Global Navigation Satellite Systems - the Present Imperfect

Professor David Last

Position, Navigation & Time - Challenges & Opportunities Symposium

Stanford University

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GPS is perfect …

isn’t it?
Captain Fache plants a battery-sized GPS dot in Langdon’s pocket to track his location, wherever he is, accurate to 2 feet.

It’s tiny!
It’s amazingly accurate!
It works indoors!
Tanker Collides with Submerged Ship in English Channel

A ship carrying 70,000 tons of highly flammable gas and oil crashed into the submerged ship Tricolor in the English Channel on Wednesday, according to a SKY News report.

What could possibly go wrong?

Well, for a start, let’s think about …

• Satellite and control system failures

• Solar flares

• Unintentional interference

• Intentional jamming

• Spoofing (and meaconing)
Satellite and Control System Failures

Official announcement:
"A significant GPS anomaly occurred on 1 Jan 04, beginning at approximately 1833Z ... (which) ... affected precise timing and navigation users over large portions of Europe, Africa, Asia, Australia, and ... North America ... and resulted in the transmission of Hazardously Misleading Information."

SVN23 clock failure

www.lr.tudelft.nl/live/pagina.jsp?id=400f4487-ed8c-4274-95cb-ebc2afa7385e&lang=en

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Satellite and Control System Failures

EGNOS

Satellite and Control System Failures

Kiel coastal DGNSS radio-beacon

• GPS satellite radiates 100W
• From 20,000km range
• Illuminates 38% of Earth
• eg Europe + Africa + Atlantic

Picture: Professor Durk van Willigen
GPS significantly impacted by powerful solar radio burst

NOAA NEWS RELEASE
Posted: April 4, 2007

"Measurements with NJIT's solar radiotelescope confirmed, at its peak, the burst produced 20,000 times more radio emission than the entire rest of the sun. This was enough to swamp GPS receivers over the entire sunlit side of Earth."

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• Threat of unintentional interference and jamming
• Risks can be reduced but not eliminated
• Consequences severe for safety, economic damage
• Tempting target for those hostile to the US
• Can be spoofed to give misleading information
• Need backup system in critical applications
Source: Clynch et al., ‘Multiple GPS RFI Sources in a Small California Harbor’. ION GPS02, Portland OR.
Dice is 1mW GPS jammer
GPS, GSM Cellphone Jammers Hit Mainstream

Pentagon fürchtet 40-Dollar GPS-Störsender der ferngelenkte Raketen blockiert.

Pictures: www.redferret.net/?p=7864
Observer, London, 29 Jan 2003

www.rin.org.uk

http://www.kenneke.com/plans.html#

GPS for the London Congestion Zone?

SABOTAGING THE SYSTEM

Gadgets aim to fool cameras

Police Laser (lidar) Radar Jammer Plans

GPS Jammer Plans

ADD TO CART

ADD TO CART
Cornwall area to lose GPS

Release date: 06 Jun 2007

An area of Cornwall has been warned that satnav systems will not work later this week as the MoD carries out a jamming exercise.

The GPS jamming exercise - due between 0800Z and 1600Z on 7 and 8 June - is to determine how interference could affect military systems.

The jamming will be centred around Portreath (5016N 00516W). The effect is expected to extend for a radius of 6 NM (11 km) - which would cover Camborne and Redruth. It could affect aircraft up to 30,000 ft.

Notice to Airmen (NOTAM): AC 5555
07 JUL 1100-1400 30000ft (A1063/02pt)
08 JUL 0715-1015 30000ft (A1063/02pt)
GPS Jamming Activity 5555N 00550W rad 320nm.
JNC Briefing on Jamming Incident
Why do we need a backup? Here is a classic case in point.

- US Navy ships doing communications jamming tests
- Their own GPS stopped working
- Jammed the whole San Diego harbour region
- Stopped phone systems, cell-phones, hospital paging
- It took NAVCEN 3 days to finger the culprits!
- GPS jamming was unintentional
Jamming

- Galileo, Compass, QZSS share L1, L2, L5 frequencies
- GLONASS uses different frequencies
- Not an integrity problem – receiver stops working
- Affects availability and continuity
Spoofing

US Government Volpe Report, on Spoofing:

• Cause a … GPS receiver to lock onto legitimate-appearing false signals.

• Spoofing … will inject hazardously misleading information.

• (And, if not) … will …create significant … errors, and jam large areas …

• A spoofer also can defeat nearly all anti-jamming equipment.

And then there’s …

• Meaconing: receive, delay, and rebroadcast signals to confuse a user.
Multi-Channel Scenario Replay GPS/SBAS Simulation System

STR4500

Picture: www.positioningtechnology.co.uk/datasheets/str4500/str4500.html

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GPS RE-RADIATORS

Re-radiators make possible the use of handheld GPS units inside a ship or vehicle, without the need for wired external antennas.

The re-radiating kit RA-50 has a coverage >2m, and ensures a wireless reception in every medium-sized vehicles.

The re-radiating kit RK-104 has a coverage about 10-20m! It is perfect for use as well in big vehicles as in indoors.

!!! FOR PRICES: PLEASE GET IN TOUCH BY PHONE OR EMAIL:
+49 89 321 990 14 or l.henault@tecsys.de

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• British ship is sunk by Chinese in international waters.

• Clue is **fake GPS signal** controlled by techno-terrorist.

• Bond discovers GPS device - and wins the girl!

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Spoofing

• Spoofing is an integrity problem.

• Civil receivers are bad at detecting spoofing.

• Detection needs another system, clever integration.

• Terrestrial back-up is the best defence.
GNSS Vulnerability ...

who cares?
Volpe says Loran-C …

- Is viable for coastal operations
- Is very effective for land tracking
- Can replace GPS for telecomms timing
- Is a potential backup for aviation
### Enhanced Loran?

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>With differential, comparable to satellite. Built-in integrity checking.</td>
</tr>
<tr>
<td><strong>Interference</strong></td>
<td>Much less vulnerable to jamming and interference than GPS – and different frequencies.</td>
</tr>
<tr>
<td><strong>Penetration</strong></td>
<td>YES. More available in urban areas and forests.</td>
</tr>
<tr>
<td><strong>Indoors</strong></td>
<td>OK. Can be better than GPS.</td>
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Locus and Brunswick MX Marine Announce First Integrated GPS/NDGPS/eLoran System at RTCM

reelektronika

LORADD Series
Integrated GPS Loran-C Receiver
The future radionavigation mix?

- **GPS**

- **Other satellite:**
  Galileo?, Compass?, QZSS, compatible, free-to-air services, plus some restricted

- **Augmentations:**
  
  **GBAS:** Radiobeacons, Eurofix
  
  **SBAS:** MSAS, WAAS, EGNOS

- **Aviation:** ILS, DME, less NDB, VOR

- **Enhanced Loran:**
  Integrated with satellite

- **Indoor navigation system(s)**
GNSS- The Present Imperfect

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