Initial Findings from the STRIKE3 GNSS Interference Monitoring Network

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Space Based PNT Advisory Board
21st Meeting, 16-17 May 2018, Baltimore, US
STRIKE3 is a project to protect GNSS...

- Standardisation of GNSS Threat reporting and Receiver testing through International Knowledge Exchange, Experimentation and Exploitation [STRIKE3]

- Project funded by European GNSS Agency (GSA) under the European Commission’s H2020 Framework Programme

- Start date = 1 February 2016
- Duration = 3 years
STRIKE3 Project Rationale

- STRIKE3 will deploy and operate an international GNSS interference monitoring network (with support from partners)

- STRIKE3 will use the data from the network to ensure that there is:
  - a standard for GNSS threat reporting and analysis
  - a standard for assessing the performance of GNSS receivers and applications under threat.
STRIKE3 International Monitoring Network

At a range of infrastructures:
- Major City Centres
- City-ring roads
- National timing labs
- Motorways/Road network
- Airports
- GNSS infrastructures
- Power stations
- Railway
- EU Borders
- Ports

At a range of locations:
- United Kingdom
- Sweden
- Finland
- Germany
- France
- Poland
- Czech Republic
- Spain
- Slovakia
- Slovenia
- Netherlands

Belgium
- Croatia
- Latvia
- India
- Vietnam
- Thailand
- Malaysia
- New Zealand
- Canada
- Japan (pending)
- US (exploring)
- Singapore (exploring)

Involving a range of entities:
- Government agencies
- Frequency regulators
- Road operators
- Tolling operators
- Airport operators
- Air Navigation Service Providers
- Power grids
- Research

30+ monitoring sites
STRIKE3 Analysis Tool

1. Spectrum/Spectrogram
2. Event power profile and impact on number of Satellites
3. Impact on Positioning Accuracy
4. Trends statistics per site/group/all
5. Summary statistics per site/group/all
STRIKE3 Fingerprint characterisation

1. Size, pressure, patterns
2. Identify distinguishing features
3. Classify the signature
4. Identify different “families”
5. Identify new “families”
6. Preserve the evidence
   - Create a catalogue
   - Reference for future events
   - Automatic pattern recognition
STRIKE3 “Database” [1/2/2016 – 30/04/2018]

Classification Types

STRIKE3 RFI database currently includes 362,310 events
STRIKE3 Denial Events [1/2/2016 – 30/04/2018]

- 50,000 GNSS denial events:
  - 39,000 jammer events
  - 10,000 NB/single tone
  - 1,000 noise+CDMA+other

Event Priority Levels (By Classification Type)
- Very Low 192,571
- Low 90,261
- Medium 28,839
- High 50,639

Classification Types
- WHITE_WB: 793
- NB_ST: 10,078
- CHIRP: 36,876
- CDMA: 527
- OTHER: 365
STRIKE3 “Durations” [1/2/2016 – 30/04/2018]

STRIKE3 database (362,000)

Duration Levels (sec)

- 231,253 [00 to 20 sec]
- 67,383 [20 to 40 sec]
- 22,141 [40 to 60 sec]
- 41,533 [60+ sec]

Most events are very short duration
11% of events are greater than 60secs

- 5840 events > 5 mins
- 972 events > 30mins
- 545 events > 60mins
- 5 events > 1 day
- Longest event = 5 days

STRIKE3 High Priority events (50,000)

Duration Levels (sec)

- 15,607 [00 to 20 sec]
- 11,814 [20 to 40 sec]
- 6,407 [40 to 60 sec]
- 16,531 [60+ sec]

30% of events are greater than 60secs

Max Epoch at 12-03-2016 01:06:40, Max Power: 6.767892, Event Duration: 49111 sec
STRIKE3 Trend Analysis

- Trends per site
- Trends per infrastructure
- Trends per week/month/year
- Trends per grouping
- Trends per event classification
- Overall trends within the database
- (Trends per GNSS, per frequency)

Same DETECTOR, two different locations

Trends at two “city centre” sites
STRIKE3 Site Comparisons (Airports)

- Results from 8 Airport installations
- Most are “national” airports. Most are air-side installations.
- 30 days data (may not be the same 30 days)

<table>
<thead>
<tr>
<th></th>
<th>RFI events</th>
<th>Jammers</th>
<th>Jammer/events ratio</th>
<th>Duration &gt; 60secs</th>
<th>GNSS denial</th>
<th>Denial/events ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Airport</td>
<td>8716</td>
<td>95</td>
<td>1%</td>
<td>282</td>
<td>362</td>
<td>4%</td>
</tr>
<tr>
<td>National Airport</td>
<td>759</td>
<td>27</td>
<td>4%</td>
<td>200</td>
<td>211</td>
<td>28%</td>
</tr>
<tr>
<td>National Airport</td>
<td>2764</td>
<td>595</td>
<td>22%</td>
<td>395</td>
<td>753</td>
<td>27%</td>
</tr>
<tr>
<td>Regional Airport</td>
<td>556</td>
<td>31</td>
<td>6%</td>
<td>6</td>
<td>95</td>
<td>17%</td>
</tr>
<tr>
<td>National Airport</td>
<td>904</td>
<td>168</td>
<td>19%</td>
<td>158</td>
<td>182</td>
<td>20%</td>
</tr>
<tr>
<td>National Airport</td>
<td>776</td>
<td>19</td>
<td>2%</td>
<td>101</td>
<td>35</td>
<td>5%</td>
</tr>
<tr>
<td>National Airport</td>
<td>1819</td>
<td>73</td>
<td>4%</td>
<td>9</td>
<td>252</td>
<td>14%</td>
</tr>
<tr>
<td>National Airport</td>
<td>4519</td>
<td>133</td>
<td>3%</td>
<td>352</td>
<td>153</td>
<td>3%</td>
</tr>
</tbody>
</table>

- Helps to diagnose issues with unintentional interference & jamming
- Helps to compare with other sites
STRIKE3 Impact Assessments

- 2x ~50m
- 2x ~50m
- ~0m
- ~5m

m’s to km’s
STRIKE3 Jammer waveforms

- There are lots of jammer waveforms, characterised by:
  - Bandwidths, power, centre frequency, signal(s)
  - Additional parameters: sweep rate, direction, return
### STRIKE3 Threat Testing waveforms

<table>
<thead>
<tr>
<th>Type of signal</th>
<th>Example Plots</th>
<th>Reason for choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow band on L1</td>
<td><img src="image1.png" alt="Example Plots" /></td>
<td>Example unintentional(?) signal – this type seen on multiple occasions and at multiple sites</td>
</tr>
<tr>
<td>Wide Sweep – fast repeat rate</td>
<td><img src="image2.png" alt="Example Plots" /></td>
<td>Very common (total number of events, and number of sites)</td>
</tr>
<tr>
<td>Triangular wave</td>
<td><img src="image3.png" alt="Example Plots" /></td>
<td>Common (and number of sites)</td>
</tr>
<tr>
<td>Triangular</td>
<td><img src="image4.png" alt="Example Plots" /></td>
<td>Common (and number of sites)</td>
</tr>
<tr>
<td>Tick</td>
<td><img src="image5.png" alt="Example Plots" /></td>
<td>Increasingly common. Evolving threat (new type).</td>
</tr>
</tbody>
</table>

*GNSS receiver industry should focus on mitigations for these popular waveforms*
Simple Rules to support validation

- It has a structure (it is deliberate, purposeful)
- It is mobile (exhibits same power profile as a jammer)
- It is seen multiple times (avoids being a one-off rogue “signal”)
- It is seen multiple sites (demonstrates a distributed product)
STRIKE3 shows Jammer industry is evolving...

5Mhz bandwidth, 1575Mhz centred

8Mhz bandwidth, drifting centre

Wideband

Waveform detected at 4 STRiKE3 sites Europe and outside EU

2012

USB L1/L2 jammer
What are the chances? Same place, same time...

- Dual signal jammer?
- One vehicle, two jammers?
- Two vehicles, one jammer in each?
- Jammer in truck, jammer in trailer?
STRIKE3 demonstrates the value of characterisation...

1. Distinguish between “unintentional” and “deliberate” threats
   - Fingerprinting eliminates false “jammer” detections
   - Fingerprinting ensures correct statistics
2. Distinguish between different types of jammer (basic >> advanced >> exotic)
3. Identify repeat threat signatures (to assess the scale of the problem)
4. Enables you to “track a jammer” across/within a monitoring network
The last unknown within STRIKE3...

May 2018: Major Capital City. Two STRIKE3 sites, separated by 10km. Same waveform detected at same times.

- Number of events = 4576
- Longest duration = 27504 secs
- High power (but from a distance)
- Unable to identify cause
STRIKE3 Draft Standards

1. Standards for Threat Monitoring and Reporting
2. Standards for Receiver testing against threats

Available from: www.gnss-strike3.eu
What next for STRIKE3?

- Deployment of a national STRIKE network
  - Multi-GNSS, multi-frequency
  - At sites of critical national infrastructure

- Validate the STRIKE3 reporting standard
  - System of systems Threat database

- Integration of crowd-sourced GNSS RINEX data to:
  - Identify GNSS interference hotspots
  - Understand the impact of wide area (high power) events on GNSS receivers

- Testing GNSS receivers against the “STRIKE3 threat database”
  - Support the development of new interference mitigation techniques

STRIKE3 live-sky demonstration and project close-out workshop in late 2018
Thank you for the opportunity to present and to participate

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