The Use of Satellite Technology in Air Navigation Services

Jorge García Villalobos

CORPAC S.A.
International Airport "Jorge Chávez"
Callao, Lima – Perú

jgarcia@corpac.gob.pe

ICG EXPERTS MEETING: GLOBAL NAVIGATION SATELLITE SYSTEMS SERVICES 15 - 18 December 2015
Vienna, Austria

Sources courtesy of: CORPAC/ICAO/ITU/BOSTON COLLEGE/FAA/DECEA/NOOA

AGENDA

I. INTRODUCTION

II. VSAT NETWORK

III. GNSS SYSTEM

IV. IONOSPHERE EFFECTS OVER GNSS (IN SAM REGION) AND PROPOSALS

V. ADS-B SYSTEMS

VI. CONCLUSIONS

I. INTRODUCTION

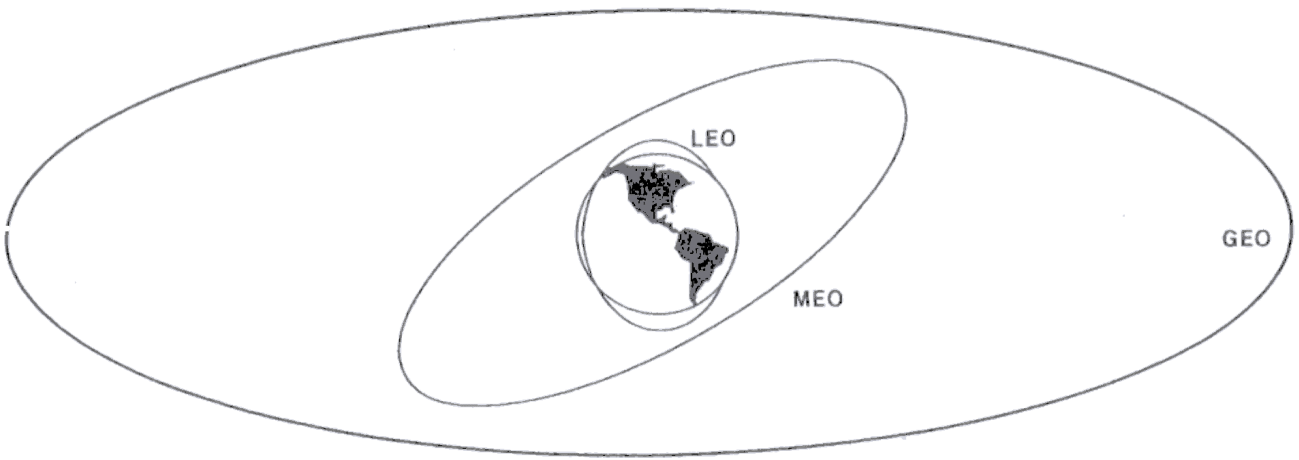
SATELLITE SYSTEMS

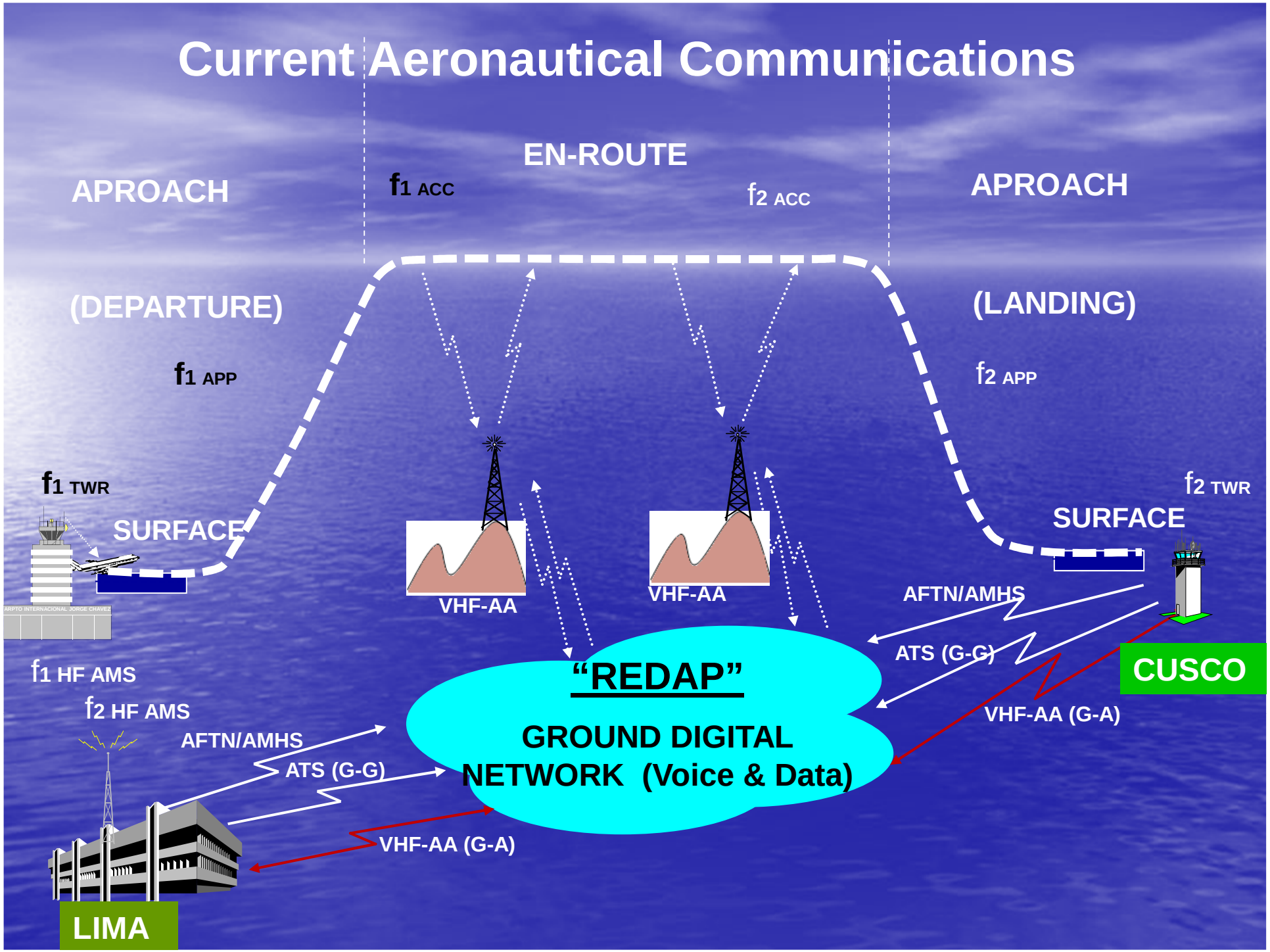
Radio links between mobile or ground stations through active and passive relays located in orbit around the Earth.

TYPE OF ORBIT

- Low Earth Orbit (LEO): Mobile Communications
- Medium Earth Orbit (MEO): GNSS: GPS, GLONASS, GALILEO
- GeoEstationary Orbit (GEO): Commercial Systems - VSAT

Period	Radio [km]	Orbital Altitude [km]	Satellite Speed [km/s]	Orbit / Band
2 h 7’	8.378	2.000	6,89	LEO / L, Ka
13 h 21’	28.378	20.000	3,75	MEO / L
23 h 56’	42.164	35.786	3,07	GEO / C, Ku




Current Aeronautical Communications
EN-ROUTE
APROACH
f1 ACC
f2 ACC
APROACH
(DEPARTURE)
(LANDING)
f1 APP
f2 APP
f1 TWR
SURFACE
f2 TWR
SURFACE
VHF-AA
VHF-AA
AFTN/AMHS
ATS (G-G)
CUSCO
f1 HF AMS
f2 HF AMS
AFTN/AMHS
ATS (G-G)
VHF-AA (G-A)
"REDAP"
GROUND DIGITAL
NETWORK (Voice & Data)
VHF-AA (G-A)
LIMA

II. VSAT NETWORK (COMMUNICATIONS)

2.1 DOMESTIC NETWORK

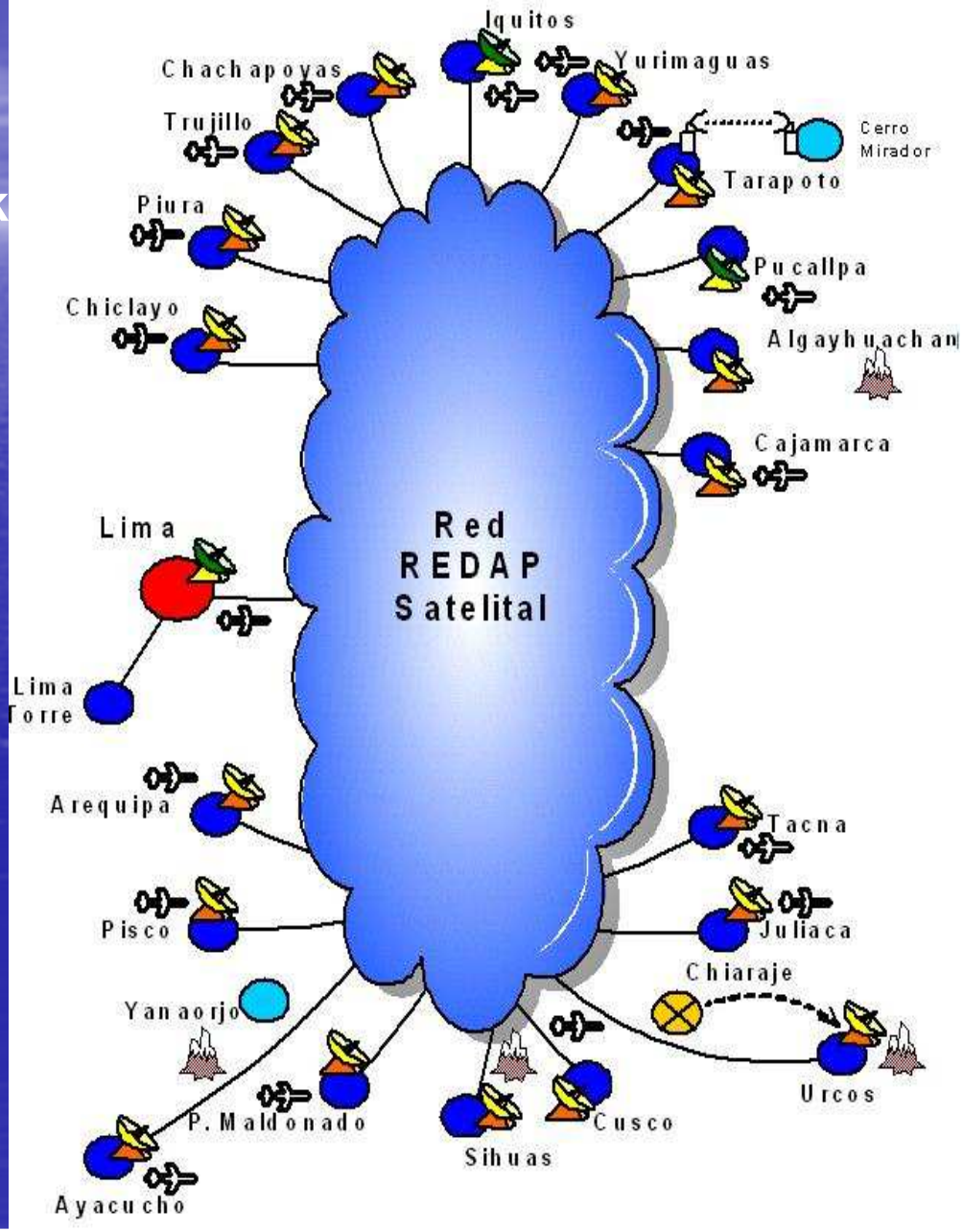
a) Phase 1: Radar Data (Since 2012)

- 7 Remote Sites + Lima (Control Center)
  - ➢ VSAT Node where a Radar System is installed
  - ➢ Use of previous ground network REDAP as Backup
- Main Service of VSAT Nodes: Radar Data
  - ➢ Full Redundancy
  - ➢ Clear Channel link
  - ➢ IP Addressing
  - ➢ Hubless
  - ➢ C Band: 4GHz/6 GHz
  - ➢ Redundant NCC :
    Main in Lima & Backup in Iquitos

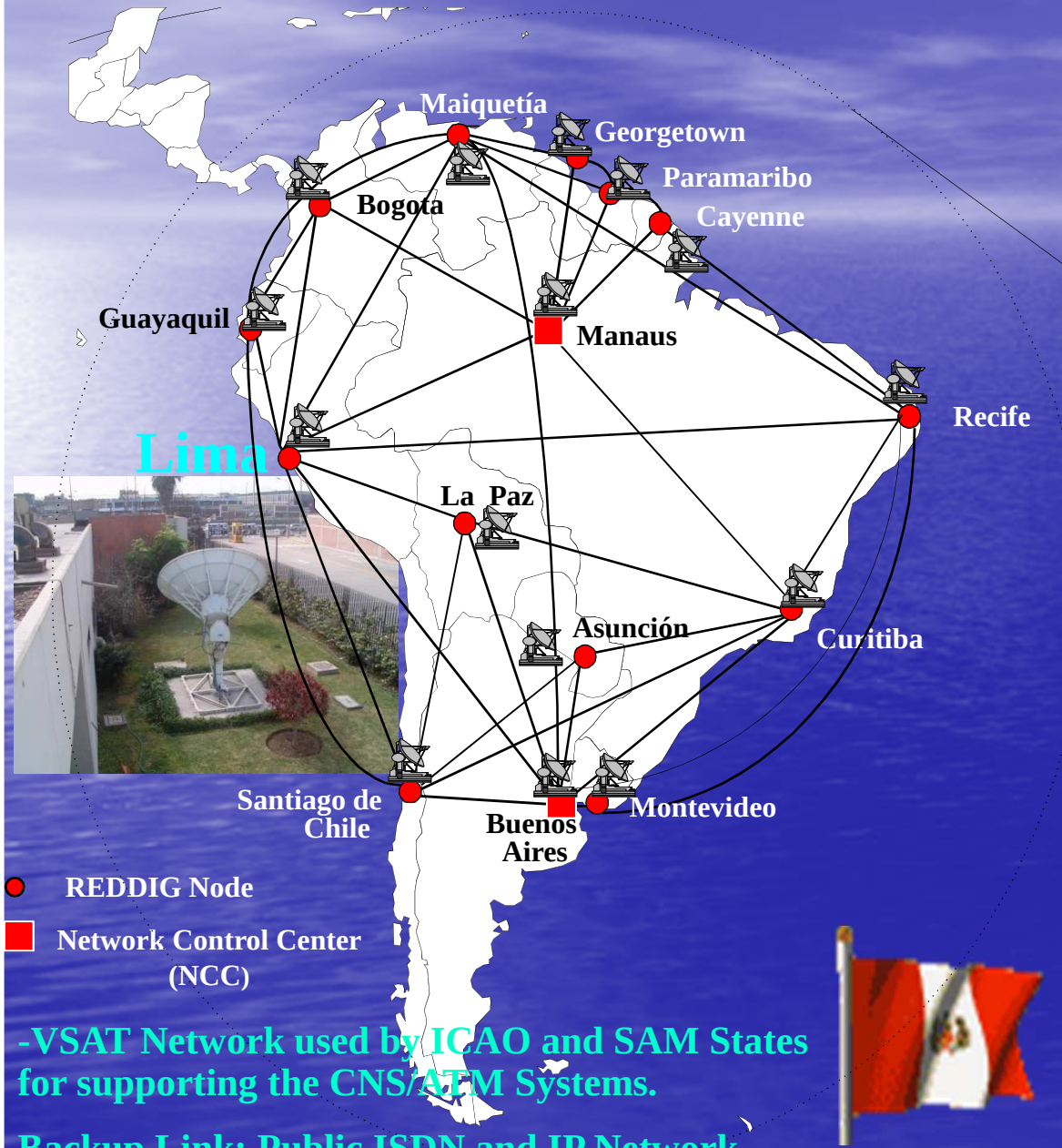
b) Phase 2: Network Migration (Since 2016)

Intelsat IS-14

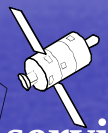
- 17 Remote Sites
  - ➢ Full Migration to Satellite network
- Integrates another services:
  - ➢VHF-AA Radio and ATS voice
  - ➢Data service: AMHS + GNSS/ADS



2.2 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

III. GNSS SYSTEMS

ICAO Concept for GNSS

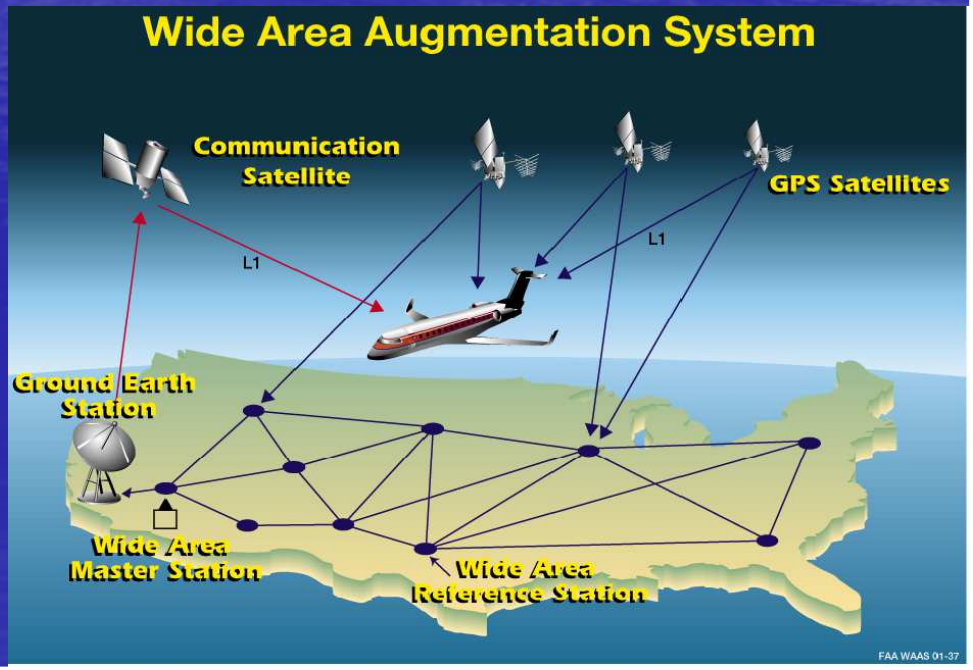
A worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented as necessary to support the required navigation performance for the intended operation. (Ref. ICAO Annex 10, Vol. I).

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.

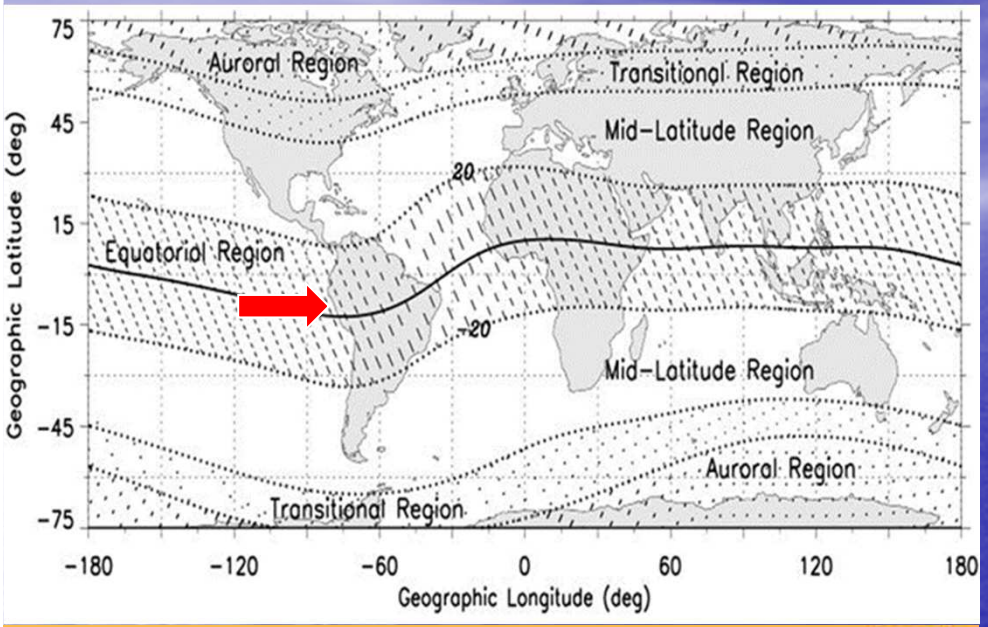
GNSS Segments:

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

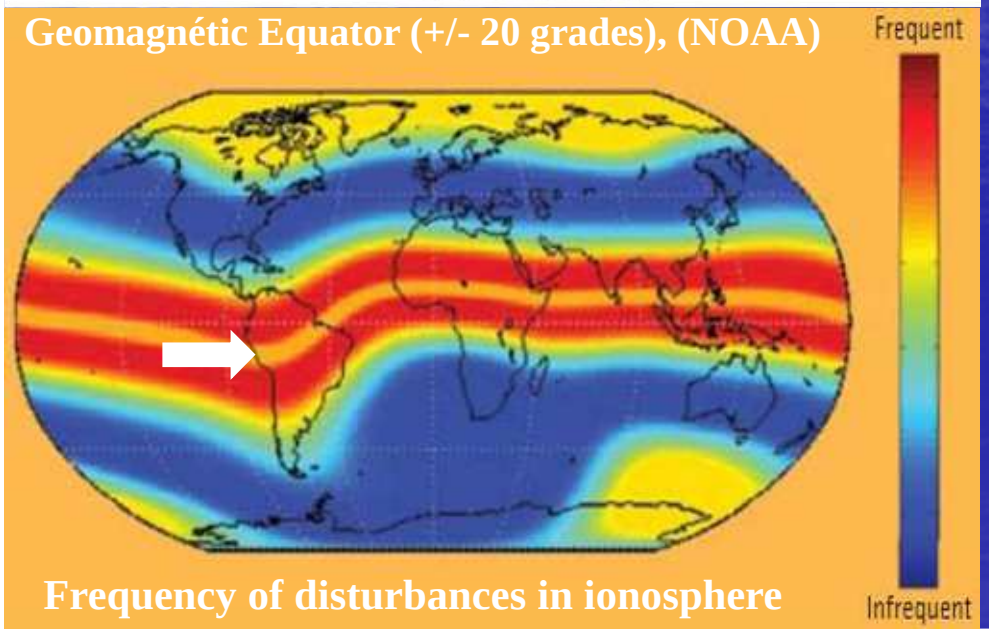
There are Augmentation Systems like SBAS (Satellite) and GBAS (Ground), to improve performance of GNSS systems



IV. IONOSPHERE EFFECTS OVER GNSS (IN SOUTHAMERICA REGION) AND PROPOSALS



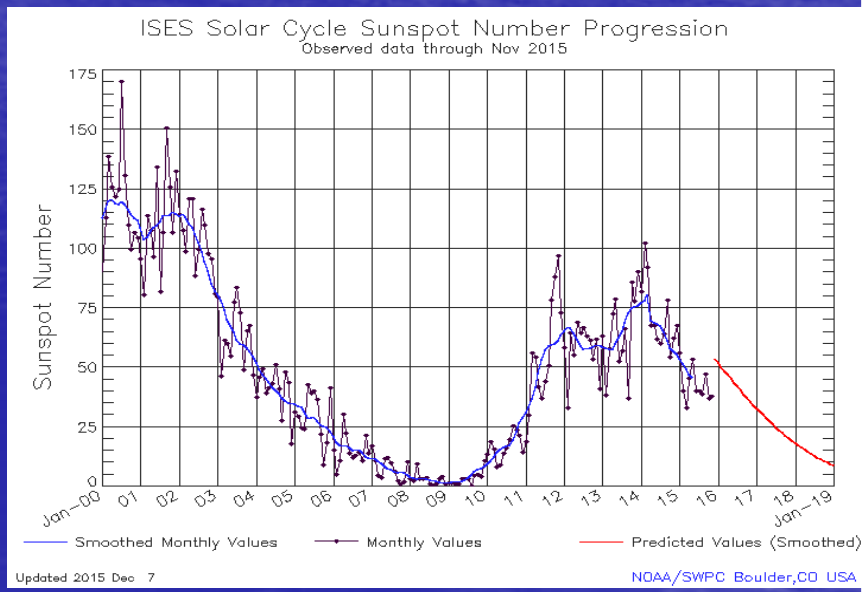
Geomagnétic Equator (+/- 20 grades), (NOAA)



Frequency of disturbances in ionosphere

Lima-Peru is the Geomagnetic Equator in Southamerica Region (low latitude), that is why the peruvian airports 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.

THE SOLAR CYCLE



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

IMPACTS DUE TO IONOSPHERE SCINTILLATIONS AND TEC OVER 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

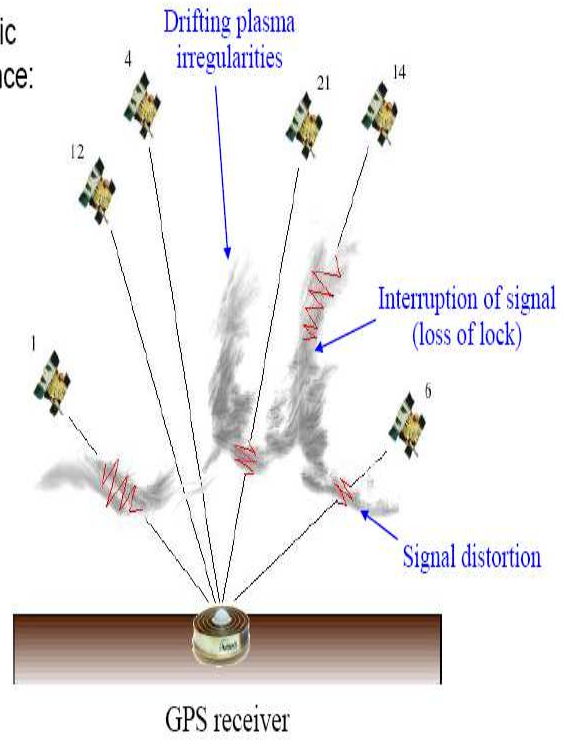
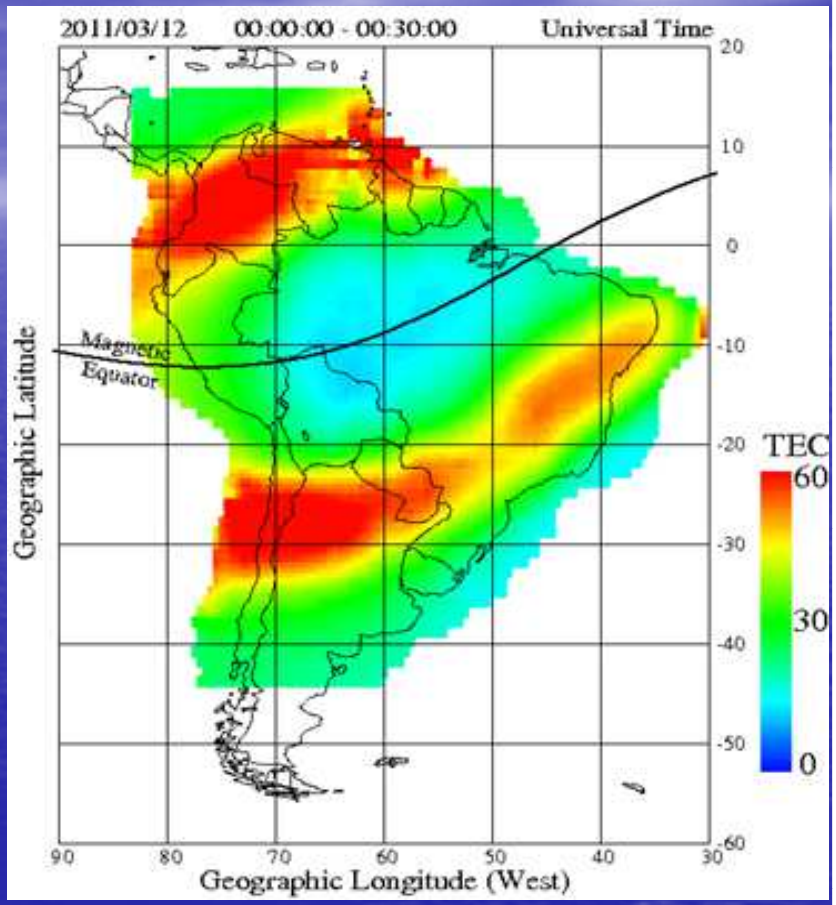


Figure Courtesy of C. Carrano, BC

Scintillations generate fading over GNSS signals



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

and (c) latitude

4.1 Proposals

A) 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

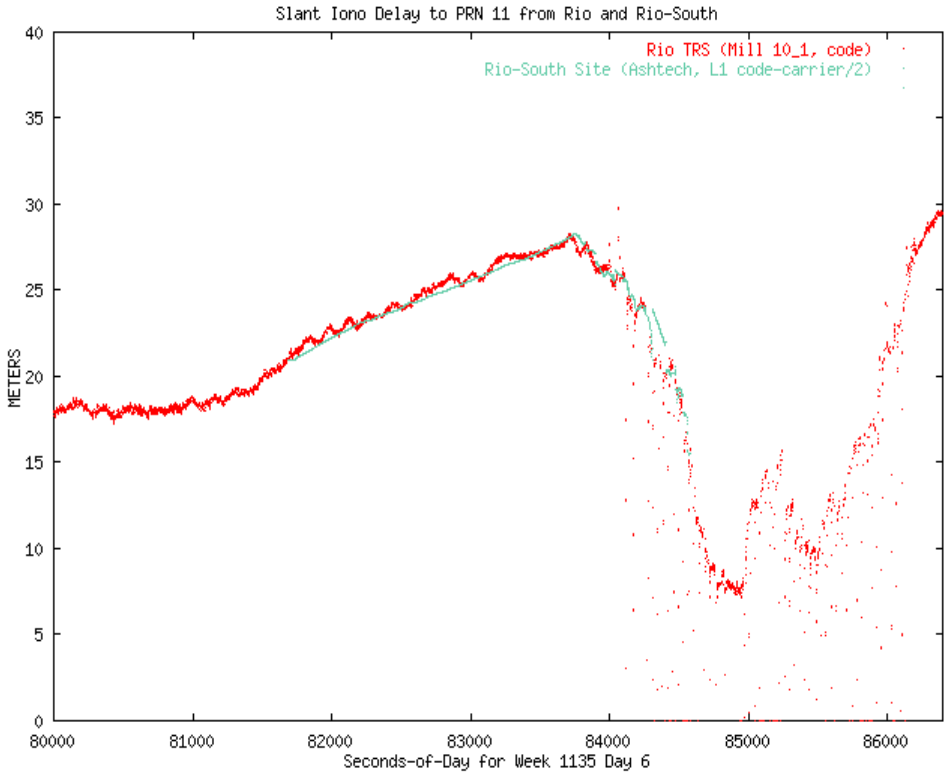
The GPS receivers used the L1 and L2 frequencies

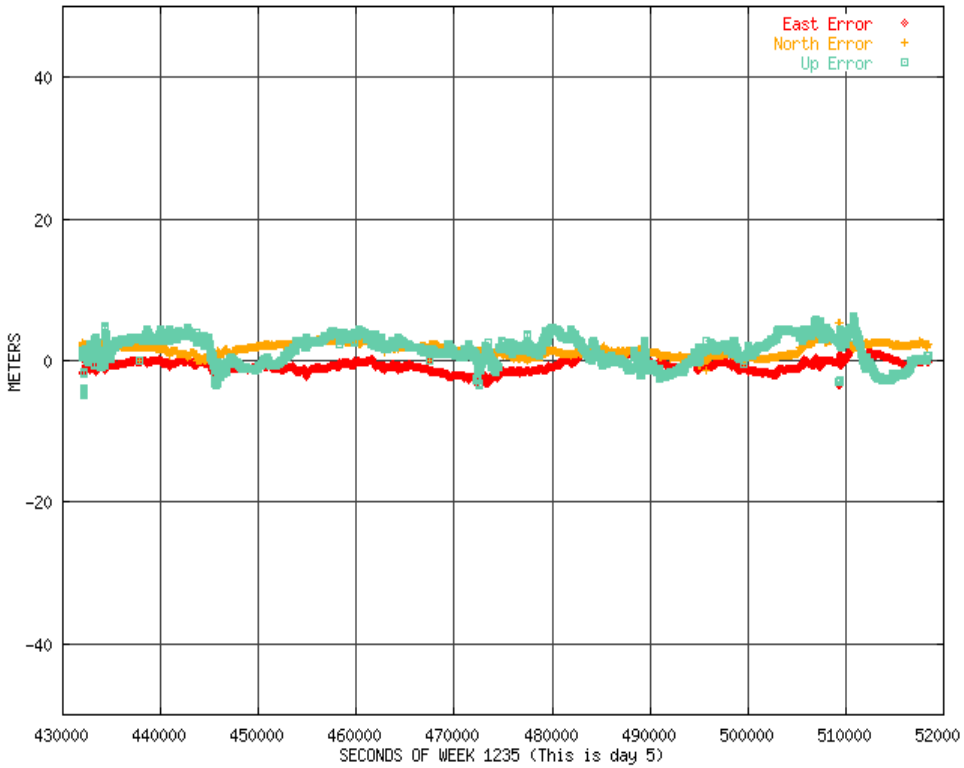
Estaciones Maestras de Ensayo (TMS):

- La estación TMS de Chile estaba conectada con las estaciones de Referencia TRS de Argentina, Chile, Perú y Bolivia.
- La estación TMS de Brasil estaba conectada con las estaciones TRS de Brasil, Colombia, y la de Centroamérica (Cocesna)

B) Results of Regional 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.





Ejemplo buble in Río de Janeiro

Horizontal and vertical error taken from GPS signal sample - Peru

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

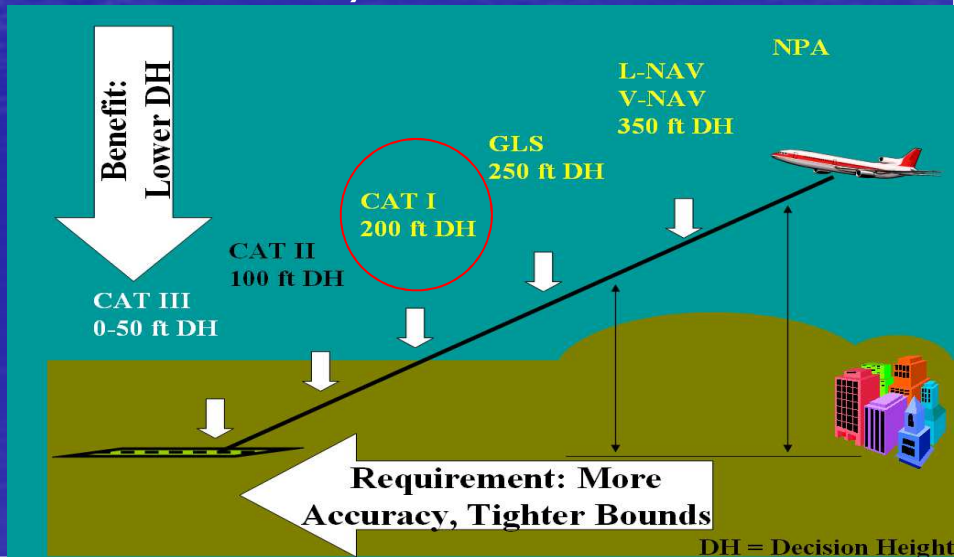
-GBAS system, in accordance with ICAO Annex 10, Volume 1, allows performing precision approach Category I with increasing values of GPS signals accuracy and integrity.

-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 .

-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



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

PERUVIAN EXPERIENCE:

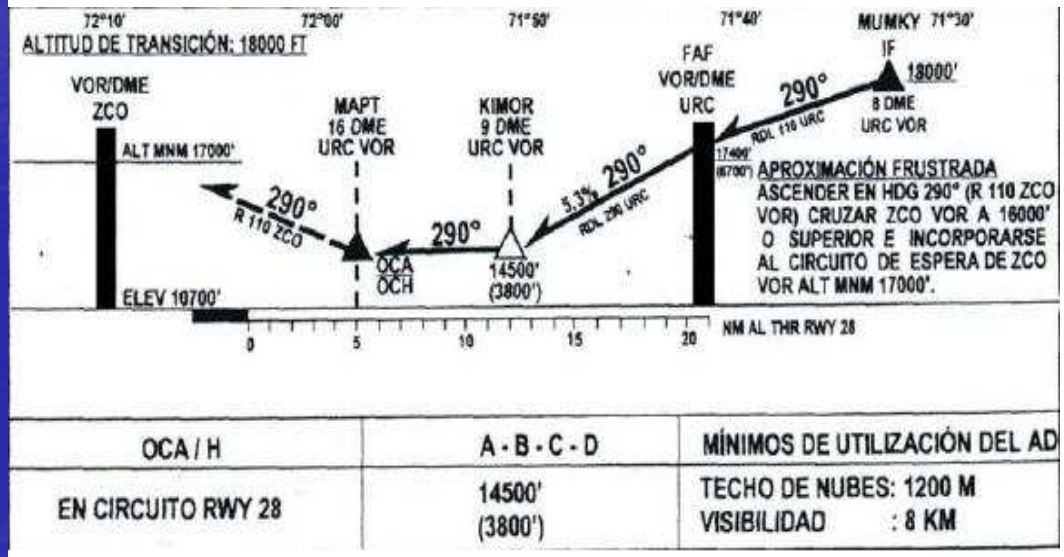
The first operational approach procedure based on GNSS and RNP Baro - VNAV information was authorized at the Cusco Airport in 2008

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.**

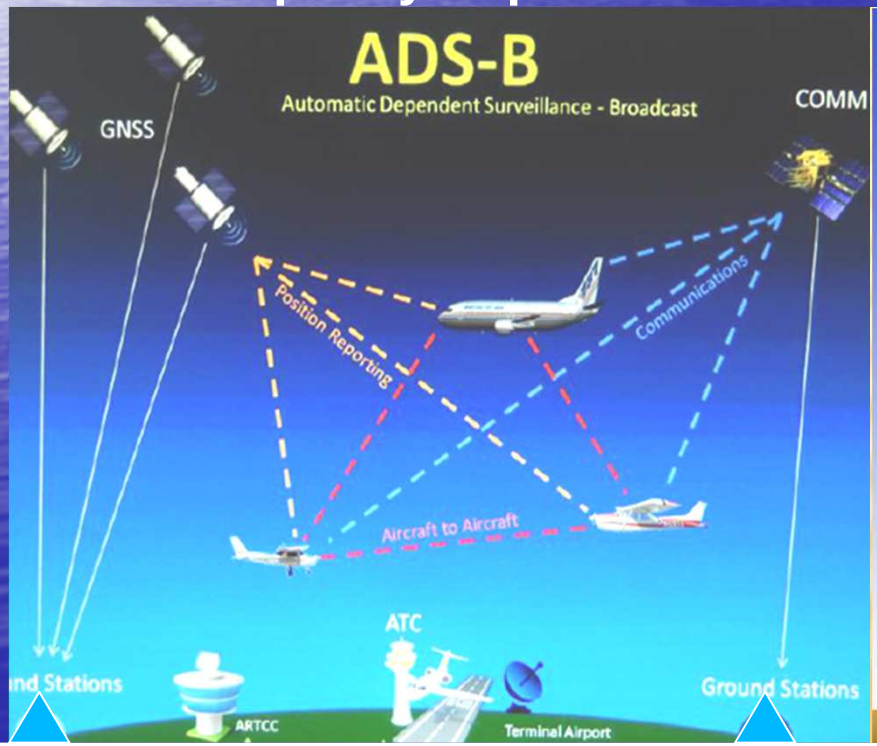


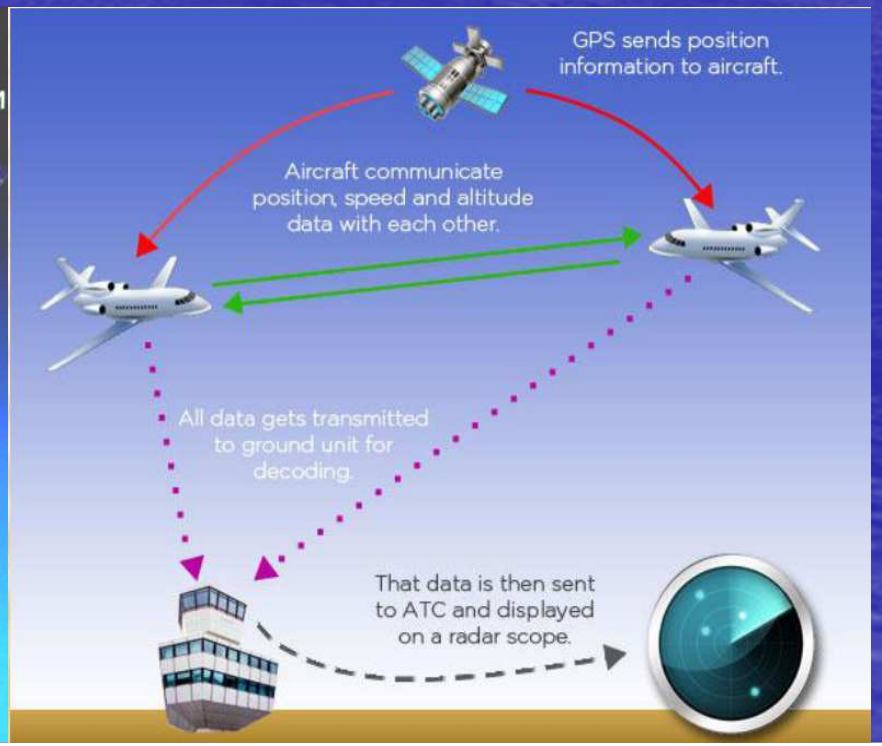
OCA / H	A - B - C - D	MÍNIMOS DE UTILIZACIÓN DEL AD
EN CIRCUITO RWY 28	14500' (3800')	TECHO DE NUBES: 1200 M VISIBILIDAD : 8 KM

V. ADS SYSTEM - Automatic Dependent Surveillance

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.





CURRENT SITUATION OF SURVEILLANCE/ADS IN PERU AND SAM REGION

-All SAM region has surveillance radar (ground sensors) .

Now, many states are in the stage of studies and tests of ADS- B, noting that Brazil has implemented ADS- C stations in your area of oceanic control.

-Today, Peru has 07 Secondary Radar Systems (SSR) Mode S nationwide (including Lima) for hedges of headspace FL 250 or more of the FIR Lima, and 01 Primary Radar (PSR) system terminal area in Lima MN 60 approx.

-In the medium term (to 2016/2017) are considered tests with ADS- B system and the first stations ADS- B (ES Mode S receivers) would be implemented nationwide.

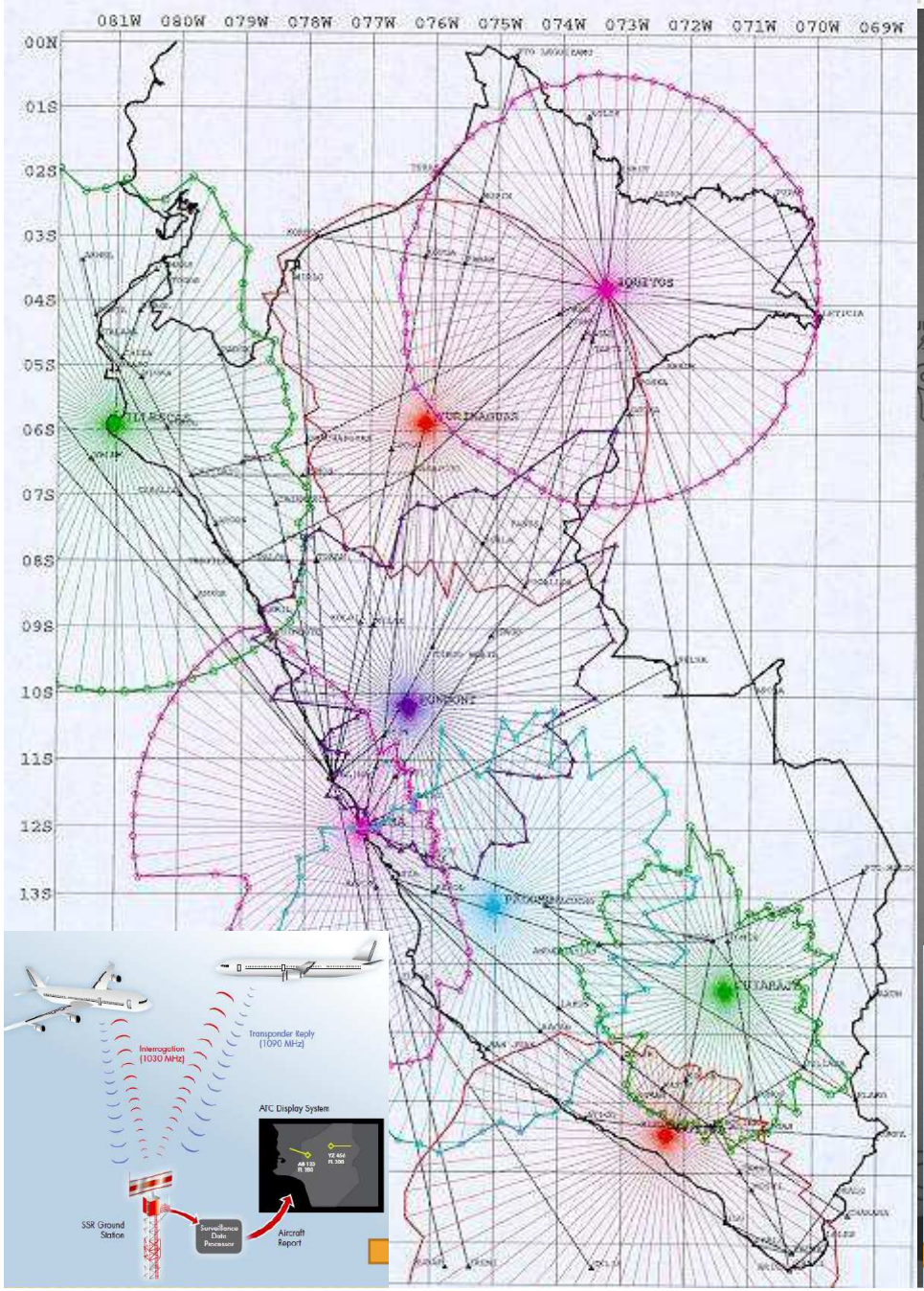
-Today, there is an ADS- B system in Pisco being integrated with the radar data in ACC Control Center of Lima.

-In the long term (2025, estimated), the current SSR Mode S radars installed would not be renewed and be replaced around 2021 by ADS -B / C systems.

AIRPORTS WITH ILS STATIONS IN PERU			
Item	AIRPORT	EQUIPMENT	INSTALLATION YEAR
1	AREQUIPA	ILS LOC-GS	2004
2	CHICLAYO	ILS LOC-GS	2003
3	IQUITOS	ILS LOC-GS	2003
4	LIMA	ILS LOC-GS	2012
5	PISCO	ILS LOC-GS	2015
6	PTO MALDONADO	ILS LOC-GS	2001
7	TACNA	ILS LOC-GS	2015
8	TRUJILLO	ILS LOC-GS	2015

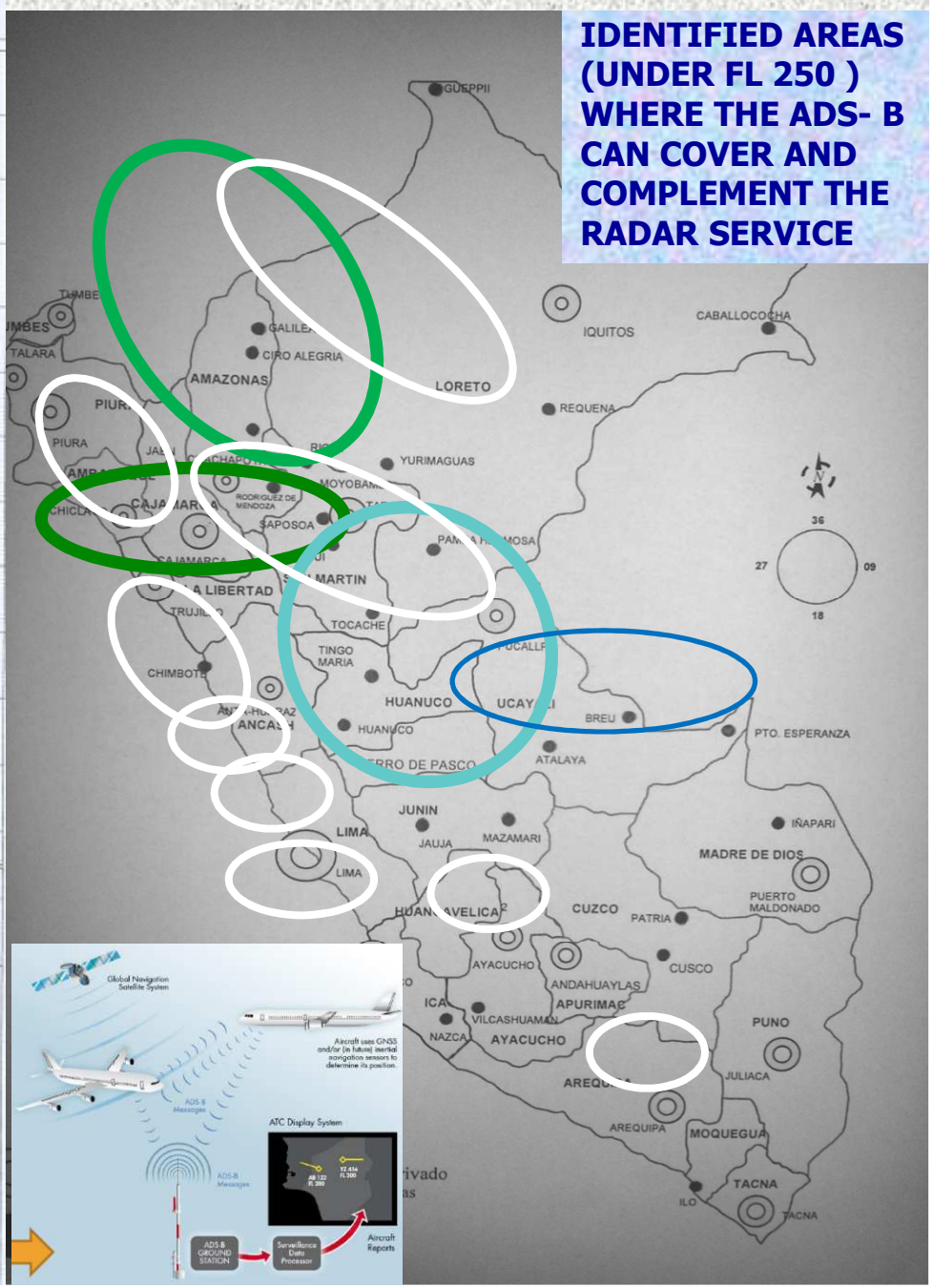
AIRPORTS WITH RADARS / ADS-B IN PERU			
Item	AIRPORT/LOCATION	EQUIPMENT	INSTALLATION YEAR
1	Arequipa - Co Rayado	(SSR)	2012
2	Cusco Co Acopía Grande	(SSR)	2012
3	Cajamarca Co Collpayoc	(SSR)	2012
4	Iquitos Airport	(SSR)	2012
5	Lima AIJCH	(PSR+SSR)	2012
6	Pisco Airport	ADS-B	2012
7	Pucallpa Airport	(SSR)	2012
8	Talara Airport	(SSR)	2012
9	Ayacucho Co Tocto	(SSR)	2012

Radar Coverage Diagram in upper airspace in the FIR (Flight Information Region) Lima



Coverage of lower airspace in the FIR Lima where ADS- B can be used

IDENTIFIED AREAS (UNDER FL 250) WHERE THE ADS- B CAN COVER AND COMPLEMENT THE RADAR SERVICE



VI. CONCLUSIONS

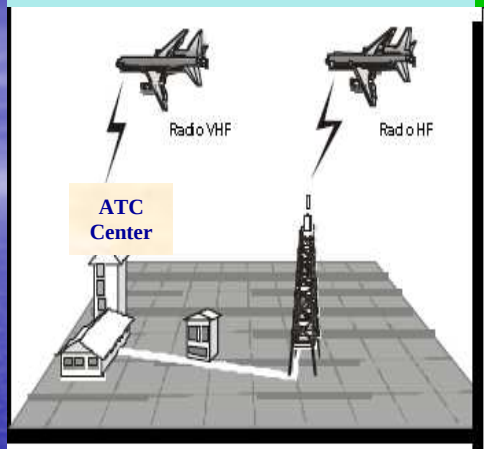
-There are benefits (VSAT, GBAS, ADS) for air navigation in Peru and the Southamerica Región, by using the satellite tecnology in accordance with ICAO recommendations.

-Most countries in South America would have to base their national airspace on GNSS/GBAS and/or SBAS

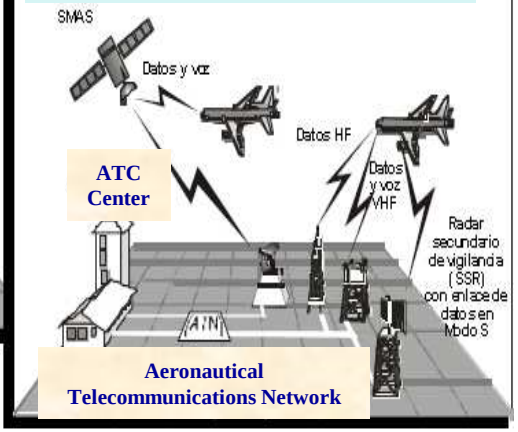
-Development of a valid Ionosphere Threat Model for Low Latitudes (Equatorial region) , is key to GBAS for the national or regional aviation community.

Communications

TODAY



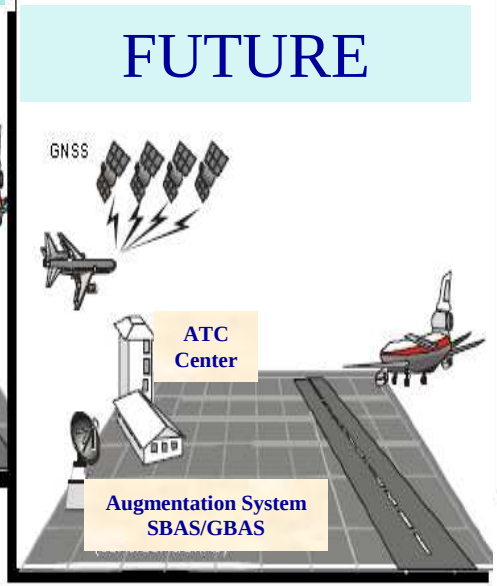
FUTURE



Navigation

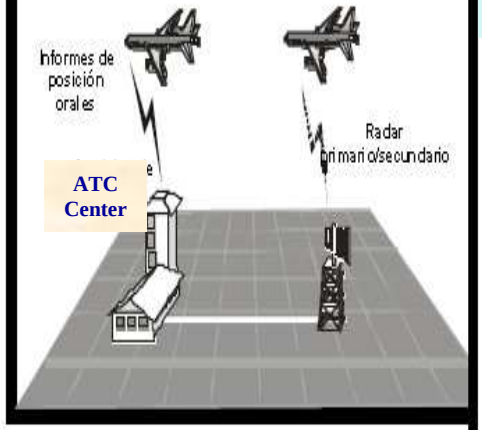
TODAY

FUTURE



Surveillance

TODAY



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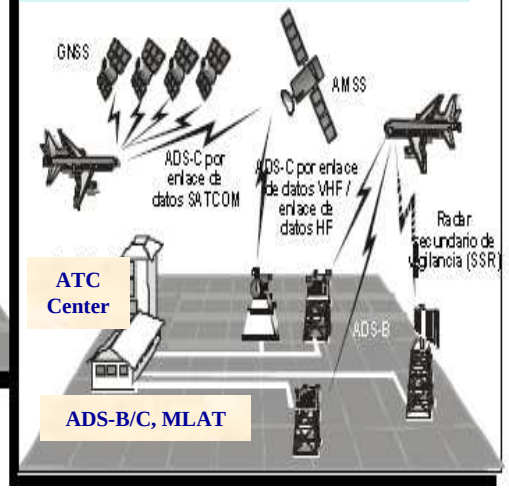

THANK YOU!!

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