out-of-band noise, discrete spurious products and intermodulation products (IMP) from radio services operating near the 1 559–1 610 MHz band can also cause interference problems.

3.4 Studies have shown that commercial VHF transmissions do not pose an operationally significant threat to GNSS users. However, further consideration should be given to this threat for specific VHF transmit antennas located in the vicinity of a runway and approach area.

3.5 Television stations do pose a threat to GNSS. Given current limitations on out-of-band emissions from TV transmitters, it is feasible for a transmitter operating within specifications to radiate significant power into the GPS L1 band. TV systems such as High Definition TV may be capable of causing significant interference to GNSS receivers. Therefore, there is a need for mitigation strategies to prevent operational impacts to GNSS aviation users operating in the airport vicinity. As the spurious emission characteristics of TV transmitters change over time (due to maintenance, weather conditions, etc.), there will be a need for an ongoing interference mitigation strategy on the behalf of the affected air navigation services provider.

On-board sources

3.6 The potential for harmful interference to GPS and GLONASS on an aircraft depends on the individual aircraft, its size, and what transmitting equipment is installed. The GNSS antenna location should take into account the possibility of on-board interference — mainly emanating from satellite communication equipment.

3.7 On large aircraft sufficient isolation between a transmitting antenna and a GNSS receiving antenna can usually be obtained to mitigate an interference problem. Transmitters of particular interest are the satellite communications equipment and VHF transmitters. The possible generation of intermodulation products on the aircraft from one transmitter with multiple carriers or multiple transmitters is controlled by a combination of transmitter filtering and frequency management. Some on-board interference could be due to harmonics generated by weathered joints and connections. It is recommended that air operators and State regulatory authorities take action to control such occurrences.

3.8 Avionics must be installed in accordance with industry standards to ensure that the equipment operates properly. These standards require testing for interference with and by other on-board systems.

3.9 The combination of appropriately shielded GNSS antenna cabling, separation of antennas and cables, and transmitter filters can solve most interference problems on board small aircraft. Transmit equipment should be filtered within its own box or as close to the transmit-antenna port as possible. Additionally, some personal electronic devices are capable of generating sufficient in-band energy to interfere with avionics when used on board an aircraft.

Malicious interference

3.10 Intentional malicious interference (jamming) to GNSS is also a possibility as it is to all radio navigation systems. Such unauthorized interference is illegal and should be dealt with by the appropriate State authorities.

3.11 Spoofing of GNSS receivers can be made extremely difficult with proper design of the RAIM fault detection, and RAIM fault detection and exclusion (FDE) algorithms resident in aviation receiver equipment.

3.12 For States that determine that the risk of intentional interference is unacceptable in specific areas, safety and efficiency can be maintained by adopting an effective mitigation strategy through a combination of on-board mitigation techniques, procedural methods and terrestrial navigation aids.

4. REGULATORY REQUIREMENTS

4.1 Protection of the aeronautical radio navigation safety services spectrum is of paramount importance. International regulations state that the aeronautical radio navigation service is afforded special protection. ITU Radio Regulation Article 4.10 states:

> *"Members recognize that the safety aspects of radio navigation and other safety services require special measures to ensure their freedom from harmful interference; it is necessary therefore to take this factor into account in the assignment and use of frequencies."*

Each State wishing to implement GNSS in support of air traffic services should ensure that regulations are in place to protect the aeronautical radio navigation spectrum allocated satellite navigation.

Interference detection, flight inspection and ground monitoring

4.2 Reliance on GNSS will require States to re-examine their respective capabilities to detect, localize and identify interference sources in order to minimize potential service disruptions in their flight information regions. This examination may result in planning efforts to investigate a need for airborne and ground-based systems for detecting and localizing potential sources of RF interference (RFI) to the GNSS signals.

4.3 In order to quickly identify and mitigate GNSS interference, a suite of systems may be required. Current technology provides RFI direction finding (DF) and localization capabilities in four main platforms of interest — aircraft, land fixed (e.g. airport), land mobile (surface vehicle), and handheld. Cooperative efforts between the responsible regulatory organizations within a State utilizing such a suite of systems will provide the capability to locate and initiate measures to terminate sources of interference.

4.4 The extent of development a particular State may desire to implement should be predicated on the extent of operational services provided by GNSS and required availability for those services.

4.5 Interference is of primary concern for approach and landing operations. States and air navigation services (ANS) providers have an obligation to validate the interference environment as part of the flight inspection of the approach operation. This can be carried out by a spectrum analysis of the frequency ranges used by core satellite constellations and their respective augmentation signals. In this way it is possible to identify any unintentional interference that has the potential to disrupt approach operations.

4.6 GNSS receivers for approach operations, developed in accordance with guidance material in the SARPs, are required to achieve a minimum level of performance in the presence of both continuous wave (CW) and pulsed interference. To assess the potential impact of received signals, a comparison of the received spectrum with the interference masks specified in the SARPs is recommended. If no incursion of the CW interference is detected, the environment can be regarded as satisfactory. Since the interference masks are only valid for the most harmful CW interference, further (post-processing) analysis of the spectrum is necessary if broadband or pulsed signals exceed the interference mask.

4.7 To achieve the required measurement sensitivity, a suitable preamplifier and a resolution bandwidth of 10 kHz or less are required. It is desirable to analyse the frequency ranges of GPS (1 575±20 MHz) and GLONASS (1 598–20 MHz to 1 604.25+20 MHz). It is recommended to use a digital signal processing (DSP) receiver rather than a spectrum analyser since only DSP-receivers allow a satisfactory sweep rate.

4.8 If the primary aim is just to detect interference, a GPS or GPS/GLONASS antenna with an appropriate preamplifier can be used. If a location of the interference source is to be determined, a direction-finding antenna or a multi-channel DSP receiver with direction-finding capability should be used.

4.9 The complexity of the interference monitoring equipment depends on the extent of operational services provided by GNSS and the required availability for those services. At airports with very high traffic that rely on GNSS as the navigation means for approach, it may be desirable to deploy a permanent interference monitoring station. In this way a timely notification to ATC of the threat of interference can be performed.

4.10 Even with a flight inspection there is no full guarantee that all interference sources have been identified. For example, some sources may be intermittent transmitters or may come from mobile transmitters. Therefore it is recommended that aircraft be equipped with interference sensors (GNSS receivers with interference detection capability producing automatic reports). In this way the ATC operator can collect and analyse reports to obtain information on the spatial distribution of interference events.

4.11 In addition to the analysis of the spectrum, a GNSS receiver should be used to determine the impact of interference to the GNSS data.

5. MITIGATION TECHNIQUES

Regulatory techniques

5.1 There is always the possibility of interference, and aircraft CNS systems should be designed with this potential in mind. Aircraft certification and installation procedures should require demonstration of protection against on-board harmful interference.

5.2 The most effective place to deal with interference is at its source. Assuming that regulatory authorities have implemented suitable frequency management procedures, appropriate measures can be mandated to limit out-of-band emissions.

5.3 The combined use of satellite constellations or additional signals on multiple frequencies in the same receiver provides a more robust design against interference, particularly unintentional interference. However, careful design must be employed, as a common wide-band RF front-end to a combined receiver has the potential to increase the level of interference rather than decrease it.

5.4 Control of the harmonic content will be necessary where TV transmitters cause interference. There are known TV transmitters with harmonics that are over 100 dB less than the carrier. This is 40 dB greater than that required by regulation. If the States' regulations are in conformance with what can be achieved and is typical in some States, then interference protection from TV transmissions could be assured. Depending upon the adequacy of existing standards and practice, the cost of additional filters for TV broadcast stations to protect GNSS operations may be reasonable.

5.5 It is important to evaluate airspace where aircraft are authorized to fly in order to identify potential sources of interference. If interference does exist, then consideration should be given to filtering the source transmitter, avoiding the source where operationally feasible, or moving the transmitter to another frequency band.

INS coupling

5.6 Protection can be obtained from the effects of interference through the coupling of GNSS receivers with inertial navigation systems (INS). The characteristics of both systems are complementary. INS is immune to external interference and offers excellent short-term position stability but suffers from a bias error that increases with the time from its last position update. GNSS on the other hand has excellent long-term position stability but can suffer from short-term signal outages including those caused by transient interference. INS coupling should, however, be considered as an extra margin for unforeseen interference events.

Adaptive antennas and adaptive notch filters

5.7 Both adaptive antenna and notch filter technologies have been applied to GNSS to help overcome the problems of interference. These technologies were originally developed to protect military users from hostile jamming of the GNSS signals and are now found in civil applications. Both techniques require additional airborne equipment, but once installed can provide significant protection from unintentional interference.

Airframe masking and antenna locations

5.8 Airframe shielding of the top-mounted GNSS antenna from ground-based transmitters can offer additional mitigation against interference. The radiation pattern of the antenna and the antenna's position on the aircraft are important in rejecting ground-based interference.

FM broadcast compatibility issues for GBAS

5.9 Receivers for the instrument landing system (ILS) have been shown to be susceptible to interference from two- and three-signal 3rd order and 5th order intermodulation products from commercial radio broadcast stations operating in the band adjacent to the bottom of the 108–117.975 MHz Aeronautical Radio Navigation Service (ARNS) band where ILS localizers operate. VHF FM broadcasters have been allowed frequency assignments below 108 MHz, assuming interference immunity performance of ILS receivers specified in Annex 10, Volume I, 3.1.4.

5.10 States currently require coordination between FM broadcasters and ILS localizer installations to protect users from the possibility of harmful unintentional interference arising from intermodulation products. The same form of protection is required for GBAS, whose receivers employ the same interference immunity standards (Annex 10, Volume I, Appendix B, 3.6.8.2.2.8.3).

6. SUMMARY

6.1 Due to the fact that GNSS signals are of a low power when received by a user receiver, interference from unintentional or intentional sources can present a risk to the safe use of GNSS, noticeably for approach and landing operations. However, there are many steps that can be taken to mitigate the influence of interference — technically, institutionally and operationally.

6.2 From a technical perspective, judicious siting of the aircraft GNSS antenna well away from satellite communications antennas and other high effective radiated power systems will provide mitigation from on-board interference sources. At the same time, consideration should be given to siting the antenna to optimize airframe shielding from ground-based interference. Adaptive antennas, notch filters and INS coupling all provide increasing levels of protection from interference effectively negating the threat altogether.

6.3 Flight inspection of GNSS approaches for interference combined with the use of ground-based monitoring and the provision of timely status information to ATC will act to protect the users of GNSS. At an institutional level, both ANS providers and States must take all necessary steps to protect users of radio navigation satellite services by ensuring proper enforcement of the GNSS spectrum protection and strict application of the ITU Radio Regulations.

6.4 The key issue for States to recognize is that of all the techniques available to mitigate interference, only those appropriate to the airfield and operations being undertaken need to be put in place. There is no need to unnecessarily burden the users or the service providers where no risk exists.

Chapter 2

AIRCRAFT-BASED AUGMENTATION SYSTEMS (ABAS) NON-PRECISION APPROACH (NPA) PROCEDURES

2.1 INTRODUCTION

General

2.1.1 This chapter details the ground and flight test procedures and tolerances to be applied to ABAS NPA procedures. For the purposes of this chapter, "ABAS procedures" means the procedures based on the use of a Basic GNSS receiver* or other aircraft-based augmentations that use information from other sensors to provide GPS data integrity and improved performance.

System description

2.1.2 ABAS augments and/or integrates the information obtained from core satellite constellations with information available on board the aircraft.

2.1.3 Receiver Autonomous Integrity Monitoring (RAIM), which is an integrity monitoring routine of the Basic GNSS receiver, provides integrity monitoring for the position solution using redundant information (e.g. multiple range measurements). The goal of RAIM fault detection employed in the Basic GNSS receiver is to detect the presence of a positioning failure for a given phase of flight. Another monitoring option employed in other GNSS receiver types is RAIM fault detection and exclusion (FDE), which determines and excludes the source of the failure (without necessarily identifying the individual satellite causing the problem), thereby allowing GNSS navigation to continue without interruption.

2.1.4 The integrity monitoring and availability of the position solution can be aided by using information from the barometric altimeter on board the aircraft, thus reducing by one the required number of satellites in view.

2.1.5 Reserved.

2.1.6 Reserved.

Testing requirements

2.1.7 A summary of testing requirements is given in Table II-2-1.

* The term "Basic GNSS receiver" designates GNSS avionics that at least meet requirements for a GPS receiver in Annex 10, Volume 1, and specifications of RTCA DO-208 or EUROCAE ED-72A, as amended by FAA TSO-C129A or JAA TSO C129 (or equivalent).

2.2 GROUND TESTING/INSPECTION

General

2.2.1 There is no requirement for local, on-site evaluation of the GNSS signals-in-space. Guidance on the accuracy of the survey data used for the procedure design, and for ground interference checking, is given in Chapter 1.

2.2.2 Reserved.

2.2.3 Reserved.

2.2.4 Reserved.

2.2.5 Reserved.

2.3 FLIGHT TESTING/INSPECTION

General

2.3.1 Flight testing/inspection of the GNSS signals-in-space is not required. Flight test is concerned with:

— validation of RNAV instrument flight procedures, as detailed further in this chapter and in Chapter 5 (Flight validation of instrument flight procedures);

— verification of adequate GNSS signal reception for the specific procedure; and

— testing for interference.

Flight test performance parameters

2.3.2 A summary of flight test requirements is given in Table II-2-3.

Flight test/inspection procedures

RAIM prediction

2.3.3 Before flight testing begins, RAIM predictions should confirm that the GNSS signals will support the flight testing without RAIM alerts. Any value of Dilution of Precision (DOP) that also meets RAIM requirements is satisfactory for the flight testing.

In-flight activities

Interference

2.3.4 For NPA approaches, the presence of a RAIM alert and/or the loss of guidance have proven to be good indicators of probable GNSS interference affecting availability rather than accuracy or integrity. Although relying on these indicators does not actually confirm that the spectrum environment meets the resistance-to-interference standards in Annex 10, Volume I, Chapter 3, 3.7.4, it is considered sufficient for the procedures covered by this chapter. Furthermore, the presence of interfering signals for NPA approaches may not require a procedural restriction unless GNSS receiver performance is affected. However, if interference is suspected, further investigation should be conducted. The suspected area should be probed to define its geographical extent, GNSS parameters such as signal/noise ratios and DOP should be documented, the approach procedure should be removed from operational status, and appropriate authorities should be notified.

Evaluation

2.3.5 Evaluation should confirm the continuous presence of guidance information, the absence of RAIM alerts and, for NPAs, the location of the GNSS-indicated missed approach point (MAPt) (see Table II-2-3).

Test equipment

2.3.6 The aircraft used for these procedural and interference tests may be of any type, if it is equipped with an appropriate receiver and external aerial/antenna installed and approved for that aircraft type.

ABAS receiver

2.3.7 The aircraft receiver should meet the appropriate type approval requirements for GPS- and/or GLONASS-based procedures, as applicable.

Table II-2-1. Summary of testing requirements — ABAS procedures

Parameter	*Annex 10, Volume I reference*	*Testing*
Procedure Design	(none)	F, G
Interference	Chapter 3, 3.7.4	F

Legend: F = Flight test/inspection, G = Ground test

Table II-2-2. Reserved

Table II-2-3. Summary of minimum flight test requirements — ABAS procedures

Parameter	*Annex 10, Volume I reference.*	*Doc 8071, Volume II reference*	*Measurand*	*Tolerance/limit*	*Uncertainty*	*Periodicity*
Procedure design validation (all segments)	(none)	5.3				C
MAPt GNSS-indicated location	(none)	2.3.5, 5.3.21	Displacement	Visual verification	Subjective	C, Sp
Interference	Chapter 3, 3.7.4	2.3.4	RAIM alerts Guidance indications	No alerts Continuous guidance	None	C, Sp
Guidance indications	(none)	2.3.5	Nav indicator	Continuous	None	C, Sp
Flyability	(none)	2.3.5, 5.3.20		Flyable	Subjective	

Note.— C = Commissioning (and when published design changes to the procedure occur).
Sp= Special, e.g. when interference is suspected or periodic interference check is desired.

Chapter 3

SATELLITE-BASED AUGMENTATION SYSTEMS (SBAS)

3.1 INTRODUCTION

General

3.1.1 This chapter provides guidance for the ground and flight test procedures and tolerances to be applied to satellite-based augmentation systems (SBAS) instrument approach procedures, including approach with vertical guidance (APV). For the purposes of this chapter, "SBAS procedures" means the procedures based on the use of SBAS receivers*.

System description

3.1.2 An SBAS augments core satellite constellations by providing ranging, integrity and correction information via geostationary satellites. The system comprises a network of ground reference stations that monitor satellite signals; master stations that collect and process reference station data and generate SBAS messages; uplink stations that send the messages to geostationary satellites; and transponders on these satellites that broadcast the SBAS messages. The SBAS aircraft receivers acquire the ranging and correction data and apply these data to determine the integrity and improve the accuracy of the derived position.

3.1.3 The SBAS ground network measures the pseudorange between the ranging source (i.e. satellites) and the SBAS reference receivers located at known locations and provides corrections for the ranging-source ephemeris, clock and ionospheric errors. The aircraft receiver applies a tropospheric delay model.

3.1.4 The ranging source ephemeris error and slow moving clock error are the primary basis for long-term corrections. The ranging source clock error is adjusted for the long-term correction and tropospheric error and is the primary basis for the fast correction. The ionospheric errors among many ranging sources are combined into vertical ionospheric errors at predetermined ionospheric grid points (IGP).

Note.— SBAS hardware and software require extensive design qualification testing. Details of these tests are specific to the design of the augmentation architecture and are beyond the scope of this document. See Chapter 1, 1.3.3.

3.1.5 It is important to distinguish between the coverage area and service areas for an SBAS. The coverage area is the area within which the SBAS broadcast can be received (e.g. the geostationary

* The term "SBAS receiver" designates GNSS avionics that at least meet requirements for an SBAS receiver in Annex 10, Volume 1, and specifications of RTCA DO-229, as amended by FAA TSO-145 and 146 (or equivalent).

satellite footprints). Within the coverage area there will be one or more defined service areas, each capable of supporting operations based on some or all of the SBAS functions. Outside of the service area(s) defined by the SBAS service provider, an SBAS may still provide accurate and reliable service. Ranging, satellite status and basic differential corrections are available throughout the entire coverage area. The performance of these functions may be technically adequate to support en route, terminal and non-precision approach operations by providing monitoring and integrity data for core satellite constellations and/or SBAS satellites.

3.1.6 The ranging signals provided by SBAS satellites may be used by SBAS-capable receivers to improve accuracy or availability of ABAS or GBAS. Where SBAS provides satellite status and basic differential corrections, these functions may support en route terminal and/or non-precision approach operations, with better accuracy and availability than provided by ABAS. Where the number of SBAS ground monitoring stations is sufficient to generate accurate ionospheric corrections, the precise differential corrections function may support APV and/or Category I precision approach operations.

3.1.7 SARPs and guidance material for SBAS are contained in Annex 10, Volume I and the *Global Navigation Satellite System (GNSS) Manual* (ICAO Doc 9849).

Testing requirements

3.1.8 A summary of testing requirements is given in Table II-3-1.

3.2 GROUND TESTING/INSPECTION

General

3.2.1 Testing of the SBAS ground subsystem is outside the scope of this document. Testing must be accomplished in accordance with manufacturer's recommendations to ensure compliance with the SARPs. Testing should include master control stations, reference stations, up-link stations, and communications links, and may be accomplished by the SBAS service provider, or by States under agreement with the service provider.

Table II-3-1. Summary of testing requirements — SBAS procedures

Parameter	*Annex 10, Volume I reference*	*Testing*
FAS Survey Data Accuracy	B 3.6.7.2.4.2	G
Procedure Design	(none)	F
Interference	B 3.7	F

Legend: G = Ground test; F = Flight test/inspection.

Survey requirements

3.2.2 GNSS instrument flight procedures are predicated on airport and runway survey coordinates. Airport survey accuracies must conform to the required standards referenced in Chapter 1, Section 1.4 of this document, to support aircraft database use. The SBAS Final Approach Segment (FAS) survey data accuracy must meet the requirements of Table II-3-2.

Ground interference testing

3.2.3 Chapter 1, Attachment 3 provides guidance on this subject specifically for GNSS.

Ground test performance parameters

3.2.4 A summary of ground test requirements for SBAS procedures is given in Table II-3-2.

3.3 FLIGHT-TESTING/INSPECTION

General

3.3.1 Flight-testing/inspection of the GNSS and SBAS signals-in-space is not required. Flight test is concerned with:

— validation of RNAV instrument flight procedures, as detailed further in this chapter and in Chapter 5 (Flight validation of instrument flight procedures);

— verification of adequate SBAS support for the specific procedure; and

— testing for interference.

Table II-3-2. Summary of minimum ground test requirements — SBAS procedures

Parameter	*Annex 10, Volume I reference*	*Doc 8071, Volume II reference*	*Measurand*	*Tolerance/ limit*	*Uncertainty*	*Periodicity*
FAS Survey data accuracy	B 3.6.7.2.4.2	3.2.2	WGS-84 Coordinates, converted to linear units	N/A		C, Sp
Horizontal					< 1 m	
Vertical					< 0.25 m	

Note: C = Commissioning (and when published design changes to the procedure occur).
Sp = Special, e.g. when interference is suspected or a periodic interference check is desired

Flight test performance parameters

3.3.2 A summary of flight test requirements is given in Table II-3-3.

Flight test/inspection procedures

Pre-departure checks

3.3.3 Each FAS data block has an associated cyclic redundancy check (CRC) code which ensures that the data is not corrupted during the data transfer. The CRC must be generated by the procedure designer and not changed before being entered into the receiver. The receiver must also confirm the validity of the FAS data block using the CRC prior to flight testing. The FAS data should be checked for consistency against the original design.

GNSS/SBAS system predictions

3.3.4 Before flight-testing begins, an analysis of GNSS and SBAS system predictions should be accomplished to confirm that the GNSS and SBAS signals will support the flight-testing without alerts. The analysis should take account of predicted GPS outages, NOTAMs and service predictions from the SBAS service provider.

In-flight activities

Interference

3.3.5 SBAS receiver standards require that receivers not provide hazardously misleading information in the presence of radio frequency interference. Excessive interference will therefore affect continuity and availability, rather than integrity. The loss of SBAS correction signals and/or the loss of guidance have proven to be good indicators of probable GNSS and/or SBAS interference. If interference is suspected, further investigation should be conducted. Some States may require a pre-commissioning survey of the interference environment. The suspected area should be probed and spectrum analysis accomplished to define its geographical extent. GNSS and SBAS parameters such as carrier-to-noise density (C/N_O), horizontal and vertical protection levels, satellites tracked and DOP should be documented to aid further investigation. If interference is confirmed, the approach procedure should be removed from operational status, pending corrective action, and appropriate authorities notified. For more details, refer to Chapter 1, Attachment 3.

3.3.6 Inspection of SBAS procedures does not require a position fixing system. However, one may be used based on individual States' regulatory requirements. GNSS receivers should meet applicable standards for the phase of flight and type of flight procedure being tested. A stand-alone SBAS receiver or FMS must have manual entry capability. The receiver should have the capability of outputting parameters required in Table II-3-3.

Note.— It has been found helpful to be able to observe and optionally record during flight-testing additional parameters beyond those listed in Chapter 1, Attachment 2, such as HPL/VPL, satellites tracked, geostationary satellite Signal-to-Noise Ratio (SNR), and SBAS sensor status. These parameters may provide an indication of marginal performance and are a baseline for further analysis of any observed anomalies.

Table II-3-3. Summary of minimum flight test requirements — SBAS procedures

Parameter	*Annex 10, Volume I reference.*	*Doc 8071, Volume II reference*	*Measurand*	*Tolerance/ limit*	*Uncertainty*	*Periodicity*
Procedure design validation (all segments)	(none)	5.3				C, Sp
FAS data	B 3.6.4.5	3.3.3	FAS data block	Consistent with FAS design	N/A	
MAPt or DA	(none)	5.3.21	Displacement	Visual verification	Subjective	C, Sp
Interference	B 3.7	3.3.5	Various alerts and guidance indications	No alerts and continuous guidance	None	C, Sp
Guidance indications	(none)	5.3.20	Nav indicator	Continuous	None	C, Sp
Flyability	(none)	5.3.20	(none)	Flyable	Subjective	C

Note 1: C = Commissioning (and when published design changes to the procedure occur).
Sp = Special, e.g. when interference is suspected or a periodic interference check is desired.

Note 2: If periodic checks are desired, parameters and intervals will be determined by individual states.

Chapter 4

GROUND-BASED AUGMENTATION SYSTEMS (GBAS)

4.1 INTRODUCTION

General

4.1.1 This chapter provides guidance for the test procedures and tolerances to be applied to ground-based augmentation system (GBAS) instrument approach procedures, including Category I precision approaches and positioning service applications. For the purposes of this chapter, "GBAS procedures" means the procedures based on the use of GBAS receivers. In some cases, the material is not complete, and additional details and procedures will be provided in the next edition of Volume II.

4.1.2 This section covers commissioning, special, and periodic testing assuming that design and site qualification procedures have been completed satisfactorily. Further information on design qualification is given in Chapter 1. Further information on site qualification can be found in EUROCAE ED-114.

System description

4.1.3 The GBAS ground subsystem receives satellite ranging signals and calculates ground-monitored differential corrections and integrity information for each satellite in view. A VHF data broadcast (VDB) transmits these and other pertinent data such as approach path information, to the aircraft subsystem. The required coverage volume is depicted in Annex 10, Volume I, Attachment D, Figure D-4.

4.1.4 The GBAS aircraft subsystem encompasses the aircraft equipment used to receive and process the satellite ranging signals and VDB, to compute and output a differentially-corrected position solution, deviations relative to a desired reference path, distance information, and appropriate alert annunciations. Aircraft subsystem outputs are formatted to interface with other aircraft equipment used to support the particular operation. For example, deviation outputs are provided to aircraft displays and/or navigation systems.

4.1.5 SARPS and guidance material for GBAS are contained in Annex 10, Volume I and the *Global Navigation Satellite Service (GNSS) Manual* (Doc 9849). The term "GBAS receiver" designates GNSS avionics that at least meet requirements for GBAS receivers contained in Annex 10, Volume I, and relevant specifications.

Testing requirements

4.1.6 A summary of testing requirements is given in Table II-4-1.

Table II-4-1. Summary of testing requirements— GBAS functional requirements

Parameter	Annex 10 , Volume I reference	Testing[1]
System requirements		
Position domain accuracy (functional test)	3.7.2.4.1 & Table 3.7.2.4-1	F/G
Pseudorange domain accuracy	App. B 3.6.7.1.1	G
Continuity (GBAS ground system)	App. B 3.6.7.1.3	G
Broadcast signal-in-space integrity		
Ground pseudorange uncertainty	App. B 3.6.7.2.2.4	G
Tropospheric delay and residual tropospheric Uncertainty	App. B 3.6.7.2.3.1	G
GCID indication	App. B 3.6.7.2.3.2	F/G
Residual ionospheric uncertainty	App. B 3.6.7.2.3.5	G
Reference antenna phase centre position accuracy	App. B 3.6.7.2.3.3	G
FAS data points accuracy	App. B 3.6.7.2.4.1	G
Integrity monitoring for GNSS ranging sources	App. B 3.6.7.2.6	G
Resistance to interference (ranging signal)	App. B 3.7	F/G
Procedure validation	(none)	F
VHF data broadcast subsystem		
Runway surface coverage (Recommendation)	3.7.3.5.3.2	G
Message block header (GBAS identification only)	App. B 3.6.3.4.1	G
Data content	App. B 3.6.4	F/G
VDB coverage	3.7.3.5.4.4	F
GBAS/H field strength		
GBAS/E field strength (incorporates phase offset)		
Carrier frequency (assigned channel)	3.7.3.5.4.1	G
Carrier frequency stability	App. B 3.6.2.1	G
Monitoring	App. B 3.6.7.3	--
TDMA slot monitoring	App. B 3.6.7.3.1.2	G
VDB transmitter power monitor	App. B 3.6.7.3.1.3	G
Unwanted emissions	3.7.3.5.4.6	G
Power in adjacent channels	3.7.3.5.4.5	G

[1]Note.— Based on individual States' preferences, parameters normally tested on the ground may be part of the flight testing programme.

4.2 GROUND TESTING

General

4.2.1 The primary purpose of ground testing is to ensure that the GBAS ground subsystem meets the requirements of Annex 10 in terms of system performance and monitor operation. Ground tests are required for initial commissioning, following system reconfiguration and corrective maintenance. Ground tests may also be required on a periodic basis as determined by the manufacturer or appropriate engineering/state authority.

4.2.2 Unlike ground-based navigation aids, for which system accuracy is measured during flight testing activities, GBAS accuracy assessments must be accomplished on the ground, due to the variation of satellite geometry over time.

4.2.3 Some ground testing activities can result in the GBAS ground subsystem radiating a signal-in-space that is not compliant with the Annex 10 SARPS. To reflect this, the equipment should be administratively removed from service and its status properly published prior to the start of testing, and the "Message Block Identifier" field of each radiated message should be set to "Test".

Ground test performance parameters

4.2.4 Ground test requirements for the GBAS ground subsystem are listed in Table II-4-2A and for the VHF Data Broadcast subsystem in Table II-4-2B.

Ground test/inspection procedures

General

4.2.5 Procedures for conducting the ground testing of the parameters listed in Tables II-4-2A and II-4-2B are intended to provide basic guidance on the method of measuring the various parameters. These procedures should not be construed as the only means of accomplishing the intended purpose. Individual States might adopt modified or new methods which better suit their requirements or local situation.

Accuracy

4.2.6 For any estimated position at a specific location, accuracy is expressed as the 95 percentile of the position error distribution. The position error is the difference between the estimated position and the actual position. Stationary ground-based systems such as VOR and ILS have relatively repeatable error characteristics, so that performance can be measured for a short period of time (e.g. during flight inspection), and it is assumed that the system accuracy does not change after the test. However, GNSS position error distributions change over time due to parameters such as the orbiting of satellites.

4.2.7 Assessment based on measurements within a sliding time window within a single approach is not suitable for GNSS. The nature of GNSS errors results in a small number of independent samples in a short period of time, which makes it impractical to assess the 95 percentile position error.

4.2.8 As the main function of the GBAS ground subsystem is to provide pseudorange corrections, the accuracy of the ground subsystem is specified in the range domain. It is therefore necessary to test the ground subsystem accuracy in this domain. In addition, it is recommended that a position domain measurement be performed as a functional check.

Pseudorange domain accuracy
(GAD Assessment)

4.2.9 The pseudorange accuracy performance of the GBAS ground subsystem is categorized by the Ground Accuracy Designator (GAD) letter and the number of installed reference receivers. Prior to commissioning, ground tests are required to confirm that the achieved accuracy of pseudorange corrections, as a function of satellite elevation angle, is below the GAD curve. Typically, ground multipath effects and the ground receiver thermal noise drive the pseudorange correction errors.

4.2.10 The GAD ground testing assumes that sufficient design qualification tests have been conducted to determine the impact of low GNSS signal levels, interference, nominal multipath, etc. The testing is based on site data collection to assess the impact of siting effects (GNSS reference receiver antenna, multipath environment, reception mask, etc.) on GBAS pseudorange measurements. The on-site measurements should confirm the statistical simulation results.

4.2.11 The following tests assume that the site selection procedures have been carried out correctly and have confirmed that the reference antenna sites have sufficiently low levels of common mode multipath.

4.2.11.1 Pseudorange correction accuracy ($RMS_{pr\_gnd)}$ can be characterized by evaluating the data either by Code Minus Carrier (CMC) analysis or B-values analysis:

a) CMC analysis provides a direct observation of the code phase errors on the pseudorange due to receiver thermal noise and multipath. CMC analysis requires either two-frequency reference receivers and antennas or separate estimates of ionospheric delay parameters. CMC carrier-phase ambiguity removal could suppress long multipath effects.

b) B-values analysis is based on the error evaluation from the set of B broadcast parameters, which represent the contribution of a pseudorange error from a particular reference receiver on the broadcast averaged pseudorange correction.

4.2.11.2 B-values analysis is the recommended assessment technique, because the GAD assessment should be done with data collected by the installed GNSS receivers and antennas, which are usually not dual-frequency, and because B-values analysis takes into account the impact of ground subsystem monitoring, which can affect the accuracy.

Position domain accuracy functional test

4.2.12 The end-to-end functional test is intended to confirm that the overall position domain accuracy is satisfactory, using a receiver independent of the GBAS ground subsystem. It is not intended to provide a statistical confidence level of the position measurement. (Although this is a ground measurement, it can also be duplicated during flight testing as described in section 4.3.) To make the position measurement, place a GBAS receiver at a precisely-surveyed position free of significant multipath and collect at least three independent samples at intervals of at least 200 seconds. The horizontal and vertical errors of each of the samples should meet the tolerance in Table II-4-2A. If this tolerance is exceeded, first confirm that the measurement was done properly and that the multipath environment is clean. If necessary, repeat the measurement at other precisely-surveyed positions to determine whether it is the GBAS accuracy or the measurement location that is flawed.

Continuity

4.2.13 Compliance with the continuity requirements is established during design qualification by analysis and by a continuity demonstration with one or more ground subsystems installed in an operational environment at typical sites. Continuity is correlated to a lack of outages, which are defined in general as any unanticipated cessation or reduction below the minimum field strength of the VDB's signal-in-space. However, the unique GBAS architecture introduces two additional events which must be considered to be outages — transmission of parameter values such that the receiver calculates protection levels greater than the alert limits and transmission of a Type 1 message with fewer than four measurement blocks (except when either of these is caused by a configuration change in the core satellite constellation or geostationary satellites).

Table II-4-2A. Summary of minimum ground test requirements — GBAS functional requirements

Parameter	*Annex 10 Volume I reference*	*Doc 8071 Volume II reference*	*Measurand*	*Tolerance*	*Uncertainty*	*Periodicity*[6]
Accuracy		4.2.6 to 4.2.8				
Pseudorange Domain (GAD Assessment)	App. B 3.6.7.1.1	4.2.9 to 4.2.11.2	Ground sub-system contribution to the corrected pseudorange error	Compliance with broadcast GAD curves <0.05m	N/A N/A	N/A[4]
Position Domain Functional Test	(none)	4.2.12	Position	<4m vertical <16m lateral	0.5m	N/A[5]
Continuity	App. B 3.6.7.1.3	4.2.13 to 4.2.17	Continuity	See 4.2.13	See 4.2.13	See 4.2.13
Broadcast s-i-s integrity parameters						
Ground Pseudorange Uncertainty		4.2.18 to 4.2.19	σ_{pr_gnd} B	N/A	See 4.2.18	N/A
Tropospheric Delay and Residual Tropospheric Uncertainty		4.2.20	N_R ,h_0,σ_N	Exact match to data provided	N/A	N/A[3]
GCID indication		[see 4.2.23]	Message Data Content	Exact match to intended value	N/A	N/A
Residual Ionospheric Uncertainty		4.2.21	$\sigma_{vert\_iono\_gradient}$	Exact Match to data provided	N/A	N/A[3]
Reference Antenna Phase Centre position accuracy	App. B 3.6.7.2.3.3	4.2.22	Survey and antenna phase centre error	<8 cm	1 cm	N/A[2]
Data content	App. B 3.6.4	4.2.23	Message Data Content	Exact Match	N/A	N/A[1]
Resistance to Interference (Ranging Signal)	App. B 3.7	4.2.24	Interference Power Level	See 4.2.13	3 dB	S, Sp
FAS data points accuracy	App. B 3.6.7.2.4.1	4.2.25	FAS data point error	0.4 m horizontal 0.25 m vertical	0.05 m 0.05 m	C/Sp
Monitoring						
Integrity monitoring for GNSS ranging sources	App. B 3.6.7.2.6	4.2.34 to 4.2.36	[TBD]	[TBD]	[TBD]	[TBD]

Notes:
1. *Message data content is confirmed during ground tests. Some States may choose to also accomplish this confirmation during commissioning flight testing.*
2. *Positioning of reference antennas should be confirmed prior to commissioning, whenever an antenna is removed and reinstalled, moved or replaced, and whenever the location of the reference antenna is suspected to have moved.*
3. *Whenever new data are provided.*
4. *Pseudorange accuracy should be confirmed prior to commissioning, and whenever siting of reference antennas changes or the multipath environment of the antennas changes. Position measurement should be confirmed prior to commissioning, and as required thereafter (e.g. change in database or antenna location).*
5. *As required.*
6. *See 1.15 of this volume for additional guidance on adjusting the periodicity.*

Table II-4-2B. Summary of minimum ground test requirements — GBAS VHF data broadcast

Parameter	*Annex 10 Volume I reference*	*Doc 8071 Volume II reference*	*Measurand*	*Tolerance*	*Uncertainty*	*Periodicity*[1]
Carrier frequency (assigned channel)	3.7.3.5.4.1	4.2.26	Frequency	Assigned Channel	N/A	12 months
Carrier frequency stability	App.B 3.6.2.1	4.2.27	Frequency	±0.0002%	0.0001%	12 months
Unwanted Emissions	3.7.3.5.4.6	4.2.28	Power	-53 dBm	1 dB	12 months
Power in Adjacent Channels 1st, 2nd, 4th Above the fourth	3.7.3.5.4.5	 4.2.29 4.2.30	Power	 See 4.2.29 See 4.2.30	1 dB	12 months
Runway surface coverage (Recommendation)	3.7.3.5.3.1.1	4.2.31 to 4.2.33	Field Strength	>-99 dBW/m^2 to –35 dBW/m^2	±3 dB	12 months
Monitoring TDMA Slot VDB Transmitter Power Monitor	App.B 3.6.7.3 App. B 3.6.7.3.1.2 App. B 3.6.7.3.1.3	4.2.34 to 4.2.36	 Slot Power	 Assigned Slot(s) 3dB	 N/A 1 dB	 12 months 12 months

Note 1. See 1.15 of this Volume for additional guidance on adjusting the periodicity.

4.2.14 The analysis must confirm that the equipment design mean time between outages (MTBO) exceeds by a significant margin the requirement of the planned category of operation. The demonstration is accomplished in an operational environment and establishes that the installed continuity meets the requirement to at least a 60 per cent confidence level. If more than one system is used for this demonstration, they must be of the same type and installation standard.

4.2.15 For subsequent installations of the same equipment type in a similar environment, there is no requirement for installations supporting Category I operations to conduct a formal reliability demonstration on each installed GBAS equipment. However, each additional facility should be operated without failure for a short period prior to commissioning to verify correct installation.

4.2.16 Once a system is in operational service, the reliability should be continually monitored to ensure compliance with the continuity requirements (equivalent to an MTBO of 1 263 hours). A suitable method to assess the behavior of a particular installation is to calculate the average MTBO over the last five to eight outages. A system showing a degradation in continuity below the requirement may have to be withdrawn from service until the cause has been rectified, for example, by a change of installation techniques or procedural methods, or by a redesign, as appropriate. Changes to the design approval baseline (e.g. due to modifications) should be assessed for their impact on continuity and integrity as established by the design qualification.

4.2.17 Further guidance material on continuity evaluation is given in Attachment C to Annex 10, Volume I, EUROCAE ED-114, and in the European Guidance Material on Continuity of Service Evaluation in Support of the Certification of ILS & MLS Ground Systems (ICAO EUR DOC 012, First Edition, December 2002).

Broadcast signal-in-space integrity parameters

Ground pseudorange uncertainty (σ_{pr_gnd})

4.2.18 The broadcast $\sigma_{pr\text{-}gnd}$ establishment process should be determined during design qualification by both an analytical model and empirically collected data at typical sites. However, data collection at each site may be needed to confirm that previously established $\sigma_{pr\text{-}gnd}$ is valid at this site.

4.2.19 The design qualification and site data collection should address at least the following:

a) ground receiver noise and diffuse multipath environment;

b) ground multipath and building reflections;

c) systematic errors (e.g. antenna phase centre accuracy);

d) long-term variation in errors due to environmental changes (e.g. seasonal variations);

e) additional integrity risks including statistical uncertainties due to the limited number of collected samples and spatial correlation between the ground subsystem reference receivers; and

f) aircraft usage of the parameters (e.g. D_{max}).

Tropospheric delay and residual tropospheric uncertainty

4.2.20 The broadcast tropospheric parameters include the refractivity index (N_R), the tropospheric scale height (h_0), and refractivity uncertainty (σ_N). Normally, these parameters are fixed values at a given site. The appropriate values are determined by analysis of regional weather and atmospheric statistics, to ensure that errors are adequately bounded without unnecessarily inflating the protection levels. Ground testing should confirm that the intended values are broadcast correctly.

Residual ionospheric uncertainty

4.2.21 The residual ionospheric uncertainty ($\sigma_{vert\_iono\_gradient}$), in conjunction with any ionospheric monitoring strategy, is determined by an analysis of regional ionospheric statistics, to ensure that errors are adequately bounded without unnecessarily inflating the protection levels. Ground testing should confirm that the intended value is broadcast correctly.

Reference antenna phase centre position accuracy

4.2.22 Due to the importance of correct reference antenna phase centre data, an independent measurement of its position relative to the GBAS reference point is required. This survey must be performed prior to commissioning, whenever an antenna is removed and reinstalled, moved or replaced, and whenever the location of the reference antenna is suspected to have moved. In addition, an optional confirmation to a lesser accuracy may be accomplished by ground maintenance personnel.

Data content

4.2.23 Ground testing can check the majority of the parameters contained within the data broadcast messages. The broadcast parameters stored in the GBAS reference station and listed in Table II-4-3 should be checked on the ground using a GBAS receiver capable of displaying or outputting the broadcast parameters. Since some parameters are checked during flight testing, the list of parameters should be provided to the flight inspectors.

Resistance to interfence (ranging signal)

4.2.24 The local interference environment for the GBAS reference receivers should be tested prior to commissioning (typically during the site selection process). If interference to the GBAS is subsequently suspected, the local interference environment may be tested using spectrum analysis. See Attachment 3, Chapter 1, of this volume for general information on interference.

FAS data points accuracy

4.2.25 GNSS instrument flight procedures are predicated on airport and runway survey coordinates. Airport survey accuracies must conform to the required standards referenced in Chapter 1, Section 1.4. For GBAS the FAS data point accuracy requirement applies to the relative survey error between the FAS data points and the GBAS reference point. It should be confirmed that the FAS survey data accuracy meets the requirements of Table II-4-2A.

Carrier frequency

4.2.26 The GBAS VHF transmitter's designated channel frequency is determined in accordance with appropriate spectrum management principles. Ground testing of the assigned channel frequency is accomplished simultaneously with the Carrier Frequency Stability test.

Carrier frequency stability

4.2.27 The GBAS VHF transmitter's output frequency should be measured periodically to confirm that the short-term and long-term drift characteristics meet the specifications. Using an appropriate frequency counter, determine the carrier frequency in accordance with the counter instruction book. If the frequency is out of tolerance, adjust in accordance with the GBAS manufacturer manual. Ground testing of the assigned channel frequency is accomplished simultaneously with the Carrier Frequency Stability test.

Table II-4-3. Data broadcast parameters to be checked on the ground

Parameters to be confirmed	*Values or special coding*
For Each Burst	SSID (Station Slot ID)
Type 1 Message Header	MBI (Message Block ID): 'AA' normal operation or 'FF' for test GBAS ID: 4 letters e.g. 'LFBO'
Type 2 Message (GBAS related data) Header	MBI (Message Block ID): 'AA' normal operation or 'FF' for test GBAS ID: 4 letters e.g. 'LFBO'
GBAS Reference Receivers GBAS Accuracy Designator Letter GBAS Continuity/Integrity Designator	Site specific, from 2 to 4 Reference Receivers Site specific, [A, B or C] '1' for Cat-I or '7' for Unhealthy
Local Magnetic Variation $\sigma_{vert\_iono\_gradient}$ Refractivity Index Scale Height Refractivity Uncertainty Latitude Longitude Ellipsoid Height	Site specific Site specific Site specific Site specific Site specific Site specific Site specific Site specific
Additional data block 1 if transmitted: Reference Station Data Selector Maximum use distance (D_{max}) $K_{md\_e\_POS,GPS}$ $K_{md\_e\_CAT1,GPS}$ $K_{md\_e\_POS,GLONASS}$ $K_{md\_e\_CAT1,GLONASS}$	 Special coding '0' when PS is not provided Special coding '0' when no limitations Special coding '0' when PS is not provided If GPS not used, this parameter is all zeros Special coding '0' when PS is not provided If GLONASS not used, this parameter is all zeros
Type 4 Message (FAS data) Header	MBI (Message Block ID): 'AA' normal operation or 'FF' for test GBAS ID: 4 letters e.g. 'LFBO'
Data Set Length	Site specific
Each FAS Block	Site specific
FASVAL	Value determines vertical alert limit, ('1111 1111' if vertical deviations not to be used)
FASLAL	Value determines approach status ('1111 1111' if approach not to be used)

Unwanted emissions

4.2.28 The measurement procedure for unwanted emissions requires a suitable attenuator, a notch filter or bandpass filter to suppress the on-channel signal by at least 60 dB, and a spectrum analyser with power band marker function. The filter is necessary to reject the on-channel signal, to increase the dynamic range of the measurement without overloading the spectrum analyser. The frequency response of the filter must be known, in order to take this into account when calculating spurious measurement results. If a bandpass filter is used, it must be tuned to several measurement frequencies, covering the overall measured frequency range. The measurement procedure is as follows:

a) connect the VDB transmitter as shown in Figure II-4-1 with the GBAS ground subsystem set in Maintenance Mode. Set the GBAS ground subsystem to produce continuous transmission of GBAS messages in the assigned slot, and key the transmitter under test “on”;

b) adjust the spectrum analyser reference level to provide the maximum dynamic range for display, and set the input attenuator to minimum required to ensure that no signal at the analyser input exceeds the maximum allowable level;

c) measure the power level at each visible spurious signal using power band markers appropriate to the bandwidths specified in Annex 10, Volume I, 3.7.3.5.4.6. Use the filter to reject the carrier in order to increase the dynamic range of the measurement without overloading the spectrum analyser. Take into account the frequency response of the filter when presenting spurious measurement results; and

d) check that the results do not exceed the limits specified in Table II-4-2B. The absolute power limits apply if the authorized transmitter power exceeds 150W.

Note 1.— Testing for unwanted emissions in the 9 kHz to 108 MHz band should be performed with the VDB transmitter operating at the lowest assignable channel during the type acceptance.

Note 2.— Testing for unwanted emissions in the 117.975 MHz to 1.7 GHz band should be performed with the VDB transmitter operating at the highest assignable channel during the type acceptance.

Note 3.— This test procedure is also suitable for the measurement of adjacent channel power performance above the fourth adjacent channel.

Power transmitted in first, second and fourth adjacent channel

4.2.29 The measurement procedure for the first, second and fourth adjacent channels requires a suitable attenuator and a spectrum analyser with power band marker function. The measurement procedure is as follows:

a) connect the VDB transmitter as shown in Figure II-4-2, with the GBAS ground subsystem set in Maintenance Mode. Set the GBAS ground subsystem to produce continuous transmission of GBAS messages in the assigned slot;

b) key the transmitter under test “on”. Adjust the attenuator in the analyser to the minimum value which does not overload the input stage of the unit. Using a 125 kHz span, display the VDB signal envelope. Use the analyser IF signal power as the trigger source for the display and set averaging to 10. Using the power band marker function of the analyser, measure the power in a 25 kHz bandwidth of the first and second upper adjacent channel;

c) repeat (b) for the first and second lower adjacent channels;

d) record the higher of the two measured values. Check that the first and second adjacent channel power is lower than the first and second adjacent channel power requirement (defined in Annex 10, Volume I, 3.7.3.5.4.5). The absolute power limits apply if the authorized transmitter power exceeds 150W;

e) adjust the centre frequency of the analyser at +50 kHz from the transmitter frequency;

f) using the analyser power band marker function, measure the adjacent channel power in the fourth upper channel;

g) adjust the centre frequency of the analyser at -50 kHz from the transmitter frequency;

h) repeat (f) for the adjacent channel power in the fourth lower channel, and record the higher of the two values; and

i) check that the fourth adjacent channel power is lower than the fourth adjacent channel power requirement (defined in Annex 10, Volume I, 3.7.3.5.4.5). The absolute power limits apply if the authorized transmitter power exceeds 150W.

Power transmitted in adjacent channels above the fourth

4.2.30 The measurement procedure for adjacent channels above the fourth is defined with the use of a filter necessary to reject the on-channel signal, to increase the dynamic range of the measurement without overloading the spectrum analyser. The procedure requires a suitable attenuator, a notch filter with a minimum of 60dB on-channel attenuation, and a spectrum analyser with power band marker function. The measurement procedure is as follows:

a) connect the VDB transmitter as shown in Figure II-4-3 with the GBAS ground subsystem set in Maintenance Mode. Use the filter to attenuate the carrier, in order to increase the dynamic range of the measurement without overloading the spectrum analyser;

b) set the GBAS ground subsystem to produce continuous transmission of GBAS messages, and key the transmitter under test “on”;

c) adjust the spectrum analyser reference level to provide the maximum dynamic range for display and set the input attenuator to minimum. Ensure that no signal at the analyser input exceeds the maximum allowable level. Using the analyser power band marker function, measure the adjacent channel power in the 8th, 16th, 32nd, 64th and 76th lower and upper adjacent channels. Record the higher of the two measured values for the i^{th} adjacent channel considered;

d) check that the power in the adjacent channels above the fourth does not exceed the limits specified in Table II-4-2B. The absolute power limits apply if the authorized transmitter power exceeds 150W; and

e) above the 76th channel and within the band 108.025–117.950 MHz, record the transmitter noise level versus the frequency displacement for each channel available and check if any power measurement exceeds the requirement defined in Annex 10, Volume I, 3.7.3.5.4.5.

Runway surface coverage

4.2.31 Where GBAS runway surface coverage is required, the minimum VDB field strength requirements must be met when measured at an altitude of 3.7 m (12 ft) above the runway surface, or as required for aircraft using the runway. In addition, the maximum VDB field strength requirements must be met at the closest runway or taxiway distance to the antenna at which the broadcast is to be used. Although these checks can be made during flight testing, it is much easier to perform with good repeatability on the ground. A calibrated GBAS receiver and a VHF antenna with known gain and omnidirectional pattern (in the horizontal plane) are mounted in a suitable ground vehicle and driven along the runway centreline. Optional recording equipment can provide a permanent record of the received signal levels, which must be converted to field strength at the antenna.

4.2.32 The field strength should be measured as an average over the period of the synchronization and ambiguity resolution bits in the training sequence portion of the message. The receiver should provide accurate power measurement within the full dynamic range necessary to confirm the minimum and maximum field strength on each received burst.

Figure II-4-1. Unwanted emissions measurement

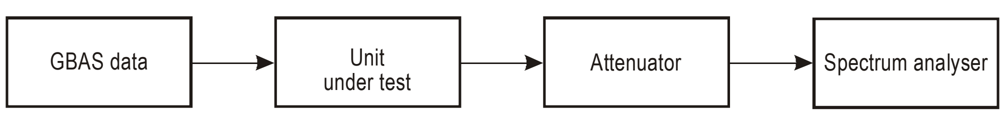

Figure II-4-2. First, second and fourth adjacent channel power measurement

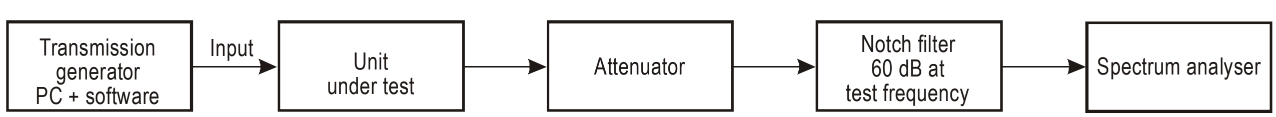

Figure II-4-3. Adjacent channel power measurement — Above fourth channel

4.2.33 As an alternate method, the VDB transmitter can be placed in CW mode and a spectrum analyser or power meter used. The power transmitted in CW mode should be the same as that measured as an average over the period of the synchronization and ambiguity resolution bits in the training sequence portion of the message.

Monitoring

4.2.34 Testing of the monitoring of the ground subsystem is a combination of design qualification activities and per-installation activities.

Integrity monitoring for GNSS ranging sources

4.2.35 Compliance with requirements for integrity monitoring of GNSS ranging sources is verified during the design qualification by simulations and data collection on test sites. Additional data collection may be necessary prior to commissioning of each site to confirm that monitor parameters derived during the design qualification are valid.

RF monitoring

4.2.36 Compliance with the executive monitoring requirements is established by analysis and testing during design qualification. For some of the monitoring functions it may also be necessary to carry out ground tests prior to commissioning and on a periodic basis as determined by the manufacturer or appropriate State authority. These are typically accomplished when it is necessary to establish and check the monitor threshold for a site dependent parameter, e.g. the VHF transmitter power monitor. Some specific executive monitor testing requirements are detailed below:

a) *VHF Data Broadcast monitoring*. Correct operation of this monitoring is verified during design qualification;

b) *TDMA slot monitoring*. Correct operation of this monitoring is verified during design qualification, but some specific designs (e.g. measurements on unassigned slot performed by a VDB receiver) may require periodic tests to confirm monitor performance. For other designs, it may be established by analysis that the failure risk is sufficiently low that the Annex 10 requirement is satisfied without a specific monitor; and

c) *VDB transmitter power monitoring*. Correct operation of this monitoring is verified during design qualification, but some specific designs (e.g. measurements performed by a VDB receiver connected to a separate VHF antenna) may require periodic tests to confirm monitor performance. The monitor threshold power level should be established during the flight test performed at commissioning. For other designs, it may be established by analysis that the risk of power increase is sufficiently low that the Annex 10 requirement is satisfied without a specific monitor.

4.3 FLIGHT TESTING/INSPECTION

General

4.3.1 Flight tests are used to confirm procedure design, final segment alignment, GNSS signal reception, and data link reception within the coverage volume. The aircraft GBAS equipment used for the flight test should meet the applicable standards required for the procedure being tested. There are situations that may require modifications to the flight test receiver that could invalidate the certification. This may require special consideration or certification if the receiver is also intended for instrument flight conditions use. This receiver may be used for all required checks. In some cases, it may be desirable to acknowledge and suppress GBAS alerts, warnings and flags for the purposes of completing required checks.

4.3.2 Flight tests of GBAS are required under the following circumstances:

a) prior to commissioning on each runway served and for each approach;

b) whenever interference is reported or suspected and ground testing cannot confirm elimination of the source of interference;

c) as a result of a procedure modification or the introduction of a new procedure;

d) whenever changes occur to the GBAS configuration such as the location of the GBAS ground subsystem antenna phase-centre, the location of the data link transmit antenna, or the system database;

e) whenever site changes such as new obstructions or major construction occur that have the potential to impact GNSS signal reception and data broadcast transmission; and

f) following certain maintenance activities.

If periodic flight tests are desired, parameters and intervals will be determined by individual States.

Flight test performance parameters

4.3.3 A summary of flight test requirements is given in Table II-4-4.

Flight test/inspection procedures

Way-point and procedure design correlation

4.3.4 The FAS data received from the ground station should be checked for consistency against the original procedure design.

GNSS system predictions

4.3.5 Before flight-testing begins, an analysis of GNSS predictions should be accomplished to confirm that the GNSS signals will support the flight-testing without alerts.

Table II-4-4. Summary of minimum flight test requirements — GBAS

Parameter	*Annex 10 Volume I reference*	*Doc 8071 Volume II reference*	*Measurand*	*Tolerance/ Limit*	*Uncertainty*	*Periodicity*
FAS data	App.B 3.6.4.5	4.3.4	FAS path	Consistent with FAS design	N/A	C, Sp
Procedure Validation	(none)	5.3	N/A	N/A	Subjective	C, Sp
Resistance to Interference (Ranging Signal)	App. B 3.7	4.3.6	Interference signal level	< interference mask definitions	±3 dB	C, Sp
VDB Coverage GBAS/H field strength GBAS/E field strength Horizontal Vertical	3.7.3.5.4.4	4.3.7 to 4.3.10	Field strength	>-99 dBW/m^2 to –35 dBW/m^2 >-99 dBW/m^2 to –35 dBW/m^2 –103 dBW/m^2 to –39 dBw/m^2	±3 dB	C, Sp
Message block header (GBAS identification only)	App. B 3.6.3.4.1	4.3.14	Facility Identification	Exact Match	N/A	C, Sp
Data content (operational)	App. B 3.6.4	4.3.15 to 4.3.16	Message Data Content	Exact Match	N/A	C, Sp
Position Domain Accuracy (optional)	(none)	4.3.17 to 4.3.18	Position	4 m vertical / 16m lateral	1m	C, Sp

Notes:

1. *N/A = Not Applicable.*
   C = Commissioning (and when published design changes to the procedure occur).
   Sp = Special, e.g. when interference is suspected or a periodic interference check is desired.
2. *If periodic checks are desired, parameters and intervals will be determined by individual States.*

In-flight activities

Procedure validation

Resistance to interference (ranging signal)

4.3.6 GBAS receiver standards require that receivers not provide hazardously misleading information in the presence of radio frequency interference. Excessive ranging signal interference will therefore affect continuity and availability, rather than integrity. The loss of GBAS correction signals and/or the loss of guidance have proven to be good indicators of probable GNSS and/or GBAS interference. If interference is suspected, further investigation should be conducted. Some States may require a pre-commissioning survey of the interference environment. The suspected area should be probed and spectrum analysis accomplished to define its geographical extent. GNSS and GBAS parameters such as carrier-to-noise density (C/No), horizontal and vertical protection levels, satellites tracked, and DOP should be documented to aid further investigation. If interference is confirmed, the appropriate action should be taken, e.g. approach procedure may be removed from operational status, pending corrective action, and appropriate authorities should be notified. For more details, refer to Chapter 1, Attachment 3.

Coverage

4.3.7 The broadcast power of an installed VDB is constrained by many factors, only one of which is the desired field strength in the defined coverage region. Other constraints include adjacent and co-channel interference to neighbouring systems and the VDB receiver sensitivity. Within the minimum required GBAS coverage volume of each final approach segment served, the minimum and maximum VDB field strength requirements must be met. Where an operational requirement exists to use GBAS to altitudes and/or distances beyond the nominal coverage volume, the field strength requirement should be inspected to the expanded altitudes and/or distances.

4.3.8 The field strength should be measured as an average over the period of the synchronization and ambiguity resolution bits in the training sequence portion of the message. As a recommended method, an on-board calibrated VDB receiver may be used to confirm adequate field strength within the coverage volume. This receiver should provide accurate power measurement within the full dynamic range necessary to confirm the minimum and maximum field strength on each received burst. Using this method allows checking the coverage in parallel with other checks (e.g. flyability, message content).

4.3.9 As an alternate method during commissioning, the VDB transmitter can be placed in CW mode and a spectrum analyser or power meter used. The power transmitted in CW mode should be the same as that measured as an average over the period of the synchronization and ambiguity resolution bits in the training sequence portion of the message.

4.3.10 If GBAS positioning service is used, the field strength requirements should be confirmed by flying the procedures. Note.— For safety reasons the height of the aircraft above obstacles should be taken into account (Doc 8071, Volume I, Chapter 1, 1.16.9).

Arcs

4.3.11 Arcs should be flown to assess the lower limit of the GBAS coverage within the required lateral region. Fly an arc ±10 degrees across the extended Final Approach Segment course at 37 km (20 NM) from the FTP/LTP. Fly an arc ±35 degrees across the extended Final Approach Segment at 28 km (15 NM). The arc can be flown in either direction. A ±35 degree arc at 20 NM may be flown in lieu of the ±10 degree 37 km (20 NM) and ±35 degree 28 km (15 NM) arcs. Arcs for parallel or multiple runways may be combined to minimize flight inspection time. Confirm minimum field strength requirements are met at the lowest vertical coverage limit. If the field strength is unsatisfactory, altitudes may be raised incrementally to an altitude that coincides with the lower limit of the coverage volume.

Flight at constant height

4.3.12 The minimum field strength level may be found not only at the edge of coverage, but within the coverage area because of fading effects. Adequate flight checks should be performed to verify that the required minimum field strength is met within the whole coverage volume. An acceptable means to assess the fading effects is to fly at a constant height along the extended runway centreline. Fly at the upper height of the required coverage volume (e.g. 7 degrees minimum, 3 000 m (10 000 ft) HAT) from the outer limit of coverage to less than 24 km (13 NM) (for 7 degrees), and at an altitude of 2 000 ft beginning at 39 km (21 NM) (corresponding to the lowest vertical coverage limit of 0.9 degrees) to within 4.6 km (2.5 NM) for each runway end served. Confirm minimum field strength requirements are met on both level runs.

Final approach path

4.3.13 The minimum and maximum field strength requirements should be confirmed along all FAS served by the ground subsystem. Proceed inbound along the final approach course following the procedure. Intercept the glidepath and fly to an altitude of 30 m (100 ft). When the coverage is required to be extended down to 3.7 m (12 ft) above runway surface, the maximum and minimum field strengths should be confirmed to the touchdown point. If the signal level is unsatisfactory prior to glidepath interception, altitudes may be raised incrementally to coincide with the lower limit of the coverage volume.

Message block header (GBAS identification only)

4.3.14 While flying within the service volume of the VDB broadcast, confirm proper GBAS identification.

Data content (operational)

4.3.15 VDB broadcast data affecting operational use of the GBAS station should be confirmed to be correct during flight testing. The list of parameters shown in Table II-4-5 should be checked. While flying within the service volume of the VDB broadcast under test, confirm that the broadcast information matches the intended values obtained from the ground maintenance personnel.

4.3.16 In addition to confirming data content, an end-to-end test of GBAS approach selection should be accomplished by using the assigned channel number as published on the approach plate. This confirms that the reference path data selector (RPDS) data field and the VDB frequency match the channel number. Alternatively, the approach to be inspected may be selected by the VDB frequency and the appropriate RPDS. If a GBAS positioning service is provided, the reference station data selector (RSDS) value should be confirmed by substituting the RSDS value for the RPDS value in the approach selection process.

Position accuracy (optional)

4.3.17 Although position accuracy is checked during ground testing, it can optionally be performed during flight testing if a suitable position fixing system is available. This functional test is intended to confirm that the GBAS contribution to the position domain accuracy is satisfactory, but is not intended to provide a statistical confidence level of the position measurement. If the deviation output signals of the receiver are used for this assessment, the position fixing system must provide accurate range information in order to convert the measured deviations to linear errors for application of tolerances.

4.3.18 Fly the final approach segment from at least 18.5 km (10 NM) to ensure that the carrier smoothing filter has converged prior to making a point measurement close to the decision height or threshold. The measured lateral and vertical errors should meet the tolerance in Table II-4-4.

Test equipment

4.3.19 Special equipment requirements include the following:

a) aircraft GNSS receivers should meet applicable standards for the phase of flight and type of flight procedure being tested. Such receivers used for flight testing activities will require some modifications (e.g. they must operate while the ground subsystem is in TEST mode). The receiver should have the capability of outputting parameters required in Table II-4-4;

b) inspection of Category I GBAS procedures does not require a position fixing system. However, one may be used based on individual States' regulatory requirements; and

c) data logging equipment, when used, should be capable of recording time and at least the parameters listed in Table II-4-4.

Note.— It has been found helpful to be able to observe and optionally record during flight-testing additional parameters beyond those listed in Chapter 1, Attachment 2, such as HPL/VPL. These parameters may provide an indication of marginal performance and are a baseline for further analysis of any observed anomalies.

Table II-4-5. Data broadcast parameters to be checked during flight testing

Parameters to be confirmed	*Values or special coding*
Type 2 Message (GBAS related data)	
GAD (GBAS Accuracy Designator) letter	A, B, or C
GCID	1 or 7
Reference Station Data Selector (RSDS)	Site-specific
Maximum use distance (D_{max}, if broadcast)	Maximum procedural use distance (km) (Special coding '0' when no limitations)
Magnetic Variation	Site-specific
Type 4 Message (FAS data)	
Operation Type	0 for straight-in approach
Airport Identification	3 or 4 alphanumeric characters
Runway Number	Site-specific
Runway Letter	Site-specific, (R, C, L, or no letter)
Approach Performance Designator	Site-specific (1 for Category I)
Route Indicator	Site-specific
Reference Path Data Selector (RPDS)	Site-specific
Reference Path Identifier (RPI)	Site-specific
FASVAL	Value determines vertical alert limit, ('1111 1111' if vertical deviations not to be used)
FASLAL	Value determines approach status ('1111 1111' if approach not to be used)

Chapter 5

FLIGHT VALIDATION OF INSTRUMENT FLIGHT PROCEDURES

5.1 INTRODUCTION

Note.— This chapter is based on Volume I, Chapter 8. It provides general guidance on flight validation of RNAV procedures and clarifies the differences between flight inspection of navigation signals and the flight validation of instrument flight procedures. Some sections of this chapter are therefore also applicable to procedures based on conventional navaids.

General

5.1.1 Instrument flight procedures depict standard routings, manoeuvring areas, flight altitudes and approach minima for instrument flight rules (IFR) flight activities. These procedures include airways, off-airway routes, jet routes, instrument approach procedures (IAPs), instrument departure procedures, terminal arrival routes and procedures predicated upon the use of Area Navigation (RNAV) systems.

5.1.2 Flight inspection of instrument flight procedures, as detailed in the other chapters of this document should assure that the appropriate radio navigation aids adequately support the procedure. Flight validation involves the verification of all obstacle and navigational data, verification of the required infrastructure and the assessment of the charting and the flyability of the procedure. When the State can verify, by ground validation, the accuracy and completeness of all obstacle and navigation data considered in the procedure design, and any other factors normally considered in the flight validation, then the flight validation requirement may be dispensed with.

5.1.3 Instrument flight procedures should be a part of the flight validation process for initial certification and a part of the periodic quality assurance programme as established by the individual States.

5.2 PRE-FLIGHT REQUIREMENTS

Instrument flight procedures specialist

5.2.1 The instrument flight procedure designer is normally responsible, in coordination with the appropriate engineering authority, for providing all data applicable to conducting a flight inspection or a flight validation to the appropriate operations activity. This includes output from the navaid infrastructure coverage analysis together with any supporting data and design assumptions. The procedure owner should also identify any alternate routes published on the chart as ‘at ATC discretion’. Such routes should be reviewed to determine if it is necessary for them to be included in the flight inspection or the flight validation. When appropriate, the procedure specialists should be prepared to provide briefings to the flight crews in those cases where flight procedures have unique application or special features.

5.2.2 The instrument flight procedures specialist should participate in the initial certification flight to assist in its evaluation and obtain direct knowledge of issues related to the procedures design from the flight validation pilot and/or validator.

Instrument approach procedure (IAP) data package

5.2.3 Each IAP flight inspection or validation package should include the following data:

a) A plan view of the final approach obstacle evaluation template, drawn on air navigation charts of sufficient scale to safely accommodate use for navigation, elevated terrain analysis, obstacles and obstructions evaluation.

b) Completed documents that identify associated terrain, obstacles and obstructions as applicable to the procedure. The controlling terrain/obstacle should be identified and highlighted on the appropriate chart.

c) Minimum altitudes determined to be applicable from map studies and database information for each segment of the procedure.

d) A narrative description of the instrument approach procedure.

e) Plan and profile pictorial views of the instrument approach procedure.

f) Documented data as applicable for each fix, intersection, and/or holding pattern.

g) Air-ground communications, as applicable to each segment of the procedure.

h) Airport marking and any special local operating procedures such as noise abatement, non-standard traffic patterns, lighting activation, etc.

i) Output from the navaid coverage analysis that was conducted by/for the procedure designer together with any supporting data and design assumptions.

5.3 FLIGHT INSPECTION AND VALIDATION PROCEDURES

Objective

5.3.1 The objective of the flight inspection and flight validation evaluation of instrument flight procedures is to assure that the navigation source supports the procedure, ensures obstacle clearance, and checks the flyability of the design. The following activities should be accomplished:

a) Verify the obstacle that serves as the basis for computing the minimum altitude in each segment of the IAP.

b) Evaluate aircraft manoeuvring areas for safe operations for each category of aircraft for which the procedure is intended.

c) Review the instrument procedure for complexity of design, and evaluate the intensity of the cockpit workload to determine if any unique requirements adversely impact safe operating practices. Check for correctness of information, propriety and ease of interpretation.

d) If appropriate, verify that all required runway markings, lighting and communications are in place and operative.

5.3.2 The flight validation of an instrument flight procedure and verification of the obstacle data may be conducted during the associated navigation aid inspection if visual meteorological conditions (VMC) prevail throughout each segment.

Verification of obstacle clearance

5.3.3 *Original flight procedures.* A ground or in-flight obstacle verification should be conducted for each route segment during the development of original flight procedures.

5.3.4 *Identification of new obstacles.* When new obstacles are discovered during flight validation activities, the fight validator should identify the location and height of the new obstruction(s) and provide the information to the procedure specialist. Procedure commissioning should be denied until the procedure specialist's analysis has been completed and the flight procedure adjusted as appropriate.

5.3.5 *Determination of obstacle heights.* If in-flight height determination of obstacles or terrain is required, accurate altimeter settings and altitude references are necessary to obtain the most accurate results possible. The method of obstacle height determination should be documented on the flight validation report.

Detailed procedures

En-route/terminal routes

5.3.6 Evaluate each en-route or terminal segment during commissioning flight validation to ensure that the proposed minimum obstacle clearance altitude (MOCA) is adequate. These segments should be flown at the proposed minimum en-route altitude (MEA) using the applicable NAVAID for guidance. For instrument departure procedures, the segment(s) should be evaluated according to an established NAVAID, fix or point where en-route obstacle clearance has been established. For a terminal arrival route, each segment should be evaluated from where the route departs established obstacle clearance to the point where the route intercepts an established approach procedure. Periodic validations of en-route and terminal route segments are not required.

Final approach segment

5.3.7 The final approach course should deliver the aircraft to the desired point. The point varies with the type of system providing procedural guidance and should be determined by the procedure specialist. After flight validation verifies the established point, it should not be changed without the concurrence of the procedure specialist. When the system does not deliver the aircraft to the established point, and if the system cannot be adjusted to regain the desired alignment, the procedure should be redesigned.

Missed approach

5.3.8 The flight validator should assure that the designed procedural altitudes provide the appropriate required or minimum obstacle clearance (ROC/MOC) and determine that the procedure is safe and operationally sound for the categories of aircraft for which use is intended.

Circling area

5.3.9 The flight validator should verify that the depicted circling manoeuvring areas are safe for each category of aircraft and that the controlling obstacle is correctly identified.

Terminal segments

5.3.10 Controlling obstacles in terminal segments should be confirmed visually by in-flight or ground observation. If unable to confirm that the controlling obstacle, as identified by the procedure specialist, is the highest obstruction in the segment, the flight validator should list the location, type, and approximate elevation of the obstacles to be provided to the procedure specialist for technical evaluation. Conduct obstacle evaluations in VMC only. The flight validator should be responsible for ensuring that instrument flight procedures are operationally safe in all areas of design, criteria application and flyability.

Instrument approach procedure (IAP)

5.3.11 An IAP intended for publication should be evaluated in flight. The final approach template should be evaluated to identify/verify the controlling obstruction. The final approach segment should be flown at an altitude 30 m (100 ft) below the proposed minimum descent altitude. Approaches with precision vertical guidance should be evaluated according to the proposed decision or missed approach altitude. Discrepancies or inaccurate data should be provided to the procedure specialist for action prior to commissioning the procedure.

Minimum en-route altitude (MEA)
and change-over points (COPs)

5.3.12 MEAs are computed and published in accordance with policies and procedures in effect within each State. MEAs and COPs should be predicated on minimum obstruction clearance altitude (MOCA), minimum reception altitude (MRA), airspace, or communication requirements. If more than one of these altitudes are procedurally applicable, the highest altitude determined through a flight validation should become the minimum operational altitude.

Fixes/holding patterns

5.3.13 Controlling obstacles should be verified to ensure the adequacy of minimum holding altitude (MHA).

Air-ground communications

5.3.14 Air-ground communications with the appropriate controlling facility should be evaluated for satisfactory performance at the minimum initial approach fix altitude and at the missed approach altitude. In those cases where air traffic control operations require continuous communications throughout the approach, flight inspection should evaluate availability of that coverage.

Area navigation (RNAV)

5.3.15 Procedures based upon RNAV (GNSS or DME/DME) should be evaluated by flight validation for conformance to safe and sound operational practices.

5.3.16 The entire procedure should be flown, including, for approach procedures, Initial, Intermediate, Final Approach and Missed Approach segments. Alternate or additional segments should be checked on commissioning to the point where the routing intersects a portion of the procedure already checked. The intent is that each segment of the procedure should be flown at least once; common segments do not need to be repeated.

5.3.17 *Survey requirements.* RNAV instrument flight procedures are predicated on airport and runway survey coordinates. Airport survey accuracies must conform to the required standards referenced in Chapter 1, Section 1.4, to support aircraft database use.

5.3.18 *Navigation data requirements*. RNAV instrument flight procedures describe a prescribed ground track which is defined by way-point location, way-point type, path terminator and, where appropriate, speed constraint, altitude constraint and course. The flight validation aircraft must fly the proposed RNAV procedure following the ground track defined by the procedure designer. One way in which this can be achieved is by using an RNAV system and an ARINC 424 compatible navigation database containing the procedures to be checked. Standard $\text{RNAV}_{\text{(GNSS)}}$ approaches may be defined by manual entry of all the way-points. In all other cases, manual entry of way-point coordinates is not an acceptable means of defining the path to be flown. The RNAV system and the database may be part of the flight inspection system or the aircraft navigation system. The flight validation should be carried out before the procedures are released for public use. This generally means before the procedures are published in the AIP. This may require the use of a special test database produced by the appropriate navigation data provider and packed for the RNAV system in use on the flight validation aircraft. If this involves the use of navigation databases produced by the commercial datahouses, the procedure owner must take account of the likely lead times.

5.3.19 *Maps and charts for flight validations.* The pilot or crew member responsible for the flight validation should have appropriate topographical maps and procedure charts of the area to the runway to be tested, showing the runway, and identifying prominent landmarks and way-point locations of the procedure. The available set of documentation for flight validation should include all relevant data such as procedure design, segment lengths, bearings, and descent and climb angles. For more details, refer to Volume I of Doc 8071.

5.3.20 *Procedure validation*. The instrument flight procedure should be evaluated for conformance with the procedure design and navaid signal reception. The following issues should also be addressed:

a) Reception of navaid signals required for the procedure may be interrupted during aircraft banking or masked by terrain. When this is encountered, the instrument flight procedure may require modification. In some locations, modification may not mitigate this situation and the instrument flight procedure should be denied. Procedures that support azimuth-only approaches should be evaluated through the MAPt. Procedures with vertical guidance should be evaluated to the decision altitude.

b) Aircraft manoeuvring must be consistent with safe operating practices for the category of aircraft intending to use the procedure.

c) Cockpit workload must be acceptable.

d) Navigation charts must properly portray the procedure and must be easily interpreted.

e) Obstacles that control the minimum altitude for each segment should be verified visually by in-flight or ground observation.

f) *Way-point accuracy*. The way-points depicted on the procedure should be verified as properly labeled and correct.

g) *Bearing accuracy*. Where applicable, the bearing, as depicted on the instrument approach procedure, should be evaluated for accuracy.

h) *Distance accuracy*. Distances should be verified for accuracy using a validated, automated flight inspection system, where applicable, or by using ground reference positions when conducting manual flight validation operations.

i) *Flyability*. The verification of the flyability of an RNAV procedure can include independent assessments by procedure designers and other experts using specialist software, full flight simulators or even trial flights conducted by flight validation or flight inspection aircraft. Where a flight validation is required to address flyability aspects, the procedure designer should identify which procedures, or parts of a procedure, should be reviewed by the flight validator from a flyability perspective.

5.3.21 The position of the missed approach point (MAPt) must be confirmed with respect to the physical environment. This verification may be achieved either visually or electronically, and descent below the published minima may be necessary. A truth system may be used when visual verification is not practical, such as for over-water or some non-threshold MAPts. Consideration must be given to the types of aircraft that will be using the procedure and the runway environment.

Additional requirements

General

5.3.22 The validation pilot should review and evaluate each segment of the procedure for conformance with safe operational practices as applicable to the following areas:

a) *Procedure safety*: The procedure should be evaluated to ensure compliance with safe operating practices, simplicity of the depiction, and a reasonable level of flight crew workload associated with programming and flying the required manoeuvres.

b) *Runway marking, lighting and communications.* The flight validator should evaluate these airport facilities to assure their suitability in supporting the procedure. Lack of suitability in any of these areas supports denying the procedure.

Airport lighting evaluations

5.3.23 *New flight procedures.* For new instrument approach procedures at airports with no prior IFR service, a night flight validation should be conducted to determine the adequacy of airport lighting systems prior to authorizing night minima.

5.3.24 *Approach/landing light system validation.* Airport light systems should be evaluated during the hours of darkness. The evaluation should determine that the light system displays the correct lighting patterns, that it operates in accordance with operational design/capabilities and that local area lighting patterns do not distract, confuse or incorrectly identify the runway environment.

5.4 ANALYSIS

General

5.4.1 The flight validation should determine that the procedure is flyable and safe. When a new procedure is found to be unsatisfactory, the flight validator should coordinate with the instrument flight procedure specialist to resolve identified problem areas and determine the necessary changes. When a published procedure is found unsatisfactory, the flight validator should initiate action to advertise the deficiency through a NOTAM publication and advise the procedure specialist.

Human Factors

5.4.2 The criteria used to develop instrument flight procedures include factors associated with minimizing cockpit workload and human limitations. The flight validator should consider whether or not an instrument approach procedure is operationally safe and flyable for a minimally qualified solo pilot, flying an aircraft with basic IFR instrumentation in instrument meteorological conditions, using standard navigation charting. The flight validator should apply the principles of Human Factors when certifying an original or amended procedure by considering the following characteristics.

5.4.3 *Complexity.* The procedure should be as simple as possible to avoid imposing an excessive workload.

5.4.4 *Presentation.* The flight validator should confirm that the procedure presentation conforms to requirements.

5.5 TOLERANCES

Distance and bearing accuracies should be in accordance with the specific chapters of this document, depending on the type of navigation source upon which the instrument procedure has been developed. The navigation aid and the procedure should consistently deliver the aircraft to a point within the depicted fix displacement area, as applicable.

5.6 ADJUSTMENTS

The flight inspection crew should support the facility maintenance technicians efforts by supplying all available data collected on the facility and providing flight inspection support where possible. Requests for ground-based equipment adjustments should be specific.

5.7 REPORTS

Once all checks have been made, and input has been received from all flight crew members, the flight validator should complete the flight validation report to document that the procedure has been checked. An example report with associated checklists and worksheets is shown in Figure II-5-1.

RNAV IFP WAY-POINT VERIFICATION WORKSHEET (RUNWAY)

Date: ________________________ Aerodrome: ________________________

Procedure: ________________________ Checked by:________________________

Runway survey:

WPT	POSITION	COMPUTED BRG, T	MAG VAR	COMPUTED BRG, M	PUBLISHED BRG, M	COMPUTED DISTANCE	RW LENGTH
Threshold	N W						
Departure end	N W						

Assessment: ____________________________

North of 60N, set MAG VAR to 0 and perform all computations using true bearings.

RNAV IFP WAY-POINT VERIFICATION WORKSHEET

Date: ________________________ Aerodrome: ________________________

Procedure: ________________________ Checked by:________________________

LEG	COMPUTED BRG, T	MAG VAR	COMPUTED BRG, M	DESIGN BRG, M	COMPUTED DISTANCE	DESIGN DISTANCE	PASS/FAIL

North of 60N, set MAG VAR to 0 and perform all computations using true bearings.

RNAV IFP FLIGHT VALIDATION CHECKLIST — PLANNING AND PRE-FLIGHT

Aerodrome: ______________________ Procedure: ______________________

Date: ______________________ Inspector: ______________________

Type of inspection: _____________

Documentation and tools			Supporting information		
Checklists	....	☐	Anticipated date/time of inspection		
IAP form	....	☐			
Inspection forms	....	☐			
Approach plate	....	☐	Wx		
Topographic maps	....	☐			
Data collection system/DTU	....	☐	Constellation predictions:		
Blank disks	....	☐			
Flight plan			RAIM (HIL)		
			Number of Sats		
			HDOP		
Programme FMS/GPS	....	☐	ATC coordination	....	☐
Wpt entry verification	....	☐	Contact Airport Authority	....	☐
Leg lengths/tracks	....	☐	Survey worksheet complete	....	☐
Duplicate way-points	....	☐	Way-point worksheet complete	....	☐

WAY-POINT VERIFICATION (AVIONICS)

LEG	WPTS	DIST	DESIGN DIST	TK	DESIGN TK	PASS
Initial L						
Initial C						
Initial R						
Intermediate						
Final						
Missed						

RNAV IFP FLIGHT VALIDATION CHECKLIST — INFLIGHT

Aerodrome: ______________________ Procedure: ________________________

Date: ______________________ Inspector:_________________________

Altimeter setting source	....	☐	Duplicate way-points	....	☐
Wpt entry verification	....	☐	Deselect non-GPS sensors	....	☐
Leg lengths/tracks	....	☐	Start data recording	....	☐
Obstacle verification:			**Confirm way-point positions:**		
Arrival	....	☐	Arrival	....	☐
Initial L	....	☐	IAF	....	☐
Initial R	....	☐	IF	....	☐
Initial C	....	☐	SDF	....	☐
Intermediate	....	☐	FAF	....	☐
Final	....	☐	SDF	....	☐
Missed	....	☐	MAPt	....	☐
Circling	....	☐	MATP	....	☐
25 NM MSA	....	☐	Hold	....	☐
Departure	....	☐			
GNSS approach — Confirm MAtP position: N XTE W ATE Num SatsHDOP					
Comments:					

RNAV IFP FLIGHT VALIDATION CHECKLIST — OPERATIONAL ACCEPTABILITY

Aerodrome: ____________________________ Procedure: ________________________________

Date: ____________________________ Inspector:__________________________________

A/C type: ____________________________ Pilot flying: _______________________________

Intended user A/C — (GA, Helo, Commuter, B/Jet, Heavy, Military)
(Circle significant types)

Intended use:	**Flyability:**
Airspace .... ☐	Suitable for critical A/C .... ☐
Noise .... ☐	Climb/Descent gradient .... ☐
Environmental .... ☐	Segment length .... ☐
Communications .... ☐	Alignment on final .... ☐
Surveillance .... ☐	Gradient/alignment combo...................... ☐
Procedure plate .... ☐	
Aerodrome facilities .... ☐	Workload rating ______________________________
	(1-7 acceptable, 8-10 excessive)

Comments:

OVERALL ASSESSMENT — Pass Fail ________________________________
(Inspector's signature)

RNAV IFP FLIGHT VALIDATION WORKSHEET
INTERFERENCE AND SIGNAL AVAILABILITY

Aerodrome: ______________________________ Procedure: __________________________________

Date: ______________________________ Inspector: __________________________________

LEG	HDOP	NUM SATS	RAIM STATUS

Comments:

RNAV IFP FLIGHT VALIDATION — SUMMARY

Aerodrome: ____________________________ Procedure: _________________________

Date: ____________________________ Inspector: __________________________

Assessments:

Survey verification	....	☐
Way-point verification	....	☐
Topo map wpt verification	....	☐
Signal coverage	....	☐
Interference	....	☐
Obstacle verification	....	☐
MAPt verification	....	☐
Human Factors	....	☐
Communications	....	☐
Lighting systems	....	☐
Operational acceptability	....	☐

Overall assessment: PASS FAIL

NOTAM issued: ☐

Inspector's signature: ____

Figure II-5-1. Example worksheets, checklists and report forms – RNAV procedures

— END —

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the Aeronautical Chart Catalogue *or the* Meteorological Tables for International Air Navigation.

International Standards and Recommended Practices are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications contained in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

Procedures for Air Navigation Services (PANS) are approved by the Council for worldwide application. They contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

Regional Supplementary Procedures (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

Technical Manuals provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

ICAO Circulars make available specialized information of interest to Contracting States. This includes studies on technical subjects.
