



**Departamento de Controle
do Espaço Aéreo**

DEPARTMENT OF AIR SPACE CONTROL - DECEA

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International
Civil Aviation
Organization

Organisation
de l'aviation civile
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Международная
организация
гражданской
авиации

منظمة الطيران
المدني الدولي

国际民用
航空组织

Workshop for the implementation of Navigation Infraestructure to support PBN and GNSS precision approach in NAM/CAR/SAM Region

Session 3: Current GNSS Situation and Evolution

Brazilian GBAS experience

Alessander de Andrade Santoro - Brazil
August 16th, 2016



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DEPARTMENT OF AIR SPACE CONTROL - DECEA





Continuos
increase of
demand

Necessity for
synchronization
of CNS/ATM
deployment in
the world

Increased
efficiency =
increased
safety and
lower costs



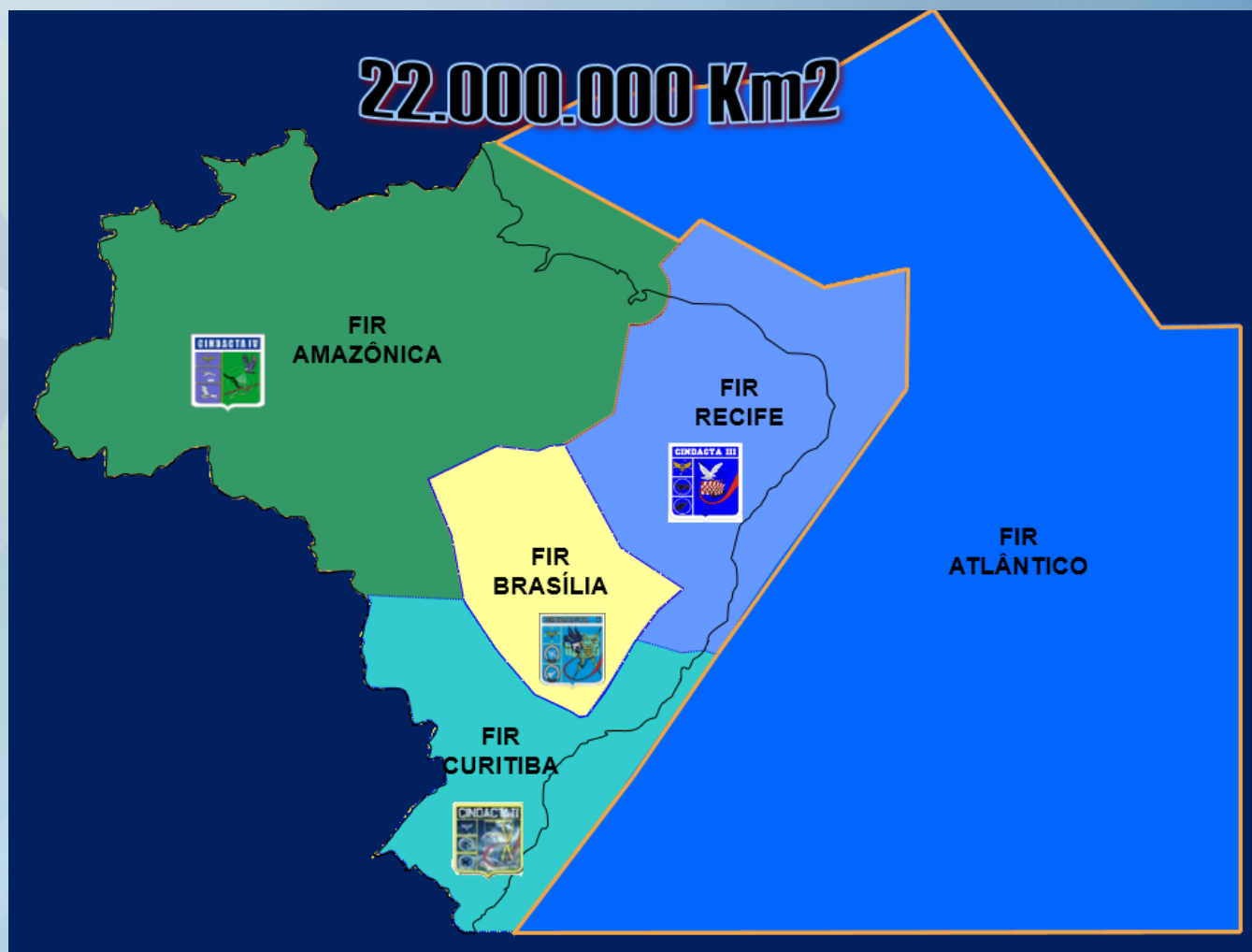
Objective



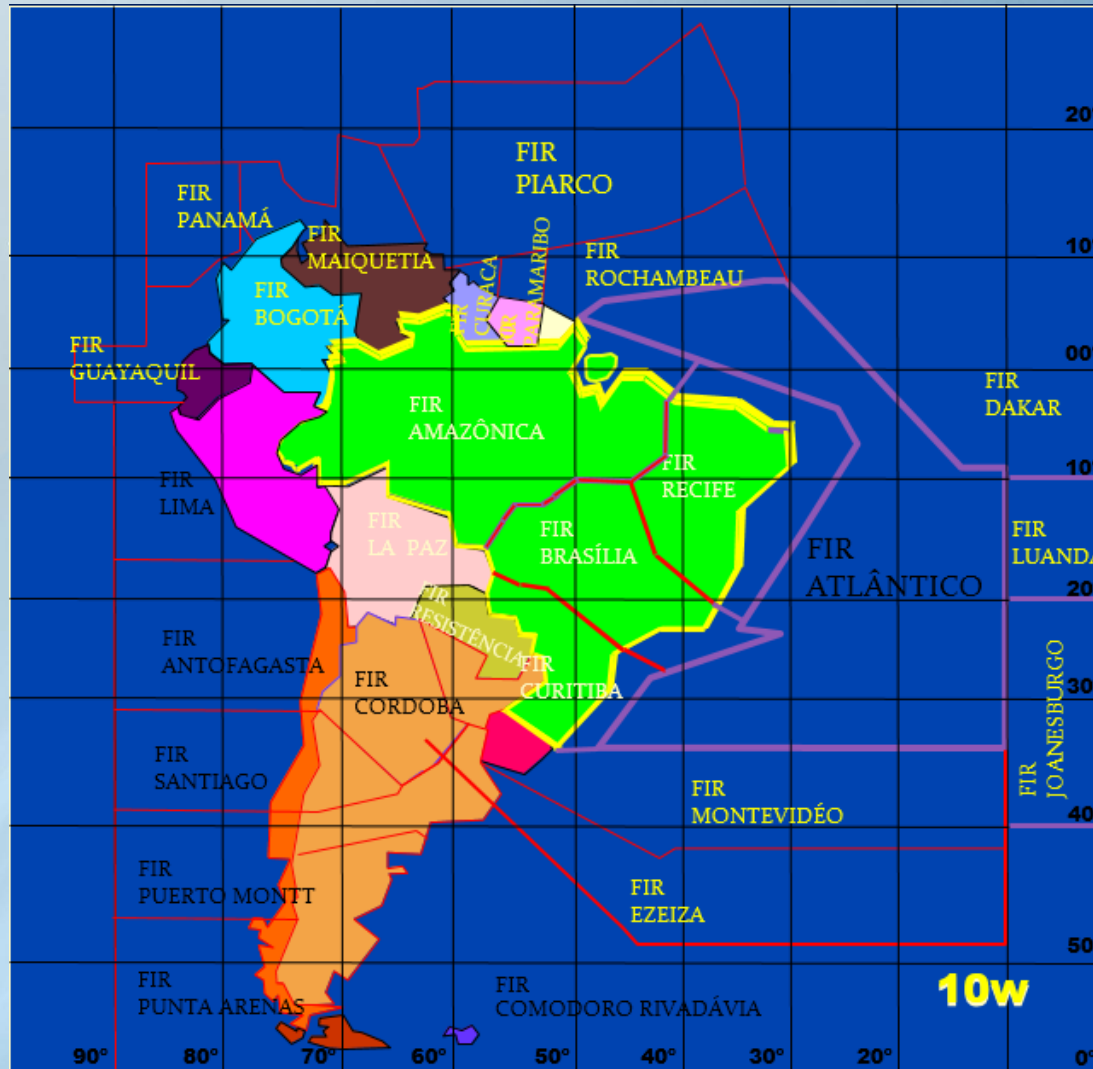
Present Brazilian
Ground Based Augmentation System (GBAS)
experience



Brazilian FIR



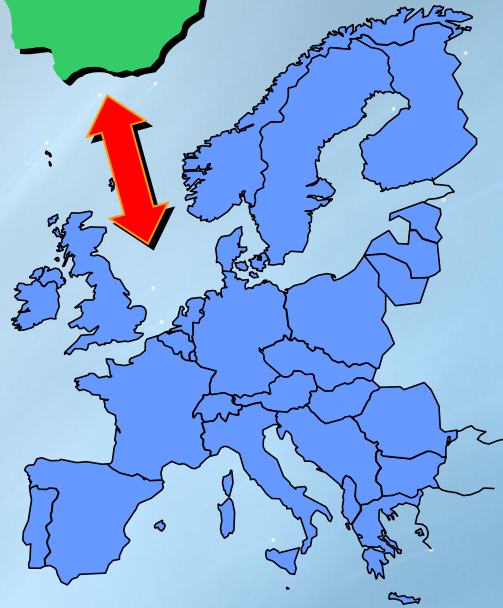
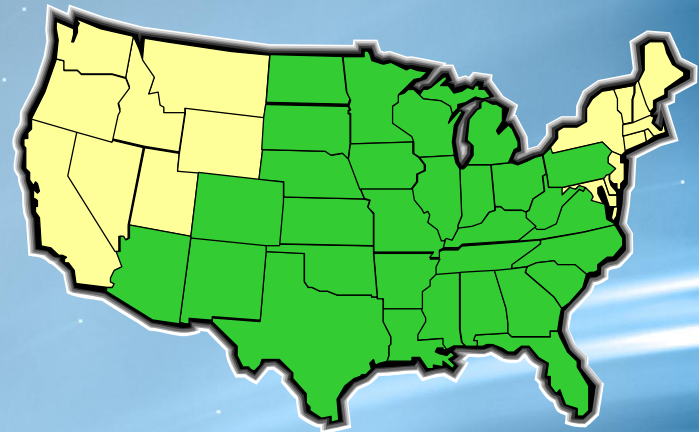
13 International Adjoint FIR



Area comparison



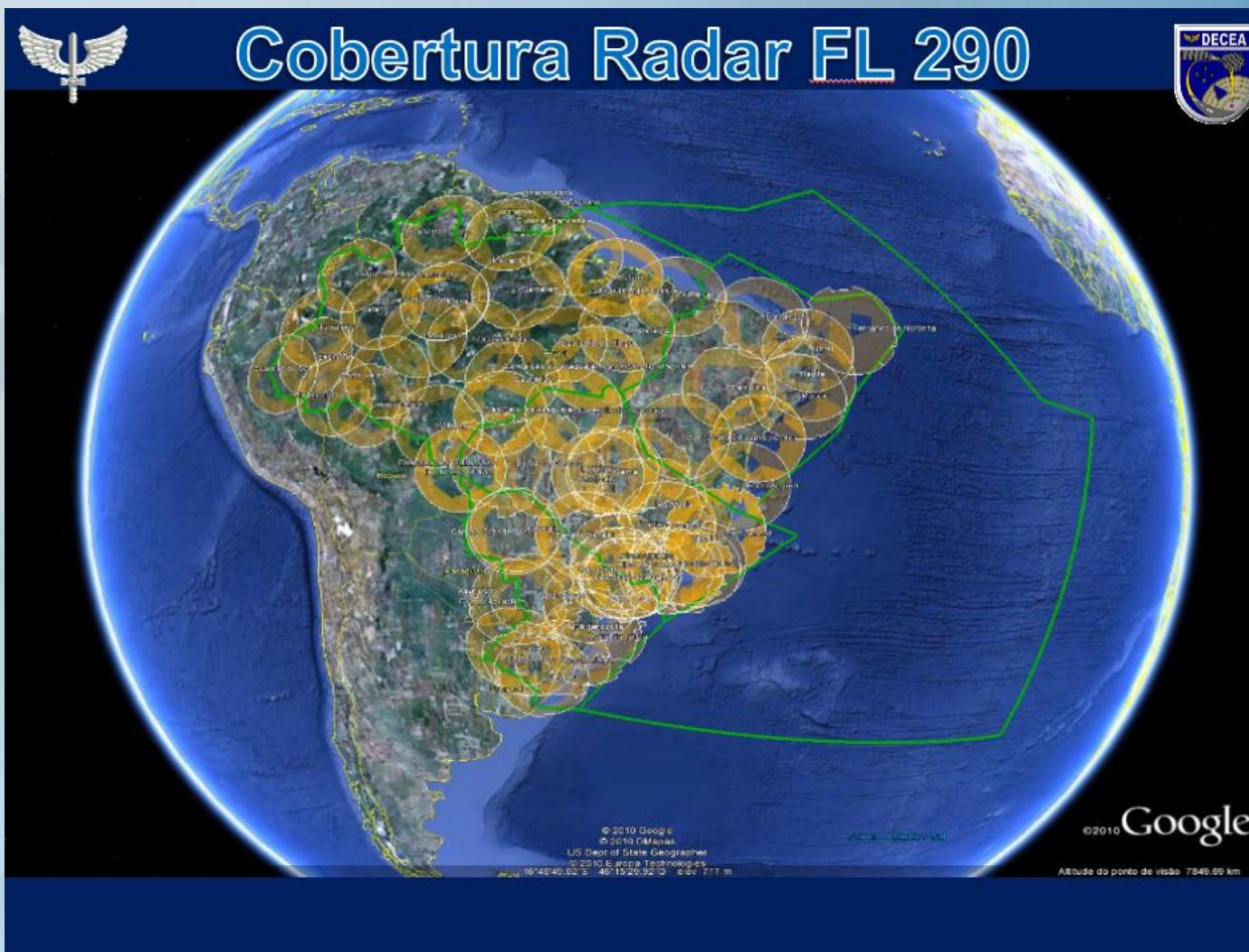
USA: 30 States



32 European countries



Radar Coverage FL290



Air traffic operations



ANO	REGRA DE VOO		TOTAL
	IFR	VFR	
2008	1.939.144	831.062	2.770.206
2009	1.995.580	896.059	2.891.639
2010	2.347.325	1.356.424	3.703.749
2011	2.794.713	1.146.414	3.941.127
2012	3.318.462	1.347.759	4.666.221
2013	2.678.038	1.273.553	3.951.591
2014	2.731.599	1.299.024	4.030.623



CNS Equipments



Equipment	Qty
Primary radar	69
Secondary radar	84
Weather radar	17
Ground radar	1
PAR	6
VOR	84
DME	112
NDB	187
ILS	88
PAPI/VASIS	83
ALS	21
VHF/UHF/HF	8458
Meteorological station	196



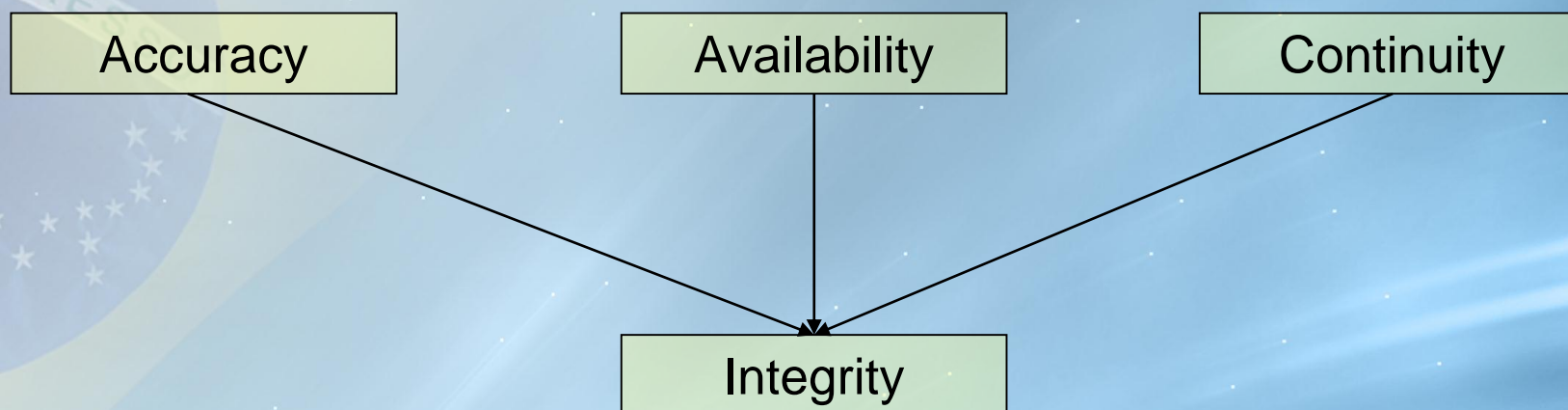
Procedures



Type	Qty
IAC NDB	157
IAC VOR	179
IAC ILS	121
IAC LOC	57
IAC RNAV	215
RNAV ROUTES	140
CONVENTIONAL ROUTES	77



Standards (Annex 10 ICAO)



According to the phase of flight





Nav Aids

ADVANTAGES

Well known technology

Operational confidence

Large network

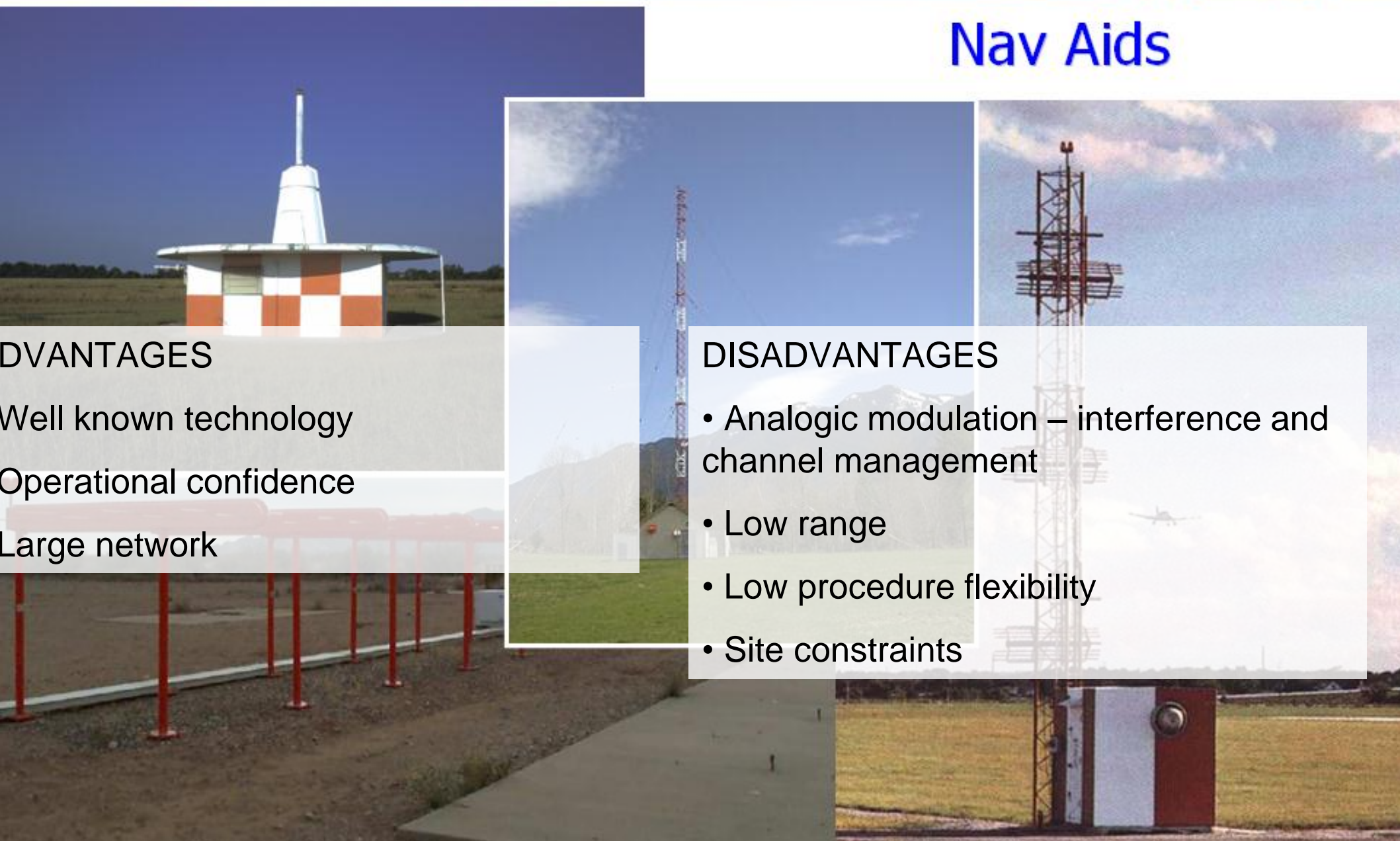
DISADVANTAGES

- Analogic modulation – interference and channel management

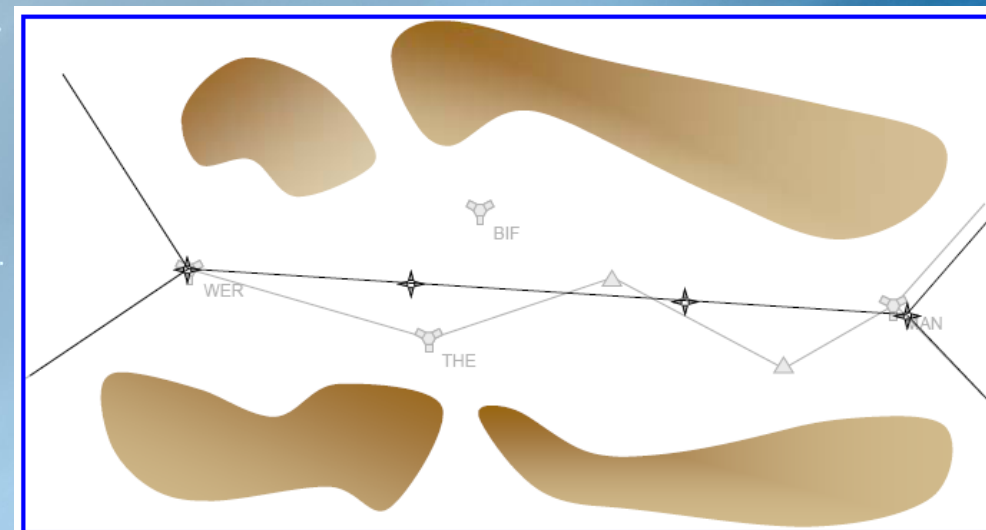
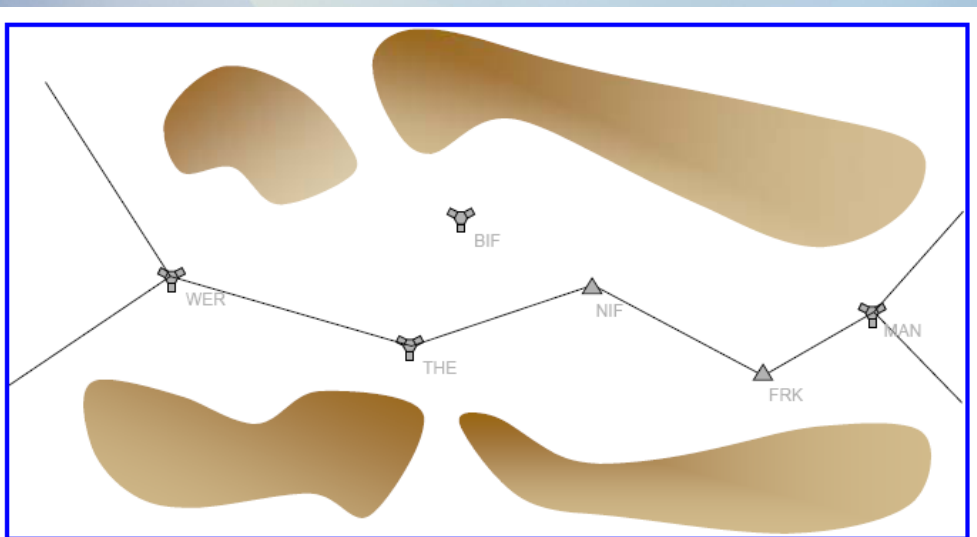
- Low range

- Low procedure flexibility

- Site constraints



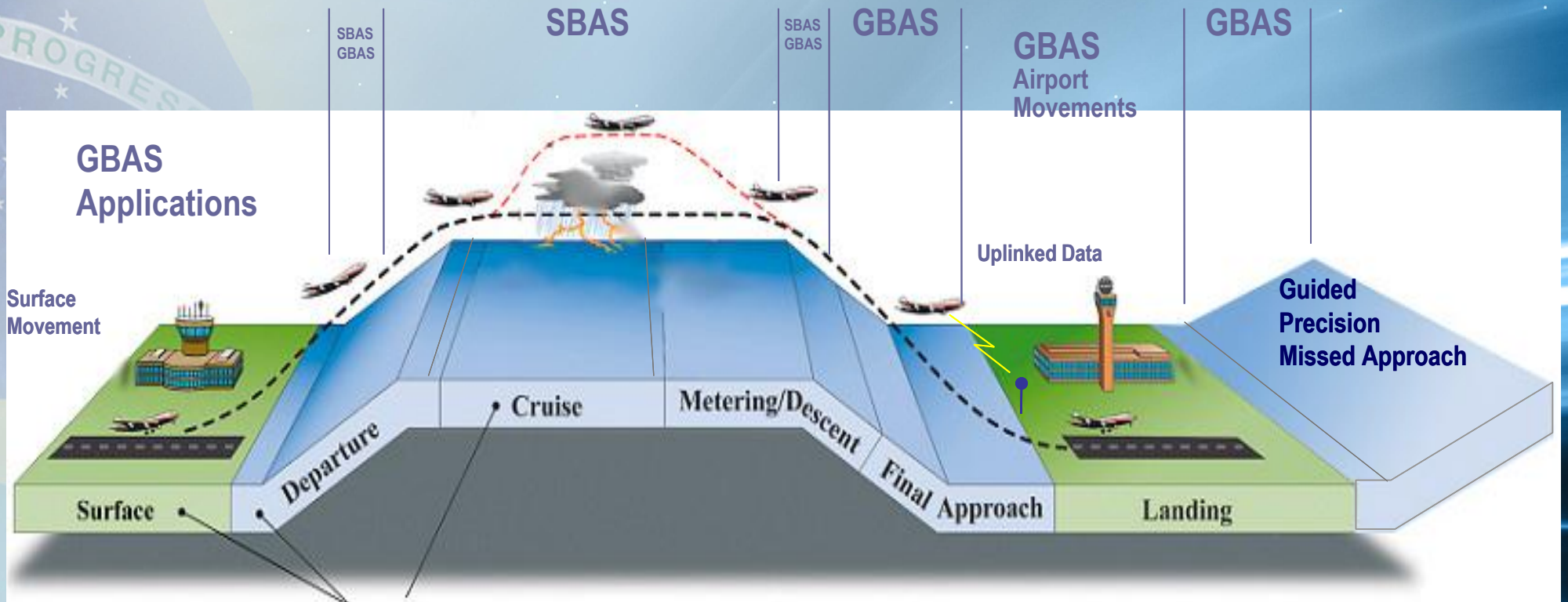
Performance Based Navigation



- Less distance
- Less fuel
- Less \$\$\$
- Less CO2



Gate to gate



Conceito GATE TO GATE

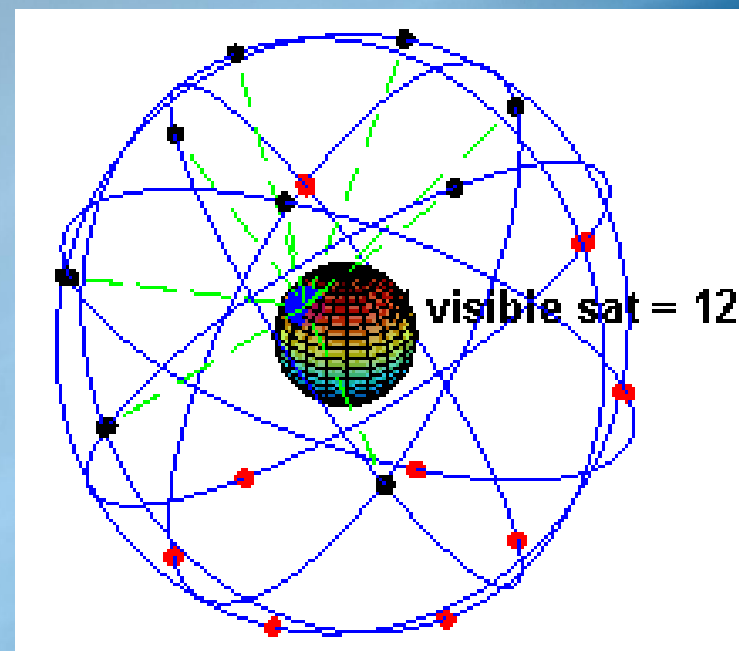
First come, first served → On time, first served



Global Positioning System



- Enroute
- Non precision Approach (reduction of MDA)
- Need of augmentation
- Accuracy
- Integrity
- Availability
- Continuity



Honeywell SLS-2000

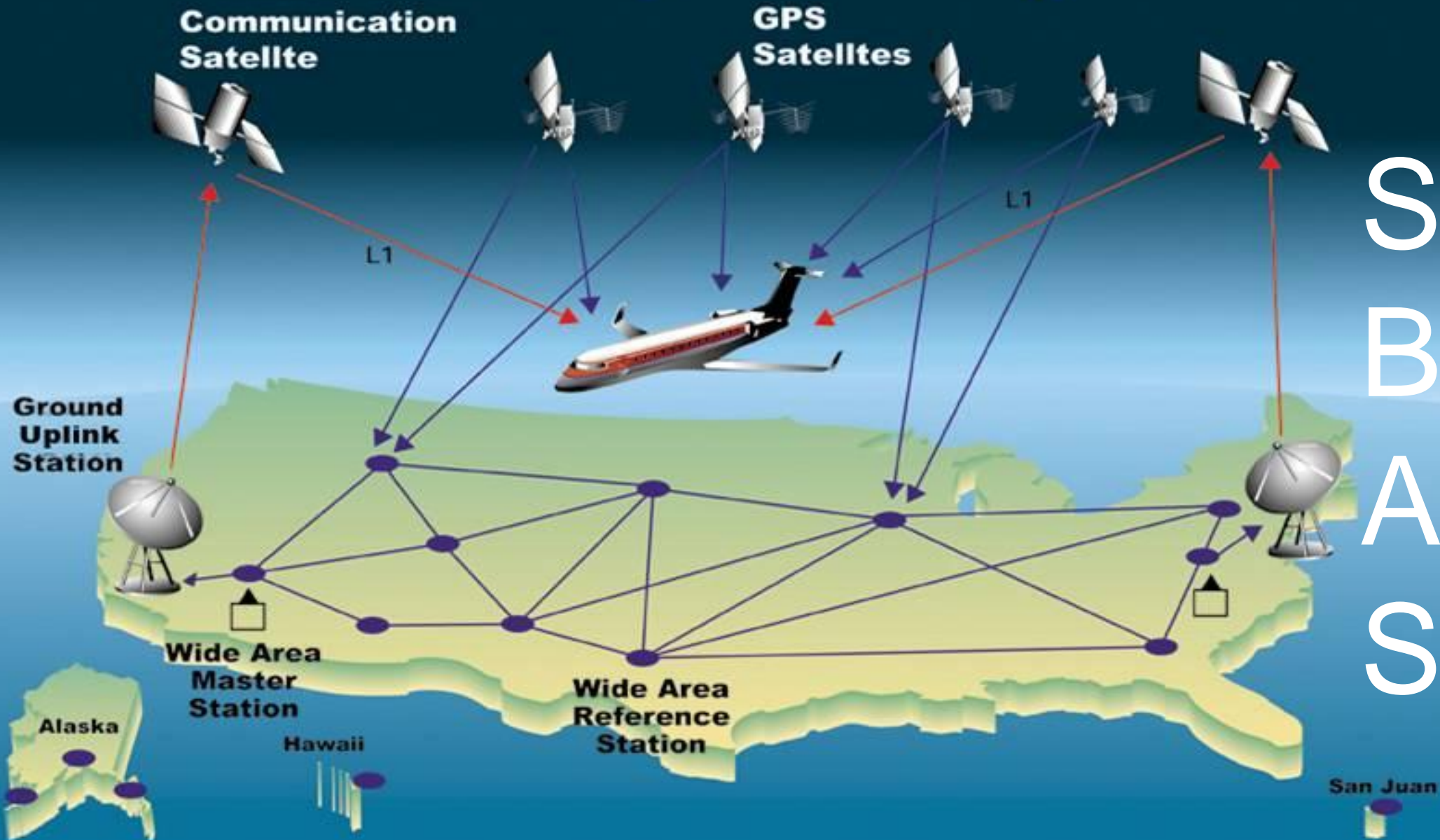


- 1998
- SCAT I operations in Joinvile (Rio Sul)
- São José dos Campos
- Flight Inspection Aircraft EMB-110
- Type of technology Operational in Norway till present

www.flygls.net



Wide Area Augmentation System






S
B
A
S



SBAS Test Platform



-  MASTER STATION
-  REFERENCE STATION
-  VHF-DL



RLA/00/009 PROJECT – GNSS AUGMENTATION TRIALS



- SBAS augmentation trials in the CAR/SAM Regions
- MOU – ICAO/FAA: signed on 2 June 2001
- First flight trials - 2002 in Brazil
- It was proven that the ionosphere effect over the GPS signal did not guarantee NPA approaches with vertical precision requirements
- Final report – RCC/5-RLA/00/009-WP/03



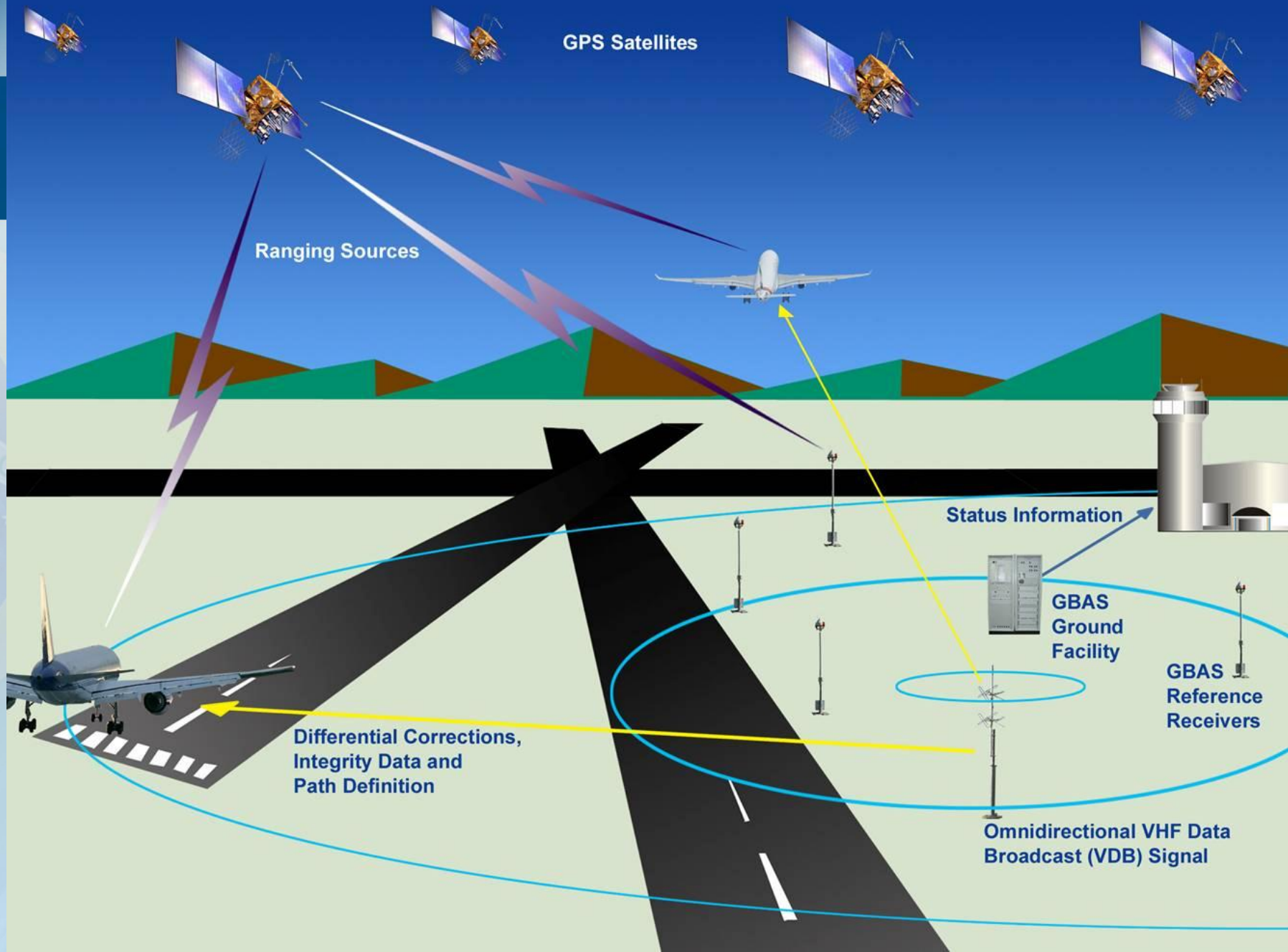
SBAS in Equatorial Regions



- RLA/00/009 PROJECT – GNSS AUGMENTATION TRIALS
- NAVIGATION SYSTEMS PANEL (NSP) - Ionospheric Effects on GNSS Aviation Operations
- ICAO Doc 9849 - GNSS Manual
- IATA Report on User Requirements for Air Traffic Services – *“Do not support the continued investment, development, and implementation of SBAS.”*



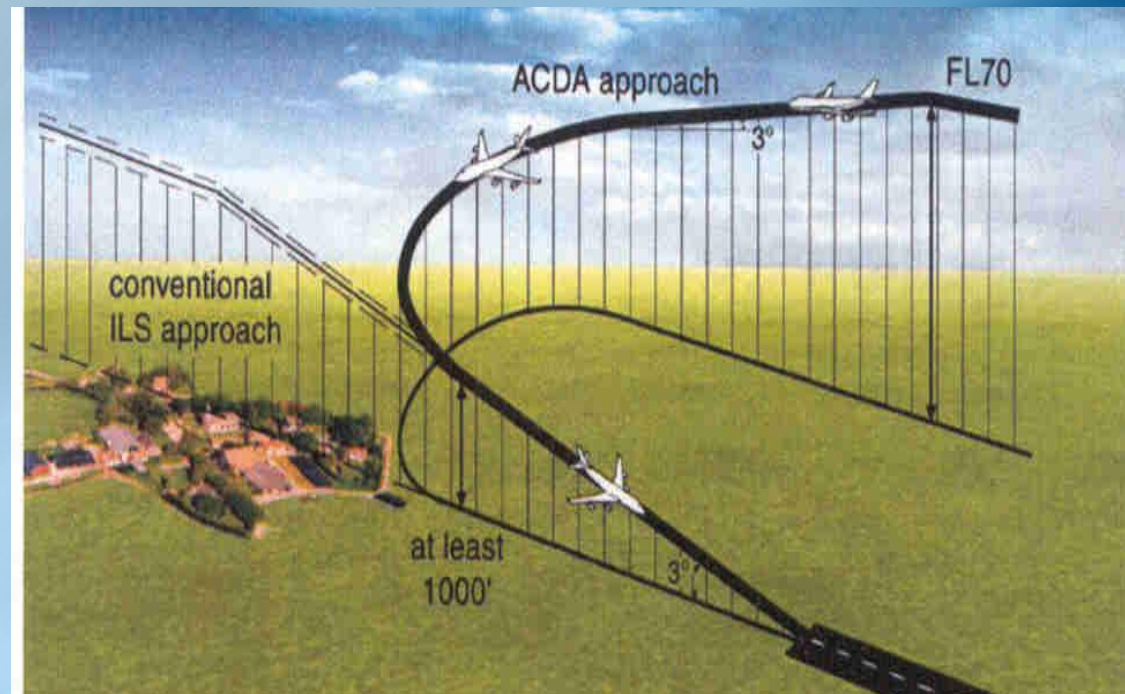
GBAS – Ground Based Augmentation System



Benefits



- **One GBAS multiple approaches** - up to 48 approach procedures
- **Flexible sitting requirements**
- **Improved accuracy of positioning service**
- **Reduced building restrictions** - construction of new terminals and hangars
- **Flexible use** - curved approach paths, different glide path angles, off set thresholds, etc



FAA / DECEA Cooperative History

MOC / NAT-I-0801

Development of Civil Aviation
Jan 2000

Annex 1 (Oct,2001)

GNSS Flight Test
Trials and Demonstrations

Appendix 1

Annex 2 (Oct,2001)
Ionosphere Research
Loan of equipment

Annex 3 (Ago,2003)
LTP
Loan of equipment

Appendix 1

MOA / NAT-I-0019

Technical Assistance
Jun 2000

Annex 1 (Nov,2000)
Purchase of equipment

Appendix 1

Annex 2 (Nov,2002)
CARSAMMA
Establishment

Appendix 1

Annex 3 (Nov,2003)
GNSS Flight Trials
Purchase of equipment

Annex 4 ETMS

MOC NAT-I-4016

Technical Assistance
Jul 2015

Annex 1 (In Coord)
Atmospheric Ionospheric
Research



LAAS Test Prototype



- SGBL
- MoU DECEA/FAA 2003



LAAS Test Prototype



- GEIV Aircrafts
- MMR – GNU 930 (Rockwell Collins) – Red label
- Achievements
- 120 approaches
- 03 airports (SBGL, SBRJ, SBAF)
- 06 runway thresholds



GPS SMART - Position, Velocity, Time Solutions, Status - Port 1

File View Window Select Port Help

Differential GPS Status Data - Port 1

Reference Station ID = SBGL
 UTC Date = 8/30/2006
 Mod Z-Count = 1006.0
 Diff Mode = ON

Receiver Mode is NAV: GBAS MODE
 UTC Date = 8/30/2006
 PUM = 1
 GPS Week = 366
 Bias = 3823010.8
 Drift = -289.3

Set Time = 144519
 UTC Time = 14:16:34.09
 GPS Time = 310608.29
 Svs Used = 8

SV	ID	PRC	RSC	OLD	I-C	SpP	HC	Position X, Y, Z	Long, Lat, Height	Velocity E, N, UP	Speed, Gnd Trk
6	122	2.84	0.001	T-T	0.08	7C		4306340.4	-4021184.7	-2437904.0	
7	192	-0.22	0.000	T-T	0.12	C4		W 43:02:19.7	S 22:36:52.8	1354.9	
16	142	-1.77	0.001	T-T	0.12	CF				0.00	
18	31	1.56	-0.002	T-T	0.08	86				318.49	
21	221	1.55	0.001	T-T	0.08	9F					
22	146	-1.02	0.000	T-T	0.12	B5					
25	156	-5.18	0.000	T-T	0.12	H1					
30	72	2.23	-0.002	T-T	0.12	95					
0	0	0.00	0.000	F-F	0.00	00					
0	0	0.00	0.000	F-F	0.00	00					
0	0	0.00	0.000	F-F	0.00	00					
0	0	0.00	0.000	F-F	0.00	00					

Position, Velocity, Time Solutions, Status - Port 1

Position X, Y, Z = 4306340.4 -4021184.7 -2437904.0
 Long, Lat, Height = W 43:02:19.7 S 22:36:52.8 1354.9
 Velocity E, N, UP = -0.00 0.00 -0.00
 Speed, Gnd Trk = 0.00 318.49

Horz-Err Vert-Err Time-Err Vel-Err HDOP VDOP PDOP TDOP

1	1	1	1.84	0.99	1.61	1.87	1.1
---	---	---	------	------	------	------	-----

NAV TO RAIN
 ALT VALID = FALSE
 ALT TYPE = 2
 ALT MBAS RESIDUAL = 0.0
 ALT TH PAT = FALSE
 SIGMA BARO = 1017.0
 K BARO B = 0.0
 TIME TAG = 0
 SIGMA VC = 1017.0

TAP Data Status - Port 1

GPS Time = 310607.1
 Reference Path Identifier = TP28
 Reference Path Data Selector = 29
 Operation Type = TAP
 Num Path Points = 3
 Active Segment = 1
 Segment Type = Straight Line
 Seg Transition = Not End
 TU Waypoint Latitude = -22.76015000
 TU Waypoint Longitude = -43.15112500
 TU Waypoint Height = 436.000
 Length of TAP = 21265.467
 Distance from TU waypoint = 19724.088
 Length of Selected Segment = 17009.721
 TAP Point Turn Angle = 0.000
 Upr Turn Angle to compl turn = 0.000
 UDS = 1070
 UDS = 282
 Descent Angle = 3.082
 Tap Valid = YES

Serial Port Recording

Port 1
 830am_mmr.bin

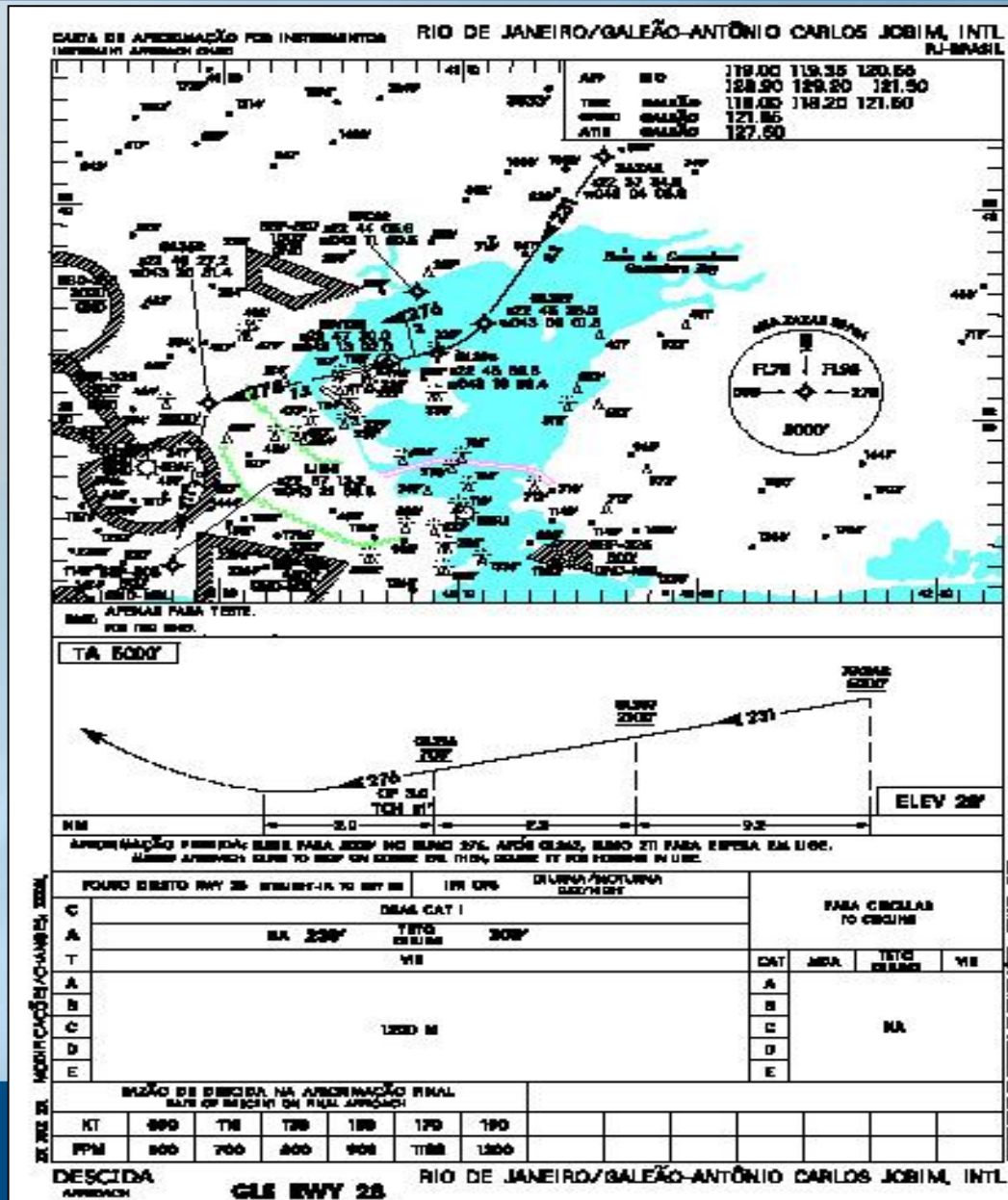
Port 2
 Set Location [Stop]

Messages Discarded: 1
 Update

Monitoring Serial Data
 Port 1 saving to 830am_mmr.bin
 00:48:10



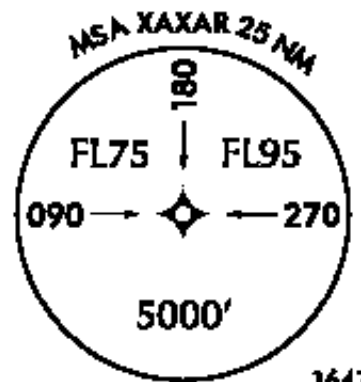
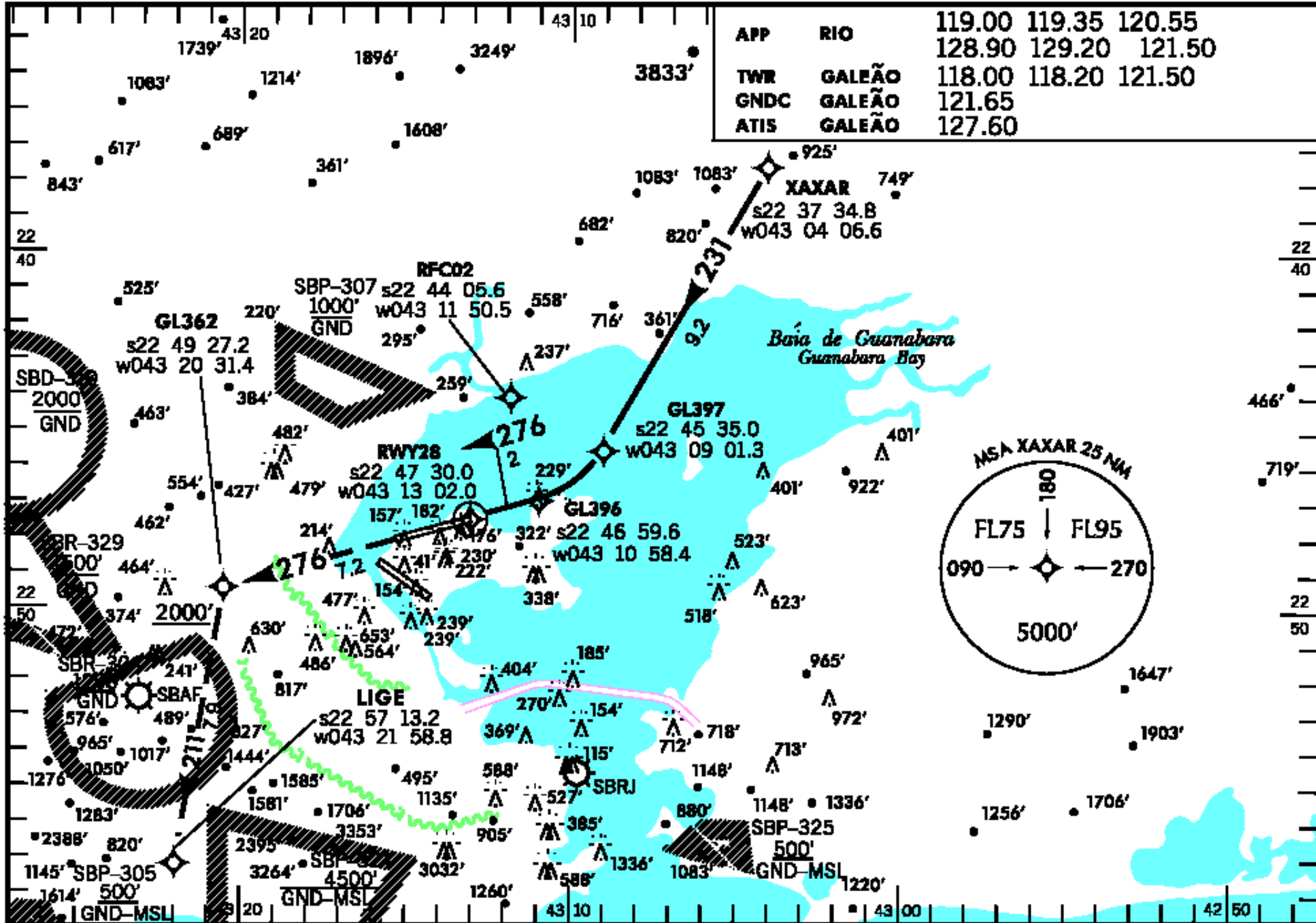
LAAS Test Prototype

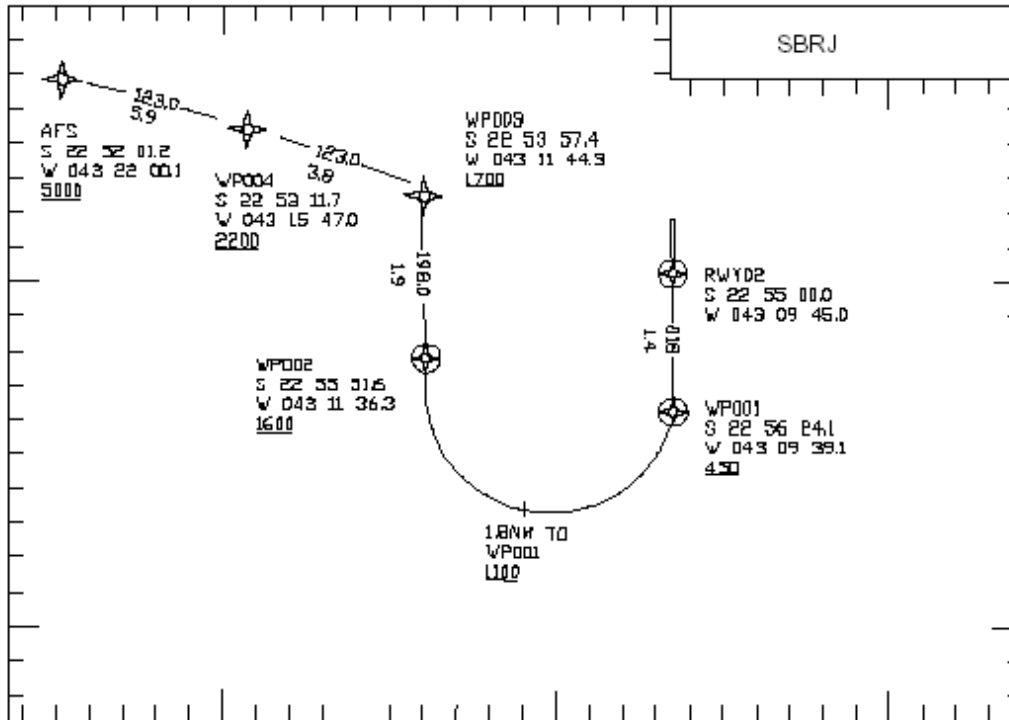


CARTA DE APROXIMAÇÃO POR INSTRUMENTOS
INSTRUMENT APPROACH CHART

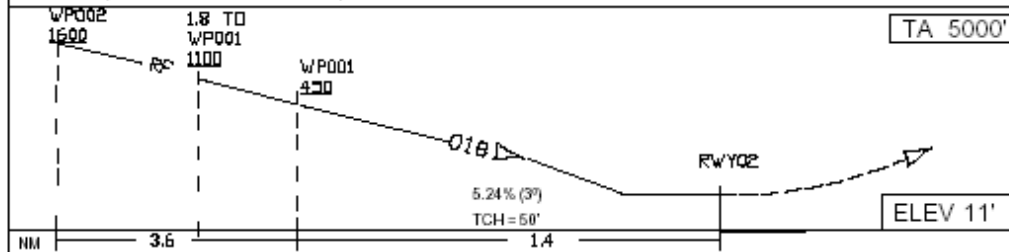
RIO DE JANEIRO/GALEÃO-ANTÔNIO CARLOS JOBIM, INTL
RJ-BRASIL

APP	RIO	119.00	119.35	120.55
TWR	GALEÃO	128.90	129.20	121.50
GNDC	GALEÃO	121.65		
ATIS	GALEÃO	127.60		





RMK: 1) SOMENTE PARA TESTES
2) IAS MÁX APÓS WP 002: 150KT 3) PROCEDIMENTO NÃO UTILIZÁVEL COM VENTO SUPERIOR A 30 KT



APROXIMAÇÃO PERDIDA: SUBIR PARA 5000FT EM CURVA À DIREITA NA PROA DE MRC PARA ESPERA.

POUSO DIRETO RWY 02		FR OPS DIURNA / NOTURNA		PARA CIRCULAR							
C	GLS										
A	DA 261'	TETO 300'									
T	VIS	CAT	MDA	TETO	VIS						
A	1200 M	A	NA	NA	NA						
B		B									
C		C									
D	NA	D									
E	NA	E									
RAZÃO DE DESCIDA NA APROXIMAÇÃO FINAL						DIST / ALT					
KT	100	110	120	130	140	150	NM	RWY02	WP001	1.8	WP002
FPM	550	600	650	700	750	800	ALT	N/A	450'	1100	1600

DESCIDA RNAV(RNP 0.1) RWY 02

RIO DE JANEIRO/SANTOS DUMONT

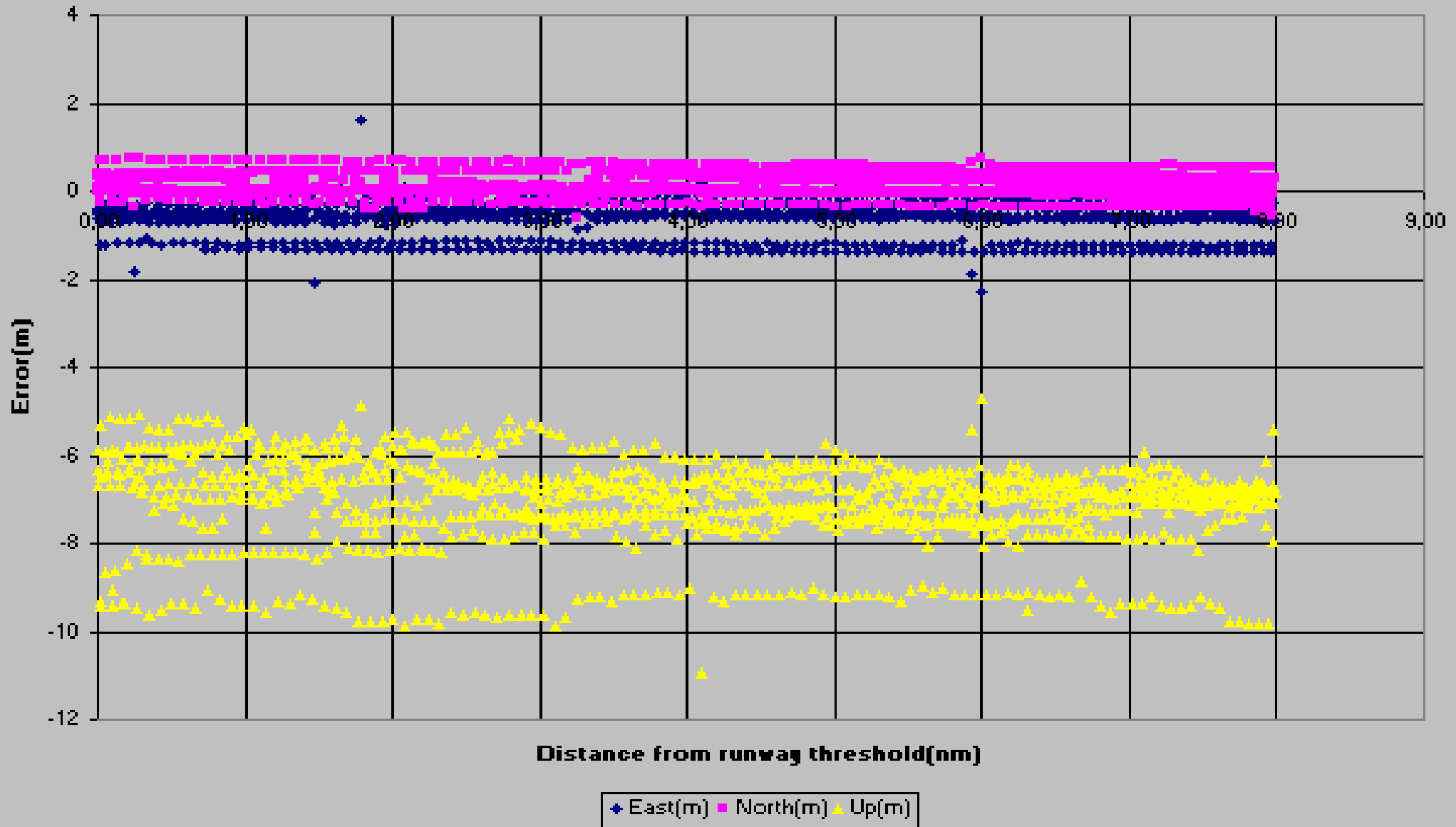






LAAS Test Prototype

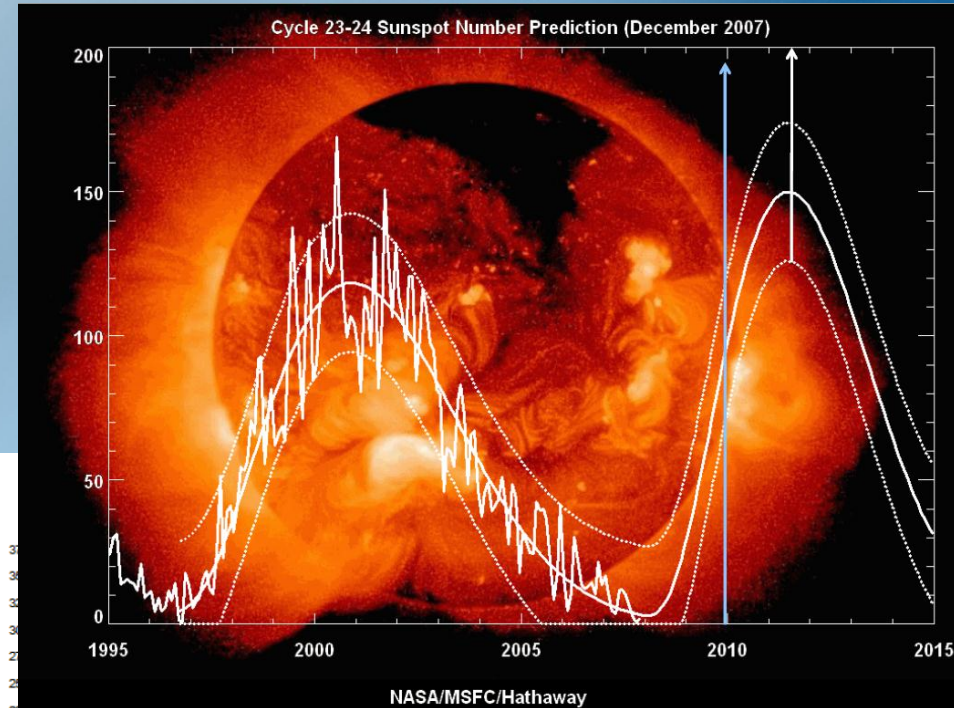
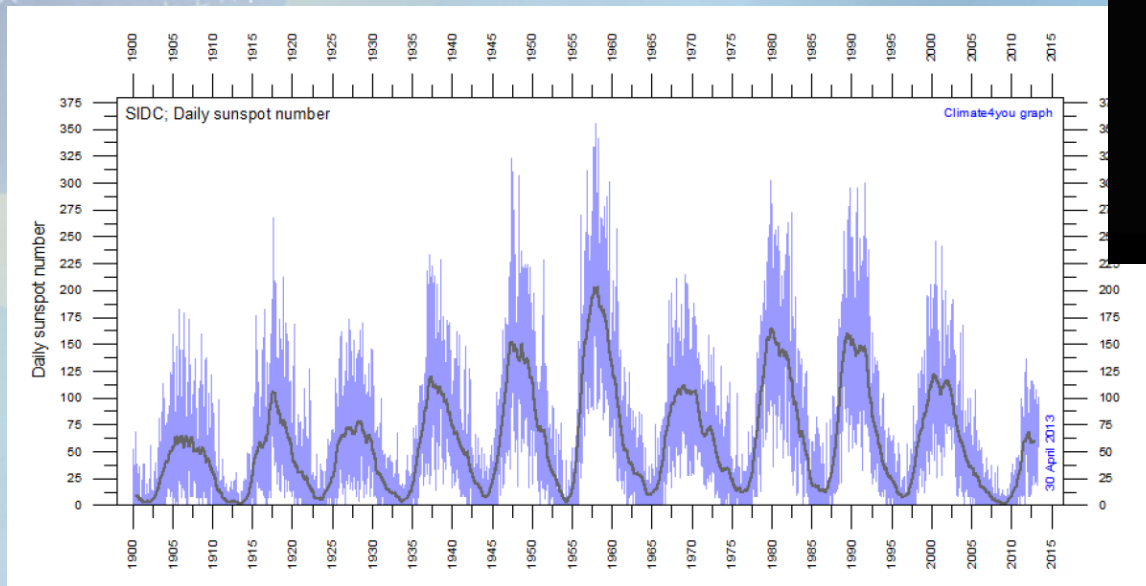
GBAS - 09 Approaches GL RWY10 23 OCT 04



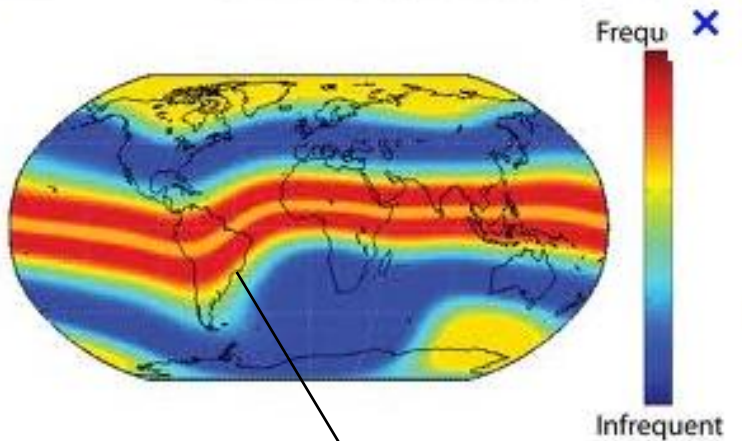
LAAS Test Prototype



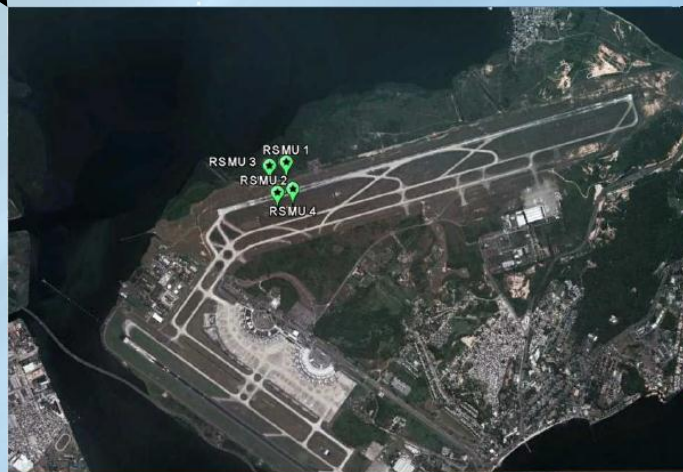
- Data collection errors
- Ionosphere
- Solar Cycle
- Reduce variables



SLS4000 – SmartPath - SBGL



- June, 2011 – Operation for testing purposes;
- Availability issues (ionosphere);
- Disabling monitors for data collection purposes;
- Approach procedures RWY 10, 15, 28 and 33.

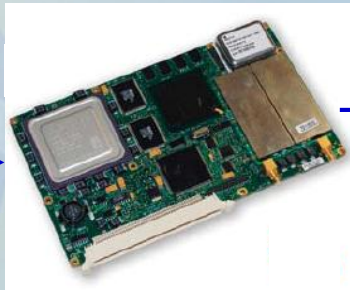


SmartPath Components



GPS Antennas

- Four GPS RRA/RSMU per GBAS
- Multipath limiting design
- Sharp cut-off/rejection at horizon



GPS Receivers

- 48-channel, L1 C/A GPS
- Signal Quality Monitoring

Corrections Processor

- Pentium M, 1.8 GHz CPU
- Real time monitoring for GPS failures, local error sources
- Differential corrections

VHF Antenna

- Horizontal polarized (HPOL)
- Omni-directional

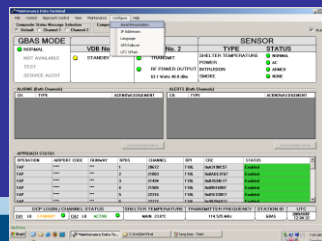
VHF Radios

- Nav band, 108-118 MHz
- D8PSK modulation, TDMA
- Digital data broadcast



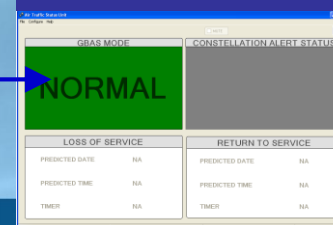
Maintenance Data Terminal

- Windows OS
- System mode & control
- Component status
- Approach control



Air Traffic Status Unit

- Windows OS
- System mode
- Current/Predicted Availability



RWY 10/28 SBGL





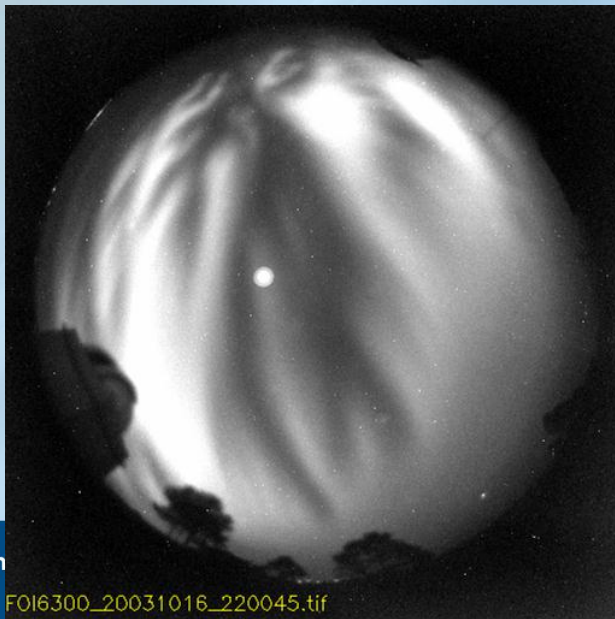
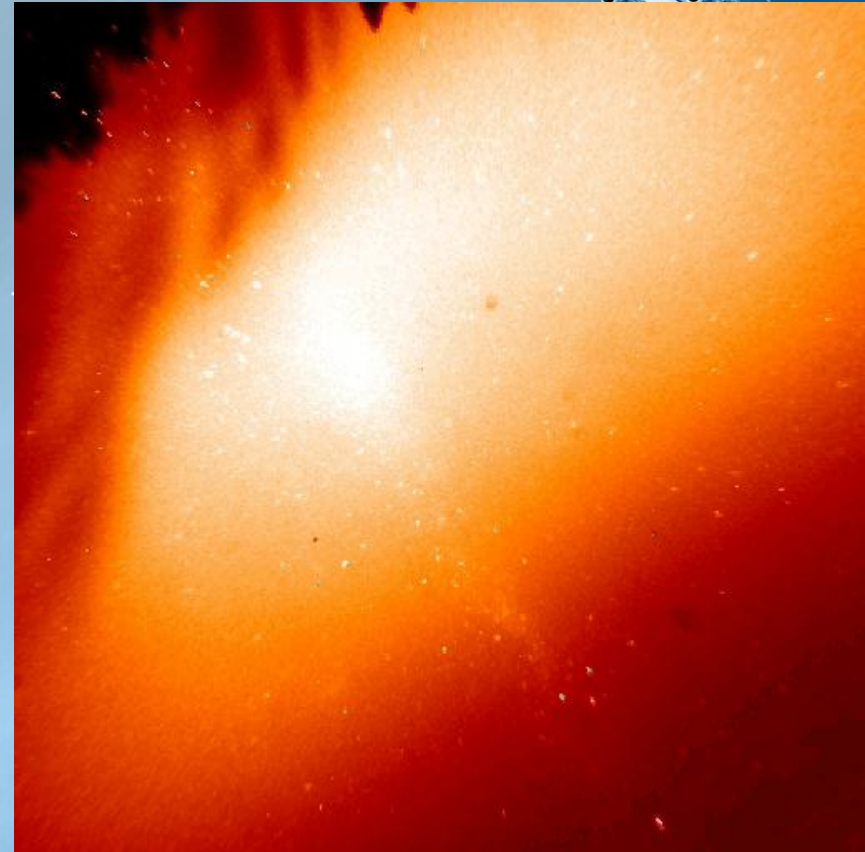
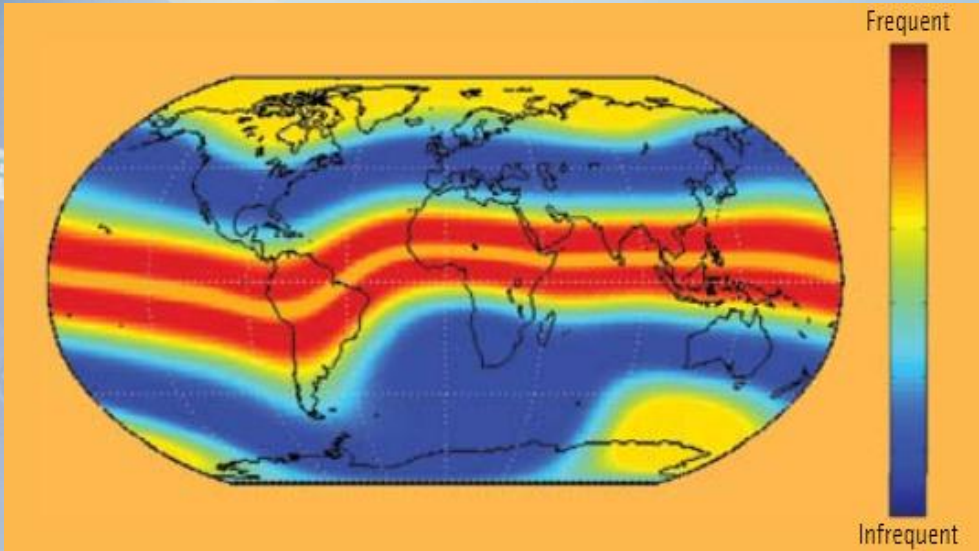
CONTEN
CF024
GBAS - GL
CISCEA - Honeywell
Pannello di controllo

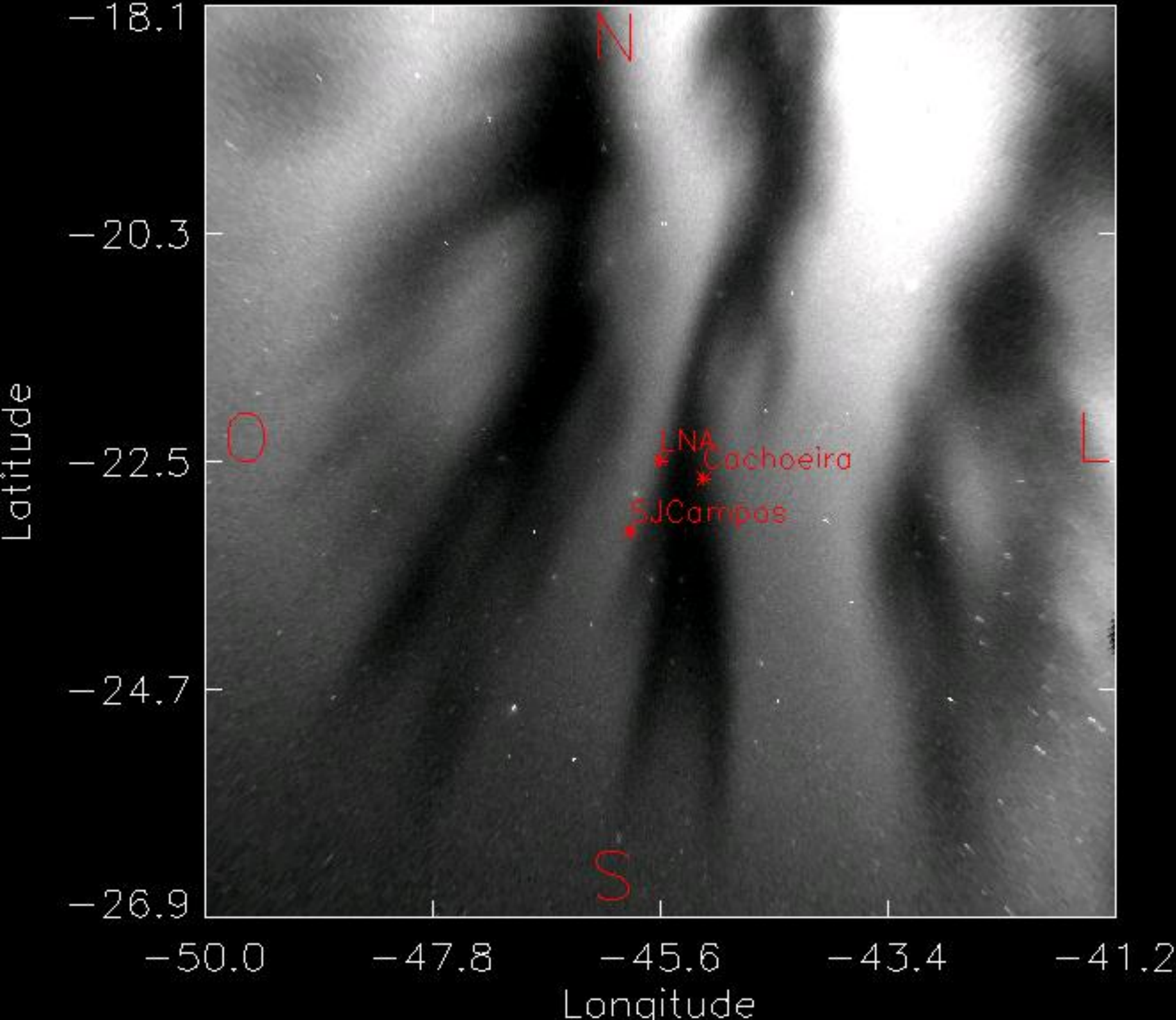
16 6:24 PM



16 6:28 PM

Ionosphere





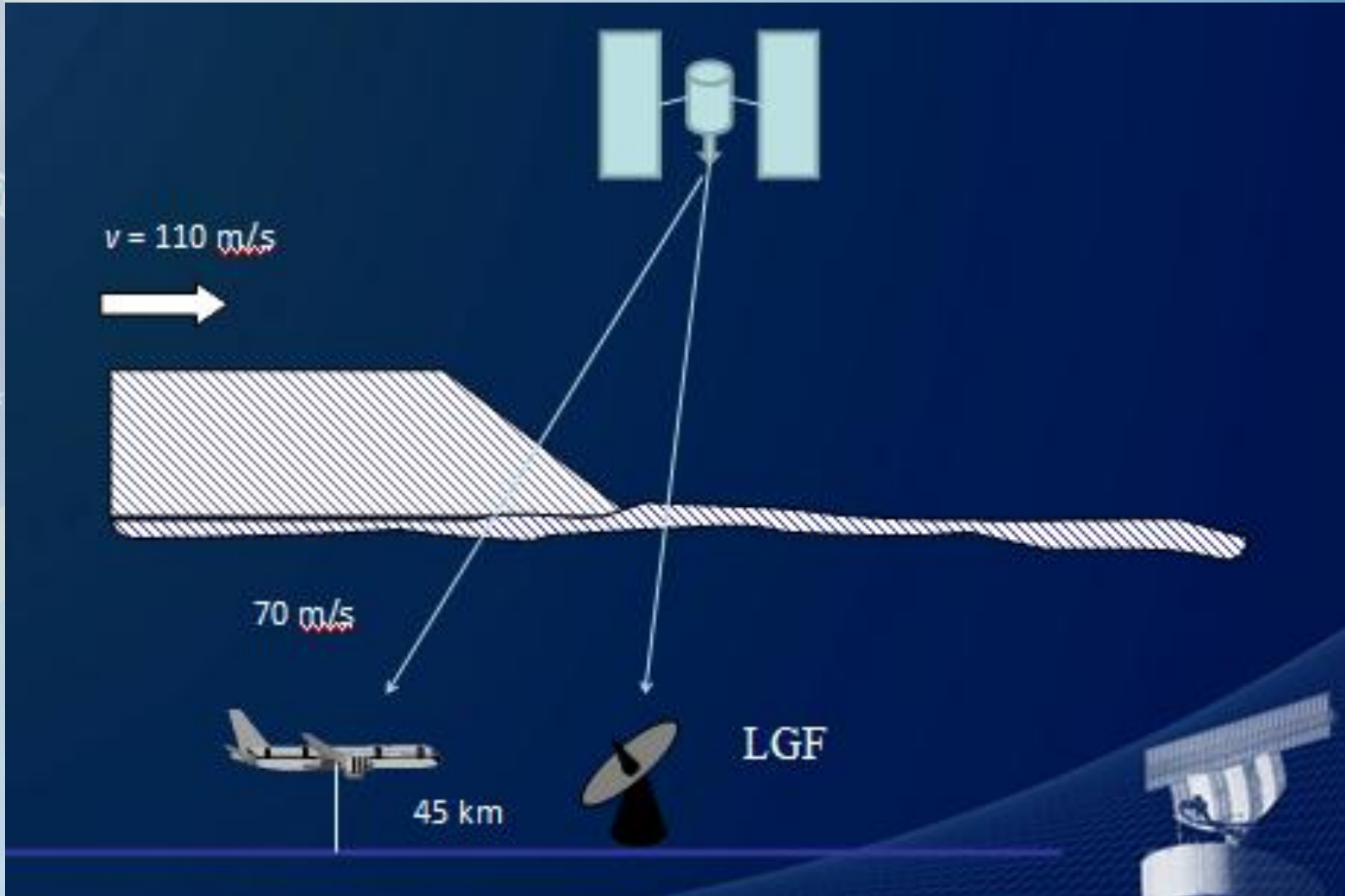
Figuras do dia 28/09/2002 observadas no LNA /Brazzopolis (MG)

Hora Local: 22:02:04

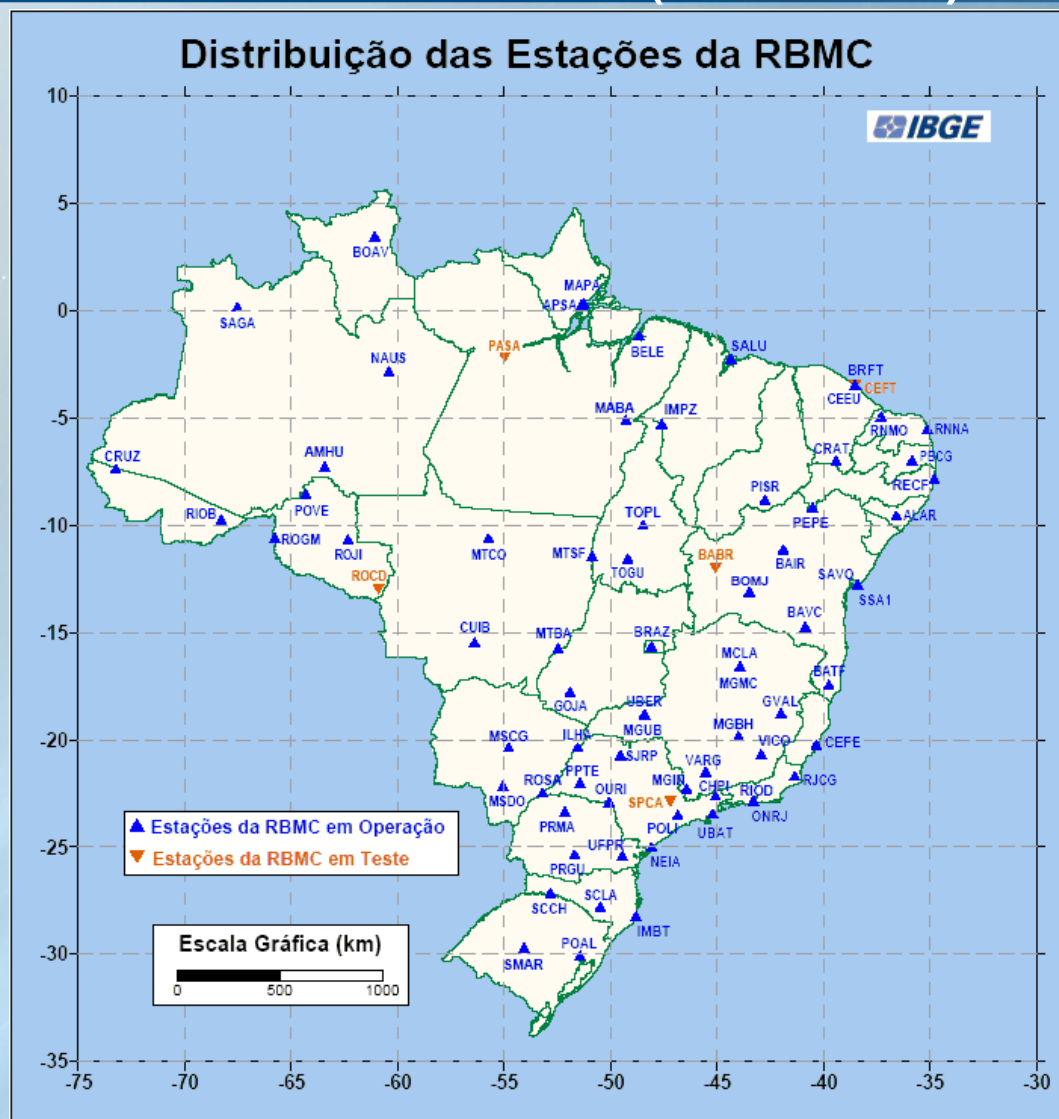
41

ROL - DECEA

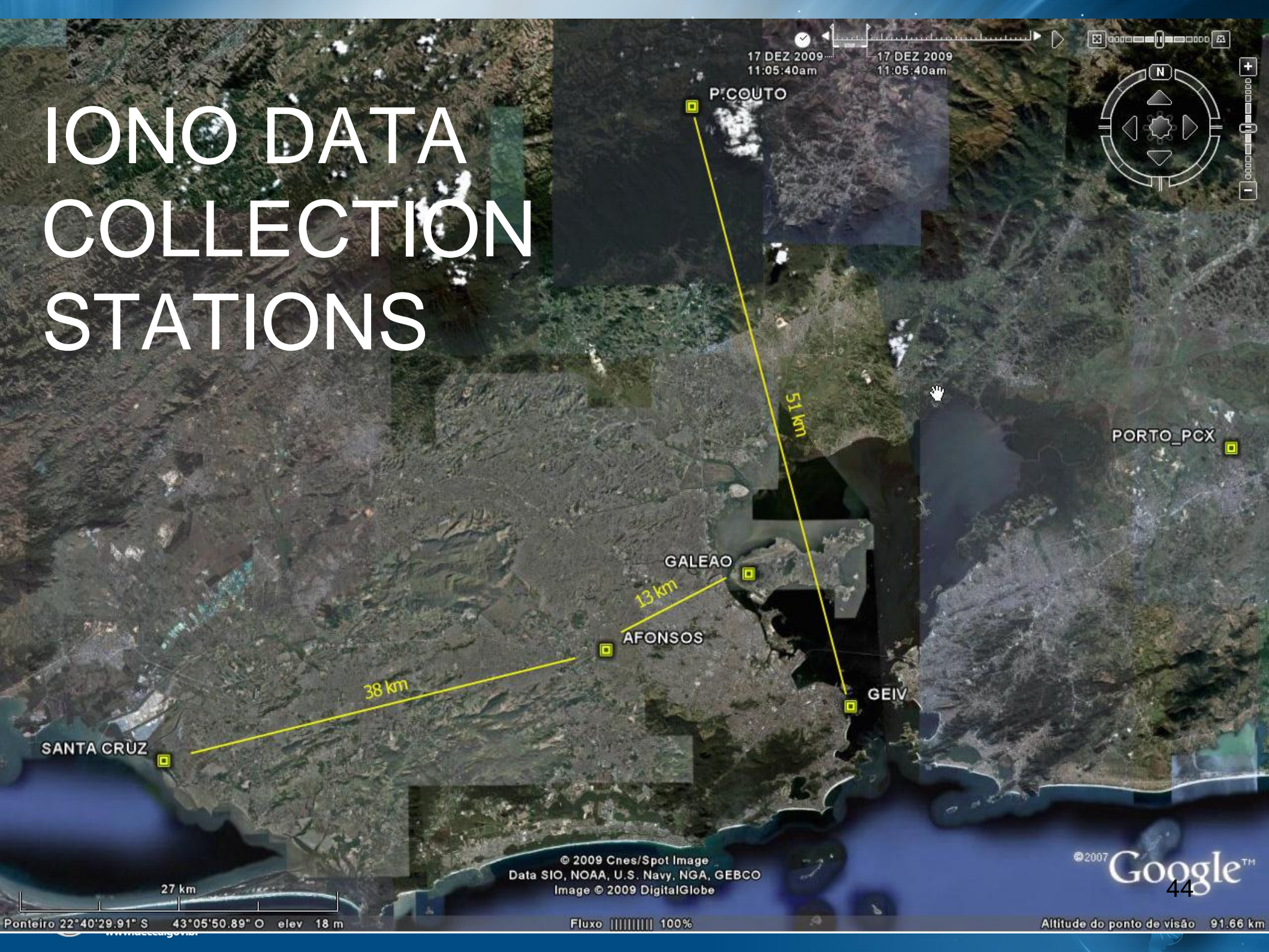
Ionosphere



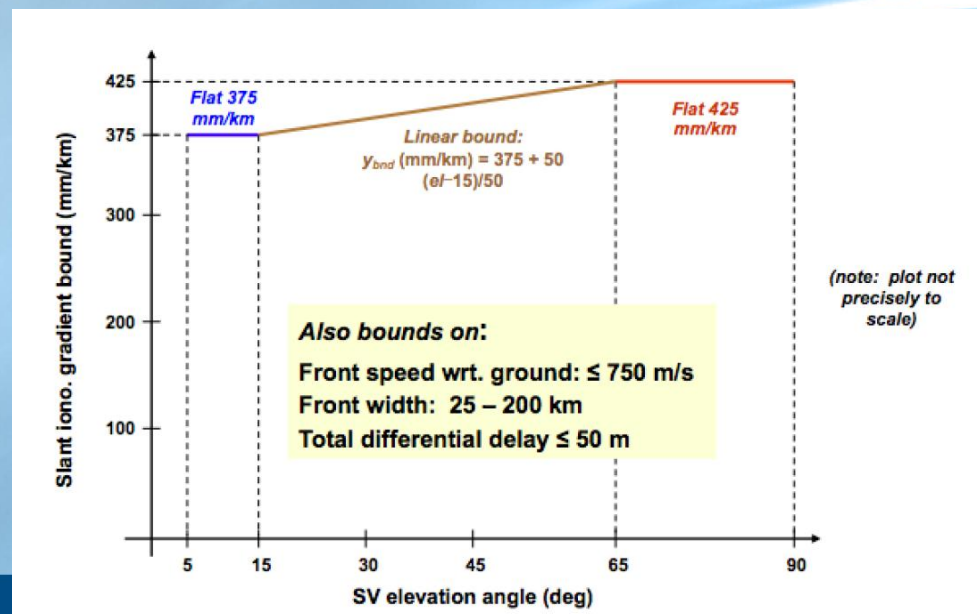
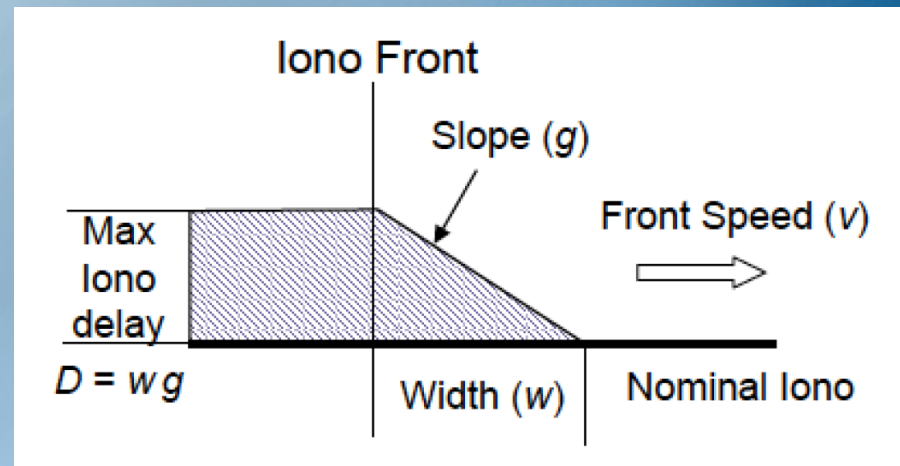
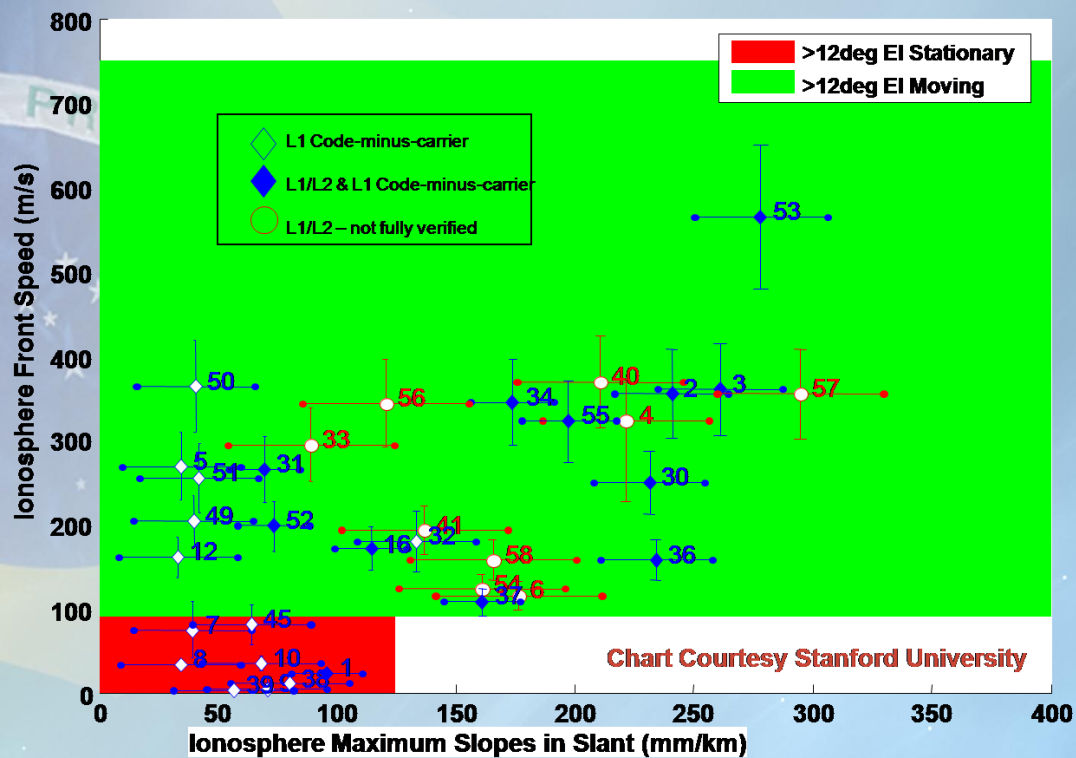
BRAZILIAN CONTINUOUS MONITORING NETWORK (RBMC)

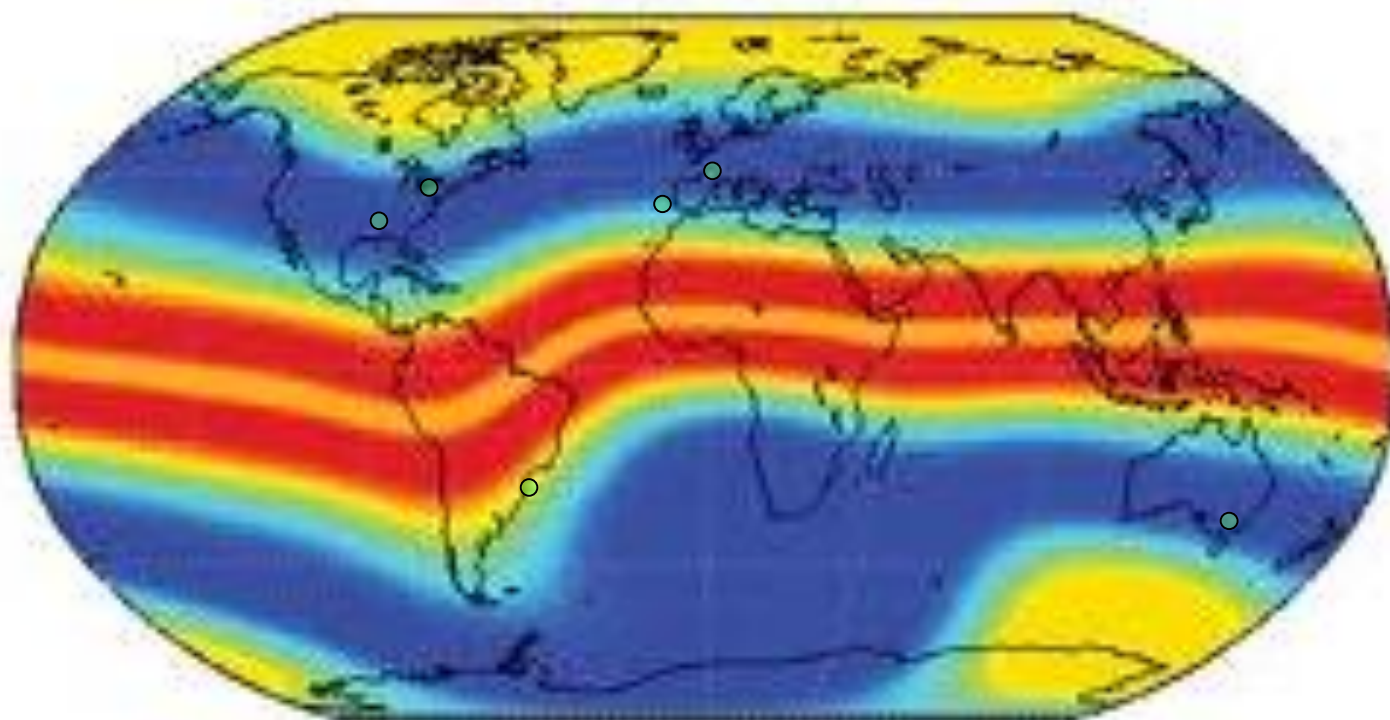


IONO DATA COLLECTION STATIONS



CONUS THREAT MODEL





Frequ X



Infrequent

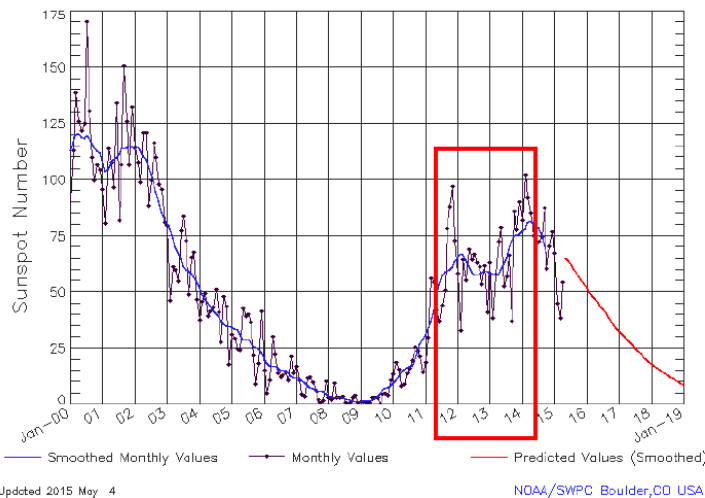
- Brehmen (Germany), Newark (USA), Houston (USA), Malaga (Spain), Sydney (Australia)



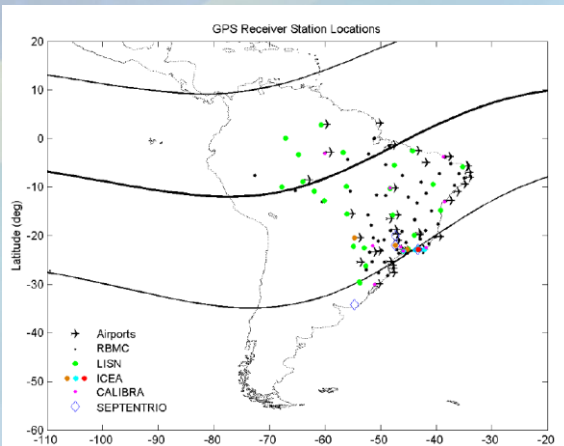
IONO Research



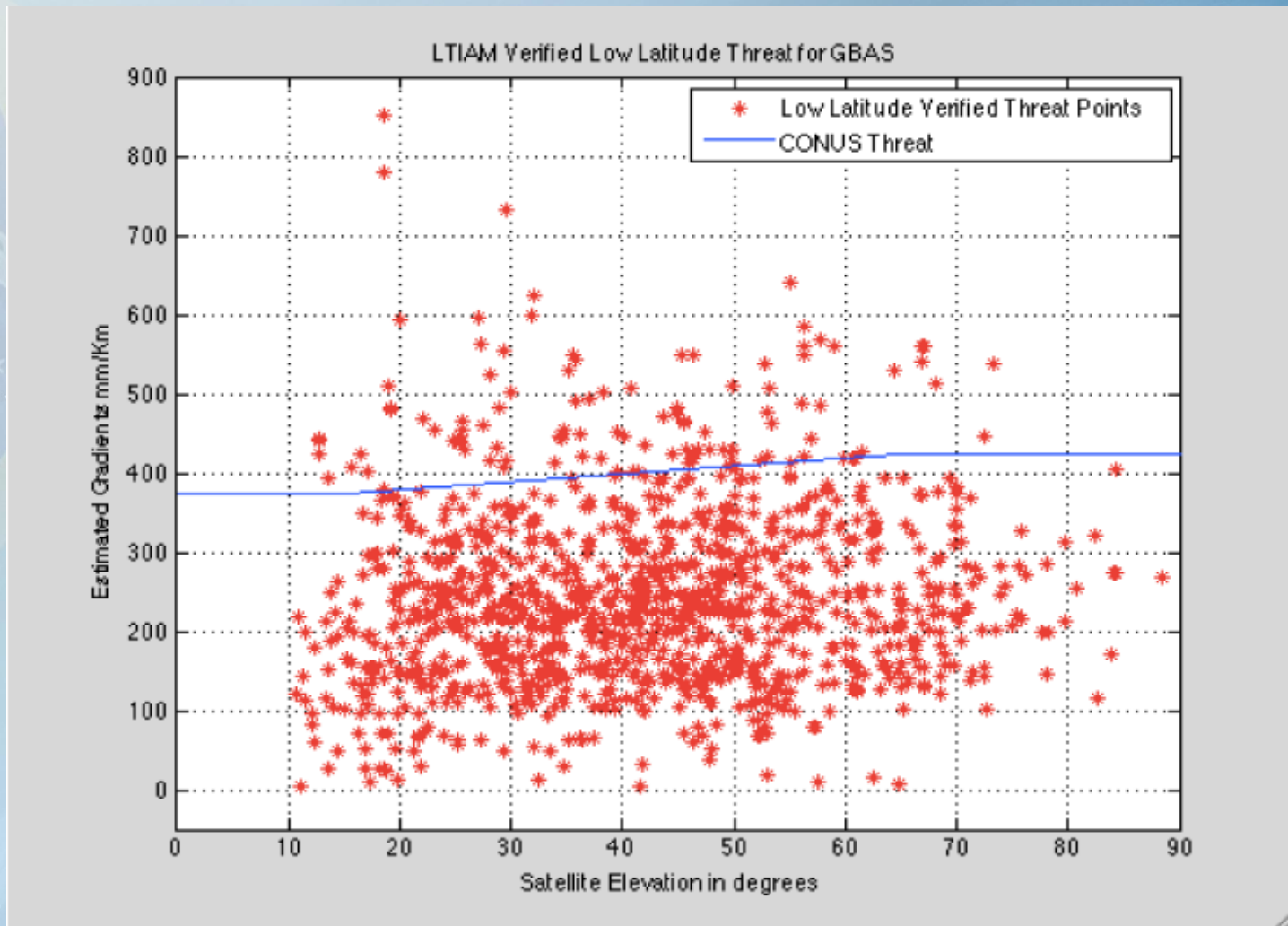
ISES Solar Cycle Sunspot Number Progression
Observed data through Apr 2015



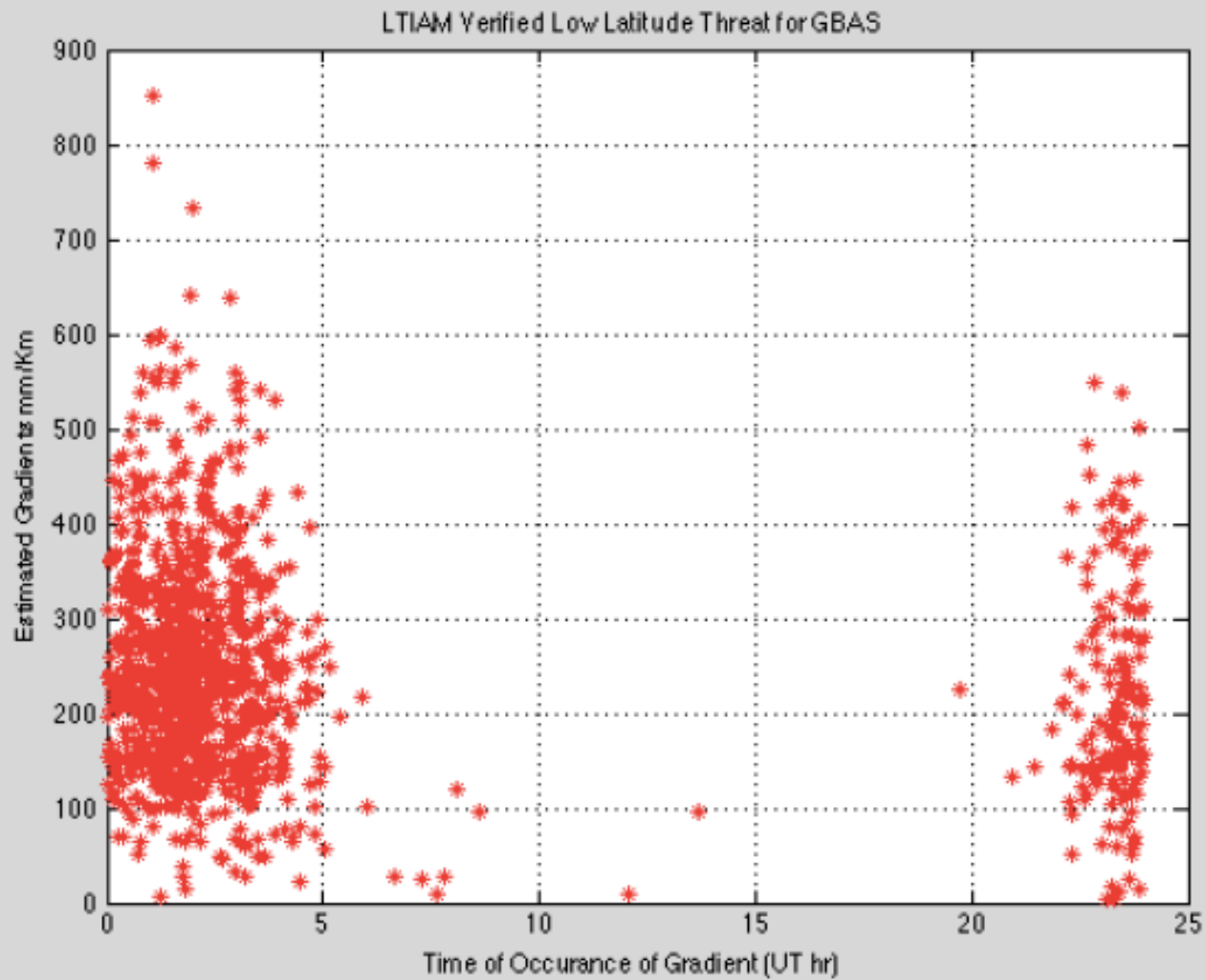
- ❑ Network – 180 receiver L1/L2 and scintillation
- ❑ 127 dates march 2011 / march 2014 (S4, Kp and Dst);
- ❑ Lowest cycle in 100 years (cycle 24);
- ❑ DECEA, ICEA, FAATC/NAVATAC, USTDA, Mirus Tech, SDTP, Stanford University, INPE, Boston College, UNESP, KAIST
- ❑ Final Report – march 2015.



IONO RESEARCH



IONO RESEARCH



CONCLUSIONS of RESEARCH



- ❑ The highest gradient identified exceeds 850 mm/km which far exceeds the events used to define the CONUS GBAS Threat Model.
- ❑ Ionospheric events in the low latitudes are greater in frequency and magnitude than those in the Northern Latitudes.
- ❑ The current threat model implemented in SLS-4000 installation at GIG does not comply with ICAO/FAA requirements for integrity or availability.



Flight Inspection



EMB110 / H-800XP / LEGACY 5000



Flight Inspection



MINISTÉRIO DA DEFESA
COMANDO DA AERONÁUTICA



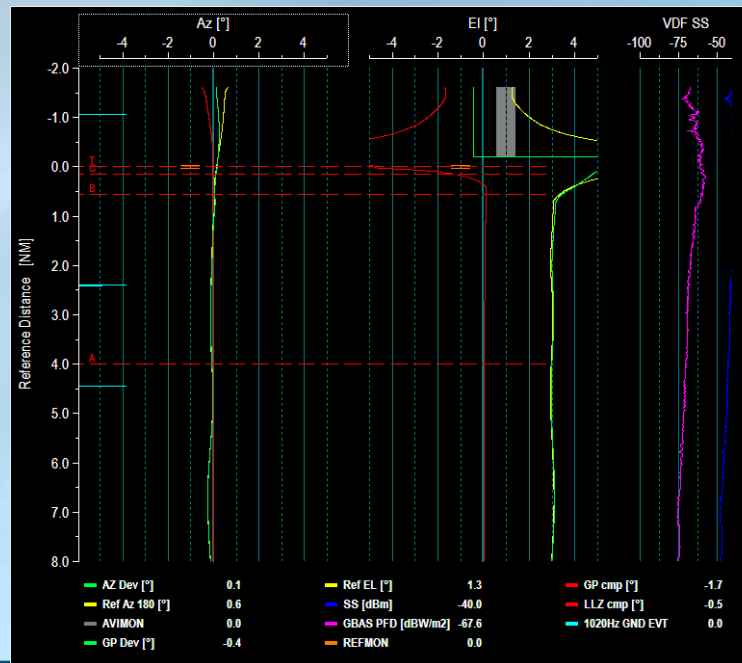
INSPEÇÃO EM VOO

MANINV-BRASIL

MANUAL BRASILEIRO DE INSPEÇÃO EM VOO

2014

	From Database	From Ground	Tolerance
FAS Data:	LTP Latitude: -22.8124301389 °	-22.8124298	Should match
	LTP Longitude: -43.2636948611 °	-43.2636946	Should match
	LTP Height: -0.4 m	-0.4	Should match
FPAP Data:	FPAP Latitude: -0.0166865	-0.0166865	Should match
	FPAP Longitude: 0.0252104167	0.0252104	Should match
Threshold Crossing Height:	61.0	61.0	Should match
Glide Path angle:	3.0	3.00	Should match
Course Width:	106.75	106.75	Should match



- MANINV-BRASIL (2014)
- GNLU-930 / GLU-925
- UNIFIS3000



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do Espaço Aéreo
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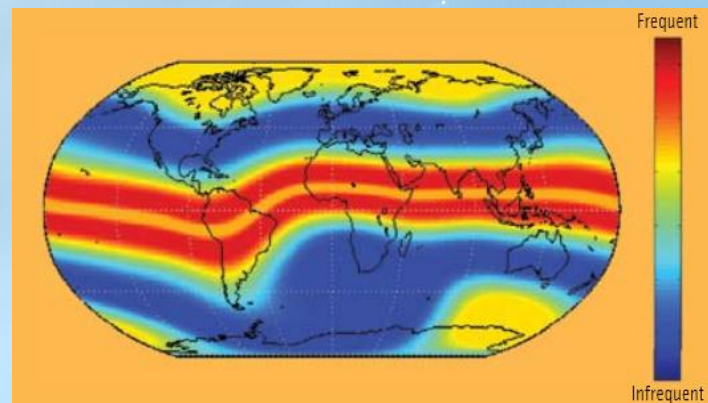
DEPARTMENT OF AIR SPACE CONTROL - DECEA



Remarks about GBAS CAT I (GAST C)



- Only Honeywell SLS-4000 certified for CAT I (Mid Latitudes)
 - DA within 6km (integrity)
 - VDB coverage
 - Block II – Iono improve (only for CONUS)
- Expensive receiver for general aviation
- Cost ILS x GBAS (CBA)
- Concurrent technologies



Concurrent technologies to GAST C



- GAST D (CAT II/III) – new receivers (SLS-5000)
- GBAS MF (L5) / MC (GLONASS, BEIDOU, GALILEO)
- SBAS LPV200 (WAAS, EGNOS) – Mid latitudes
- SBAS MF
- BARO VNAV
- RNP-AR



SBRJ



Concurrent technologies to GAST C

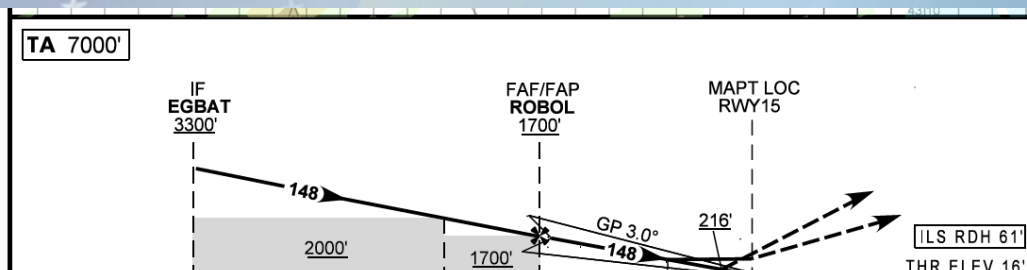


Concurrent technologies to GAST C



CARTA DE APROXIMAÇÃO POR INSTRUMENTOS (IAC) RIO DE JANEIRO / Galeão - Antônio Carlos Jobim, INTL (SBGL)
INSTRUMENT APPROACH CHART (IAC) **ILS W ou/ou LOC W RWY 15**

AD ELEV: 28'	ATIS 127.60	APP RIO 128.90 119.35 129.80 125.95 129.20 134.40 119.00 124.95 126.20 121.50	TWR GALEÃO 118.00 118.20 121.50	GNDC GALEÃO 121.35 121.65
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TO THR 15 (NM)	10.0	6.0	5.0	1.8	0.4	0.2	0.0	
TO IGL (DME)	11.8	7.8	6.8	3.6	2.2	2.0	1.8	

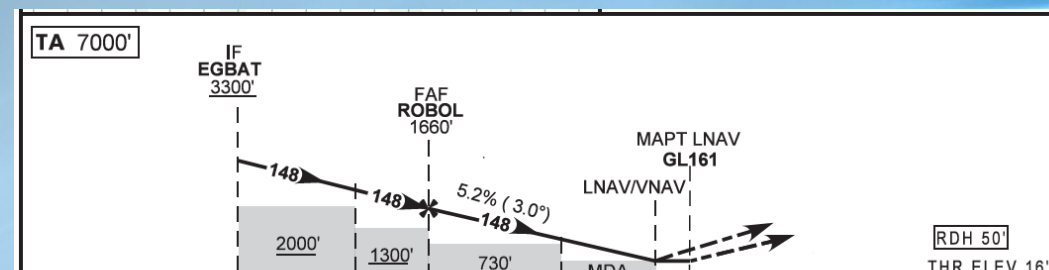
ROBOL	4.0	3.0	2.0	1.0	0.4	RWY15	KT	90	110	130	150	170	190
1700	1365	1040	717	396	216	ALT	FPM	500	600	700	800	900	1000
1684	1349	1024	701	380	200	(HGT)	FAF-MAPT	NIL					

POUSO DIRETO STRAIGHT-IN	CAT	A	B	C	D	E
CAT I	DA / OCH / TETO			216 / 200 / 200		
	ALS/NO ALS/ RVR ALS (m)			800 / 1200 / 700 (*)		
LOC	MDA / OCH / TETO			650 / 640 / 700		
	ALS/NO ALS/RVR ALS (m)		800 / 1600 / NIL		2200 / 2900 / NIL	
CIRCULAR TO CIRCLE	MDA / OCH / TETO	NA				
	VIS (m)					

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CARTA DE APROXIMAÇÃO POR INSTRUMENTOS (IAC) RIO DE JANEIRO / Galeão - Antônio Carlos Jobim, INTL (SBGL)
INSTRUMENT APPROACH CHART (IAC) **RNAV(GNSS) Y RWY 15**

AD ELEV: 28'	ATIS 127.60	APP RIO 126.20 133.30 134.40 121.25 129.80 125.95 128.90 119.35 121.50	TWR GALEÃO 118.00 118.20 121.50	GNDC GALEÃO 121.35 121.65
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TO THR 15 (NM)	10.0	6.1	5.0	2.2	1.0	0.9	0.0	
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ROBOL	4.0	3.0	2.0	1.0	RWY15	KT	090	110	130	150	170	190
1660	1340	1020	703	372	ALT	FPM	500	600	700	800	900	1000
1644	1324	1004	687	356	(HGT)	FAF-MAPT	NIL					

POUSO DIRETO STRAIGHT-IN	CAT	A	B	C	D	E
NAV / VNAV	DA / OCH / TETO			372 / 360 / 400		
	ALS/NO ALS/ RVR ALS (m)			900 / 1600 / NIL		
LNAV	MDA / OCH / TETO			380 / 370 / 400		
	ALS/NO ALS/RVR ALS (m)		800 / 1600 / NIL		1000 / 1700 / NIL	
CIRCULAR TO CIRCLE	MDA / OCH / TETO	NA				
	VIS (m)					

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SIRIUS Program



- ❑ March, 2012 (PCA 351-3);
- ❑ Aligned with the GANP and ASBU;
- ❑ Subprograms and projects CNS, ATM, MET, AIS, SAR
 - PFF 12 – Navigation Systems Upgrade (GBAS evaluation);
 - PFF 04 – Approach RNP Implementation (GBAS CAT I procedures).



Information available in http://www.decea.gov.br/novo_sirius/



CONCLUSION



- GBAS GAST C is operational in a few countries in mid latitudes but is still a challenge to low latitudes
- Since 2003 Brazil tests GBAS stations in SBGL and technology did not meet ICAO SARPs for availability and integrity
- Brazil continues in the effort to set SLS-4000 at SBGL operational for public use
- New Technologies are coming to challenge GBAS GAST C



Questions?



Rio 2016



Thank you Gracías Merci شكرا 谢谢

Obrigado!

santoroaas@decea.gov.br