

GNSS as Primary Time Source

WSTS 2026 TUTORIAL SESSION



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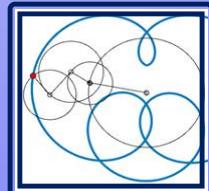


Two Messages About GNSS

1. GNSS are extremely useful

- Constellations are growing
- Provide reliable, extremely accurate real-time UTC time and frequency for mostly free
- Excellent navigation
- A global > \$100B industry

2. GNSS signals are dangerously vulnerable to both accidental and intentional interference



The Family of Global Navigation Satellite Systems

GPS

US

Galileo

EU

GLONASS

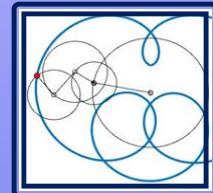
Russia

Beidou/Compass

China



Others are Regional Navigation Satellite Systems, (RNSS),
typically from satellites in geostationary (GEO) orbits



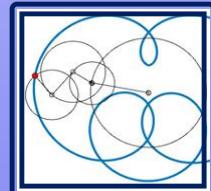
Navigation with Indian Constellation (NavIC)

- IRNSS is the longer acronym, but NavIC is still correct. See

https://en.wikipedia.org/wiki/Indian_Regional_Navigation_Satellite_System

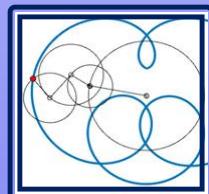
- GAGAN is essentially the Indian version of QZSS, based on GPS. See

<https://www.isro.gov.in/spacecraft/satellite-navigation>

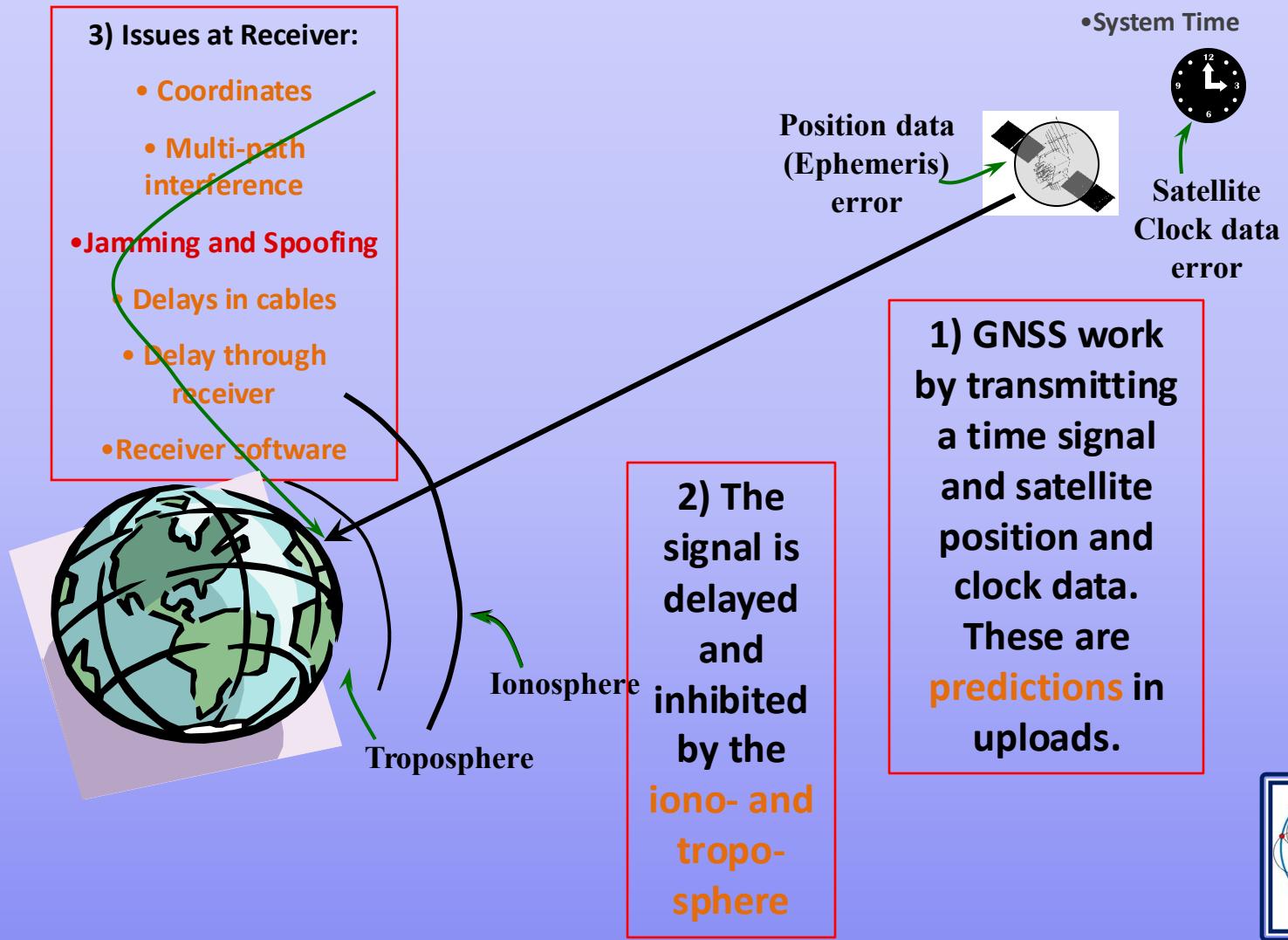


GNSS: General Properties

- Position, Navigation, Timing (PNT)
- Four + synchronized timing signals from known locations in space—timestamped at receiver and used to solve for x,y,z, and t or lat, lon, hgt and time
- Two + frequencies measure ionosphere
- Control, Space, User Segments
- Open and Restricted Services
- All signals are weak and clustered in the L-band spectrum
 - Allows interoperability
 - But also makes it is relatively easy to jam GNSS and spoof

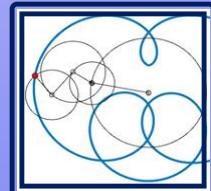


Time from GNSS: Intentional and Unintentional Error Sources

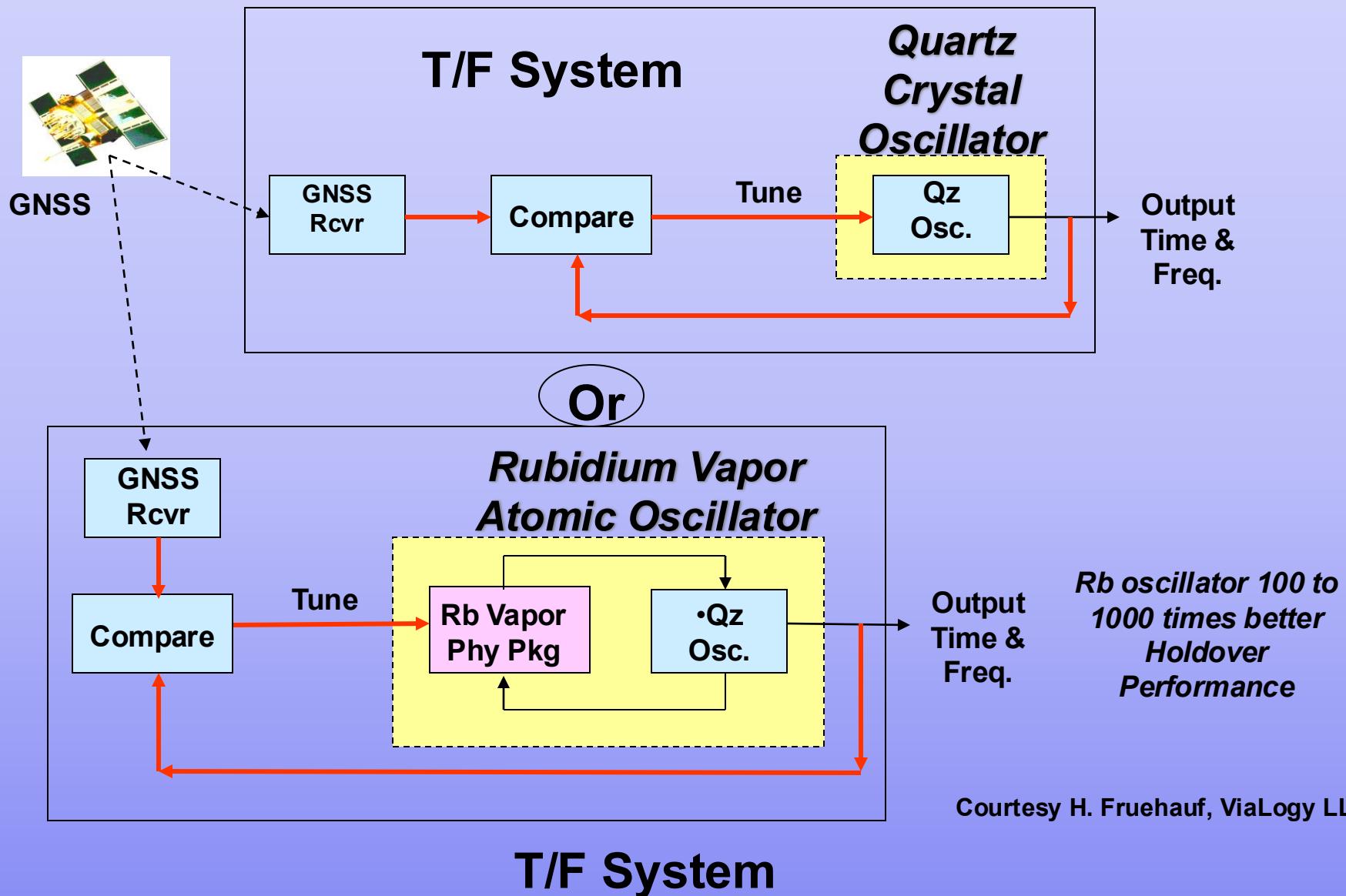


Time From GNSS

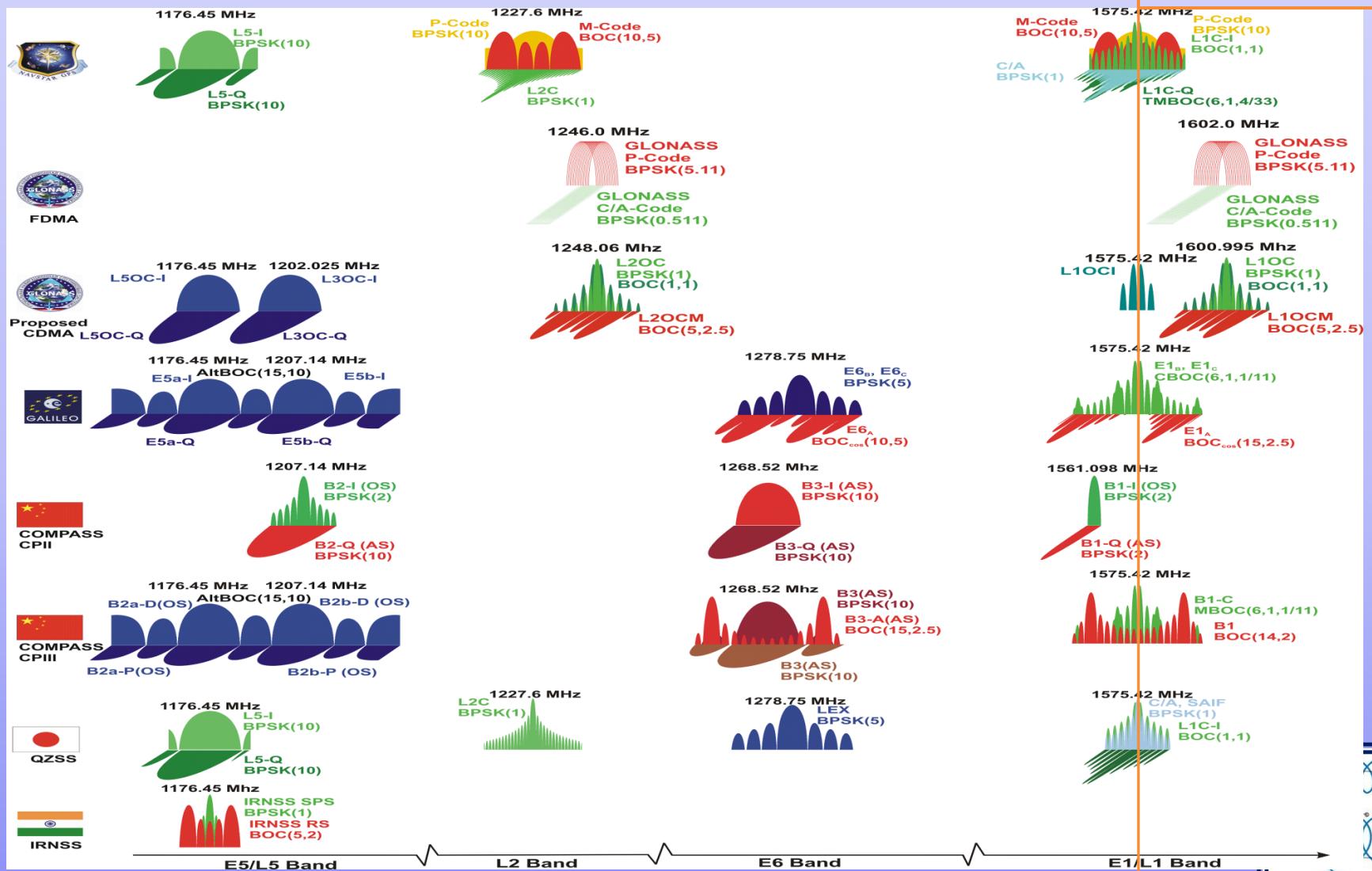
- Time signals are the basis of positioning
- Clocks on Satellite Vehicles (SVs) are free-running
 - Data provides the offset in Time and Frequency
 - System time is offset from UTC
- The positions of the satellite and receiver are needed for the delay
- SV Clocks and positions are ***predicted*** and uploaded, for GPS about once per day



GNSS-aided Time and Frequency Systems



Spectra of GNSS's



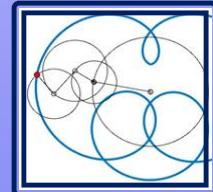
GNSS Vulnerability

- GNSS best feature and worst problem: it is extremely reliable
 - Leads users to not use backup systems
- Jamming Power Required at GNSS Antenna
 - On order of a Picowatt (10^{-12} watt)
- Many Jammer Models Exist
 - Watt to MWatt Output – Worldwide Militaries
 - Lower Power (<100 watts); Available online, though perhaps illegal

**“Personal
Privacy”
Device**

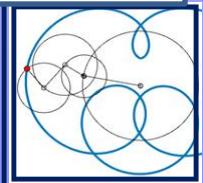
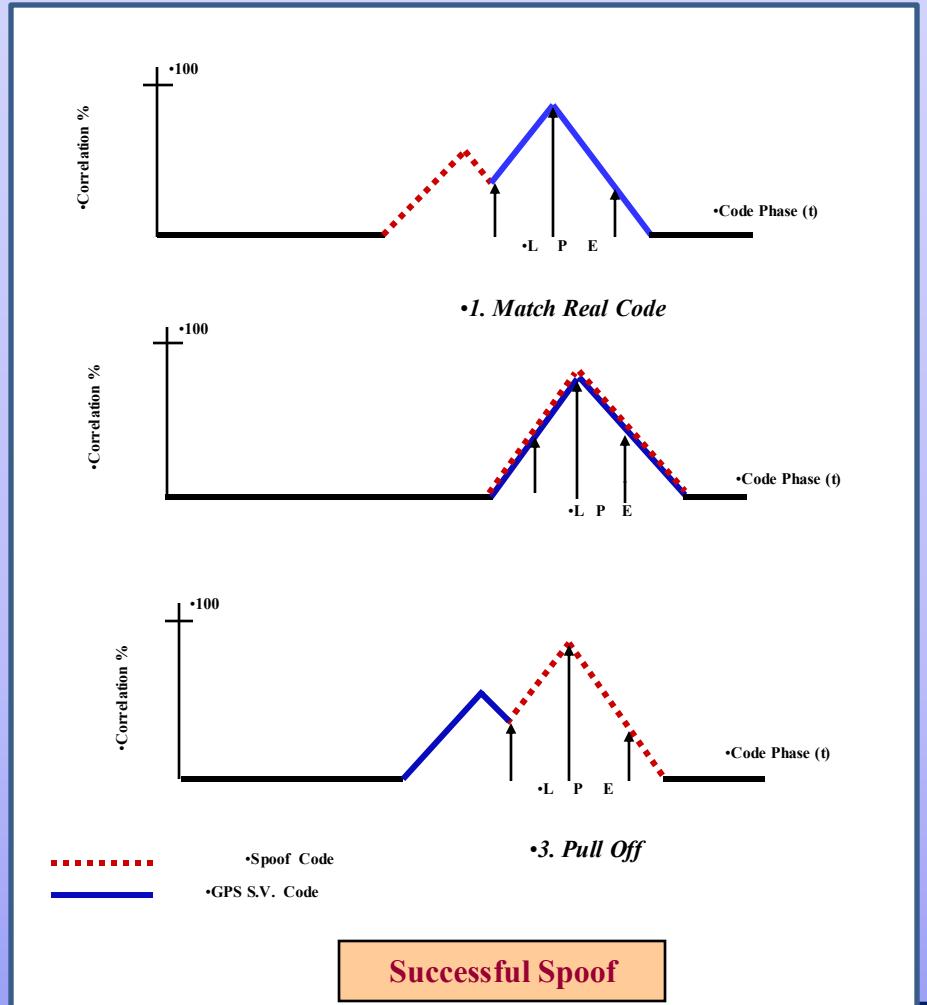


**Military
Jammer**

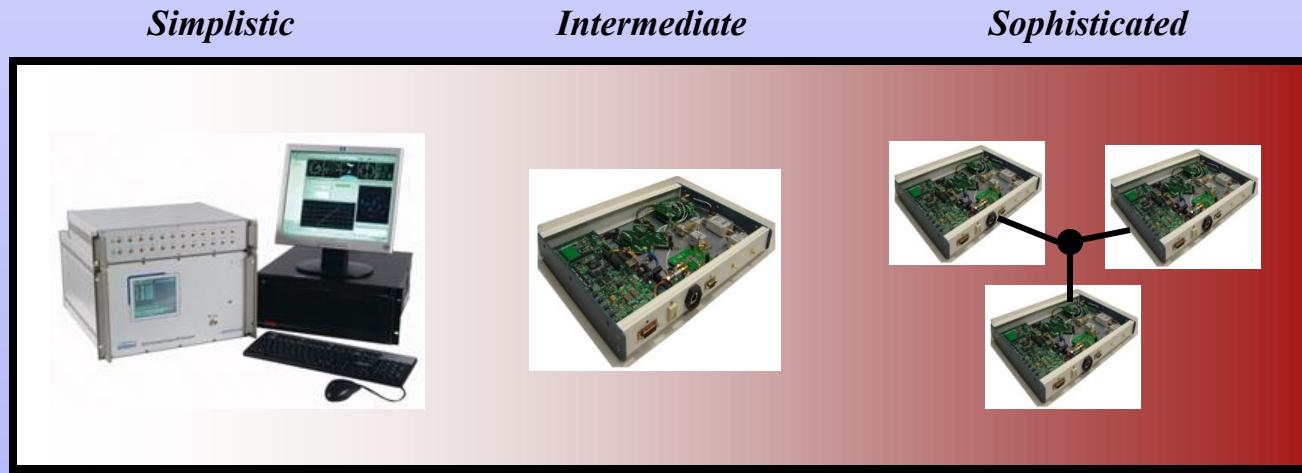


Spoofing/Meaconing

- Spoof – Counterfeit GNSS Signal
 - C/A Code Short and Well Known
 - Widely Available Signal Generators
 - Many possible techniques
- Meaconing – Delay & Rebroadcast
- Possible Effects
 - Force receiver to give wrong position or time or both
 - No warning from receiver without special anti-spoof design
- No “Off-the-Shelf” Mitigation



Civil GNSS Spoofing Threat Continuum*



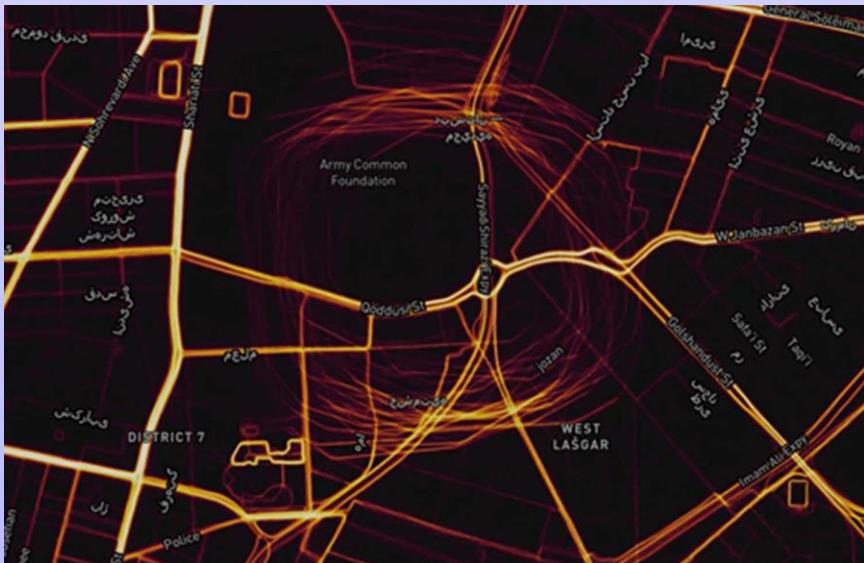
Commercial signal simulator

Portable software radio

Coordinated attack by multiple phase-locked spoofers

* Courtesy of Coherent Navigation, Inc

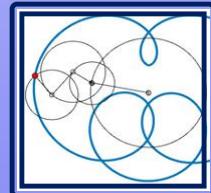
Spoofing example, GPS World, April 2020: ‘circle spoofing’ in Tehran



This heat map shows GPS spoofing at a government complex in Tehran, which houses the Ministry of Defense, Communication Regulatory Authority, Telecommunications Infrastructure Company, and Ministry of Telecommunications and Technology. (Screenshot: courtesy of Dana Goward)

“Some of GPS devices received fake signal and show the fake valid location. Yesterday I test a device, it can get signal and give real position. After 10 minutes the device show moving around a big circle in Tehran by 35 km/h speed. I can’t fix this problem by restarting the device. “The GPS module time is correct but the location is not. I attach Excel file of data and map of the track. I can’t get any response from Communications Regulatory Authority (CRA) of The I.R. of Iran. Do you know about this?”

<https://www.gpsworld.com/gps-circle-spoofing-discovered-in-iran/>



Conclusions

Global Navigation Satellite Systems are very accurate both for time and frequency, many signals free for use, and are extremely reliable

Perhaps both their greatest advantage and disadvantage!

Signals are subject to interference

