

GPS VULNERABILITY IN MOBILE NETWORKS

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Outline:

GPS Vulnerability in Mobile Networks

- ▣ Generally, what is the problem?
- ▣ What are the tight timing requirements?
- ▣ How serious are the risks?
- ▣ What are the timing alternatives?
- ▣ Conclusions

The Problem: GPS Vulnerability in Mobile Networks

- ▣ Mobile networks have **increasingly tight timing** requirements
 - Time, frequency, phase
 - Timing generally optimizes bandwidth
 - Different services have different requirements
- ▣ Most timing is **dependent on GPS** (or GNSS)
 - GPS is extremely accurate, reliable, and virtually free
 - This is perhaps the best and worst aspect of GPS
- ▣ GPS (and all GNSS) signals are **extremely vulnerable** to interference

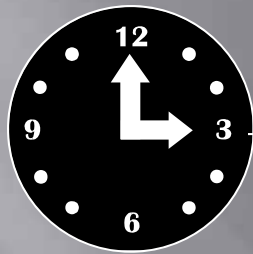
Evolving Telecom Sync Requirements: Time, Phase, Frequency, and UTC

- ▣ Until the last few years, most precision telecom sync requirements were for **Frequency**
 - Directly from a clock, usually one locked to a master

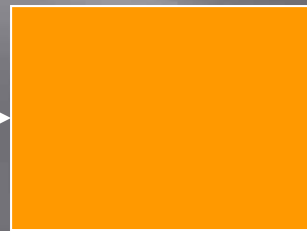
- ▣ More recently, largely to optimize mobile bandwidth, requirements are needed for **Phase** and **Time**
 - Phase must be transferred between clocks
 - **UTC or TAI Time** must come from a national lab, generally from GNSS
 - These are generally **harder to hold-over**

Sync from GPS

GPS Clock

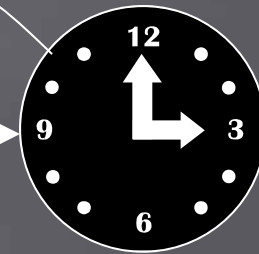


GPS Clock
Systematics
and Noise



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

Base Station Clock



User Clock
Systematics
and Noise

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Summary of Some Timing Requirements

Standard	Timing Accuracy	Frequency Accuracy
CDMA2000	10 μ s	100 ppb
GSM	–	100 ppb
WiMAX	1 μ s (TDD)	8 ppm
LTE	3 μ s (TDD)	250 ppb
WCDMA	2.5 μ s (TDD)	250 ppb
TD-SCDMA	2.5 μ s	100 ppb

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Civil GPS Vulnerabilities

	Attack	Description
Jamming	Unintentional	Solar radio bursts
	Intentional	Denial of service via RF noise
Spoofing	Meaconing	Record and playback of entire RF spectrum
	Security Code Estimation and Replay	Estimate security code on-the-fly and playback with estimated value to defeat security enhanced GPS (not publically available)
	Data Bit Forgery	Alter ephemeris or leap second indicators

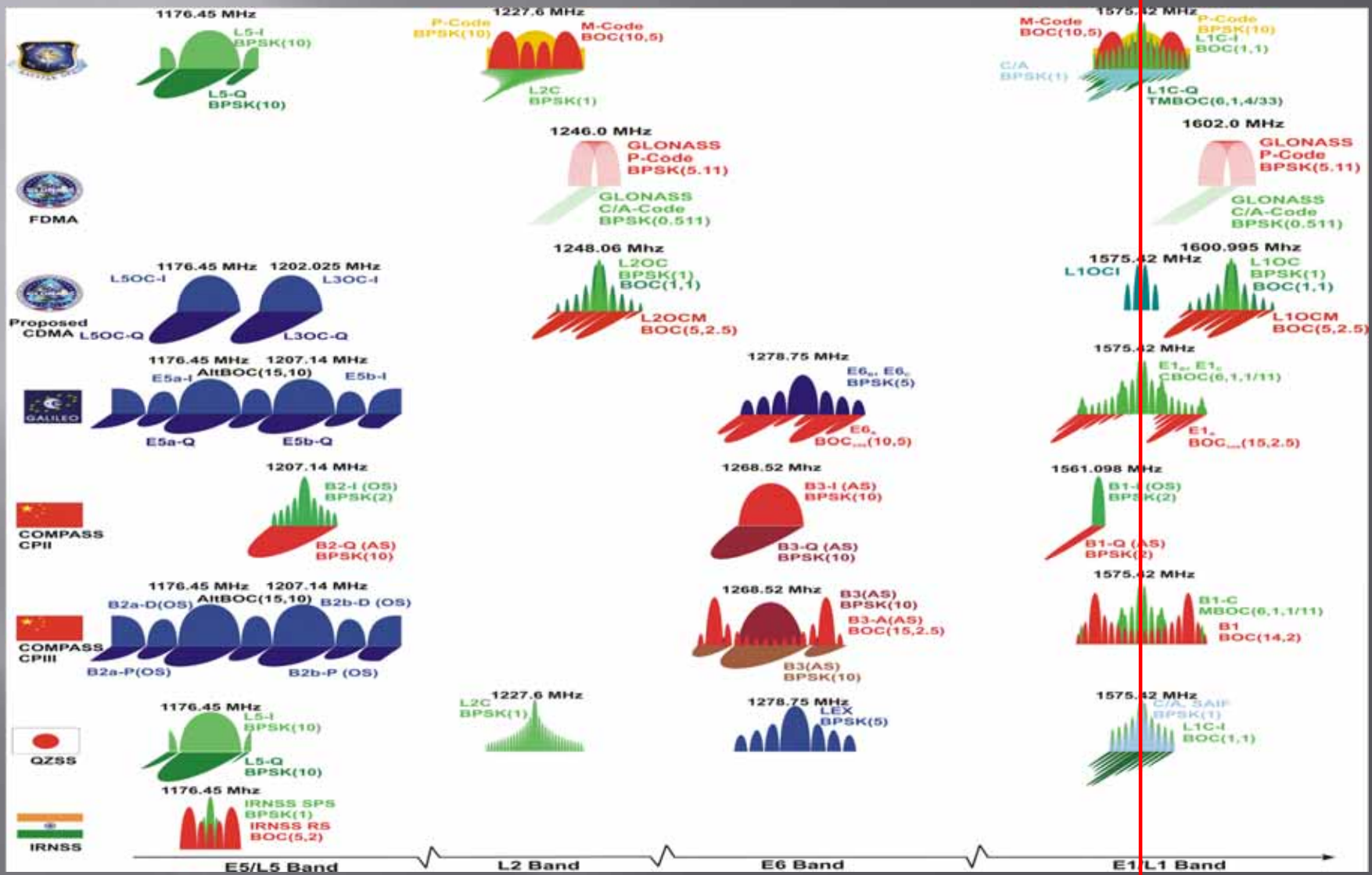
GNSS Vulnerability

- ▣ 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; Easily Available on the Internet

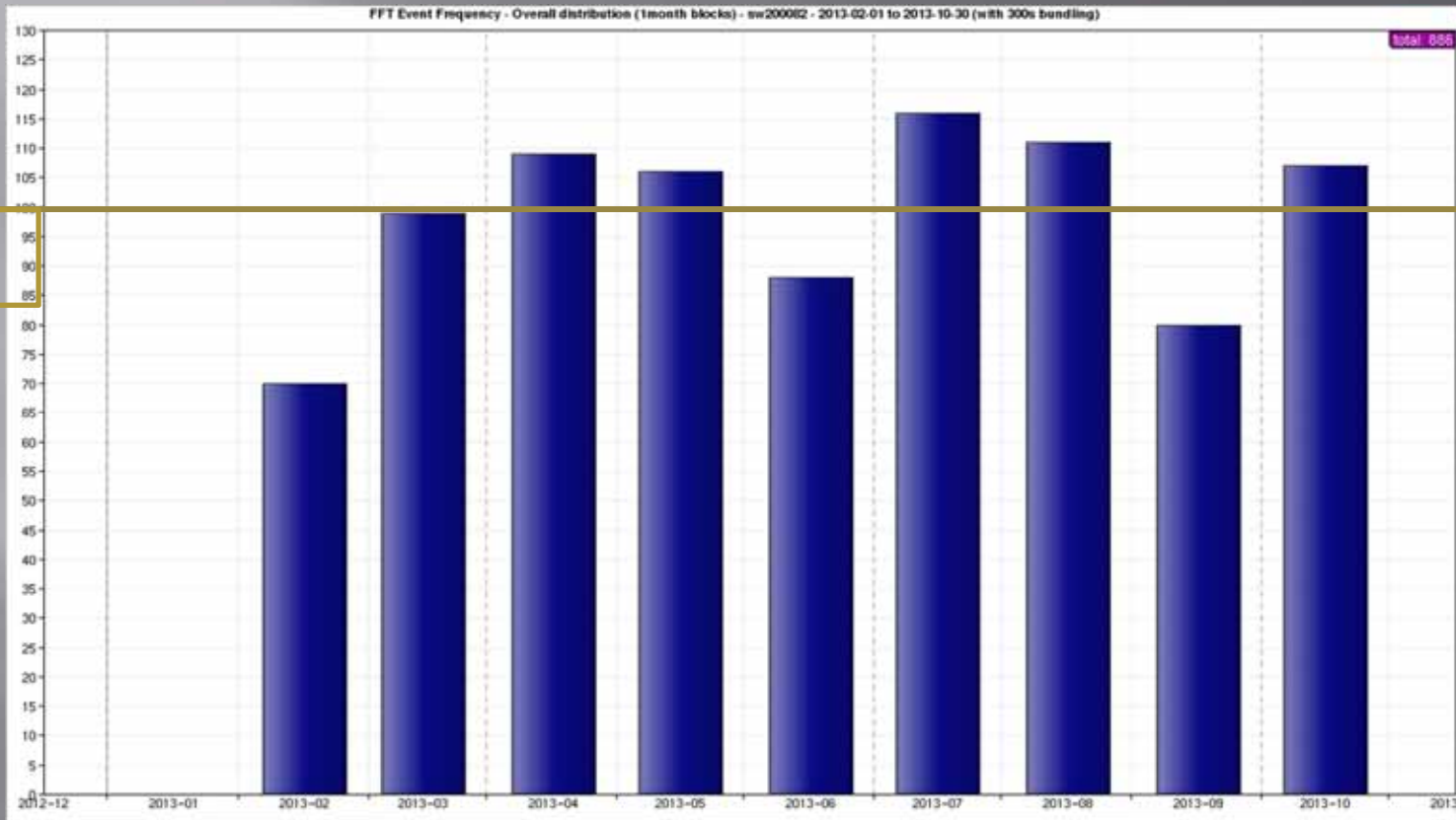


GNSS Spectrum

Primary Signal



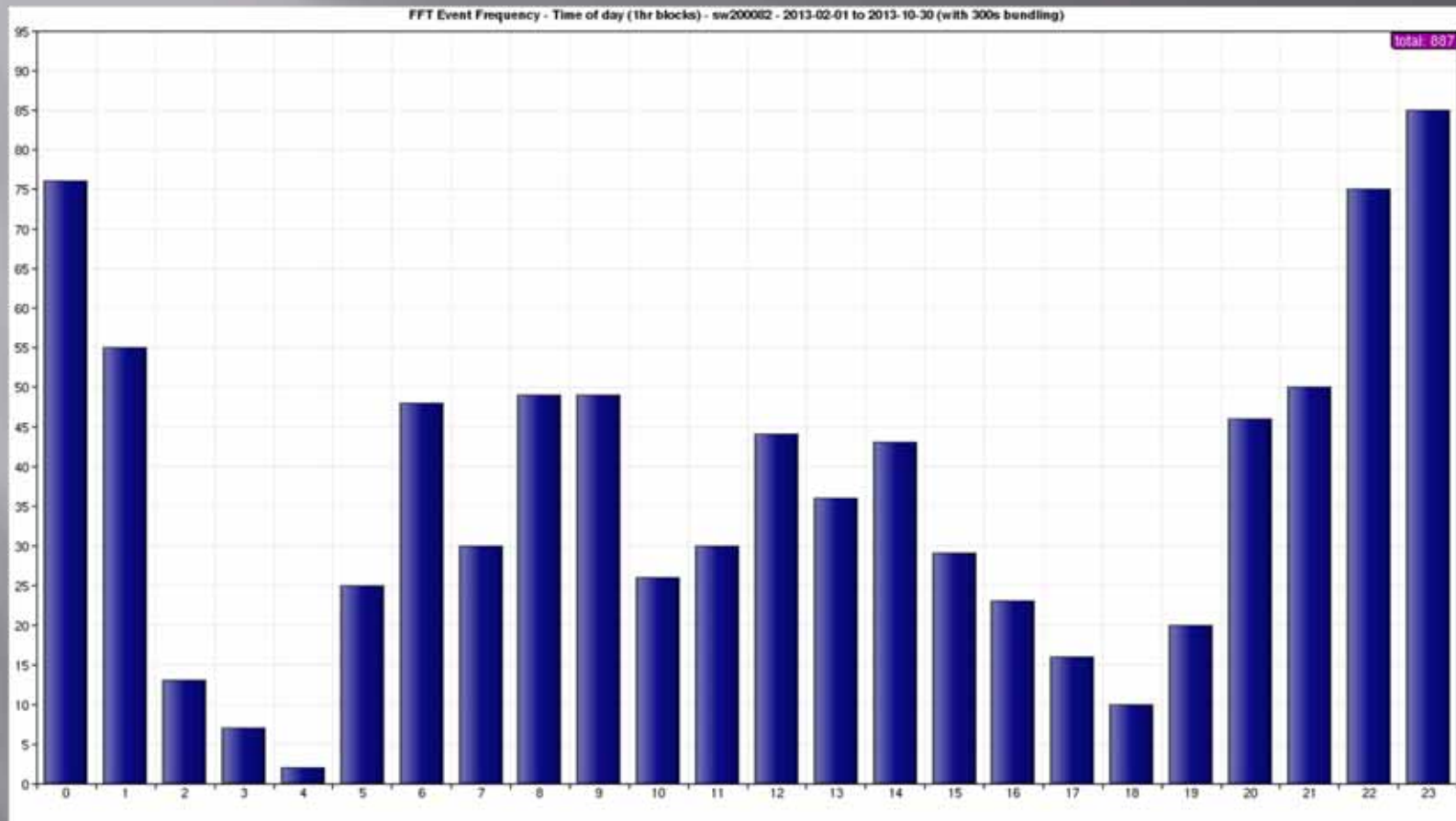
Jamming Events Each Month, Feb – Oct 2013: London Financial District



100
Events/Month

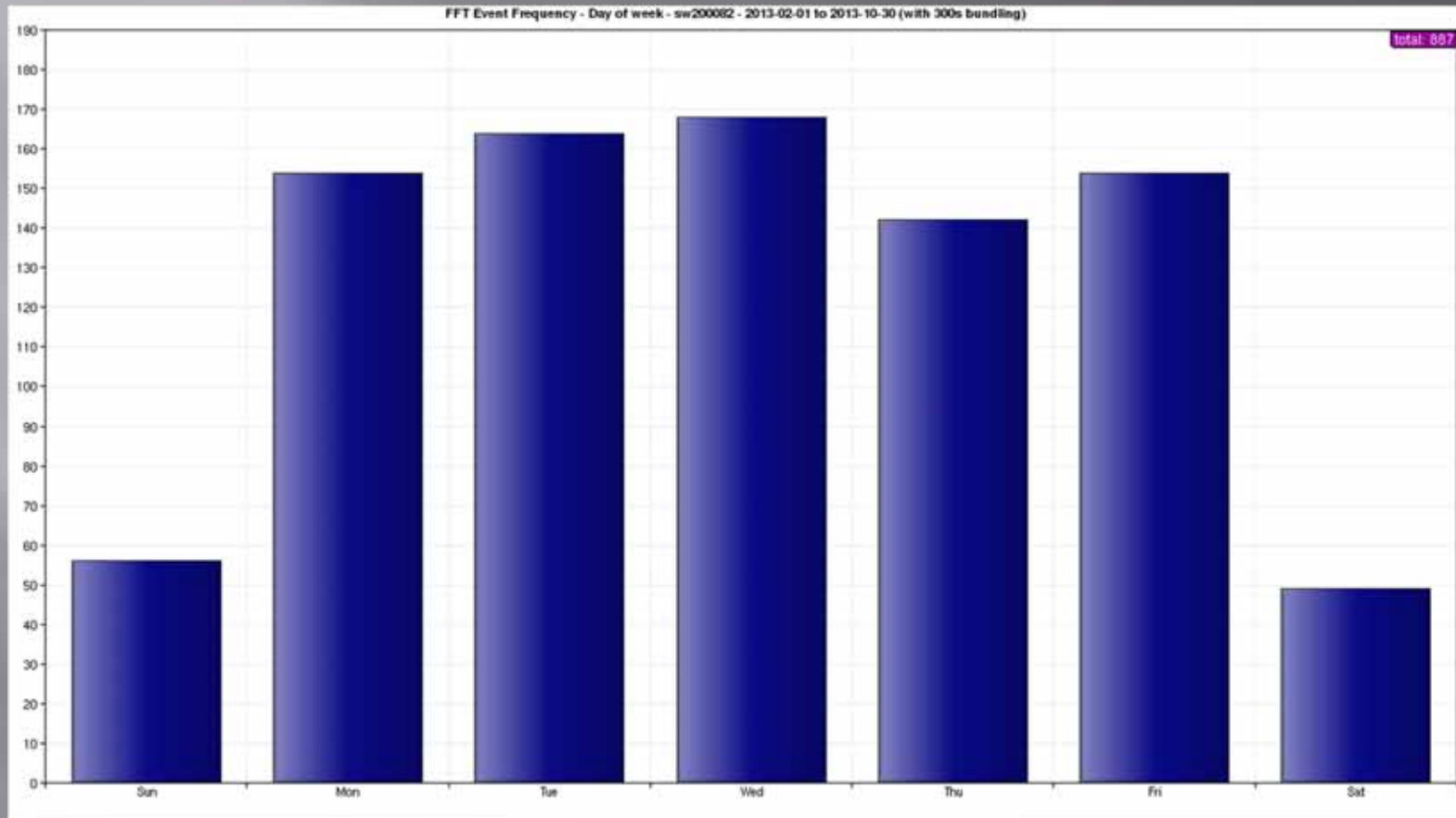
Data and image courtesy of Charles Curry, Chronos Technology Ltd and the SENTINEL Research Project

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



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



ENFORCEMENT BUREAU SIGNAL JAMMER ENFORCEMENT INITIATIVE



Education and Outreach Efforts

Coupled with increasingly aggressive enforcement action, the FCC Enforcement Bureau (EB) continues to educate the public, coordinate with other USG agencies, and form international partnerships. For example, EB has:

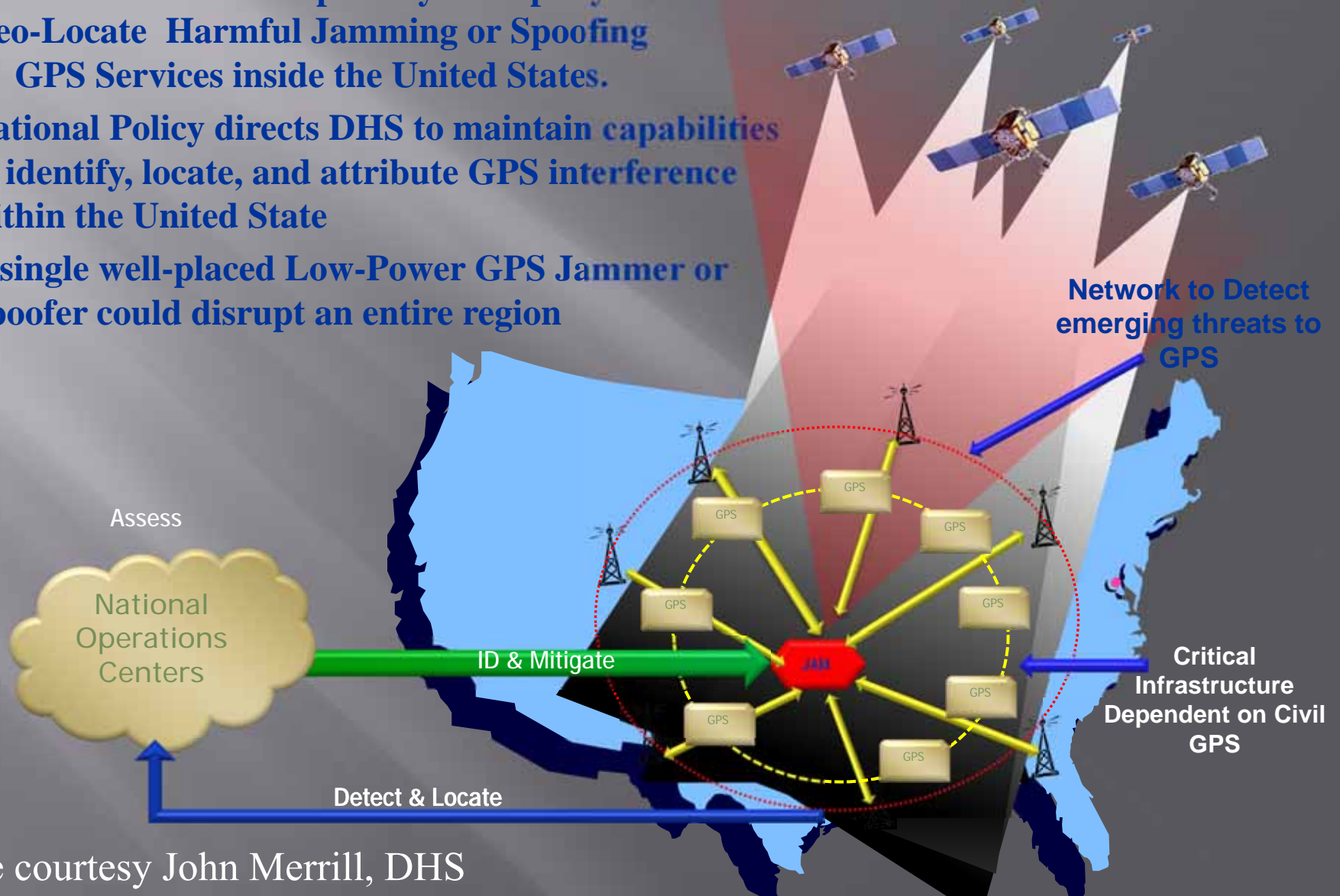
- released three Enforcement Advisories (one of which was translated into Spanish and Mandarin) designed to (i) educate retailers and consumers, (ii) emphasize that jammers are illegal, and (iii) note that violators risk substantial civil and criminal penalties;
- launched a webpage focused on jammer enforcement (<http://www.fcc.gov/jammers>);
- developed and released detailed Frequently Asked Questions on signal jamming devices;
- created jammerinfo@fcc.gov, a one-stop shop for consumer questions regarding jammers;
- instituted a dedicated tip line for jammers: **1-855-55NOJAM (1-855-556-6526)**;
- issued a downloadable poster highlighting the jamming prohibition and describing how to file a complaint; and
- developed jammer-related reference bulletins for law enforcement officers and other critical audiences.

Slide courtesy John Merrill, DHS

1-855-55NOJAM (1-855-556-6526) – jammerinfo@fcc.gov – <http://www.fcc.gov/jammers>

DHS Patriot Watch Overview

- The U.S. Lacks the Capability to Rapidly Detect and Geo-Locate Harmful Jamming or Spoofing of GPS Services inside the United States.
- National Policy directs DHS to maintain capabilities to identify, locate, and attribute GPS interference within the United State
- A single well-placed Low-Power GPS Jammer or Spoofer could disrupt an entire region

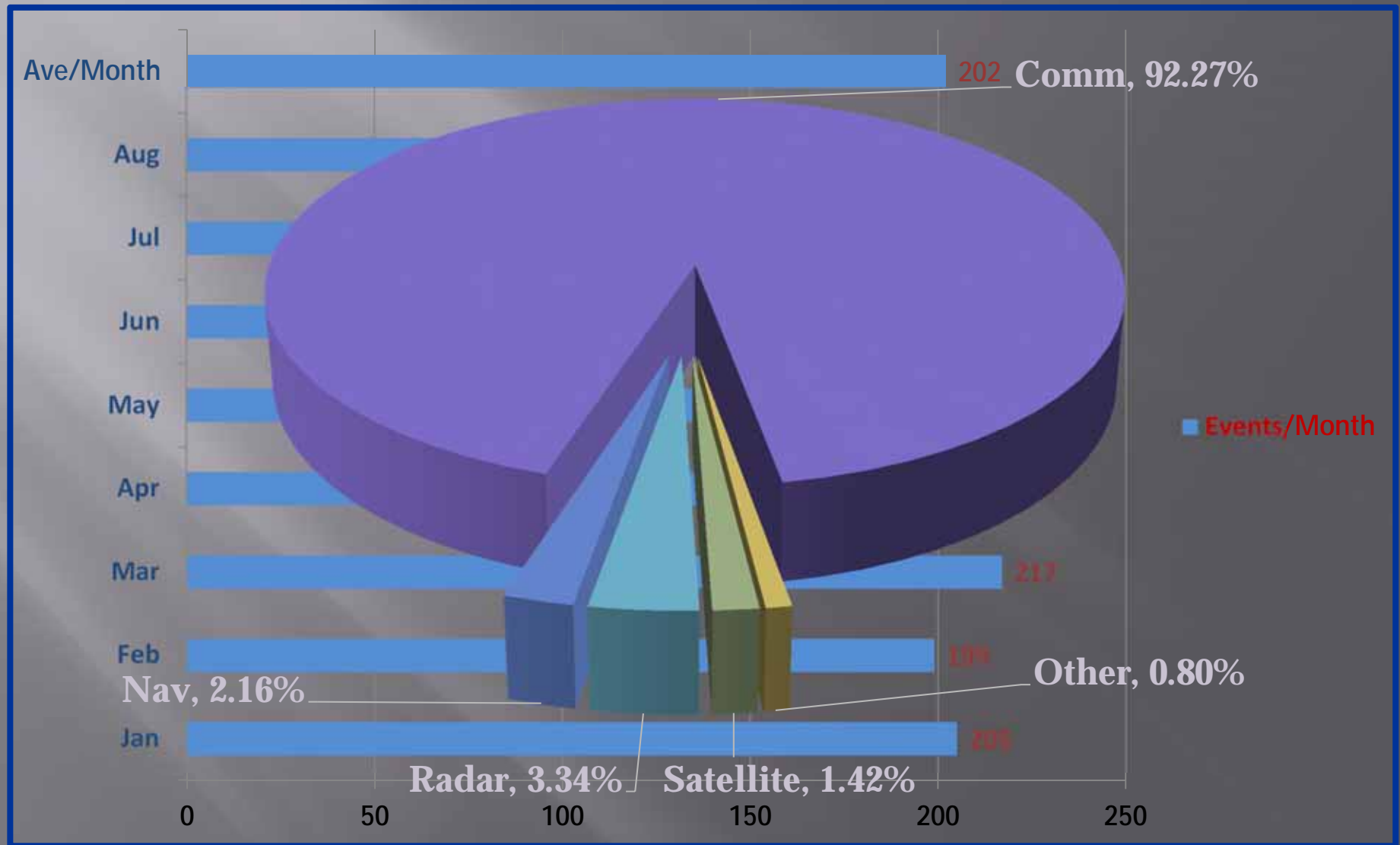


Slide courtesy John Merrill, DHS

Slide courtesy John Merrill, DHS

2013 FAA RFI Events by Month

Source: August 2013 FAA Spectrum Engineering Office



Spoofing: A Growing Threat

IEEE SPECTRUM INSIDE TECHNOLOGY
MAGAZINE MULTIMEDIA
AEROSPACE BIOMEDICAL COMPUTING CONSUMER ELECTRONICS ENERGY

risk factor

The views expressed and do not represent IEEE

BLOGS of THE RISK FACTOR

Commercial Drones and GPS Spoofers a Bad Mix

POSTED BY ROBERT N. CHARETTE / MON, JUNE 25, 2012

Researchers at the [University of Texas at Austin Radioavigation Laboratory](#) have successfully demonstrated that a drone with an unencrypted GPS system can be taken over by a person wielding a GPS spoofing device. You can see a video accompanying a [Fox News story](#) on it, as well as a video [here](#) of an experiment conducted by the researchers, led by Professor [Todd Humphreys](#).

Drone Hijacking? That's Just the Start of GPS Troubles

By [Lorenzo Franceschi-Budini](#) 24 July 6, 2012 (8:55 am) Categories: [Crime and Homeland Security](#), [Drones](#)

The University of Texas Radioavigation Laboratory drone, an Adaptive Flight Home Mini. Photo: Courtesy: Todd Humphreys

On the evening of June 19, a group of researchers from the university of Texas successfully hijacked a [Jordan drone](#) at the White Sands Missile Range in New Mexico during a test organized by the Department of Homeland Security.

EXCLUSIVE: Drones vulnerable to terrorist hijacking, researchers say

By [John Roberts](#) 7:17 PM EST on 06/24/2012 | [Business](#)

A small surveillance drone flies over an Austin stadium, diligently following a series of GPS waypoints that have been programmed into its flight computer. By all appearances, the mission is routine.

Suddenly, the drone veers dramatically off course, careening eastward from its intended flight path. A few moments later, it is clear something is seriously wrong as the drone makes a hard right turn, streaking toward the south. Then, as if some phantom has given the drone a self-destruct order, it hurtles toward the ground. Just a few feet from certain

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Could GPS Hackers Cause the Next Flash Crash?

GPS attacks risk maritime disaster, trading chaos

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Tue Feb 21, 2012 7:01pm EST

- * Jamming of GPS now poses real danger-experts
- * Tests show serious impact on ships in English Channel
- * GPS "spoofing" could pose serious risk to markets

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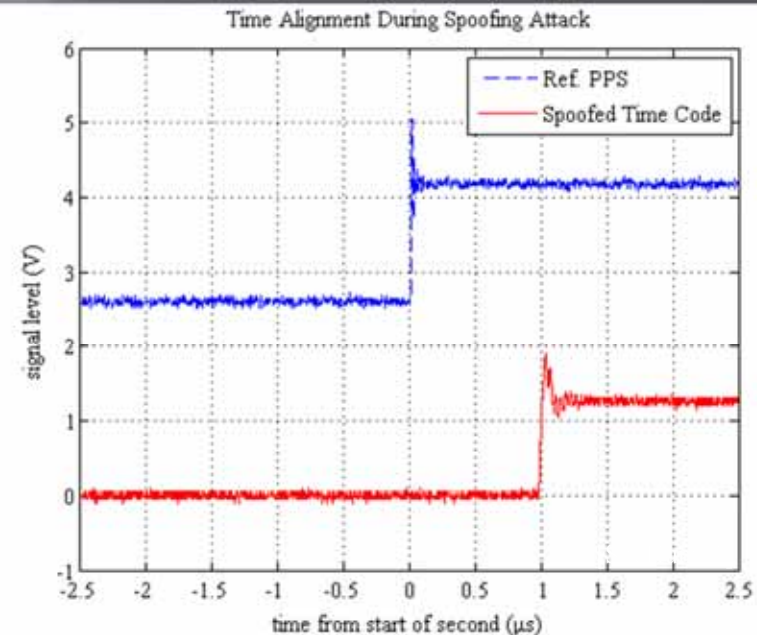
Slide courtesy Kyle Wesson, University of Texas, Austin

Spoofing GPS: Telecom Network Vulnerabilities

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[PesWes&11]

In 35 minutes, spoofer can shift time 10 μs , which would disrupt CDMA call hand-off



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How long can you hold a microsecond?

- Much harder to hold time/phase than frequency
- Hold-over time depends on many things
 - Type of local oscillator (LO)
 - Initialization of LO
 - Environment: in telecom mostly temperature

Holding a Microsecond

	Temperature Controlled Crystal Oscillator (TCXO)	Oven Controlled Crystal Oscillator (OCXO)	Rb Oscillator (5E-12/mo. aging)
Range of times to hold a microsecond	10 minutes – 1 hour	1 – 8 hours	8 hours – 3 days
Cost Range	\$5-25	\$50-150	\$500-1500

Alternative Time Transfer

- ▣ Through the Network
 - SONET has frequency sync, but is being phased out
 - Modern native packet networks need special equipment to pass sync
 - Synchronous Ethernet (**SyncE**) can provide excellent frequency sync
 - Precise Time Protocol (**PTP**) can provide sub – us time sync over a few hops with special equipment
- ▣ Over Air
 - Signals from other wireless base-stations (“macrosniff”)
 - PTP over microwave
- ▣ **eLORAN** Could be a Complete Backup Including UTC
 - Currently towers are being taken down

Conclusions: GPS Vulnerabilities

- ▣ GPS has been **extremely reliable, yet is highly vulnerable** to attack
 - So far, GPS interference has been incidental
 - Much like the internet started with no viruses or attacks, GPS could become a target
 - Telecom has accepted the current risk level

- ▣ **Very dangerous scenarios are possible**
 - GPS could be denied, impacting first responders
 - Could be part of a larger attack
 - Removing a GPS attack could take more than a day, for example if done with multiple mobile intermittent jammers

Overall Conclusions

- ▣ GNSS provides very accurate and free all three types of sync: Time and Frequency and Phase
- ▣ Mobile sync specs are getting tighter
- ▣ GNSS are vulnerable, best feature and worst problem: extremely reliable
- ▣ Backup options: good LO, other transfer source

For More About Sync

NIST & ATIS present



WSTS

**Workshop on Synchronization in
Telecommunication Systems**

**JUNE 10 - 12, 2014
SAN JOSÉ, CALIFORNIA**

<http://www.atis.org/wsts/>

Thank you for your interest!