GNSS in ATM, Space Weather, Lessons Learned in Perú

DGAC PERU Dirección General de Aeronáutica Civil

Beacon Satellite SYMPOSIUM 2016

GNSS , PBN, ADS Service in Perú

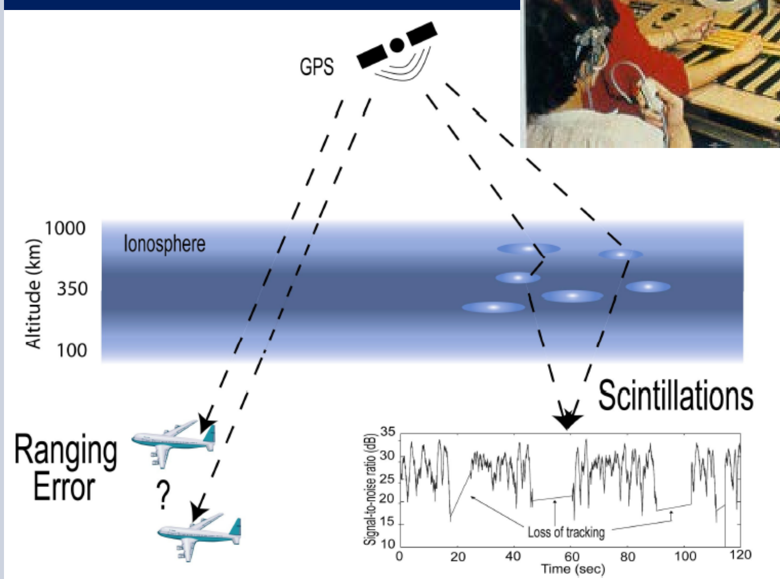
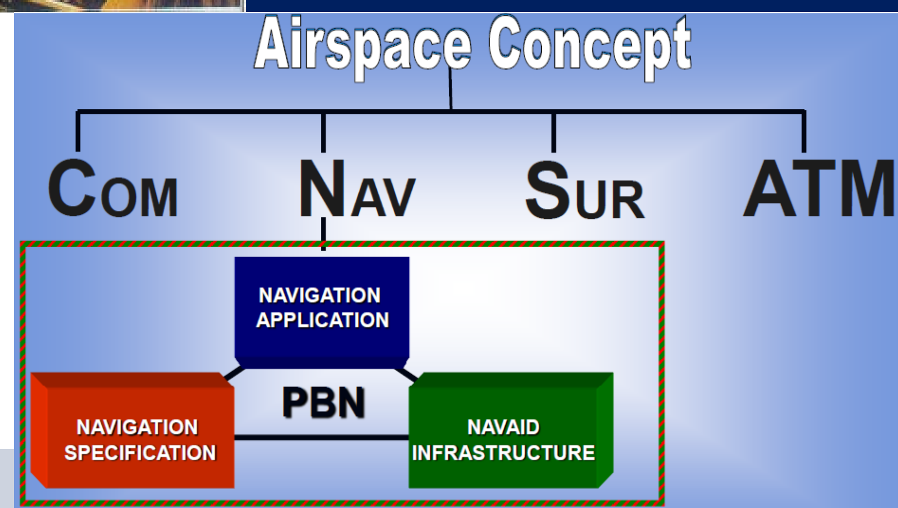


Image Courtesy by Cornell University GPS Lab



Eng. Jorge D. Taramona
Air Navigation Inspector
Ministry of Transport and Communications

July 1st, 2016, Trieste, Italy

OUTLINE

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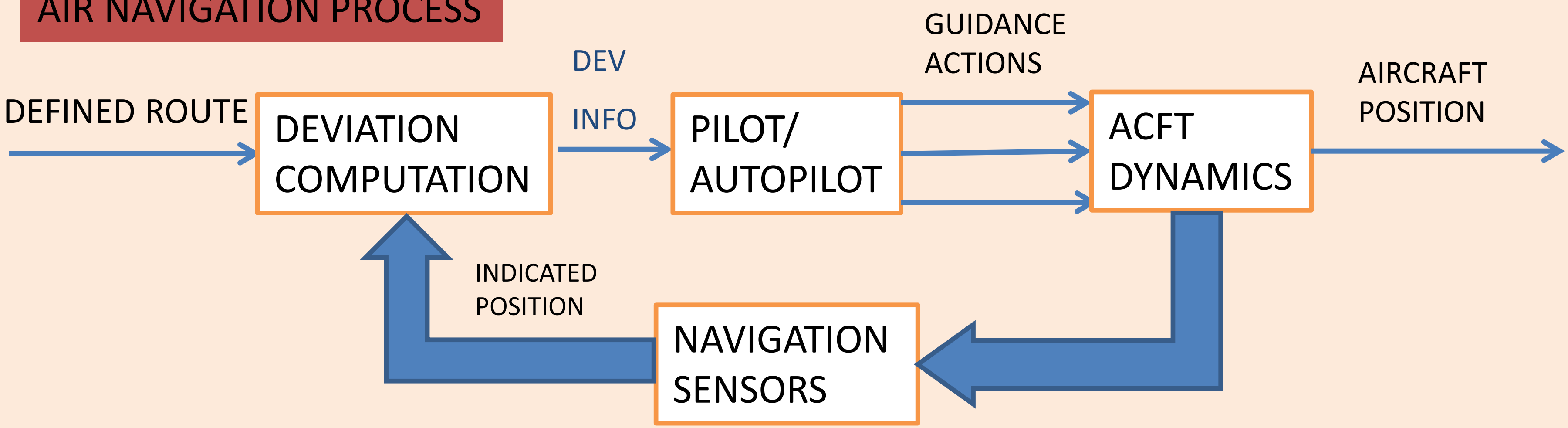
INTRODUCTION

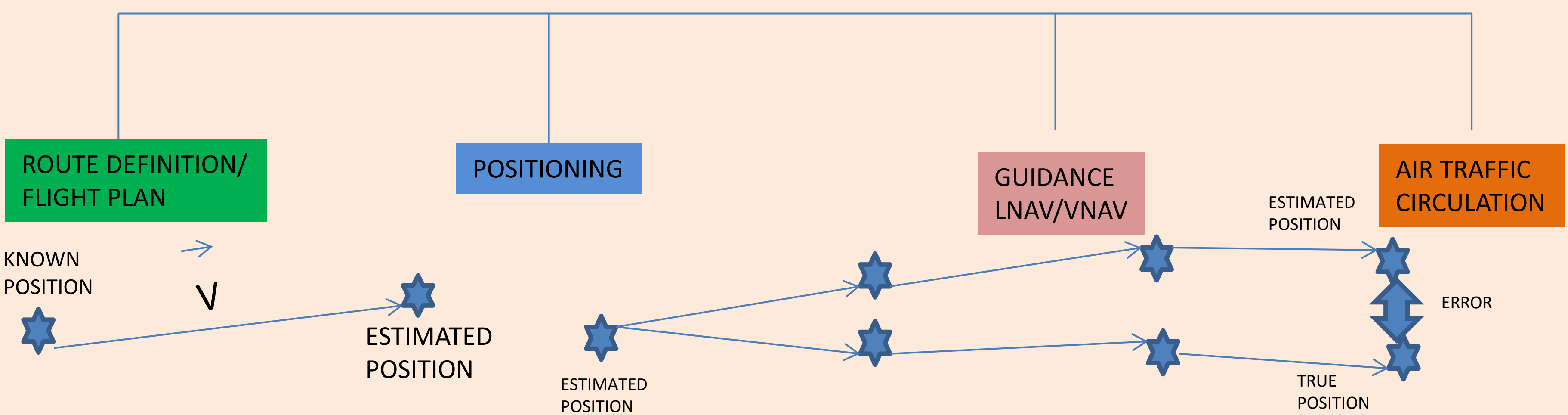
- Nowadays, the air traffic has increased dramatically. On the other hand, in Peru the geography and climate are constraining factors for air traffic operations.
- PBN concept is a good alternative to deal with that, but it strongly relies on GNSS, and the GNSS has its own vulnerabilities, one of them are the space weather, particularly the equatorial ionosphere (ICAO Resolution A37-11-Performance-based navigation global goals).
- States must form their own planning teams for GNSS implementations, but with scientific assessment during the whole process (DOC 9750 GANP).

Navigation Fundamentals

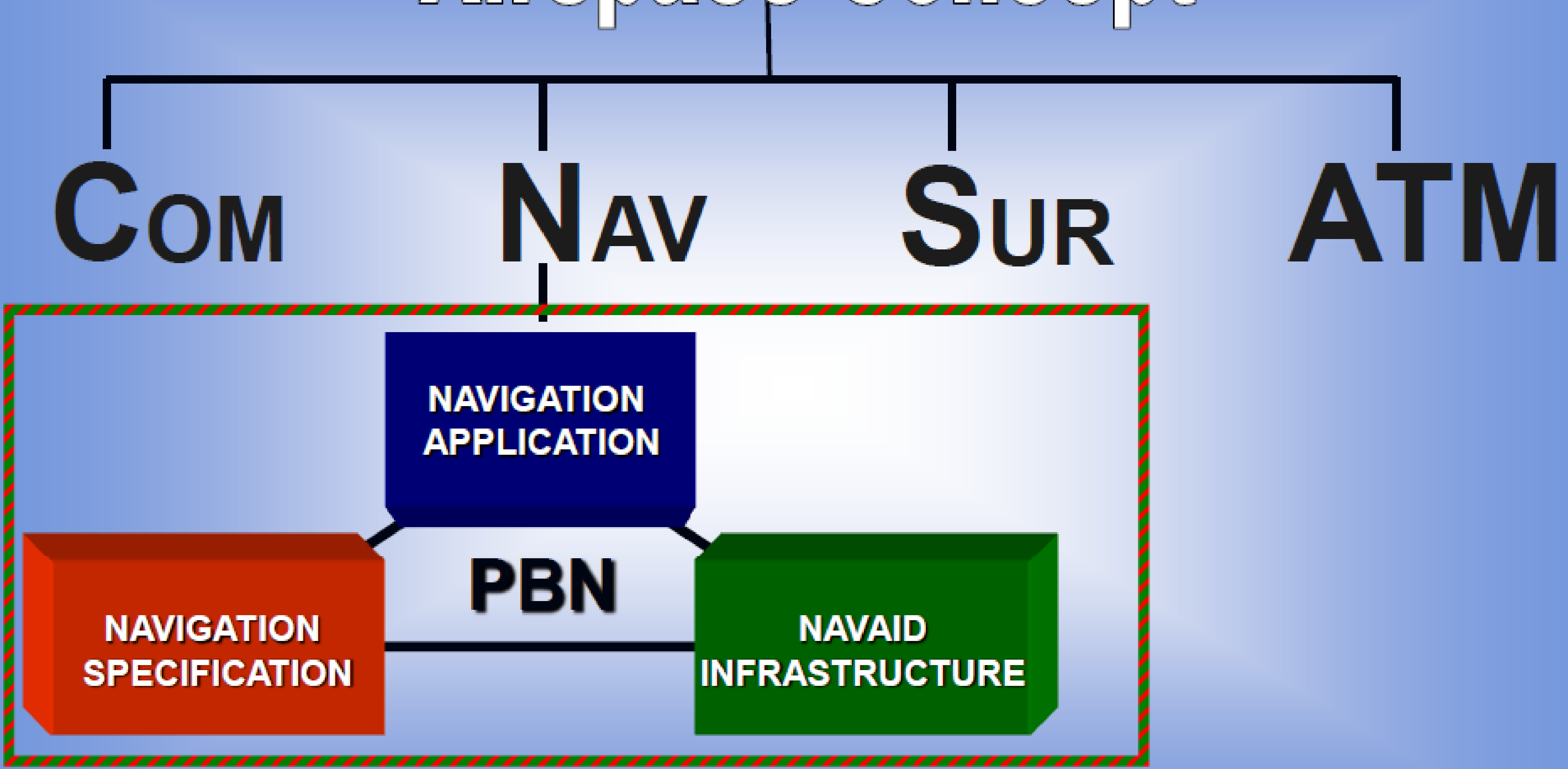
AIR NAVIGATION PROCESS



NAVIGATION TASKS/FUNCTIONS



Airspace Concept



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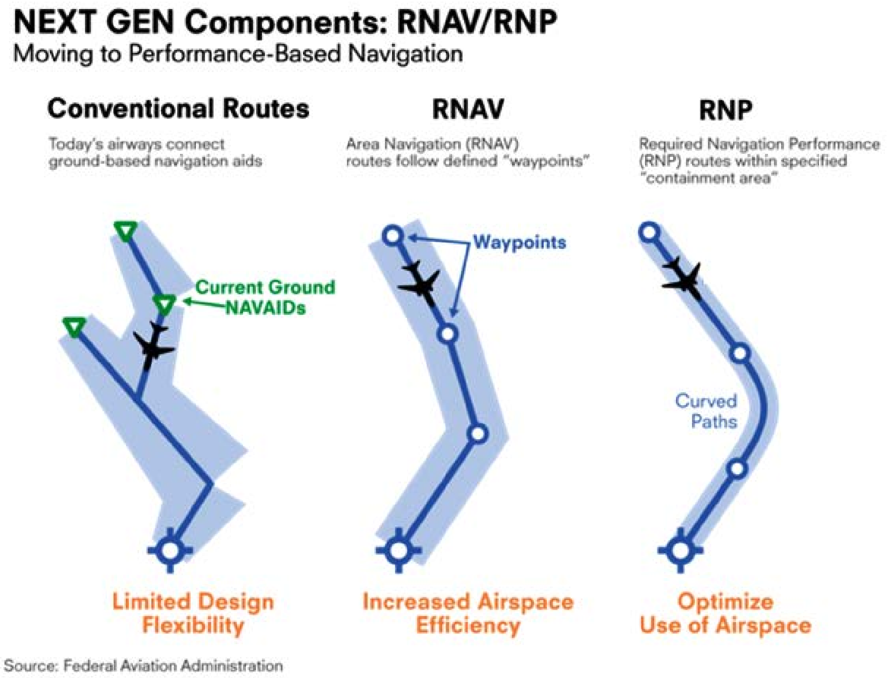
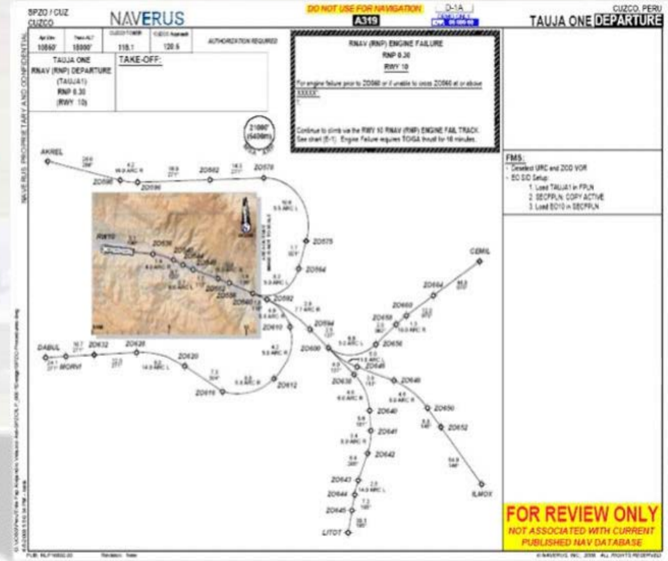
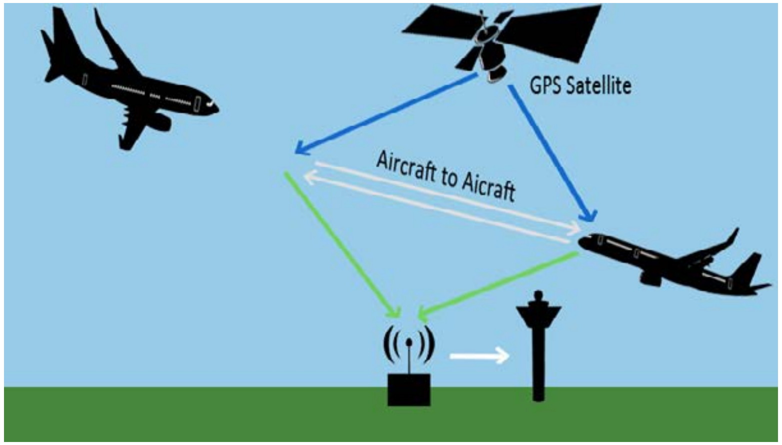
WHY GNSS? RNAV/RNP

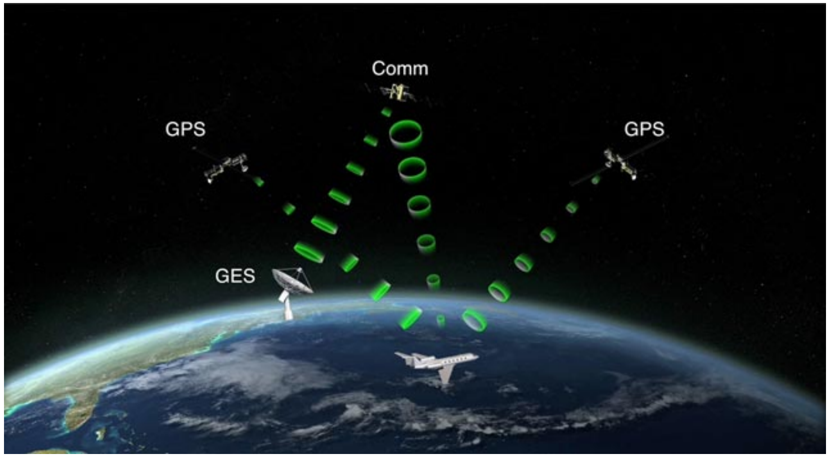


Cuzco

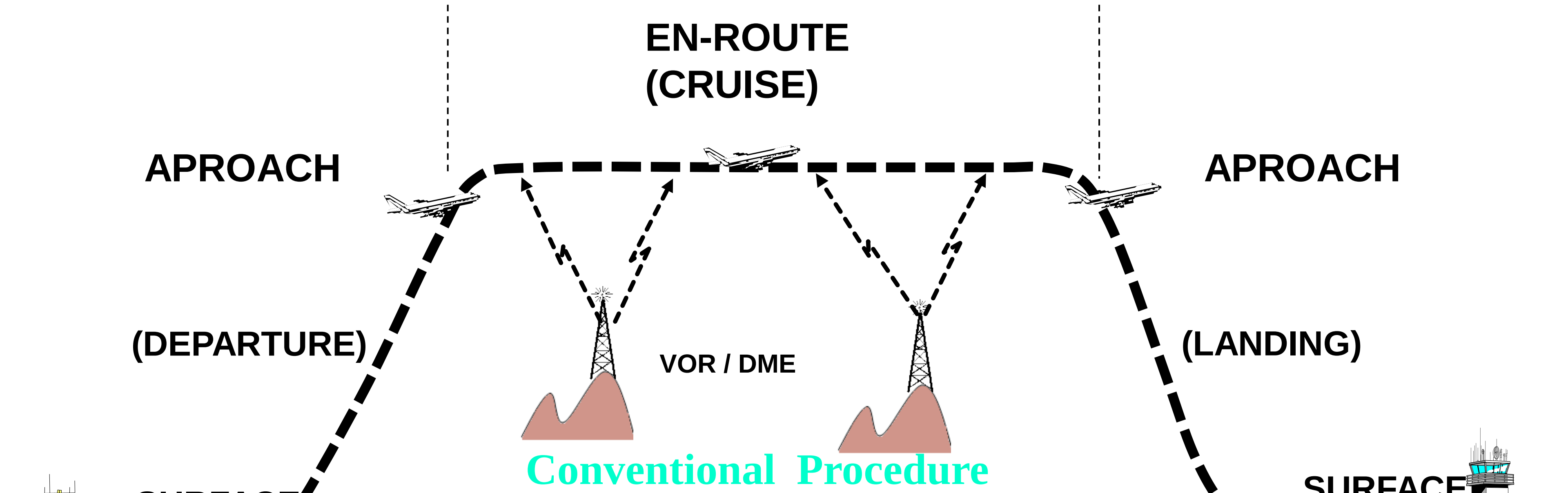
- RNP Departure.
- Provision for 5 exit gates, depending on flight destination.



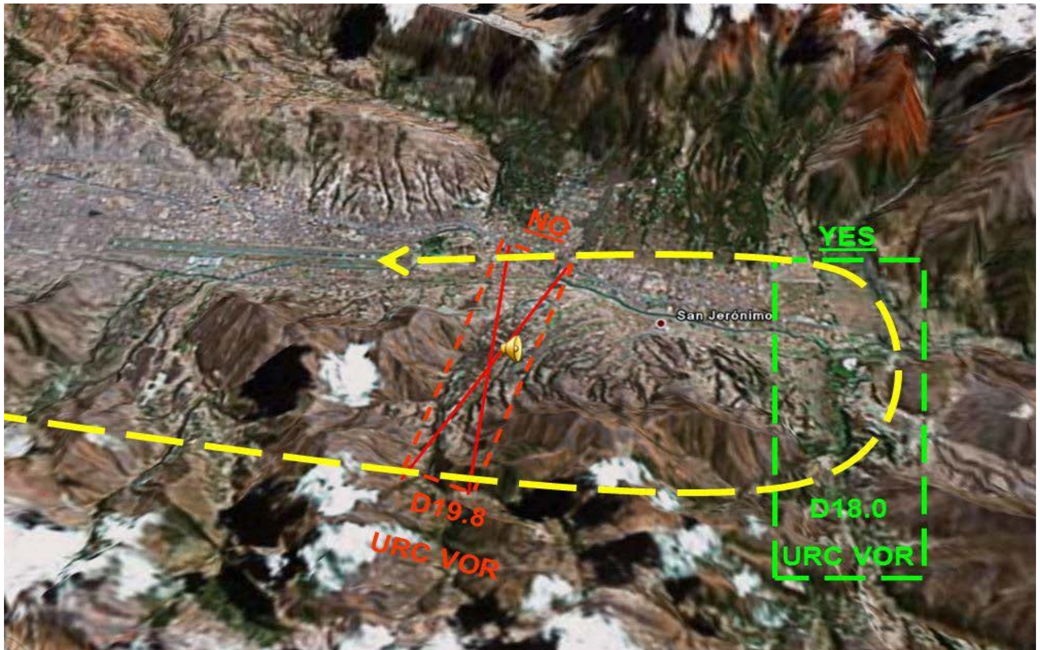




CURRENT NAVIGATION (BASED ON RADIO-AIDS)



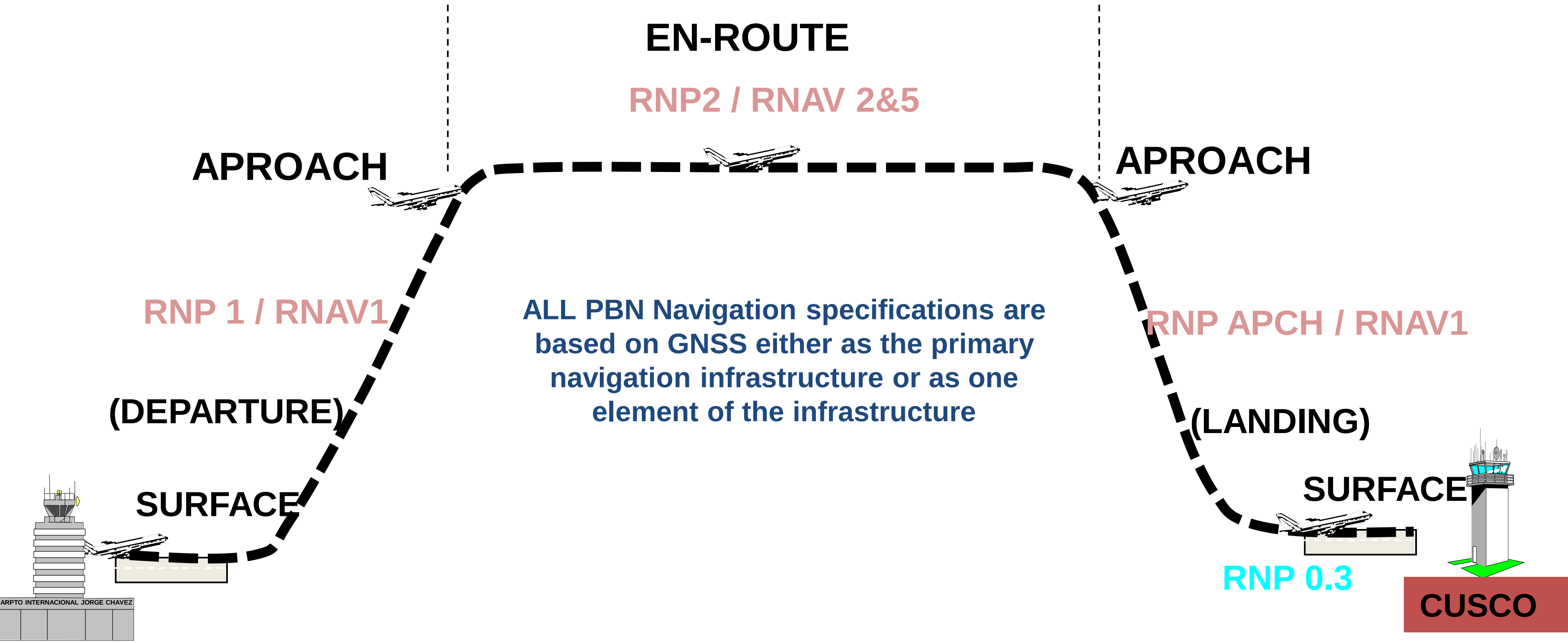
Conventional Procedure



ILS: (Instrument Landing System
VOR: Very High Frequency Omnidirectional Range
DME: Distance Measurement Equipment

Jorge García, Corpac S.A.

PBN: PERFORMANCE BASED NAVIGATION - RNAV/RNP



PBN enables RNAV/RNP navigation by mean of the following requirements:

- Accuracy
- Integrity
- Continuity
- Availability
- Functionability

PERUVIAN EXPERIENCE:

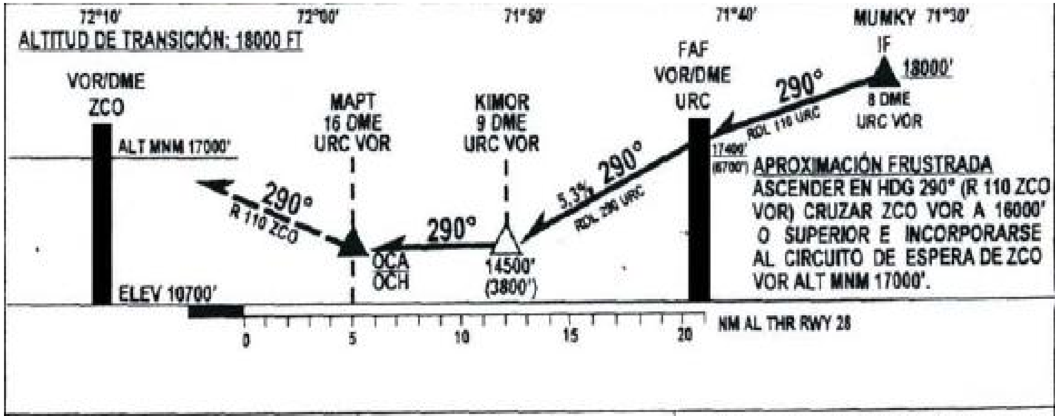
The first operational approach procedure based on GNSS and RNP Baro - VNAV information was authorized at the Cusco Airport in 2008

Cusco Airport:

- **Location: Cusco, Peru**
- **Elevation: 10745 ft.**
- **IFR Daylight operations only**

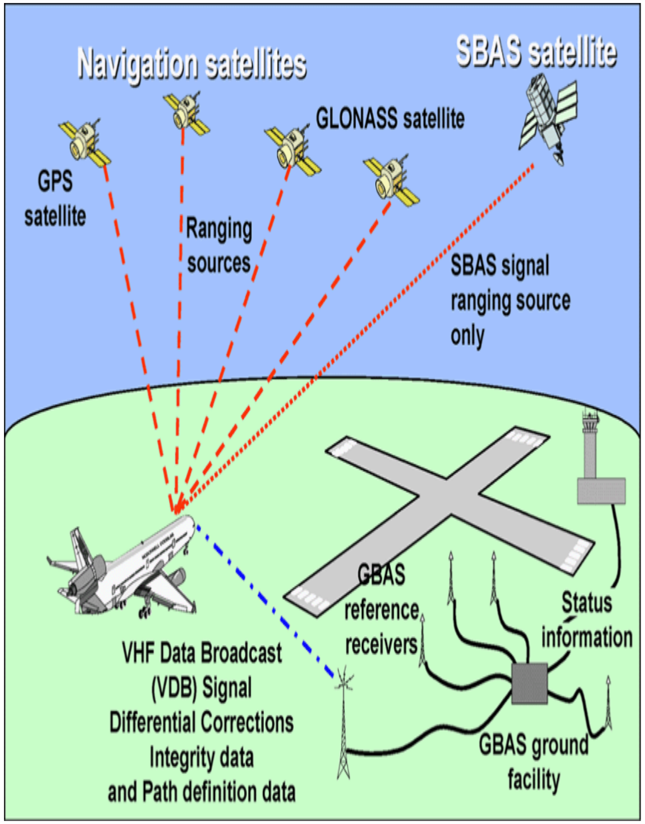
RWY28 served by two IFR approaches, ending in visual circling maneuvers.

- **Minimum approach (DA 14500’,visibility required 8Km) often higher than actual weather conditions.**



OCA / H	A - B - C - D	MÍNIMOS DE UTILIZACIÓN DEL AD
EN CIRCUITO RWY 28	14500' (3800')	TECHO DE NUBES: 1200 M VISIBILIDAD : 8 KM

GNSS/SBAS/GBAS/ABAS



ICAO Concept for GNSS:

It is a worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented if is neccesary to support the required navigation performance for the intended operation, Ref. ICAO ANNEX 10, VOL I,

Augmentation systems:

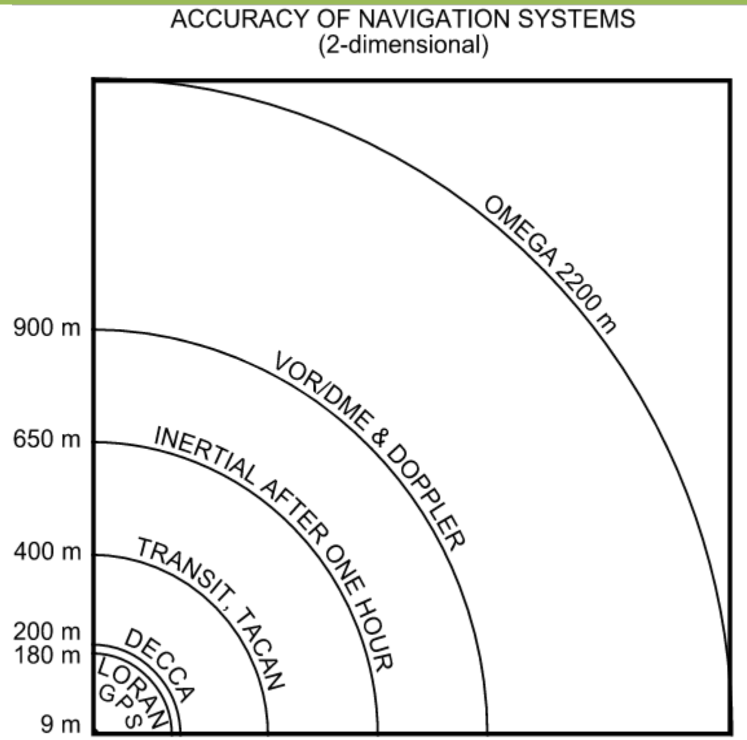
The existing core satellite constellations (GPS and GLONASS) require augmentation by ABAS, GBAS or SBAS to meet ANNEX 10 performance requirements for specific operations, GNSS avionics process signals from core satellite constellations, and where available GBAS or SBAS to meet ANNEX 10 requirements.

http://ieeexplore.ieee.org/ieee_pilot/articles/96jproc12/jproc-TMurphy-2006101/article.html

TYPICAL ERROR BUDGET AND 2D ACCURACY OF NAVIGATION SYSTEMS

Typical Error Budget (in Meters)

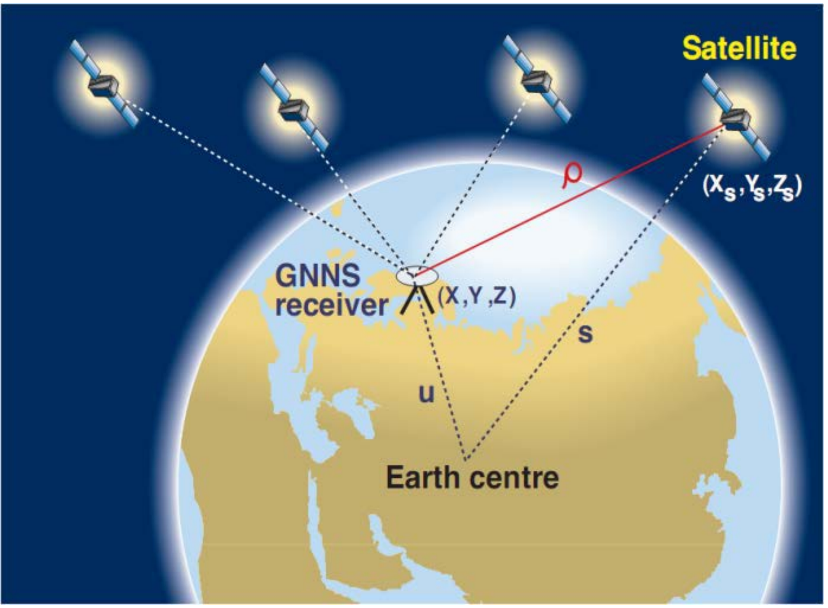
Per Satellite Accuracy	*Standard GPS*	*Differential GPS*
Satellite Clocks	1.5	0
Orbit Errors	2.5	0
Ionosphere	5.0	0.4
Troposphere	0.5	0.2
Receiver Noise	0.3	0.3
Multipath (Reflections)	0.6	0.6
Selective Availability (SA)	30.0	0
Typical Position Accuracy		
Horizontal	50	1.3
Vertical	78	2.0
3-D	93	2.8

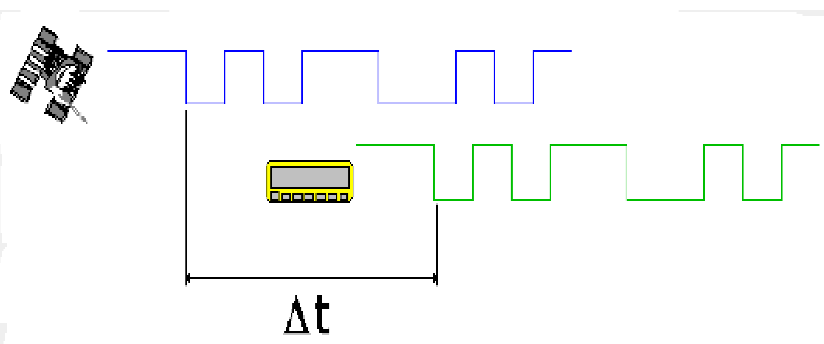


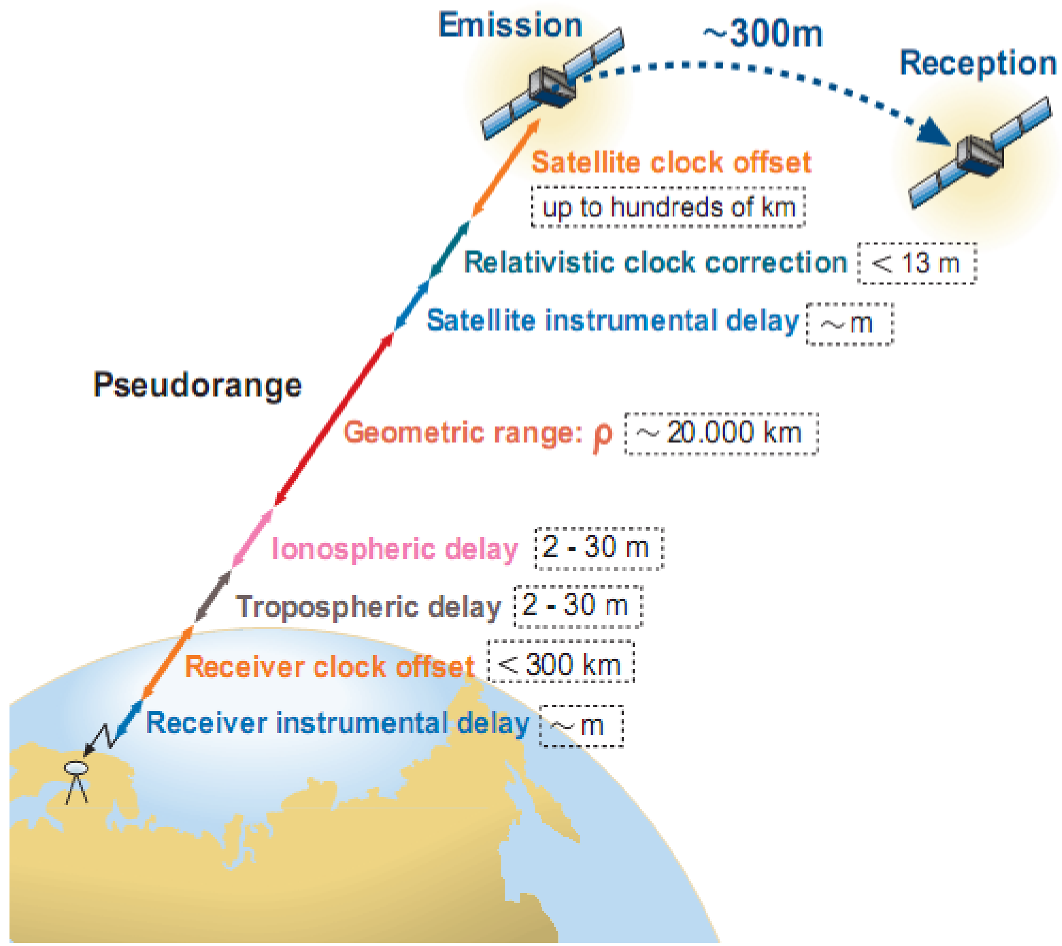
- These are the sources of user equivalent range errors (UERE) in standard and in differential GPS. The term UERE refers to the error of a component in the distance from the receiver to a satellite. These UERE errors are given as +/- errors thereby implying that they are unbiased or zero mean errors.
- Apart from the selective availability, ionosphere is the most important source error during signal propagation through that dispersive medium.

https://en.wikipedia.org/wiki/Error_analysis_for_the_Global_Positioning_System

GNSS SIGNAL PROPAGATION







Source: http://gage.upc.edu/tutorials

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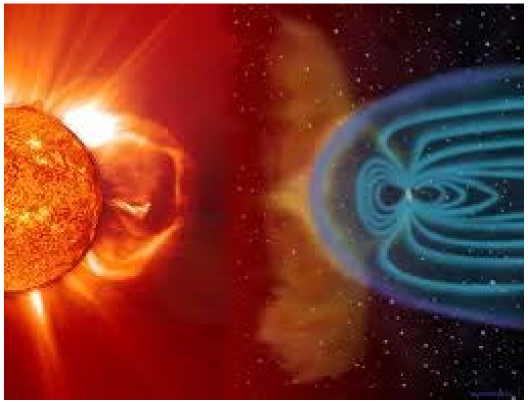
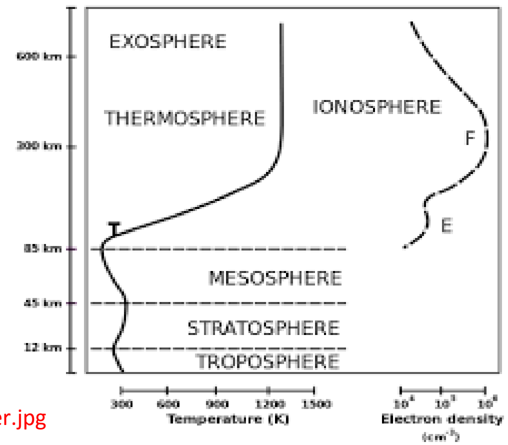
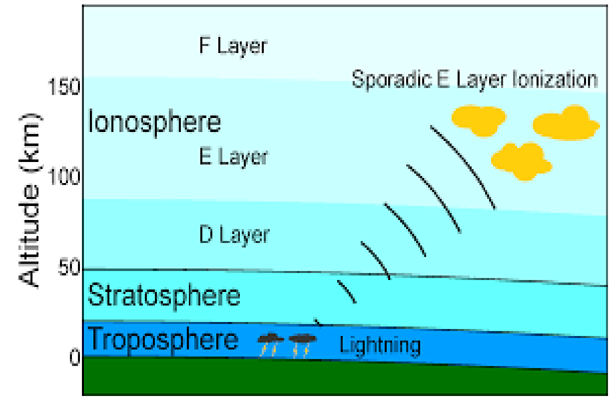
SPACE WEATHER/IONOSPHERE/GNSS/EQUATORIAL IONOSPHERE



http://www.land-of-kain.de/docs/spaceweather/nasa_spaceweather.jpg





https://sess.stanford.edu/talis

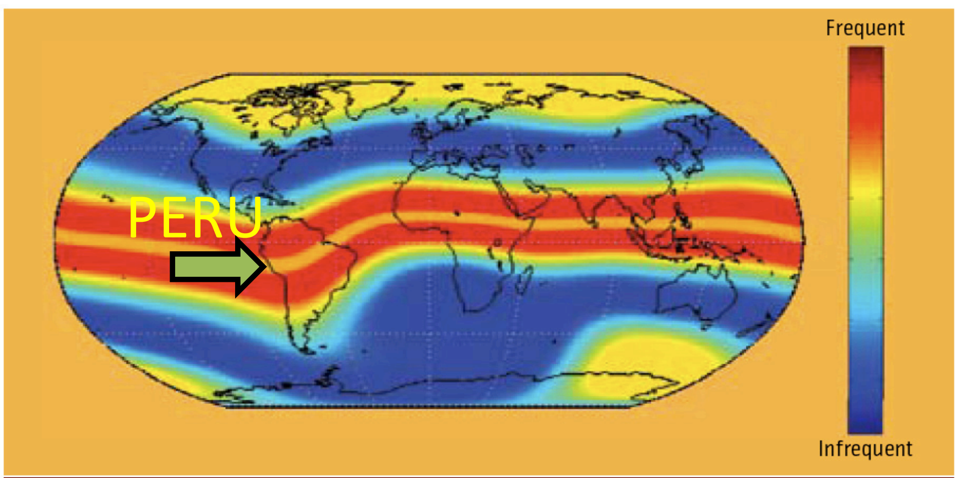
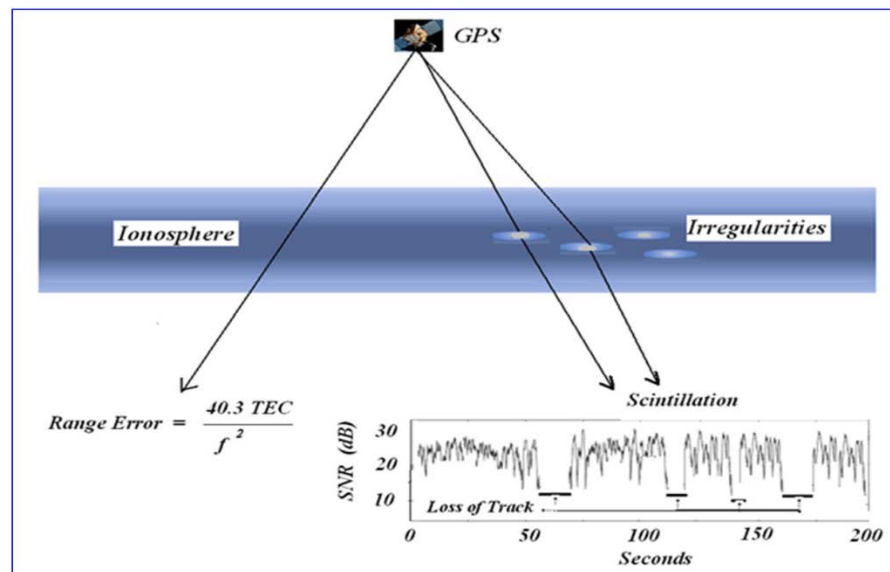


FIGURE 1 Scintillation map showing the frequency of disturbances at solar maximum. Scintillation is most intense and most frequent in two bands surrounding the magnetic equator, up to 100 days per year. At poleward latitudes, it is less frequent and it is least frequent at mid-latitude, a few to ten days per year.



https://www.insidegnss.com/auto/popupimage/Sun_Figure_1.jpg

http://www.cpi.com/capabilities/sw.html

Signal-in-Space Performance Requirements

Typical operation	Accuracy horizontal 95%	Accuracy vertical 95%	Integrity	Time-to-alert	Continuity	Availability
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	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999

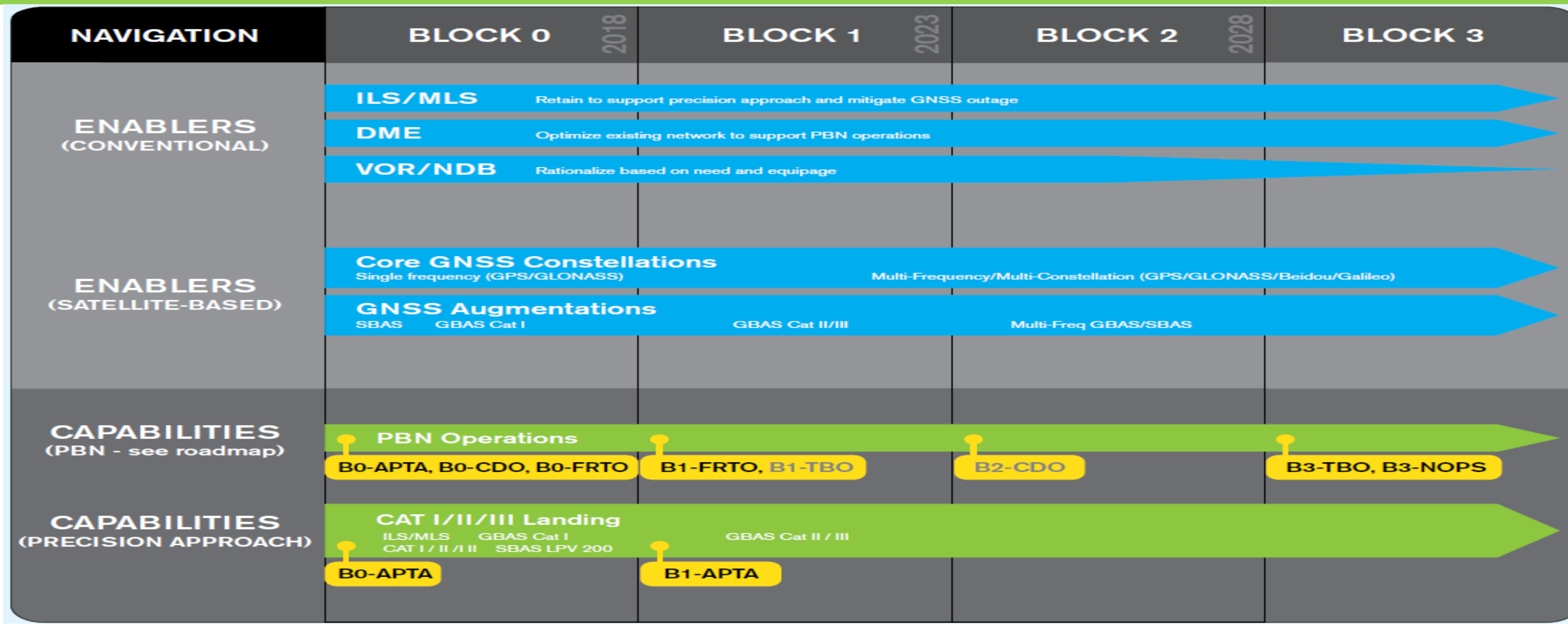
Table 3.7.2.4-1, Annex 10 – Aeronautical Communications, Volumen I, ICAO

Signal-in-Space Performance Requirements

Operation	*Oceanic en-route*	*Continental en-route*	*Terminal*	*Non-precision approach*	*Approach procedure with vertical guidance (APV)*		*Category I (CAT I)*
					APV-I	*APV-II*	
Horizontal alert limit	7.4 km (4 NM)	3.7 km (2 NM)	1.85 km (1 NM)	556 m (0.3 NM)	40 m (130 ft)	40 m (130 ft)	40 m (130 ft)
Vertical alert limit	N/A	N/A	N/A	N/A	50 m (164 ft)	20 m (66 ft)	35 to 10 m (115 to 33 ft)
Time-to-alert	5 min	5 min	15 s	10 s	10 s	6 s	6 s

Table 2-1, Doc. 9849 - ICAO, GNSS Manual

ICAO AVIATION SYSTEM BLOCK UPGRADE (ASBU) FOR NAVIGATION (DOC9750 GANP)



APTA

FRTO

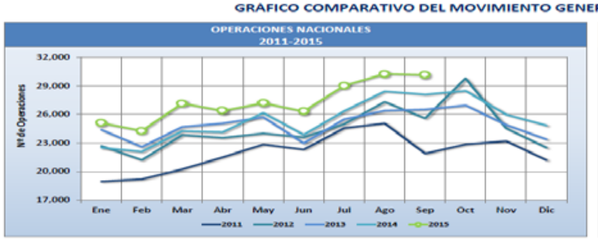
CORPAC S.A.

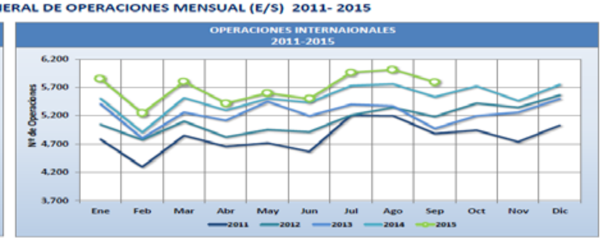
MOVIMIENTO GENERAL AEROPORTUARIO NACIONAL E INTERNACIONAL
OPERACIONES (E/S)
2011-2015

NAC/INT	Años	OPERACIONES (E/S) Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic	Total Ene-Dic	Var %
NACIONAL	2015	25,098	24,276	27,161	26,389	27,199	26,318	29,031	30,278	30,149				245,899	8.8
	2014	22,508	22,091	24,251	24,140	26,178	23,861	26,361	28,426	28,094	28,484	25,996	24,833	305,223	2.0
	2013	24,395	22,589	24,696	25,065	25,717	22,972	25,504	26,411	26,534	26,962	24,901	23,382	299,128	1.9
	2012	22,693	21,209	23,847	23,556	24,012	23,606	24,983	27,325	25,595	29,803	24,544	22,497	293,670	11.3
	2011	18,961	19,202	20,246	21,497	22,848	22,310	24,571	25,059	21,881	22,861	23,202	21,179	263,817	
INTERNACIONAL	2015	5,852	5,241	5,800	5,418	5,598	5,497	5,962	6,013	5,795				51,176	4.1
	2014	5,503	4,903	5,514	5,294	5,503	5,430	5,729	5,758	5,529	5,722	5,460	5,749	66,094	5.0
	2013	5,408	4,801	5,259	5,116	5,449	5,196	5,398	5,370	4,972	5,198	5,258	5,498	62,923	2.0
	2012	5,043	4,773	5,100	4,822	4,952	4,912	5,209	5,344	5,183	5,418	5,345	5,562	61,663	6.6
	2011	4,784	4,293	4,849	4,656	4,720	4,564	5,207	5,200	4,883	4,943	4,738	5,030	57,867	

Información preliminar 2015
Nota: Se incluyen vuelos regulares, no regulares, aviación general y militares.
Se consideran aeropuertos concesionados y administrados por CORPAC S.A.
(E/S) = Entradas y Salidas
Fuente: Propia.

GRÁFICO COMPARATIVO DEL MOVIMIENTO GENERAL DE OPERACIONES MENSUAL (E/S) 2011- 2015





CCO

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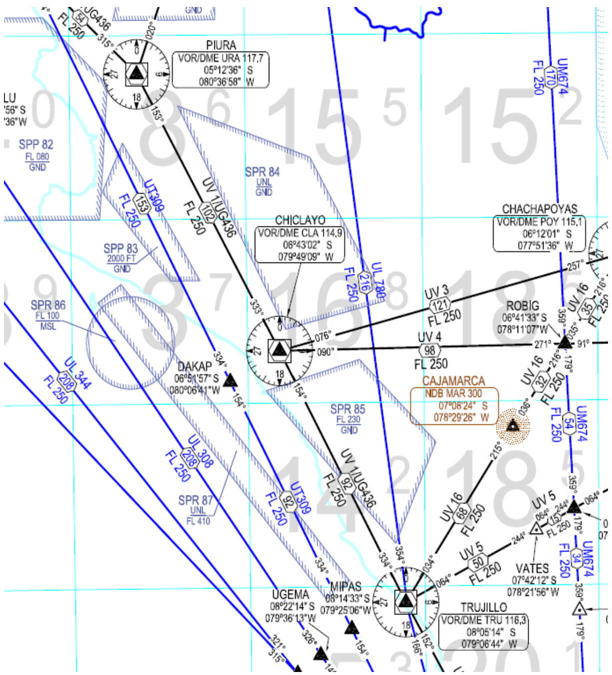
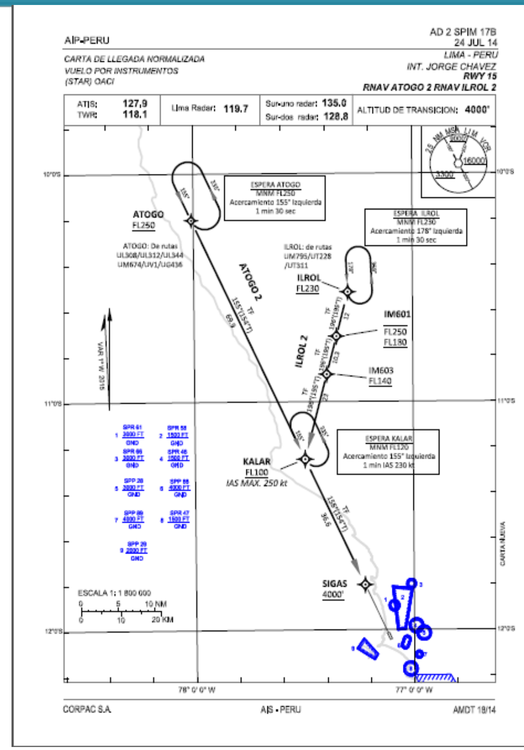
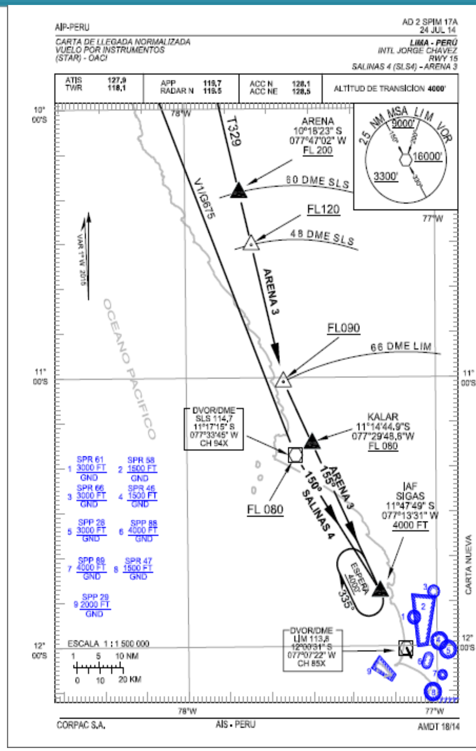
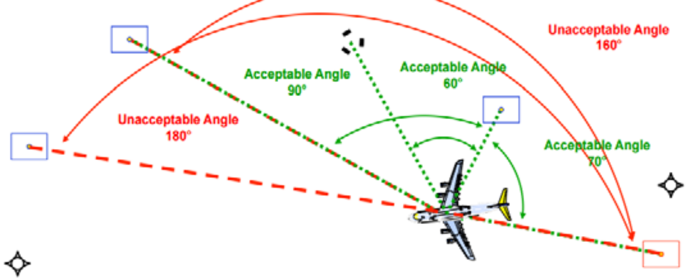
GNSS SERVICE IN PERU/PBN-PROESA

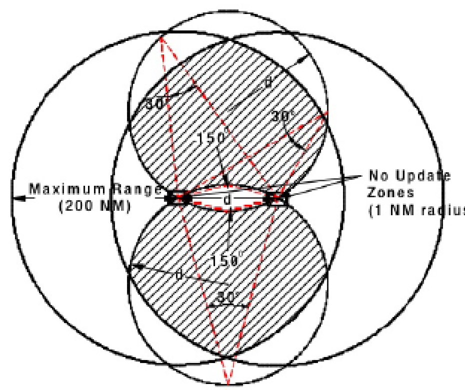




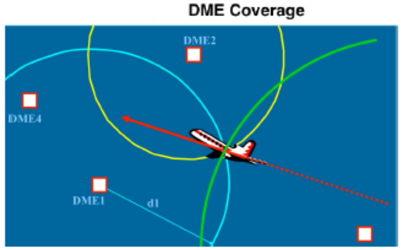


- For DME/DME systems using DME facility pairs, geometry solutions require two DMEs to be ≥ 30°and ≤ 150°





DME Coverage



LEARNED LESSONS/CONCLUSIONS/SCIENTIFIC ASSESSMENT

- GNSS is the enabler of the PBN concept through RNAV/RNP requirements/specifications. SBAS is no longer accepted in PERU because of their intrinsic threats. GBAS is a good alternative but some irregularities involving sudden temporary changes in the signal propagation due to equatorial ionosphere remain a concern.

- In Perú is not longer possible to provide PBN by means of DME/DME or VOR/VOR or other similar ways of positioning because of the geometry and insufficient number of those installations. So GNSS is essential and it must be included in our contingency plans and regulations.

- Finally, scientific and technical assessment are required, because we need permanent advisory when we are forming the planning team before implementation. GBAS is expected to be in implantation process by 2018 according to ICAO ASBU schedule.

ICAO SUGGESTED READING FOR GNSS

- ANNEX 10, AERONAUTICAL TELECOMMUNICATIONS, VOLUMEN I, RADIO NAVIGATION AIDS.
- DOCUMENT 4444, PROCEDURES FOR AIR NAVIGATION SERVICES - AIR TRAFFIC MANAGEMENT (PANS-ATM).
- DOCUMENT 8168, PROCEDURES FOR NAVIGATION SERVICES – AIRCRAFT OPERATIONS, VOLUMEN I, FLIGHT PROCEDURES.
- DOCUMENT 9613, PERFORMANCE-BASED NAVIGATION (PBN) MANUAL.
- DOCUMENT 9734, SAFETY OVERSIGHT MANUAL.
- DOCUMENT 9750, GLOBAL ARI NAVIGATION PLAN (GANP).
- DOCUMENT 9849, GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) MANUAL.
- DOCUMENT 9859, SAFETY MANAGEMENT MANUAL (SMM).
- DOCUMENT 9905, REQUIRED NAVIGATION PERFORMANCE AUTHORIZATION REQUIRED (RNP-AR) PROCEDURE DESIGN MANUAL.
- DOCUMENT 9992, MANUAL ON THE USE OF PERFORMANCE-BASED NAVIGATION (PBN) IN AIR SPACE DESIGN.
- DOCUMENT 9997, PERFORMANCE-BASED NAVIGATION (PBN) OPERATIONAL APPROVAL MANUAL.
- CIRCULAR 321, GUIDELINES FOR THE IMPLEMENTATION OF GNSS LONGITUDINAL SEPARATION MINIMA.
- CIRCULAR 322, GUIDELINES FOR THE IMPLEMENTATION OF GNSS LATERAL SEPARATION MINIMA BASED ON VOR SEPARATION MINIMA.

GRACIAS

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