Time and Frequency from GNSS
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Marc A. Weiss, Ph.D.
NIST Time & Frequency Division
303-497-3261
mweiss@nist.gov

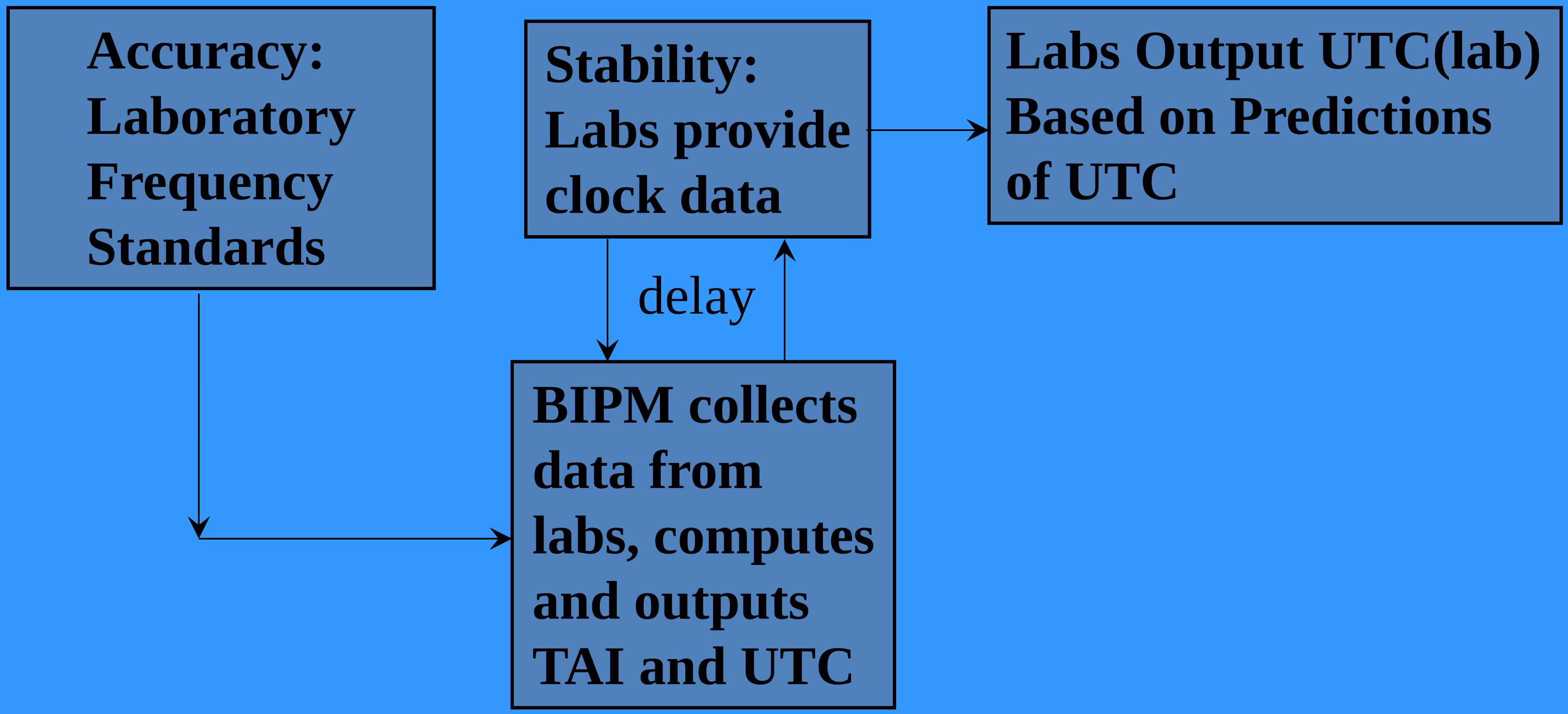
Outline:
Time and Frequency from GNSS

- What does it mean?
- What can you get?
- A little bit of how it works
- Vulnerabilities/options
- Conclusions

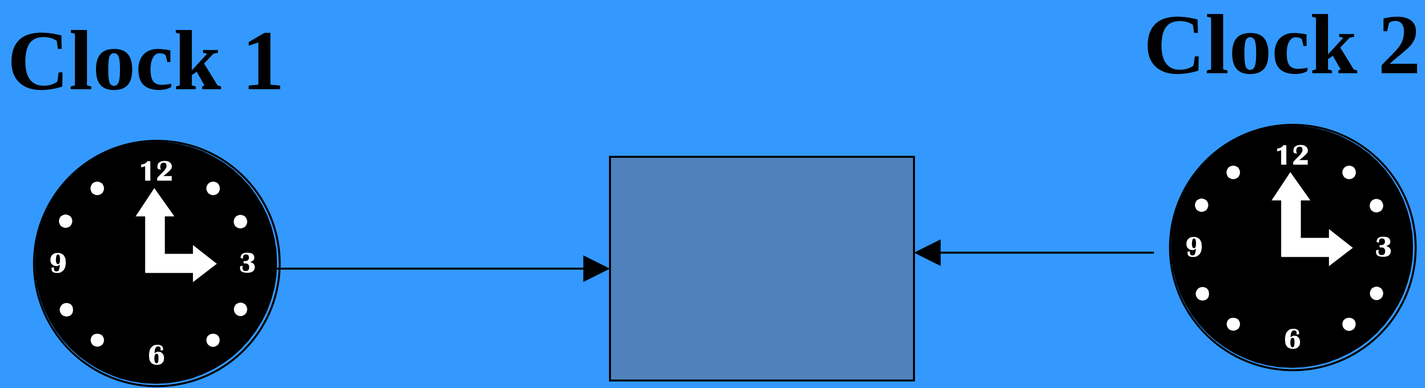
Time, Phase, Frequency, and UTC

- **Frequency** comes from a clock, usually one locked to a master
- **Phase** must be transferred between clocks
- **UTC Time** must come from a national lab, generally from GNSS

The Generation of UTC: Time Accuracy
Any Real Time UTC is only a Prediction
A PLL with a one-month delay



Dissemination or Comparison System

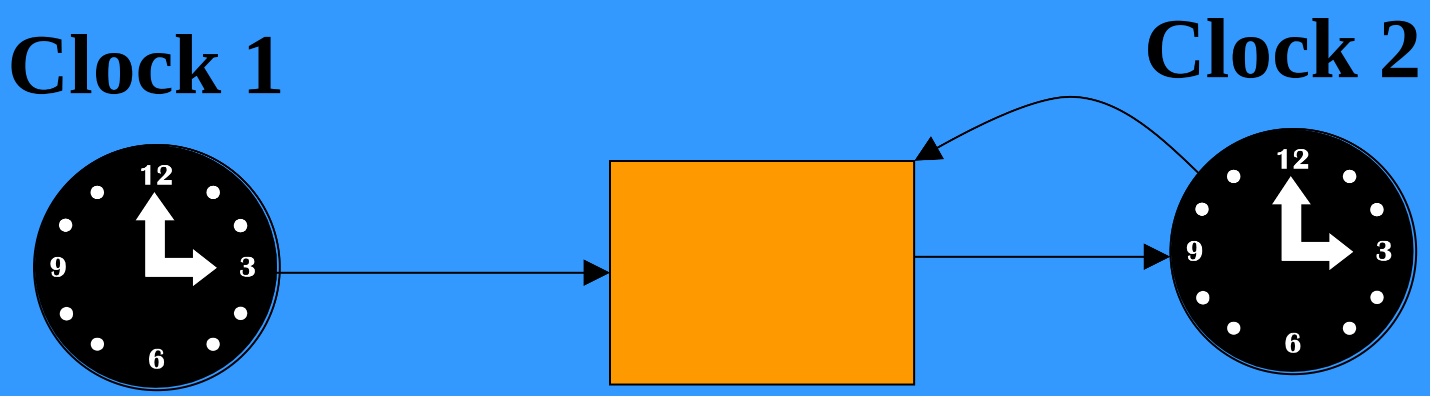


Clock 1 Systematics and Noise

Delay, Perturbations, and Measurement Noise

Clock 2 Systematics and Noise

Clock Hierarchies

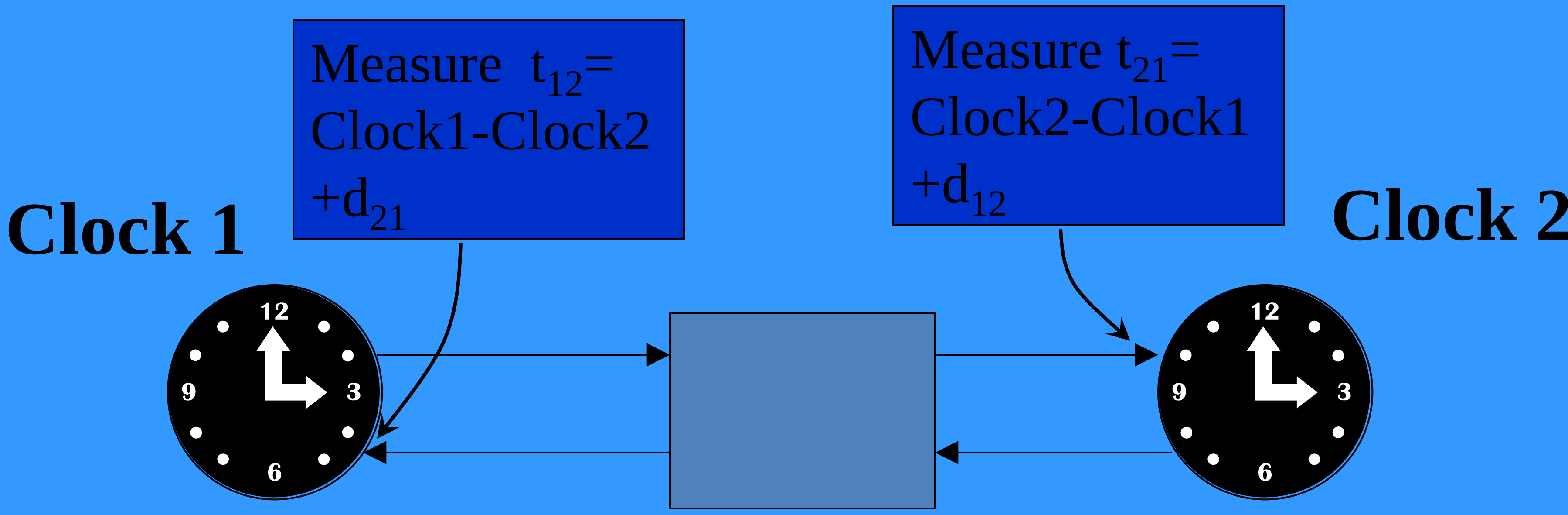


Clock 1 Systematics and Noise

Lock Loop Systematics and Noise: Contributions from Measurement Noise and Path Perturbations

Clock 2 Systematics and Noise

Two -Way Comparison System



Clock 1 Systematics and Noise

Measurement Noise and Path Perturbations Largely Reciprocal:

$d_{21} = d_{12}$

Clock 2 Systematics and Noise

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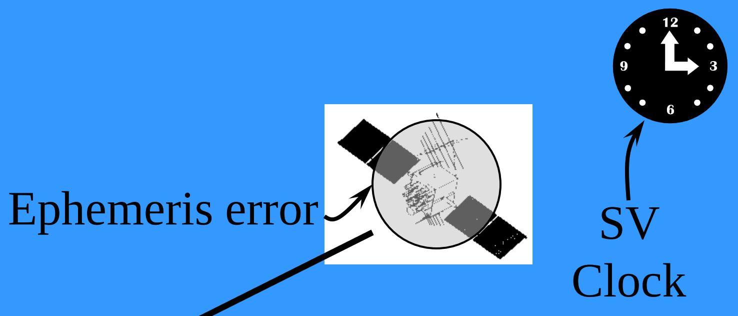
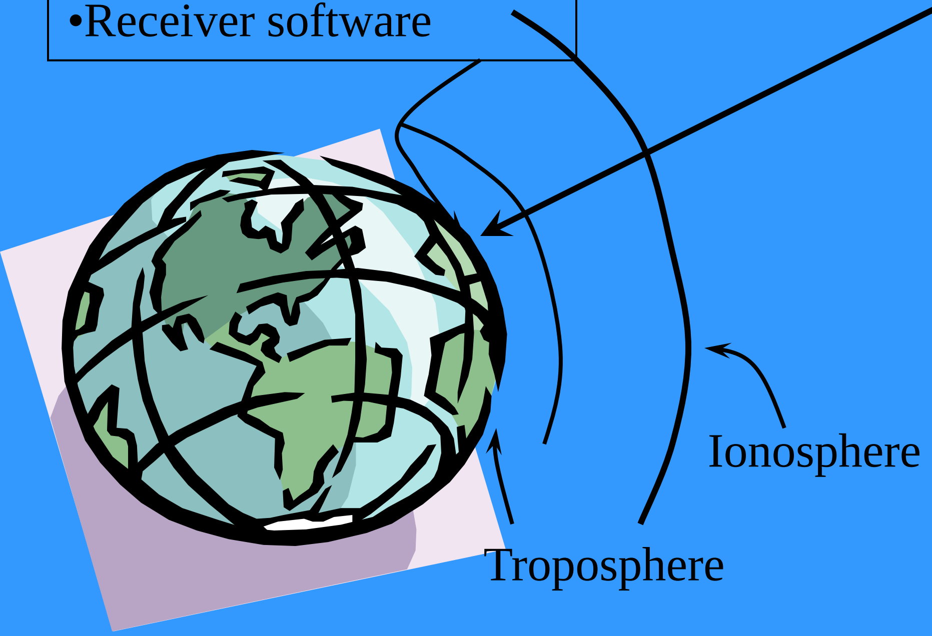
Time from GPS: Noise Sources

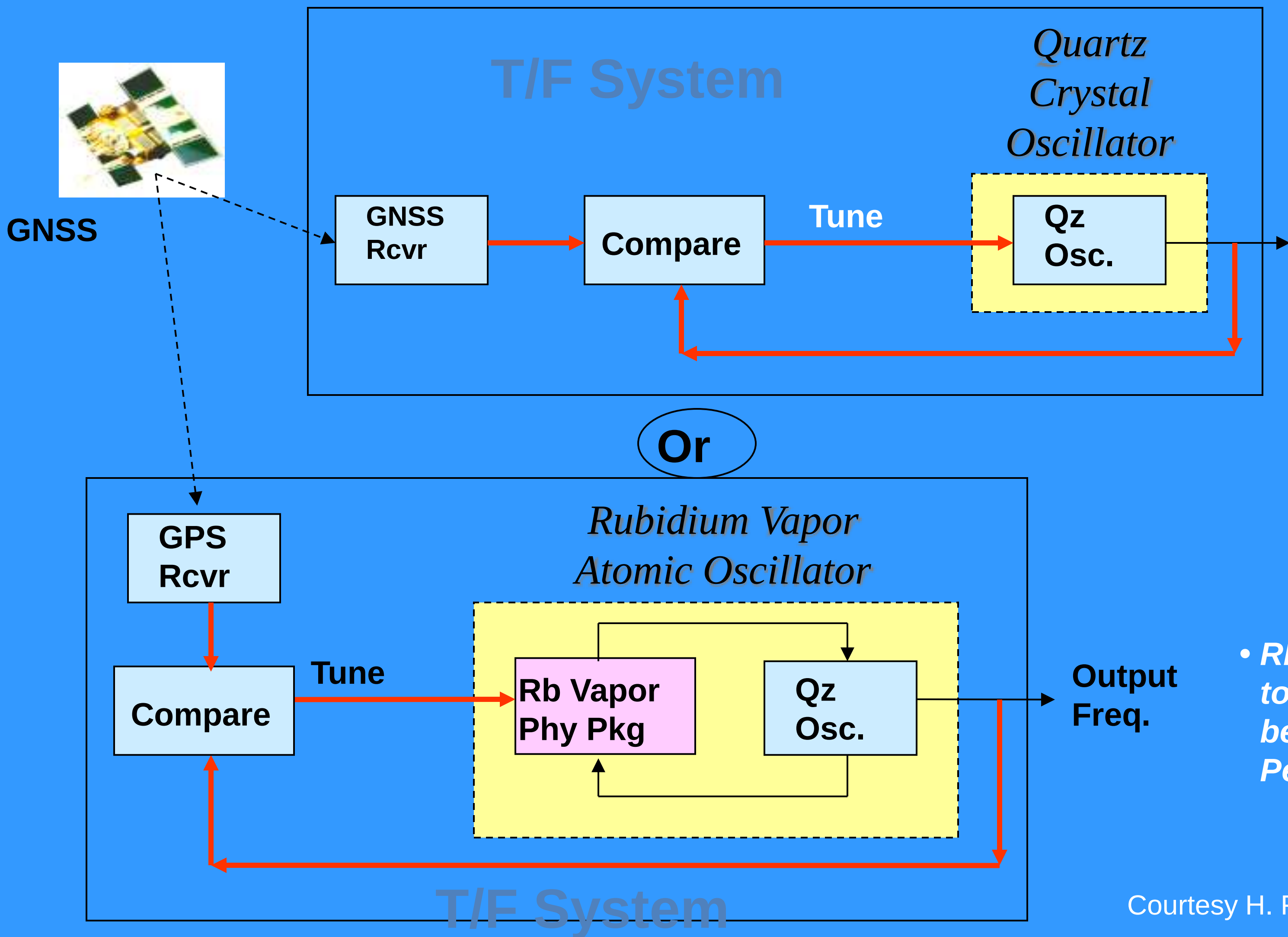
Problems at Receiver:

- Coordinates
- Multi-path interference
- Delays in cables
- Delay through receiver
- Receiver software





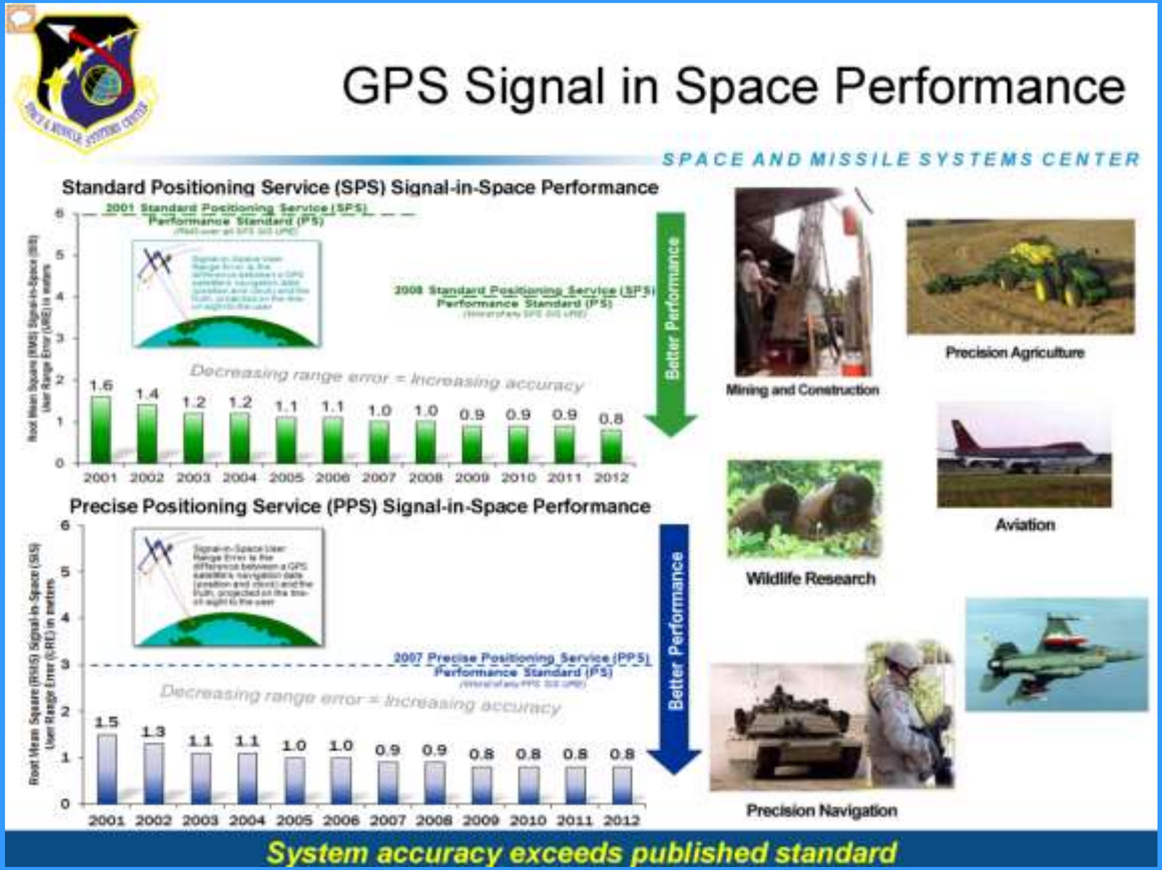
GNSS-aided Time and Frequency Systems



- ***Rb oscillator 100 to 1000 times better Holdover Performance***

Courtesy H. Fruehauf, ViaLogy LLC

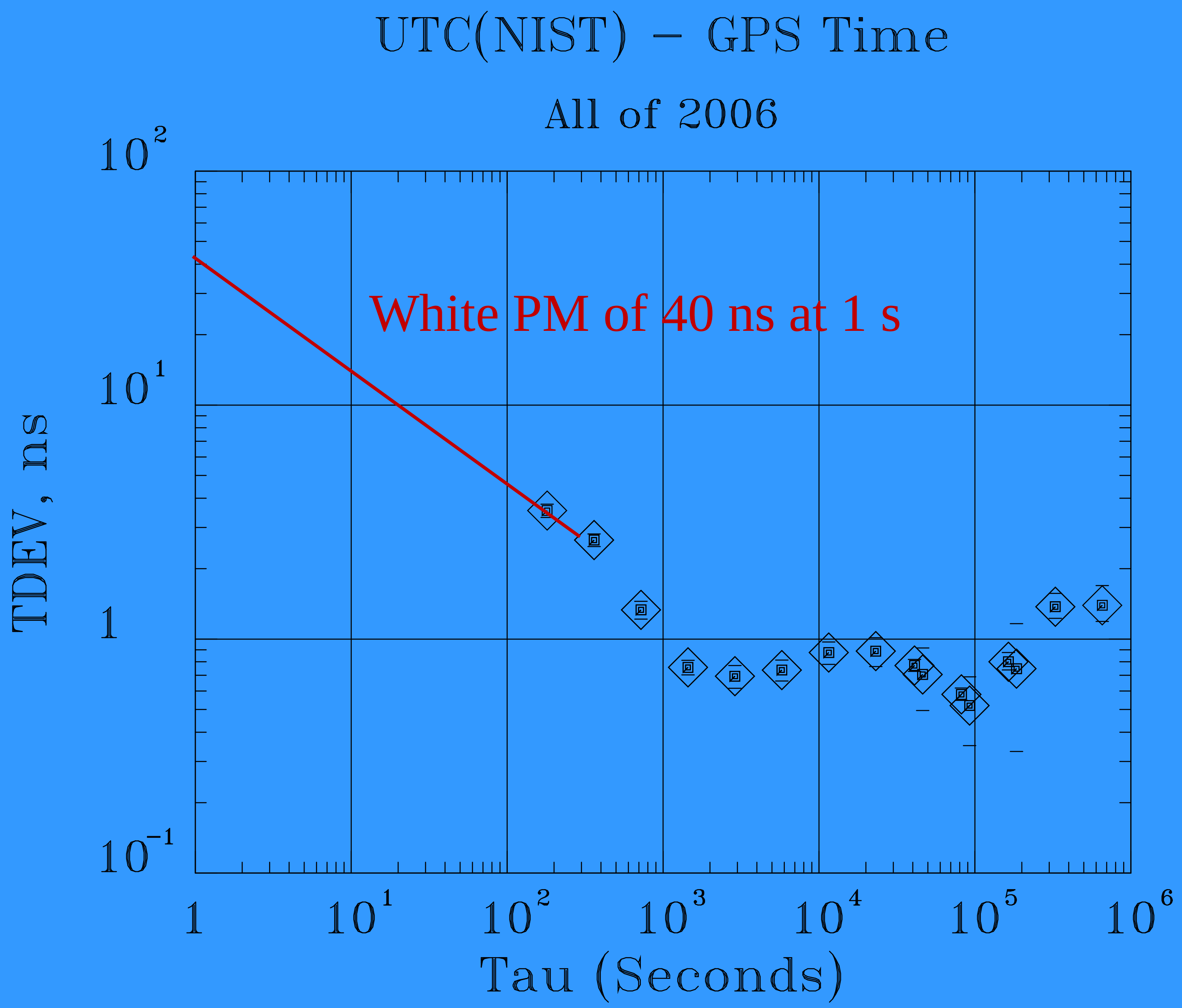
GPS Signal in Space Performance



0.8 m in range = 2.7 ns!

Presented by Col. Bill Cooley, Director GPS, 17 Sep 2013, CGSIC

GPS Stability



GNSS Accuracy with Best Receivers

- With Rb. local oscillator time accuracy can be within 20 ns of UTC

- Frequency accuracy with Rb. better than 1 part in 10^{13}, probably about 10^{-14} with Cs.

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The Family of Global Navigation Systems

GPS
US
(24+, Now 31)

Galileo
EU
(27, Now 4 IOV)

GLONASS
Russia
(24, Now 24)

Beidou/Compass
China
(35, Now 15=
5GEO+5IGSO+4MEO)

GNSS Systems: General Properties

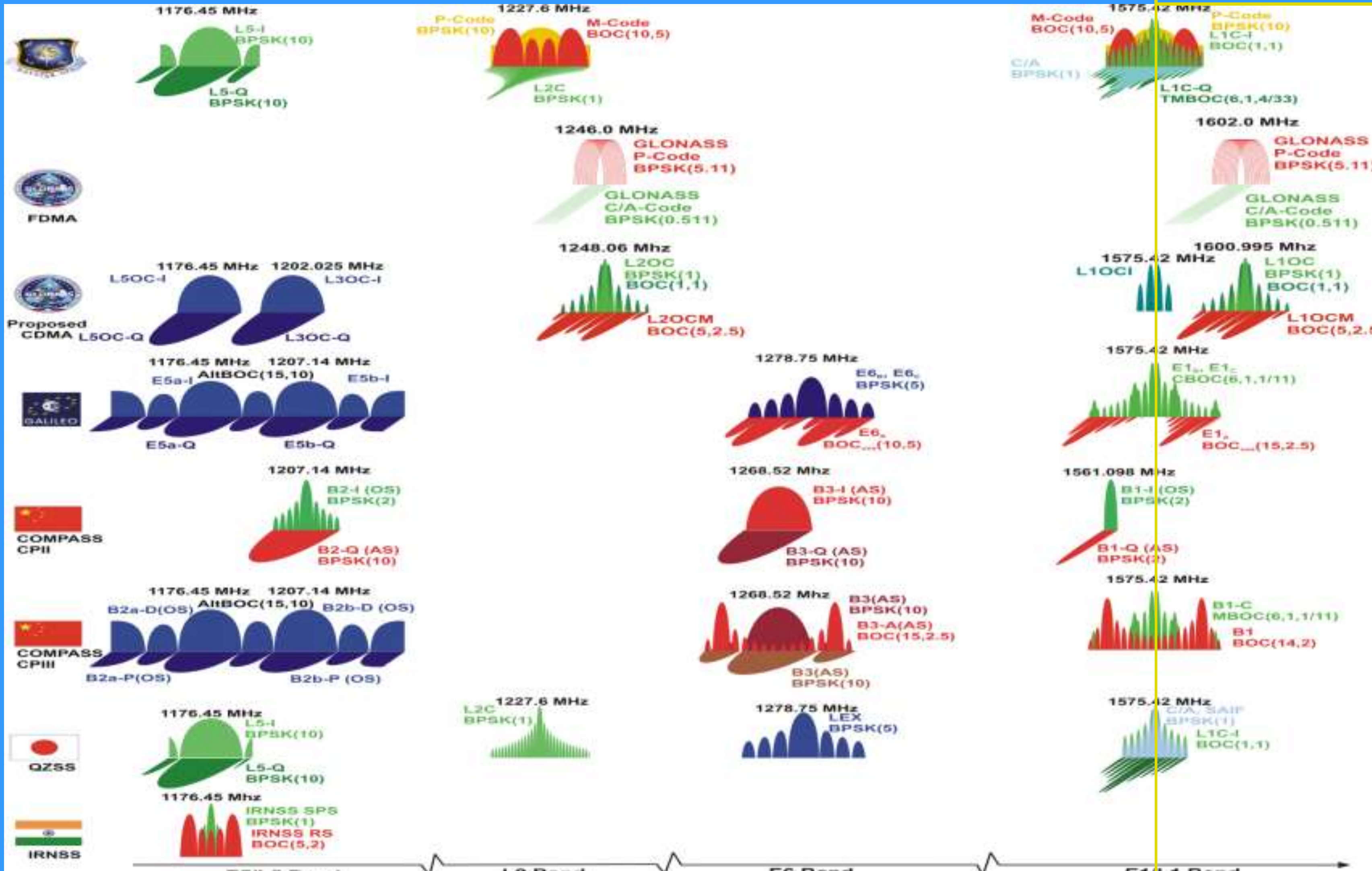
- Position, Navigation, Timing (PNT)
- Four + synchronized timing signals from known locations in space required for navigation
- Two + frequencies measure ionosphere
- Control, Space, User Segments
- Open and Restricted Services

GNSS Systems: General Properties

- All signals are weak
  - E.g. GPS is ~-160dBm
  - All are deliberately well below the noise until the process gain
- Signals are clustered in the spectrum
- Hence it is relatively easy to jam GNSS and becoming easy to spoof

Spectra of GNSS's

Primary Commercial Signal



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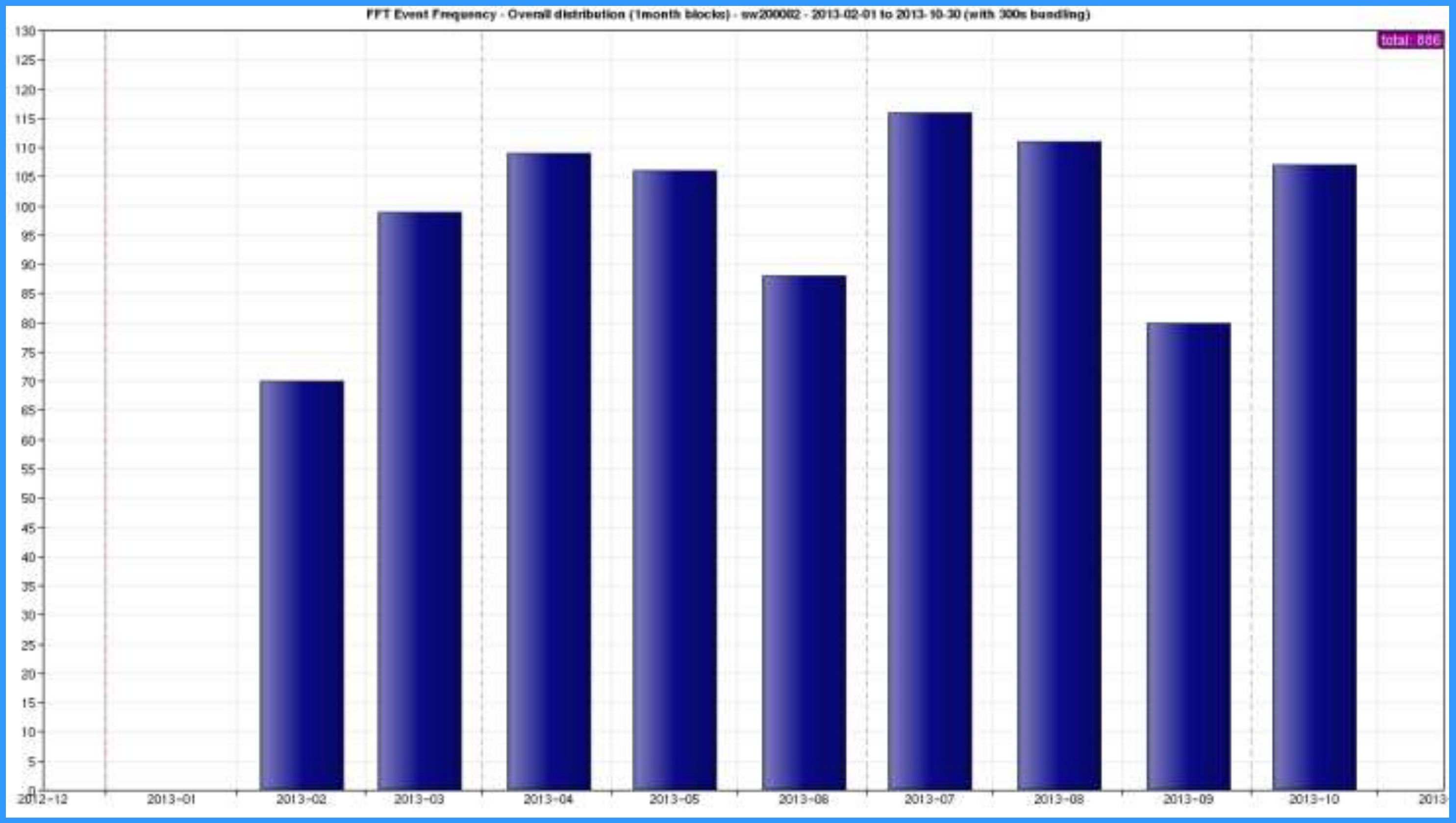
GNSS Vulnerability

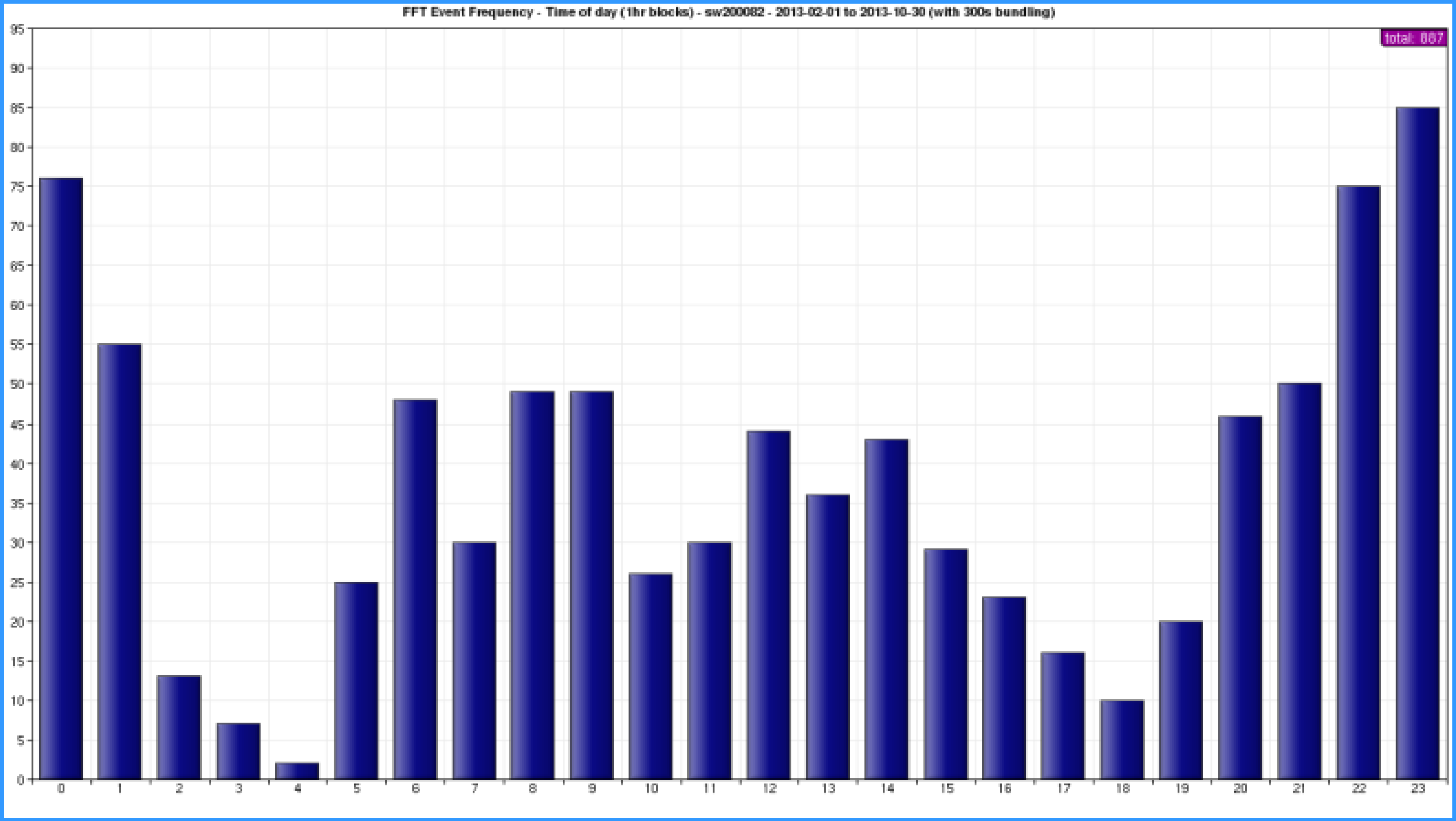
- GNSS best feature and worst problem: it is extremely reliable
- Jamming Power Required at GPS Antenna
  - On order of a Picowatt (10^{-12} watt)
- Many Jammer Models Exist
  - Watt to MWatt Output – Worldwide Militaries
  - Lower Power (<100 watts); "Hams" Can Make

Jamming Events Each Month, Feb – Oct 2013: London Financial District



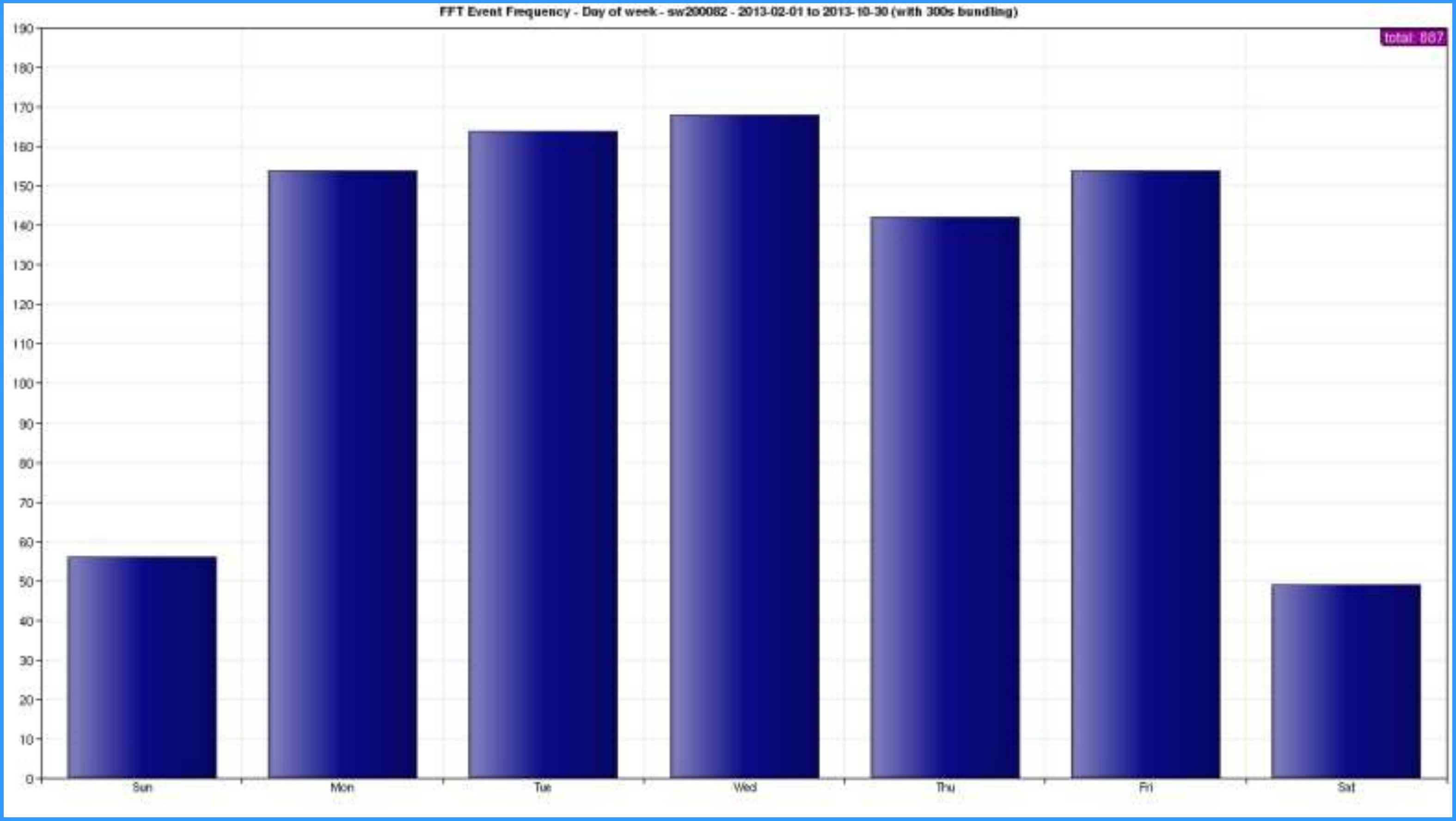
Data and image courtesy of Charles Curry, Chronos Technology Ltd and the SENTINEL Research Project

Jamming Events Each Hour, Feb – Oct 2013: London Financial District



Data and image courtesy of Charles Curry, Chronos Technology Ltd and the SENTINEL Research Project

Jamming Events Day of Week, Feb – Oct 2013: London Financial District



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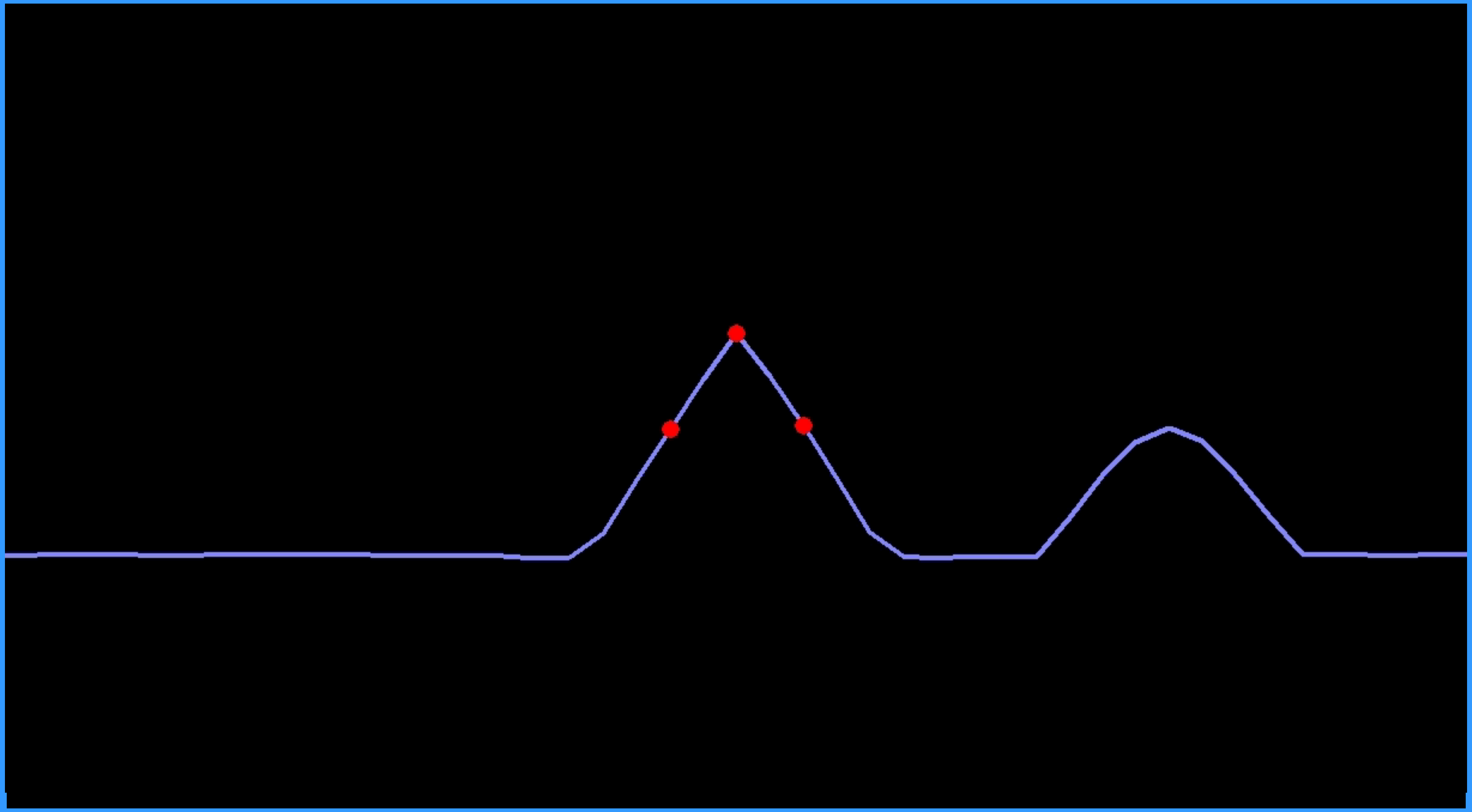
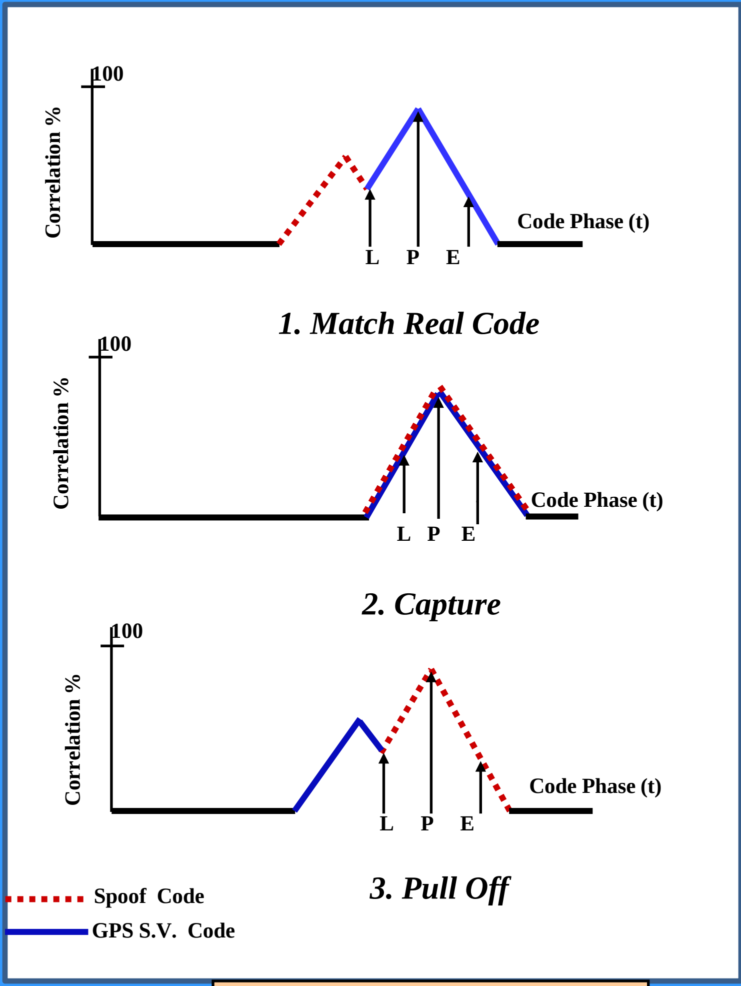
GNSS Spoofer



Slide courtesy of Kyle D. Wesson, The University of Texas at Austin

Disruption Mechanisms - Spoofing/Meaconing

- Spoof – Counterfeit GNSS Signal
  - C/A Code Short and Well Known
  - Widely Available Signal Generators
- Meaconing – Delay & Rebroadcast
- Possible Effects
  - Long Range Jamming
  - Injection of Misleading PVT Information
- No "Off-the-Shelf" Mitigation



Successful Spoof

Civil GPS Spoofing Threat Continuum*

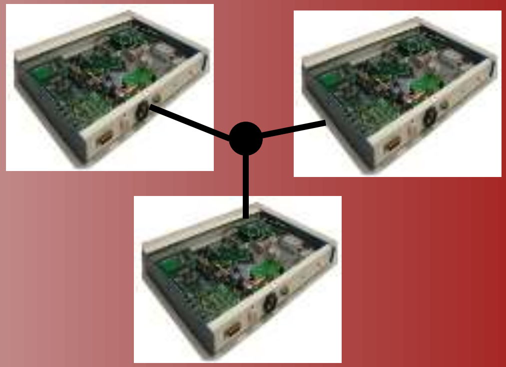
Simplistic

Commercial signal simulator

Intermediate

Portable software radio

Sophisticated



Coordinated attack by multiple phase-locked spoofers

* Courtesy of Coherent Navigation, Inc

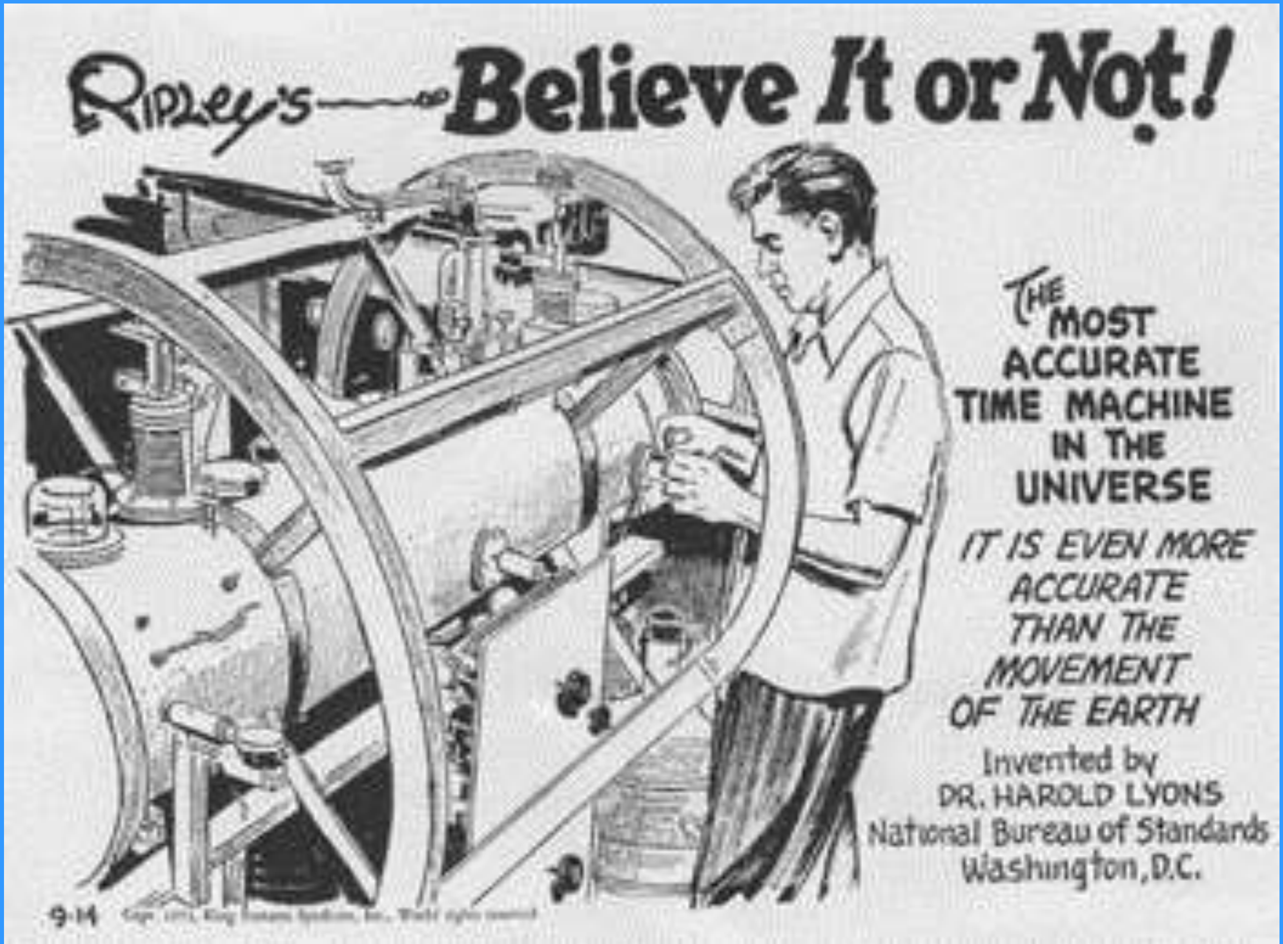
Conclusions

- GNSS provide all three types of sync: Time and Frequency and Phase
- GNSS accuracy meets PRTC and PRC specs
- GNSS are growing internationally
- GNSS are Vulnerable,

  best feature and worst problem:

  extremely reliable

And that's all



- Thank you for your interest