International Civil Aviation Organization

MIDANPIRG STEERING GROUP

Sixth Meeting (MSG/6)
(Cairo, Egypt, 3 - 5 December 2018)

Agenda Item 5.3: Specific Air Navigation issues

NAVIGATION MATTERS

(Presented by the Secretariat)

SUMMARY

This paper presents the Guidance on GNSS Implementation in the MID Region, for endorsement.

Action by the meeting is at paragraph 3.

1. INTRODUCTION

1.1 GNSS is defined by ICAO SARPs as a worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented as necessary to support the required navigation performance for the intended operation.

2. DISCUSSION

2.1 GNSS is a key enabler of the PBN Implementation in the MID Region. Guidance material on GNSS Implementation has been developed to complement the information in the PBN Plan and provide guidance on the implementation aspects of GNSS in order to assist States in the introduction of GNSS operations.

2.2 The meeting may wish to note that the CNS SG/8 reviewed the Draft Guidance on GNSS Implementation in the MID Region and through Draft Conclusion 8/6 invited States to review the Draft Guidance and provide the ICAO MID Office with their comments/inputs by **15 May 2018**.

2.3 The Final version of the GNSS Implementation in the MID Region at **Appendix A** was consolidated taking into consideration the replies received from Bahrain, Egypt and Jordan.

3. ACTION BY THE MEETING

3.1 The meeting is invited to agree to the following Draft Conclusion:

DRAFT CONCLUSION 6/X: GUIDANCE ON GNSS IMPLEMENTATION

That, the Guidance on GNSS Implementation in the MID Region at ***Appendix A*** *is endorsed and be published as ICAO MID Doc 00X.*

APPENDIX A

INTERNATIONAL CIVIL AVIATION ORGANIZATION

MIDDLE EAST

AIR NAVIGATION PLANNING AND IMPLEMENTATION REGIONAL GROUP (MIDANPIRG)

GUIDANCE ON GNSS IMPLEMENTATION IN THE MID REGION

AMENDMENTS

The GNSS Guidance in the MID Region should be reviewed and updated by the CNS Sub-Group. States shall submit their proposal for amendment to the Plan to the ICAO MID Regional Office, the changes can be coordinated by correspondence with main CNS focal points/ or State letters.

The table below provides a means to record all amendments. An up to date electronic version of the Plan will be available on the ICAO MID Regional Office website.

Edition	Date	Comment	Section affected
V0.1	11/2/2018		All
V0.2	1/4/2018	Add NDB IDs to the Appendix A	Page 26-28

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ACRONYMS

AO	Aircraft Operators
AAIM	Aircraft Autonomous Integrity Monitoring
ABAS	Aircraft Based Augmentation System
APCH	Approach
CAPEX	Capital Expenditure
DME	Distance Measuring Equipment
DOP	Dilution of Precision
EGNOSS	European Geostationary Navigation Overlay Service
FD	Fault Detection
FDE	Fault Detection and Exclusion
GAGAN	GPS Aided GEO Augmented Navigation
GBAS	Ground Based Augmentation System
GLONASS	Global Navigation Satellite System
GLS	GBAS Landing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ILS	Instrument Landing System
INS	Inertial Navigation System
IRS	Inertial Reference System
LNAV	Lateral Navigation
MLS	Microwave Landing System
MSAS	MTSAT Satellite based Augmentation System
NDB	Non-Directional Beacon
NPA	Non-precision Approach
NSE	Navigation Sensor Error
OPEX	Operating Expense
PA	Precision Approach
PBN	Performance Based Navigation
RAIM	Receiver Autonomous Integrity Monitoring
RNAV	Area Navigation
RNP	Required Navigation Performance
SBAS	Satellite Based Augmentation
SDCM	System of Differential Correction and Monitoring
VOR	Very High Frequency Omni Directional Radio Range

THE OBJECTIVE AND SCOPE OF THE DOCUMENT

The objective of this document is to provide States in the Middle East Region with guidance for GNSS implementation based on the Global Air Navigation Plan and Regional Requirements.

The document outlines the status of Satellite constellations and Augmentation systems worldwide, with focus on the available Augmentation systems that can be implemented in the MID Region; the services provided, and requirements to exploit these Navigation services. Moreover, the document provides practical information on GBAS deployment, with reference to other Regions experience and factors to be considered in the process of cost estimation for the cost benefit analysis.

The GNSS application is out of scope of this document and addressed in the MID PBN implementation plan and the MID Region Surveillance Plan. As the GNSS is the key enabler for PBN implementation, this guidance document developed to complement the information in the MID PBN implementation Plan; ICAO MID DOC 007.

This document is divided into three parts; Part one includes information about the GNSS and Augmentation systems worldwide, and ICAO GANP Navigation Roadmap.

Part II identifies the current conventional Navigation aids infrastructure in the MID Region. And focuses on the SBAS Systems that may extends their services to the MID states.

Part III addresses the GNSS vulnerabilities due to intentional and unintentional sources of interference and to certain ionospheric effects. Also, it defines mitigation strategies to be deployed by States to reduce the likelihood and impact of the GNSS interference as defined by ICAO.

Part I: General Navigational Infrastructure

Navigation Aids Infrastructure refers to the ground and space-based NAVAIDs and provides positioning capability.

1- TERRESTRIAL NAVIGATIONS

Terrestrial Navigation Aids “conventional” refers to ground-based navigations such as NDB, ILS, VOR, TACAN, DME, …, etc.

The basic principle of all of these navigation facilities is the fact that aircraft in general navigate towards and away from the navigation aid itself, “point to point”. This means that the location of the navigation aid must be in an optimized location. This optimized position is, in many cases, not achievable (due to being situated in high terrain, open seas, politically unacceptable areas, etc.). Therefore, the route structure must be aligned with the position of the navigation aid and not aligned in the ideal position for its purpose. This results in additional distances being flown by aircraft which has a number of disadvantages including economic, environmental and efficiency drawbacks.

In addition to the additional distance flown a number of other problem areas arise;

- High terrain. At airports located in high terrain with difficult accessibility arrival procedures, based upon conventional ground based navigation aids, may result in aircraft being unable to land at the airport safely during periods of low visibility.

- Lateral containment of tracks. With conventional ground based navigation aids the accuracy of the track to be flown is a factor of how close to the aid the aircraft is. The closer the aircraft is to the aid the more accurate the track keeping capability. As the aircraft gets further away from the aid the accuracy reduces. This requires that a maximum distance for the aid to be used must be published and that the route spacing requires to be established on the worst case scenario.

In the global context, GNSS based PBN procedures have been implemented, and several GLS (CAT I) procedures are in place.

2- GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

GNSS is a satellite-based navigation system utilizing satellite signals, for providing accurate and reliable position, navigation, and time services to airspace users. It provides location and time information anywhere on, or near, the earth in all weather conditions.

In 1996, the International Civil Aviation Organization (ICAO) endorsed the development and use of GNSS as a primary source of future navigation for civil aviation. ICAO noted the increased flight safety, route flexibility and operational efficiencies that could be realized from the move to space-based navigation. Today several GNSS systems are available in the world, the first system in operation was the Global Positioning System (GPS).

2-1 GPS

The Global Positioning System (GPS) is a space-based radio-navigation system consisting of a constellation of satellites and a network of ground stations used for monitoring and control. Currently 32 GPS satellites orbit the Earth at an altitude of approximately 11,000 miles providing users with accurate information on position, velocity, and time anywhere in the world and in all weather conditions.

GPS is operated and maintained by the Department of Defense (DoD).

2-2 GLONASS

The Russian Global Navigation Satellite System, which began operation in 1993. GLONASS network provides real-time positioning and speed data for surface, sea and airborne objects with an accuracy of one meter (three feet).

A group of 28 GLONASS satellites was in orbit as of April 2014, with 24 in operation, three spares, and one in the test-flight phase.

2-3 Galileo

Galileo is Europe's Global Satellite Navigation System (GNSS), providing improved positioning and timing information with significant positive implications for many European services and users. The system is still under deployment.

2-4 BeiDou

The BeiDou Navigation Satellite System (BDS) built and operated by China with a three-step strategy of development: to complete the construction of the BDS-1 and provide services to the whole country by the end of 2000; to complete the construction of the BDS-2 and provide services to the Asia-Pacific region by the end of 2012; and to complete the construction of the BDS and provide services worldwide around 2020.

2-5 RNSS

Regional Navigation Satellite System (RNSS) like NAVIC and QZSS. The Indian Regional Navigation Satellite System (IRNSS) with an operational name of NAVIC. QZSS is a system especially for usage in the Asia-Oceania regions, with a focus on Japan.

3- AUGMENTATION

Augmentation System provides additional data to users of GNSS equipment to improve accuracy, integrity, availability, or any other improvement to positioning, navigation, and timing. A wide range of different augmentation systems have been developed.

3-1 Space Based Augmentation System (SBAS)

SBAS systems are designed to augment the navigation system constellations by broadcasting additional signals from geostationary (GEO) satellites. The basic scheme is to use a set of monitoring stations (at very well-known position) to receive GNSS signals that will be processed in order to obtain some estimations of these errors that are also applicable to the users (i.e. ionospheric errors, satellite position/clock errors, etc.). Once these estimations have been computed, they are transmitted in the form of "differential corrections" by means of a GEO satellite.

Wide range of SBAS systems, designed according to the same standard have already been commissioned by the US (Wide Area Augmentation System WAAS) and Japan (MTSAT Satellite based Augmentation System MSAS).

Other systems are under commissioning or deployment in other regions of the world (e.g. GPS Aided GEO Augmented Navigation GAGAN in India and System of Differential Correction and Monitoring SDCM in Russia).

The current and planned SBAS systems coverage depicted in the figure (1-1)

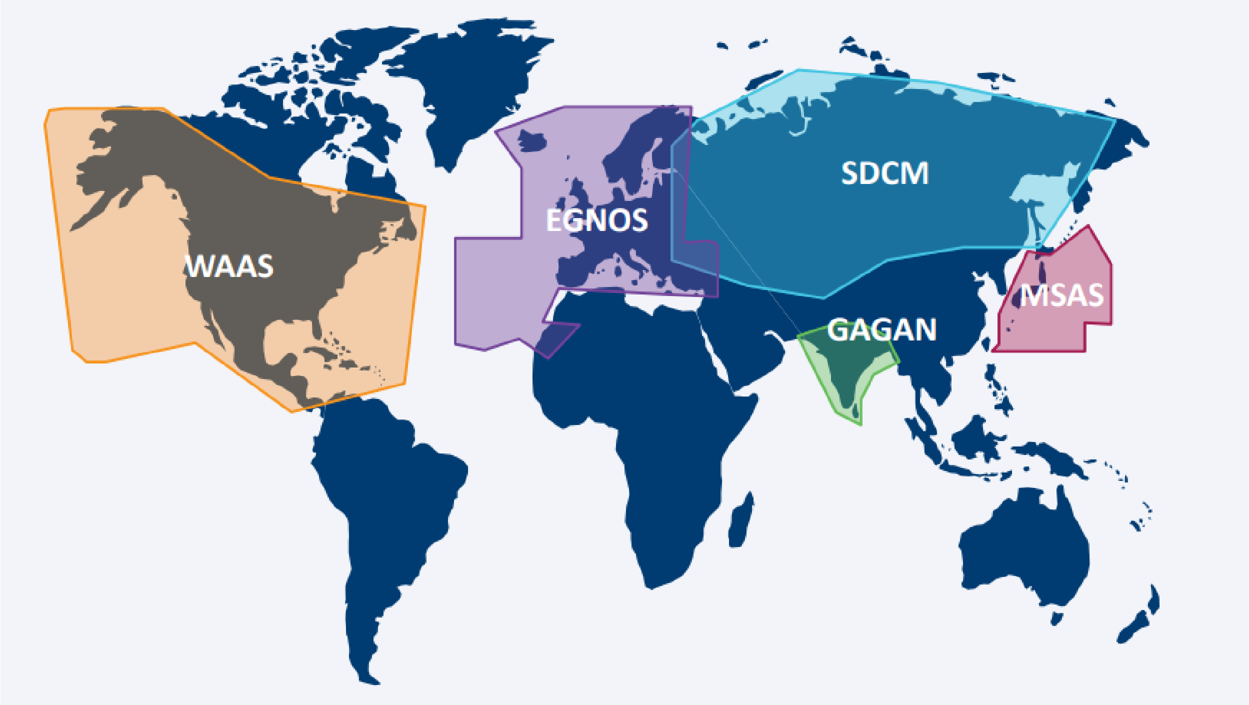

Figure (1-1)

3-1-1 WAAS

The Wide Area Augmentation System (WAAS) is an Air navigation aid developed by the Federal Aviation Administration to augment the Global Positioning System (GPS), with the goal of improving its accuracy, integrity, and availability.

3-1-2 EGNOS

The European Geostationary Navigation Overlay Service Navigation (EGNOS) is the European implementation of SBAS. Originally it was planned to augment GPS and GLONASS. Today, EGNOS augments GPS signals. EGNOS provides corrections and integrity information to GPS signals over a broad area centered over Europe and it is fully interoperable with other existing SBAS systems.

EGNOS provides three services:
- Open Service (OS), freely available to any user;
- Safety of Life (SoL) Service, that provides the most stringent level of signal-in-space performance to all Safety of Life user communities;
- EGNOS Data Access Service (EDAS) for users who require enhanced performance for commercial and professional use.

The main objective of the EGNOS SoL service is to support civil aviation operations down to Localizer Performance with Vertical Guidance (LPV) minima. In order to provide the SoL Service, the EGNOS system has been designed so that the EGNOS Signal-In-Space (SIS) is compliant to the ICAO SARPs for SBAS.

The Services provided by EGNOS:

- Non-Precision Approach operations and other flight operations supporting PBN navigation specifications other than RNP APCH, not only for approaches but also for other phases of flight.
- Approach operations with Vertical Guidance supporting RNP APCH PBN navigation specification down to LPV minima as low as 250 ft.
- Category I precision approach with a Vertical Alert Limit (VAL) equal to 35m and supporting RNP APCH PBN navigation specification down to LPV minima as low as 200 ft.

A NOTAM (Notice to Airmen) is a notice issued to alert pilots of potential hazards along a flight route that could affect the safety of the flight. The objective of the EGNOS NOTAM proposal generation is to:

- Predict APV-I and LPV-200 services outages at given airports.
- Create and format the corresponding NOTAM proposals into an ICAO format and according to the European Concept for GNSS NOTAM to ease the validation process to be performed by the NOF (NOTAM Offices).
- Distribute the NOTAM proposals to the concerned NOFs through the AFTN network.

3-1-3 GAGAN

GAGAN is the acronym for GPS Aided GEO Augmented Navigation. The GAGAN uses a system of ground stations to provide necessary augmentations to the GPS standard positioning service (SPS) navigation signal. A network of precisely surveyed ground reference stations (INdian Reference Stations INRES) is strategically positioned across the country to collect GPS satellite data. Using this information, the master control center (Indian Master Control Centre INMCC) generates messages to correct any signal errors. These correction messages are then uplinked through (Indian Land Uplink Station INLUS) and broadcast through communication satellites (Geostationary) to receivers onboard aircraft using the same frequency as GPS.

The Indian Space Research Organization (ISRO) and Airports Authority of India (AAI) have implemented the GPS Aided Geo Augmented Navigation-GAGAN project as a Satellite Based Augmentation System (SBAS) for the Indian Airspace. The objective of GAGAN to establish, deploy and certify satellite based augmentation system for safety-of-life civil aviation applications in India has been successfully completed. The system is inter-operable with other international SBAS systems like US-WAAS, European EGNOS, and Japanese MSAS etc. GAGAN GEO footprint extends from Africa to Australia and has expansion capability for seamless navigation services across the region. GAGAN provides the additional accuracy, availability, and integrity necessary for all phases of flight, from enroute through approach for all qualified airports within the GAGAN service volume.

The services provided by GAGAN are the following:

- RNP 0.1 within India FIR
- APV-1 in the landmass of Indian FIR.

Due to impact of ionosphere behavior over the equatorial regions, availability of GAGAN APV -1 service is better than 76% of landmass on nominal iono days.

3-1-4 SDCM

The System for Differential Corrections and Monitoring (SDCM) is the SBAS currently being developed in the Russian Federation as a component of GLONASS.

3-1-5 MSAS

MTSAT Satellite Based Augmentation System (MSAS) is the Japanese SBAS, the system in operation since September 27, 2007.

MSAS provide GPS Augmentation Information for RNAV, from En-route through NPA (RNP 0.3) within Fukuoka FIR. Due to ionosphere horizontal navigation information only provided.

MSAS provide users with NOTAM when required, including alert for Service Interruption or Predicted Service Outage.

3-2 GROUND BASED AUGMENTATION SYSTEM (GBAS)

GBAS is an augmentation system in which the user receives augmentation information directly from a ground-based transmitter. GBAS support precision approach, landing, departure and surface movement.

GBAS cat I is now operational at many Airports, GBAS classified based on approach service type as following:

- GAST-A : APV I Performance
- GAST-B : APV II Performance
- GAST-C : CAT I Performance
- GAST-D : CAT III Performance (amendment 91 to Annex 10 Vol I)
- GAST-F : CAT III Performance (multiconstellation, multifrequency, ICAO Standards will be available 2025-2028)

The cost of a single certified GBAS ground station is from SESAR studies and deployment in Europe 1,5 to 2 M€ per airport, which is equal roughly to the cost of three ILSs.

3-3 AIRCRAFT BASED AUGMENTATION SYSTEM (ABAS)

ABAS is achieved by features of the onboard equipment designed to overcome the performance limitations of the GNSS constellations. The two systems currently in use are Receiver Autonomous Integrity Monitoring (RAIM) and the Aircraft Autonomous Integrity Monitor (AAIM). ABAS considered low cost integrity supervision.

3-3-1 Receiver autonomous integrity monitoring (RAIM)

RAIM is a technology developed to assess the integrity of the GPS in a GPS receiver system and can predict areas in which the GPS signal may be compromised. RAIM requires no data from outside the satellite receiver, only from GPS.

Fault detection and Exclusion (FDE) mechanism is used in RAIM, minimum five (5) satellite is needed for ‘fault detection’ and six (6) for ‘fault exclusion’.

3-3-2 Aircraft Autonomous Integrity monitoring (AAIM)

AAIM uses the redundancy of position estimates from multiple sensors, including GNSS, to provide integrity performance that is at least equivalent to RAIM. An example is the use of an inertial navigation system or other navigation sensors as an integrity check on GPS data when RAIM is unavailable but GPS positioning information continues to be valid. AAIM requires data from GPS and other sensor (INS).

AAIM uses GNSS signal plus onboard Inertial (INS) to achieve primary means for enroute though non-precision approach.

4- Global Air Navigation Plan

The GANP and ASBUs recognize the Global Navigation Satellite System (GNSS) as a technical enabler supporting improved services. Roadmaps in the GANP outline timeframes for the availability of GNSS elements, the implementation of related services and the rationalization of conventional infrastructure. The ICAO Navigation roadmap depicted in figure (1-2)

Figure (1-2)

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Part II: GNSS in ICAO Middle East Region

1- The Conventional Ground Based Navigation systems in the MID

States Should introduce rationalizing terrestrial navigation aids, retaining a minimum network of terrestrial aids necessary to maintain safety of aircraft operations; in accordance with AN-Conf/12 recommendations 6/10. Some ILSs may be retained to support precision approach and to mitigate GNSS outage.

Removal of conventional ground infrastructure should be planned carefully to ensure that safety is not compromised, such as by performance of safety assessment, consultation with users through regional air navigation planning.

The NDB should be rationalized based on need and equipage, MIDANPIRG/12 urged states to plan for complete decommissioning of NDBs by 2012 and to terminate the use of NDB for approach operations not later than 2012. The list of current NDBs and purpose of use in the MID Region is at Appendix A.

Furthermore, table (2-1) shows the current conventional infrastructure in the MID Region.

System	Frequency	Ground Stations	Status
NDB	200 – 1600 MHz	150 NDBs in (Egypt, Iraq, Iran, Jordan, Libya, Qatar, Syria, UAE, and Yemen)	States should plan for Complete decommissioning of NDBs by 2012 unless its operational justified.
ILS	108 – 112 MHz 329 – 335 MHz		-
VOR	108 – 118 MHz		-
TACAN	960 – 1215 MHz	38 TACANs	TACAN used in Egypt, Iran, Iraq, Qatar and Saudi Arabia
DME	960 – 1215 MHz		
MLS	5031 – 5091 MHz	MLS is not implemented in the MID Region	-

Table (2-1)

2) SBAS

The implementation of GNSS and augmentations systems in the MID Region should be in full compliance with ICAO Standards and Recommended Practices and PANS; due to geographic location of some MID States, taking advantages of adjacent SBAS services (EGNOS and GAGAN) is possible.

SBAS-based procedure does not require any infrastructure at the Airport served, but SBAS elements (e.g. reference stations, master station, satellites) must be in place to support required service level*

2-1 EGNOS

Some of MID Region States who are member in the EUROMED* can exploit the use of EGNOS in various applications, mainly in the transport sectors. As of the time of developing this document; five (5) States have officially notified their interest in EGNOS implementation (Algeria, Jordan, Lebanon, Libya, and

Tunisia).
**Euromed countries (Algeria, Egypt, Jordan, Lebanon, Libya, Morocco, Palestine, Syria and Tunisia)*

The requirements to use EGNOS services are as follow:

a) Installation of additionnel RIMS, three RIMS Stations are sufficient to extend the service to EURCOMED States.
b) Air Navigation Service Providers should sign an EGNOS Working Agreement (EWA) with the ESSP (Certified provider of Safety of Life service in aviation in EU) to be able to activate use of EGNOS SoL.
c) International bilateral agreements should be signed between EU and each State to define liability in case of EGNOS failure which results in death/injury/loss/damage to equipment.

EGNOS Service Maps

The current service maps shown in the figures (2-1, 2-2, 2-3 and 2-4), the current availability and continuity for APV-I and LPV service level in the MID Region are less than the minimum required signal-in-space performance specified in Annex 10 Vol. I., the requirements are shown in table (2-2)

a) APV-I Service Level

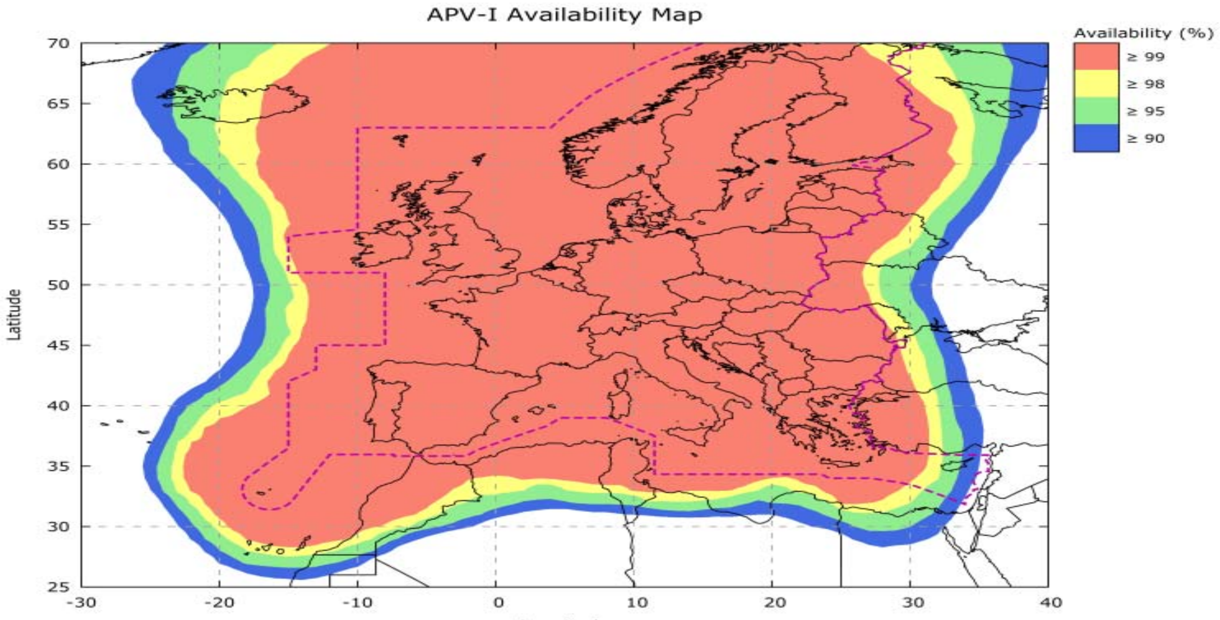


Figure (2-1)

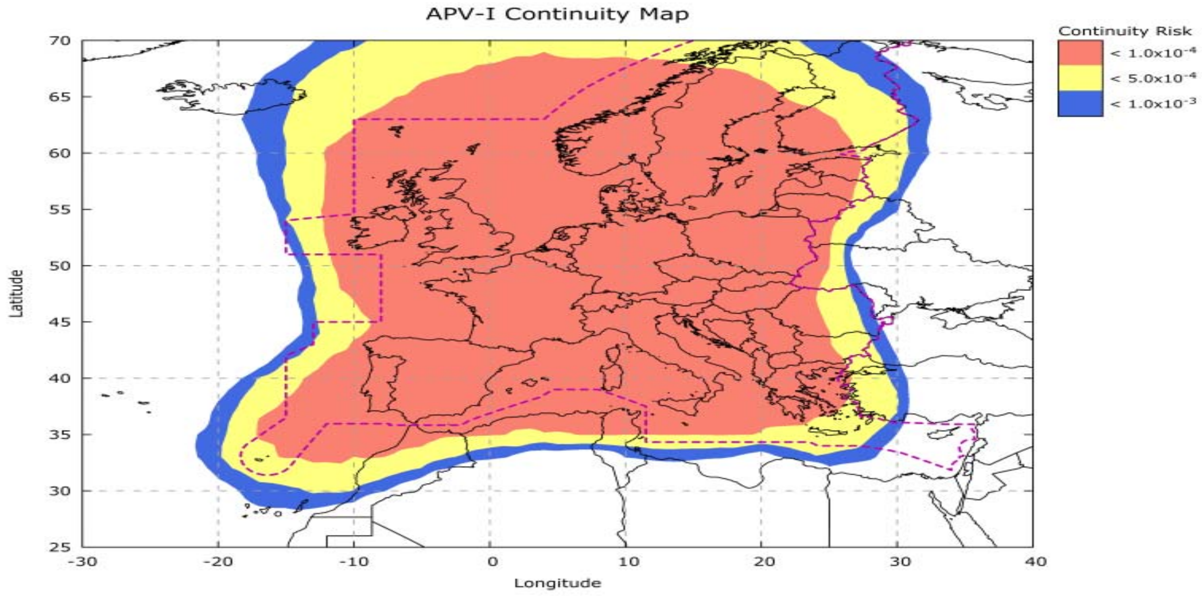


Figure (2-2)

b) LPV200 Service Level

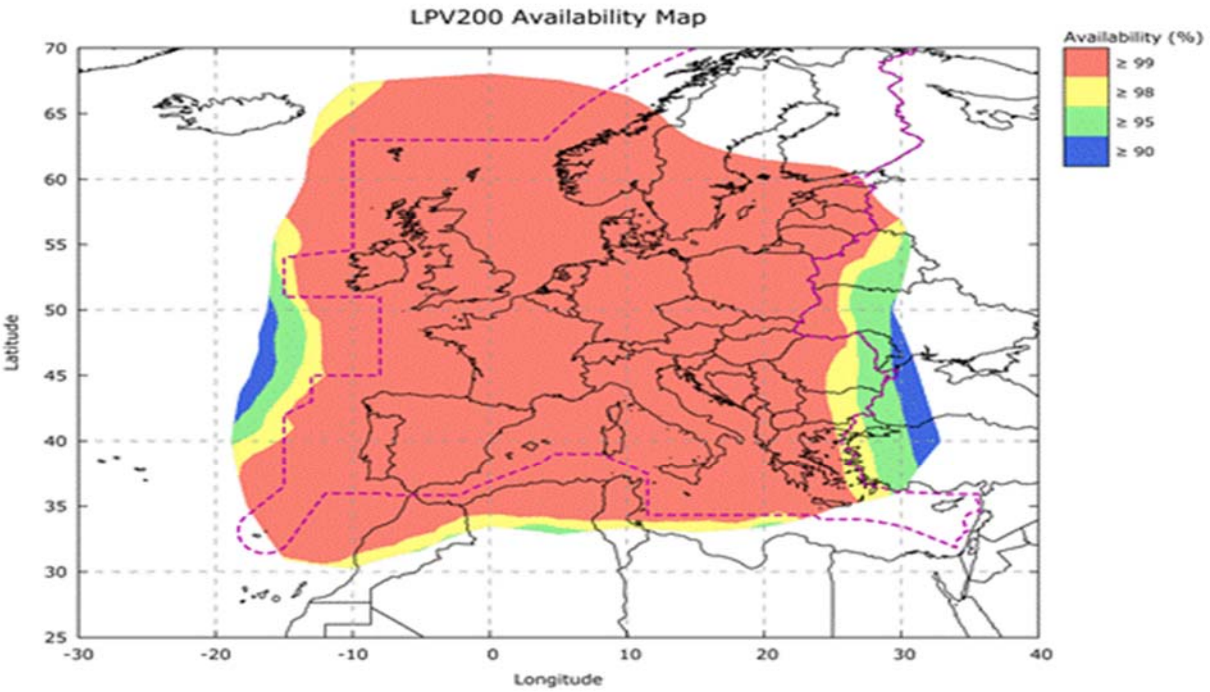


Figure (2-3)

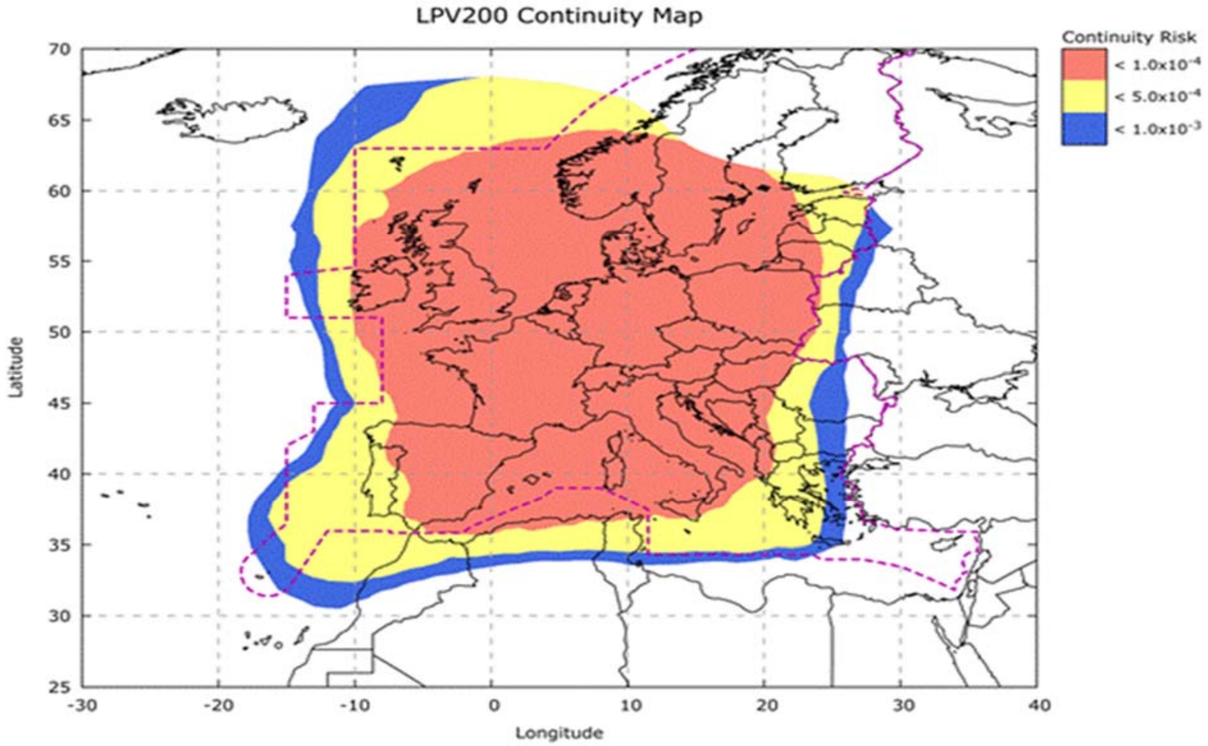
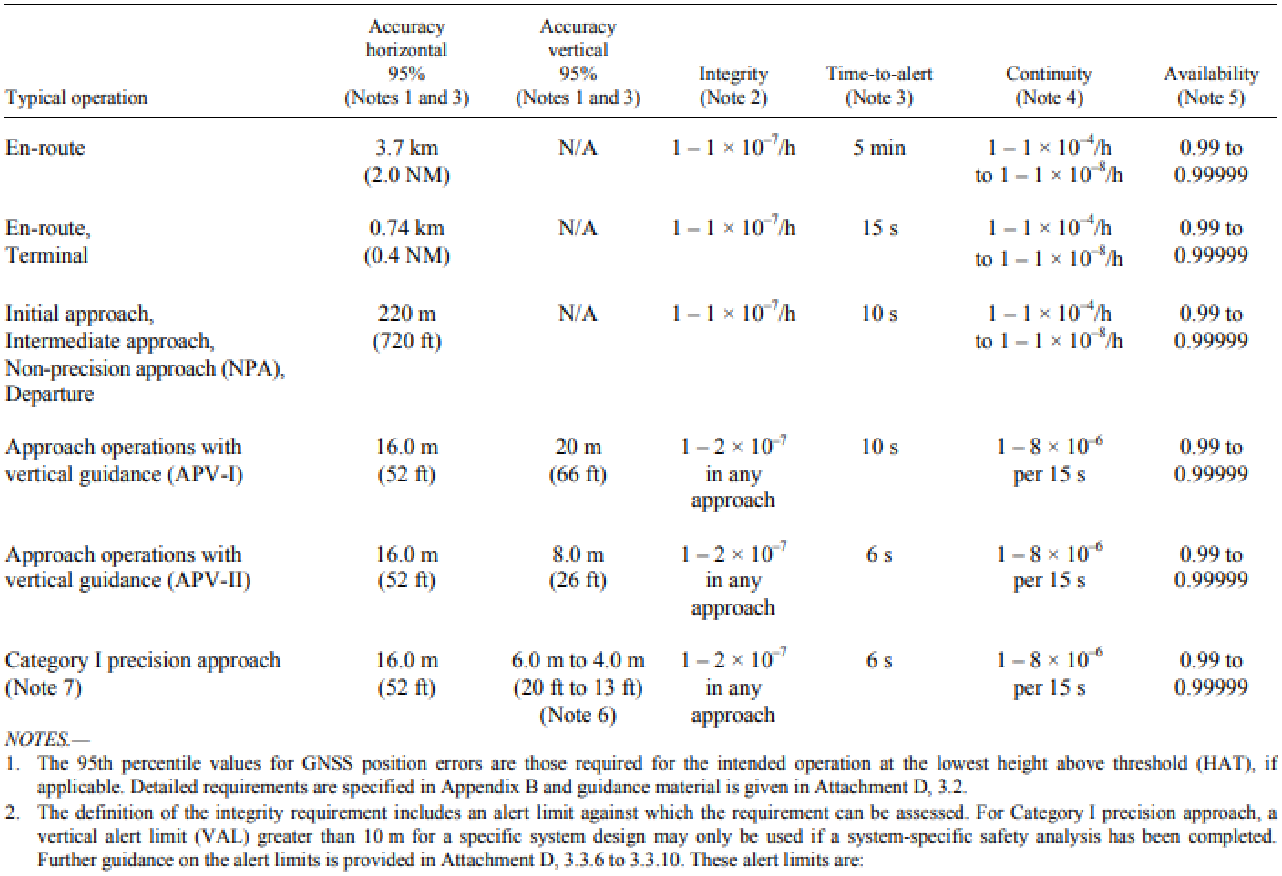


Figure (2-4)



Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Note 3)	Continuity (Note 4)	Availability (Note 5)
En-route	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7}$/h	5 min	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
En-route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7}$/h	15 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7}$/h	10 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Approach operations with vertical guidance (APV-I)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}$ in any approach	10 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Approach operations with vertical guidance (APV-II)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Category I precision approach (Note 7)	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft) (Note 6)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999

NOTES.—

1. The 95th percentile values for GNSS position errors are those required for the intended operation at the lowest height above threshold (HAT), if applicable. Detailed requirements are specified in Appendix B and guidance material is given in Attachment D, 3.2.
2. The definition of the integrity requirement includes an alert limit against which the requirement can be assessed. For Category I precision approach, a vertical alert limit (VAL) greater than 10 m for a specific system design may only be used if a system-specific safety analysis has been completed. Further guidance on the alert limits is provided in Attachment D, 3.3.6 to 3.3.10. These alert limits are:

Table (2-2)

2-2 GAGAN

Gulf region falls within the GAGAN GEO footprint as shown in figure (2-5), GCC States can take advantage of GAGAN infrastructure to implement the RNP 0.1 and APV 1 service in the respective states without having the full SBAS infrastructure in their country.

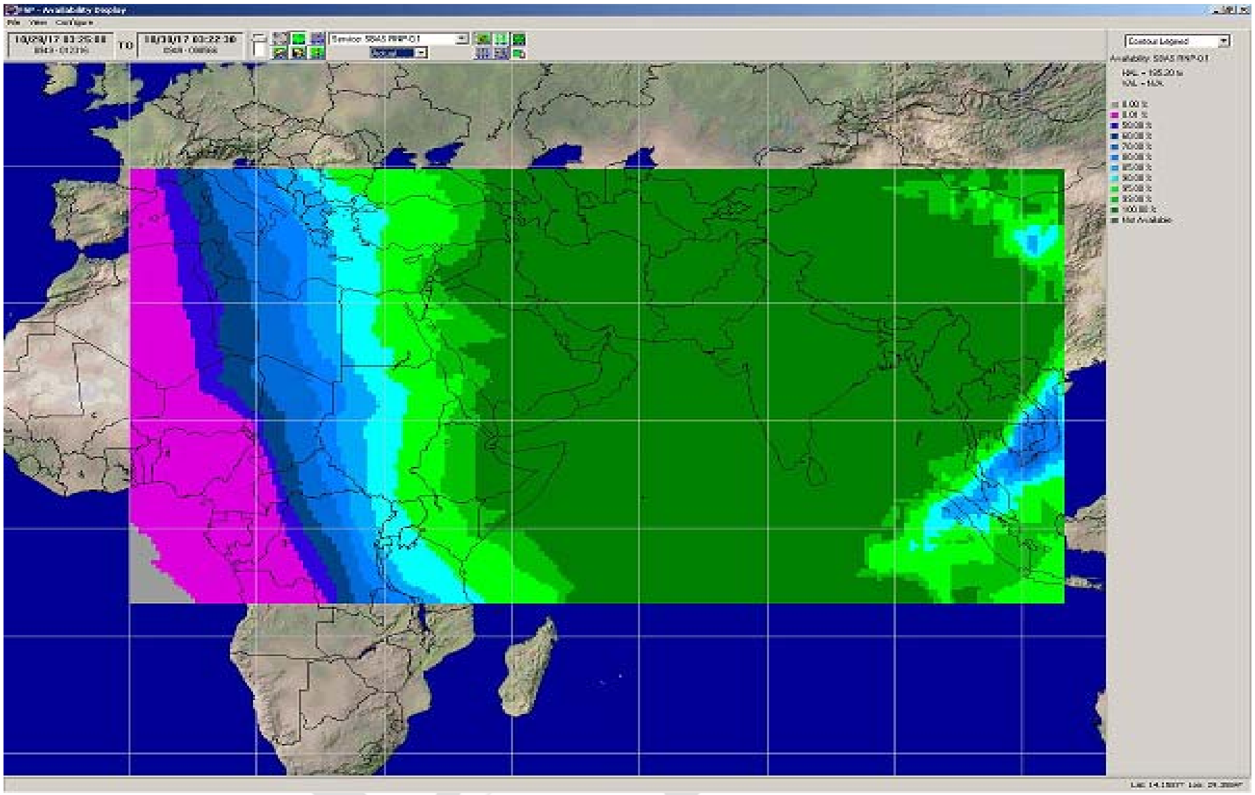


figure (2-5)

India and Gulf regions are on equatorial anomaly region. Ionosphere Scintillation is most intense and most frequent in that equatorial region. It can severely affects the performance of SBAS, Therefore, An MLDF (Multi-Layer Data Fusion) iono model suitable to serve the equatorial anomaly region was implemented in GAGAN system .

The Requirements to use GAGAN as follow:

1- Installing additional reference stations at strategic locations in gulf region and forward the measurements data to GAGAN-INMCC, RNP 0.1/APV 1 services can be extended to gulf region.
2- States to notify Indian Airport Authority (IAA) about their interest to use GAGAN

3-GNSS Application in the MID Region

The GNSS is the foundation for the Regional implementation of PBN, Automatic dependent surveillance (ADS-B), the Multilateration System (MLAT), in addition to many other aircraft and ground applications that require position or time information.

4-GBAS

Transition from ILS to GBAS should be based on an economic assessment, an operational assessment and from a safety and security perspective. Cost benefits analysis should be conducted taking on consideration that one GBAS can be used for several runways ends and even in some cases more than one Airports.

5- Cost Benefits Analysis

The use of GNSS in PBN applications reduces the overall running cost of Navigation infrastructure. Also deploying GBAS reduces the cost for ground infrastructure since a single GBAS ground station can provide approach guidance to all runways at an airport. GBAS can increase the Airport capacity, because it does not have sensitive areas that must be protected. However, the CBA is very dependent on specific operational and airport infrastructure aspects.

States may consider the following factors during the process of estimating the cost associated with competing alternative in CBA:

a) CAPEX
   a.1 Installation Cost;
   - One GBAS costs around 1.5 -2 M euro (equal to the cost of 3 ILSs).
   - ILS(s) must be retained to ensure the service continuity during the GNSS/GBAS outage.

   a.2 Training for operational and technical staff.

b) OPEX
   c.1 Cost of Flight Check (Calibration).
   c.2 Maintenance costs (Preventive, Reactive, maintenance Contract, less Spare parts).

It has been reported by several CBA studies, that GBAS initial investment is higher than for ILS, and lower OPEX. However, Net Present Cost need to be calculated based on Airport infrastructure and operational requirements.

6- GBAS Implementation in the MID Region

Currently GBAS is not implemented in the MID Region.

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PART III: GNSS VULNERABILITIES

1- Introduction

GNSS signals are very weak at the receiver antenna therefore the signal is vulnerable, and also susceptible to ionosphere effects. Current GNSS use a single frequency band common to GPS, GLONASS and SBAS. This makes it easier to intentionally jam GNSS signals.

2- Unintentional Interference Sources

There are a number of sources of potential interference to GNSS, including mobile and fixed VHF communications, Solar effect and other sources. The likelihood and operational effect of interference vary with the environment.

Unintentional interference is not considered a significant threat provided that States exercise proper control and protection over the electromagnetic spectrum for both existing and new frequency allocations.

2-1 Solar Effect

GNSS signals are delayed by varying amounts of time depending on the density of ionized particles (ionosphere) which itself depends on the intensity of solar radiation and other solar energy bursts. The solar activity can cause GNSS service to be degraded or temporarily lost.

The type and severity of ionospheric effects vary with the level of solar activity, the region of the world and other factors such as time of year and time of day. Rare solar storms can affect GNSS service over a wide area. The Solar activity peaks happens every eleven years.

The availability of a second frequency will allow avionics to calculate ionospheric delay in real time, effectively eliminating a major error source.

2-2 Radio Frequency Interference

Harmonics of television stations, certain radars, mobile satellite communications and military systems can cause interference with GNSS signals.

2-3 On-board systems

Many reported instances of GNSS interference have been traced to on-board systems; such interference can be prevented by installing advanced avionics.

3-Intentional Interference Sources

3-1 Jamming

Personal privacy devices (PPDs) have been recognized as being responsible for causing interference to GPS receivers in many occurrences. The intention of PPDs is to protect the privacy of the user so that the user’s location is not revealed, therefore the user will not be tracked or monitored. PPDs are low-cost jammers to mask GPS signal.

3-2 Spoofing

Spoofing is the broadcast of GNSS-like signals that cause avionics to calculate erroneous positions and provide false guidance. It is considered that the spoofing of GNSS is less likely than the spoofing of traditional aids because it is technically much more complex.

Spoofing of the GBAS data broadcast is virtually impossible, because of an authentication scheme that has been developed.

4-Reducing the Likelihood of Interferences

The likelihood of interference depends on such factors as population density and the motivation of individuals or groups in an area to disrupt aviation and non-aviation services

a) Effective spectrum management, this comprises creating and enforcing regulations/laws that control the use of spectrum and carefully assessing applications for new spectrum allocations.

b) The introduction of GNSS signals on new frequencies will ensure that unintentional interference does not cause the complete loss of GNSS service (outage) although enhanced services depending upon the availability of both frequencies might be degraded by such interference

c) State should develop and enforce a strong regulatory framework governing the use of intentional radiators, including GNSS repeaters, pseudolites, spoofers and jammers, should forbid the use of jamming and spoofing devices and regulate their importation, exportation, manufacture, sale, purchase, ownership and use.

d) Multi-constellation GNSS would allow the receiver to track more satellites, reducing the likelihood of service disruption.

5- Mitigation Strategies

The disruption of GNSS signals will require the application of realistic and effective mitigation strategies to both ensure the safety and regularity of air services and discourage those who would consider disrupting aircraft operations.

There are three principal methods which can be applied in combination:

a) taking advantage of on-board equipment, such as IRS;
b) taking advantage of conventional navigation aids and radar; and
c) employing procedural (aircrew and/or ATC) methods.

Mitigation of GNSS vulnerabilities needs to be balanced in the context of the overall threats to communications, navigation, and surveillance/air traffic management (CNS/ATM) operations to ensure that the applied effort is neither too small (leading to potentially unacceptable risks and/or preventing realization of GNSS enabled benefits) nor too large (in comparison with the effort expended on mitigating other risks).

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APPENDIX A

LIST OF NDBs IN THE MID REGION AND PURPOSE OF RETAIN

NO.	State	NDB ID	Purpose of retain	Plan to remove
1.	EGYPT	MB	Used at local airport for homing	Until the end of lifetime
2.	EGYPT	NWB	Used for enroute	Until the end of lifetime
3.	EGYPT	OCT	Used at local airport for homing	Until the end of lifetime
4.	IRAN	ABD		
5.	IRAN	ABM		
6.	IRAN	AJ		
7.	IRAN	ARB		
8.	IRAN	ARK		
9.	IRAN	AWZ		
10.	IRAN	BAM		
11.	IRAN	BND		
12.	IRAN	BRD		
13.	IRAN	BRG		
14.	IRAN	BRN		
15.	IRAN	BUZ		
16.	IRAN	DNZ		
17.	IRAN	DZF		
18.	IRAN	ESH		
19.	IRAN	FSA		
20.	IRAN	GGN		
21.	IRAN	GSN		
22.	IRAN	HAB		
23.	IRAN	HAM		
24.	IRAN	HAS		
25.	IRAN	IFN		
26.	IRAN	IKA		
27.	IRAN	ILM		
28.	IRAN	ISR		
29.	IRAN	JAM		
30.	IRAN	JIR		
31.	IRAN	JRM		
32.	IRAN	JSK		
33.	IRAN	KAZ		
34.	IRAN	KER		
35.	IRAN	KHG		
36.	IRAN	KHM		
37.	IRAN	KHY		
38.	IRAN	KIH		
39.	IRAN	KLH		
40.	IRAN	KMS		
41.	IRAN	KRD		

42.	IRAN	LAM		
43.	IRAN	LAR		
44.	IRAN	LEN		
45.	IRAN	LVA		
46.	IRAN	MSD		
47.	IRAN	NSR		
48.	IRAN	OMD		
49.	IRAN	PAD		
50.	IRAN	PIM		
51.	IRAN	PRG		
52.	IRAN	PSR		
53.	IRAN	RAF		
54.	IRAN	RST		
55.	IRAN	SAV		
56.	IRAN	SBZ		
57.	IRAN	SHD		
58.	IRAN	SHR		
59.	IRAN	SIR		
60.	IRAN	SKD		
61.	IRAN	SMN		
62.	IRAN	SNJ		
63.	IRAN	SR		
64.	IRAN	SRN		
65.	IRAN	SRS		
66.	IRAN	TBS		
67.	IRAN	TBZ		
68.	IRAN	UMH		
69.	IRAN	VR		
70.	IRAN	YSJ		
71.	IRAN	YZD		
72.	IRAN	ZAJ		
73.	IRAN	ZAL		
74.	IRAN	ZD		
75.	IRAQ	ALI		
76.	JORDAN	AQC		
77.	JORDAN	MDB		
78.	JORDAN	QA		
79.	Lebanon	BOD	Used by Helicopters and light aircraft	Not Determined
80.	LIBYA	BNA		
81.	LIBYA	CW		
82.	LIBYA	GAD		
83.	LIBYA	GAL		
84.	LIBYA	GHT		
85.	LIBYA	GRT		
86.	LIBYA	GS		
87.	LIBYA	HON		

88.	LIBYA	IZD		
89.	LIBYA	JFR		
90.	LIBYA	KDR		
91.	LIBYA	KFR		
92.	LIBYA	KH		
93.	LIBYA	LAB		
94.	LIBYA	MB		
95.	LIBYA	OA		
96.	LIBYA	OB		
97.	LIBYA	OJ		
98.	LIBYA	OR		
99.	LIBYA	OV		
100.	LIBYA	OXY		
101.	LIBYA	PRB		
102.	LIBYA	PRC		
103.	LIBYA	RAG		
104.	LIBYA	ROO		
105.	LIBYA	SAH		
106.	LIBYA	SEB		
107.	LIBYA	SRT		
108.	LIBYA	STF		
109.	LIBYA	TRO		
110.	LIBYA	TZR		
111.	LIBYA	UBR		
112.	LIBYA	VA		
113.	LIBYA	VG		
114.	LIBYA	VH		
115.	LIBYA	VO		
116.	LIBYA	VR		
117.	LIBYA	WF		
118.	LIBYA	WLD		
119.	LIBYA	XS		
120.	LIBYA	XY		
121.	LIBYA	ZAR		
122.	LIBYA	ZEL		
123.	LIBYA	ZT		
124.	LIBYA	ZUE		
125.	QATAR	AK		
126.	QATAR	QPC	Used for Qatar Petroleum Company	-
127.	SYRIA	ABD		
128.	SYRIA	ALE		
129.	SYRIA	DAL		
130.	SYRIA	DAN		
131.	SYRIA	DRZ		
132.	SYRIA	HAS		

133.	SYRIA	KAM		
134.	SYRIA	KAR		
135.	SYRIA	LTK		
136.	SYRIA	MER		
137.	SYRIA	MEZ		
138.	SYRIA	PAL		
139.	UAE	BH		
140.	UAE	JD		
141.	UAE	RNZ		
142.	UAE	ZKU		
143.	YEMEN	BDE		
144.	YEMEN	GDA		
145.	YEMEN	HD		
146.	YEMEN	MRB		
147.	YEMEN	SCT		
148.	YEMEN	SYE		
149.	YEMEN	SYN		
150.	YEMEN	TZ		

NUMBER OF RETAINED NDBs PER STATES

STATE	NUMBER OF NDBs
EGYPT	**3**
IRAN	**71**
IRAQ	**1**
JORDAN	**3**
LEBANON	**1**
LIBYA	**45**
QATAR	**2**
SYRIA	**12**
UAE	**4**
YEMEN	**8**
TOTAL	**150**

- END -