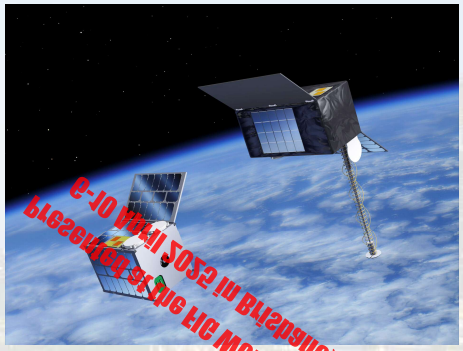
WORKING WEEK 2025
AND Locate25
THE NATIONAL GEOSPATIAL CONFERENCE
FIG Geospatial Council of Australia
Collaboration, Innovation and Resilience: Championing a Digital Generation
Brisbane, Australia 6–10 April

Navigating the Future: Harnessing LEO PNT and Building Australia's First PNT Testing Facility



Eldar Rubinov
PNT and Geodesy Lead, FrontierSI

ORGANISED BY FIG Geospatial Council of Australia
PLATINUM SPONSORS Australian Government CHCNAV esri THE SCIENCE OF WHERE Leica Geosystems HD Meter Surveyors Australia

Outline of Presentation

- Introduction
- About FrontierSI
- The need for Resilient PNT
- LEO PNT Overview
- PNT Labs – Australia's First Dedicated PNT Testing and Evaluation Facility
- Conclusion

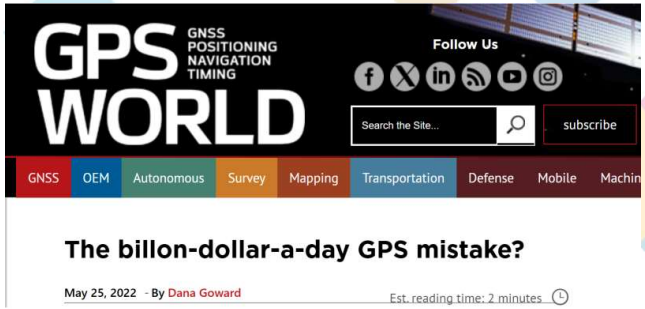
About FrontierSI

FrontierSI is a not-for-profit space and spatial collaborative research & innovation organisation.

- **Our purpose** is to anticipate and solve large problems using our space and spatial expertise.
- **We are a partner-driven organisation** and represent organisations across government, academia and industry.
- **Our role** is to formulate, broker, facilitate and manage collaborative research for and with our partners.
- **We co-invest** with our partners in projects that deliver economic growth and improved environmental and social well-being.

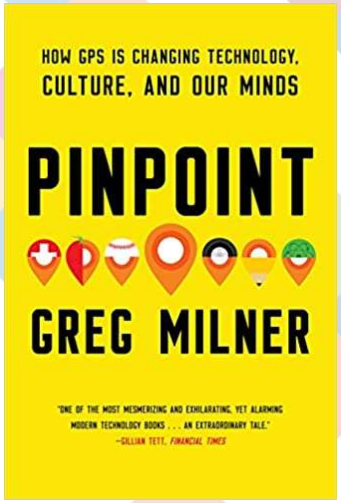
Why is PNT Resilience now Matters More than Ever

- PNT underpins nearly every modern system—yet it's often invisible until it fails
- Precision agriculture, autonomous vehicles, financial systems, and more depend on uninterrupted, accurate signals
- As reliance grows, the cost of failure increases
- Various studies have suggested that GPS loss will cause an economic loss of 1B dollars to the economy of the US alone
- However, it has been argued that this value is grossly underestimated



Yet the U.S. annual gross domestic product is more than $22 trillion a year. That's more than $60B a day. One billion dollars is less than 1.7%.

That just doesn't seem right.



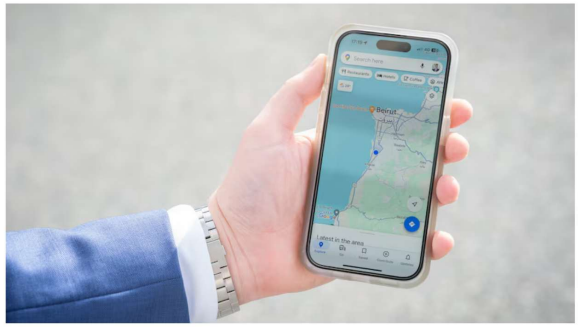
Examples of GNSS failures

Israel GPS 'spoofing' against missiles disrupts civilian life, aviation in Lebanon and Middle East

By Basel Hindeleh and Matthew Doran in Jerusalem and Chérine Yazbeck in Beirut

Unrest, Conflict and War

Sun 22 Sep



A map shows the phone's location as Beirut airport, while it is actually in Haifa. *(ABC News)*

September 12, 2024

GNSS JAMMING AND SPOOFING: NAVIGATING CHALLENGES IN THE BALTIC SEA

GPS error caused '12 hours of problems' for companies

4 February 2016

THINKSTOCK

System engineers were "called out of bed" over the problems

By Chris Baraniuk

Technology reporter

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Airlines

QANTAS PILOTS SUBJECT TO GPS JAMMING FROM 'CHINESE WARSHIPS'

written by Adam Thorn | March 19, 2023

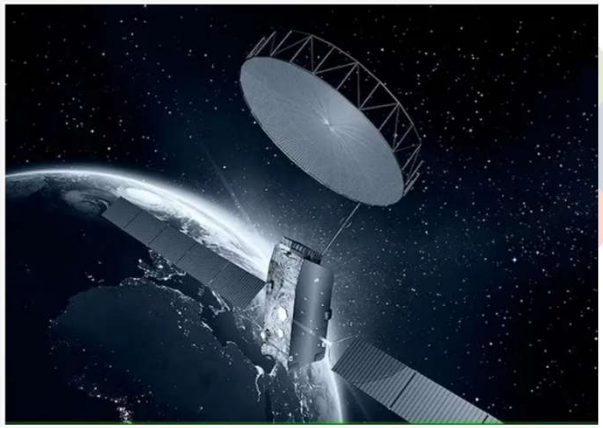
Qantas A380 VH-OQH as shot in 2015 by Seth Jaworski.

Australian Government

Spatial Source | Surveying | 3D & BIM | Uncrewed | Company &

SouthPAN service outage following Inmarsat failure

By **jnally** on 19 April, 2023

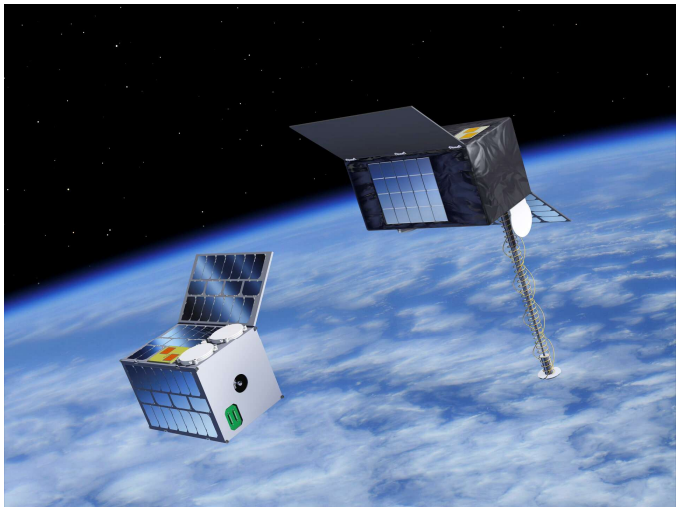


Users of the Australia-New Zealand Southern Positioning Augmentation Network (SouthPAN) Satellite Based Augmentation System (SBAS) have been left without service following a failure of the Inmarsat satellite that provides the facility.

Need for Alternate and Assured PNT Solutions

- Extensive work is underway on solutions that either complement GNSS or provide independent PNT capabilities
- One example of alternative solutions is the Low Earth Orbit (LEO) PNT solutions
- Others include terrestrial positioning systems (e.g. eLoran, Locata)
- A lot of effort is also spent on research in inertial navigation systems, quantum, visual, AI and more

Part 1 – Overview of LEO PNT Technology and Market

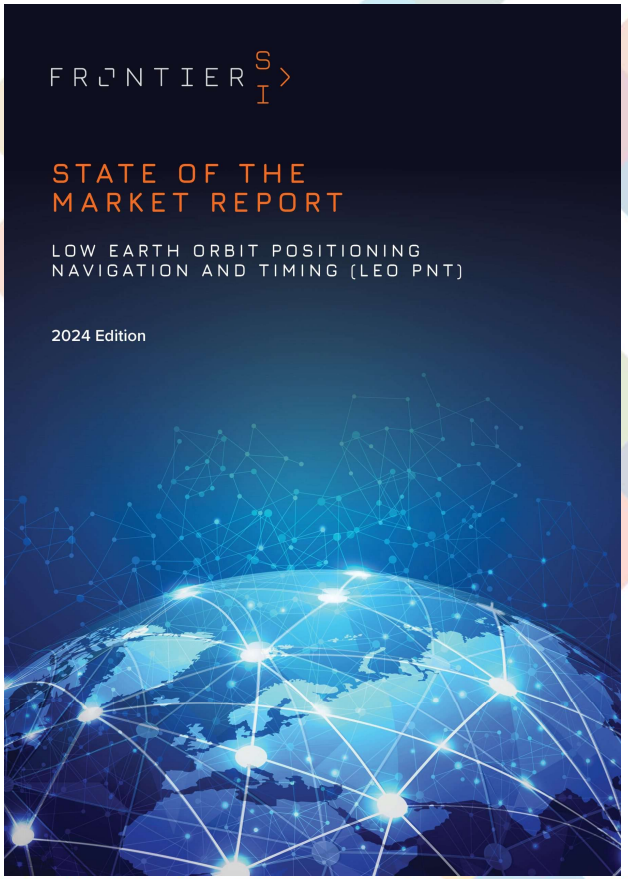


LEO PNT Overview

- LEO PNT is a disruptive technology that is currently being developed at a dynamic pace
- Aimed to augment GNSS in a number of key areas such as vulnerability to RF interference (e.g., jamming, spoofing) and poor performance in obstructed environments
- Unlike GNSS, which is run by governments, LEO PNT is largely driven by market demands
- There are different ways to do PNT from LEO:
  - Dedicated PNT Constellations
  - Signals of Opportunity (SOP) from non-PNT satellites
  - Fused Communications and PNT Systems

FrontierSI LEO PNT State of the Market Report

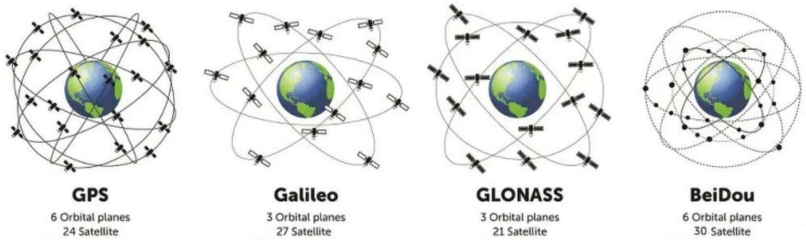
- At least 11 LEO PNT systems are currently being deployed at the moment from USA, China, Japan, Europe, Türkiye and UAE
- The systems all differ in the architecture, use cases, performance, etc.
- In January 2025, FrontierSI has released the LEO PNT State of the Market Report summarising the current state of the technology



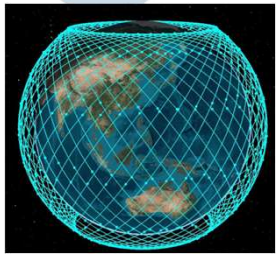
https://frontiersi.com.au/frontiersi-releases-leo-pnt-state-of-the-market-report-a-comprehensive-look-at-the-future-of-satellite-navigation/

GNSS and LEO PNT – Key Differences

	GNSS	LEO PNT
Orbital Altitude	19,000 – 23,000km	500 – 1,200km
Number of Satellites	~30	200 – 500
Signal Frequency	L	UHF, VHF, L, S, and C
Satellite SWaP	Medium (~1000kg)	Nano to Mini (10 – 100kg)
Timescale Reference	Onboard Atomic Clocks	Ground stations, GNSS, GEO, OISLs
Ownership & Business Model	Government	Government, Private

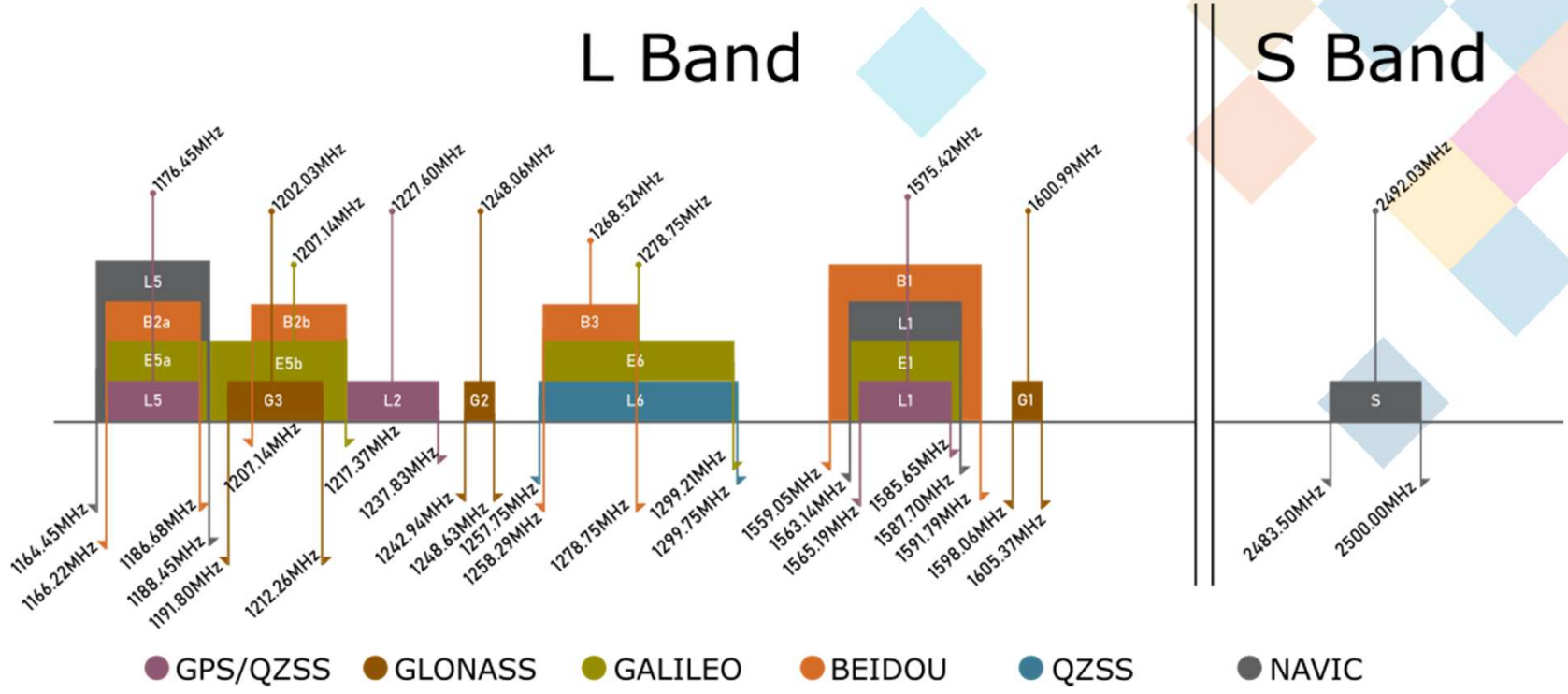


Source: https://inertiallabs.com/what-are-the-limitations-of-gnss/



Source: Murata (2024) – Preliminary Study on LEO PNT

GNSS Frequencies

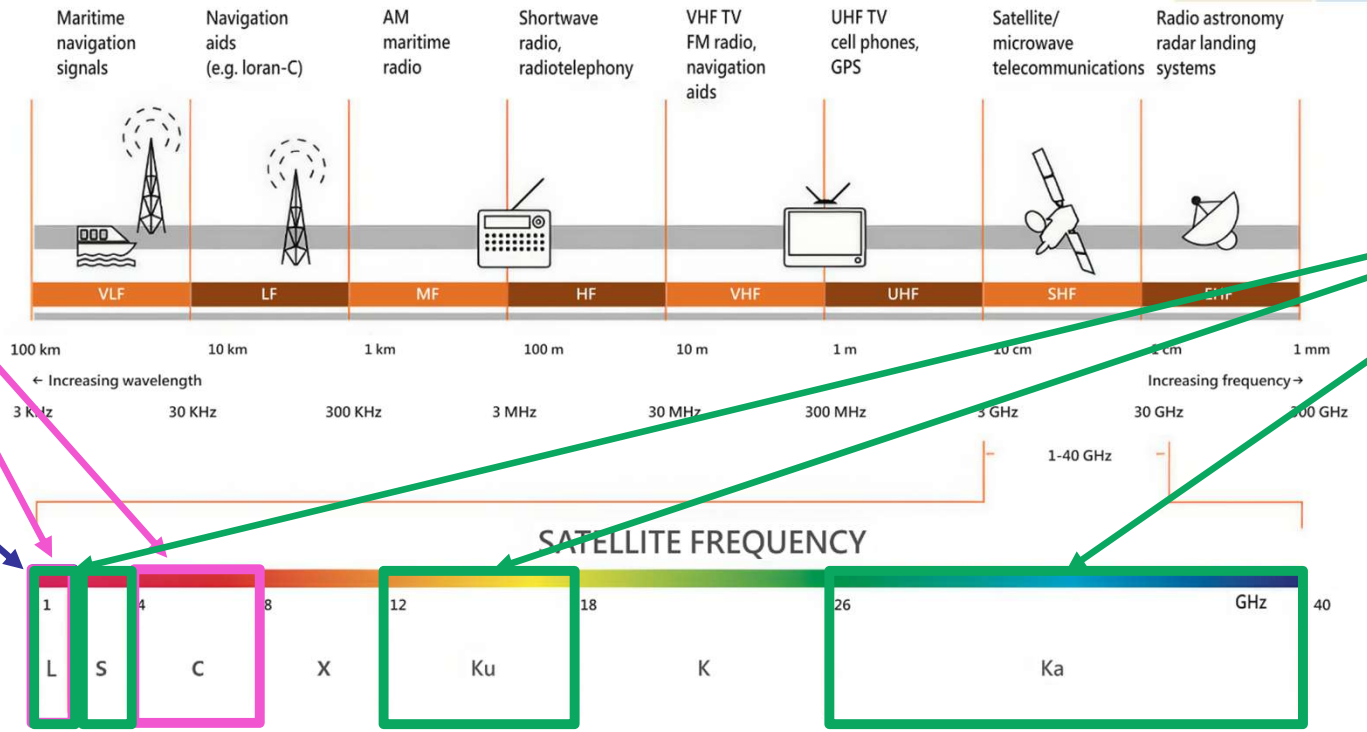


Satellite Frequencies

Dedicated LEO PNT

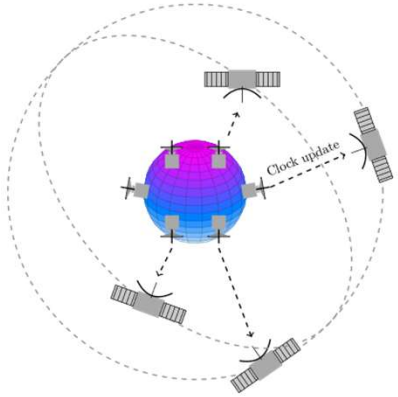
GNSS

Satellite Communications

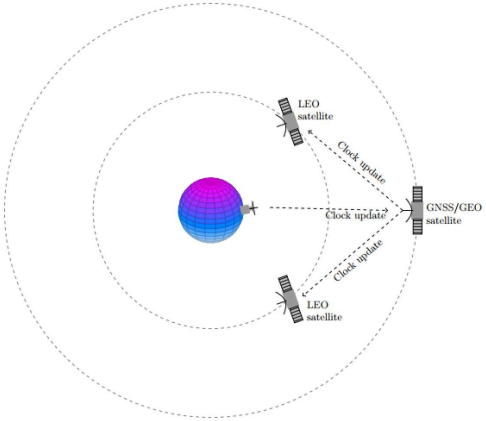


Technical Aspects of LEO PNT

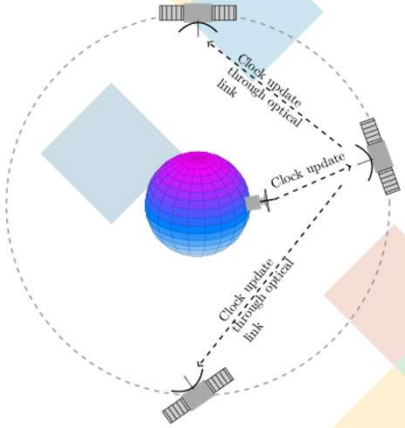
- Precise Orbit Determination
- Timescale Reference
- Ionospheric Effects
- Resilience of RF Interference



Time transfer using ground stations



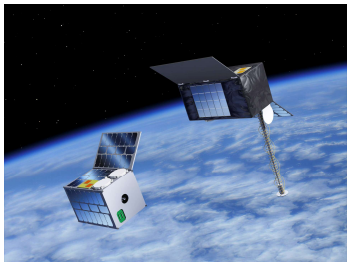
Time transfer using GNSS/GEO satellites

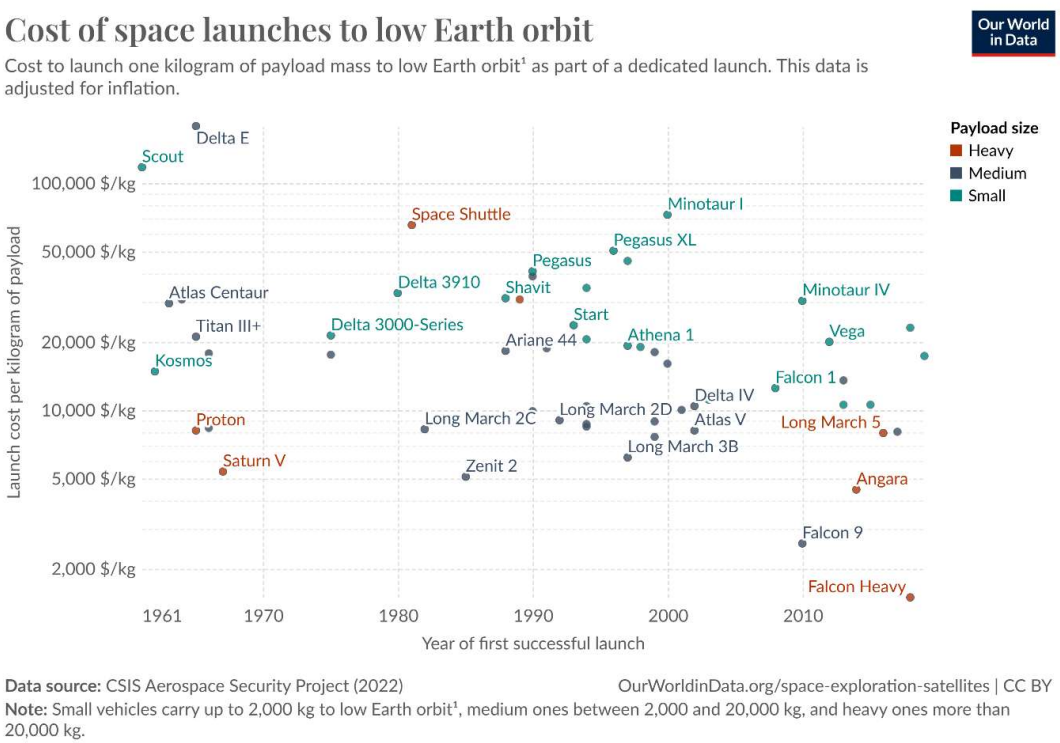


Time transfer using inter-satellite links

Space Segment Considerations

- Launch Cost
- Satellite Platform
  - Satellite SWaP
  - Navigation Payload
- Constellation Design





LEO Satellite Constellations

Dedicated PNT Constellations

Company	Country	Frequency Band	Total Planned
Iridium	USA	L	66
Xona Space	USA	L	258
TrustPoint	USA	C	300
JAXA	Japan	C	480
ArkEdge Space	Japan	VHF	50-100
Centispace	China	L	190
Geely	China	L	240
SatNet LEO	China	L	506
ESA's FutureNAV LEO-PNT IoD	Europe	L, S, C, UHF	10 demos (up to 263)

Communication Constellations

Company	Constellation	Country	Frequency	Total Planned
SpaceX	Starlink	USA	Ku, Ka	42,000
China SatNet	Guowang	China	Ku, Ka	12,992
SSST	G60	China	Ku	12,000
Hongqing Technology	Honghu-3	China		10,000
GeeSpace	GEESATCOM	China		5,676
Lynk	Lynk	USA	L	5,000
Amazon	Kuiper	USA	Ku, Ka	3,236
Skykraft	Skykraft	Australia	S	2,976
EutelSat OneWeb	OneWeb Gen I	France, UK	Ku, Ka	648
Rivada	OuterNET	USA	Ka	576
CASC	Hongyan-1	China	Ka, L	320
SpaceRise	IRIS^2	EU	Ka, S	290
Sateliot	Sateliot	Spain	L	250
Telesat	Lightspeed	Canada	Ku, Ka	198
AST SpaceMobile	Bluebird	USA	L, S	168
ArkEdge	ArkEdge	Japan	VHF	50-100
Iridium	NEXT	USA	L	80
Globalstar	Globalstar	USA	S	65
Orbcomm	Orbcomm	USA	L, S	31

Xona Space Example

Receivers capable of decoding Xona PULSAR Signals

Trimble

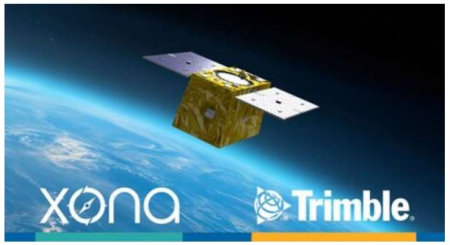
Xona Space Systems Announces Collaboration with Trimble to Deliver Next-Gen Navigation Services

03/11/2025

Download

Collaboration is Poised to Deliver Reliable, High-Precision Navigation Anywhere on Earth

BURLINGAME, Calif. and WESTMINSTER, Colo., March 11, 2025 /PRNewswire/ -- Xona Space Systems (Xona), a leading pioneer of advanced commercial satellite navigation solutions announces a new collaboration with Trimble® (Nasdaq: TRMB), a global leader in construction, transportation and geospatial technology. Xona and Trimble are pursuing the integration of Trimble correction services with Xona's PULSAR™ high-performance navigation service. Initial satellite launches are expected in late 2026 with service starting in 2027 through the PULSAR satellite network, enabling secure, high-precision positioning for applications ranging from geospatial to low-power mass mobile and IoT. In support of this new and developing collaboration, Xona has received an investment from Trimble Ventures.



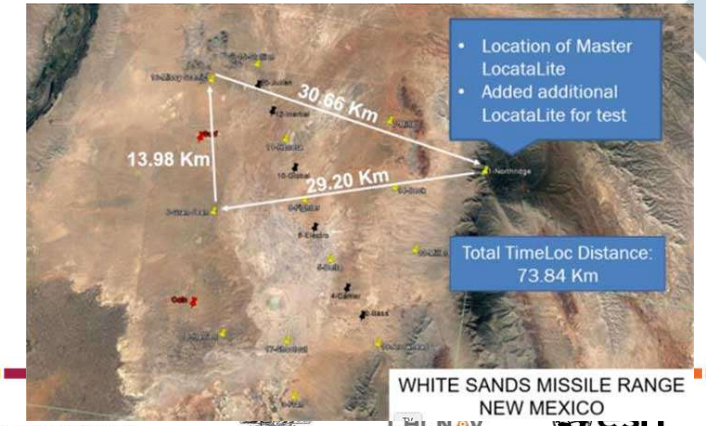
LEO PNT Summary

- LEO PNT ecosystem and market are evolving rapidly
- Will have a significant impact on the PNT community in the next 5 years
- Even though the satellites are not in orbit yet, many deals and partnerships are being signed
- As a community we need to be aware of the developments

Part 2 – PNT Labs – Australia's First Dedicated PNT Testing and Evaluation Facility

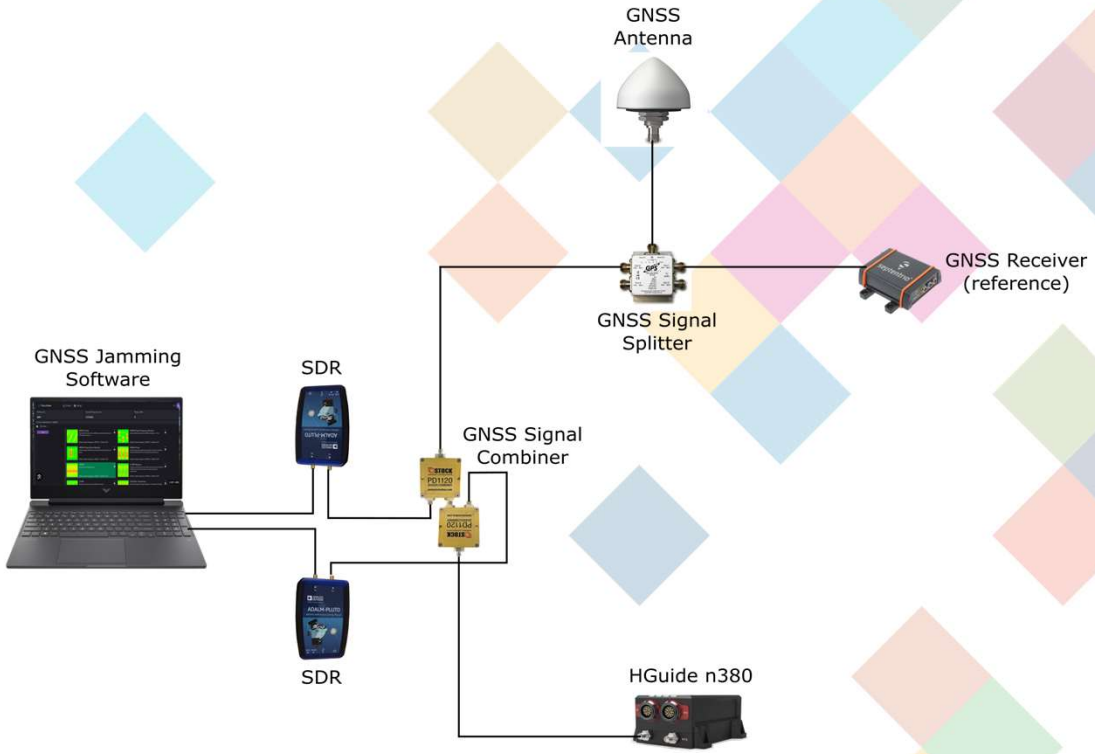
PNT Resilience Testing

- PNT Resilience testing is complicated and requires a lot of investment into dedicated infrastructure
- Jamming and spoofing are illegal, and hence cannot be implemented easily for testing and evaluation purposes
- Two examples of dedicated facilities and events include the White Sands Military Range in the USA and the annual Jammertest event in Norway



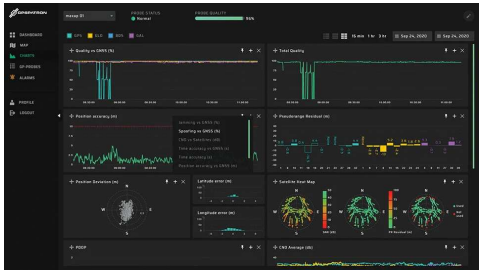
FrontierSI PNT Labs

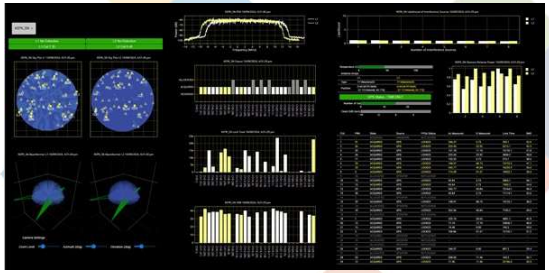
- FrontierSI offers a novel and cost-effective way to conduct PNT Resilience testing
- Consists of a number of “Labs” to conduct testing in different environment
- Using novel hardware and software solutions from our technology partners, we can introduce controlled RF interference directly into device, without doing on-air jamming and spoofing
- We have the ability to jam one, two or three frequencies simultaneously to significantly disrupt GNSS receivers



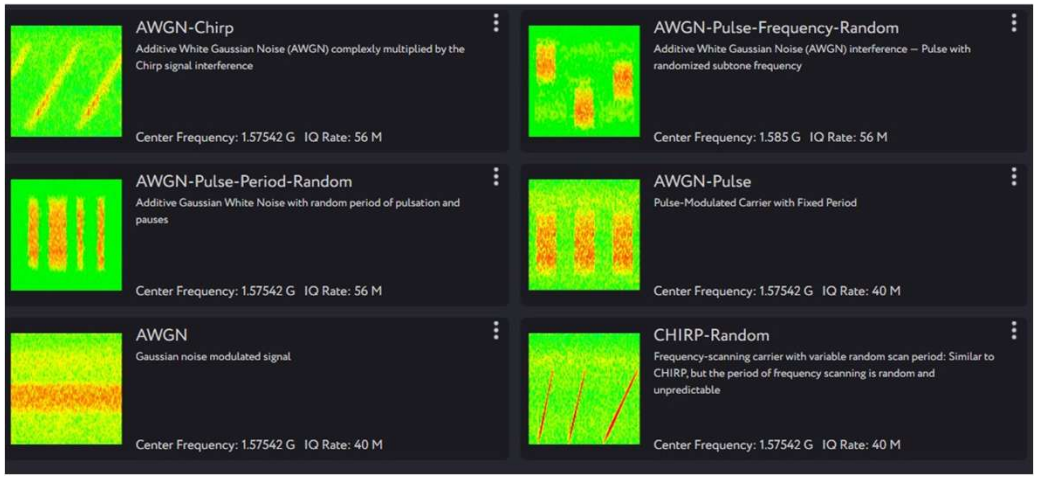
PNT Labs Technology Partners

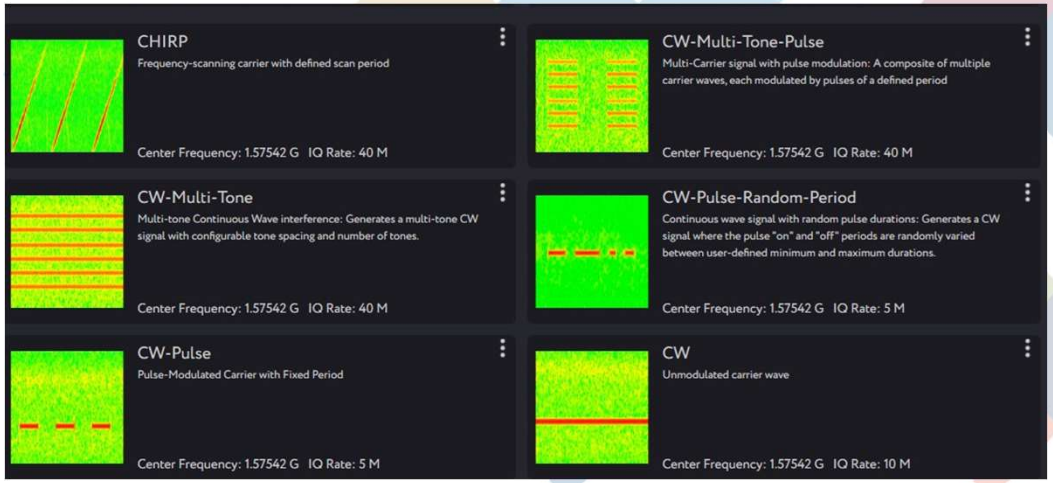
Spirent™ SAFRAN GPSPATRON GPSat SYSTEMS AUSTRALIA Pty Ltd

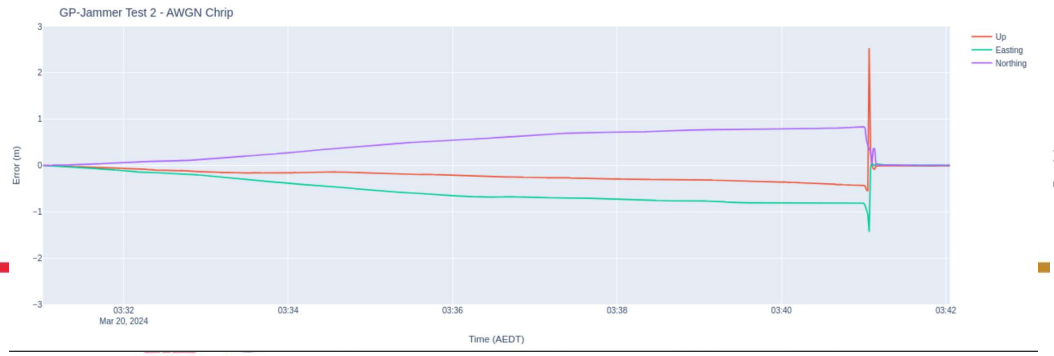


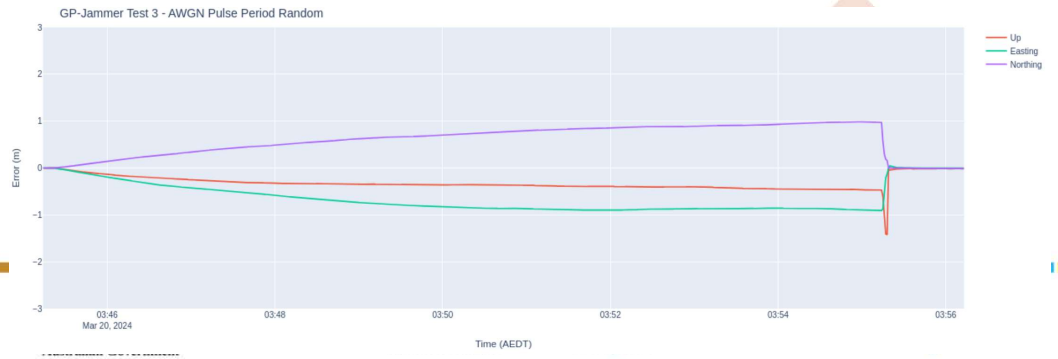


GNSS Jamming Library – GPS Patron









FrontierSI PNT Labs – Railway Lab

	Mean Horizontal XTE (m)	Mean Vertical XTE (m)	Mean 3D XTE (m)
Run 1 - Forward	0.009	0.011	0.015
Run 1 – Backward	0.006	0.011	0.014
Run 2 – Forward	0.007	0.012	0.015
Run 2 – Backward	0.006	0.01	0.013

FrontierSI PNT Labs – Aviation Lab

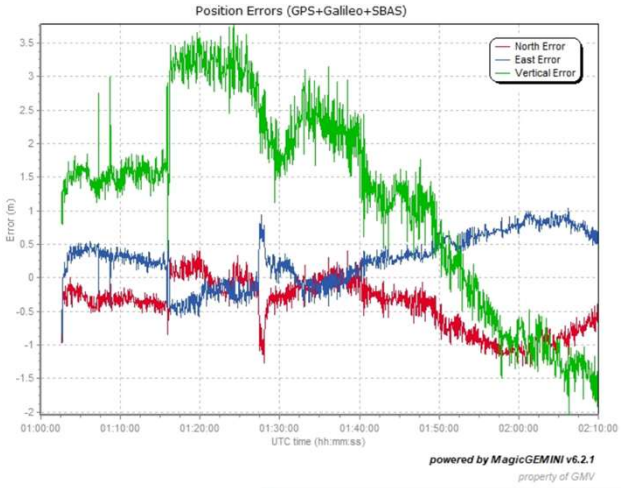
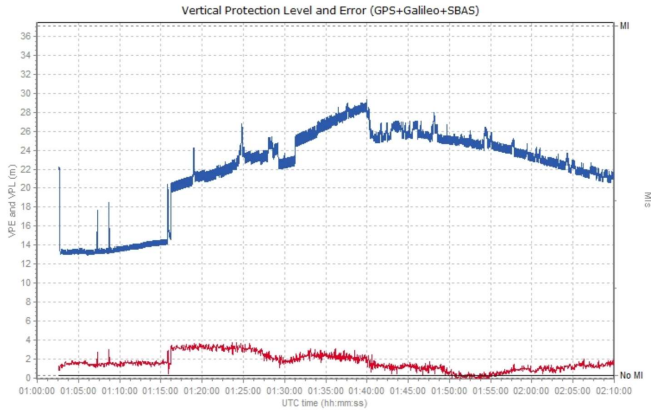
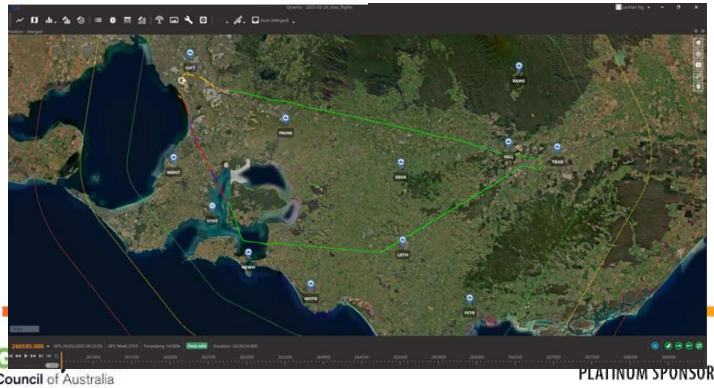
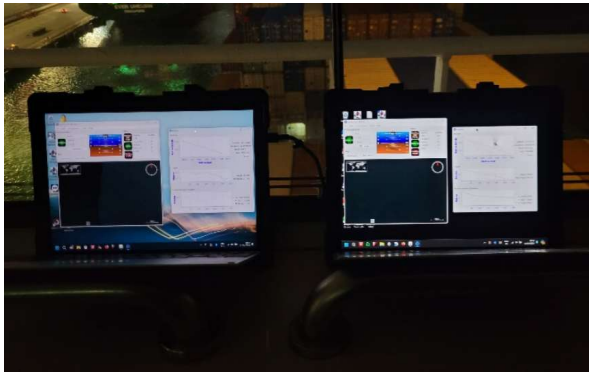


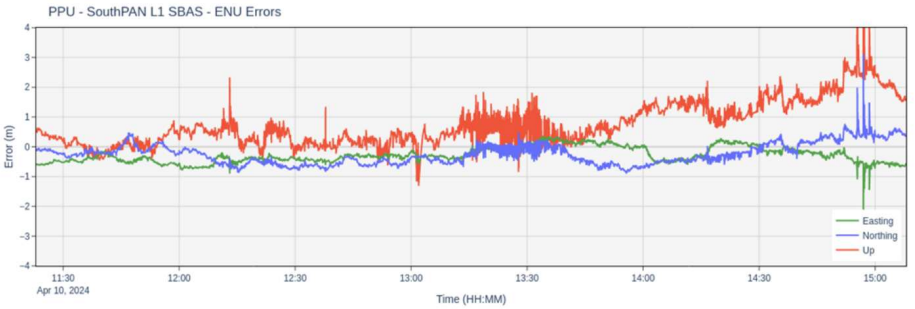
Figure 3-2: VPL and VNSE temporal evolution

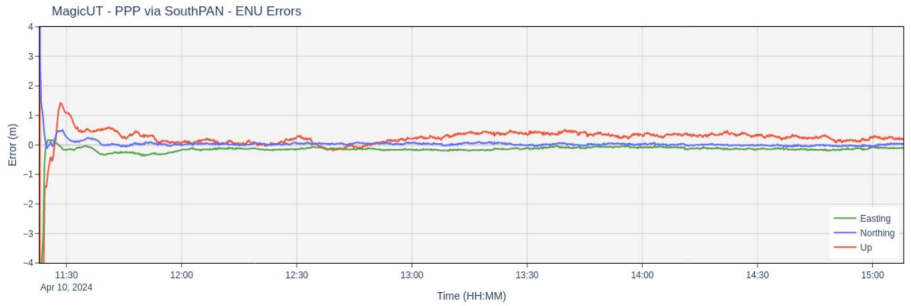


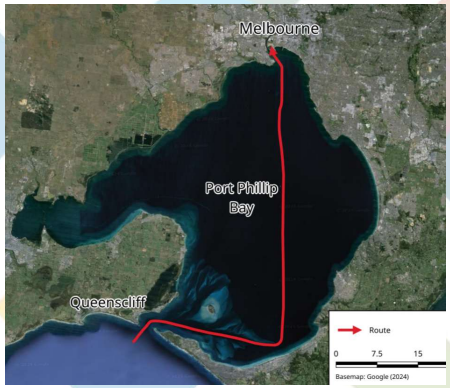


FrontierSI PNT Labs – Maritime Lab



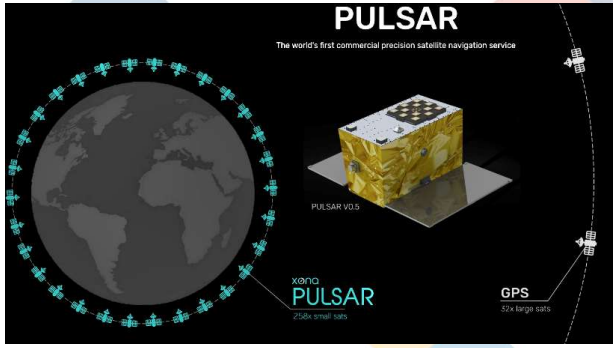






FrontierSI PNT Labs – LEO PNT Lab

- FrontierSI has procured a LEO PNT receiver capable of receiving signals in L-band, S-band, as well as Xona Pulsar X1 and X5 signals
- The receiver will be used to receiver S-band signals from Australia's Skykraft satellites in S-band
- Will also be used to do simulations with Xona PULSAR's signals for positioning and timing



PNT Labs Summary

- FrontierSI is building a dedicated testing and evaluation capability to test all aspects of PNT technologies
- Testing will be carried out on all types of platforms including cars, trains, boats, planes, UAVs and more
- Number of technology, infrastructure and research partners

Conclusion

- As we move into a decade where resilience is a necessity, the convergence of cutting-edge technologies like LEO PNT and next-gen testing capabilities is both timely and critical
- Australia has an opportunity to lead in this space - not just as adopters, but as innovators and enablers of a more resilient, robust PNT ecosystem
- Through PNT Labs, we're building the foundational infrastructure to test, validate, and ultimately trust the systems that will guide our autonomous vehicles, secure our timing infrastructure, and support the next generation of geospatial applications
- Let's collaborate, challenge assumptions, and shape the future of Positioning, Navigation and Timing together

Questions

https://www.linkedin.com/in/elrubinov/