

GLONASS e GALILEO: características



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GNSS - Histórico

- **Significado de GNSS:**

Global Navigation Satellite System

- **Sistema de posicionamento por satélites.**
- **Envolve todos os sistemas de navegação via satélite como por exemplo:**
 - **GPS**
 - **GLONASS**
 - **GALILEO**
 - **Etc...**



GLONASS - Rússia

Sistema de posicionamento por satélite similar ao sistema GPS americano.

GLONASS - GLObal NAvigation Satellite System



Características do Sistema GLONASS

- 1 relógio de césio embarcado
- Acurácia de 1000 nano-segundos
- Órbita circular = 19.100 km
- Inclinação da órbita = 64.8 graus
- Repetibilidade = 8 dias
- 3 planos orbitais
- Vida útil estimada em 1 a 2 anos par os primeiros satélites. A nova geração deve durar pelo menos 7 anos.

Características do Sistema GLONASS

- 1º bloco lançado em 1982
- Estrutura
 - 24 satélites
 - 3 planos orbitais
 - 64.8° de inclinação dos planos orbitais em relação ao plano do equador
 - 19100 km de altura acima da superfície da Terra

Características do Sistema GLONASS

- 2 portadoras com frequências distintas:

Frequências

L1 = 1602MHz

$\Delta f1 = 562.5\text{KHz}$

L2 = 1246MHz

$\Delta f2 = 437.5\text{KHz}$

cada satélites possui uma frequência diferente:

$$\mathbf{L1 = 1602MHz + n \ 0.5625MHz}$$

Onde n é o número correspondente ao satélite

■ 2 tipos de sinais:

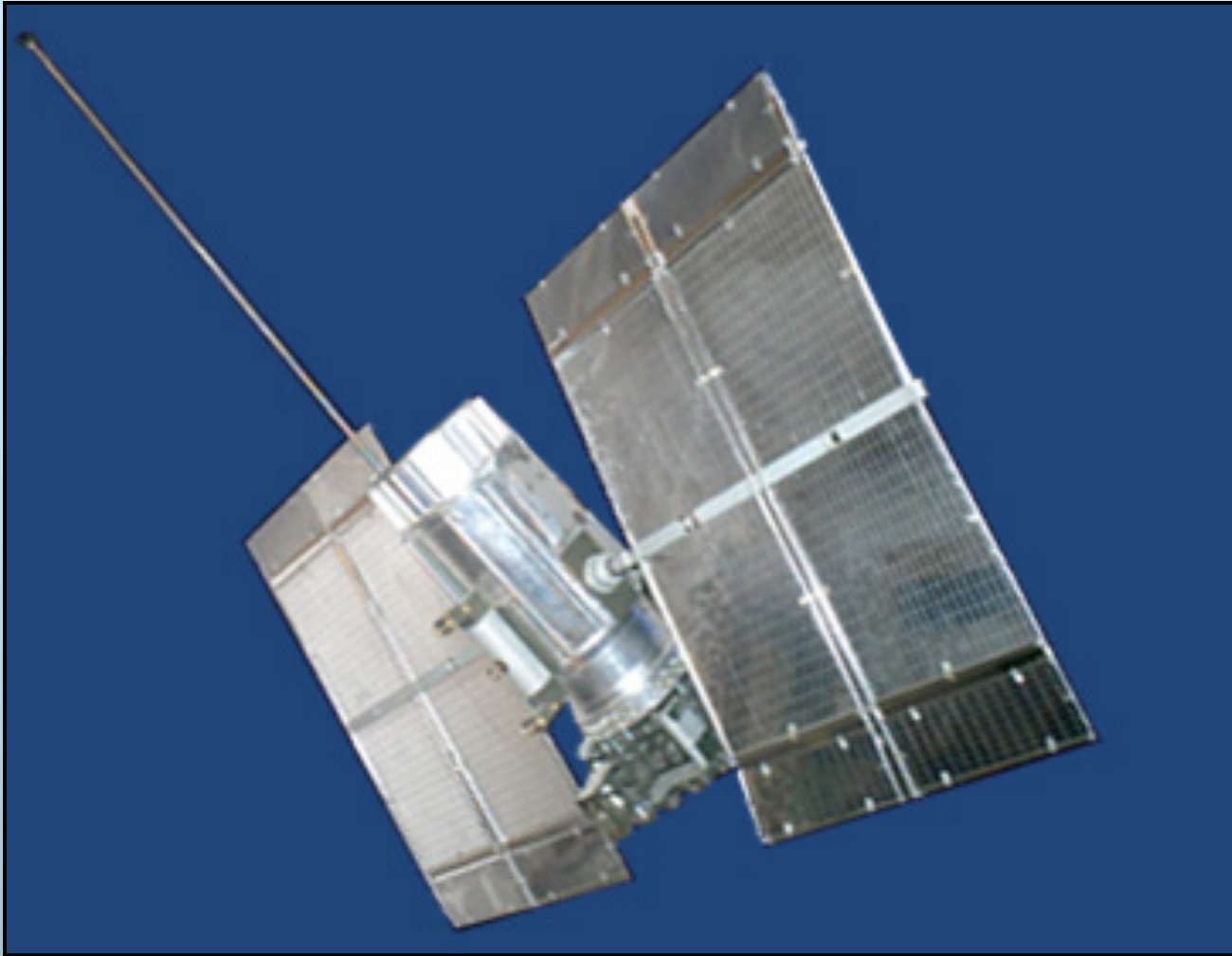
- Precisão padrão (SP) – disponível para uso civil

precisão de 57 a 70m horizontal (99,7%)

70 m vertical (99,7%)

- Alta precisão (HP) – uso militar

Vista de um satélite do sistema GLONASS



Status constelação Sistema GLONASS (atualizado em 23/0/2018) (Rússia)

Fonte: <https://www.glonass-iac.ru/en/GLONASS/>

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GLONASS CONSTELLATION STATUS, 23.04.2018

Total satellites in constellation	25 SC
Operational	23 SC
In commissioning phase	-
In maintenance	1 SC
Under check by the Satellite Prime Contractor	-
Spares	-
In flight tests phase	1 SC

GLONASS CONSTELLATION STATUS AT 23.04.2018 BASED ON BOTH THE ALMANAC ANALYSIS AND NAVIGATION MESSAGES RECEIVED AT 15:00 23.04.18 (UTC) IN IAC PNT TSNIMASH

Orb. slot	Orb. pl.	RF chnl	# GC	Launched	Operation begins	Operation ends	Life-time (months)	Satellite health status		Comments
								In almanac	In ephemeris (UTC)	
1	1	01	730	14.12.09	30.01.10		100.3	+	+ 15:31 23.04.18	In operation
2	1	-4	747	26.04.13	04.07.13		59.9	+	+ 15:31 23.04.18	In operation
3	1	05	744	04.11.11	08.12.11		77.7	+	+ 15:31 23.04.18	In operation
4	1	06	742	02.10.11	25.10.11		78.7	+	+ 15:31 23.04.18	In operation
5	1	01	734	14.12.09	10.01.10	19.04.18	100.3	-	- 15:31 23.04.18	Maintenance
6	1	-4	733	14.12.09	24.01.10		100.3	+	+ 15:31 23.04.18	In operation
7	1	05	745	04.11.11	18.12.11		77.7	+	+ 15:31 23.04.18	In operation
8	1	06	743	04.11.11	20.09.12		77.7	+	+ 15:31 23.04.18	In operation
9	2	-2	702	01.12.14	15.02.16		40.7	+	+ 15:31 23.04.18	In operation
10	2	-7	717	25.12.06	03.04.07		136.0	+	+ 15:31 23.04.18	In operation
11	2	00	753	29.05.16	27.06.16		22.8	+	+ 15:31 23.04.18	In operation
12	2	-1	723	25.12.07	22.01.08		124.0	+	+ 15:31 23.04.18	In operation
13	2	-2	721	25.12.07	08.02.08		124.0	+	+ 15:31 23.04.18	In operation
14	2	-7	752	22.09.17	16.10.17		7.0	+	+ 15:31 23.04.18	In operation
15	2	00	716	25.12.06	12.10.07		136.0	+	+ 15:31 23.04.18	In operation
16	2	-1	736	02.09.10	04.10.10		91.7	+	+ 15:31 23.04.18	In operation
17	3	04	751	07.02.16	28.02.16		26.5	+	+ 15:31 23.04.18	In operation
18	3	-3	754	24.03.14	14.04.14		49.0	+	+ 15:31 23.04.18	In operation
19	3	03	720	26.10.07	25.11.07		126.0	+	+ 15:31 23.04.18	In operation
20	3	02	719	26.10.07	27.11.07		126.0	+	+ 15:31 23.04.18	In operation
21	3	04	755	14.06.14	03.08.14		46.3	+	+ 15:31 23.04.18	In operation
22	3	-3	731	02.03.10	28.03.10		97.8	+	+ 15:31 23.04.18	In operation
23	3	03	732	02.03.10	28.03.10		97.8	+	+ 15:31 23.04.18	In operation
24	3	02	735	02.03.10	28.03.10		97.8	+	+ 15:31 23.04.18	In operation
20	3	-5	701	26.02.11			85.9			Flight Tests

GALILEO - Europa

Sistema de posicionamento por satélites desenvolvido pela Agência Espacial Europeia (ESA) e a Comunidade Europeia (UE).

Galileo - European Satellite Navigation System



Características do Sistema GALILEO

- Em fase de Validação (Início de Operação previsto inicialmente para 2008) – (agora a previsão é para 2018 – 2020)
- O primeiro satélite GIOVE-A foi lançado em 28 dezembro de 2005
- O segundo satélite GIOVE-B foi lançado em 27 de abril de 2008

Características do Sistema GALILEO

Estrutura

- 30 satélites
- 3 planos orbitais
- Inclinação da órbita = 56 graus
- Altitude da órbita = 23222 km
- Poderá transmitir até 4/5 frequências da banda L (em fase final de definição)

Características do Sistema GALILEO

■ 3 portadoras com frequências distintas:

E5 = 1164 – 1215 MHz

E6 = 1260 – 1300 MHz

L1 = 1559 – 1593 MHz

■ Tipos de Serviços:

- SERVIÇO ABERTO (OS)
- SERVIÇO DE SEGURANÇA DA VIDA (SoL)
- SERVIÇO COMERCIAL (CS)
- SERVIÇO REGULADO AO PÚBLICO (PRS)
- SERVIÇO DE PROCURA E RESGATE (SAR)

Sistema GALILEO - Status constelação

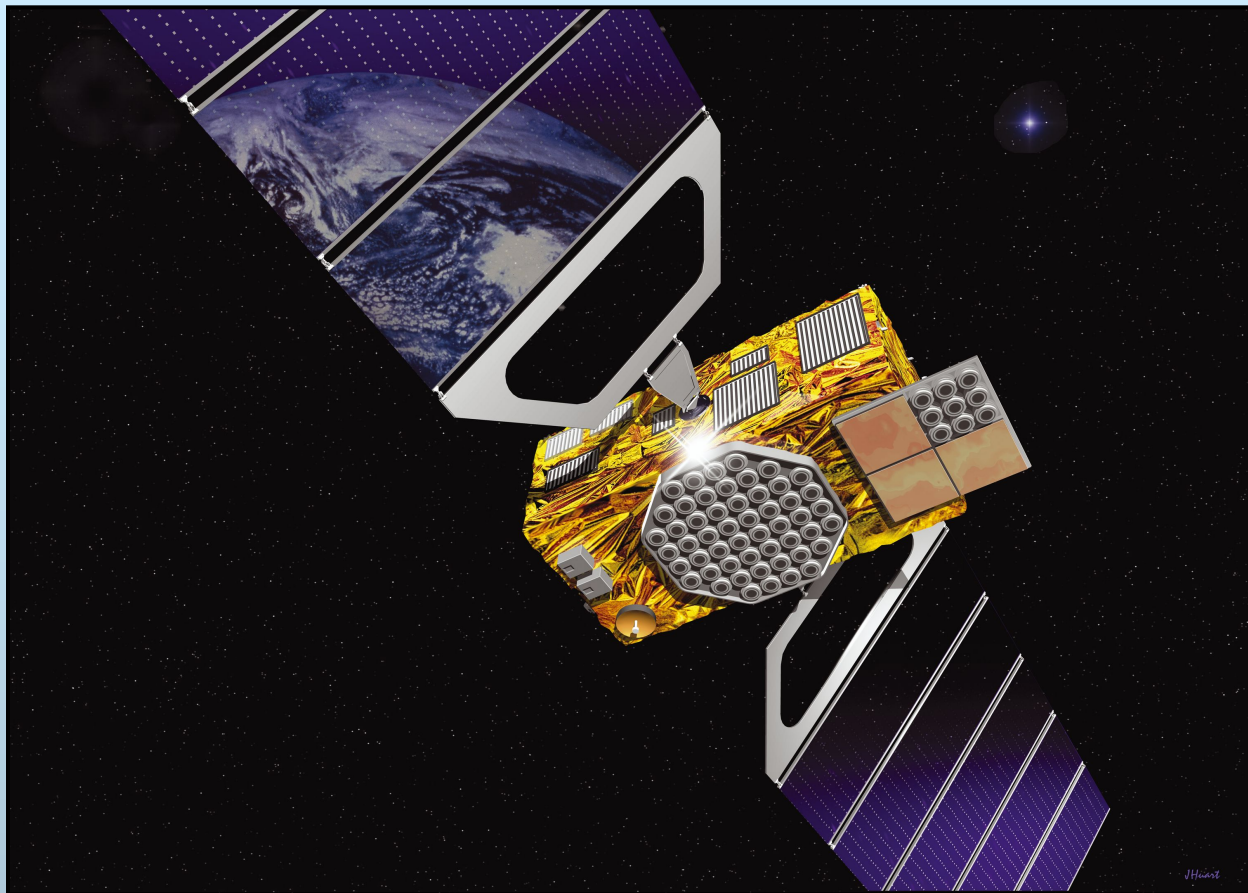
(Atualizado em 23/04/2018)

Satellites

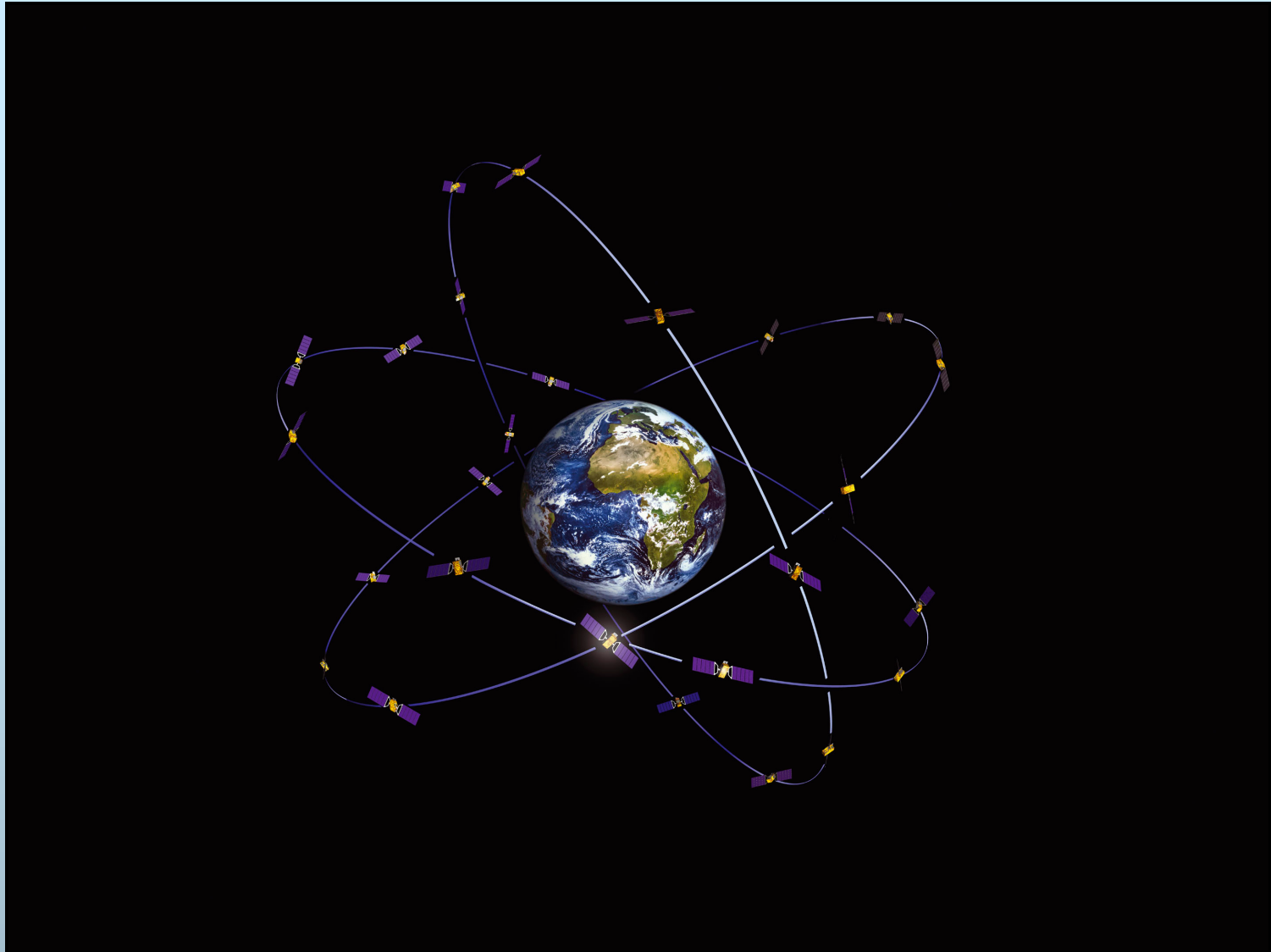
Common Name	SVN	Int. Sat. ID	NORAD ID	PRN	Notes
IOV-1, Galileo PFM	E101	2011-060A	37846	E11	Slot B05
IOV-2, Galileo FM2	E102	2011-060B	37847	E12	Slot B06
IOV-3, Galileo FM3	E103	2012-055A	38857	E19	Slot C04
IOV-4, Galileo FM4	E104	2012-055B	38858	E20	Slot C05
FOC-1	E201	2014-050A	40128	E18	Orbit injection failure (i=49.7° e=0.23)
FOC-2	E202	2014-050B	40129	E14	Orbit injection failure (i=49.7° e=0.23)
FOC-3	E203	2015-017A	40544	E26	Slot B08
FOC-4	E204	2015-017B	40545	E22	Slot B03
FOC-5	E205	2015-045A	40889	E24	Slot A08
FOC-6	E206	2015-045B	40890	E30	Slot A05
FOC-8	E208	2015-079B	41174	E08	Slot C07
FOC-9	E209	2015-079A	41175	E09	Slot C02
FOC-10	E210	2016-030B	41550	E01	Slot A02
FOC-11	E211	2016-030A	41549	E02	Slot A06
FOC-7	E207	2016-069A	41859	E07	Slot C06
FOC-12	E212	2016-069B	41860	E03	Slot C08
FOC-13	E213	2016-069C	41861	E04	Slot C03
FOC-14	E214	2016-069D	41862	E05	Slot C01
FOC-15	E215	2017-079A	43055	E21	Slot A03
FOC-16	E216	2017-079B	43056	E25	Slot A07
FOC-17	E217	2017-079C	43057	E27	Slot A04
FOC-18	E218	2017-079D	43058	E31	Slot A01

Fonte: http://mgex.igs.org/IGS_MGEX_Status_GAL.php

Vista artística de um satélite do sistema Galileo

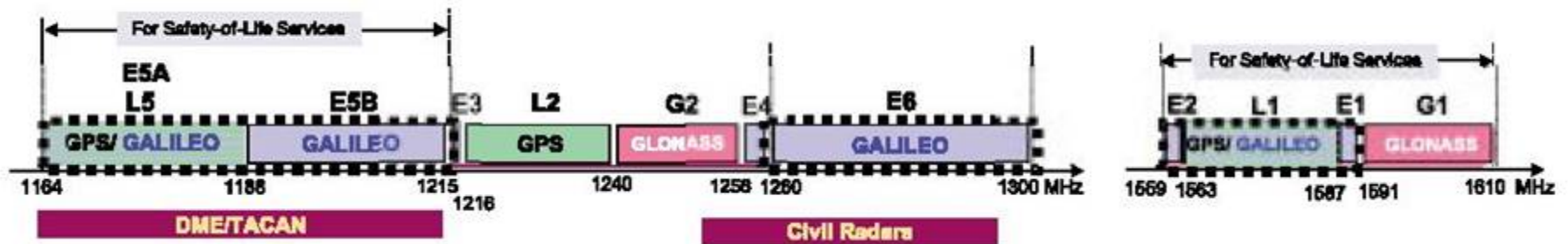


Concepção da Constelação do Sistema Galileo



Bandas de frequências dos sinais GNSS

GPS / GLONASS / GALILEO



Há ainda os seguintes sistemas:

- BeiDou - Navigation Satellite System (BDS) / China (atualizado em 23/04/2018)

BEIDOU CONSTELLATION STATUS 23.04.18						
Total satellites in constellation					28	
SV is included in operational orbital constellation					15	
SV is not included in operational orbital constellation					13	
BEIDOU CONSTELLATION STATUS 23.04.18						
Satellite Number	NORAD	Satellite Name	Type of sistem	Launch date	Life-time (months)	Notes
C01	36287	GE001	BeiDou-2	17.01.10	3018	In operation
C02	38953	GE006	BeiDou-2	25.10.12	2006	In operation
C03	36590	GE003	BeiDou-2	02.06.10	2882	In operation
C04	37210	GE004	BeiDou-2	01.11.10	2730	In operation
C05	38091	GE005	BeiDou-2	25.02.12	2249	In operation
C06	36828	IGS001	BeiDou-2	01.08.10	2822	In operation
C07	37256	IGS002	BeiDou-2	18.12.10	2683	In operation
C08	37384	IGS003	BeiDou-2	10.04.11	2570	In operation
C09	37763	IGS004	BeiDou-2	27.07.11	2462	In operation
C10	37948	IGS005	BeiDou-2	02.12.11	2334	In operation
C11	38250	ME003	BeiDou-2	30.04.12	2184	In operation
C12	38251	ME004	BeiDou-2	30.04.12	2184	In operation
C13	38774	IGS006	BeiDou-2	30.03.16	754	In operation
C14	38775	ME006	BeiDou-2	19.09.12	2042	In operation
C17	41586	GE007	BeiDou-2	12.06.16	680	In operation
C31	40549	IGS001-S	BeiDou-3	30.03.15	1120	Not in operational orbital constellation
C32	40938	IGS002-S	BeiDou-3	30.09.15	936	Not in operational orbital constellation
C33	40748	ME001-S	BeiDou-3	25.07.15	1003	Not in operational orbital constellation
C34	40749	ME002-S	BeiDou-3	25.07.15	1003	Not in operational orbital constellation
C35	41315	ME003-S	BeiDou-3	01.02.16	812	Not in operational orbital constellation
C19	43001	ME001	BeiDou-3	05.11.17	169	Not in operational orbital constellation
C20	43002	ME002	BeiDou-3	05.11.17	169	Not in operational orbital constellation
C21	43207	ME003	BeiDou-3	12.02.18	70	Not in operational orbital constellation
C22	43208	ME004	BeiDou-3	12.02.18	70	Not in operational orbital constellation
C27	43107	ME007	BeiDou-3	12.01.18	101	Not in operational orbital constellation
C28	43108	ME008	BeiDou-3	12.01.18	101	Not in operational orbital constellation
C29	43245	ME009	BeiDou-3	30.03.18	24	Not in operational orbital constellation
C30	43246	ME010	BeiDou-3	30.03.18	24	Not in operational orbital constellation

Há ainda os seguintes sistemas:

- NAVIC – Navigation with Indian Constellation/ Índia
- (atualizado em 23/04/2018)

NAVIC

This page provides an overview of the [Satellites](#) in the "Navigation with Indian Constellation" (NAVIC), formerly known as the Indian Regional Navigation Satellite System (IRNSS). Technical parameters of the individual satellites and related conventions applied within the MGEX project are summarized in the [Spacecraft Characteristics](#) section. Furthermore, a list of [Events](#) of interest for the NAVIC data processing are given.

Satellites

The Navigation with Indian Constellation (NAVIC) comprises 3 geostationary (GEO) satellites located at 34°E, 83°E and 129.5°E as well as two pairs of satellites in inclined geosynchronous orbit (IGSO) with their ascending nodes at 55°E and 111.75°E and an inclination of 29°.

Common Name	SVN	Int. Sat. ID	NORAD ID	PRN	Notes
IRNSS-1A	I001	2013-034A	39199	I01	IGSO 55°E; launched 1 July 2013
IRNSS-1B	I002	2014-017A	39635	I02	IGSO 55°E; launched 4 April 2014
IRNSS-1C	I003	2014-061A	40269	I03	GEO 83°E; launched 15 Oct. 2014
IRNSS-1D	I004	2015-018A	40547	I04	IGSO 111.75°E; launched 8 Mar. 2015
IRNSS-1E	I005	2016-003A	41241	I05	IGSO 111.75°E; launched 20 Jan. 2016
IRNSS-1F	I006	2016-015A	41384	I06	GEO 32.5°E; launched 10 Mar. 2016
IRNSS-1G	I007	2016-027A	41469	I07	GEO 129.5°E; launched 28 Apr. 2016
IRNSS-1I	I009	2018-035A	43286	I0?	IGSO ???°E; launched 11 Apr. 2018

Há ainda os seguintes sistemas:

- QZSS / Japão
 - com 4 satélite já lançado (atualizado em 23/04/2018)

Satellites

The Quasi-Zenith Satellite System (QZSS) currently comprises three satellites in an inclined geo-synchronous orbit and one satellite in geo-stationary orbit.

Common Name	SVN	Int. Sat. ID	NORAD ID	PRN	Notes
QZS-1 (Michibiki)	J001	2010-045A	37158	J01	launched 2010/09/11
QZS-2 (Michibiki-2)	J002	2017-028A	42738	J02	launched 2017/06/01
QZS-3 (Michibiki-3)	J003	2017-048A	42917	J07	launched 2017/08/19
QZS-4 (Michibiki-4)	J004	2017-062A	42965	J03	launched 2017/10/09

Há ainda os seguintes sistemas:

• SBAS – Satellite Based Augmentation Systems (atualizado em 23/04/2018)

- EGNOS,
- WAAS,
- GAGAN,
- MSAS,
- Etc...

System	Common Name	Long.	Int. Sat. ID	NORAD ID	PRN	Signals	Notes
EGNOS	Inmarsat 3-F2 (AOR-E)	15.5°W	1996-053A	24307	120	L1	Inmarsat 3-F2 began Safety-of-Life Service on March 2, 2011, and is transmitting message type 2.
	SES-5 (Sirius-5, Astra-4B)	5°E	2012-036A	38652	136	L1/L5	Launched 2012/07/10, operational since Sep. 02, 2015.
	Astra-5B	31.5°E	2014-011B	39617	123	L1/L5	Launched March 22, 2014. Transmission of L1 test signals started Dec. 11, 2014.
GAGAN	GSAT-8	55°E	2011-022A	37605	127	L1/L5	Launched May 20, 2011. Certified horizontal/vertical service since Feb. 2014/April 2015.
	GSAT-10	83°E	2012-051B	38779	128	L1/L5	Launched Sep. 28, 2012. Certified horizontal/vertical service since Feb. 2014/April 2015.
GATBP	Inmarsat 4-F1 (PAC-W)	143.5°E	2005-009A	28628	122	L1/L5	Transmitting message type 0; not for safety-of-life use. L1 transmissions began May 31, 2017.
MSAS	MTSAT-1R	140°E	2005-006A	28622	129	L1	MSAS commissioned for aviation use on September 27, 2007. Either satellite can transmit both PRN signals if necessary.
	MTSAT-2	145°E	2006-004A	28937	137	L1	MSAS commissioned for aviation use on September 27, 2007. Either satellite can transmit both PRN signals if necessary.
NSAS	NigComSat-1R	42°E	2011-077A	38014	147	L1/L5	L1 tests
QZSS	QZS-1	137.5°E	2010-045A	37158	183	L1	See QZSS Status Page
	QZS-2	136°E	2017-028A	42738	184/196	L1/L5	See QZSS Status Page
	QZS-3	127°E	2017-048A	42917	189/197	L1/L5	See QZSS Status Page
	QZS-4	136°E	2017-062A	42965	185/200	L1/L5	See QZSS Status Page
SDCM	Luch-5A	167°E	2011-074B	37951	140	L1	Launched on December 11, 2011. Initially positioned at 58.5°E, it was shifted to 95°E between about May 30 and June 28, 2012, then shifted 167°E between about Nov. 30 and Dec. 22, 2012. Transmissions as PRN 140 began on July 12, 2012. Transmitted occasional, non-coherent code/carrier test signals.
	Luch-5B	16°W	2014-023A	39727	141	L1	Launched April 28, 2014. Testing may have started using PRN 140, not 141.
	Luch-5V	16°W	2012-061A	38977	125	L1	Launched Nov. 2, 2012, and started transmitting signals on Jan. 17, 2013.
WAAS	TeleSat Anik F1R (CRE)	107.3°W	2005-036A	28868	138	L1/L5	Anik F1R ranging supports enroute through precision approach modes. The payload, operated by Lockheed Martin for the FAA, is known as LMPRS-2.
	Intelsat Galaxy 15 (CRW)	133°W	2005-041A	28884	135	L1/L5	Galaxy 15 ranging supports enroute through precision approach modes. Switched to backup satellite oscillator on Jan. 6, 2012. The payload, operated by Lockheed Martin for the FAA, is known as LMPRS-1.
	EUTELSAT 117W B	117°W	2016-038B	41589	131	L1/L5	Not yet approved for operational use

Status constelação Sistema GPS (Atualizado em 23/04/2018) (USA)

GPS CONSTELLATION STATUS, 23.04.18

Total satellites in constellation	32 SC
Operational	31 SC
In commissioning phase	-
In maintenance	1 SC
In decommissioning phase	-

GPS CONSTELLATION STATUS FOR 23.04.18 UNDER THE ANALYSIS OF THE ALMANAC ACCEPTED IN IAC

Plane	Slot	PRN	NORAD	Type SC	Launch date	Input date	Outage date	Life-time (months)	Notes
A	1	24	38833	II-F	04.10.12	14.11.12		65.3	
	2	31	29486	IIR-M	25.09.06	13.10.06		138.4	
	3	30	39533	II-F	21.02.14	30.05.14		46.8	
	4	7	32711	IIR-M	15.03.08	24.03.08		121.1	
B	1	16	27663	II-R	29.01.03	18.02.03		182.2	
	2	25	36585	II-F	28.05.10	27.08.10		91.9	
	3	28	26407	II-R	16.07.00	17.08.00		212.3	
	4	12	29601	IIR-M	17.11.06	13.12.06		136.4	
	5	26	40534	II-F	25.03.15	20.04.15		36.1	
	6		34661	IIR-M	24.03.09				
C	1	29	32384	IIR-M	20.12.07	02.01.08		123.7	
	2	27	39166	II-F	15.05.13	21.06.13		58.1	
	3	8	40730	II-F	15.07.15	12.08.15		32.4	
	4	17	28874	IIR-M	26.09.05	13.11.05		149.4	
	5	19	28190	II-R	20.03.04	05.04.04		168.7	
D	1	2	28474	II-R	06.11.04	22.11.04		161.1	
	2	1	37753	II-F	16.07.11	14.10.11		78.3	
	3	21	27704	II-R	31.03.03	12.04.03		180.5	
	4	6	39741	II-F	17.05.14	10.06.14		46.5	
	5	11	25933	II-R	07.10.99	03.01.00		219.8	
	6	18	22877	II-A	26.10.93	22.11.93		293.2	
E	1	3	40294	II-F	29.10.14	12.12.14		40.4	
	2	10	41019	II-F	30.10.15	09.12.15		28.5	
	3	5	35752	IIR-M	17.08.09	27.08.09		103.9	
	4	20	26360	II-R	11.05.00	01.06.00		214.8	
	6	22	28129	II-R	21.12.03	12.01.04		171.5	
F	1	32	41328	II-F	05.02.16	09.03.16		25.5	
	2	15	32260	IIR-M	17.10.07	31.10.07		125.8	
	3	9	40105	II-F	02.08.14	17.09.14		43.2	
	4	23	28361	II-R	23.06.04	09.07.04		165.6	
	5	14	26605	II-R	10.11.00	10.12.00		208.5	
	6	13	24876	II-R	23.07.97	31.01.98		242.9	

Fonte: <https://www.glonass-iac.ru/en/GPS/>



Saiba mais ...



Órbitas precisas: <http://igscb.jpl.nasa.gov>

Informações sobre GPS: <http://tycho.usno.navy.mil/gps.html>

GALILEO home-page: www.galileo-pgm.org

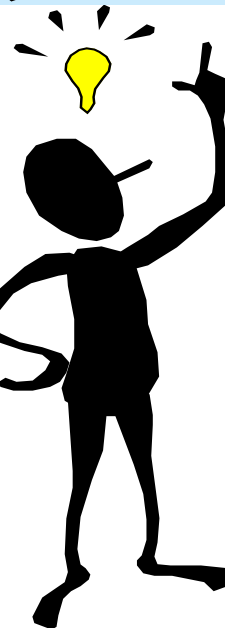
GLONASS home-page: http://www.glonass-center.ru/frame_e.html

PMRG/IBGE: <http://www.ibge.gov.br/home/geografia/geodesico/srg/>

Projeto SIRGAS: <http://www1.ibge.gov.br/home/geografia/geodesico/sirgas/principal.htm>

Dados da RBMC: <http://www.ibge.gov.br/home/geografia/geodesico/rbmcpesq.shtm>

Rede GPS do Estado de São Paulo: <http://www.ptr.poli.usp.br/lgt/proj/RedeSP/Rede-SP.htm>





Dúvidas ?

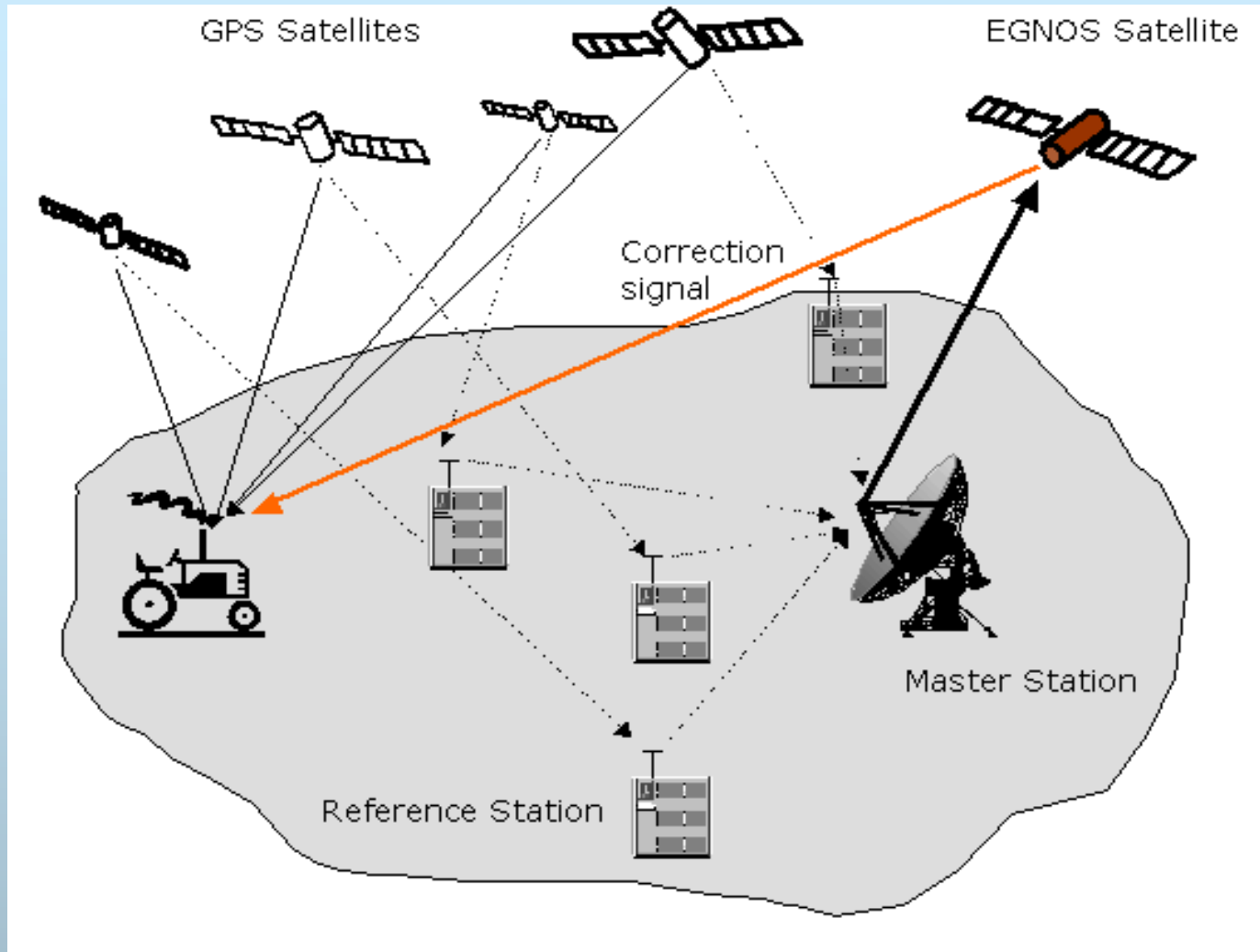
Perguntas ?



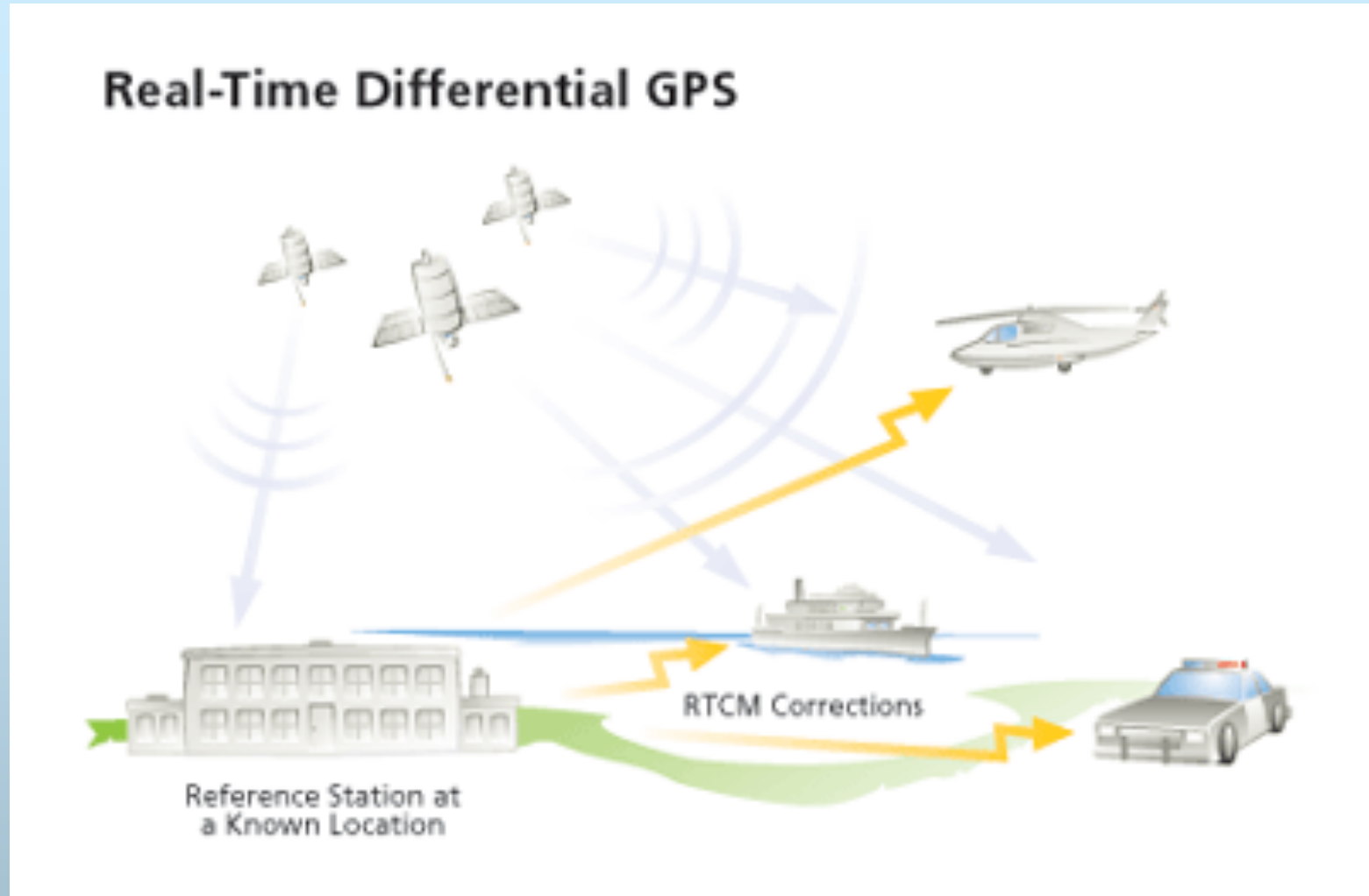
Efeitos que afetam o posicionamento por satélites

- ◆ Ionosfera $\pm 5\text{m}$
- ◆ Erro nas efemérides $\pm 2.5\text{m}$
- ◆ Deriva relógio satélites $\pm 2\text{m}$
- ◆ Multicaminho $\pm 1\text{m}$
- ◆ Troposfera $\pm 0.5\text{m}$
- ◆ Erros Numéricos $\pm 1\text{m}$ ou menos

Esquema com o princípio do posicionamento preciso



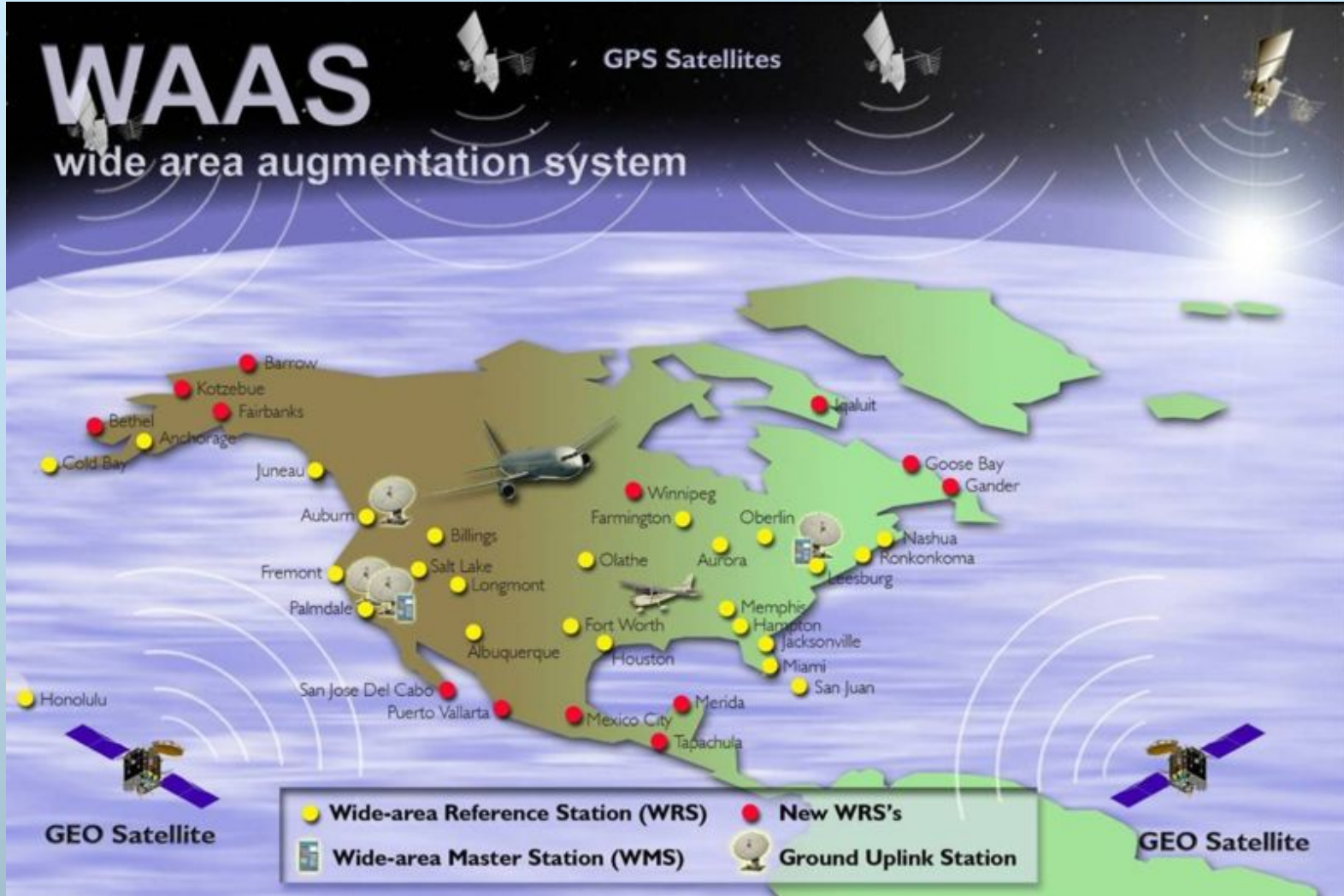
Esquema de rede para DGPS



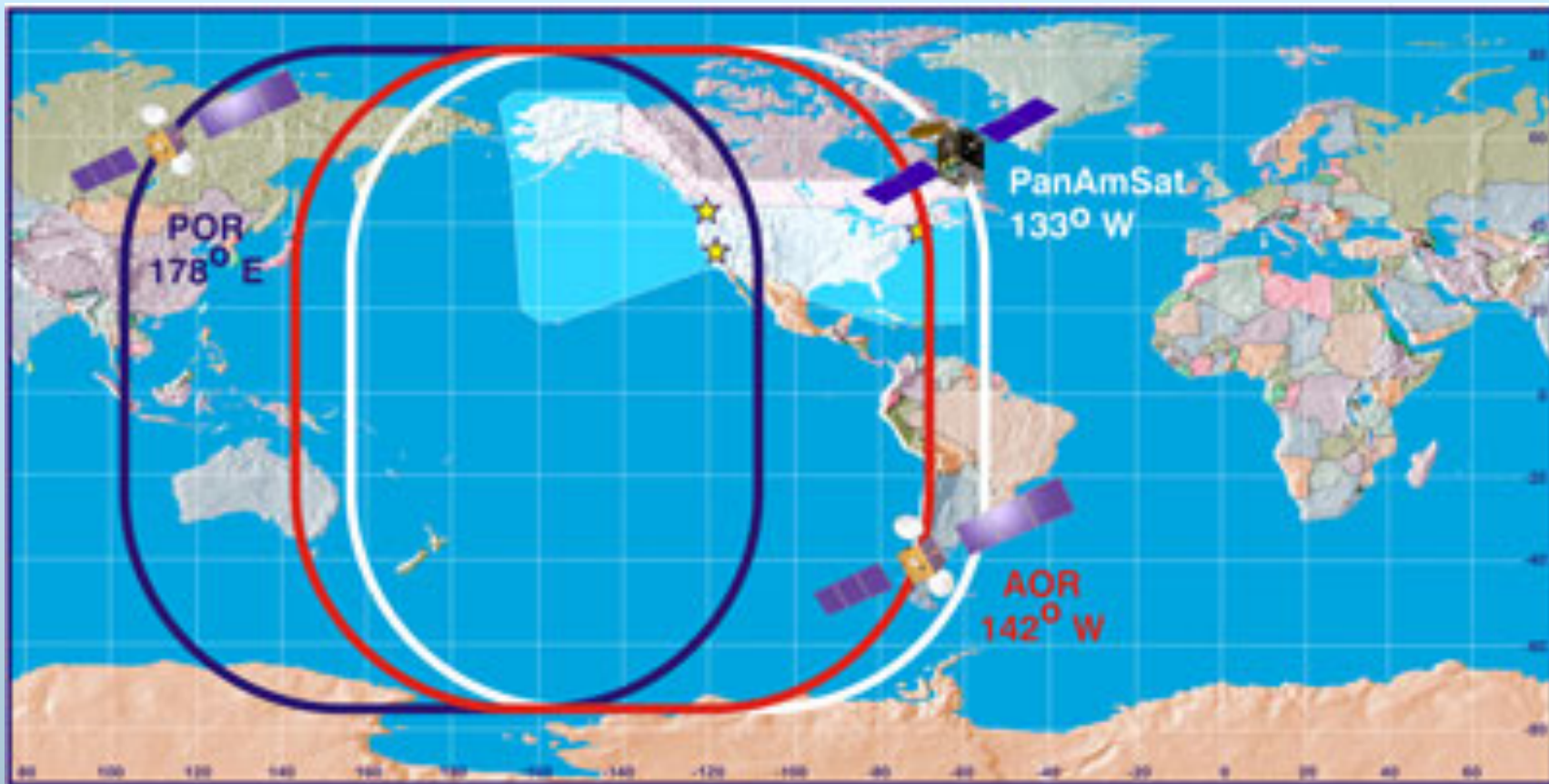
CDGPS - Canadá



Esquema da rede WAAS - USA



Cobertura WAAS



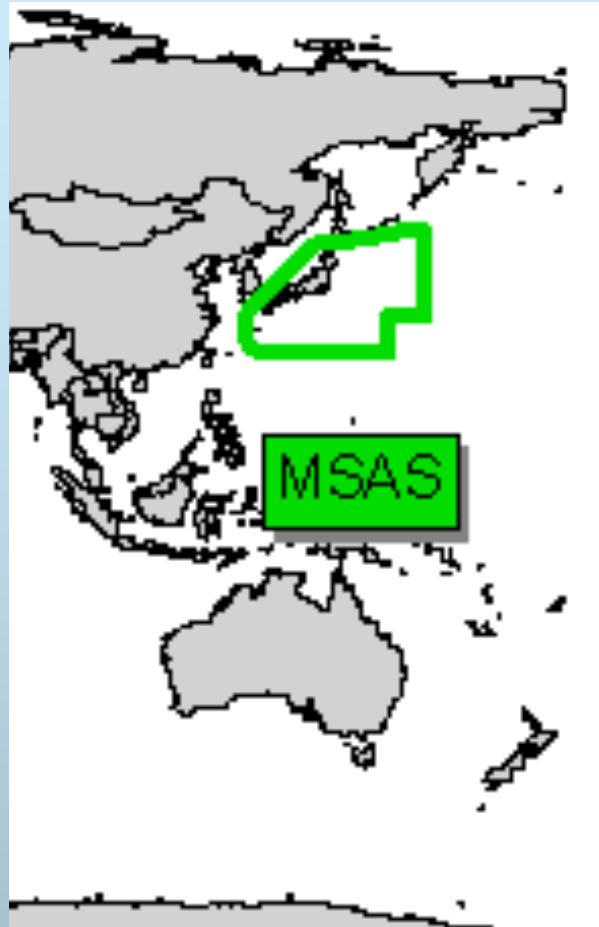
EGNOS – Europa

European Geostationary Navigation Overlay Service

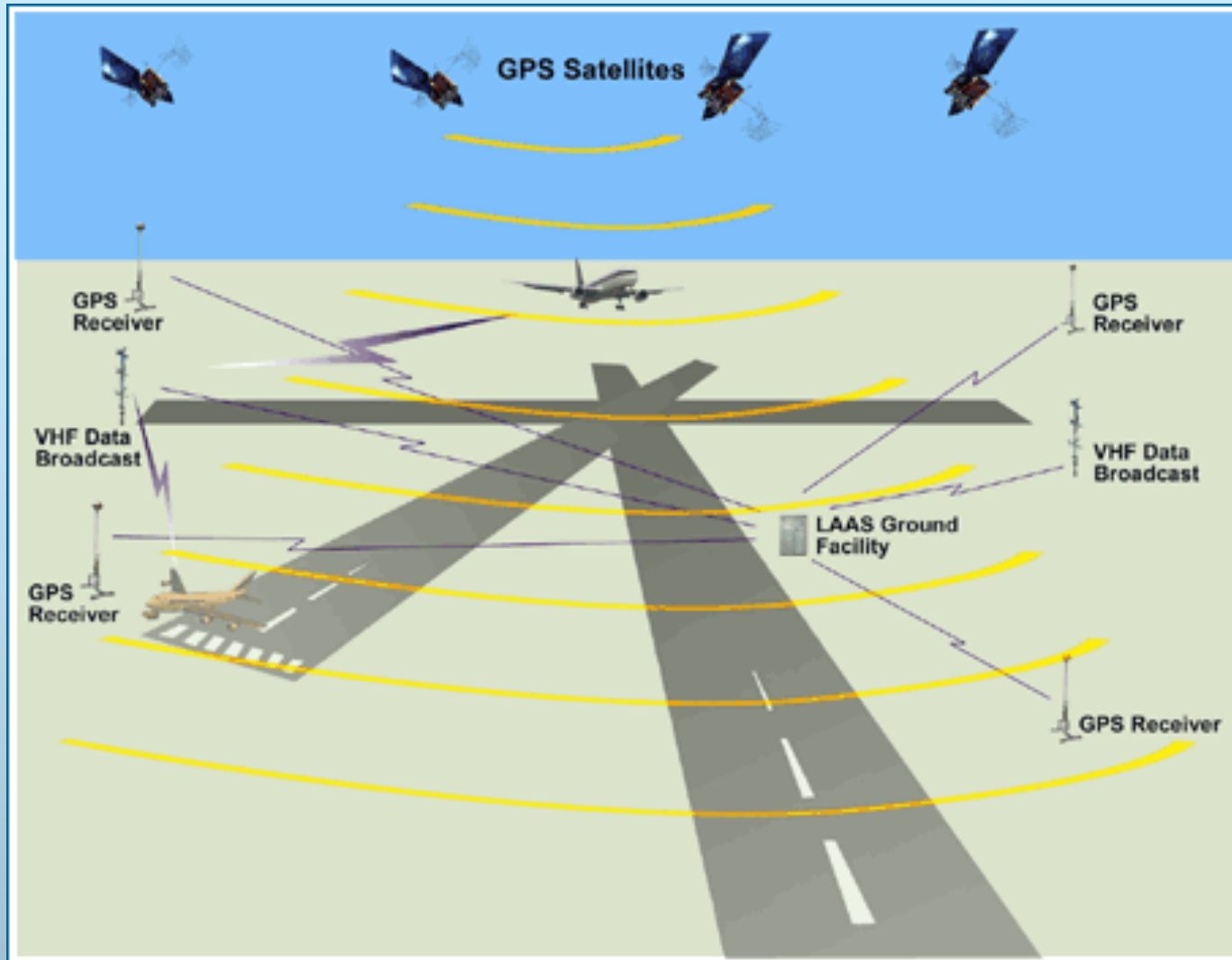


MSAS - Japão

MTSAT Satellite based Augmentation System

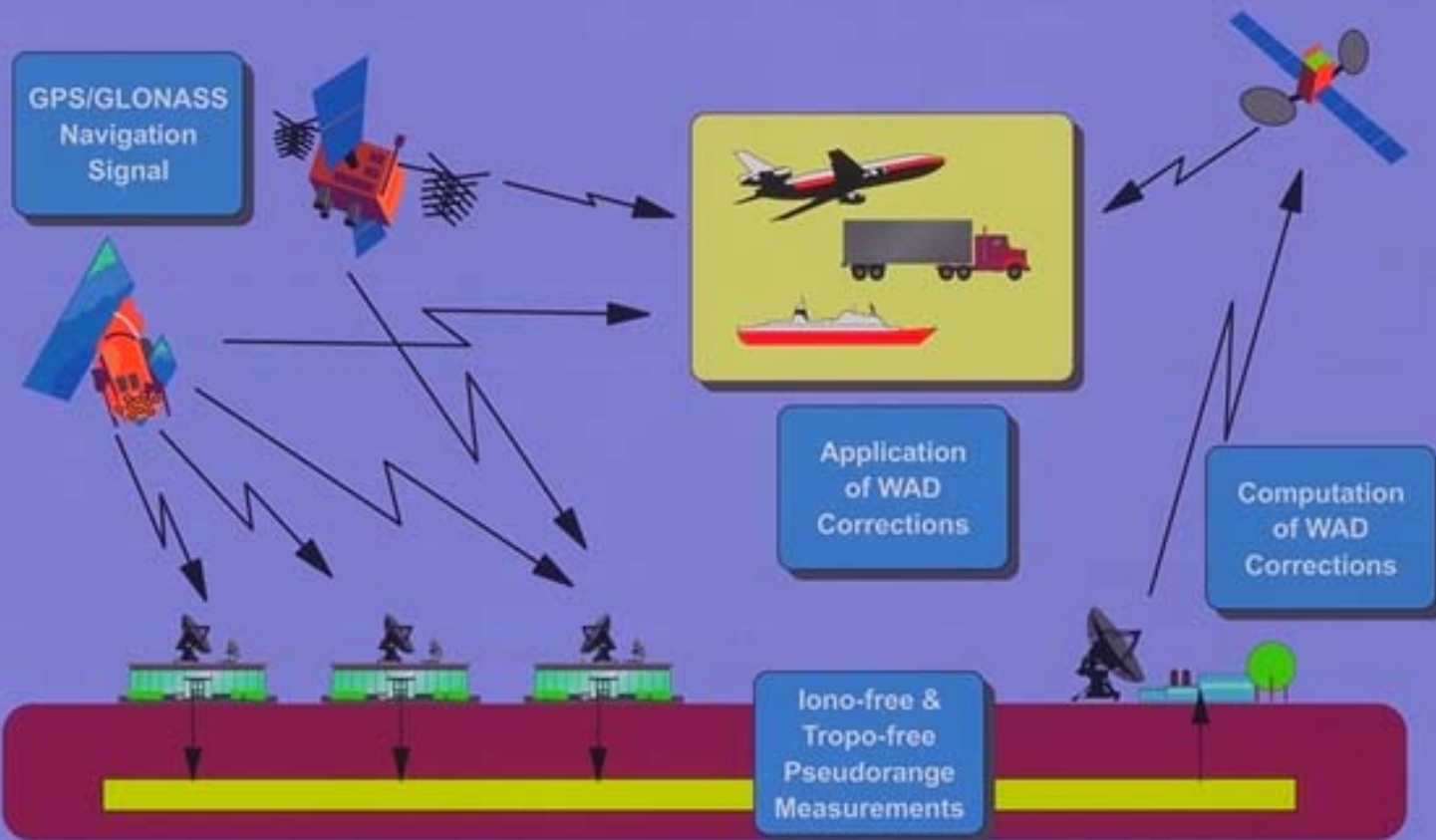


LAAS - Local Area Augmentation System



Configuração

Wide Area Differential (WAD) GPS corrections



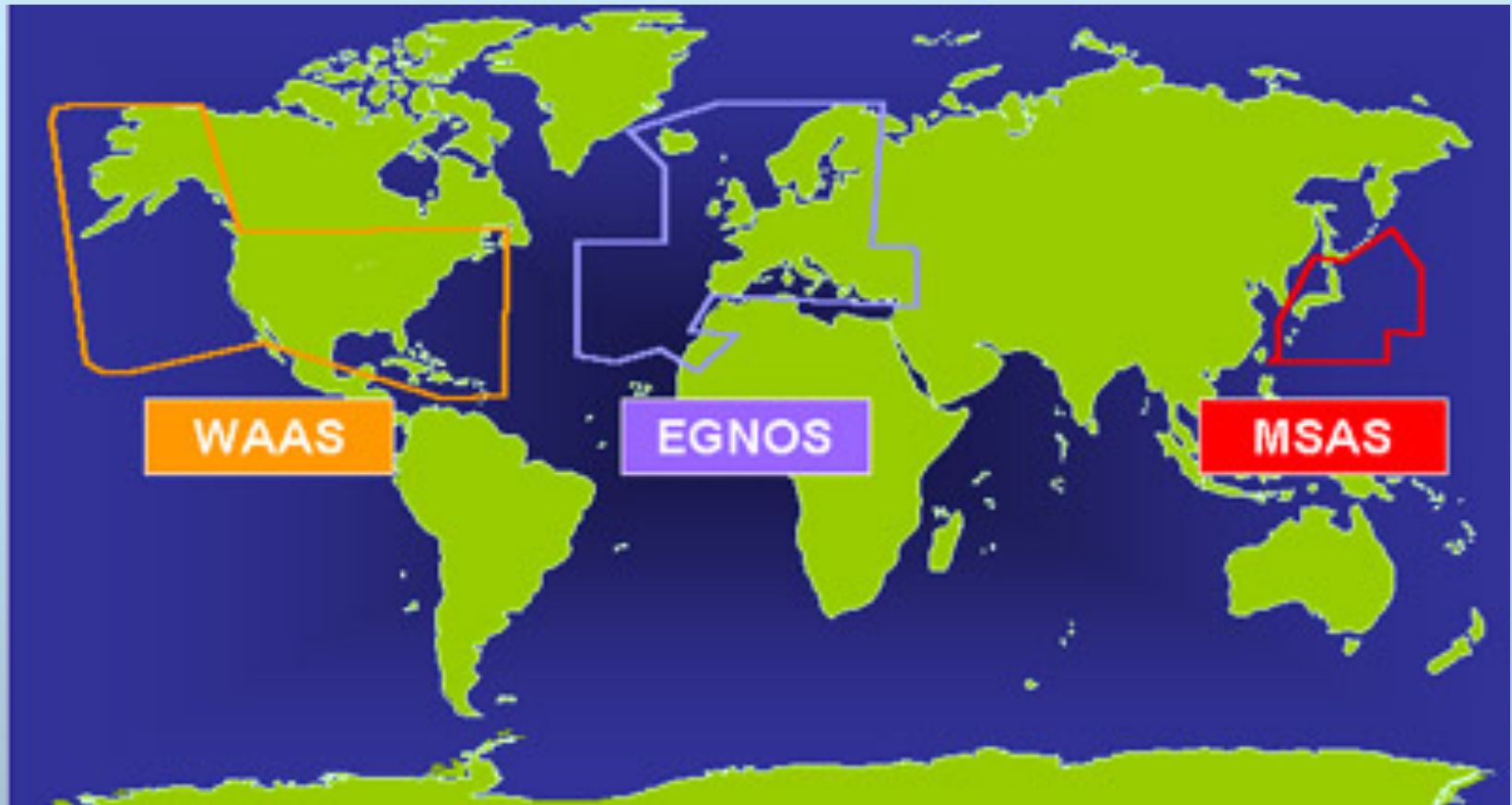
Comparação de vários sistemas de radio navegação: acurácia

sistema	95% Acurácia (Lateral / Vertical)	Detalhes
LORAN-C Specification	460 meters / 460 meters	The specified absolute accuracy of the LORAN-C system.
Distance Measuring Equipment (DME) Specification	185 meters / 185 meters	DME is a radionavigation aid that can calculate the distance from an aircraft to ground equipment.
GPS Specification	100 meters / 150 meters	The specified accuracy of the GPS system with the <i>Selective Availability</i> (SA) option turned on. SA was employed by the U.S. Government until May 1, 2000.
LORAN-C Measured Repeatability	50 meters / 50 meters	The U.S. Coast Guard reports "return to position" accuracies of 50 meters in time difference mode.
loran Repeatability	10 meters / 10 meters <i>[citation needed]</i>	Modern LORAN-C receivers, which use all the available signals simultaneously and H-field antennas.

Comparação de vários sistemas de radio navegação: acurácia

sistema	95% Acurácia (Lateral / Vertical)	Detalhes
Differential GPS (DGPS)	10 meters / 10 meters	This is the Differential GPS (DGPS) worst-case accuracy. According to the 2001 Federal Radionavigation Systems (FRS) report published jointly by the U.S. DOT and Department of Defense (DoD) , accuracy degrades with distance from the facility; it can be < 1 m but will normally be < 10 m.
Wide Area Augmentation System (WAAS) Specification	7.6 meters / 7.6 meters	The worst-case accuracy that the WAAS must provide to be used in precision approaches.
GPS Measured	2.5 meters / 4.7 meters	The actual measured accuracy of the system (excluding receiver errors), with SA turned off, based on the NSTB's findings.
WAAS Measured	0.9 meters / 1.3 meters	The actual measured accuracy of the system (excluding receiver errors), based on the NSTB's findings.
Local Area Augmentation System (LAAS) Specification	1.0 meter / 1.0 meter [citation needed]	The goal of the LAAS program is to provide Category III ILS capability. This allows aircraft to land with zero visibility utilizing 'autoland' systems and indicates a very high accuracy of < 1 m.

Cobertura dos Sistemas WAAS, EGNOS e MSAS



Obrigado!

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