Space Weather Effects on Air Navigation Systems

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and ICAO Weather Information Exchange Model (IWXXM)
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Sources courtesy of: CORPAC/ICAO/ITU/BOSTON COLLEGE/FAA/DECEA/NOAA/SOHO-NASA

AGENDA

I. INTRODUCTION

II. ICAO CONCEPT FOR GNSS

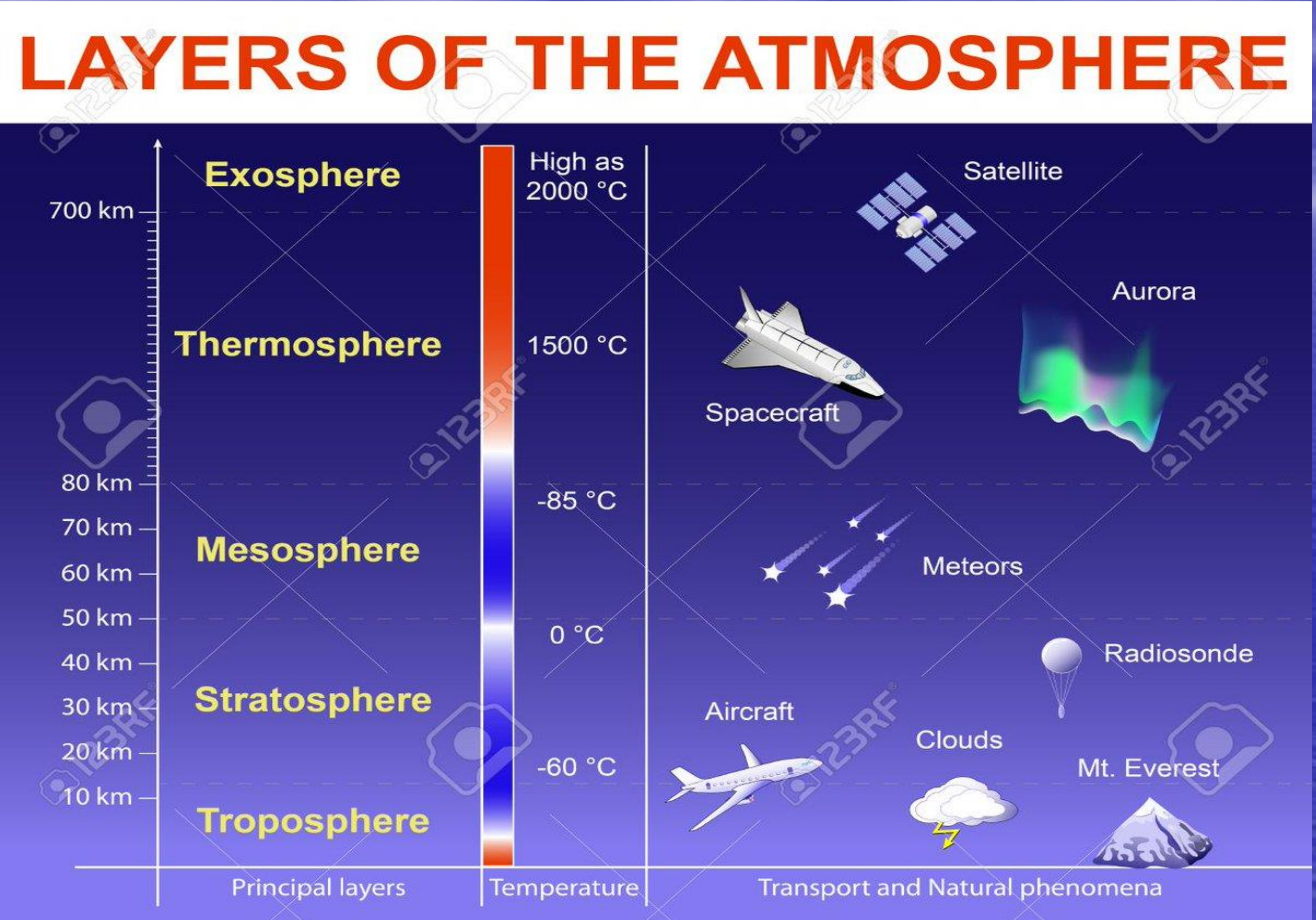
III. SPACE WEATHER

IV. IONOSPHERE EFFECTS OVER GNSS IN LOW LATITUDE (PROPOSALS)

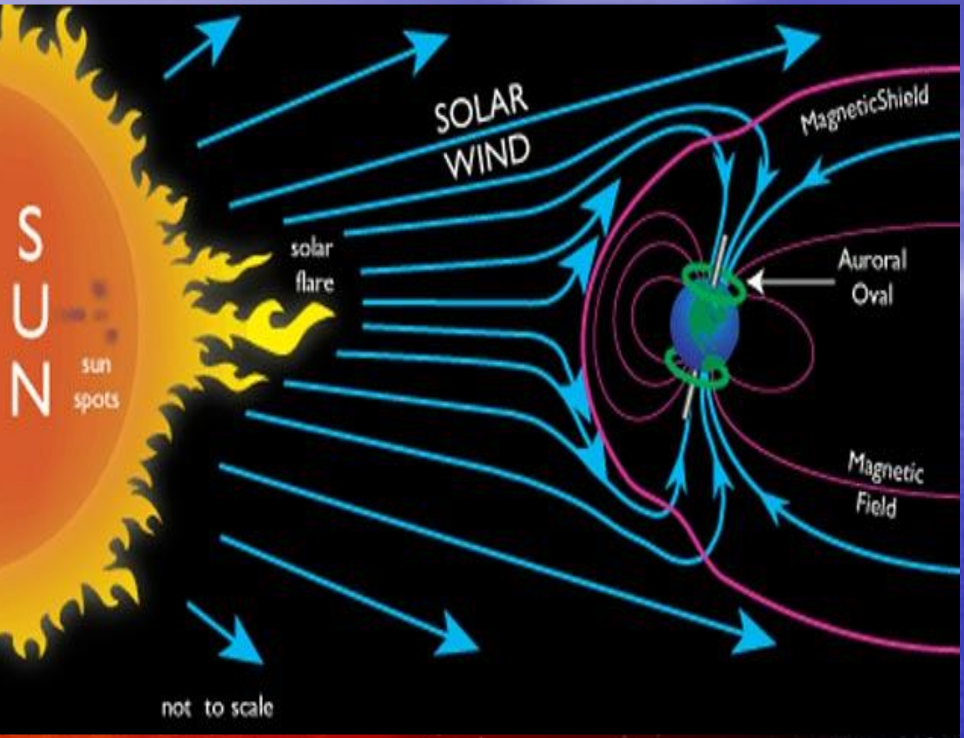
V. CONVENTIONAL WEATHER AND ITS EFFECTS

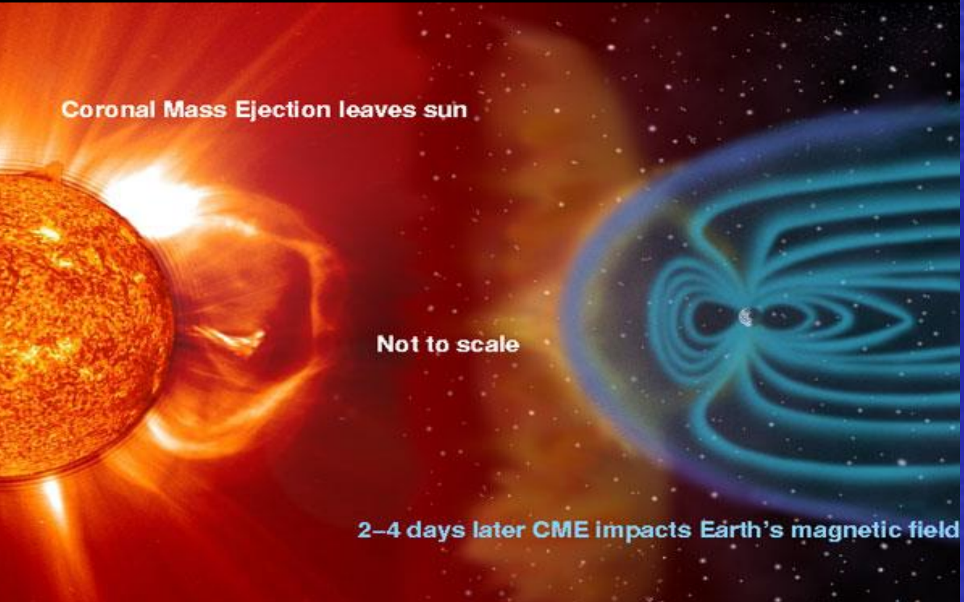
VI. REMARKS

I. INTRODUCTION



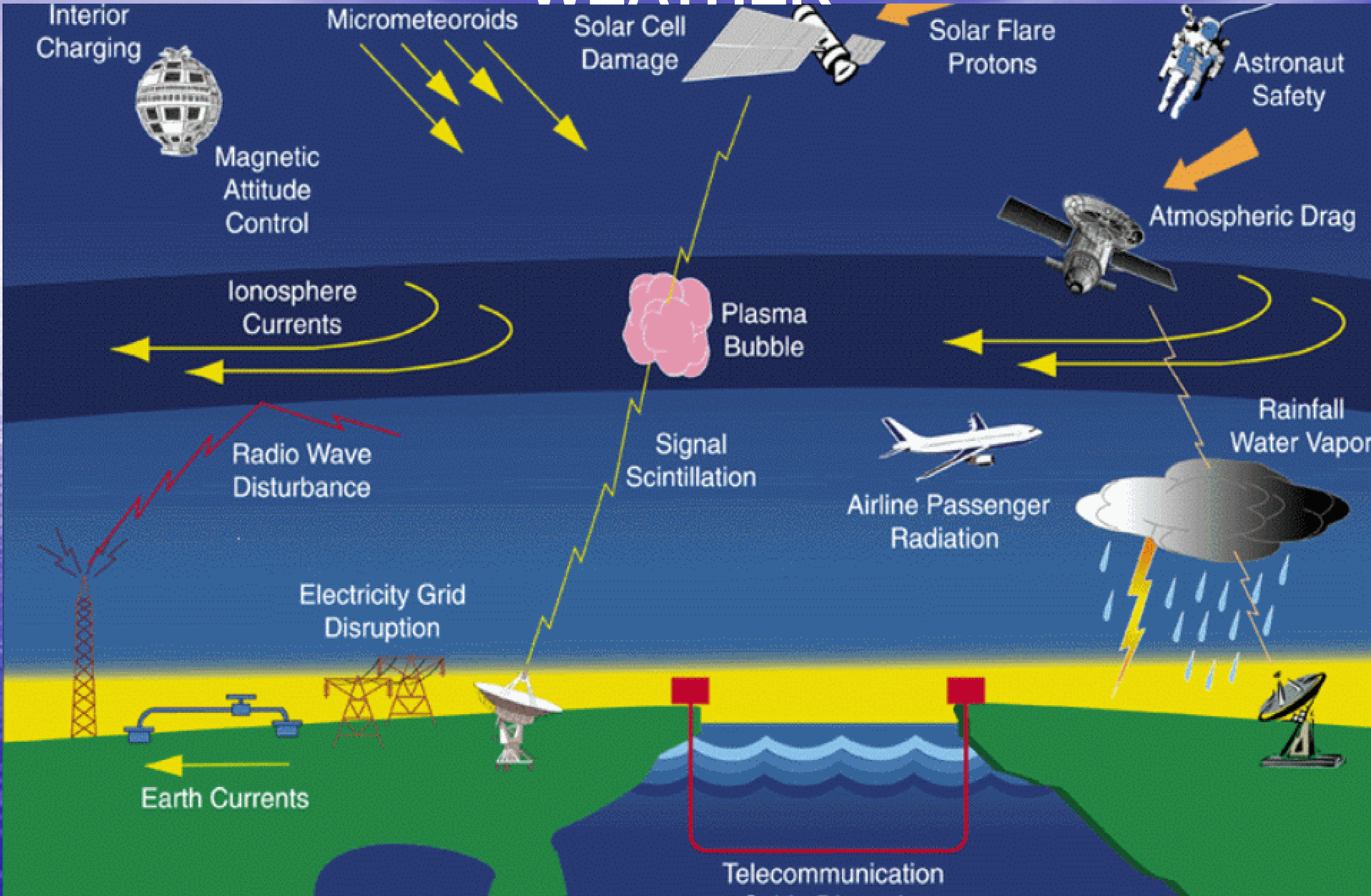
III. SPACE WEATHER (SW)





Space weather is related to the behaviour of the Sun, the nature of Earth's magnetic field and atmosphere, and our location in the solar system. The active elements of space weather are particles, electromagnetic energy and magnetic fields, rather than the more commonly known weather contributors of water, temperature and air. Magnetic fields, radiation, particles and matter which have been ejected from the Sun can interact with the Earth's magnetic field and upper atmosphere to produce a variety of effects

EFFECTS OF IONOSPHERE AND SPACE WEATHER



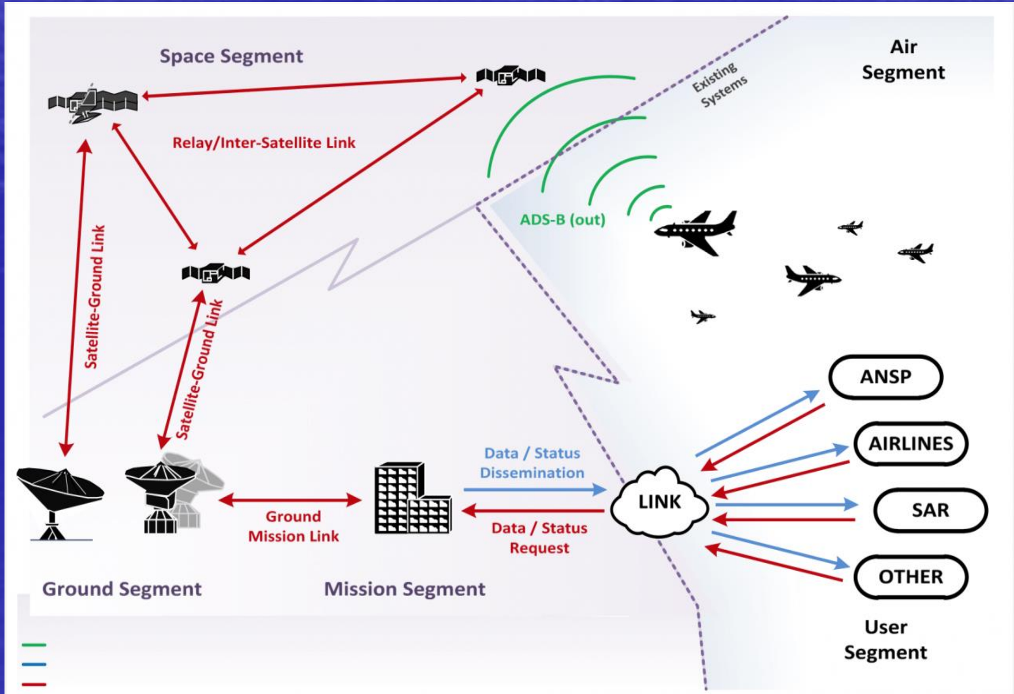
ICAO CONCEPT FOR GNSS

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. (Ref. ICAO Annex 10, Vol. I).

There are four essential criteria: i) Accuracy, ii) Integrity, iii) Continuity, and iv) Availability, in correspondence with the new PBN (RNAV/RNP) procedure which permits flying direct routings, precise navigation capability and permits efficient operations in terrain constrained or congested airspace.

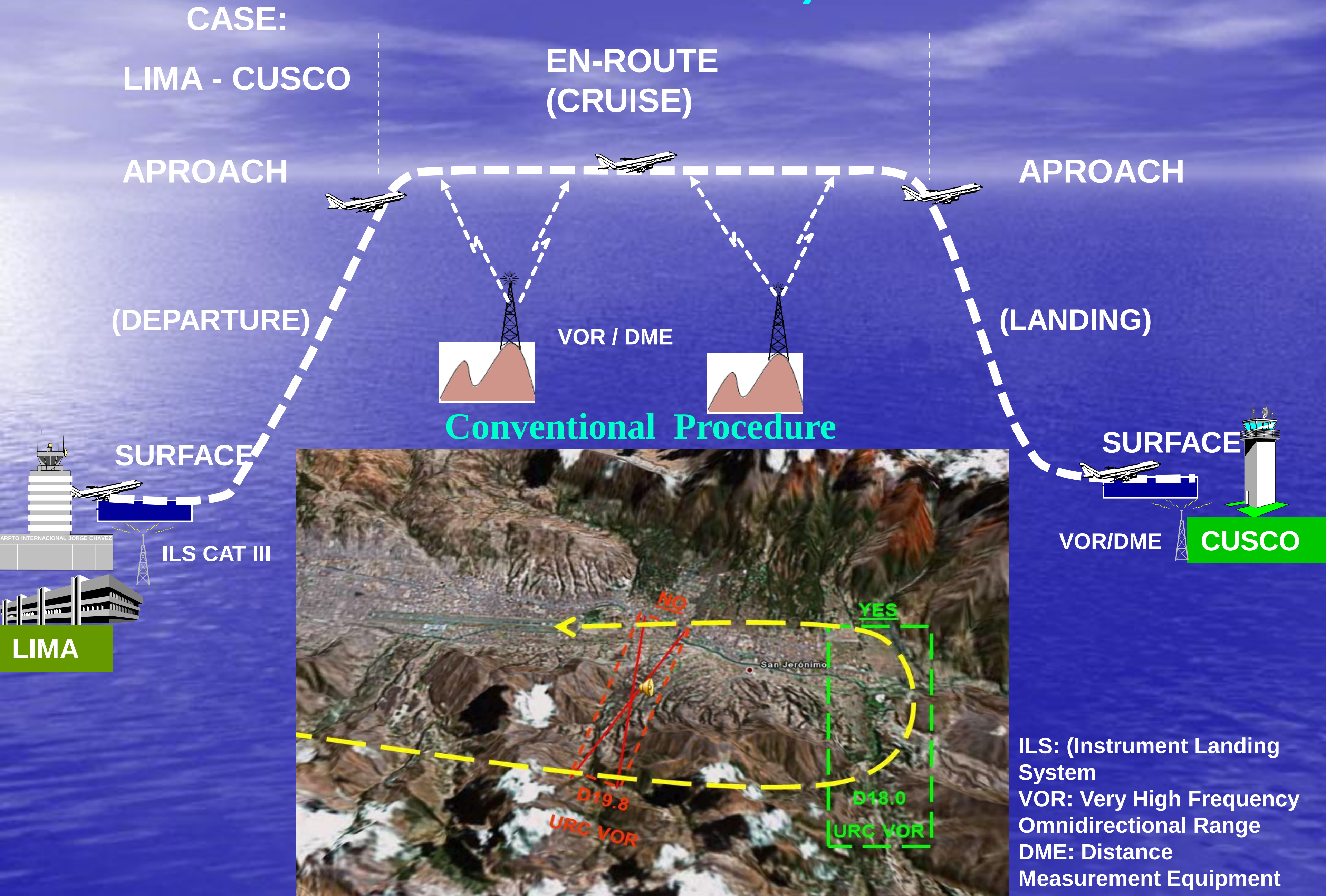
GNSS Segments:

1) Space: satellite constellations (GPS, GLONASS, GALILEO, BEIDOU)
2) Control: monitor, control and syncronization of satellites
3) Users: receivers, aircraft



There are Augmentation Systems like SBAS (Satellite) and GBAS (Ground), to improve performance of GNSS systems

EXAMPLE OF CURRENT NAVIGATION (BASED ON RADIO-AIDS)



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

GNSS SYSTEMS

ICAO Concept for GNSS

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GNSS Segments:

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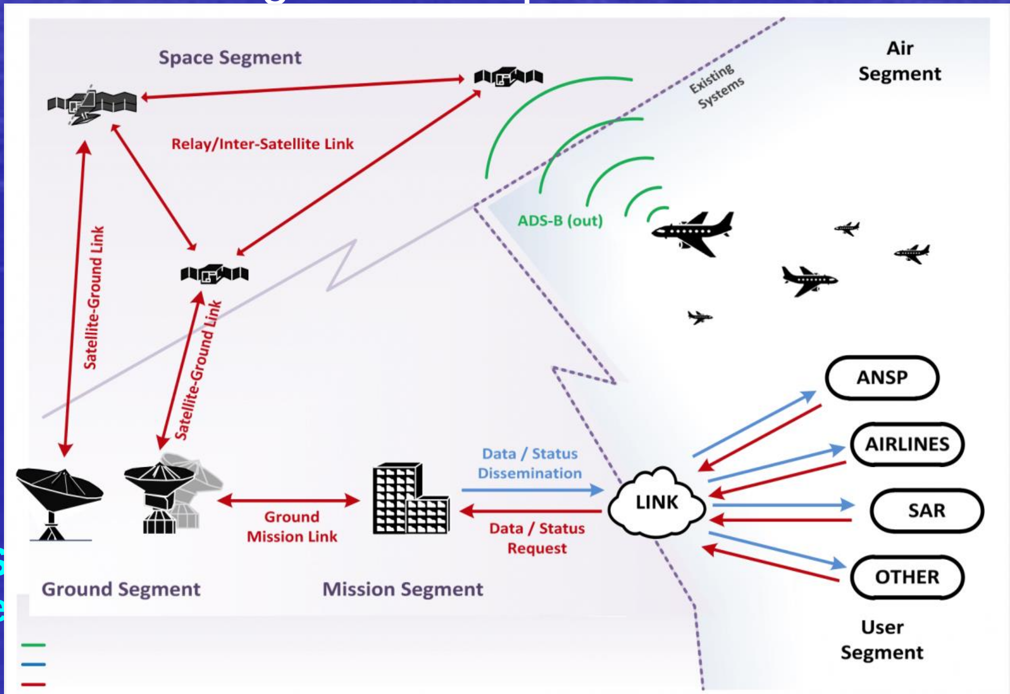
(GPS, GLONASS, GALILEO, BEIDOU)

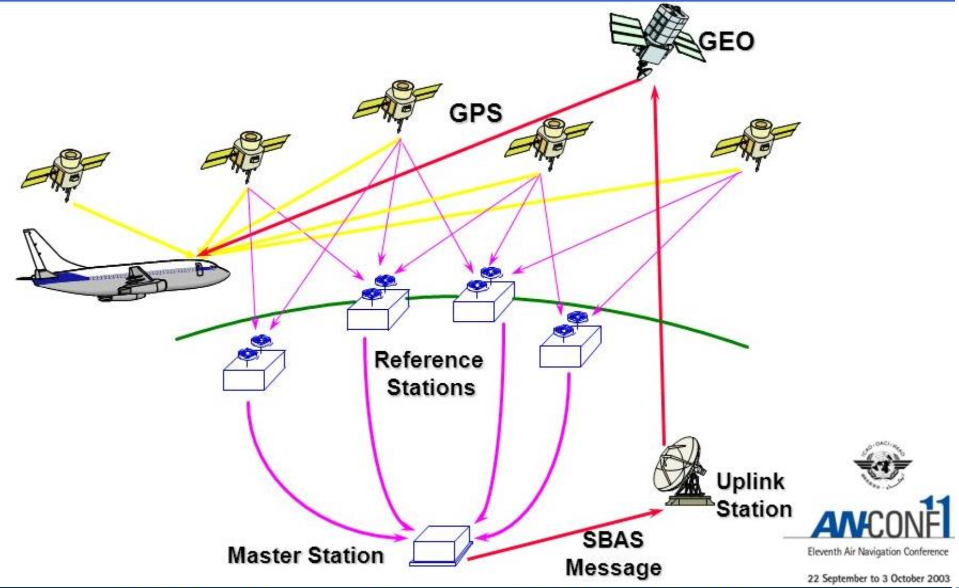
2) Ground: Control, monitor and syncronization of satellites

3) Users: receivers, aircraft

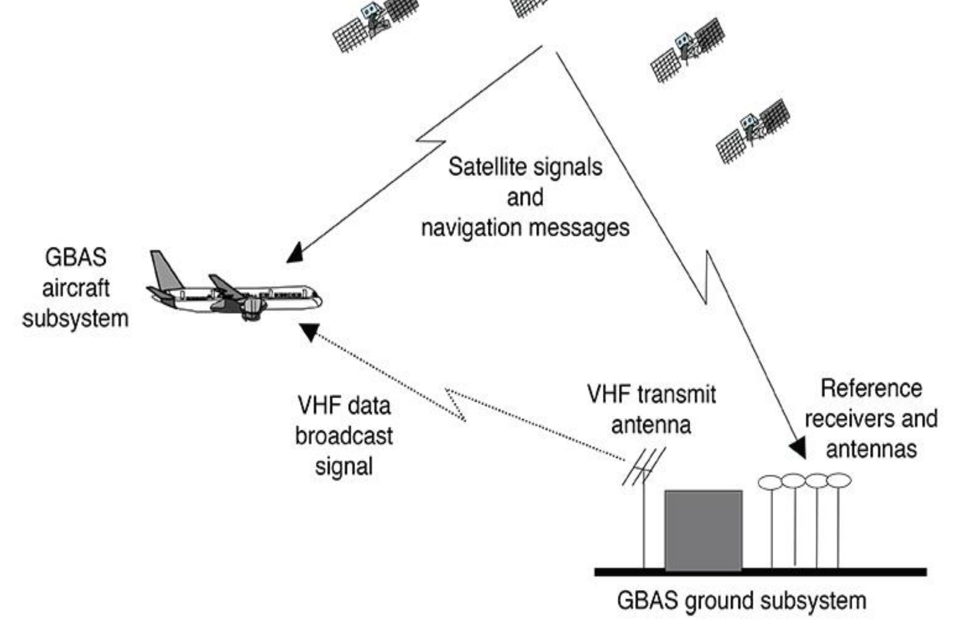


There are Augmentation Systems like SBAS (Satellite) and GBAS (Ground), to improve performance of GNSS systems

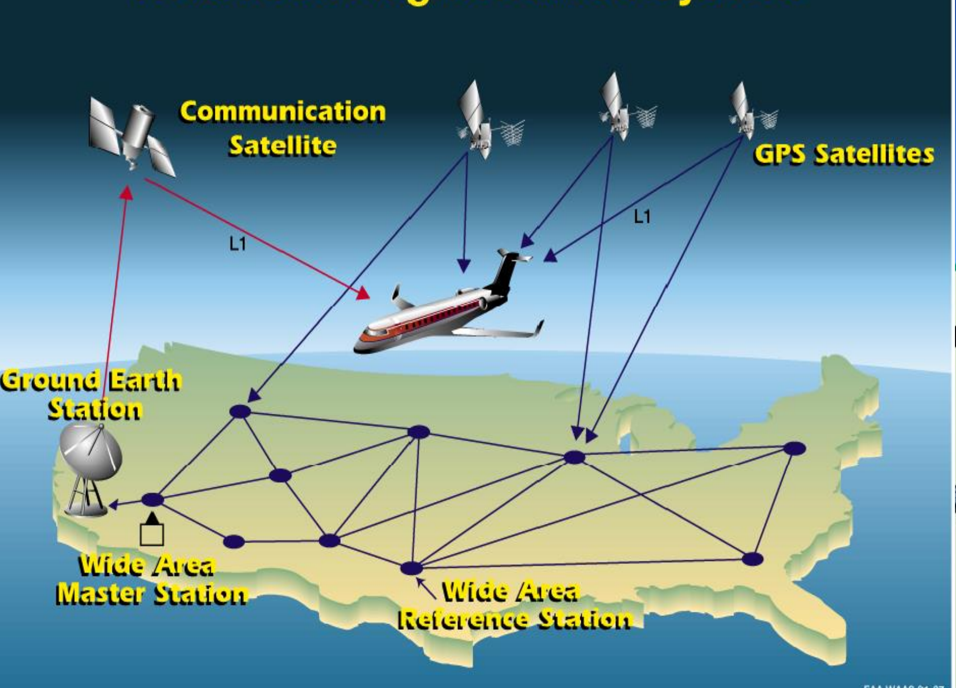
SBAS Architecture



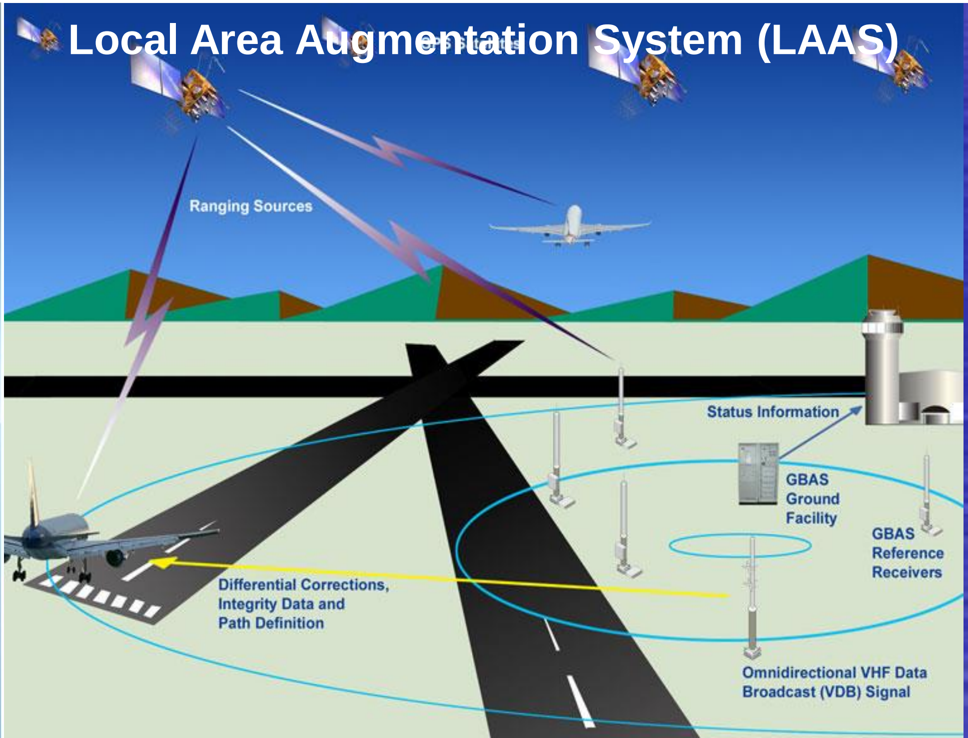
GBAS Architecture



Wide Area Augmentation System



Local Area Augmentation System (LAAS)



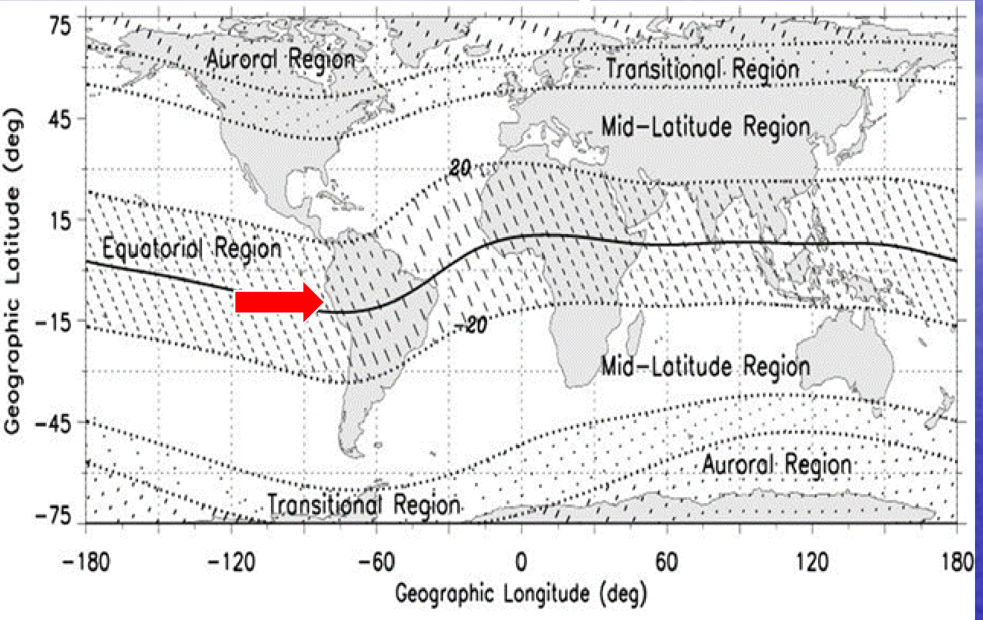
PBN: PERFORMANCE BASED NAVIGATION - RNAV/RNP

The PBN is a shift from sensor-based navigation to performance-based navigation(Doc 9613-AN / 937 "Manual Navigation Based Performance “) ICAO. There are two kinds of Navigation Specifications:

RNAV (Req. Area Navigation): It is based on area navigation that does not include the requirement for monitoring and alerting board performance, e.g RNAV 5, RNAV 1.

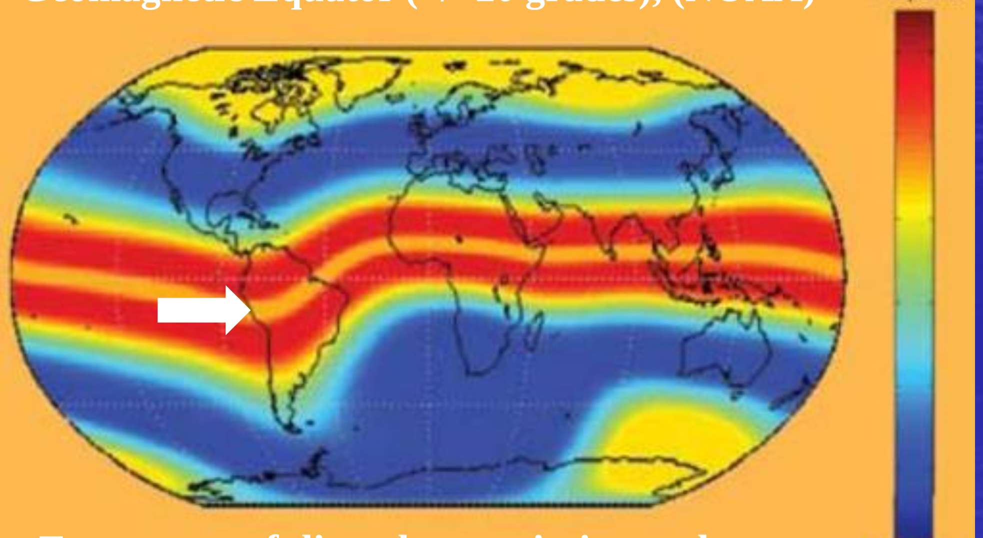
RNP (Req. Navigation Performance): It is based on area navigation that includes the requirement for monitoring and alerting board performance, e.g RNP 4, RNP APCH.

SPACE WEATHER EFFECTS ON GNSS IN LOW LATITUDE (EQUAT. REGION) - PROPOSALS



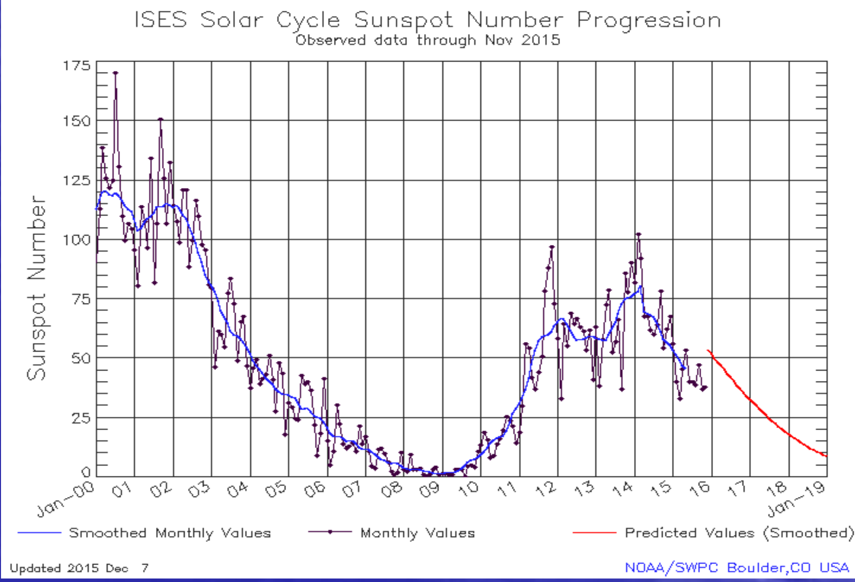
Lima-Peru is the Geomagnetic Equator in Southamerica Region (low latitude), that is why the airports at this Region have an intense ionosphere activity, as well as countries located between 20° N and 20° S (aprox) from the geomagnetic Equator, especially during periods of maximum solar activity (Panama is at the border)

Geomagnétic Equator (+/- 20 grades), (NOAA)



Frequency of disturbances in ionosphere

THE SOLAR CYCLE



- At the end of 2013 and 2014 it was the maximum solar cycle Nr 24. Next cycle would be in 2025

(…) SCINTILLATIONS AND TEC EFFECTS OVER AIR NAVIGATION SYSTEMS (GNSS)

Principal impacts of ionospheric scintillation on GPS performance:

- Loss of lock / outages
- Induced ranging errors

Consequences of these effects on GPS positioning accuracy depends on constellation geometry

For example, losing multiple satellites in the same region of the sky can lead to large errors

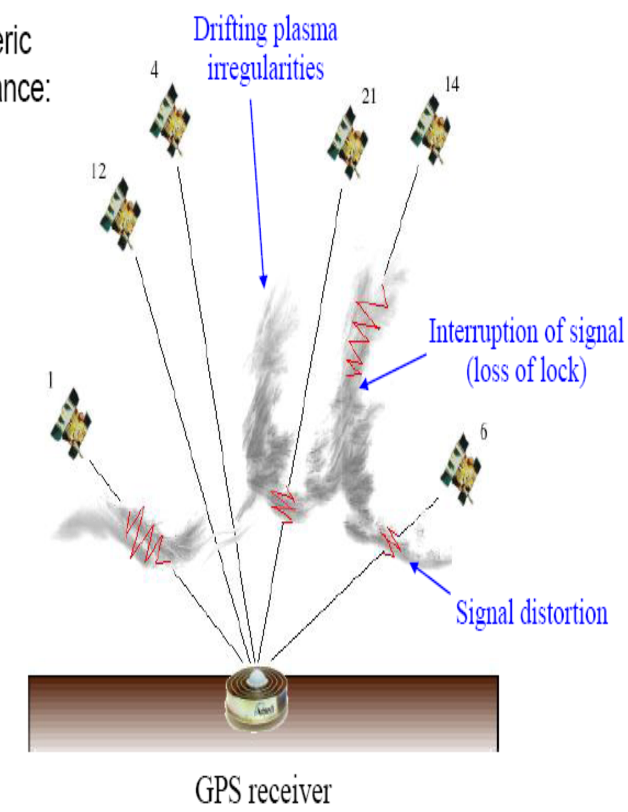
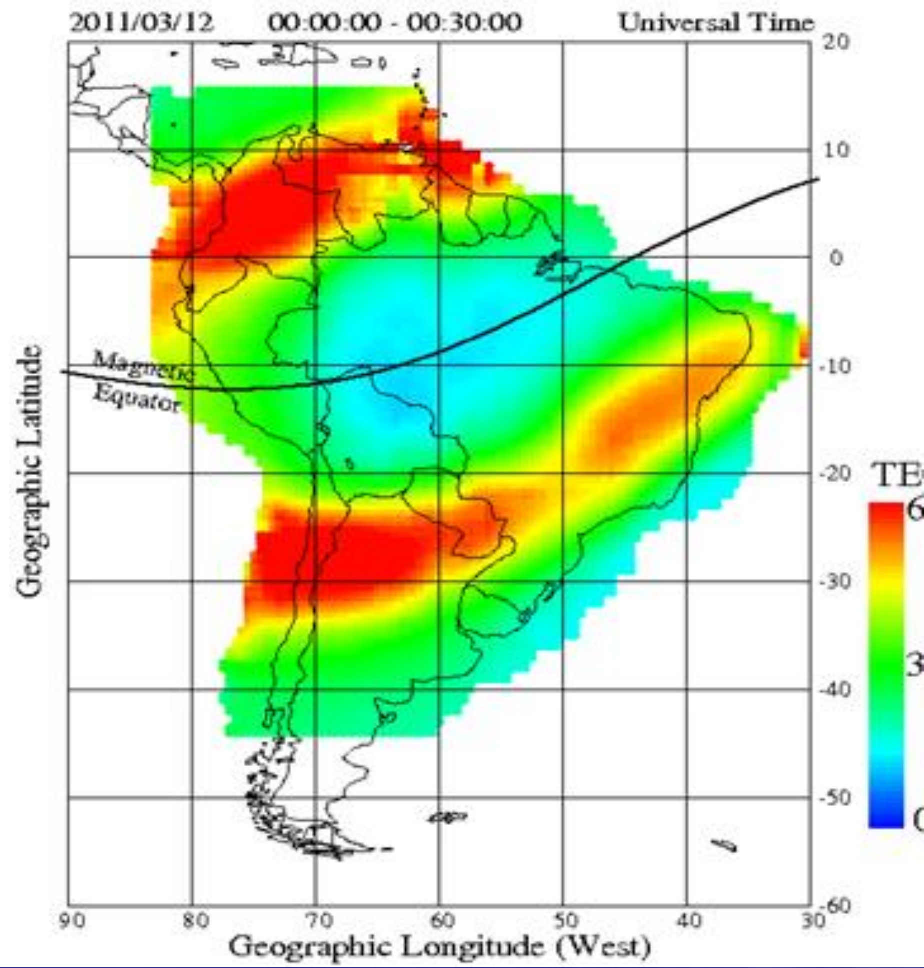


Figure Courtesy of C. Carrano, BC



Scintillations generate fading over GNSS signals

TEC generates delays, measurements made by LISN (Low-latitude Ionosphere Sensor Network) – Courtesy of Boston College

Proposals

1) Test Bed SBAS/WAAS/GPS - Regional Project RLA/00/009 (ICAO – FAA)

The main objective was to develop a plan of test bed (trials) and evaluation of the technical and operational benefits of SBAS Augmentation System/GNSS based on GPS / WAAS for CAR/SAM

The GPS receivers used the L1 and L2 frequencies

Results of Project RLA/00/009:

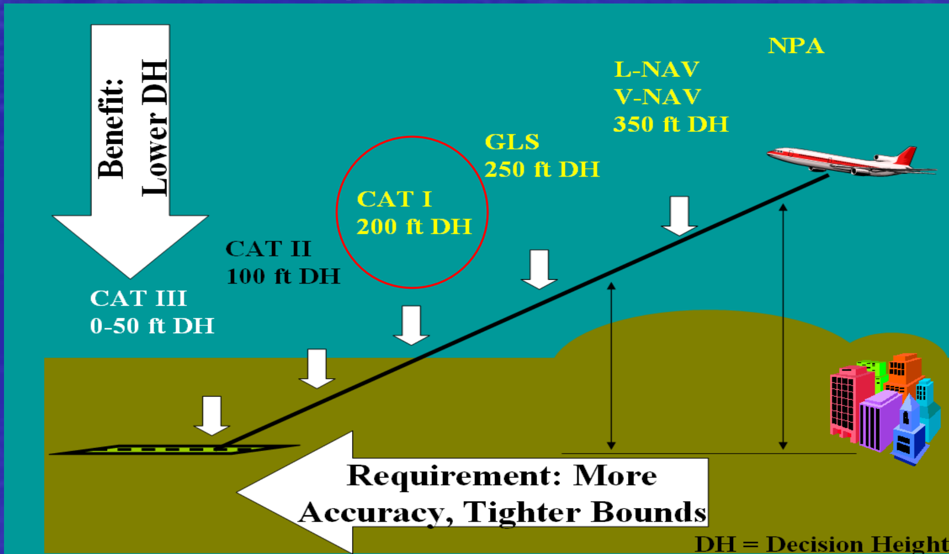
- The Scintillation generated lost of messages and data in collection stations

- Lack of an algorithm more robust to interference or ionospheric scintillation , especially in the equatorial region (low latitude)

- It may also be considered as an aspect of risk in the development of SBAS systems for procedures of accuracy or vertical guidance.

Reference: Results of ionosphere impact evaluation on GBAS operation in Brazil (Published in SAM/IG/15-20)

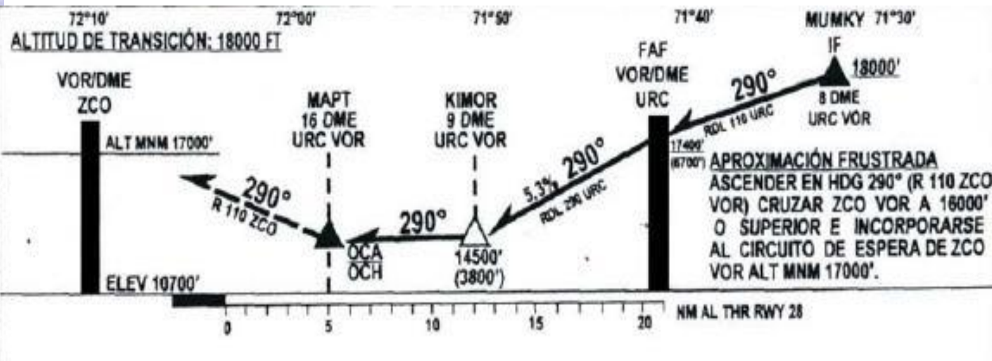
-GBAS system, in accordance with ICAO Annex 10, Volume 1, allows performing precision approach Category I with increasing values of GPS signals accuracy and integrity.
-The purpose of the evaluation was to study the impact of the ionosphere on the operation of the SLS-4000 station (Rio de Janeiro – Southamerica region) during solar cycle 24 by using a mid-latitude ionosphere threat model. Software is in process of updating/test
-As result of the ionosphere impact evaluation on GBAS (operations in Brazil) : It was concluded that the mid-latitude ionosphere threat model is not directly applicable to low latitudes like Equatorial Region
-Like the mentioned Regional Project RLA/00/009, the receivers used the L1/L2 GPS frequencies.



Using this model, the most critical situation for GBAS operation would be an aircraft on approach (landing) receiving wrong correction from the ground station caused by different ionosphere delay received by aircraft and ground station

EXAMPLE OF PERUVIAN EXPERIENCE:

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

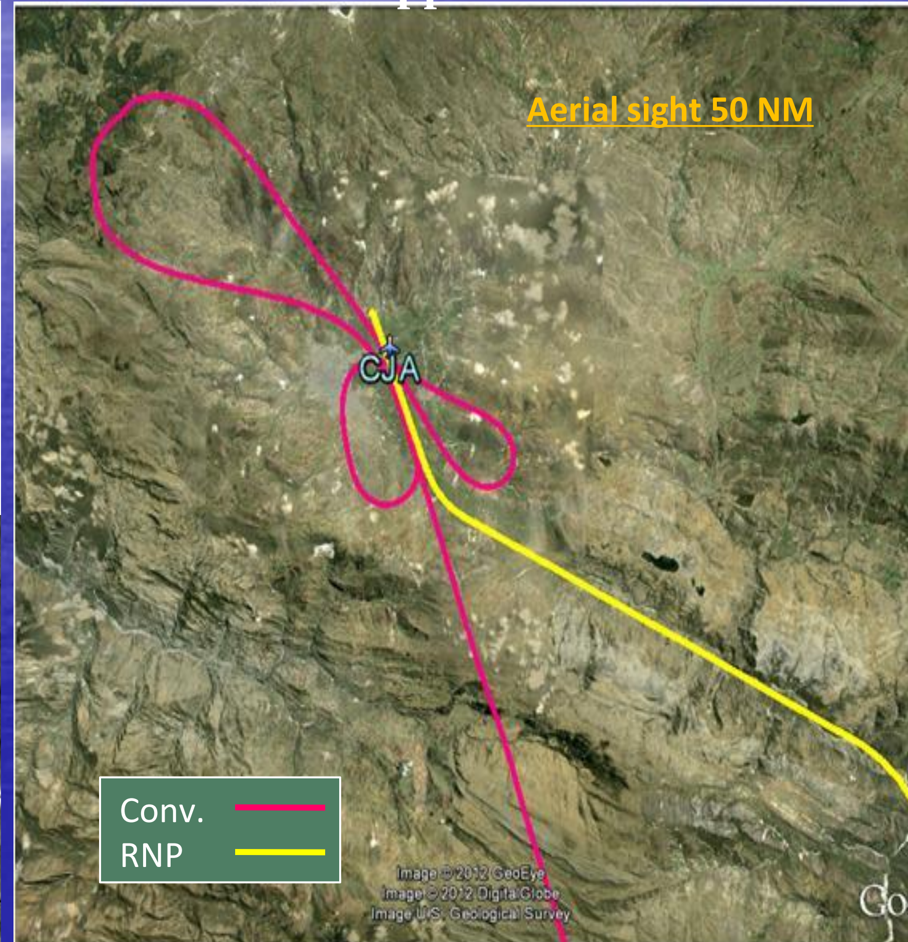


OCA / H	A - B - C - D	MÍNIMOS DE UTILIZACIÓN DEL AD
EN CIRCUITO RWY 28	14500' (3800')	TECHO DE NUBES: 1200 M VISIBILIDAD : 8 KM

Elevation: 10745 ft.
Minimum approach (DA 14500', visibility required 8Km) often higher than actual weather conditions.

Caxamarca Airport

Shorter Flight distance/Best minimum of approach



Saving per flight			
Distance	Time	Fuel	CO2
34.8 nm	**11.6 min**	**375.9 gal**	**1186 kg**

SBAS O GBAS SYSTEM FOR SOUTHAMERICAN REGION?

-Equatorial region (Low Latitude) is hostile for the GNSS signals, requires more investigation.
-Less air traffic in Southamerica than Northamerica (Medium Latitude) .
-Brazil is doing the study and testing of a national GBAS Augmentation system, which could be a model extended for the South America Region .
-Continuos study of the scintillation in more detail as the main constraint on the use of two frequencies (L1 and L5) for vertical guidance.
-The scintillation can seriously affect the continuity and availability of GNSS.
-Cost - benefit analysis

Regional VSAT Network - REDDIG

(PANAMSAT)
PAS 1R/ (IS-14, INTELSAT)

- In service from September 2003 for fixed communications
- For international links: ATS voice and aeronautical messagging AMHS/AFTN
- Administered by ICAO: Regional Project RLA/03/901 "Sistema de Gestión de la REDDIG y Administración del Segmento Satelital"
- Capacity for transmiting Radar and GNSS data

-In 2016 it will be installed Node Nr. 17 in Brazil

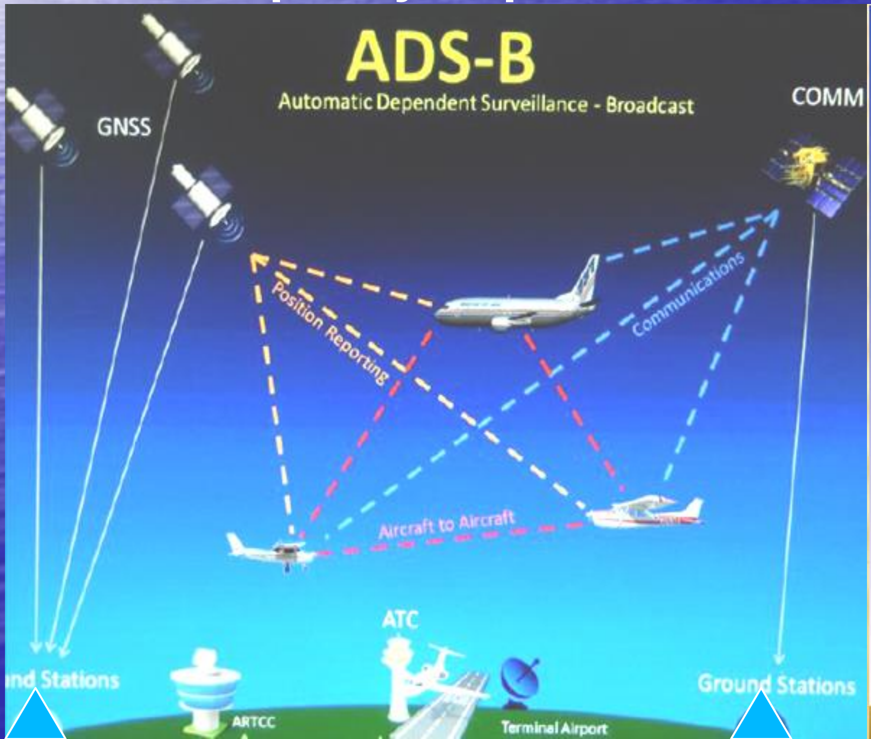
-VSAT Network used by ICAO and SAM States for supporting the CNS/ATM Systems.

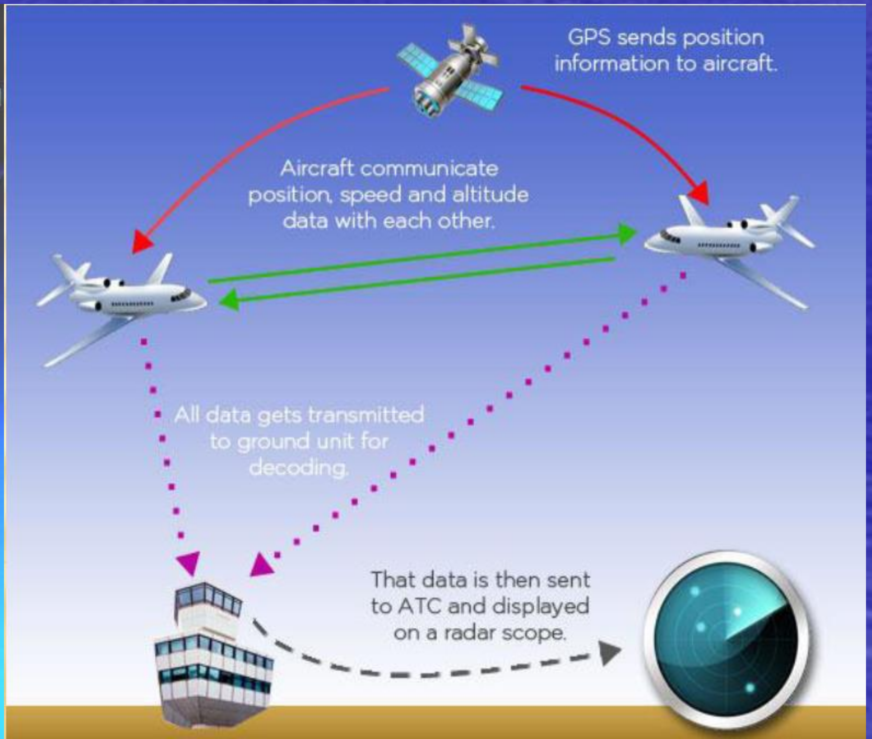
Backup Link: Public ISDN and IP Network

ADS SYSTEM - Automatic Dependent Surveillance by Satellite

It is broadcasting the position (latitude and longitude), altitude, speed, aircraft identification and other information obtained from the onboard systems. Because their coverage is satellite (GNSS), the ADS nicely complements the current radar information (ground) giving coverage to remote areas, low flight level and oceanic areas, which is integrated with the radar data.

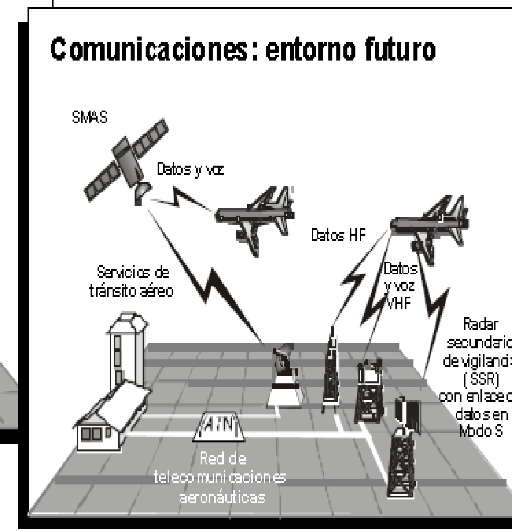
There is currently 1090 ADS-B technology that works in S Mode format and with capacity to provide information for air traffic control.

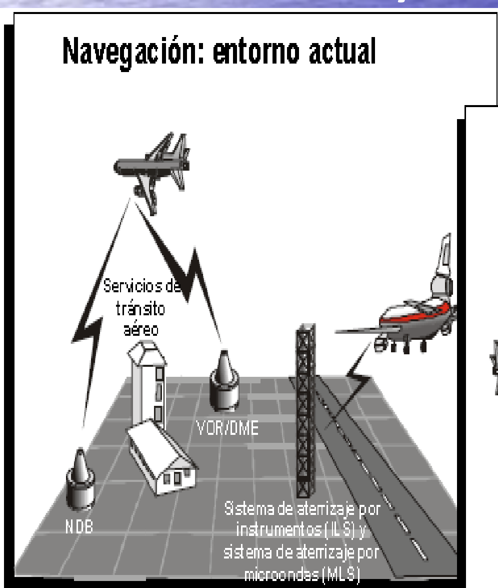


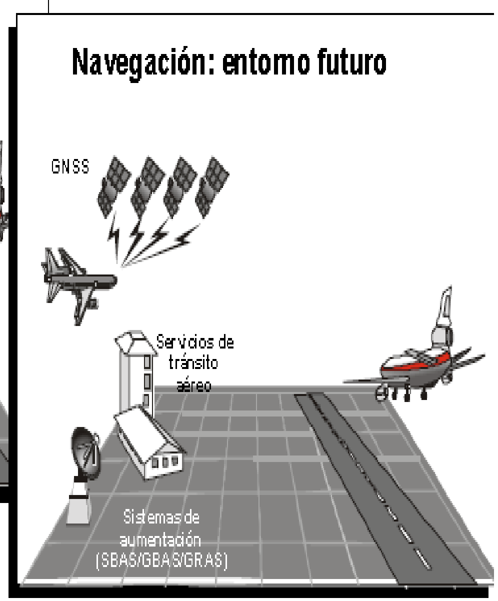


CONCLUSIONS

-There are benefits (VSAT, GBAS, ADS) for air navigation around the world, by using the satellite tecnology in accordance with ICAO recommendations.
-Most countries in South America would have to base their national airspace on GNSS/GBAS and/or SBAS
-Development of a valid Ionosphere Threat Model for Low Latitudes (Equatorial region) is key to GBAS for the national or regional aviation community.



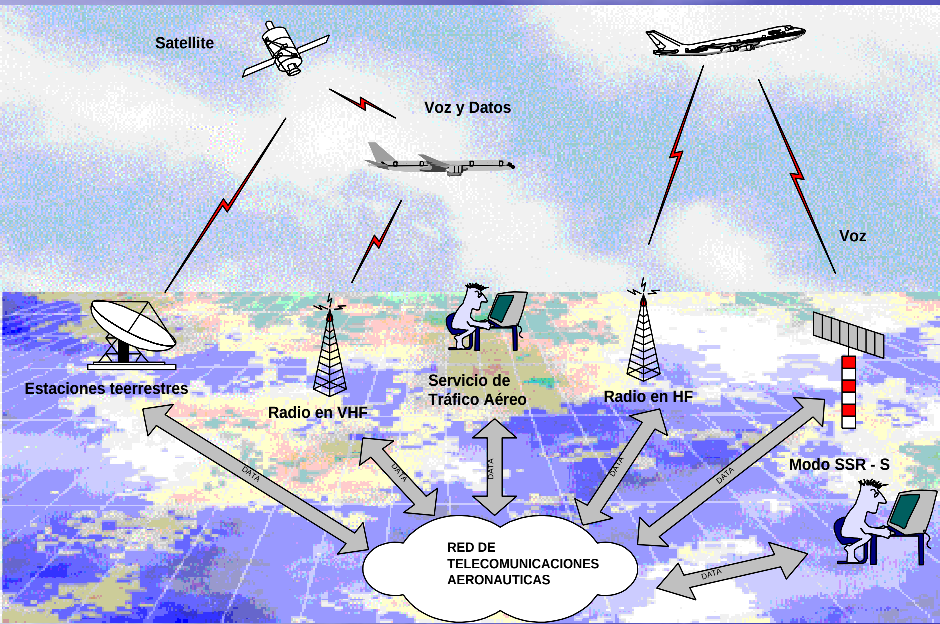


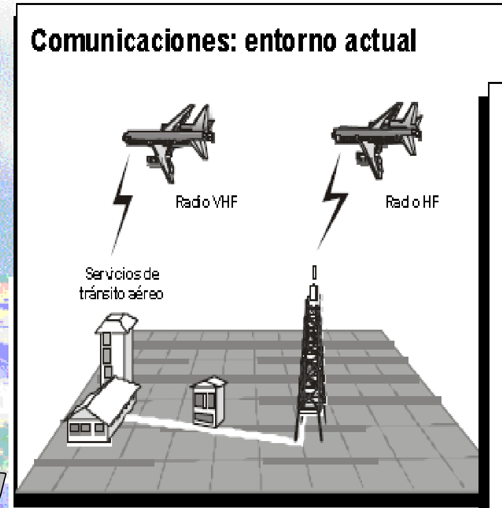


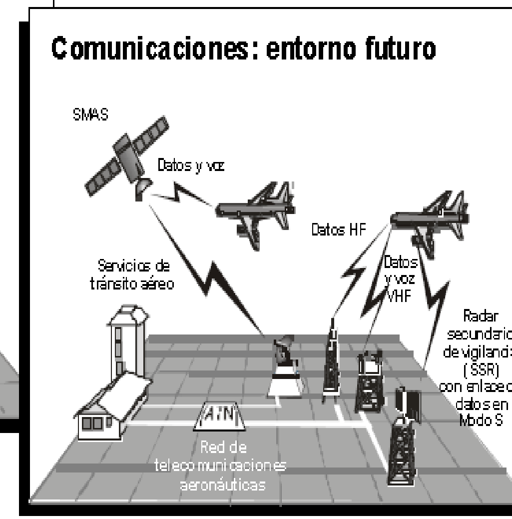
REMARKS

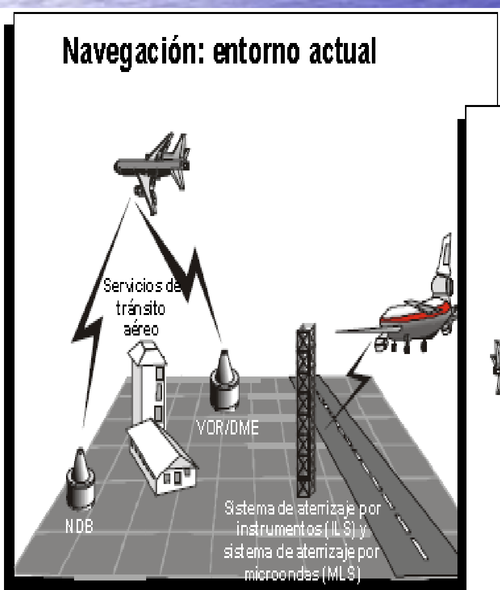
- No SBAS and GBAS operation in CAR/SAM Regions, No infrastructure deployed in these Regions
- Ionospheric effects over the GNSS signals (Low Latitude)
- Need of strategy analysis to identify SBAS/GBAS implementation.
- Opportunity: Aircraft would be equipped with SBAS/GBAS capability
- For example in Peru, use of GNSS is currently limited to supplemental navigation of "No-Precision" like GPS/RAIM on board and it is not enough.
- Space Weather effects happen in the Ionosphere between 50 to 600 Km aprox.

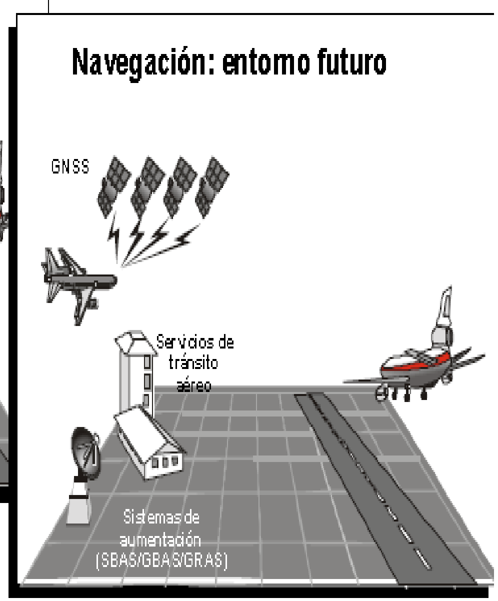
CONCLUSIONES











CONCLUSIONES

1. Esta presentación trató sobre la importancia de la tecnología satelital en los servicios de aeronavegación a nivel internacional tales como Redes VSAT, Sistemas de Navegación Global (Global Navigation Satellite System - GNSS) y la Vigilancia Dependiente Automática (Automatic Dependent Surveillance - ADS) que se han convertido en pilares del Tráfico Aéreo.
2. Se han visto los potenciales beneficios para la aviación civil en las Regiónes CAR/SAM), del uso de la tecnología satelital para los sistemas de navegación aérea.

THANK YOU!!

Note: The opinions expressed here are solely those of the author