

Fugro Satellite Positioning: status update 2022

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8 December 2022, Hydro 22 Monaco

GPS status and future

Satellite	Number On (Off*)	Age (Year)	Oldest	Signals	Comments	Initial Operational
GPSIIR Revised	7(5*)	20.3	24.7	L1,L2, P1, P2	Standard setup Nuclear Detection	
GPSIIR-M Modified	7(1*)	14.5	16.5	+L2C	+Stronger L2 signal	2023
GPSIIF Follow on	12	8.2	11.8	+L5 +M-Code	+3rd Frequency in protected band New Military code Better Clocks	2024 2025
GPSIII	5 Still 5 SV to launch	2.0 >MTBF	3.3	+L1C	Compatible with Galileo Even better Clocks Better jamming protection 60x Regional Military Protection	>2030
GPSIIIF Follow on	22 to be built	>>MTBF	2026		Laser Reflectors for precise orbits Search en Rescue (SAR) Better Nuclear Detection	>2035?

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Galileo status

~21 working satellites

- E14 E18 in elliptic orbits unhealthy: Will never be used
- E20 IOV 104 switched off since 2014
- E01 unhealthy until further notice since August 2022
- Galileo has very accurate clocks, good for improved accuracy and higher age of corrections
- Possible problems with reliability of existing clocks. In 2017 investigated and improved procedures
- 10 Batch3 Galileo satellites are ready for launch
- New launches delayed until Q3 2023 or 2024 because Soyuz can not be used and Ariane6 Vega delayed
- Currently new INAV format update. Satellite set unhealthy.
- Galileo high accuracy service @ 20 cm horizontal/40 cm height in test.
- Galileo 2nd Generation is being designed





BeiDou2 (Since 2014)

Status 2022



source: www.gnssplanningonline.com

~15 working satellites

5 Geostationary at equator C1-C5 Near China CONUS

5 Inclined Geostationary Orbit (IGSO) C6-C10, C13 Rotate 8 over equator

3 Medium Earth Orbit (MEO) C11, C12, C14

Rotate around the earth. So limited coverage in America's, Europe, Africa



BeiDou3 C19-C60 (Since 2020)



Source: www.gnssplanningonline.com

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~45 working satellites

27 Medium Earth Orbit(MEO) C19-C37, C41-C46 Rotate around the earth

3 Geostationary C59-C61 near China.

3 Inclined Geostationary Orbit.C38-C40 8 pattern near China

C31, C56-C58, Experimental

UGRO



BeiDou3+2 coverage



Source: www.gnssplanningonline.com

GLONASS

GLONASS now 19 useful Marinestar satellites with L1 and L2 frequencies R16, R22 Unhealthy R06, R10, R23 L2 frequency does not work

R20 launched July 2022 R25 launched October 2022

15 Satellites are older than nominal live expectation! For Marinestar PPP short periods only 2/3 GLONASS Satellites available in some parts of the world

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Source: https://www.gpsworld.com/directions-2022-a-new-epoch-for-GLONASS/ https://aviationweek.com/defense-space/space/russias-GLONASS-add-high-orbital-satellites-2026

Status of GNSS

UNITED	2		ENT AND		RIA		
	CUTOPED				RECEILS NO	Glig	×
	SAT visi	ble at	a place			X	
	System	Mir	Max	Total		C24	<u>623</u>
(C28) (C15) (C28) (C15) (C15)	GPS	6	13	31	CUECOS COST COS	NE	
G10 R28	Galileo	4	9	21	CCU2 CCS CET		C26
C23 EQ7	BeiDou	8	26	45		220 CG53	
C21 C45	<mark>GLONASS</mark>	<u> 2 </u>	9	<u> 19</u>	B (614	CEB	
	🦉 Typical 🛛	~20	~50	117	CES COI	012 622	
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Ocean

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Typical performance Netherlands: 23 August 2022



SD 6 mm 95%=15 mm Max=16 mm

North SD= 9 mm 95%=19 mm Max=40 mm

Hor. SD =6 mm95% = 21 mm Max 40 mm

Height SD= 21 mm 95%=48 mm Max=76 mm

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Fugro Marinestar[®] G4+ accuracy 95 % height (cm)



Mid-Latitudes < 5 cm Equatorial zone 6-7 cm (Humidity main cause) Pacific Ocean 8 cm

individual sites with radic interference removed.

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Fugro PPP-G4+ position accuracy



East ~10 cm North ~10 cm Height ~20 cm

GPS, Galileo, GLONASS, BeiDou3



Marinestar[®] improvements

95 % Improvement

Year



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Scintillation 2022 till 10 November: Up to 5 hours

Maximum minutes of continuous Scintillation per site



Scintillation= >1 cm range noise

Solar cycle 25: stronger? than predicted



Example of Scintillation 12/13 November South America



Cape Verde Scintillation: BeiDou3 helps





can eliminate jamming sources

Incremental improvements in Fugro PPP Marinestar®

- Multi-Lband corrections with 4 L-band Satellites and NTRIP Internet (Septentrio AsteRx-M3/U3)
- Lband MPOC3 New internal format for new GNSS signals. BeiDou3, more frequencies
- Restore position after interruption under bridge/jamming. Up to 90 seconds
- Many small improvements at millimeter level
- Horizontal 6 mm, 9 mm and height 20 mm standard deviation in Europe/North America

Challenges

- Troposphere (heavy rain in the tropics)
- Move from ITRF2014 to ITRF2020
- Scintillation jitter (coverage large part of sky around the equator and polar region)

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- Convergence time (use more frequencies)
- Even better robustness for autonomous applications

Test Rotterdam harbour and highway

October 2021 BeiDou C1-C30



"Kop van Zuid"

"De Hef" Rotterdam

High position update for Hydrography

GNSS receivers 100/50 Hz capable

- Septentrio
 - AsteRx-M3, AsteRx-U3
- SBG
 - Apogee-D, Ekinox-D
- Trimble
 - R750, Applanix

INS Systems 100-200 Hz output 0.01 degree More biases

Speeds in hydrography

Multibeam up to 30 pings per second in shallow water Standard survey 5 knots = 2.5 m/s = 25 mm /0.01 sec Maximum 20 knots = 5 m/s 50 mm/0.01 sec Wave height 3.5 Meter in 5 sec

Accelerations in hydrography

Vibrations of vessels

Waves buoys

Crane movements

3D Multi-Antenna GNSS with 25, 50 of 100 Hz Position will support INS/IMU, Heave...?

The value of many satellites

- Constellations can fail. Galileo 1week 2019. GLONASS 1-April-2014.
- 2) Radio interference can blockL1/E1, but L2/E5, L3/E6 remain available
- Scintillations can cover a large part of the horizon in equatorial and polar zone
- 4) Radio interference has highest effect on SNR at low elevation satellites. (Higher change to survive)
- 5) In harbours near large Sea going vessels and under bridges
- 6) More Satellites help





Marinestar[®] capable GNSS receivers

- Septentrio Receivers and OEM
- SBG Navsight/Apogee-D/EKINOX-D
- Seatex DPS110/112 and Seapath systems

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- Trimble Receivers and OEM
- Applanix POSMV
- Advanced Navigation Spatial Dual
- Norbit Multibeam
- R2Sonic
- And others...

Unlocking **Insights** from **Geo-data**





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