



NAVIGATING THE LANDSCAPE
OF
NavWar

Essence of NavWar

Offensive NavWar

- Deny enemy access to critical PNT data
 - *'Where am I, how do I get there, and what time is it?'*
- Coordinated employment of space, cyberspace, and EW operations

Defensive NavWar

- Preventing the enemy from denying PNT information
- Involves efforts to assure PNT information to own forces
- PNT assurance is analogous to *"information assurance"* in NW operations

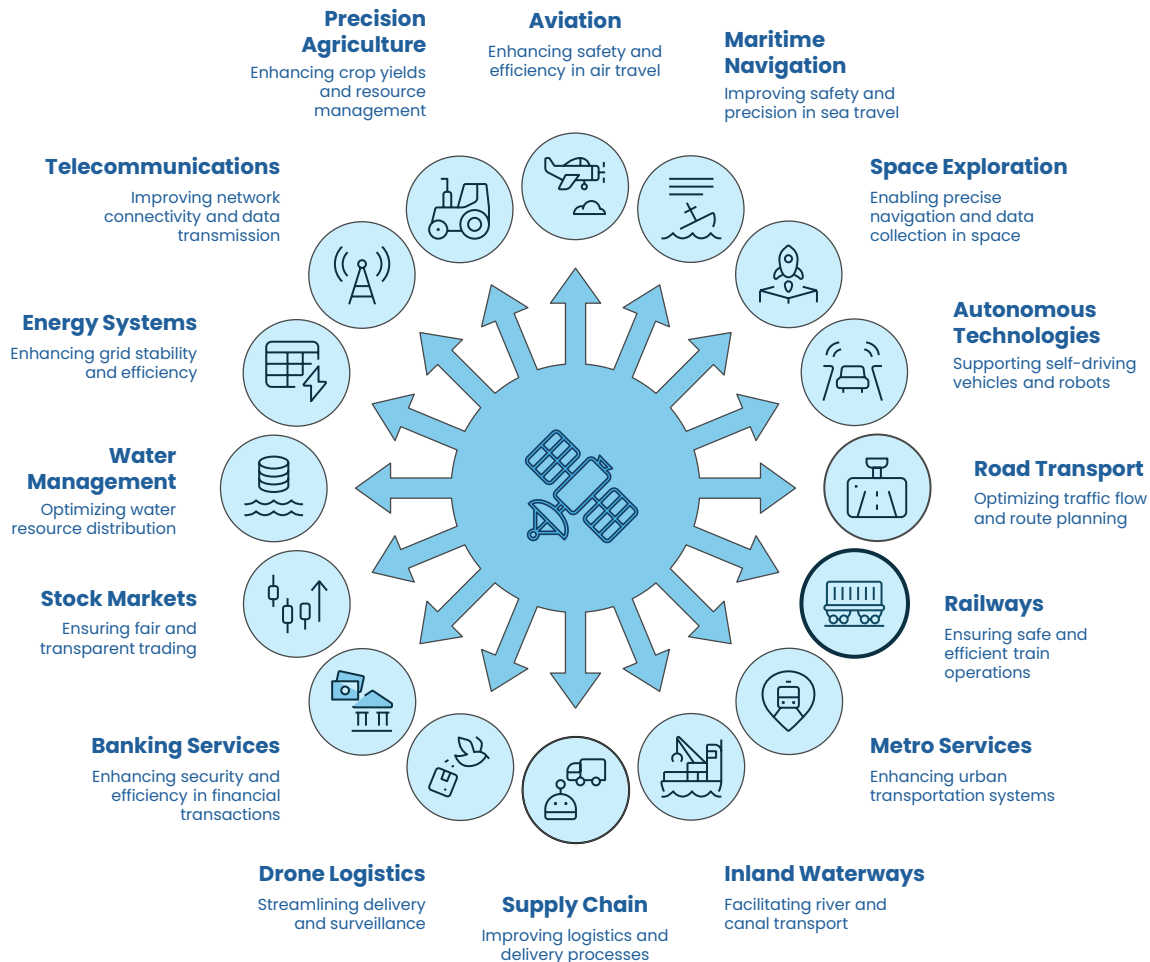
Actions in NavWar

- Focuses on weakening adversaries' PNT capabilities
 - **D5** - **D**eceive, **D**eny, **D**isrupt, **D**egrade and **D**estroy
- Grey-zone probing of a nation's PNT infrastructure and airspace resilience

NavWar in Civil Domain

- Hypothesis - Civilian PNT dependent systems - Collateral victims in NavWar theatres
- Waging economic warfare with high degree of deniability, without direct military confrontation

Civil Infrastructure Dependencies on GNSS



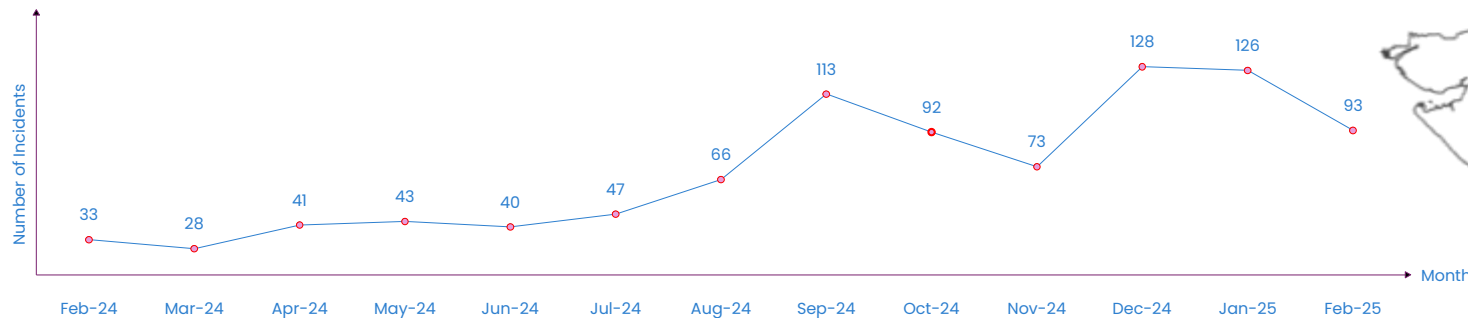
Key Aspects

- 2023 - 5.6 Billion GNSS dependent devices currently in use
- 2033 - Projected to grow to nearly 9 billion devices
- Monoculture Vulnerability - Most civilian systems are completely dependent on GNSS for PNT
 - Critical Infrastructure - Dependent for “T” aspect of PNT on GNSS
- Weak GNSS signal strength - Asymmetric opportunities for interference
- Rise in intentional GNSS RFI - 4.3 lakh cases in aviation & 10000+ cases in maritime sector globally - 2024
- Aviation & Maritime Navigation - Most affected
- Civilian sector centered NavWar - Critical risk to life, property and economy
- Redundancy - Need for GNSS-independent backup systems

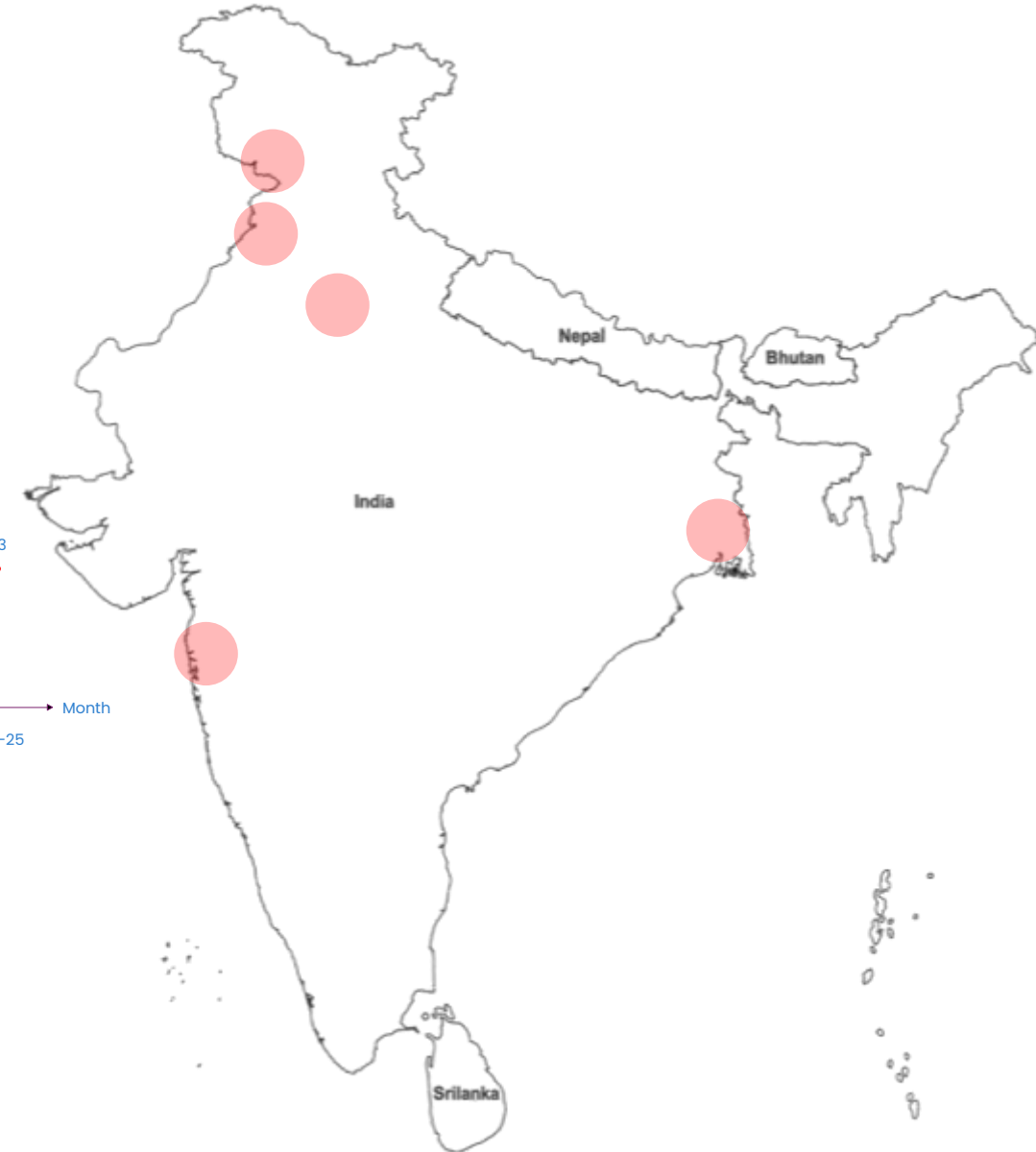
Indian Civil Aviation & GNSS RFIs

Key Aspects

- India-Pakistan and India-Myanmar borders – Among top global hotspots for frequent GNSS RFIs
- Lok Sabha – 465 GNSS RFI cases reported between Nov 23 and Feb 25
 - Majority being along Amritsar and Jammu regions
- AAI Data (Feb 24 – Feb 25)



- @Delhi
 - GNSS RFIs reported within 60 NM radius of Delhi
 - Reported positional jumps up to 335 km within seconds
- Focused deception rather than simple denial indicates deliberate & complex capability; not accidental
- Airports – Alternate redundancies Vs over reliance on GNSS



Defensive NavWar: Strengthening GNSS Based PNT

Analysis

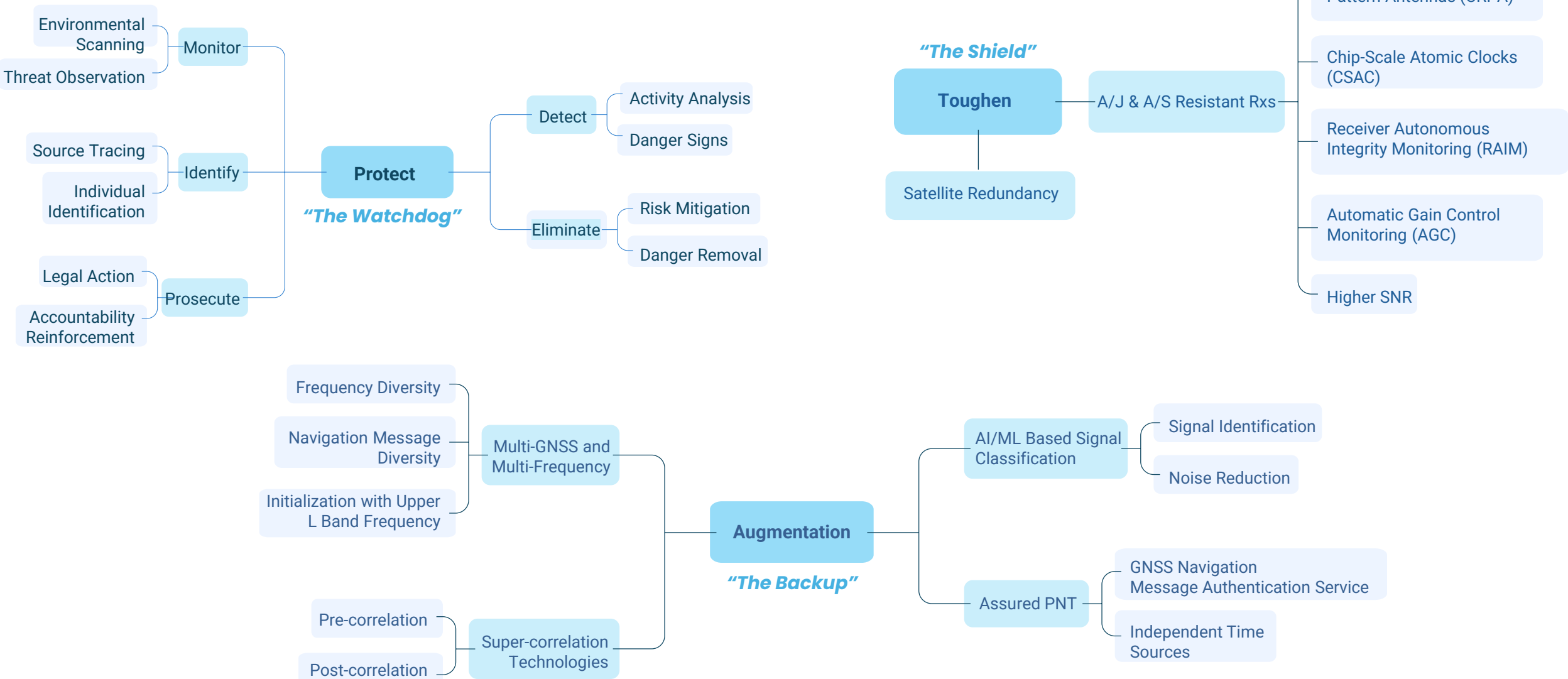
- NavWar has evolved into a strategic domain that underpins modern state sovereignty
- PNT domain is now part of an active & contested grey-zone battlespace.
- Criticalities
 - GNSS is *the "invisible PNT utility"* for civilian critical infrastructure & synchronization
 - GNSS can be a single point of failure in any nation's PNT architecture
- Need to pivot towards a Layered PNT Architecture that assumes GNSS will be denied

US PNTAB Assessment & Strategy

- *"No current or demonstrated alternative to GNSS can deliver equivalent PNT accuracy and world-wide 24/7 availability"*
- Need - PTA (Protect, Toughen and Augment) GNSS for Assured-PNT
 - Adopt Alternate-PNT Technologies where possible - *"One size does not fit all"*

Defensive NavWar: Strengthening GNSS Based PNT

Protect - Toughen - Augment Strategy



Defensive NavWar: Enhancement With Alternate/Complimentary PNT

Emerging Alt-PNT Technologies

MagNav

Determines location by detecting known variations in the Earth's magnetic field.

Inertial Navig System

Provides continuous, high-rate PNT data for mobile and drone/aircraft based spatial data acquisition.

eLORAN

- 2D positioning + Time
- Horizontal accuracy - Up to 20 m (95%)
- UTC synchronization within 50 ns
- Can range up to 1500 km
- Signal is virtually un-jammable
- NY Stock Exchange - Tested the use as backup of GPS for time synchronization
- China, UK, South Korea, Netherlands, Saudi Arabia and US(?)

Low Earth Orbit GNSS

LEO provides stronger and resilient signals. Can compliment existing GNSS. Provides 3D/2D+Time as a service.

Celestial Navigation

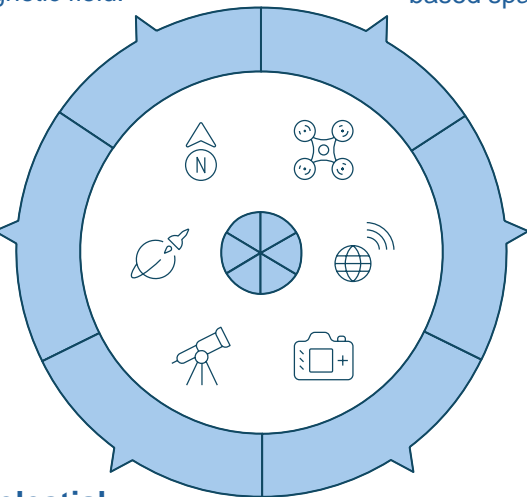
Independant and un-jammable PN source for maritime domain.

VNav

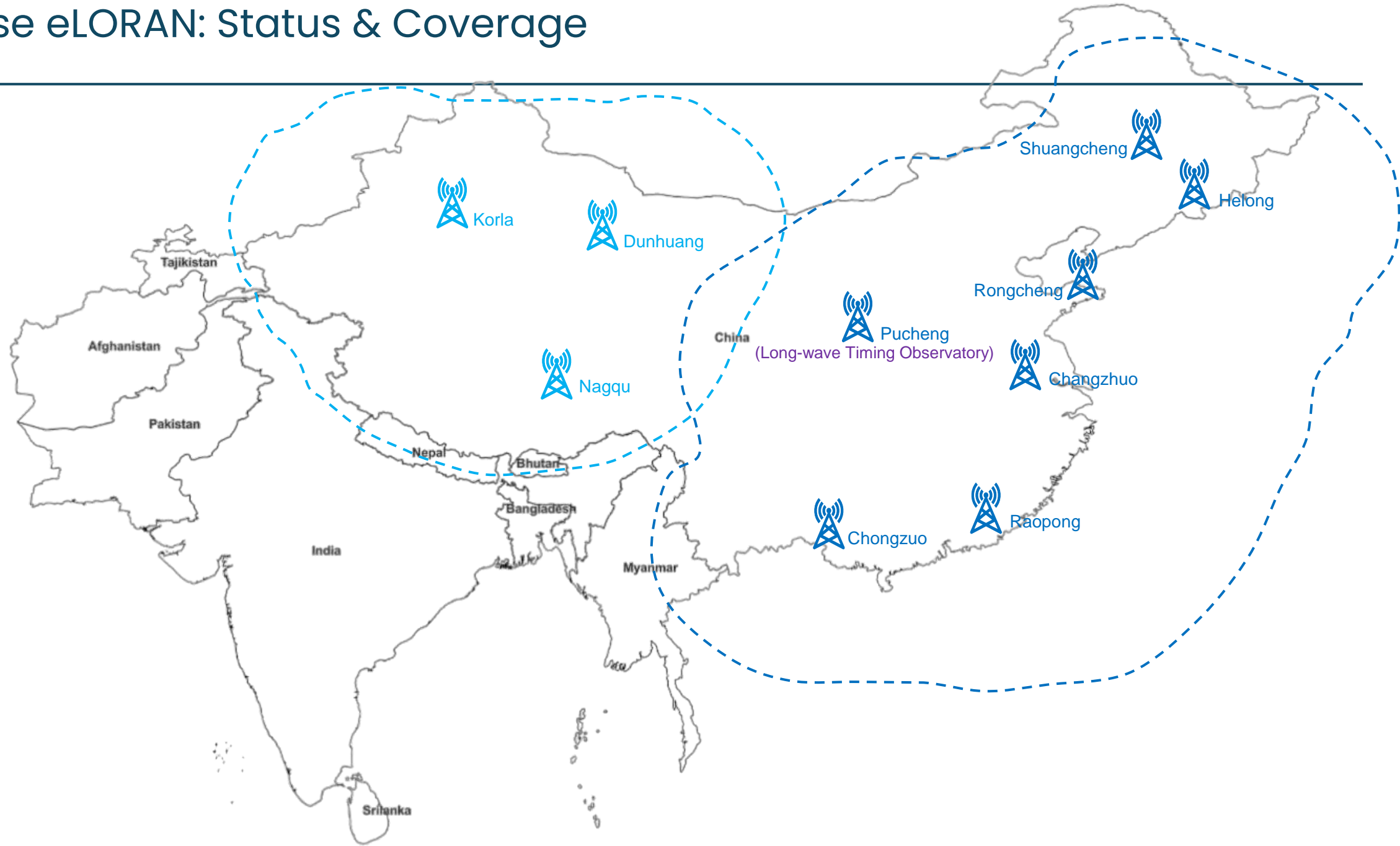
Integrates VIO and pattern recognition with onboard sensors.

eLoran






Terrestrial-based, strong, low-frequency radio signals transmitted from ground stns.



Chinese eLORAN: Status & Coverage



LEO PNT: Constellations & Launch Status

LEO PNT Satellite Constellations	 Satellites in Orbit	 Total Satellites Planned	 Orbital Height	 Positioning Type	 Country
Geespace	64	6000	600 km	3D	China
Qianfan (SSST)	108	14000	1160 km	3D	China
China SatNet (Guowang)	100	13,000	500 - 1145 km	3D	China
Centispace	-	190	650 - 1100 km	3D	China
ESA FutureNav (Celeste)	-	10	510 km	3D	EU
VyomIC	-	150 - 200	700 - 1000 km	3D	India
OneWeb Eutelsat	648	6300	1200	Potential(?)	UK
Iridium NEXT (STL)	72	66	780 km	2D + Time	USA
Starlink	10413	42000	550 km	Potential(?)	USA
Xona Space	1	258	1080 km	3D	USA
TrustPoint	3	300	590 km	3D	USA

LEO PNT

- Higher accuracy - UREs
- More resilient - Stronger signals
- Better availability (indoors)
- Low SWaP-C
- Dual use - SatNav <> SatCom

Conclusion

- NavWar has become the weapon of choice for state and non-state actors
 - Common denominator being cost asymmetry; *the cost to disrupt is lower than the cost to defend*
- *NavWar can disrupt economy without crossing the threshold of kinetic war*
 - PNT denial can be considered *a tactical equalizer*
- Defensive NavWar is no longer just a niche technical field - *it is a cornerstone of national resilience*
 - Era of PNT contention - Alternate/ assured-PNT is not merely a "*backup*"; but source of PNT diversity & redundancy



THANK YOU