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ICAO Global Provisions and Regional Developments related to GNSS

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- GNSS performance requirements
- GNSS elements
- Future GNSS evolution
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Introduction - ICAO

- Convention (Chicago, 1944) and Annexes
- UN Specialized Agency
- 191 member States
- Assembly (every 3 years)
- Council (36 States)
- Air Navigation Commission (19 members)
- Air Navigation Bureau
- Standards, Recommended Practices (SARPs)
- Headquarters: Montreal
- 7 Regional Offices: Bangkok, Cairo, Dakar, Lima, Mexico, Nairobi, Paris

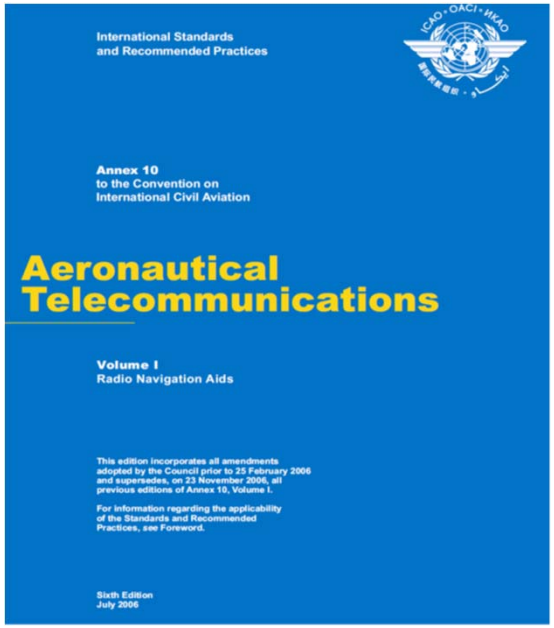
Introduction - GNSS

- The ICAO definition:
  - "**GNSS**. *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."* [ICAO Annex 10, Volume I]

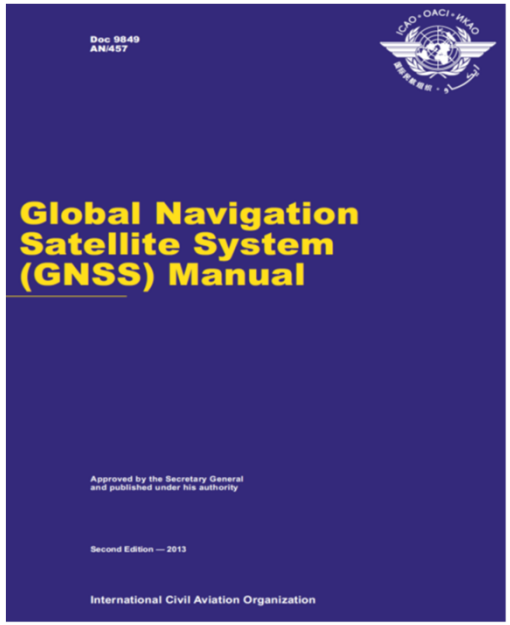
- The practical foundation:
  - 1994/1996: US and Russia offer to ICAO to provide GPS (Global Positioning System)/GLONASS (GLObal NAvigation Satellite System) service for the foreseeable future on a continuous worldwide basis and free of direct user fees

Global Provisions

Annex 10, Volume I



GNSS Manual



GNSS developments in ICAO

- **1991**: 10th Air Navigation Conference requests the initiation of an agreement between ICAO and GNSS-provider States concerning quality and duration of GNSS
- **1993**: ICAO GNSS Panel established to develop SARPs in support of aeronautical applications of GNSS
- **1994/1996**: GPS/GLONASS offers from US/Russia
- **1999**: GNSSP completes the development of GNSS SARPS (applicable 2001)
- **2002 – today**: GNSSP (subsequently renamed NSP) develops GNSS SARPs updates and enhancements
- **2003**: 11th Air Navigation Conference recommends a worldwide transition to GNSS-based air navigation and implementation of APV-I (SBAS)
- **2007**: 36th Assembly calls for implementation of PBN RNAV and RNP and for implementation of APV BaroVNAV and/or APV I (SBAS) for all instrument runways by 2016
- **2010**: 37th Assembly confirms and updates the commitment
- **2012**: 12th Air Navigation Conference addresses issues of use of multiple constellations and GNSS vulnerabilities
- **2017**: Global Air Navigation Industry Symposium (GANIS, 11-13 December) will revisit the issues
- **2018**: 13th Air Navigation Conference charting the way forward

ICAO policy on GNSS

- 1994: Statement of ICAO policy on CNS/ATM systems implementation and operation approved by the ICAO Council:
  - *"GNSS should be implemented as an evolutionary progression from existing global navigation satellite systems, including the United States' GPS and the Russian Federation's GLONASS, towards an integrated GNSS over which Contracting States exercise a sufficient level control on aspects related to its use by civil aviation. ICAO shall continue to explore, in consultation with Contracting States, airspace users and service providers, the feasibility of achieving a civil, internationally controlled GNSS"*
- 1998: Assembly resolutions A32-19 ("*Charter on the Rights and Obligations of States Relating to GNSS Services*") and A32-20 ("*Development and elaboration of an appropriate long-term legal framework to govern the implementation of GNSS*")

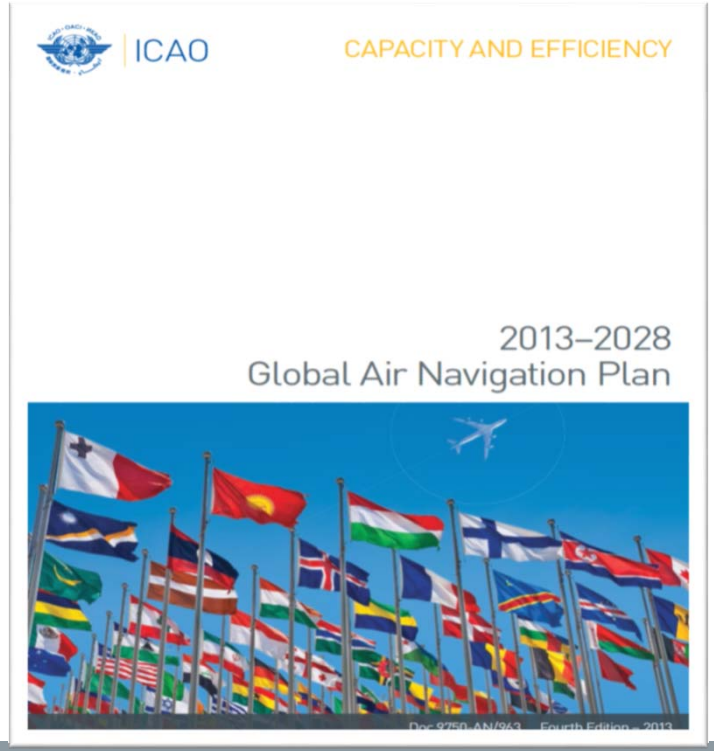
GNSS Manual

- The **ICAO *Charter on the Rights and Obligations of States Relating to GNSS Services*** highlights the principles that shall apply in the implementation and operation of GNSS, including: the primacy of safety; non-discriminatory access to GNSS services; State sovereignty; the obligation of provider States to ensure reliability of services; and cooperation and mutual assistance in global planning.

- The availability of multiple constellations broadcasting on multiple frequencies will make GNSS more robust and will allow service expansion with increased benefits after 2020 when systems and avionics are available.

- In the meantime, ANS providers can work with aircraft operators to expand GNSS-based services and benefits while planning next generation services.

GANP



When planning to implement GNSS-based operations, States are encouraged

- to refer to the **GANP** and relevant **ASBUs**,
- to comply with ICAO provisions; and
- to take advantage of the expertise and information available at the ICAO **planning and implementation regional groups (PIRGs).**

Current ICAO Directives on GNSS Implementation

12th Air Navigation Conference (2012) - Recommendations

- Recommendation 6/5 – ICAO work programme to support global navigation satellite system evolution
- Recommendation 6/6 – Use of multiple constellations
- Recommendation 6/7 – Assistance to States in mitigating global navigation satellite system vulnerabilities
- Recommendation 6/8 – Planning for mitigation of global navigation satellite system (GNSS) vulnerabilities
- Recommendation 6/9 – Ionosphere and space weather information for future global navigation satellite system implementation.

Current ICAO Directives on GNSS Implementation

ICAO Assembly Resolution A37/11

Implementation of performance – based navigation (PBN) approaches with vertical guidance (APV)

GNSS signal-in-space performance requirements (ICAO Annex 10, Volume I)

- Accuracy – The difference between the estimated and actual aircraft position
- Integrity – A measure of the trust which can be placed in the correctness of the information supplied by the total system. It includes the ability of the system to alert the user when the system should not be used for the intended operation (alert) within a prescribed time period (time-to-alert)
- Continuity – The capability of the system to perform its function without unscheduled interruptions during the intended operation
- Availability – The portion of time during which the system is simultaneously delivering the required accuracy, integrity and continuity

GNSS signal-in-space performance requirements (ICAO Annex 10, vol.I)

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.—
[…]

GNSS elements: ICAO GNSS Standards Menu

System	ICAO Standard?	Infrastructure in place today?	Aircraft provisions today?	In operational use by aviation today?
GPS L1	Yes	Yes	Yes	Yes, globally
GLONASS	Yes	Yes	Russia	Russia
SBAS L1	Yes	Regional support (WAAS, MSAS, EGNOS, GAGAN, SDCM…)	Yes	Yes, regionally
GBAS Cat I	Yes	Local support (individual airports)	Yes	Yes, locally
GBAS Cat II/III	2018	No	Advanced development	No
GPS L5	2018+	Partial (12 satellites)	Early development	No
Galileo	2018+	Partial (8 Full Operational Capability satellites +4)	Early development	No
Beidou	2018+	Partial (18 satellites)	Early development	No
SBAS L1/L5	2018+	No	Early development	No

GNSS elements

- **GPS**
- **GLONASS**
- **Augmentation Systems**
  - ABAS: Aircraft-Based Augmentation System
  - SBAS: Space-Based Augmentation System
  - GBAS: Ground-Based Augmentation System

Purpose: to overcome inherent limitations in the service provided by the core constellations and meet GNSS signal-in-space performance requirements

GNSS elements: GPS

- ICAO GPS Standards:
  - ICAO Annex 10, Volume I, section 3.7.3.1, applicable since 2001
- Purpose of ICAO standardization of GNSS systems:
  1) To enable global legal recognition of a system implemented by a single ICAO State
     - GPS example: it was implemented by the US and turned into an international civil aviation system by ICAO standardization
  2) To enable technical interoperability of systems implemented in different States (such as SBAS or GBAS):
     - GBAS example: we want all GBAS ground stations to behave in the same way to ensure that the aircraft receiver can deal with all of them regardless of the State it is flying to (same as ILS)

GNSS elements: GLONASS

- Nominal constellation: 24 satellites (current: 23 operational + 1 in commissioning + 3 undergoing checks, as of 9 February 2016)
- Three orbital planes
- Near-circular, 19,100 km altitude (25,500 radius) 11:15-hour orbits
- First experimental satellite launched in 1982, operational in 1995, subsequent decline. Full operational capability subsequently restored.
- Operated by the Ministry of Defence of the Russian Federation
- Channel of standard accuracy (CSA) frequencies: 1602 MHz ± 0.5625*n* MHz (FDMA)
- Uses PZ-90 reference datum instead of WGS-84
- ICAO GLONASS Standards:
  - Annex 10, Volume I, section 3.7.3.2 (including conversion from PZ-90 to WGS-84)

GNSS elements: ABAS

- **ABAS: aircraft-based augmentation system**
- The **foundation** of ICAO GNSS
- Purpose: to improve positioning quality by exploiting redundancy in satellite measurements and by augmenting GNSS information with on-board aircraft information
- Required to ensure that performance meets Annex 10 requirements (Volume I, Table 3.7.2.4-1, see above)
- Uses redundant satellite range measurements (and/or barometric and other position information) to detect faulty signals and alert the pilot
- Receiver-autonomous integrity monitoring (RAIM) – five satellites required (or four + baro)
- Fault detection and exclusion (FDE) – six satellites required (or five + baro)
- RAIM/FDE availability: are sufficient redundant measurements available?
- ICAO Annex 10, Volume I, section 3.7.3.3

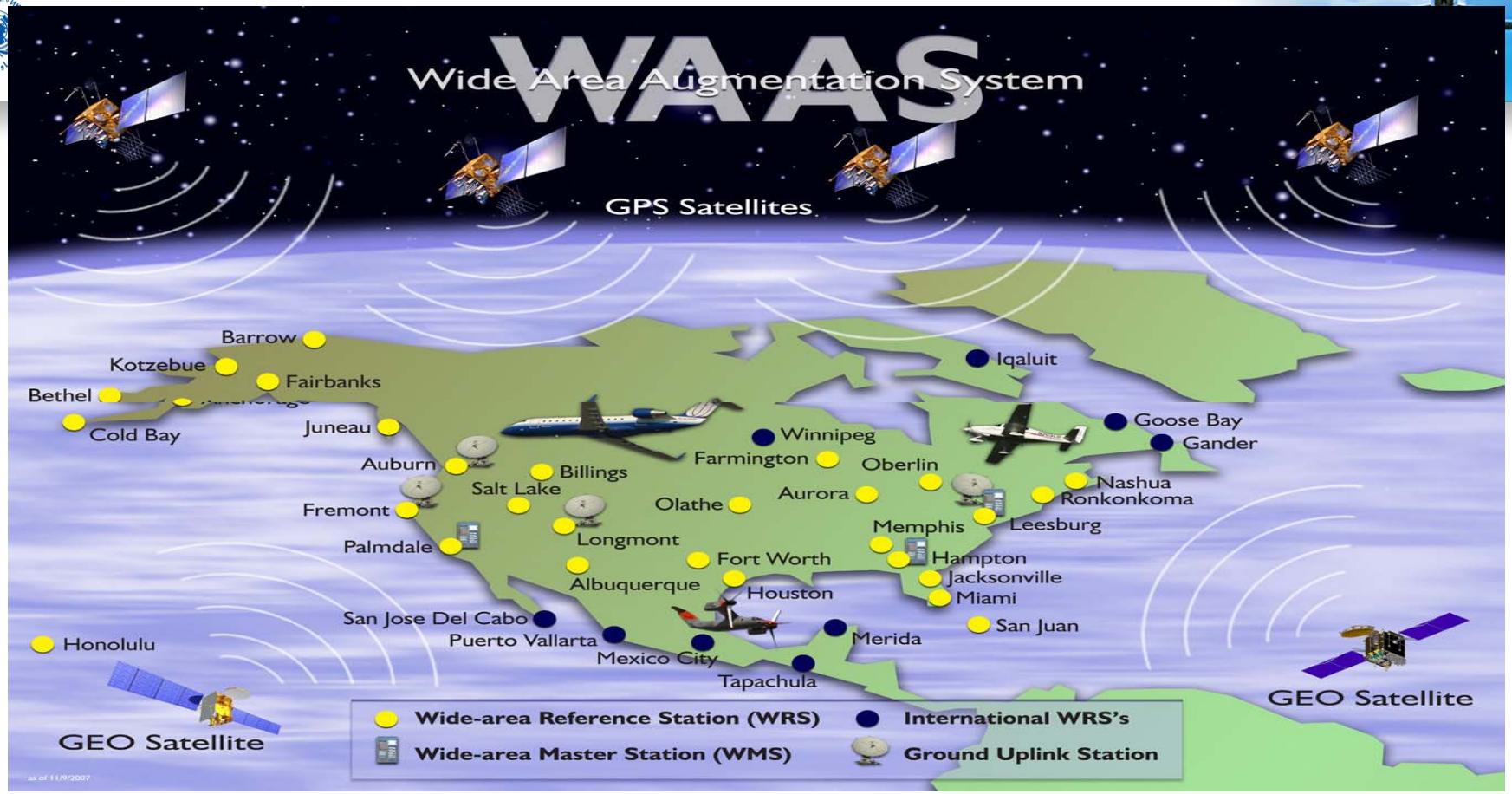
GNSS elements: SBAS

- **SBAS: satellite-based augmentation system**
- Augments core satellite constellations by providing ranging, integrity and correction information
- The information is broadcast via geostationary satellites, in the same band as the core constellations
- SBAS components:
  - a network of ground reference stations that monitor satellite signals
  - master stations processing reference stations data and generating SBAS signals
  - uplink stations to send the messages to the geostationary satellites
  - transponders on the satellites to broadcast SBAS messages
- SBAS (where supported) provides higher availability of GNSS services and lower minima than ABAS
- Approach procedures with vertical guidance (APV-I)
- CAT I-like minima (“LPV200”) achieved with WAAS and EGNOS, developments underway for other SBAS
- ICAO Annex 10, Volume I, section 3.7.3.4

- Examples: WAAS, EGNOS, MSAS, GAGAN, SDCM

SBAS example: WAAS

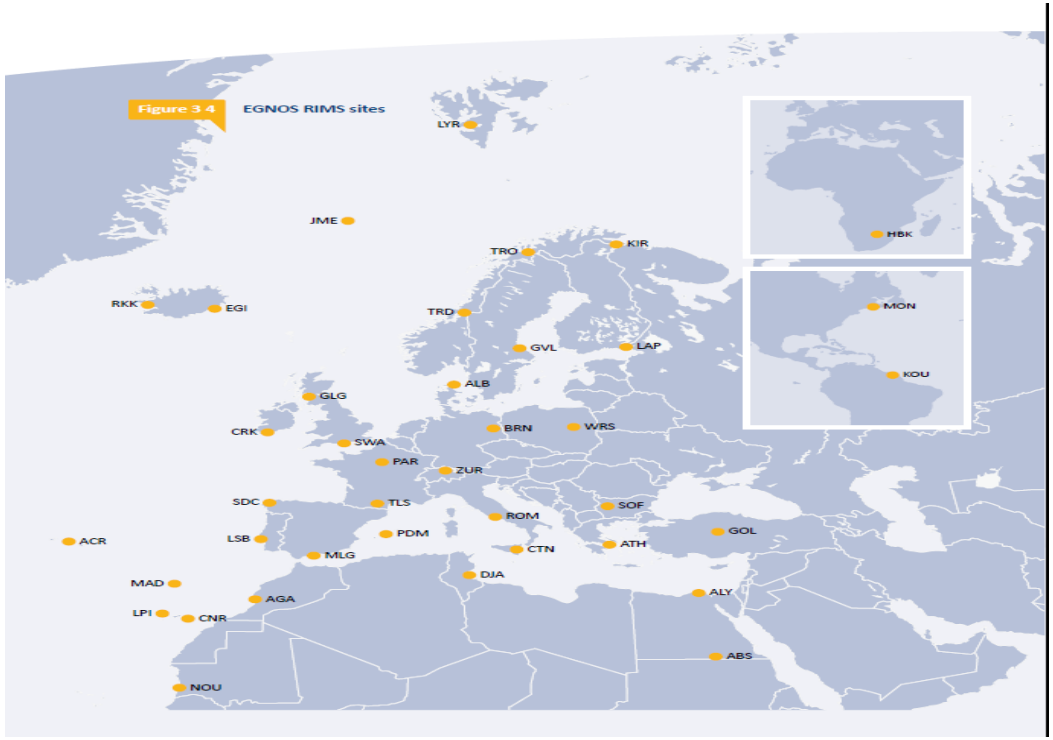
- Wide Area Augmentation System (USA)
- Operational since 2003
- 38 reference stations
- 3 geostationary satellites
- International service agreements with Canada and Mexico
- Supports LPV200 approaches (CAT I - equivalent)
- Planned to transition to dual frequency operation (L1-L5)


WAAS
Wide Area Augmentation System
GPS Satellites
Barrow
Kotzebue
Fairbanks
Bethel
Cold Bay
Juneau
Auburn
Billings
Salt Lake
Fremont
Palmdale
Longmont
Albuquerque
Farmington
Winnipeg
Olathe
Aurora
Oberlin
Iqaluit
Goose Bay
Gander
Nashua
Ronkonkoma
Leesburg
Memphis
Hampton
Jacksonville
Miami
Fort Worth
Houston
San Jose Del Cabo
Puerto Vallarta
Mexico City
Tapachula
Merida
San Juan
Honolulu
GEO Satellite
GEO Satellite
Wide-area Reference Station (WRS)
International WRS's
Wide-area Master Station (WMS)
Ground Uplink Station

SBAS example: EGNOS

- EGNOS: European Geostationary Navigation Overlay Service
- Serves Europe and Northern Africa
- Open Service available since 2009
- Safety-of-Life Service (Declaration of Service for Aviation): March 2011
- Declaration of LPV-2000 service level: September 2015
- Extension of service area under consideration

EGNOS: locations of reference stations



EGNOS expansion in MID Region

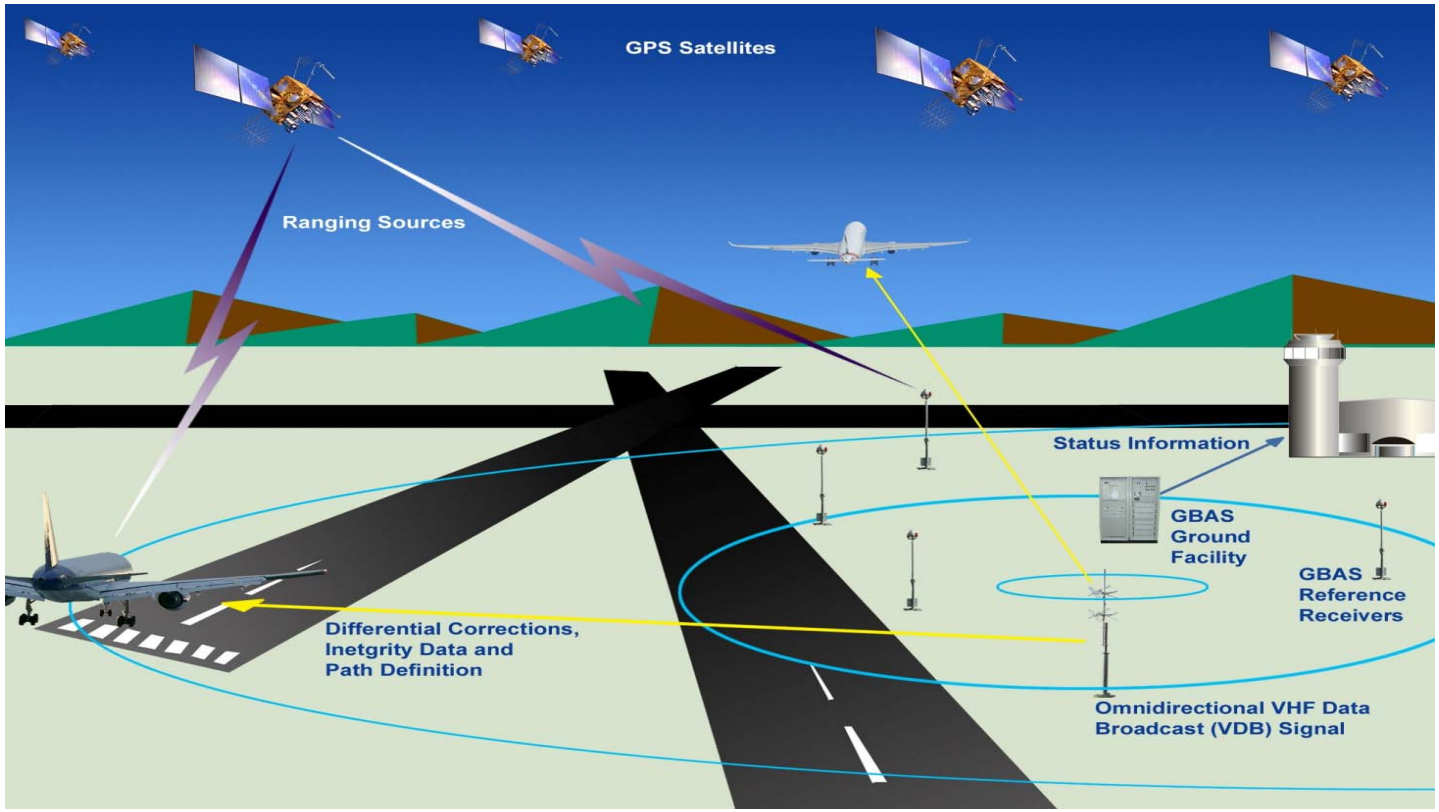
- See EGNOS SAFETY OF LIFE SERVICE ROADMAP (January 2016)
- https://egnos-user-support.essp-sas.eu/new_egnos_ops/?q=content/service-implementation-roadmaps

SBAS examples: MSAS, GAGAN, SDCM

- Japan: MSAS
  - Operational since 2007, under the responsibility of the Japan Civil Aviation Bureau (JCAB)
  - Providing aircraft with navigation service from en-route through non precision approach all over Japan (APV-I after 2023)
  - Based on MTSAT satellite until 2020. From 2020, based on QZSS geostationary satellite
- India: GPS and Geo Augmented Navigation system (GAGAN)
  - South and East Asia
  - Certified to RNP0.1 service level (en-route and non-precision approach) in 2013 and to APV-I service level in 2015
- Russia: System for Differential Correction and Monitoring (SDCM)
  - Operational APV service expected to be approved in 2018/2019
- More under development/consideration: South Korea, China, ASECNA, Australia/New Zealand

GNSS elements: GBAS

- GBAS: Ground Based Augmentation System ("LAAS: local area augmentation system" in the US)
- Operates in the VHF NAV band (108 [112] – 117.975 MHz)
- Supports precision approach service (currently up to CAT I, with CAT II/III SARPs due for adoption in 2018) and optionally positioning service
- Precision approach service provides "ILS-like" deviation guidance for final approach segments
- Can support multiple runways
- ICAO Annex 10, Volume I, section 3.7.3.5


GPS Satellites
Ranging Sources
Status Information
GBAS
Ground
Facility
GBAS
Reference
Receivers
Differential Corrections,
Inetgrity Data and
Path Definition
Omnidirectional VHF Data
Broadcast (VDB) Signal

GBAS current implementation status

- Cat I operations authorized or underway:
  - Australia: Sydney (current), Melbourne (planned)
  - Brazil: Rio de Janeiro (2016)
  - China: Shanghai trials
  - Germany: Bremen, Frankfurt (5 out of 6 runways)
  - Russia: procedures at 4 airports (installed at most major airports)
  - Spain: Malaga
  - US: Memphis, Newark, Houston
  - …
- Aircraft provisions:
  - Several Boeing and Airbus aircraft types equipped (optional/ standard)
  - Over 1500 air transport category aircraft equipped
- Cat II/III developments underway

GNSS evolution

- GPS evolution
  - GPS Block IIF satellites: add L5 safety-of-life signal in DME band
  - 12 satellites already transmitting “pre-operational” L5 signal (24 by 2024)
  - GPS III satellite acquisition program underway (L1C civil signal in addition to existing ones, backward compatible with current L1, with performance improvements)
- GLONASS
  - Achieved nominal configuration (24 satellites)
  - The new GLONASS-K satellites and the upgraded GLONASS-M satellites support the L3 CDMA safety-of-life signal in DME band (1202.025 MHz)
- Galileo
  - 8 Full Operational Capability satellites , 4 In-Orbit Verification satellites, Full 30 Satellites aimed 2020
- BeiDou
  - China’s GNSS system, 18 satellites in orbit, full deployment planned by 2020,

GNSS evolution: Multi-Constellation/Dual frequency (MCDF)

- Technically promising
  - Performance improvements (increased availability, better protection against interference and ionosphere effects)
  - Potential operational benefits
- Open challenges
  - Regulatory issues: conflicting mandates/authorizations
  - Human factors issues: potential additional cockpit complexity due to different mandates/authorizations
  - Avionics development/certification/equipage

MID Region GNSS Strategy

- Based on ICAO GNSS implementation guidance
- Developed through MIDANPIRG structure
- MID Region Air Navigation Strategy (MID Doc 002)
- MID Region PBN Implementation Plan (MID Doc 007)

MID ASBU Block 0 Modules Prioritization

Performance Improvement Areas (PIA)	Module	Priority	Module Name
PIA 1: Airport Operations	**APTA**	**1**	Optimization of Approach Procedures including vertical guidance
	WAKE	2	Increased Runway Throughput through Optimized Wake Turbulence Separation
	RSEQ	2	Improved Traffic Flow through Sequencing (AMAN/DMAN)
	SURF	**1**	Safety and Efficiency of Surface Operations (A-SMGCS Level 1-2)
	ACDM	**1**	Improved Airport Operations through Airport-CDM
PIA 2: Globally Interoperable Systems and Data - Through Globally Interoperable System Wide Information Management	**FICE**	**1**	Increased Interoperability, Efficiency and Capacity through Ground-Ground Integration
	DATM	**1**	Service Improvement through Digital Aeronautical Information Management
	AMET	**1**	Meteorological information supporting enhanced operational efficiency and safety
PIA 3: Optimum Capacity and Flexible Flights – Through Global Collaborative ATM	**FRTO**	**1**	Improved Operations through Enhanced En-Route Trajectories
	NOPS	**1**	Improved Flow Performance through Planning based on a Network-Wide view
	ASUR	2	Initial Capability for Ground Surveillance
	ASEP	2	Air Traffic Situational Awareness (ATSA)
	OPFL	2	Improved access to Optimum Flight Levels through Climb/Descent Procedures using ADS-B
	ACAS	**1**	ACAS Improvements
	SNET	2	Increased Effectiveness of Ground-based Safety Nets
PIA 4: Efficient Flight Path – Through Trajectory-based Operations	**CDO**	**1**	Improved Flexibility and Efficiency in Descent Profiles (CDO)
	TBO	2	Improved Safety and Efficiency through the initial application of Data Link En-Route
	CCO	**1**	Improved Flexibility and Efficiency Departure Profiles - Continuous Climb Operations (CCO)

B0 – APTA: Optimization of Approach Procedures including vertical guidance			
Elements	**Applicability**	**Performance Indicators/Supporting Metrics**	**Targets**
States' PBN Implementation Plans	All States	Indicator: % of States that provided updated PBN implementation Plan Supporting metric: Number of States that provided updated PBN implementation Plan	100% by Dec. 2018
LNAV	All RWYs Ends at International Aerodromes	Indicator: % of runway ends at international aerodromes with RNAV(GNSS) Approach Procedures (LNAV) Supporting metric: Number of runway ends at international aerodromes with RNAV (GNSS) Approach Procedures (LNAV)	All runway ends at Int'l Aerodromes, either as the primary approach or as a back up for precision approaches by Dec. 2016
LNAV/VNAV	All RWYs ENDs at International Aerodromes	Indicator: % of runways ends at international aerodromes provided with Baro-VNAV approach procedures (LNAV/VNAV) Supporting metric: Number of runways ends at international aerodromes provided with Baro-VNAV approach procedures (LNAV/VNAV)	All runway ends at Int'l Aerodromes, either as the primary approach or as a back-up for precision approaches by Dec. 2017

GNSS as per the MID Region PBN Implementation Plan

For GNSS implementation States need to provide effective spectrum management and protection of GNSS frequencies by enforcing strong regulatory framework governing the use of GNSS repeaters, and jammers. States need to assess the likelihood and effects of GNSS vulnerabilities in their airspace and apply, as necessary, recognized and available mitigation methods.

During transition to GNSS, sufficient ground infrastructure for current navigation systems must remain available. Before existing ground infrastructure is considered for removal, users should be consulted and given reasonable transition time to allow them to equip accordingly.

GNSS as per the MID Region PBN Implementation Plan

GNSS implementation should take advantage of the improved robustness and availability made possible by the existence of multiple global navigation satellite system constellations and associated augmentation systems.

Operators consider equipage with GNSS receivers able to process more than one constellation in order to gain the benefits associated with the support of more demanding operations. States allow for realization of the full advantages of on-board mitigation techniques.

Implementation targets of each PBN navigation specification in the MID Region

Airspace	Short term (2013-2018)		Medium term (2019-2025)	
	Navigation Specification Preferred	Targets	Navigation Specification Acceptable	Targets
En-route – Oceanic	RNAV 10	100 % by 2016	RNP 4*, RNP 2*, Defined airspace, (A-RNP)	TBD
En-route - Remote continental	RNAV 5 RNAV 10	W/A 100% by 2016	RNP 4*, RNP 2* Defined airspace (A-RNP)	TBD
En-route – Continental	RNAV 5 RNAV 1	100 % by 2017 W/A[1]	RNP 2* Defined airspace (A-RNP)	TBD
En-route - Local / Domestic	RNAV 5 RNAV 1	100 % by 2017 W/A	RNP 2* Defined airspace (A-RNP)	TBD
TMA – Arrival	RNAV 1 in surveillance environment RNP 1 in non-surveillance environment	50% by 2016 100% by 2018	RNP 1 and RNP 2 beyond 30 NM from ARP (A-RNP)	TBD
TMA – Departure	RNAV 1 in surveillance environment. RNP 1 in non- surveillance environment	50% by 2016 100% by 2018	RNP 1 and RNP 2 beyond 30 NM from ARP (A-RNP)	TBD
Approach	LNAV: for all RWY Ends at International Aerodromes LNAV/VNAV: for all RWY Ends at International Aerodromes	80 % by 2014. 100% by 2016 70% by 2016 and 100% by 2018	GLS (GBAS) For the defined RWY Ends	TBD
CCO and CDO	W/A	100% by 2018	W/A	TBD

– *W/A: where applicable/defined Airspace, in accordance with State PBN implementation Plans, the MID Region Air navigation Strategy and the MID ANP.*

– ** would be considered for implementation at the identified Airspace/TMAs, When no month is specified (e.g. by 2017) means by the end of the year (December 2017).*

The way forward

- Embrace early benefits from Basic GNSS (ABAS) implementation (PBN RNP APCH operations)
- Recognize the regional SBAS infrastructure available (and expanding) today, and the local GBAS developments taking place around the world
- Be responsive to operator needs and fleet capabilities
- Coordinate regional implementation through ICAO regional structure (MIDANPIRG)
- Address the open issues on the basis of specific cost/benefit considerations as opposed to rigid across-the-board positions
- Monitor future developments of basic constellations for >2025 fruition

Conclusion

- Implementation of GNSS and achievement of agreed targets in the MID Air Navigation Strategy and the MID PBN plan
- States to share experience on GNSS implementation including sharing of training and implementation packages
- Identify operational requirements/Scope and improvements and plan for implementation
- Engage all Stakeholders in all planning process
- Maximize the use of the available technologies before investing in any new technologies
- Assess the likelihood and effects of GNSS vulnerabilities in the MID Region
- Augmentation systems issues
  - No easy solution
  - Early benefits through ABAS-supported PBN RNP APCH procedures (“Basic GNSS”)
  - Address challenges associated with SBAS/GBAS implementation, including Cost-Benefit Analyses (CBA)

ICAO

North American Central American and Caribbean (NACC) Office
Mexico City

South American (SAM) Office
Lima

ICAO Headquarters
Montréal

Western and Central African (WACAF) Office
Dakar

European and North Atlantic (EUR/NAT) Office
Paris

Middle East (MID) Office
Cairo

Eastern and Southern African (ESAF) Office
Nairobi

Asia and Pacific (APAC) Sub-office
Beijing

Asia and Pacific (APAC) Office
Bangkok

THANK YOU

Slides for Reference

12th Air Navigation Conference

Recommendation 6/6 – Use of multiple constellations

That States, when defining their air navigation strategic plans and introducing new operations:

a) take advantage of the improved robustness and availability made possible by the existence of multiple global navigation satellite system constellations and associated augmentation systems;

b) publish information specifying the global navigation satellite system elements that are approved for use in their airspace;

c) adopt a performance-based approach with regard to the use of global navigation satellite system (GNSS), and avoid prohibiting the use of GNSS elements that are compliant with applicable ICAO Standards and Recommended Practices;

d) carefully consider and assess if mandates for equipage or use of any particular global navigation satellite system core constellation or augmentation system are necessary or appropriate;

That aircraft operators:

e) consider equipage with GNSS receivers able to process more than one constellation in order to gain the benefits associated with the support of more demanding operations.

12th Air Navigation Conference

Recommendation 6/8 – Planning for mitigation of global navigation satellite system vulnerabilities

That States:

a) assess the likelihood and effects of global navigation satellite system vulnerabilities in their airspace and apply, as necessary, recognized and available mitigation methods;

b) provide effective spectrum management and protection of global navigation satellite system (GNSS) frequencies to reduce the likelihood of unintentional interference or degradation of GNSS performance;

c) report to ICAO cases of harmful interference to global navigation satellite system that may have an impact on international civil aviation operations;

d) develop and enforce a strong regulatory framework governing the use of global navigation satellite system repeaters, pseudolites, spoofers and jammers;

e) allow for realization of the full advantages of on-board mitigation techniques, particularly inertial navigation systems; and

f) where it is determined that terrestrial aids are needed as part of a mitigation strategy, give priority to retention of distance measuring equipment (DME) in support of inertial navigation system (INS)/DME or DME/DME area navigation, and of instrument landing system at selected runways.

GNSS elements today: GPS

- History
  - Programme approved in 1973 by the US DoD
  - First experimental satellite launched in 1978
  - Initial operational capability (IOC) and commitment to ICAO in 1994
  - Full operational capability (FOC) in 1995
  - Currently: satelllite replacement and modernization
  - Procurement history: Block I, II, IIA, IIR, IIR-M, IIF, IIIA..
  - Evolution (IF, IIIA): L5 signal in the DME band, L1C signal…
  - Currently managed by the US National Space-Based Positioning, Navigation, and Timing (PNT) Executive Committee

GNSS elements: GPS

- Nominal constellation: 24 satellites (currently 31 “healthy satellites” and 1 in on-orbit checkout as of 9 February 2016)
- Six orbital planes
- Near-circular, 20,200 km altitude (26,600 km radius) 12-hour orbits
- Managed by the US National Space-Based Positioning, Navigation, and Timing (PNT) Executive Committee
- Standard positioning service (SPS) frequency: 1 575.42 MHz