

Jamming and Spoofing mitigation by Fugro

20 Nov 2024

MCN Wismar Germany

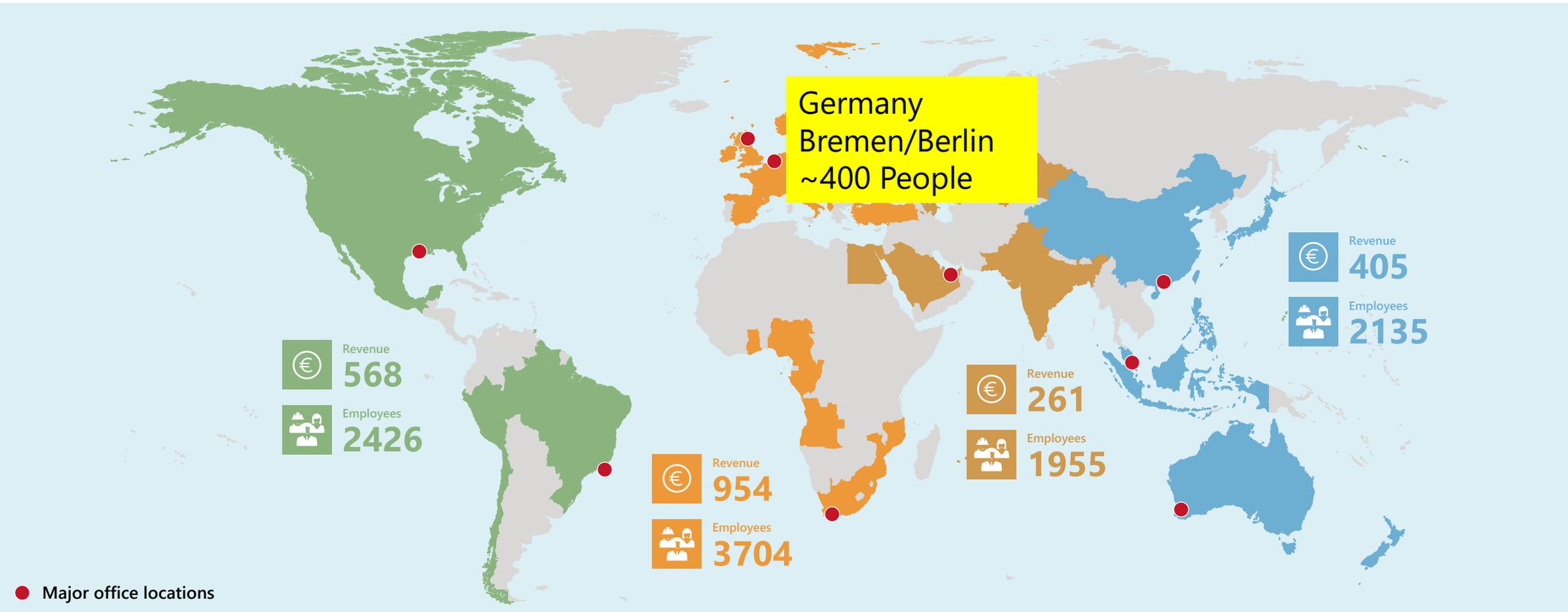
Presenter: Hans Visser (Hans.visser@fugro.com)

Product Manager: Jamming and Spoofing(Satguard)

Fugro Innovation & Technology Center, The Netherlands

Fugro Global player with local presence

We meet our clients' local Geo-data needs by mobilising global resources quickly and effectively



Note: Revenue in EUR million. Charts are based on FY2022 results

Fugro overview

40
specialised
service vessels



10
uncrewed
surface vessels



7
autonomous
underwater
vehicles



69
remotely
operated
vehicles



113
cone
penetration
testing systems



240
geotechnical
drilling rigs



8
remote
operations
centres



36
laboratories



31
jack-up
platforms



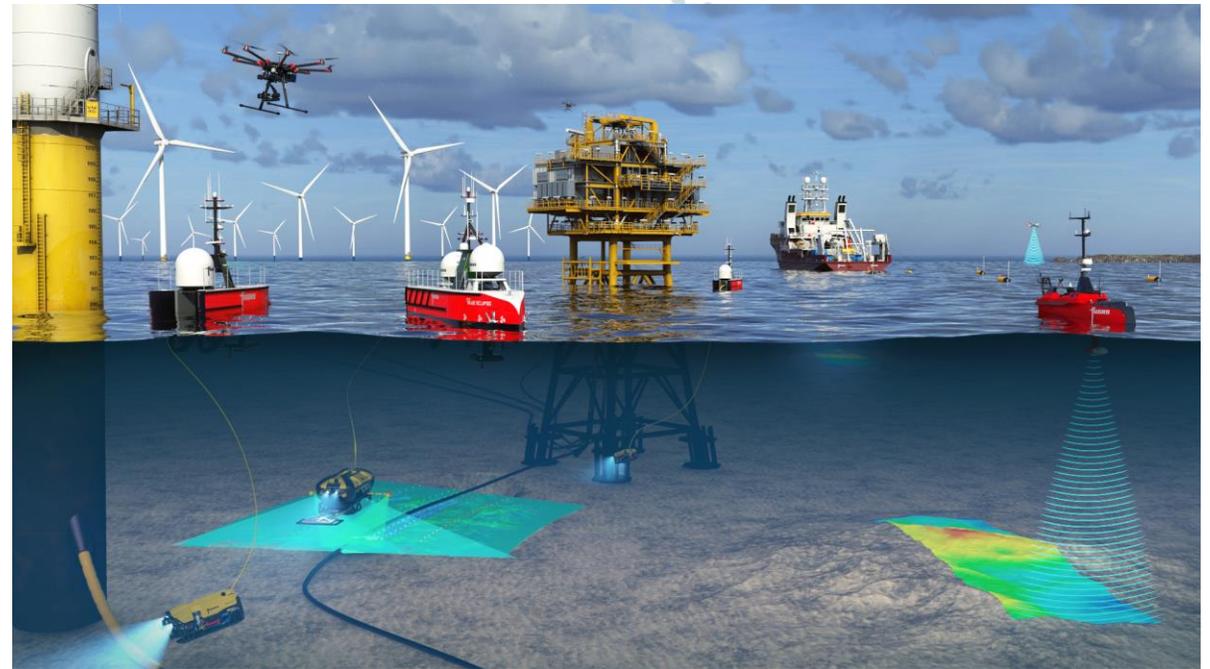
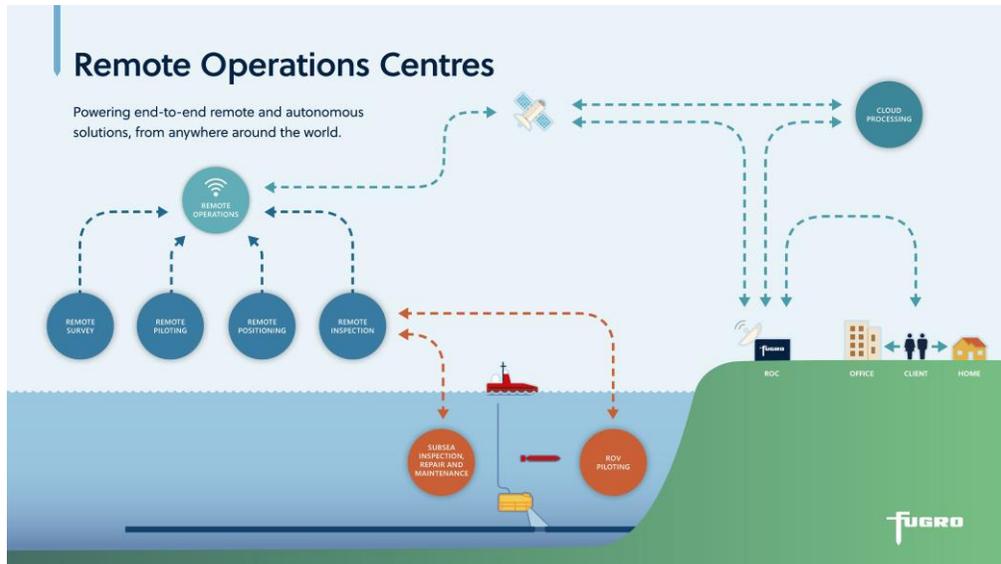
Remote Hydrography



Blue Shadow
8 Meter

Blue Essence
12 Meter

Blue Eclipse
18 Meter

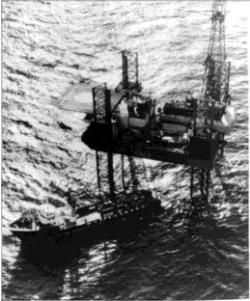


The current future



Fugro positioning service evolution

Transit system first used



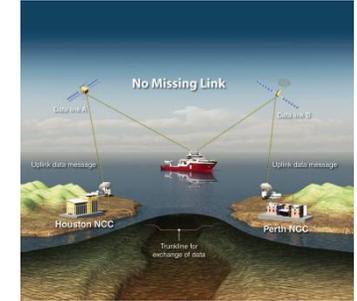
High frequency DGPS L1 service



HP dual-frequency DGPS service



G2 GPS & GLONASS PPP service



1984

1996

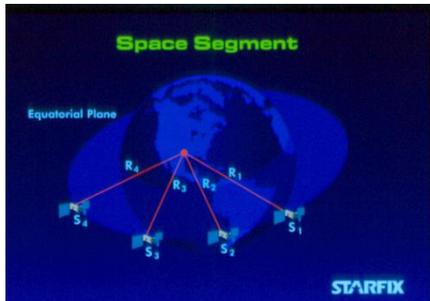
2006

2009

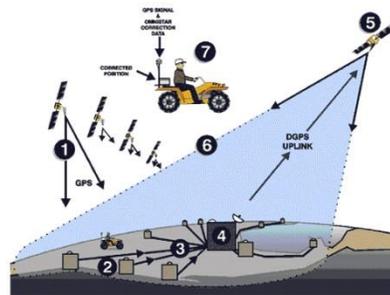
1974

1986

2001



Starfix positioning system



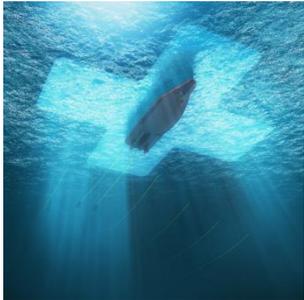
Omnistar Satellite based code L1 VBS



XP PPP service

Fugro positioning service evolution

G2+ ambiguity-fixed
PPP Service



2015

Added Galileo
into G4 service



2016

AtomiChron
timing service



2021

Independent
Orbit+Clock
GPS+GIO+Galileo

XP3

2023

3 Frequency
fast
convergence



2024

2015



Added BeiDou
into G4 service

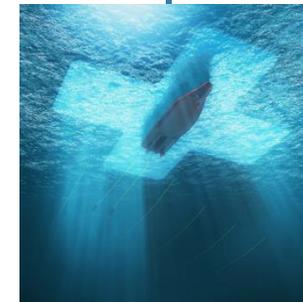


OceanStar
Cruise Vessels



SpaceStar
LEO PPP

2022



G4
ambiguity
fixing



Satguard
NMA Spoofing
Protection

FUGRO

Fugro Satellite Positioning

- thousand active users globally



Research vessels



Hydrographic Survey vessels



Dredging vessels



Cable Lay vessels



Windfarm installation/support vessels



Navy / Coast guard vessels



Fishing / Fish farming vessels



USVs

Fugro Satellite Positioning integrated in GNSS receivers



Trimble



Septentrio



SBG



KONGSBERG



Marinestar Compatible Receivers(1/3)



MPS566



SPS855



MPS865 (MB2)



R750



BX992 (BD992)



Applanix POSMV



KONGSBERG

Seapath Series using a 3610 or 3710 demodulator



Marinestar Compatible Receivers(2/3)



AsteRx-u3 Marine



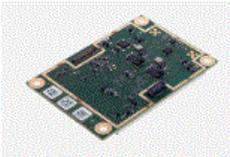
AsteRx-m3 OEM



AsteRx-u-fg



AsteRx4-Fg OEM



Navsight Ekinox Marine



Apogee-D



Ekinox-D



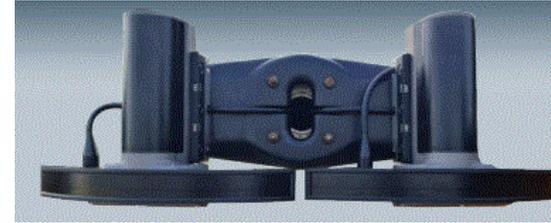
3DSS-iDX Sonar



UKKO2



New Marinestar Integrated products in 2024



Norbit Winghead



Teledyne Intrepid



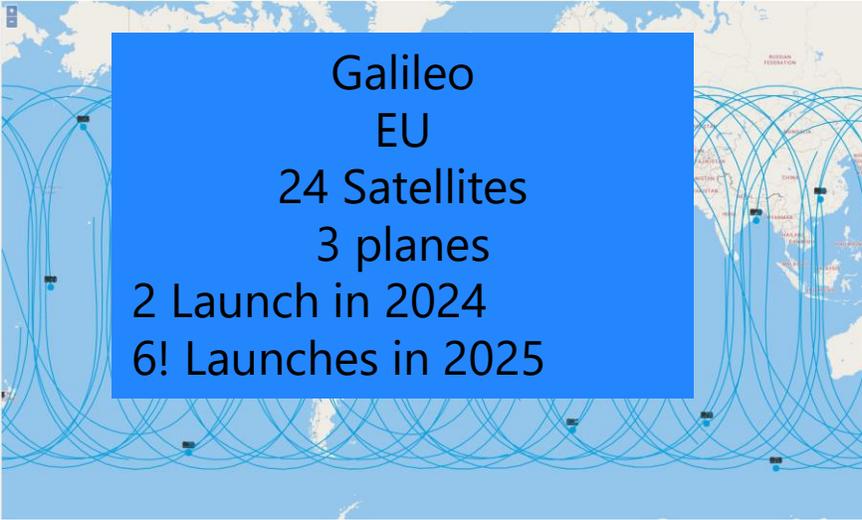
SIGMA

GNSS Constellations 2024

55 N



55 S



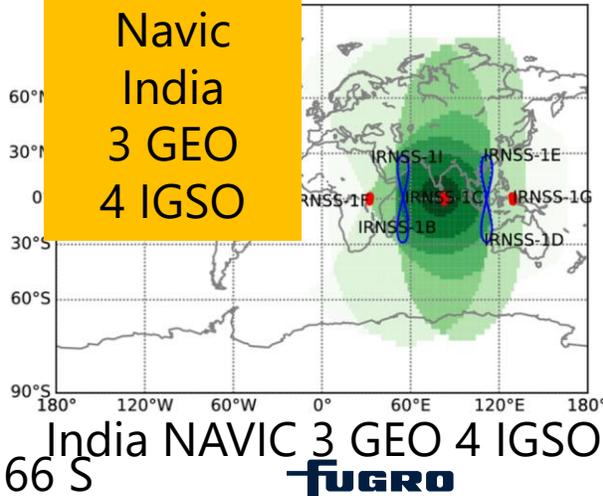
QZSS
Japan
4 SV



55 S



Navic
India
3 GEO
4 IGSO



Source: <https://www.gnssplanning.com/#/satellites>

Changes in the GNSS Satellite Constellation in 2024

18-Sep-2024 MEO 59 and 60

FUGRO
MARINESTAR®

Uses over 100 GNSS reference stations to measure precise distances of satellite constellations



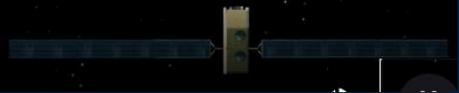
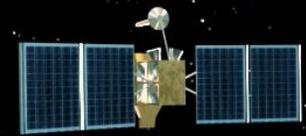
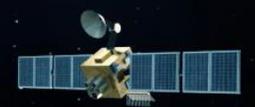
GPS
32

GALLILEO
24

BEIDOU
46

GLONASS
24

INMARSAT
6



GPS 31
Next Launch Jan 2025
2025 from 31->32 SV

G1
Galileo 24
2 Launch in 2024
6! Launches in 2025

E1
BeiDou 35
4 Launches in 2024

C46
Glonass 20
1 Launch Dec? 2024?
R6,R10, R13,R23,R25

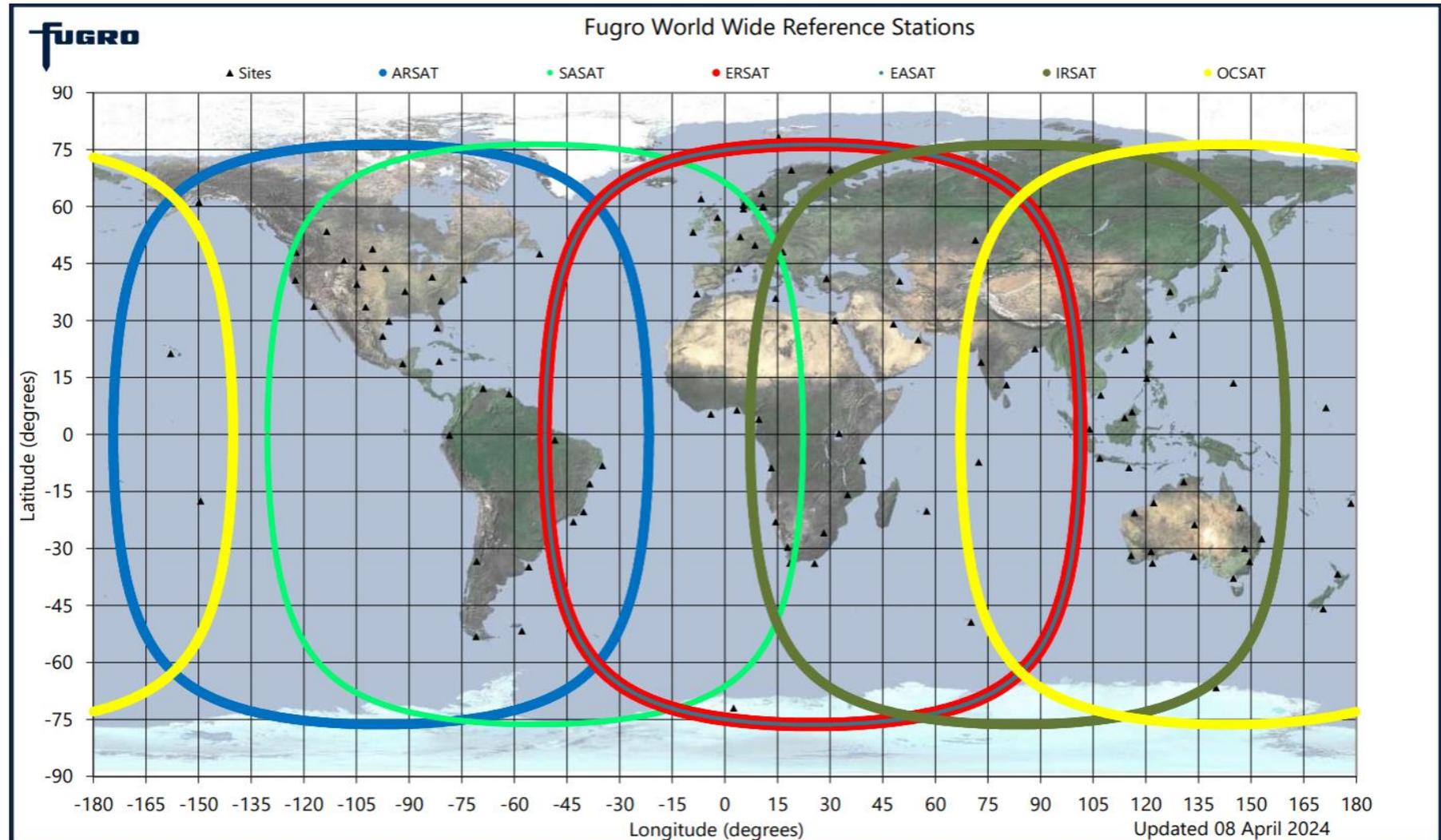
NextG4: Fugro infrastructure

100+ reference stations

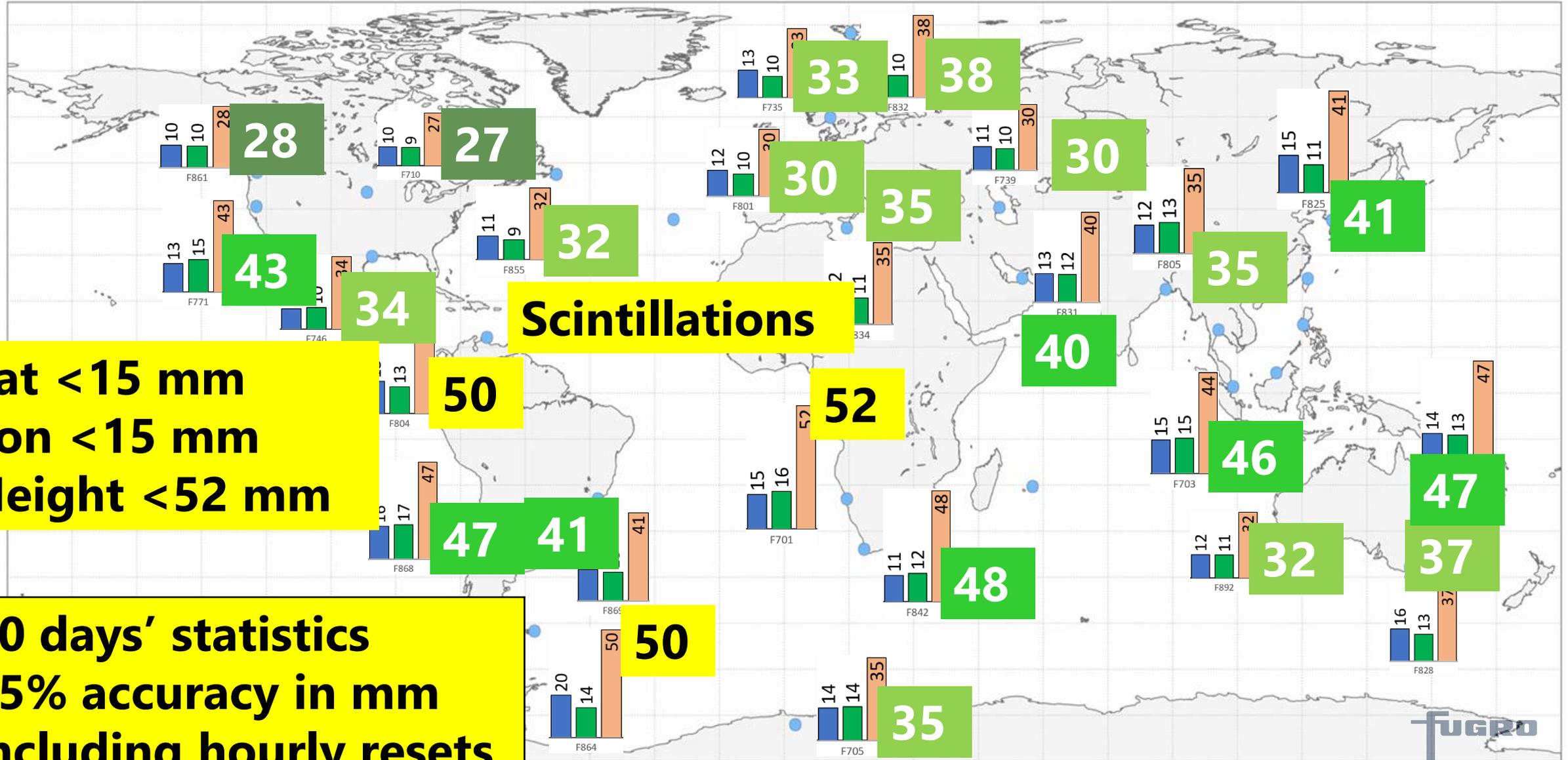
6 global L-band GEO broadcast satellite beams

2 fully redundant Network Control Centers (NCCs)

Using Orbit and Clocks From G4
We calculate precise Positions



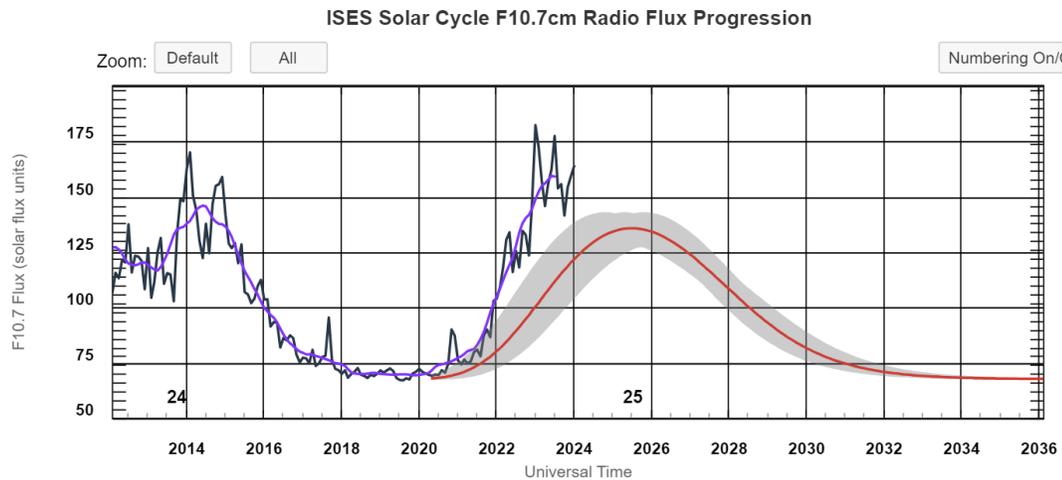
95% Positioning accuracy results triple frequency Spring 2024



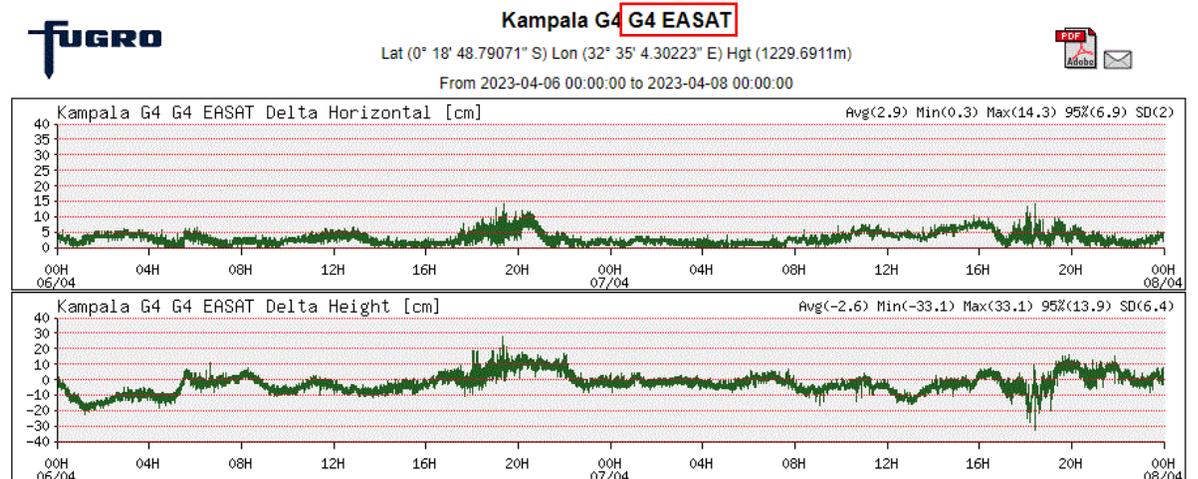
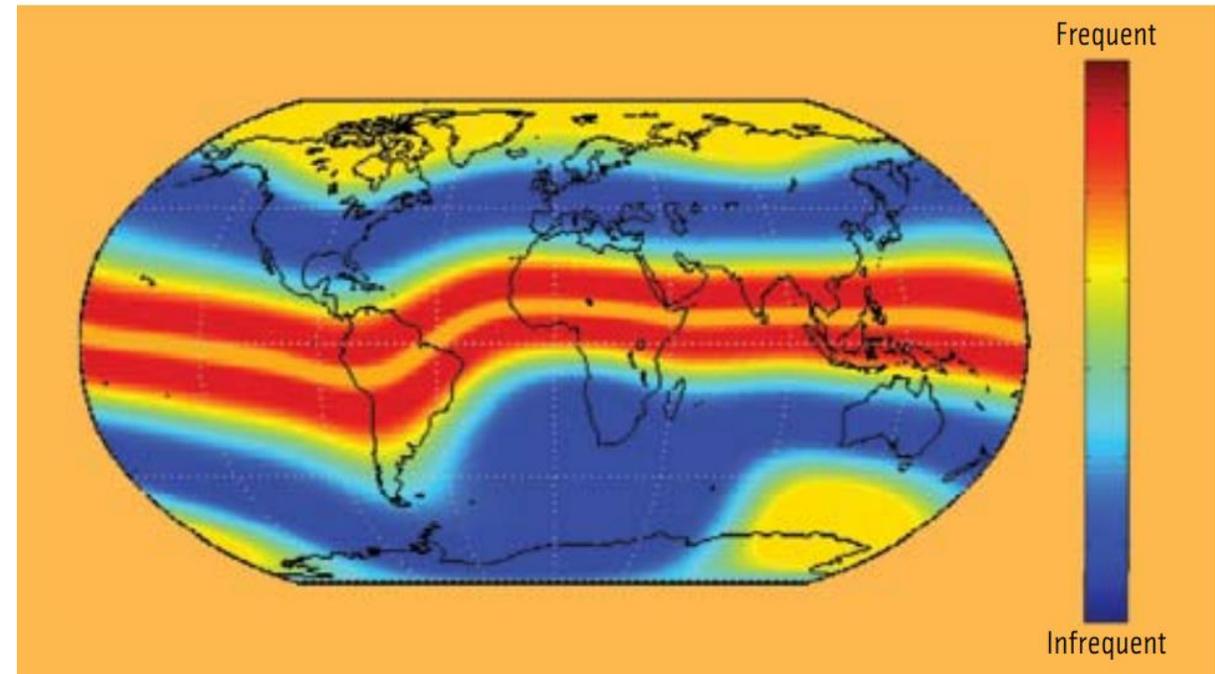
Lat < 15 mm
Lon < 15 mm
Height < 52 mm

10 days' statistics
95% accuracy in mm
including hourly resets

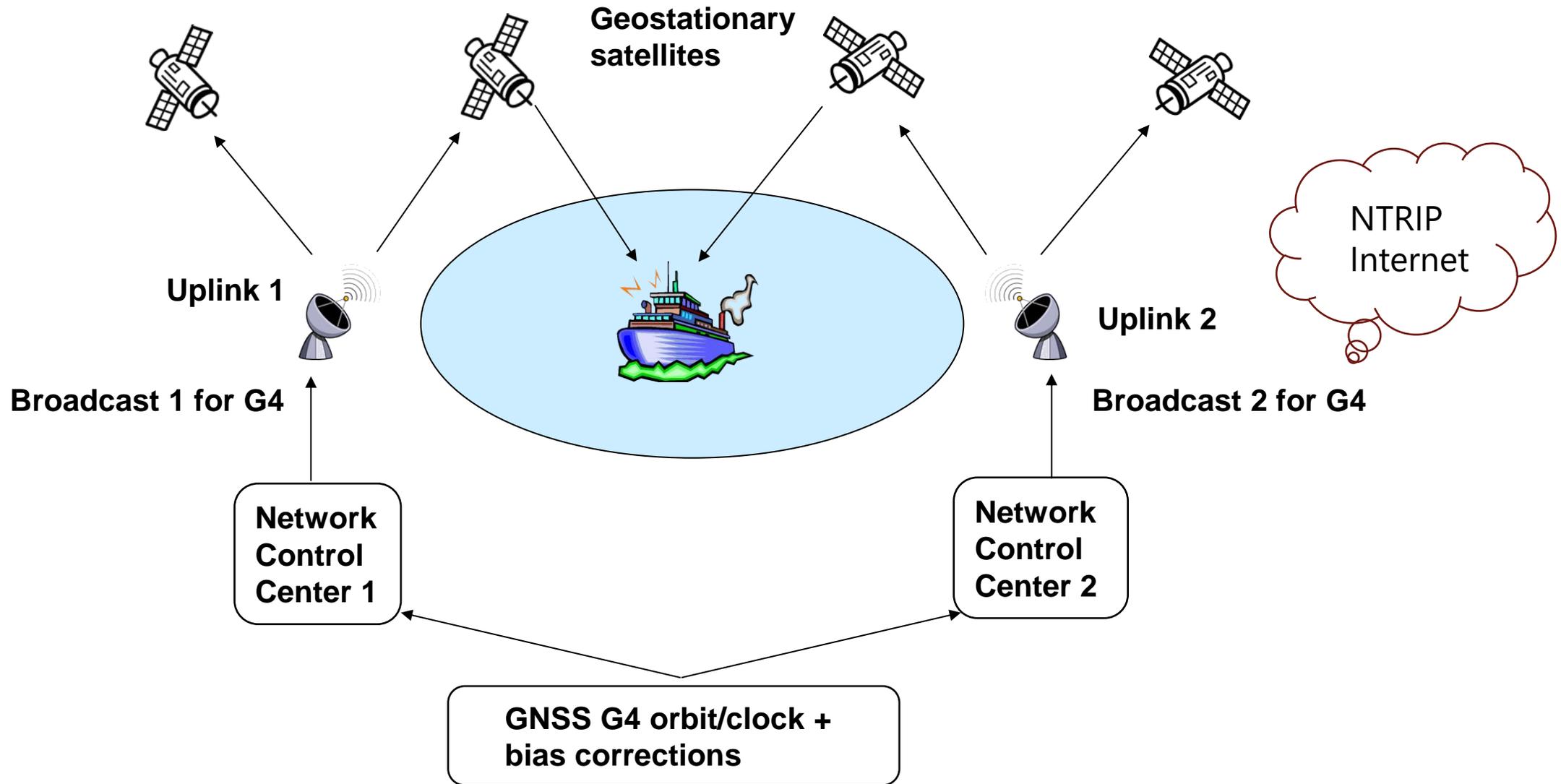
Worst Jamming now Solar cycle 25



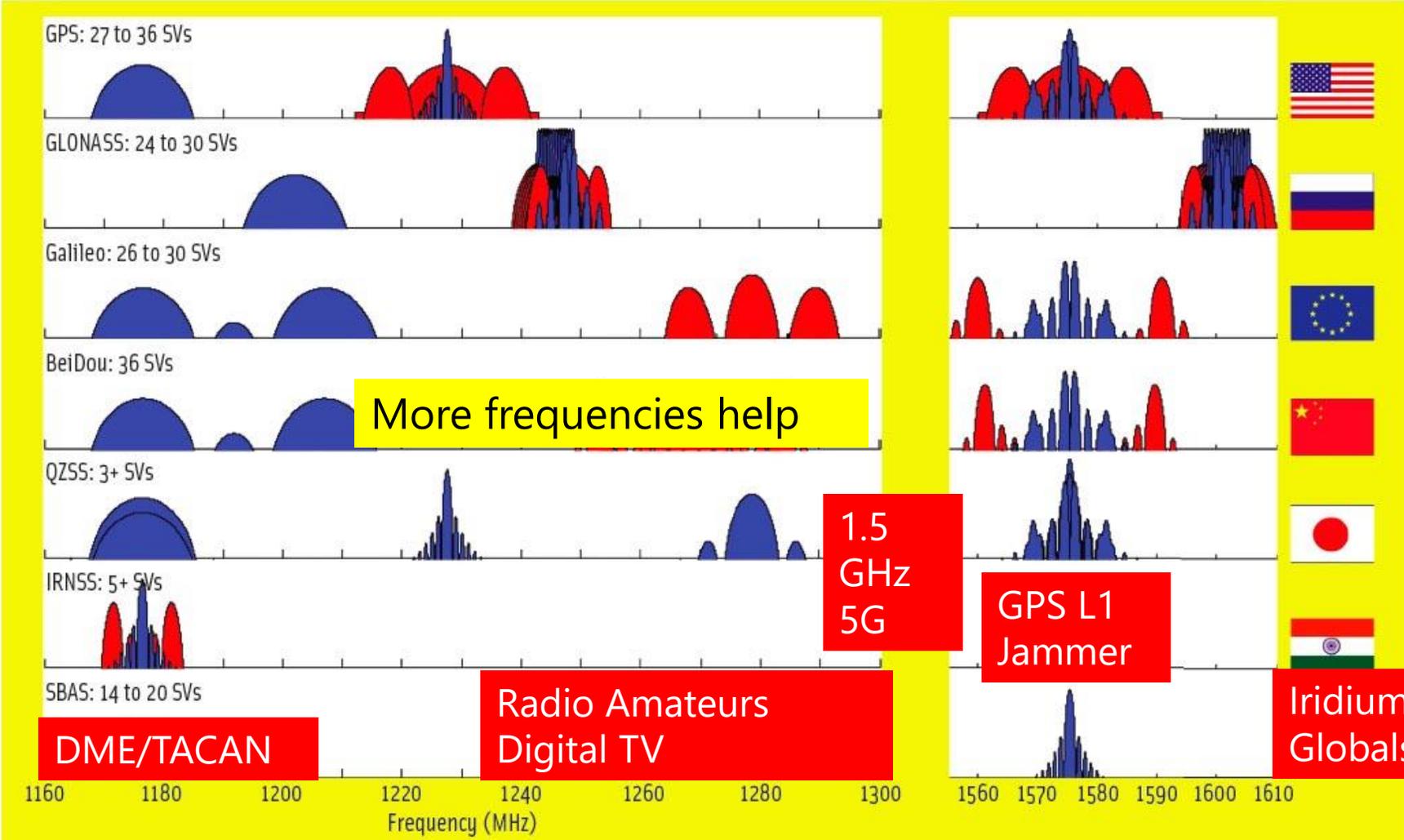
- Solar cycle 25 expecting to peak 2024-2025
- Affects predominately equatorial less in polar regions
- To mitigate the effects of solar activity:
 1. Use G4 with BeiDou3
 2. Use 5 degrees elevation mask.
 3. Use receivers that can receive multiple L-band satellites simultaneously
 4. Use NTRIP for back-up corrections



Fugro Satellite Positioning infrastructure



GNSS Frequencies



More frequencies
Improve robustness.

Improve convergence
time.

New signals are
stronger and more
robust.

FIGURE 1 Prospective satnav signal structures, with open signals in blue and restricted signals in red



Different sources of Jamming. E.g.



Local Electronics



Iridium/Globalstar
1610-1630 Mhz



Legal radio Amateur
Secondary user 1240-1300 Mhz

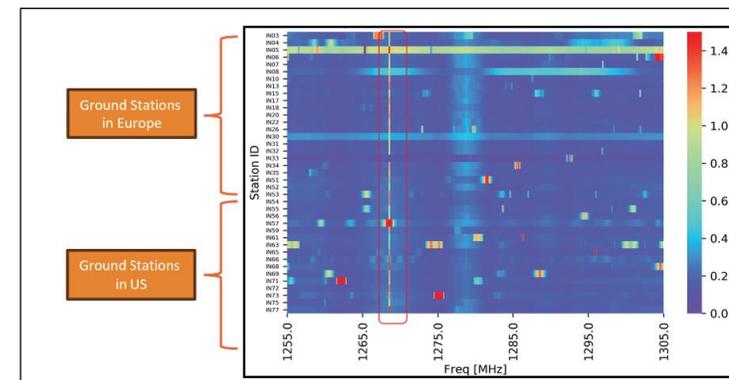
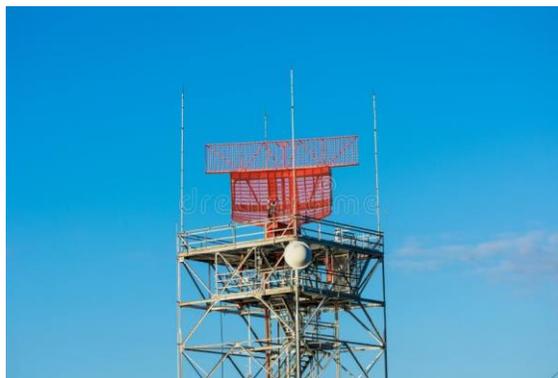


FIGURE 4 Received Power Variation in the B3-E6 Spectrum Across all Stations on February 3,

GNSS Satellites from space
e.g. BeiDou C57



Airport Radar
Ship radar if direct in
radio path!



GPS Jammer
Taxi drivers
Illegal activity



GNSS Re-
Radiating
KIT



Military Jamming radar

FUGRO Worldwide Beams – January 2024

AMSAT
Ends 04/03/24

ARSAT
Started 23/01/24 at 1400

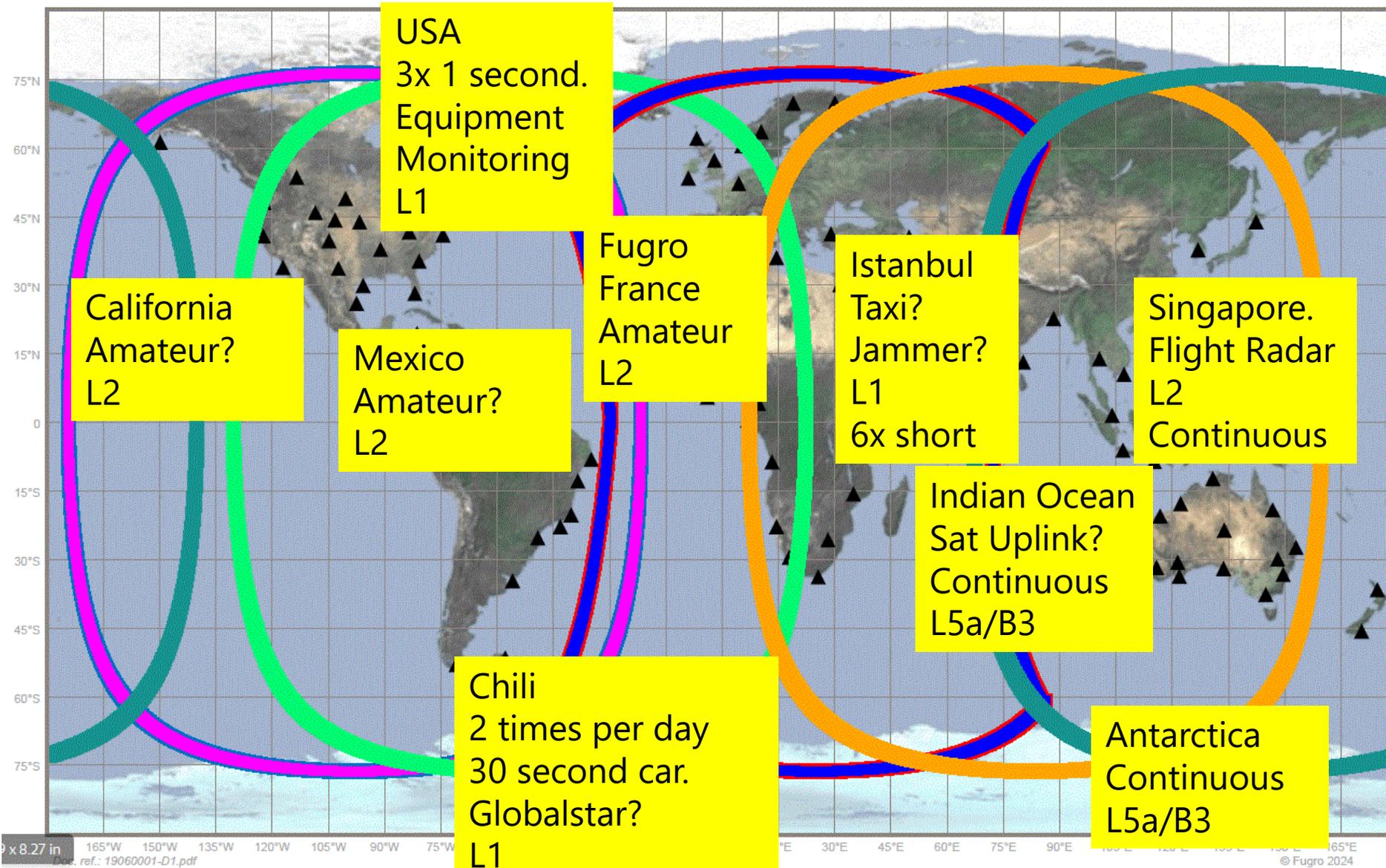
SASAT

EASAT

ERSAT

IRSAT

OCSAT

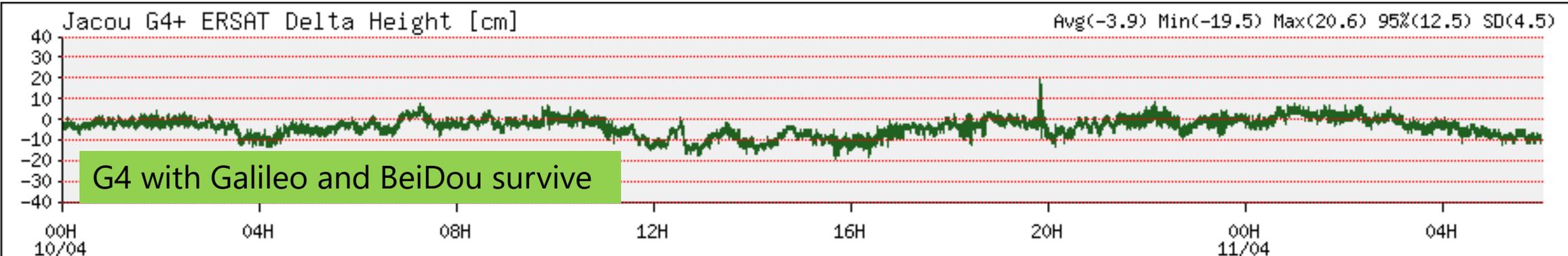
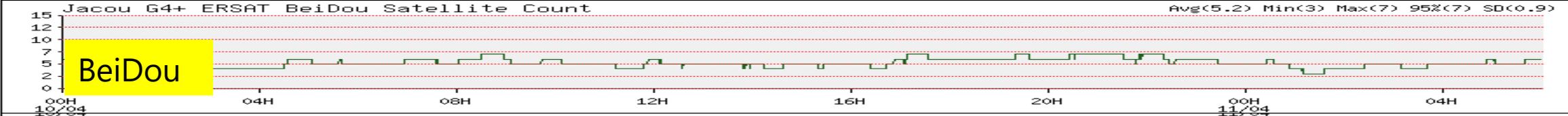
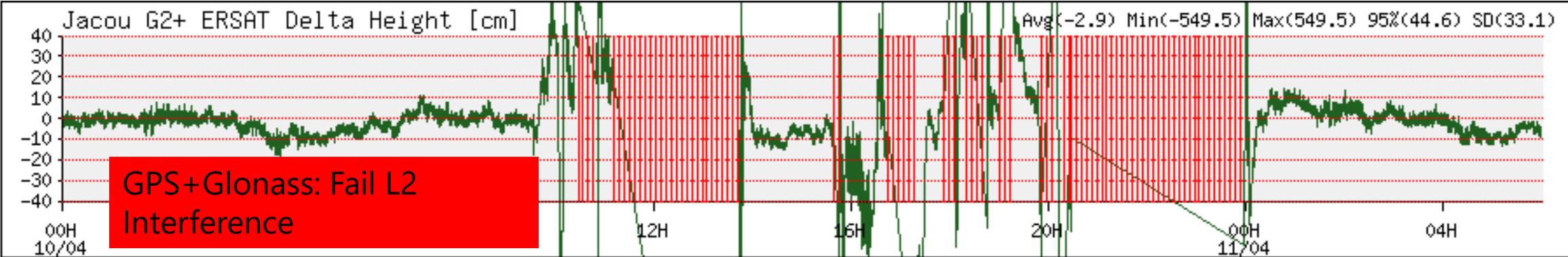


9 Sites from ~130 sites is 10%.
90% of sites is mostly unaffected.

Interference is a marginal problem.

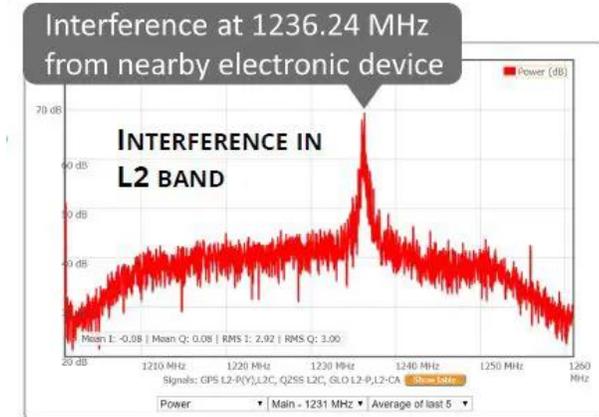
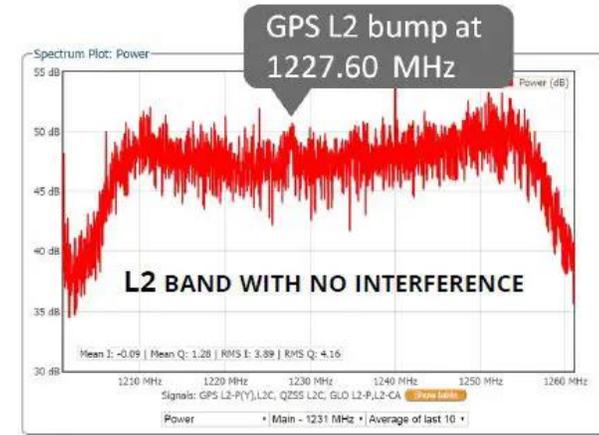
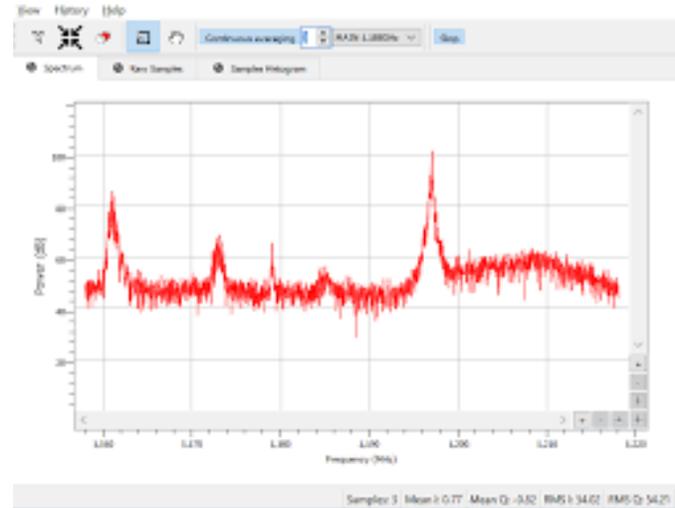
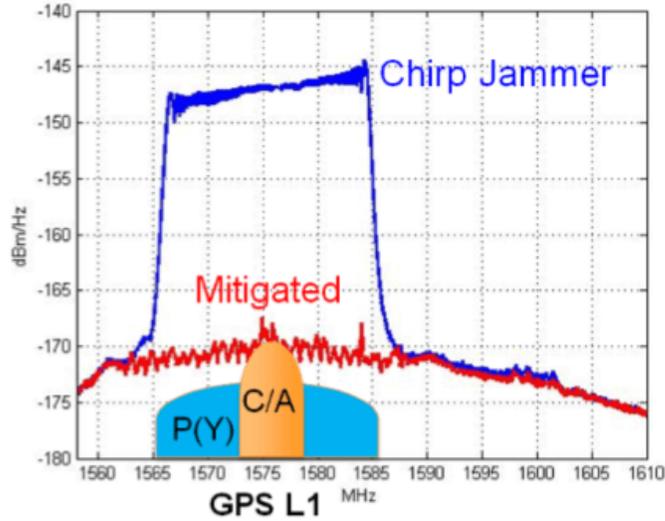
Till it hits you

GPS+Glonass L2 Fail: More GNSS constellations help

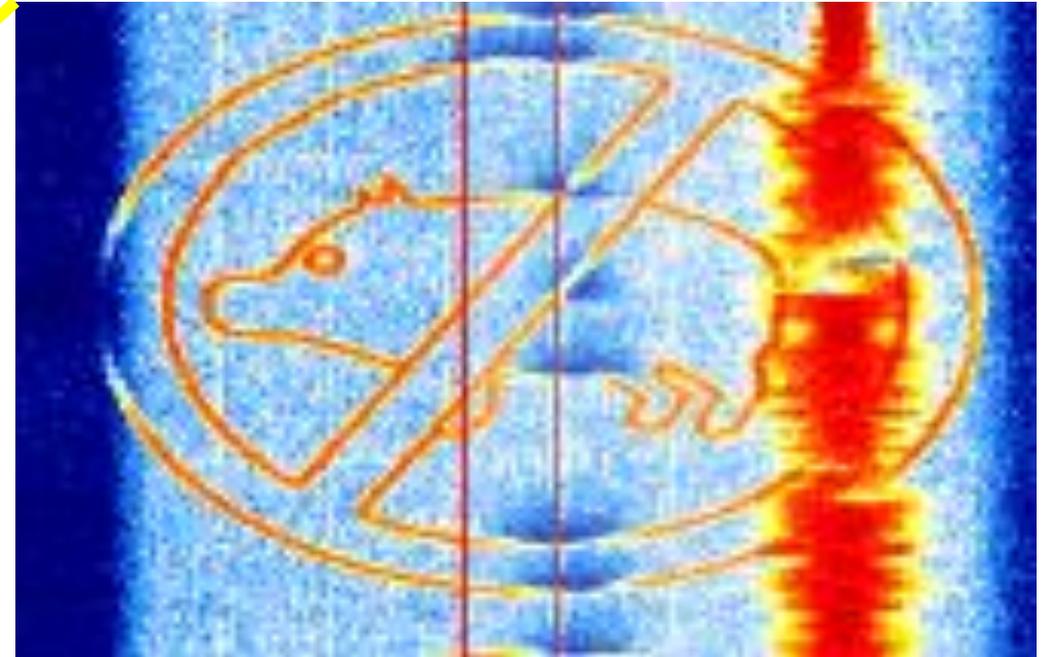
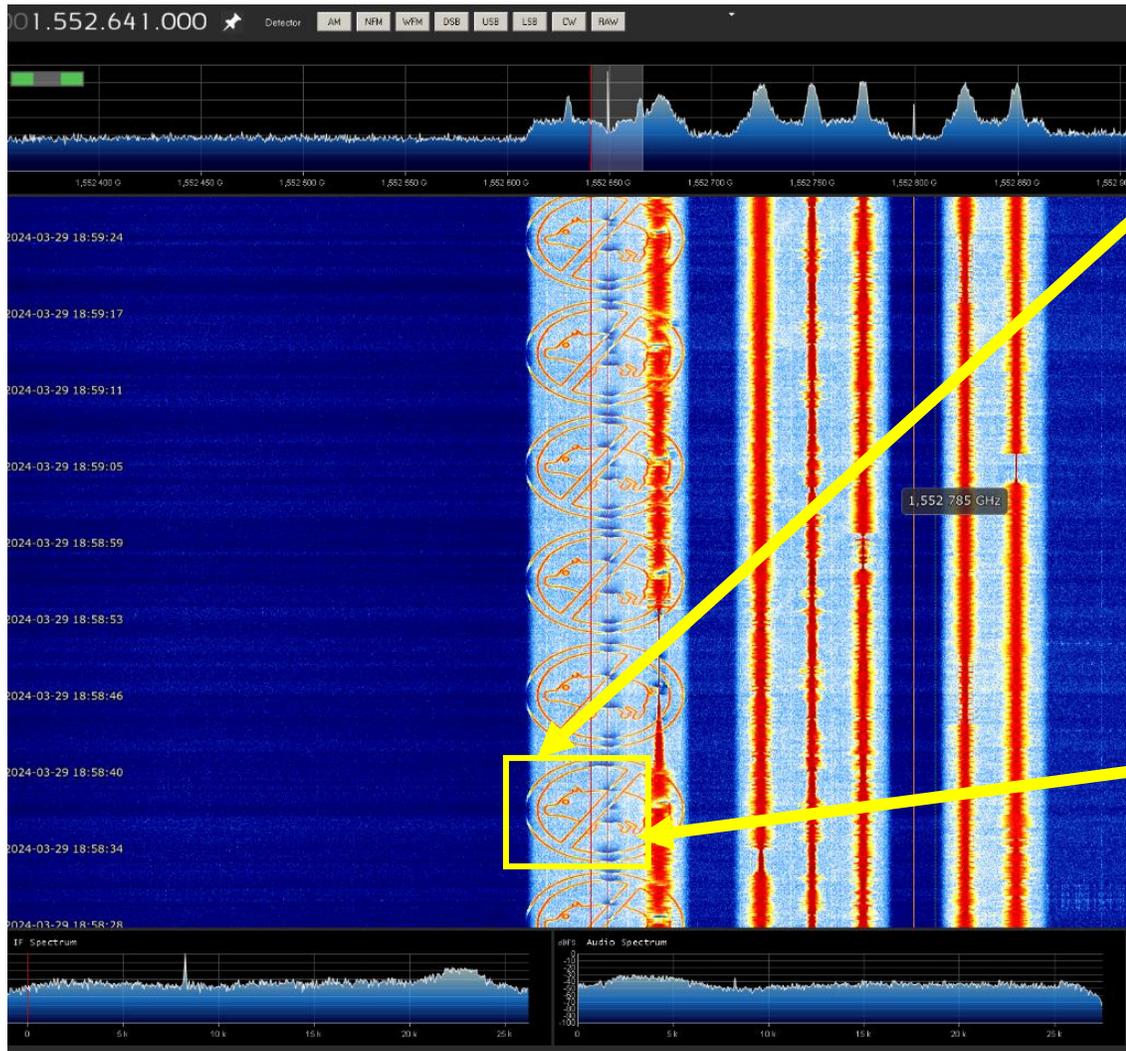


Different forms of Radio Interference (Source Septentrio)

Glonass L2 Radio Amateur



Inmarsat Lband Uplink Jamming.1552 Mhz.



GPSJAM

Daily maps of GPS interference
[About](#) | [FAQ](#)

03/03/2024

More

Level of GPS interference	
Low	0-2%
Medium	2-10%
High	> 10%



GPS Jam collects airplane data.
Ship has no jamming problem

GPSJAM

Daily maps of GPS interference

[About](#) | [FAQ](#)

03/03/2024 📅

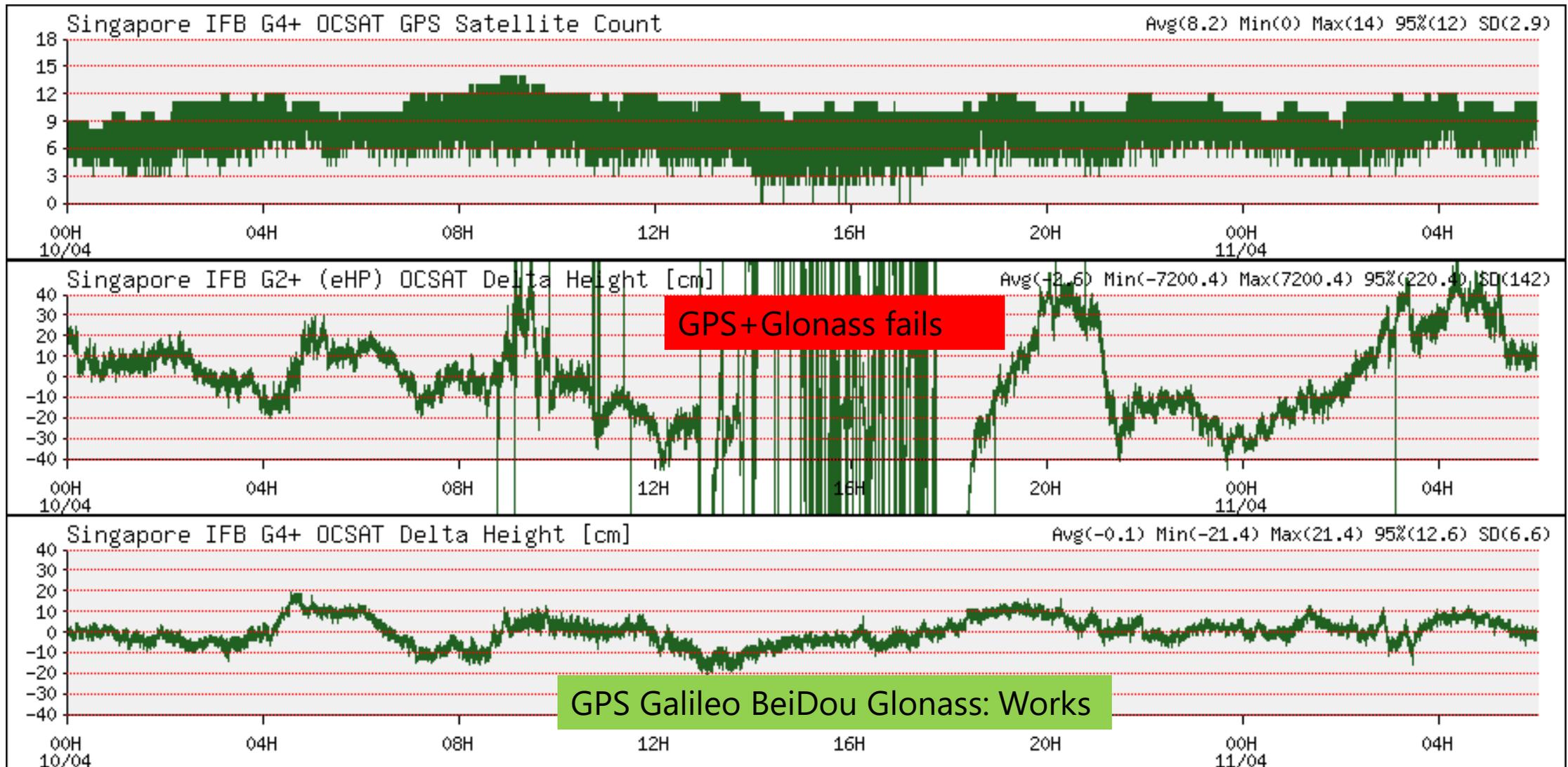
More

Rumania

KRIM



Level of GPS interference	
Low	0-2%
Medium	2-10%
High	> 10%

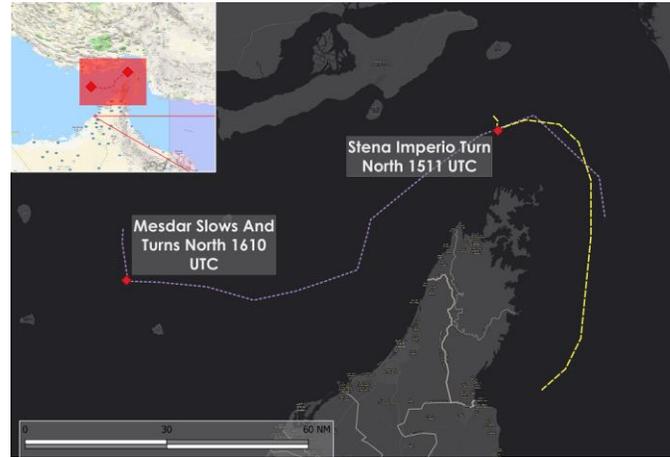


Examples of China Circles, Iran ship spoofing, Russia aircraft circles.

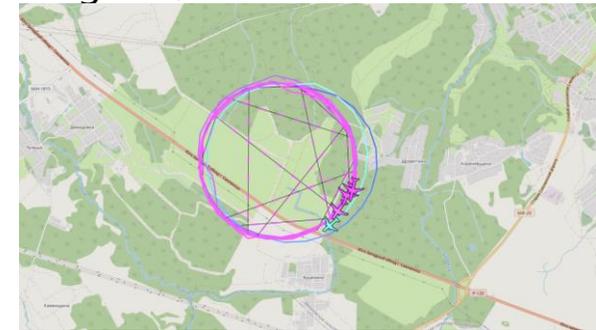


<https://rntfnd.org/2019/07/24/mi-6-probe-if-seized-british-tanker-was-given-spoofed-iran-coordinates-by-russian-spies-the-register/>

Circle spoofing is done with a GNSS Simulator.



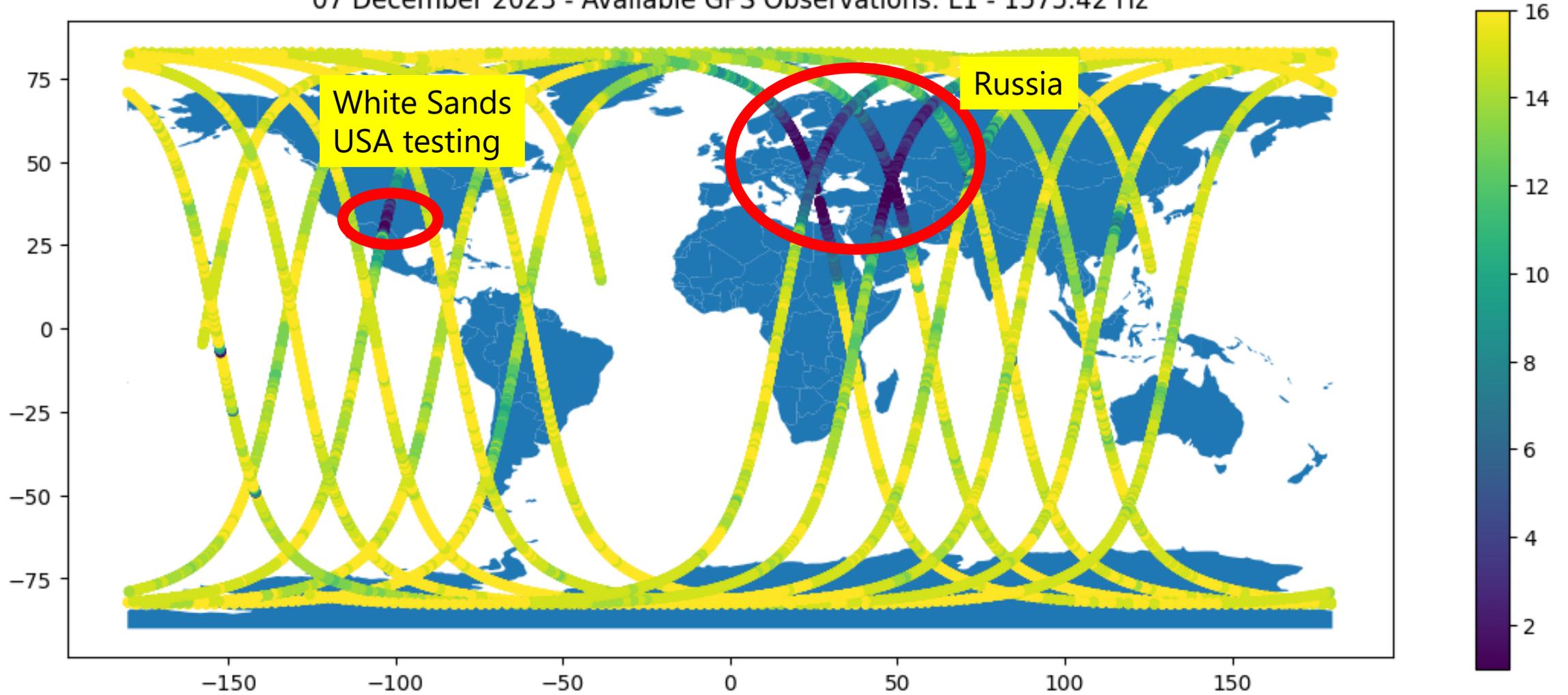
<https://rntfnd.org/2019/07/24/mi-6-probe-if-seized-british-tanker-was-given-spoofed-iran-coordinates-by-russian-spies-the-register/>



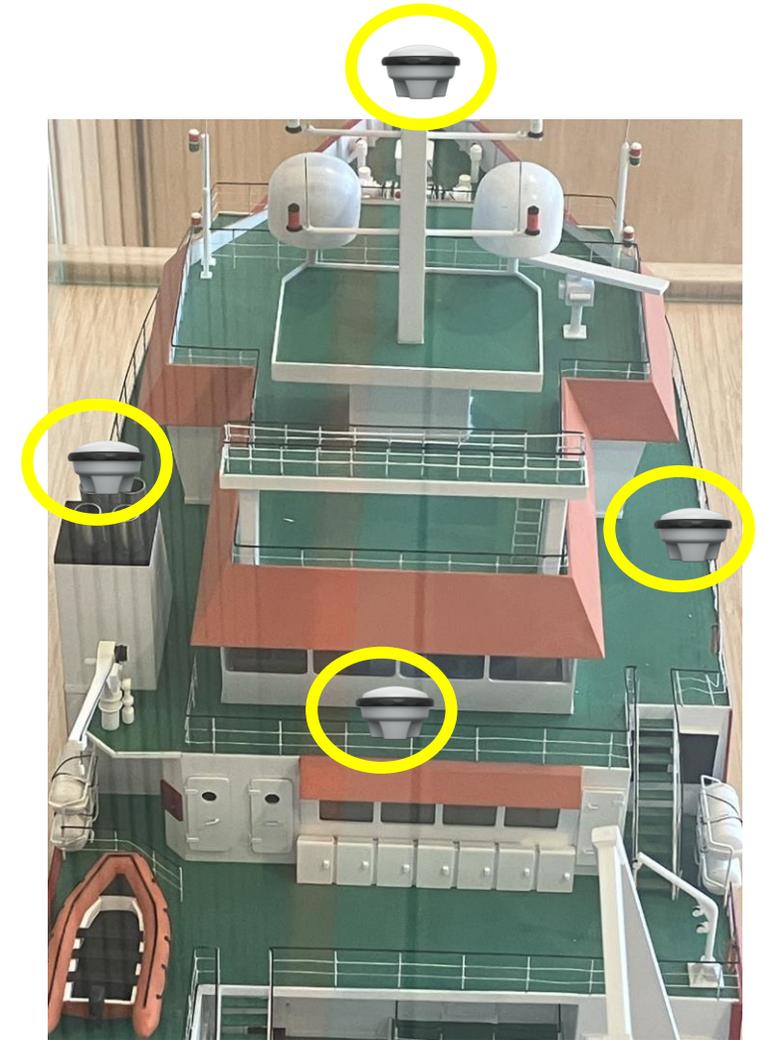
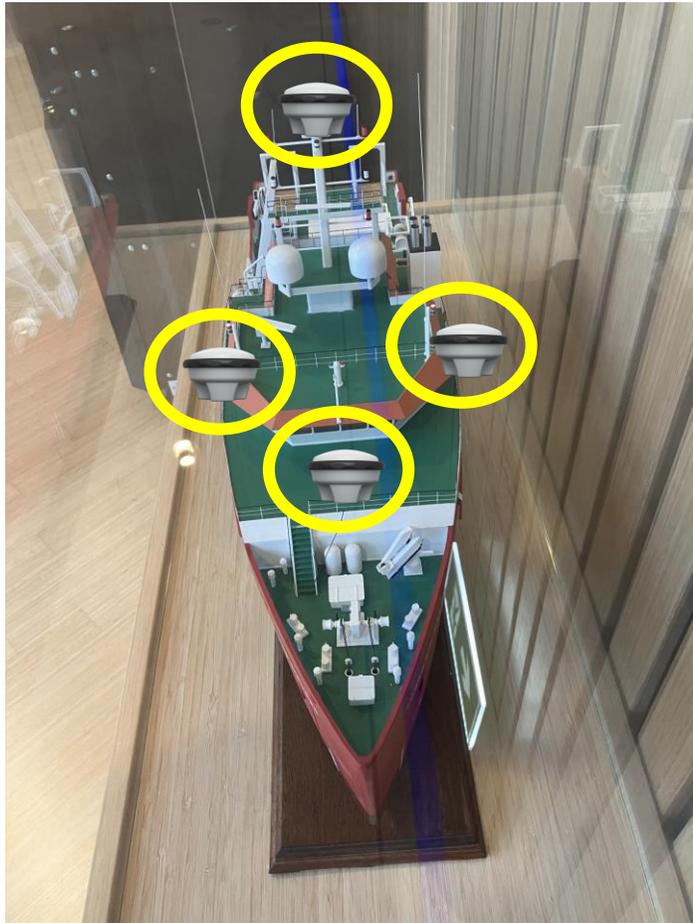
<https://www.linkedin.com/pulse/circle-spoofing-comes-aviation-first-baltic-now-dana-a-goward-disle/>

Fugro Spacestar : Norsat TD :Number of Sat.

07 December 2023 - Available GPS Observations: L1 - 1575.42 Hz



Metal object blocking Interference source 5! antennas. Front Bow, Starboard, Port, Top Mast



How: Android Software Data Radio device Spectrum analyser.



30 Euro Cost



OTF cable



Antenna filters

External filter

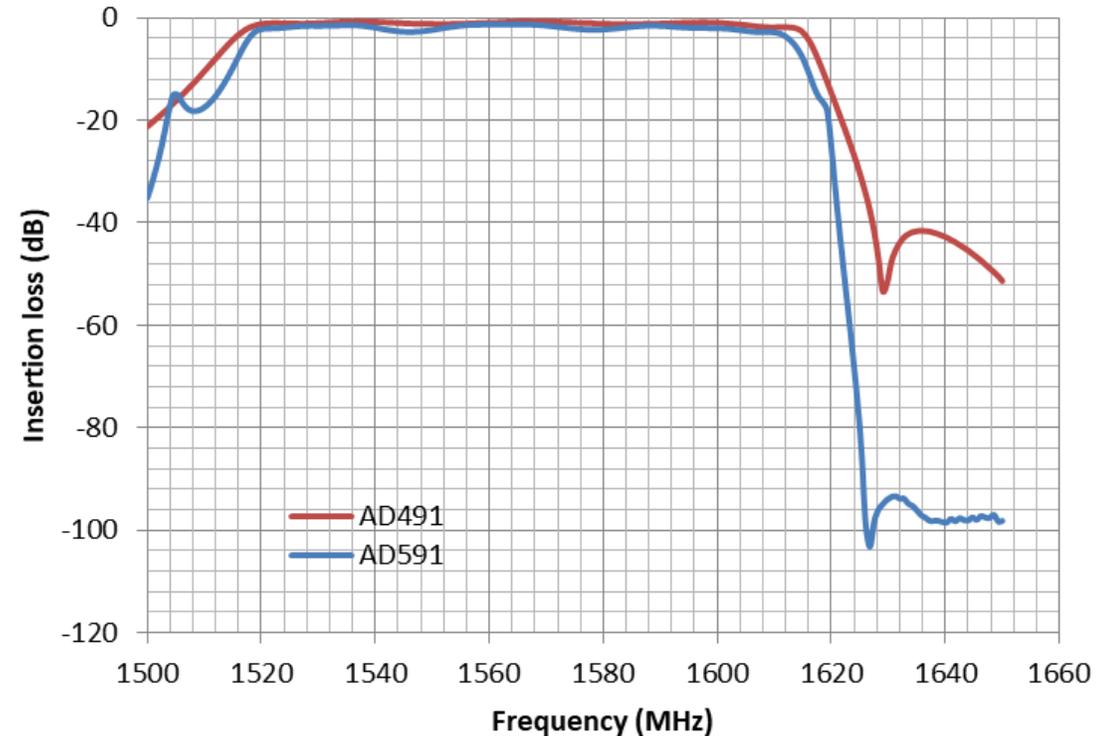
Alison Microwave ad492 ad591 ad493 low elevation gp ad431-391..

Antenna integrated filter

Allison AD492, 591, cavitation filter

Trimble GA830 (Against Iridium)

Trimble Zephyr3 (Against Iridium and 5G)



Antennas with lower sensitivity at low elevations.



Safran
8230AJ L1/E1

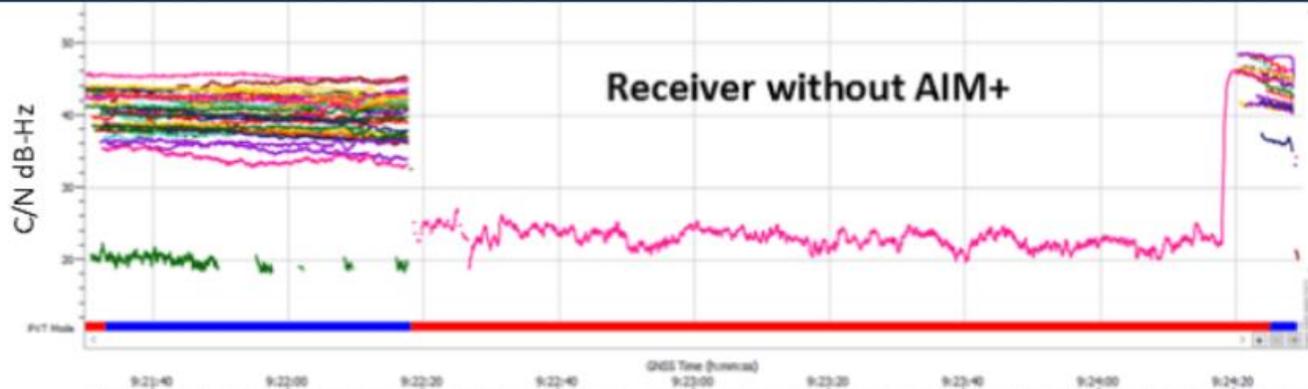


Calian
AJ977XF G4

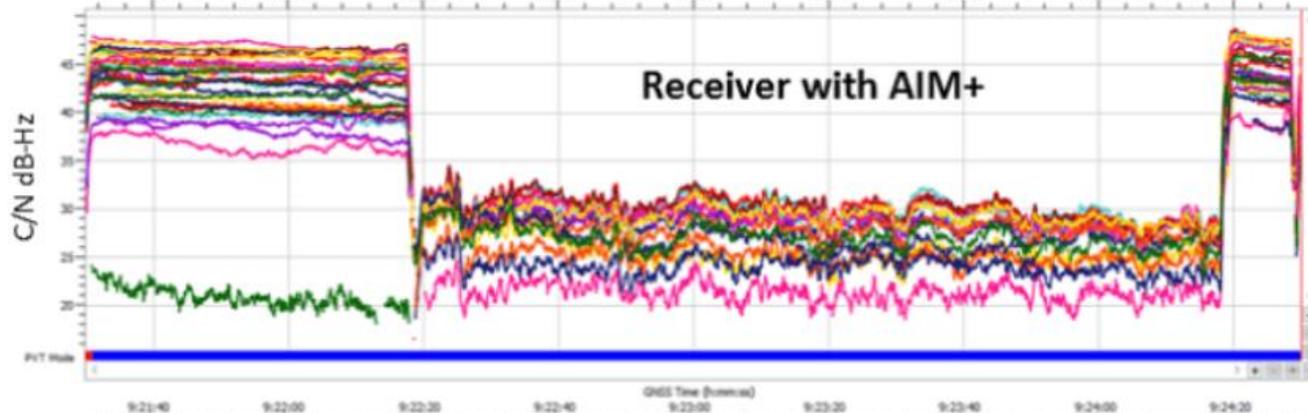
Frequency Bandwith		Out of Band Rejection
Lower Band	1164 -1254 MHz	> 85dB @ < 1100 MHz > 82dB @ > 1300 MHz > 90dB @ < 1325 MHz
L-Band Corr.	-	> 75 dB @ < 1526 MHz > 47 dB @ < 1536 MHz > 35 db @ > 1626 MHz > 90 dB @ > 1700 MHz
Upper Band	1559 - 1606 MHz	

20 dB suppression at 0 degrees elevation

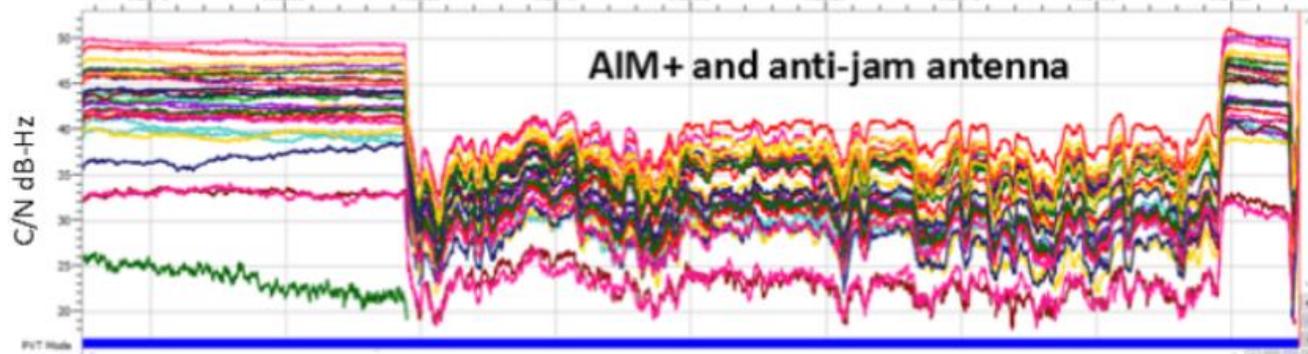
Septentrio GNSS Manufacturer: WBI+Notch Filter works better than CRPA.



Standard antenna: loss of position without AIM+

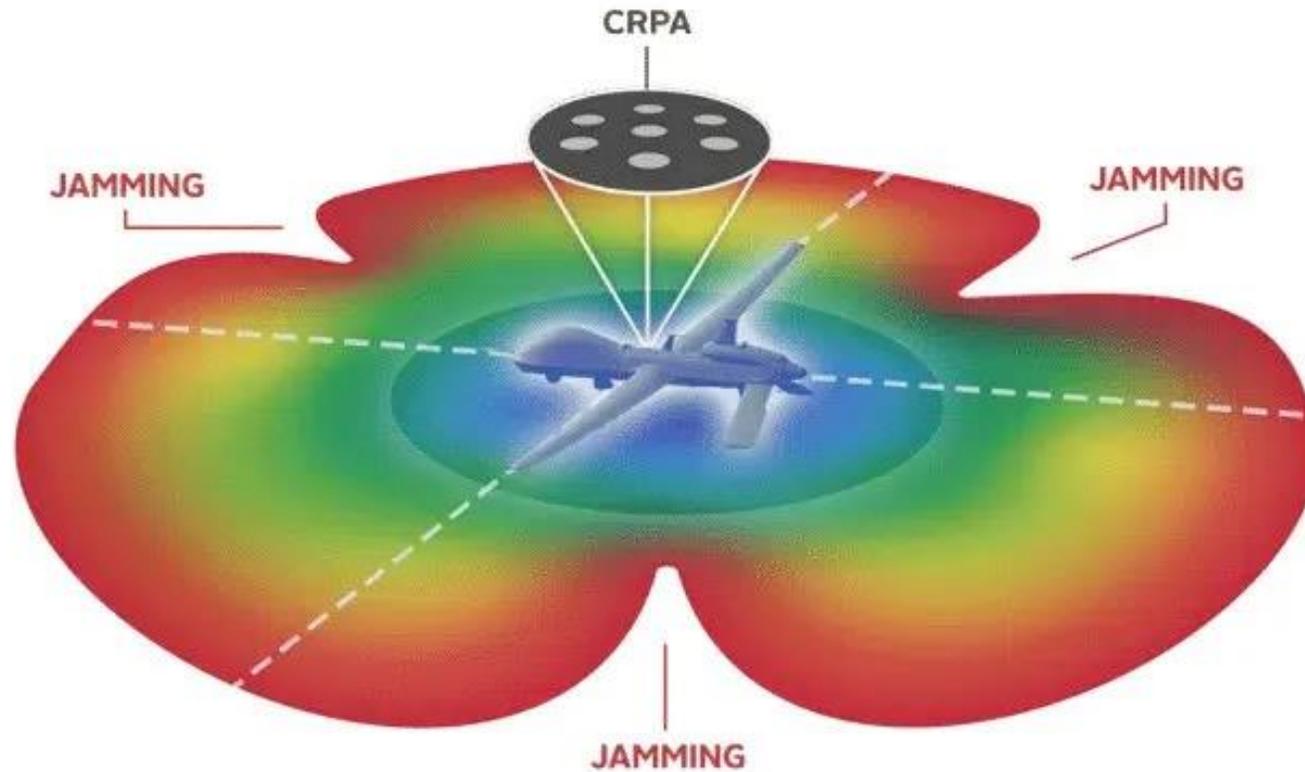


Standard antenna: positioning during jamming with AIM+



Anti-jam antenna: positioning with AIM+ and a small improvement in signal quality due to antenna

Controlled Radiation Pattern Antenna's CRPA



Hexagon GAJT Antenna



Tualcom 8300D



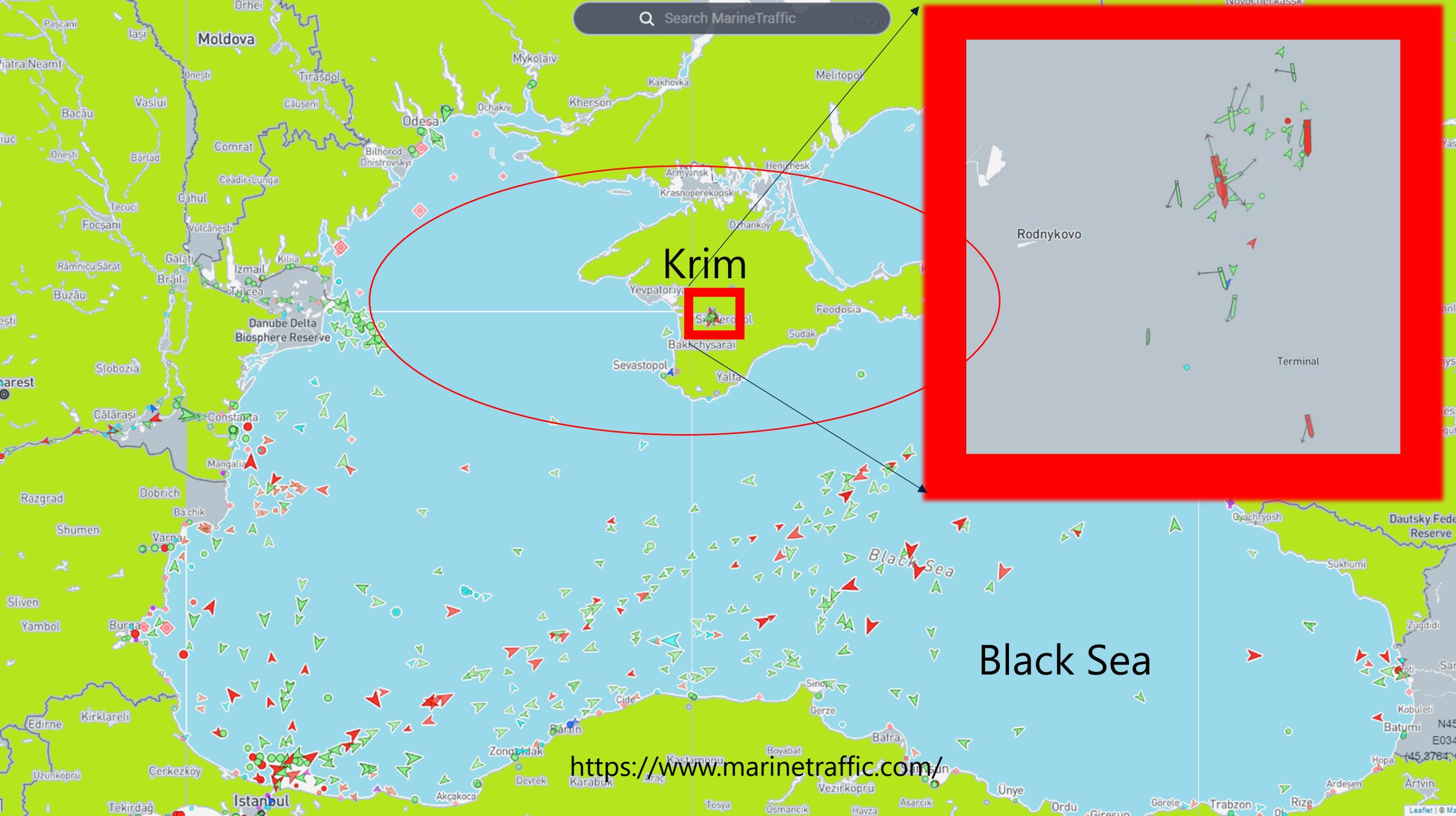
Meteksan

How to protect against Jamming?

- 1) Antenna filter to remove out of band interference
- 2) Signal sampling
 - 1) Apply Notch Filters
 - 2) Apply Wide Band Interference mitigation
- 3) Use multiple GNSS Frequencies.
- 4) Use antenna with lower sensitivity for low elevations.
- 5) Creating a metal block between interferer and GNSS antenna
- 6) Find the source of radio interference and remove the source.
 - 1) Use of direction finder. USB.
 - 2) Spectrum analyser
 - 3) GNSS antenna manual pointing.

Fugro SATGUARD : Still safe with SATGUARD!





Search MarineTraffic

Krim

Simferopol

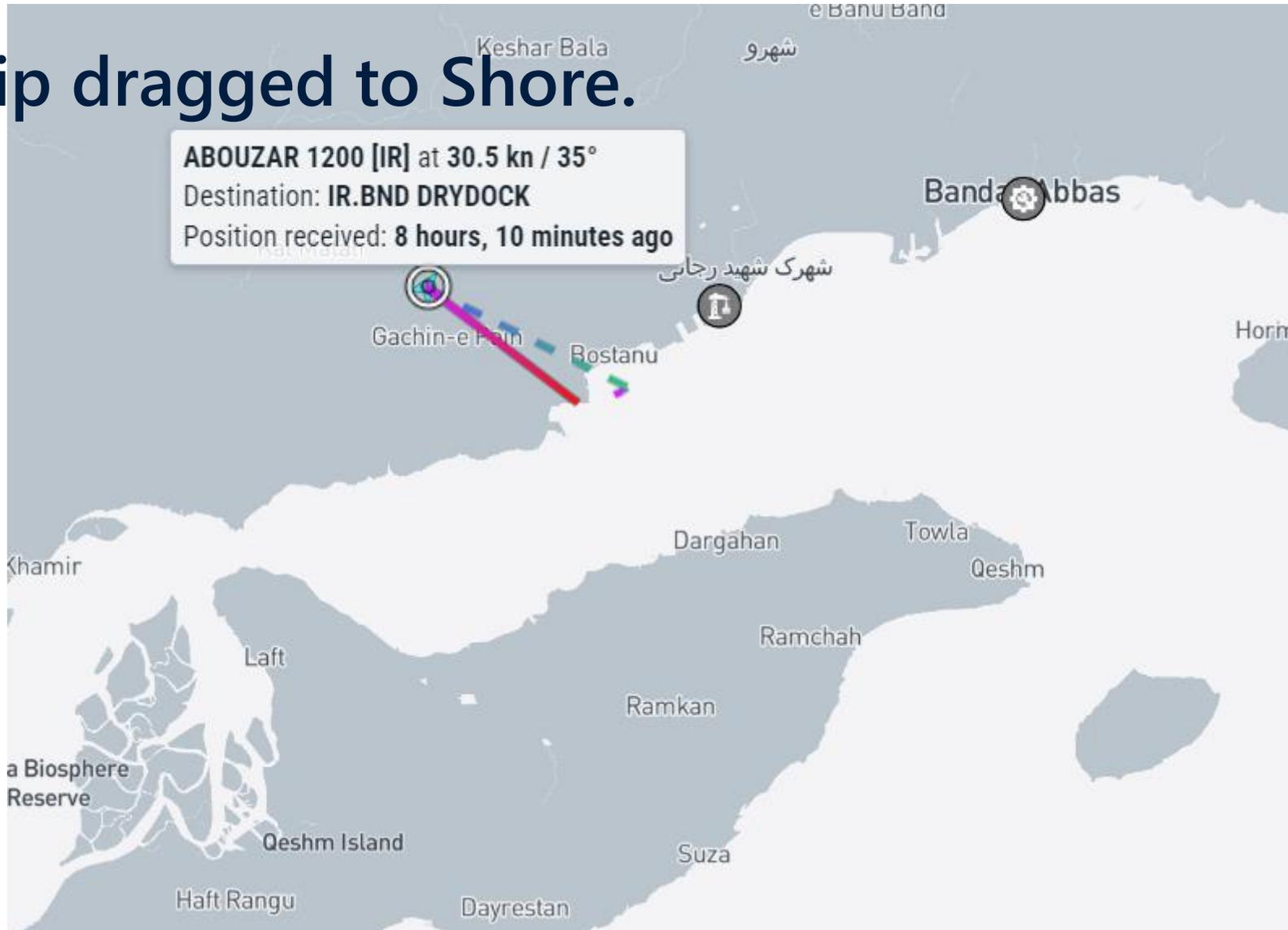
Rodnykovo

Terminal

Black Sea

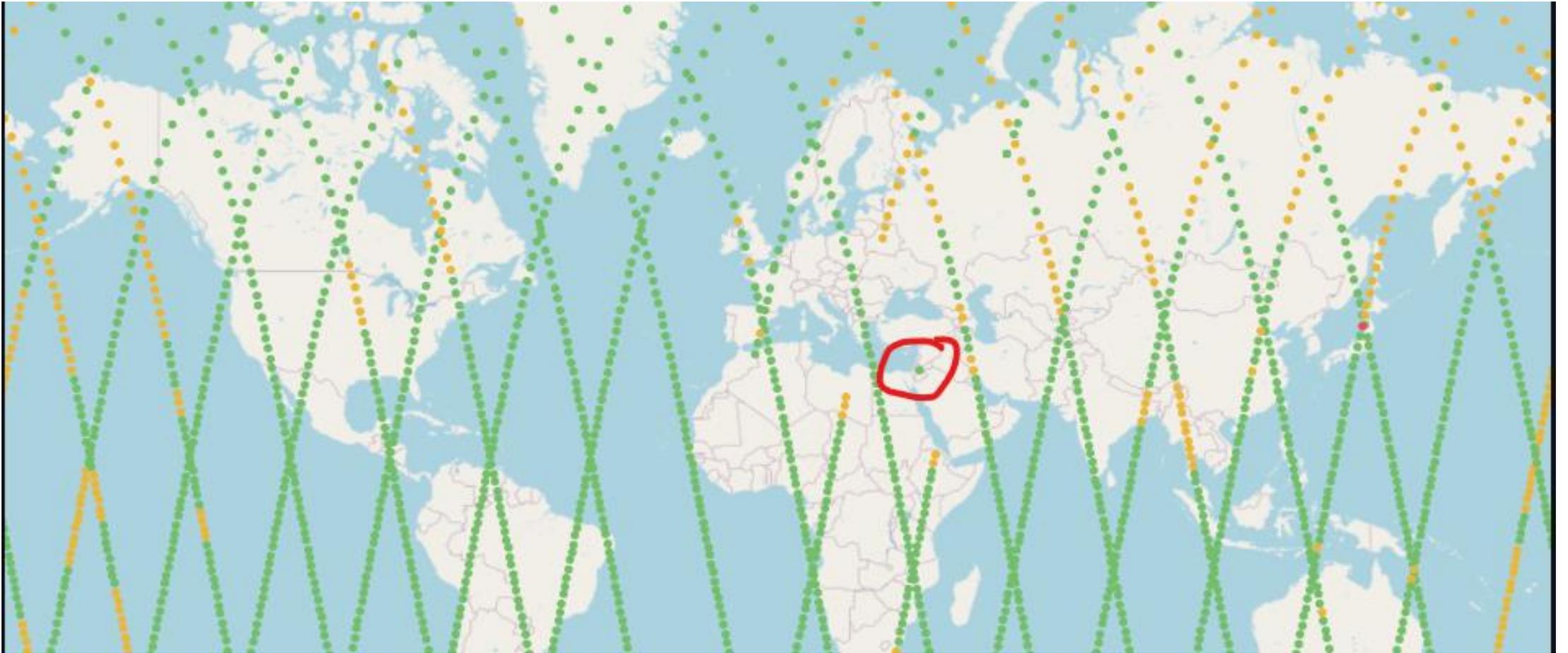
<https://www.marinetraffic.com/>

Iran: Ship dragged to Shore.

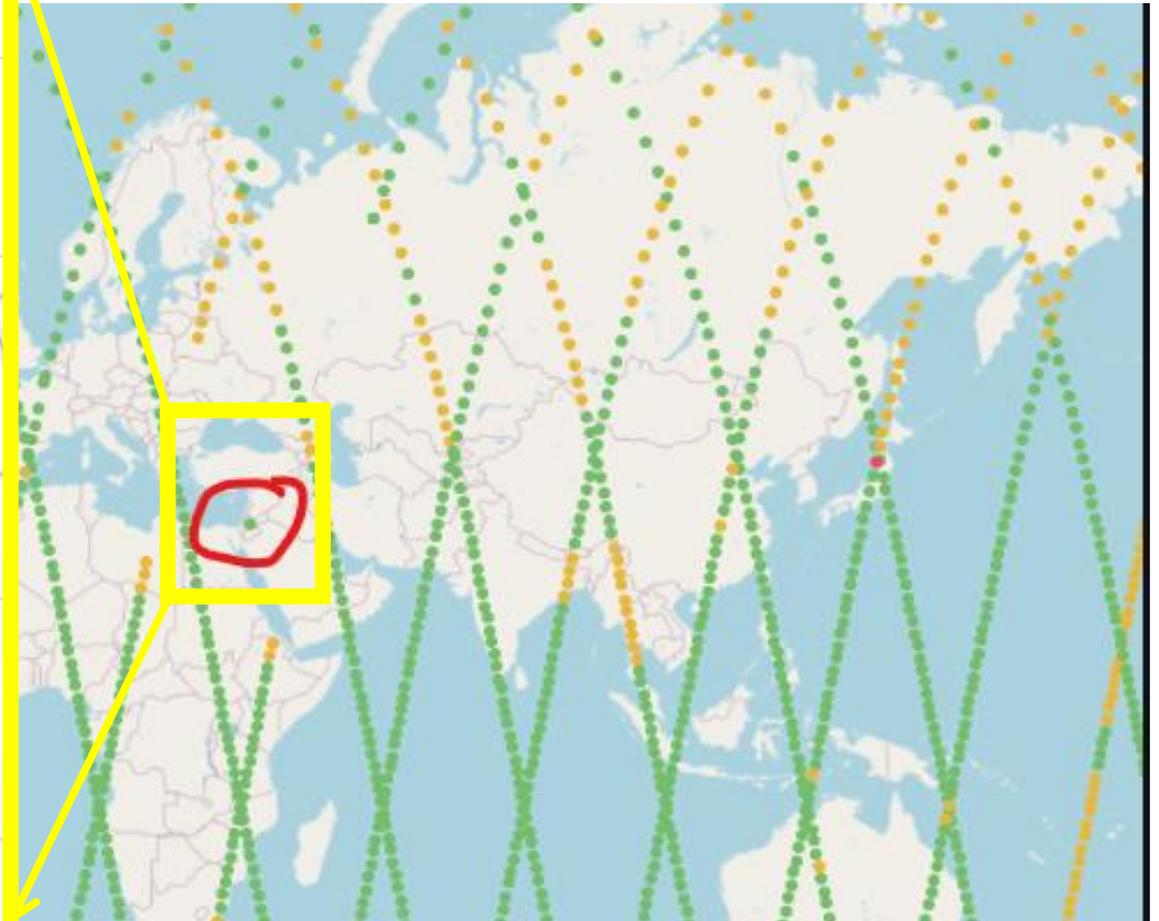
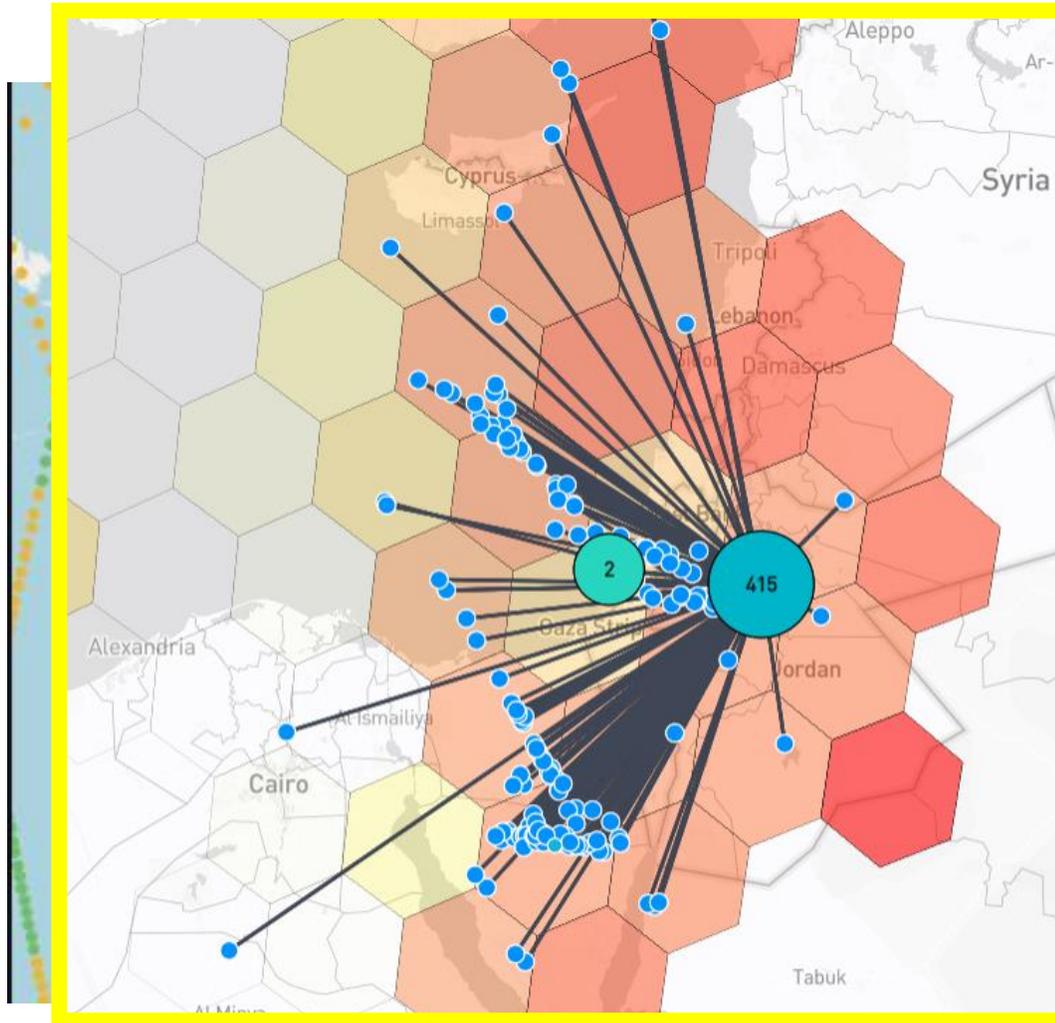


<https://www.marinetraffic.com/en/ais/home/centerx:46.2/centery:26.1/zoom:7>

Fugro Spacestar Norsat TD Spoofing to Jordanian Airport



Fugro Spacestar Norsat TD Spoofing Jordanian Airport



<https://spoofing.skai-data-services.com/>

Email sent to Airport: No reaction

GPS disruptions in Tel Aviv as Israel braces for possible Iranian attacks

April 10, 2024 - By **Jesse Khalil**

Est. reading time: 2 minutes



Tel Aviv

Beirut Airport

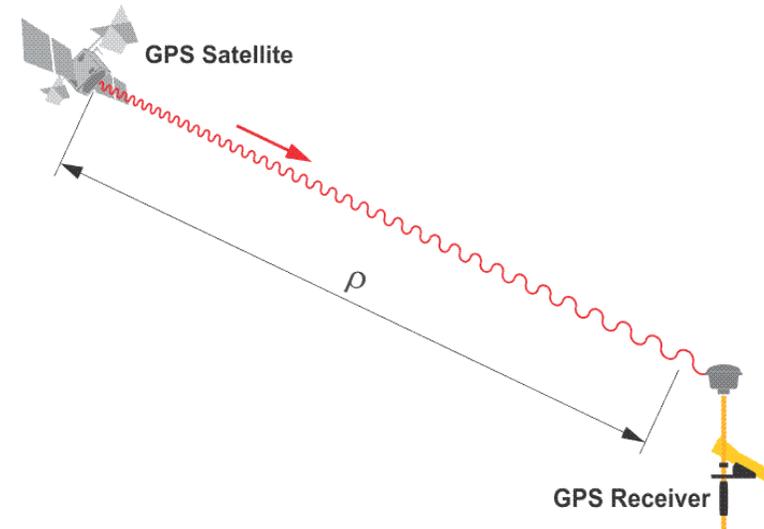
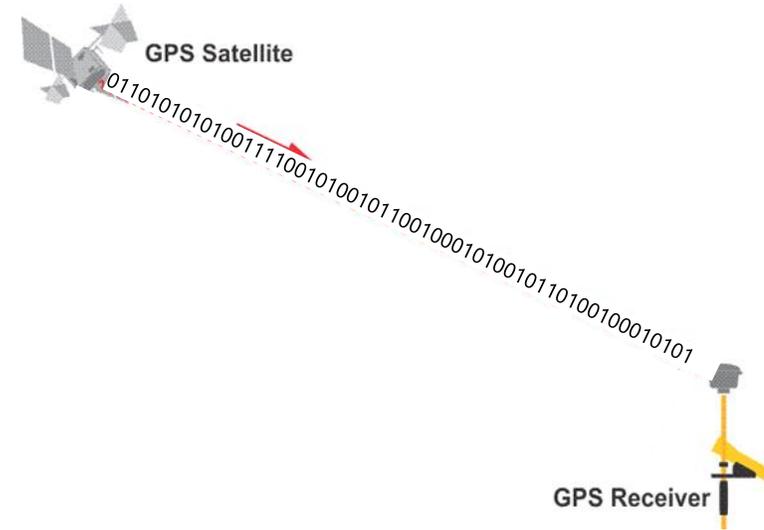
- Source Israeli Airbase
- Taxi driver navigation
- Dating App matches wrongly
- Rental Scooter trip to Beirut
- Landing aircraft
- Pilots turn GPS off

<https://www.gpsworld.com/gps-disruptions-in-tel-aviv-as-israel-braces-for-possible-iranian-attacks/>



What is GNSS authentication?

- There are two parts of GNSS authentication
 1. Navigation Message Authentication (NMA)
 2. Signal (pseudo-range) authentication
- Both parts are essential
 - Then the position is proven to be determined using only the original GNSS signals



Fugro SATGUARD: GNSS Authentication Infrastructure

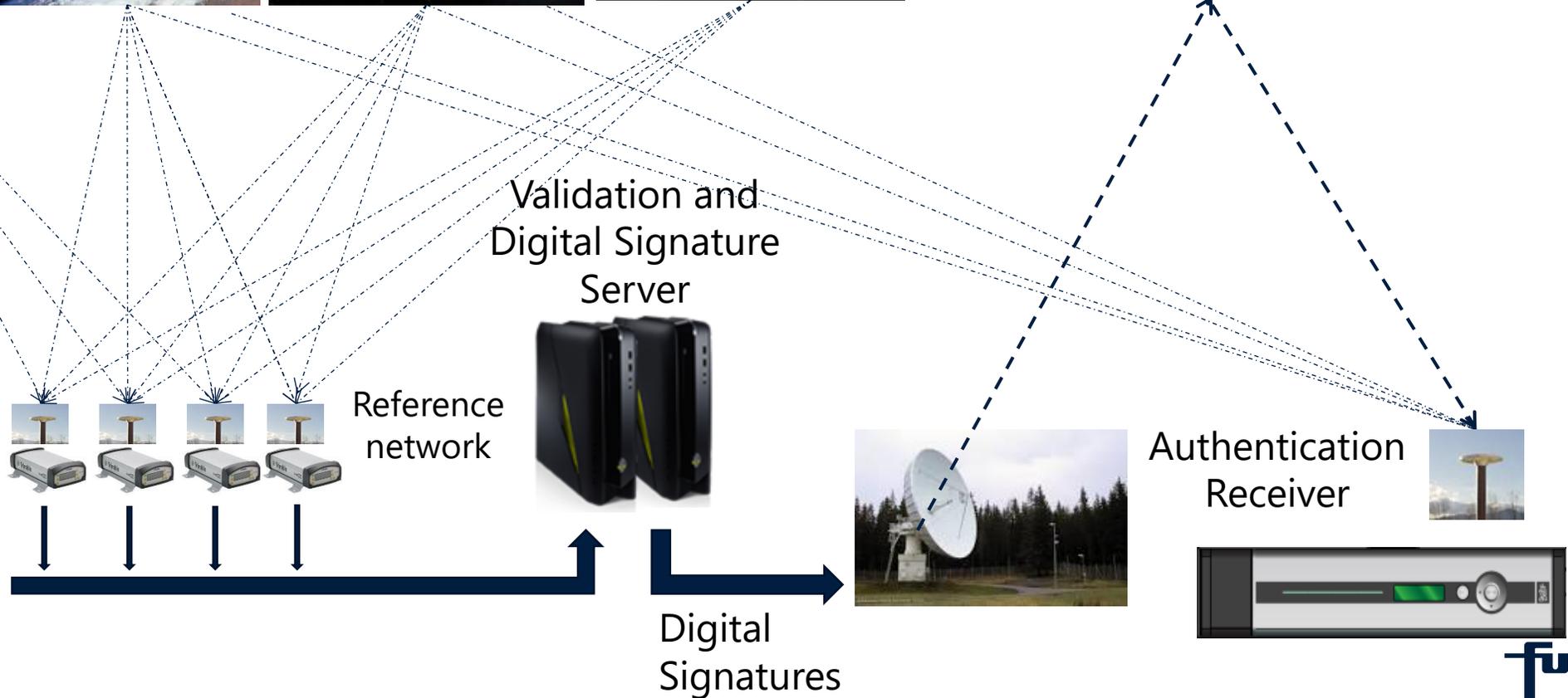
GPS

GLONASS

BeiDou

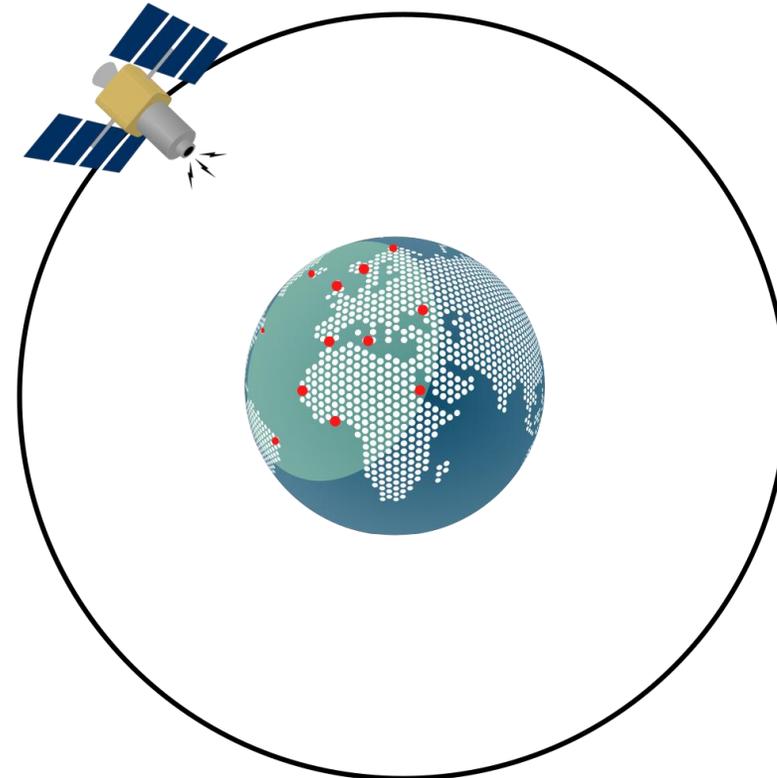
Galileo

Fugro GEO Lband



NMA in SATGUARD

- **FSP has no direct access to original Navigation Messages (NM)**
- **The NMs need to be collected and proven authentic**
 - Observe in global network*)
 - All sites with satellite in view shall receive the same message*)
 - No site outside the area of visibility should report the satellite*)
 - NM contents validation against known information*)
- **Difficulties for a spoofer**
 - Synchronise an attack at many sites
 - Need concurrent presence over multiple continents
 - Or replace a satellite as in "Tomorrow Never Dies"
- **Once authenticated by the server**
 - NMs are signed
 - Signatures broadcast
 - * Patented

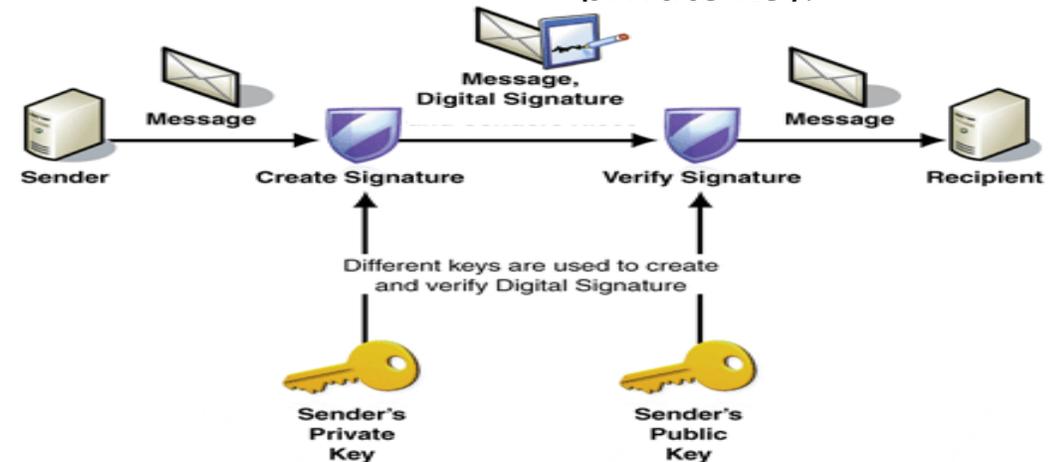


Digital Signatures

- Each NM summarized in a unique hash
- Hashes broadcast in signed message
- FSP has a private key used to sign
- User has the public key
- The public key can be used to verify that the signature is made from a combination of the NMs and FSP's private key
- Specially developed efficient protocol^{*)}



Number generator for internet banking used to authenticate you and ensure the information sent to the bank is secure. The number and your password represents your private key.



Message authentication system with a private and public key pair

^{*)} Patented

Satguard NMA

Spoofing

- Change orbits
- Pseudo Range.

Modes:

Strict: Only use Authenticated SV.

Relaxed: Start Position if no NMA.

Flag: Report Status in Display/Nmea

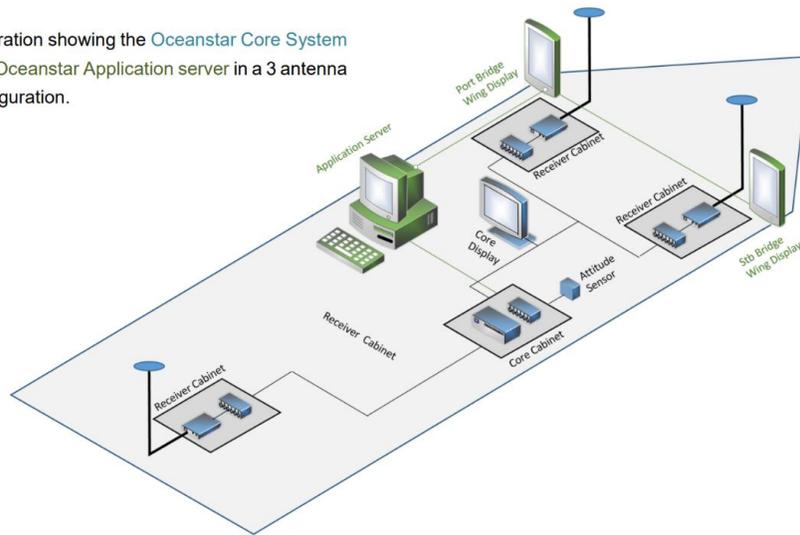


Navigation Message Authentication
GPS, Galileo, BeiDou, Glonass, Corr.
Compare Checksum with
received Orbit.

Satguard capable receivers



Illustration showing the Oceanstar Core System and Oceanstar Application server in a 3 antenna configuration.



- Oceanstar multi receiver multi antenna system



- 9410AUT



- Fugro Starpack II,



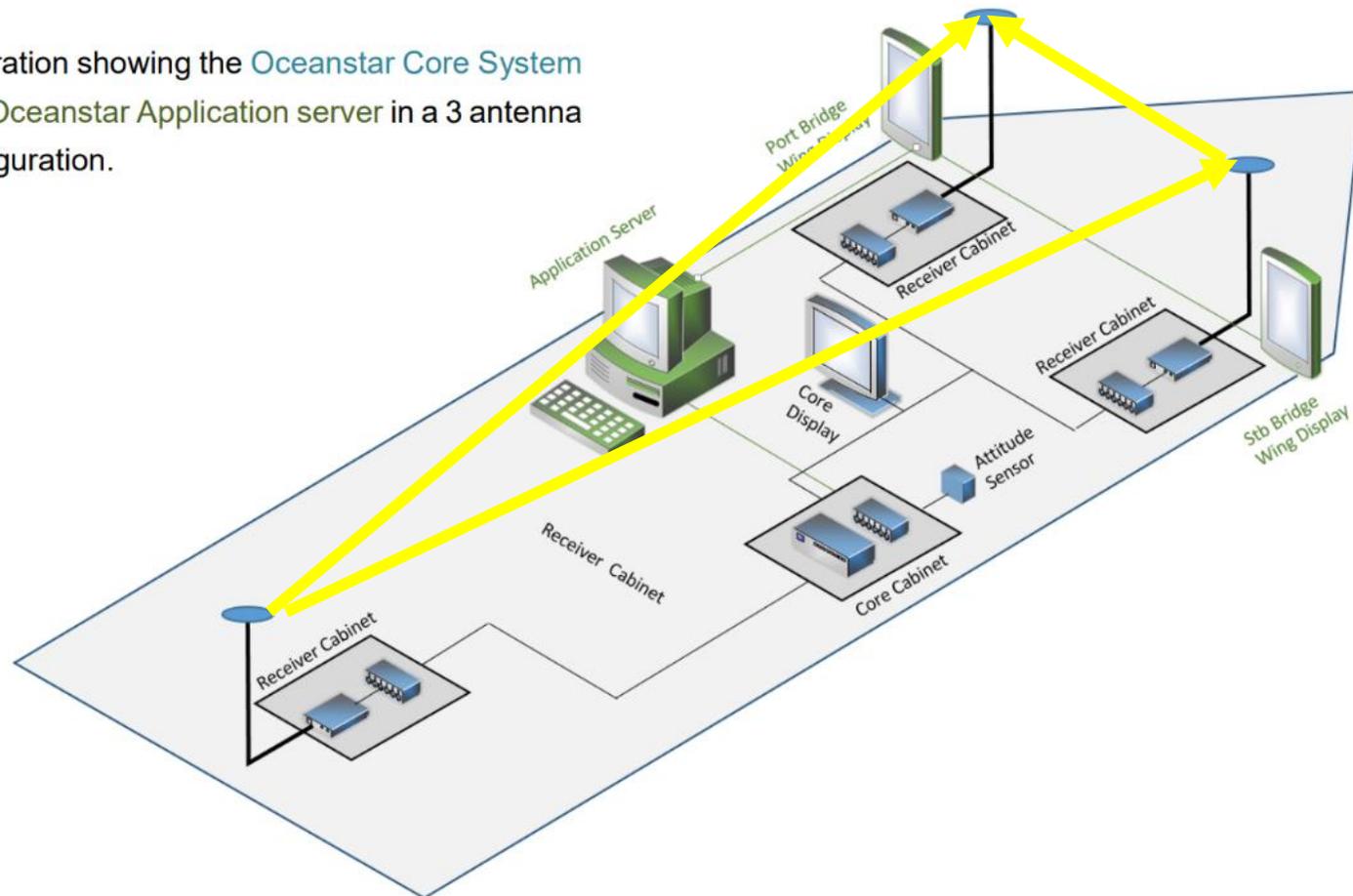
- Septentrio Mosaic-T Chip (For timing)



Spatial Integrity using multiple Antennas



Illustration showing the Oceanstar Core System and Oceanstar Application server in a 3 antenna configuration.



Use of Multiple
Antenna Baselines
Does allow
Spoofing detection

SATGUARD on 9410-Aut(hentication)

Receiver Status

- Fugro
- Activity
- Position
- Graphs
- Vector
- Google Earth
- Identity
- Receiver Options
- Spectrum Analyzer

Satellites

Data Logging

Receiver Configuration

I/O Configuration

Bluetooth

Fugro

Network Configuration

Wi-Fi

Security

Firmware

Help

FUGRO

UTC: **2023-Oct-5 08:45:27**

Latitude: **059° 55.118' N**

Longitude: **010° 41.164' E**

Height Above MSL: **37.41 m**

SOG: **0 Kn**

COG: **006°**

Quality: ●

RAIM: ● **Safe(0.3m)**

Auth: ● **NMA(Age 29s)**

● **Corr A(Age 33s)**

Accuracy of Solution:

Position: **0.04 m**

Height: **0.05 m**

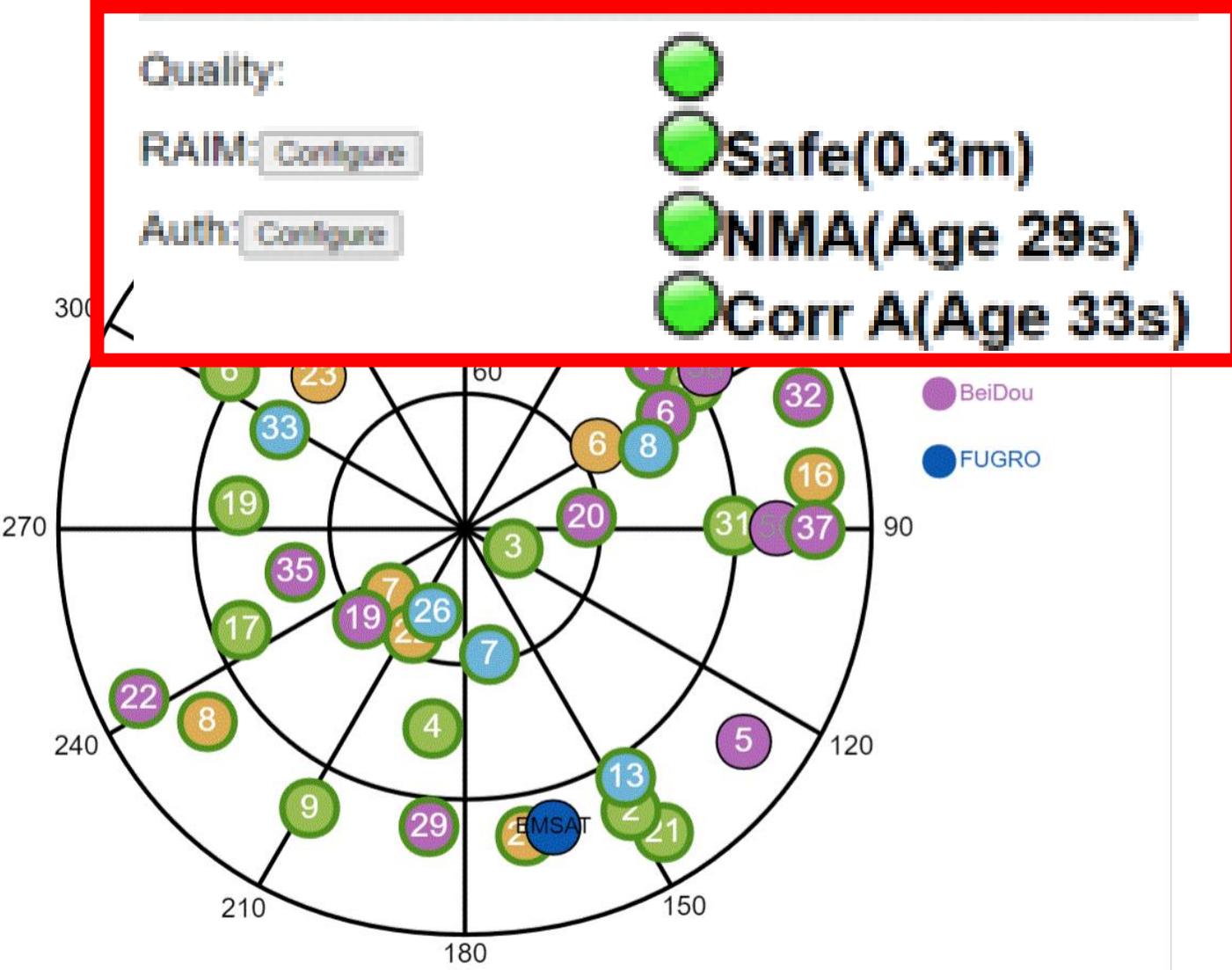
Position Type: **G4(519)**

Corr. Age: **6 s**

HDOP: **0.4**

G4/G2/XP Expiration Date: **2024-1-2 0:0:0**

L1 Expiration Date: **2024-1-2 0:0:0**



9410-Aut



Conclusions and outlook

Measures against Spoofing

- Navigation Message Authentication helps
- Spatial Integrity using Multiple Antennas does help

Future possible improvements

Add Navigation Message Authentication to GNSS receivers using Internet or Lband.

Get multifrequency CRPA antennas for lower price levels

Monitor Ship Spoofing like is available for Aviation using ADS-B using AIS.

The logo for FUGRO features a large, stylized white letter 'F' on the left. The vertical stem of the 'F' is a thick, downward-pointing arrow. To the right of the 'F', the word 'FUGRO' is written in a bold, white, sans-serif font.

FUGRO

Unlocking Insights
from **Geo-data**