



# Detector

Fingerprinting GNSS Threats

**ICG Workshop on GNSS Spectrum Protection and Interference Detection and Mitigation**  
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**Deploy systems**

**Detect Interference**

**Characterise the threat**



# DETECTOR Introduction



**Detector**  
Fingerprinting GNSS Threats

GSA 

Detection, Evaluation and Characterisation of Threats to Road applications

		
Deploy roadside units	Detect interference	Characterise interference



## DETECTOR Consortium

		 <small>Gründen. Anbinden. Fördern.</small>
GNSS Technology developer	GNSS Road Toll Operator	Automotive Test Site
 <small>ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA</small>	<b>Black Holes B.V.</b>	  <small>Institute for the Protection and Security of the Citizen</small>
GNSS Interference R&D	Legal Experts	* EC Joint Research Centre

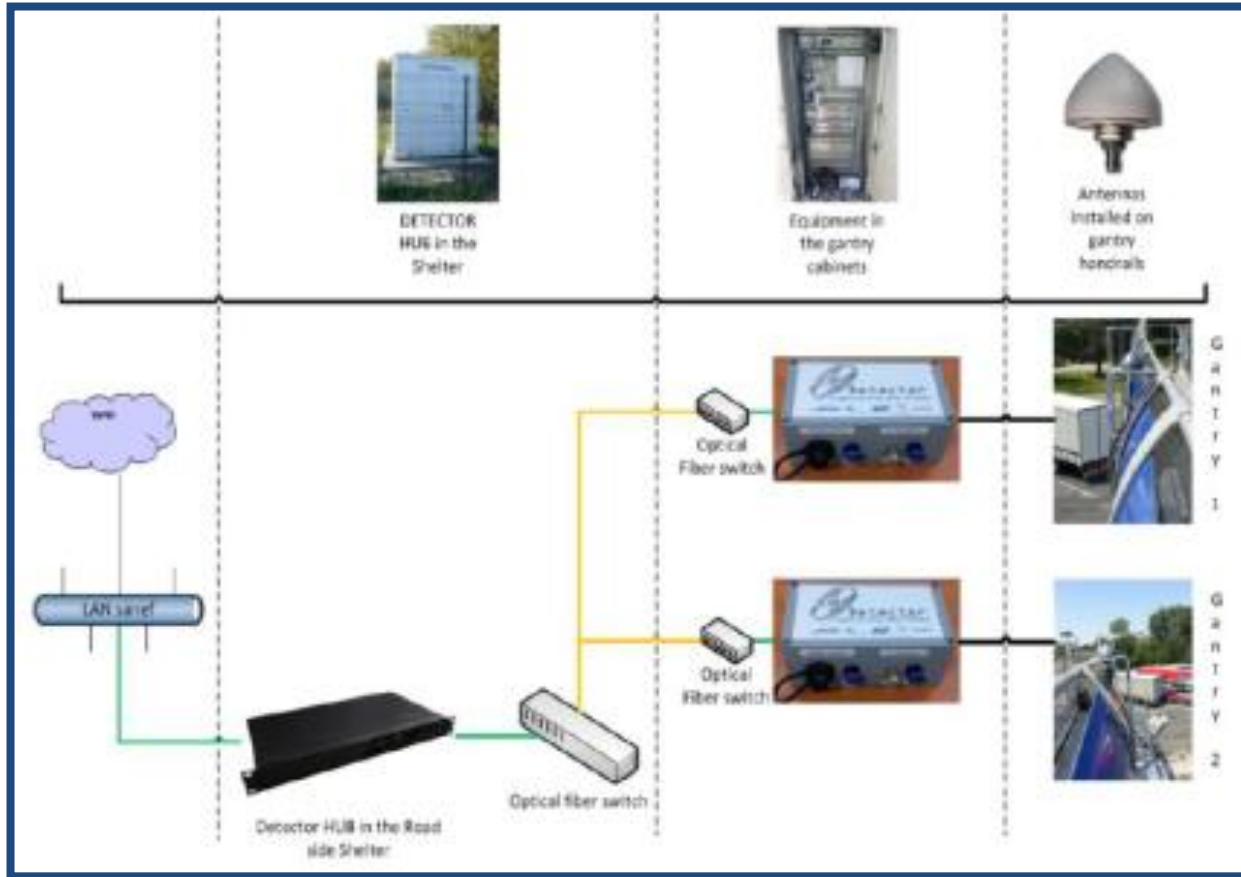
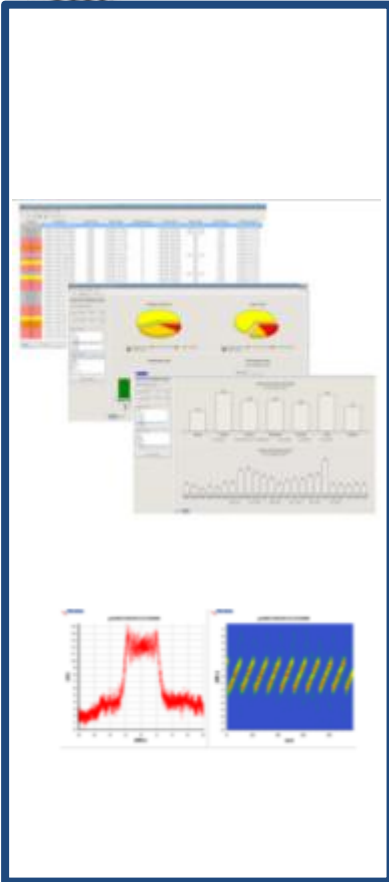
The **DETECTOR** consortium brings together GNSS technology, GNSS road tolling, GNSS testing, GNSS interference and legal expertise

**DETECTOR originates from an EU sponsored FP7 Project. Project ended Oct 2013. DETECTOR is now a commercial offering under a service contract model.**



# DETECTOR System

Incorporates Field units and office systems



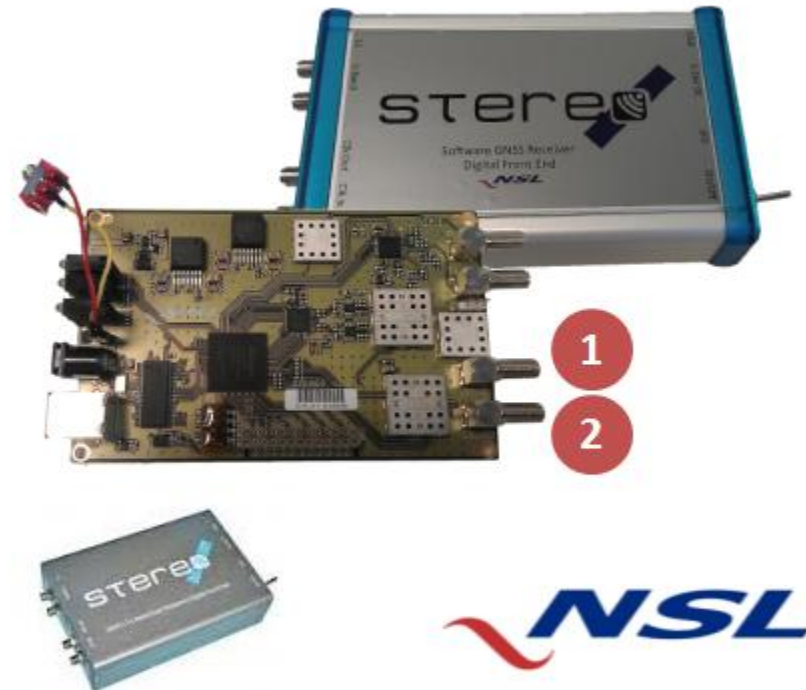


# DETECTOR Technology

Based on dual-channel GNSS software receiver technology

Frequency	Channel 1	Channel 2
GPS L1	X	X
GPS L2		X
GPS L5		X
Galileo E1	X	X
Galileo E5		X
Galileo E6		X
Glonass L1	X	X
Glonass L2		X
GSM		X
Satcom		X

RF front end covers all GNSS + GSM



DETECTOR utilising existing STEREO product

DETECTOR technology is compatible all GNSS services, GSM/GPRS/3G/satcom and Galileo (E1/E5/E6) bands. There is 40+Mhz bandwidth available on Channel 2.

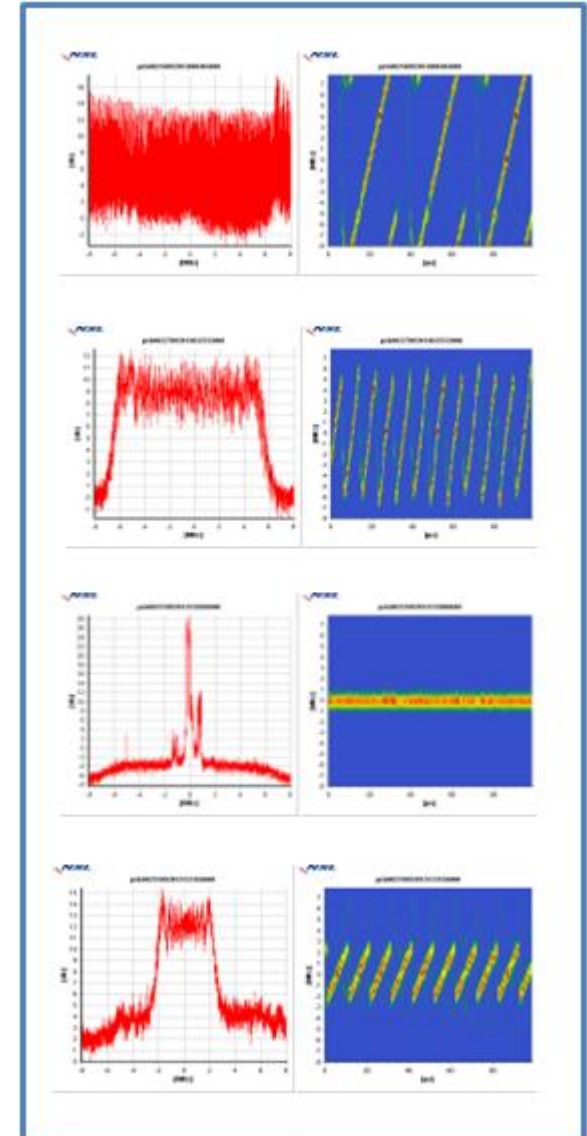


# DETECTOR Characterisation

Characterisation and parameterisation of incoming signals

1. Determine likely impact on users
2. Differentiate unintentional interference from jamming
3. Differentiate between jammer types
4. Identify multiple detections of the same interference versus one-offs
5. Identify trends in the evolving threat
6. Develop countermeasures
7. Catalogue the threats

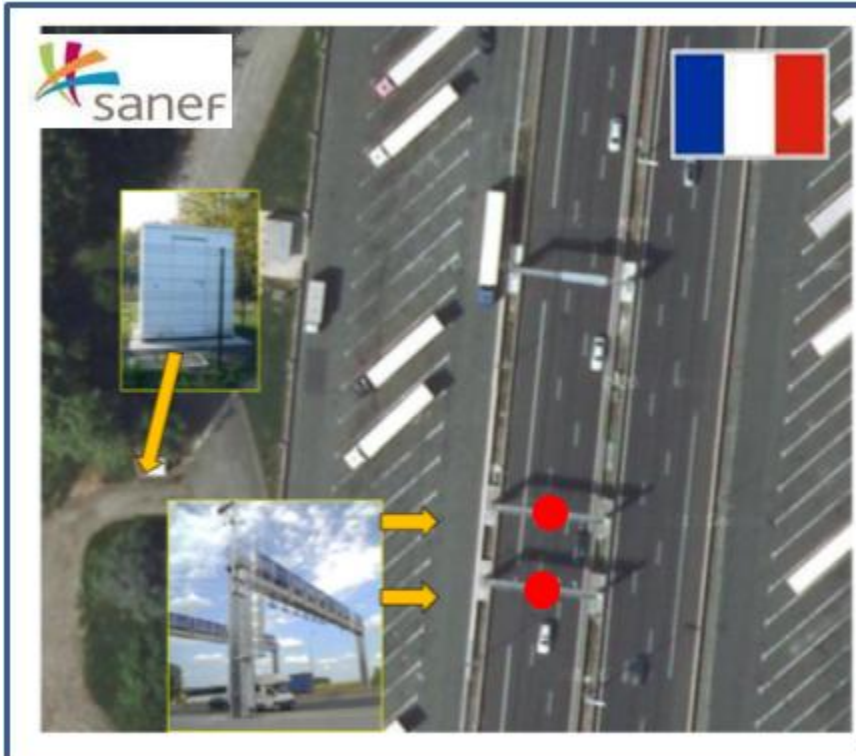
DETECTOR captures and characterises the threat



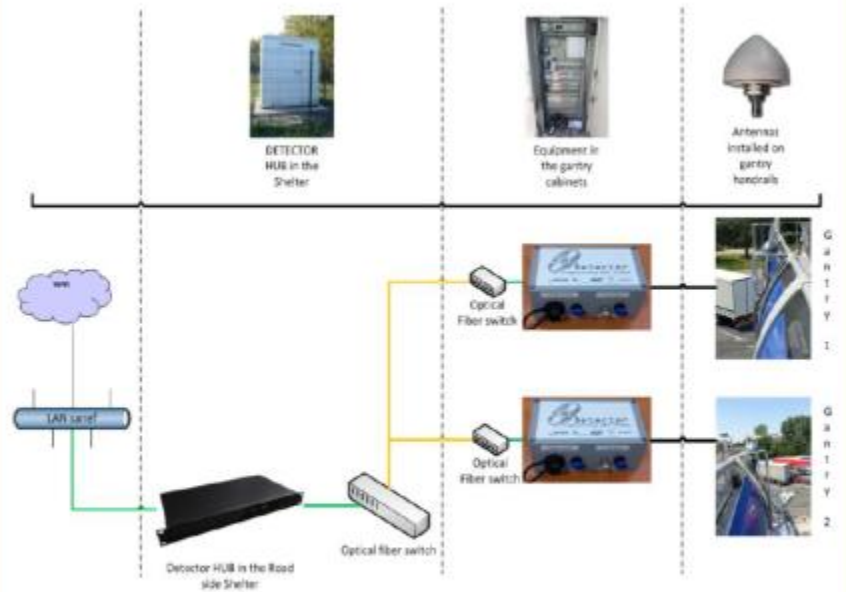


# DETECTOR Results (~12 mths)

DETECTOR demonstrator was installed in France in July 2013



A1 autoroute (north of CdeG airport)



System setup

DETECTOR is interested in exploring opportunities for trials and demonstrations in EU member states (airports, ports, railways, roads, energy, telcoms, banks...)





# DETECTOR Database

Detected events are characterised, parameterised and stored

Contains "severity" of detection events

Priority	Event ID	Device ID	Start Time	Duration (sec)	Event Type	Class Type	Max Power	Time Received
Low	pb0020402201410350000	pb002	04/02/2014 10:35:00	21	Automatic_Detection	ST	2.1126	04/02/2014 10:35:24
High	pb00204022014103210000	pb002	04/02/2014 10:32:01	45	Automatic_Detection	CHIRP_SAWTOOTH	6.8524	04/02/2014 10:32:21
Very Low	pb00204022014103042000	pb002	04/02/2014 10:04:42	24	Automatic_Detection	WHITE_OR_WB	1.0039	04/02/2014 10:05:11
Very Low	pb00204022014175447000	pb002	04/02/2014 17:54:47	21	Automatic_Detection	WHITE_OR_WB	1.0071	04/02/2014 17:55:13
Very Low	pb00204022014105530000	pb002	04/02/2014 16:53:08	15	Automatic_Detection	WHITE_OR_WB	1.0088	04/02/2014 16:53:29
High	pb0020402201416125000	pb002	04/02/2014 16:12:55	57	Automatic_Detection	WB	6.5968	04/02/2014 16:13:58
High	pb00204022014155622000	pb002	04/02/2014 15:56:22	15	Automatic_Detection	EDOCHIRP_SAWTOOTH	1.1285	04/02/2014 15:56:42
Very Low	pb0020402201415362000	pb002	04/02/2014 15:36:09	24	Automatic_Detection	WHITE_OR_WB	1.0047	04/02/2014 15:36:40
High	pb00204022014151153000	pb002	04/02/2014 15:11:53	33	Automatic_Detection	CHIRP_SAWTOOTH	7.6009	04/02/2014 15:12:33
Very Low	pb00204022014150540000	pb002	04/02/2014 15:05:40	21	Automatic_Detection	WHITE_OR_WB_OR_WB	1.0619	04/02/2014 15:06:07
Very Low	pb00204022014120947000	pb002	04/02/2014 12:09:47	15	Automatic_Detection	WHITE_OR_WB	1.0000	04/02/2014 12:10:08
Very Low	pb00204022014120913000	pb002	04/02/2014 12:09:13	27	Automatic_Detection	WHITE_OR_WB	1.0030	04/02/2014 12:09:45
High	pb00204022014112404000	pb002	04/02/2014 11:24:04	44	Automatic_Detection	LEOCHIRP_SAWTOOTH	4.3551	04/02/2014 11:25:01
Very Low	pb00204022014110309000	pb002	04/02/2014 11:03:09	15	Automatic_Detection	WHITE_OR_WB	1.0074	04/02/2014 11:03:34
Very Low	pb002040220141094548000	pb002	04/02/2014 10:45:48	24	Automatic_Detection	WHITE_OR_WB	1.0022	04/02/2014 10:46:17
Medium	pb00204022014107542000	pb002	04/02/2014 07:54:24	21	Automatic_Detection	WB	3.7700	04/02/2014 07:54:50
Very Low	pb002040220141071647000	pb002	04/02/2014 07:16:47	15	Automatic_Detection	WHITE_OR_WB	1.0013	04/02/2014 07:17:06
Medium	pb002040220141060802000	pb002	04/02/2014 06:08:02	30	Automatic_Detection	WB	4.9742	04/02/2014 06:08:37
Very Low	pb002040220141052437000	pb002	04/02/2014 05:24:37	24	Automatic_Detection	WB	1.3876	04/02/2014 05:25:05
High	pb002040220141044007000	pb002	04/02/2014 04:40:07	26	Automatic_Detection	CHIRP_SAWTOOTH	8.2076	04/02/2014 04:40:47
High	pb002040220141041657000	pb002	04/02/2014 04:16:57	48	Automatic_Detection	CHIRP_SAWTOOTH	8.3567	04/02/2014 04:17:52
Very Low	pb002040220141014225000	pb002	04/02/2014 01:42:25	15	Automatic_Detection	WHITE_OR_WB	1.0024	04/02/2014 01:42:44

DETECTOR Event database

August – Jan 2013



2171 events, 329 "chirp" jammers

DETECTOR Event Statistics

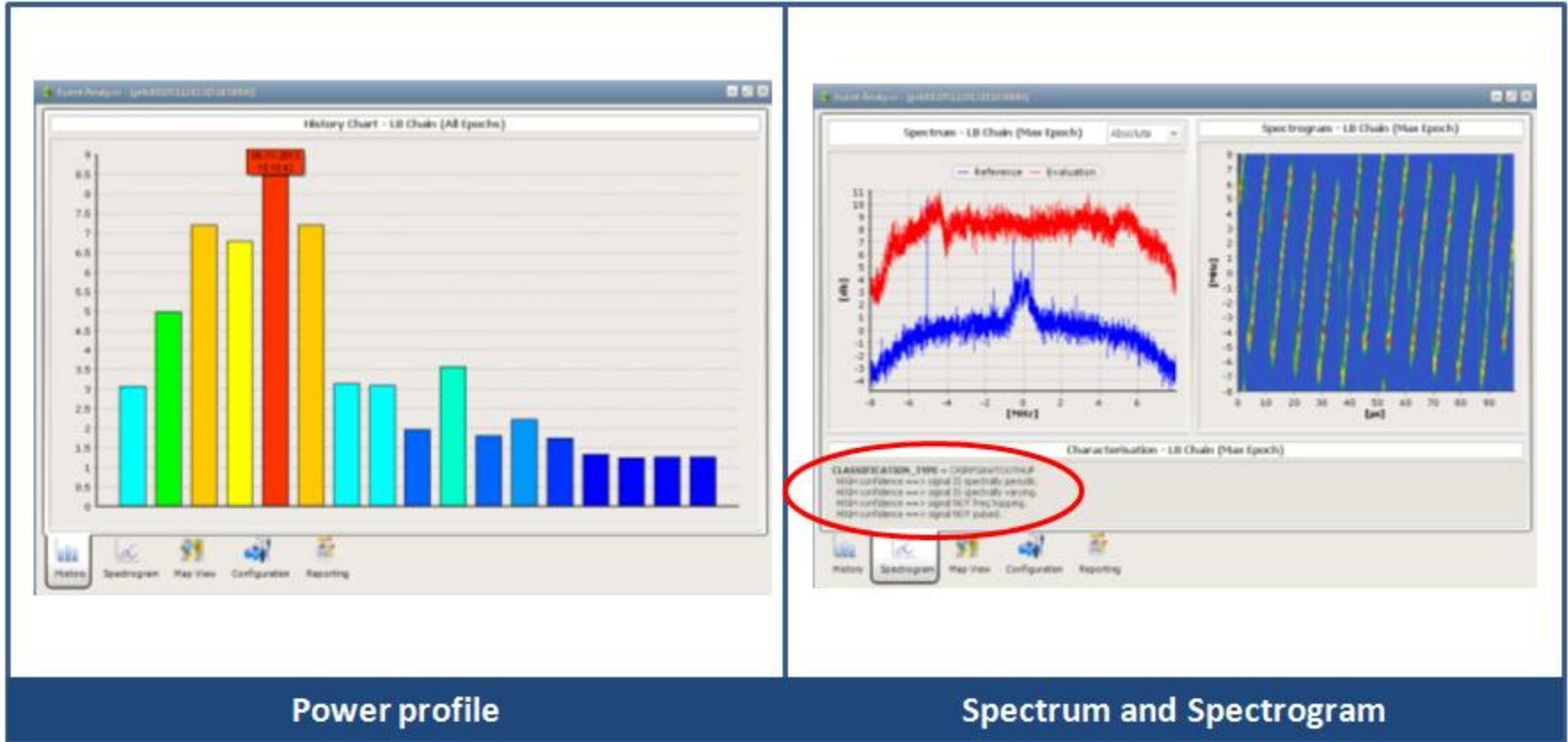
Displays the parameters for each event

Displays the statistics for the time period under inspection (ie one month, one year etc..)



# DETECTOR Event Reports

Database entries can be accessed and displayed for analysis purposes.



**DETECTOR captures the power profile** of the interference event. This enables the system to infer “static or dynamic” as well as direction”.

**DETECTOR captures the signature of the jammer** in a spectrum and spectrogram form.





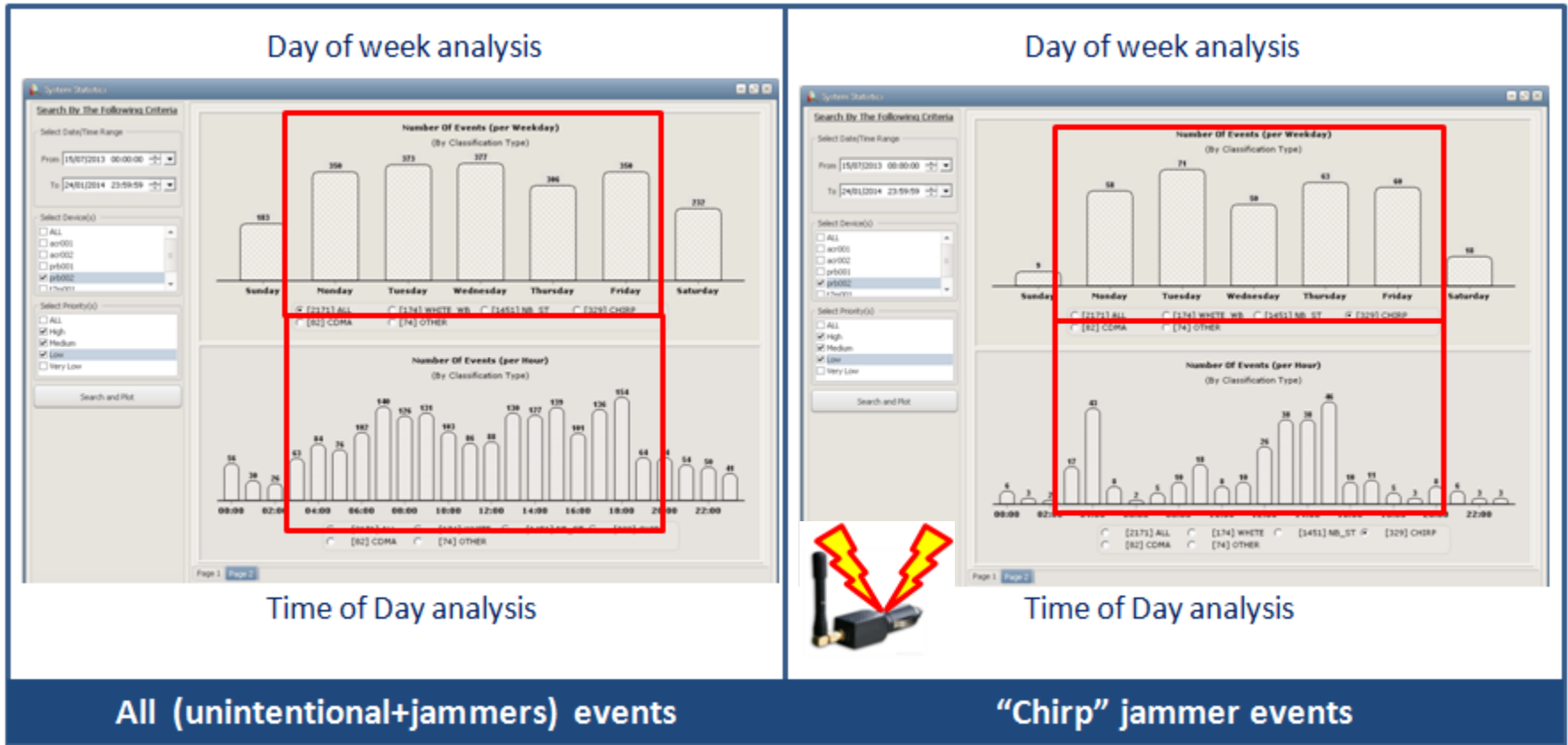
# DETECTOR Event Catalogue

All detected events are captured, processed, analysed and stored



# DETECTOR Database Analysis

Database entries can be analysed collectively to detect patterns and trends



DETECTOR enables the user to analyse the database on daily, hourly, type basis.



# DETECTOR Customer Portal

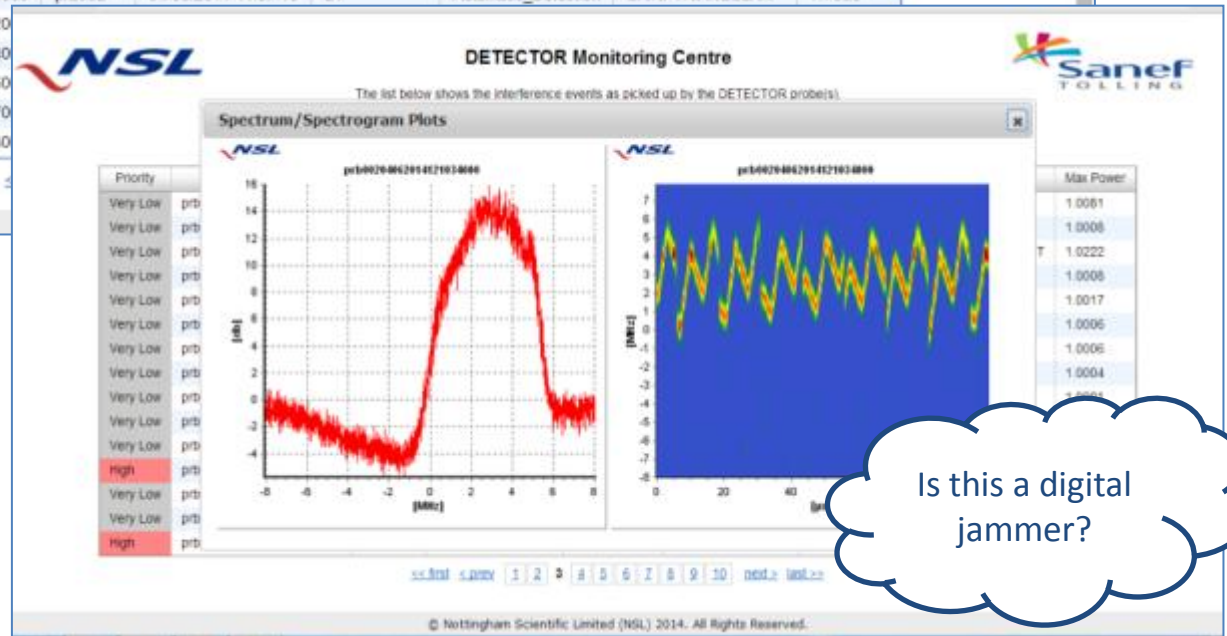
Some customers like reports, some customers like a portal.

The screenshot shows the NSL DETECTOR Monitoring Centre interface. At the top, it says "The list below shows the interference events as picked up by the DETECTOR probe(s)." Below this is a table with columns: Priority, Event ID, Device ID, Start Time (UTC), Duration (sec), Event Type, Class Type, and Max Power. The table contains 18 rows of data. A red box highlights the row with Event ID prb00204062014121034000, which has a High priority and a Max Power of 7.5932. The interface also includes navigation links like "<< first", "prev", "71", "72", "73", "74", "75", "76", "77", "78", "79", "80", "next", "last >>".

Priority	Event ID	Device ID	Start Time (UTC)	Duration (sec)	Event Type	Class Type	Max Power
Very Low	prb00204062014165912000	prb002	04/06/2014 16:59:12	24	Automatic_Detection	WHITE_OR_WB	1.0006
Very Low	prb00204062014165538000	prb002	04/06/2014 16:55:38	15	Automatic_Detection	WHITE_OR_WB	1.0004
Very Low	prb00204062014161856000	prb002	04/06/2014 16:18:56	15	Automatic_Detection	WHITE_OR_WB	1.0001
Very Low	prb00204062014161249000	prb002	04/06/2014 16:12:49	24	Automatic_Detection	CDMA	1.6555
Very Low	prb00204062014154203000	prb002	04/06/2014 15:42:03	15	Automatic_Detection	WHITE_OR_WB	1.0018
High	prb00204062014151941000	prb002	04/06/2014 15:19:41	36	Automatic_Detection	CHIRPSAWTOOTHUP	8.2388
Very Low	prb00204062014151813000	prb002	04/06/2014 15:18:13	15	Automatic_Detection	WHITE_OR_WB	1.0010
Very Low	prb002040620141452348000	prb002	04/06/2014 14:52:34	15	Automatic_Detection	WHITE_OR_WB	1.0128
High	prb00204062014121034000	prb002	04/06/2014 12:10:34	33	Automatic_Detection	CHIRPTRIANGULAR	7.5932
High	prb00204062014115710000	prb002	04/06/2014 11:57:10	24	Automatic_Detection	CHIRPTRIANGULAR	7.7536
Very Low	prb00204062014114942000	prb002	04/06/2014 11:49:42	15	Automatic_Detection	WHITE_OR_WB	1.0006
Very Low	prb00204062014113414000	prb002	04/06/2014 11:34:14	15	Automatic_Detection	WHITE_OR_WB	1.0008
Very Low	prb00204062014102256000	prb002	04/06/2014 10:22:56	15	Automatic_Detection	WHITE_OR_WB	1.0022
Very Low	prb00204062014093137000	prb002	04/06/2014 09:31:37	15	Automatic_Detection	WHITE_OR_WB	1.0017
Very Low	prb00204062014085113000	prb002	04/06/2014 08:51:13	15	Automatic_Detection	WHITE_OR_WB	1.0006

Dedicated customer web portal

The demonstration portal is available for guest login.

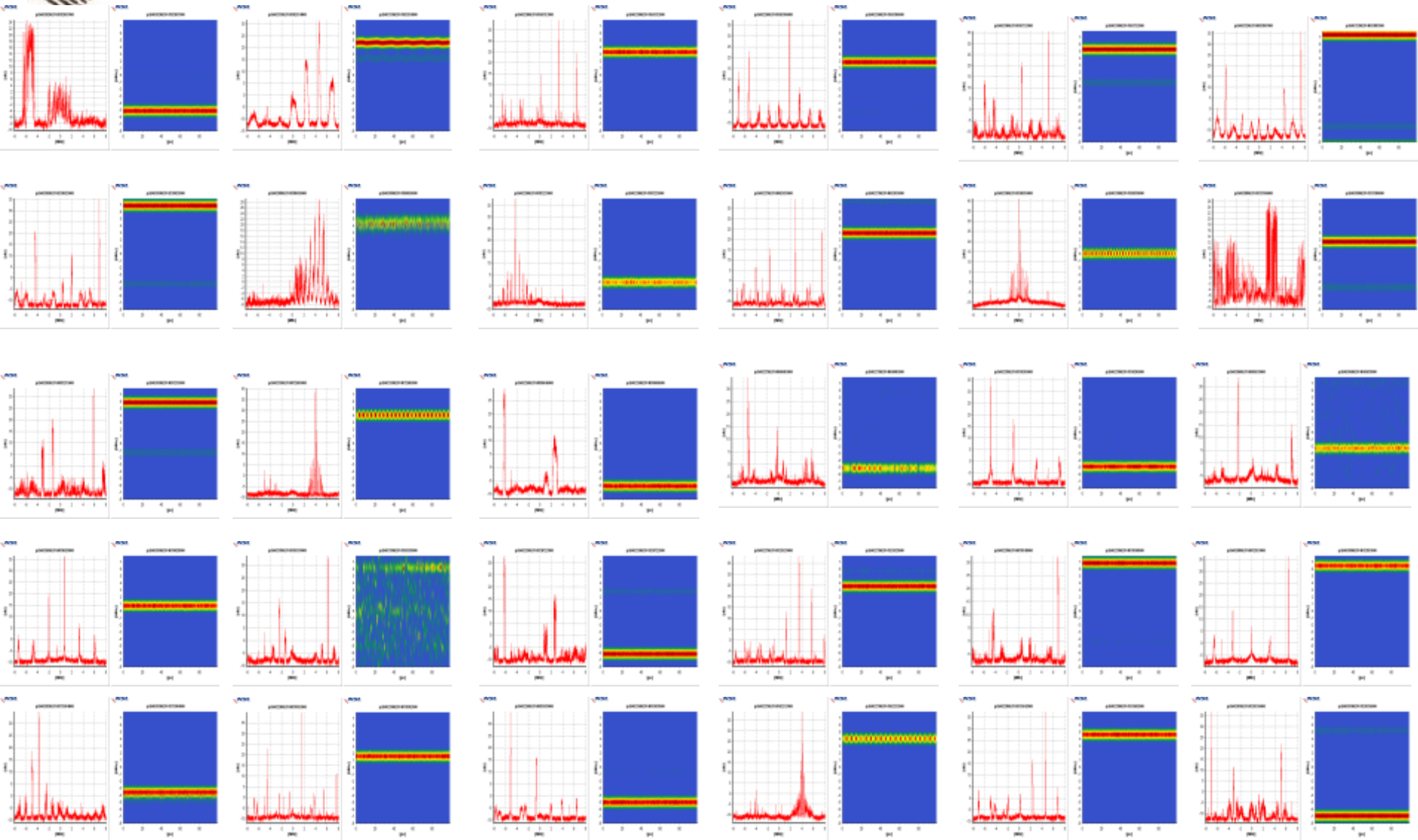


Is this a digital jammer?



# Extract of “June 2014” Interferences

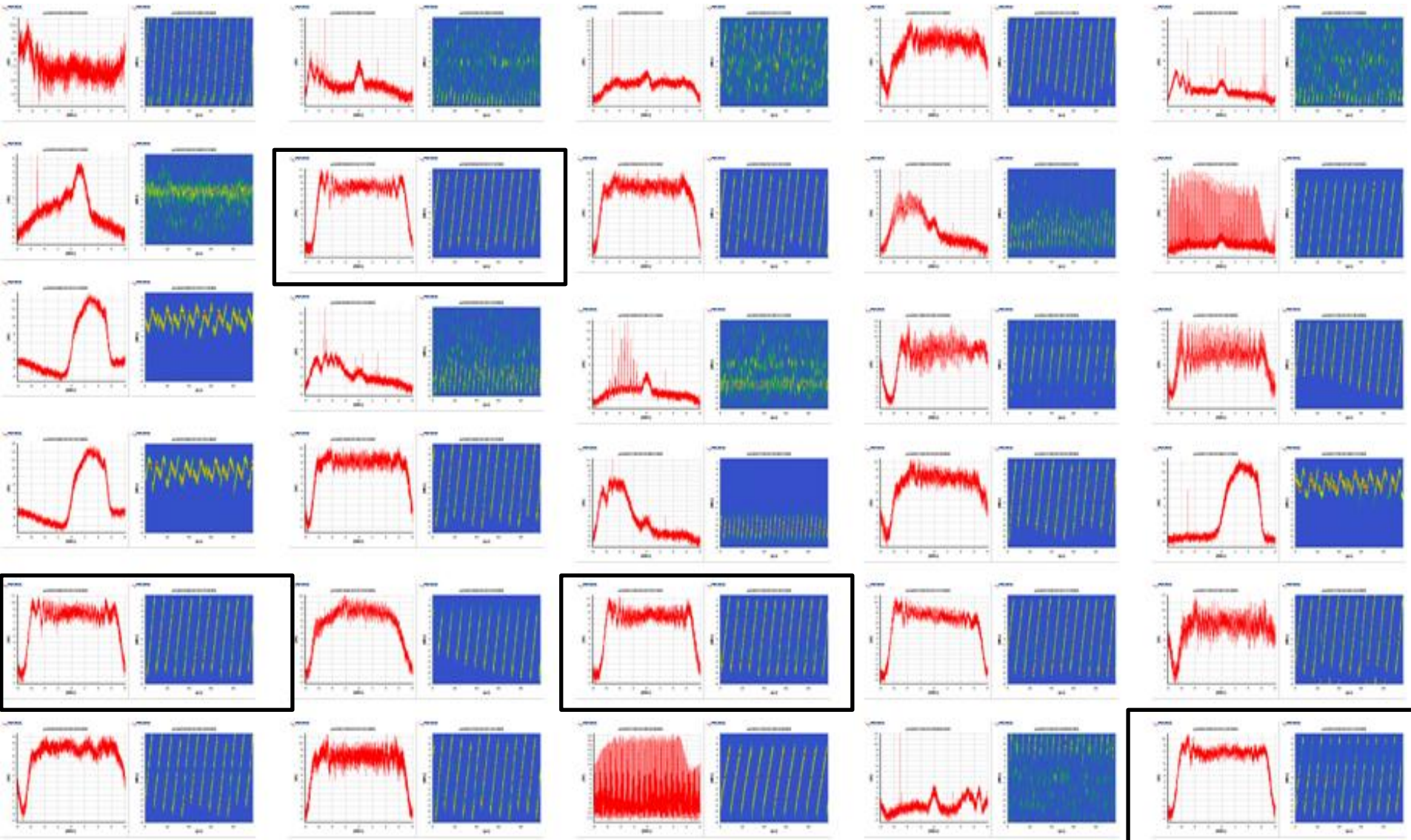
A wide range of interferences covering entire L1 band





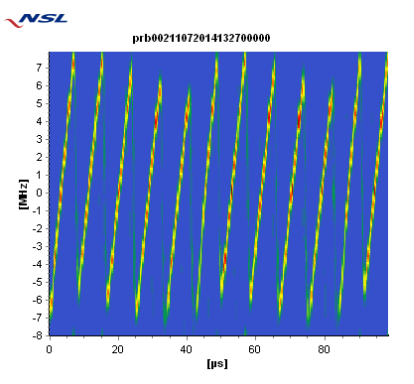
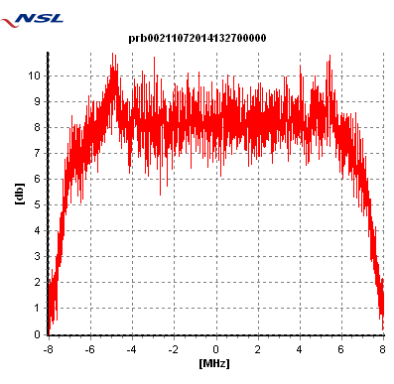
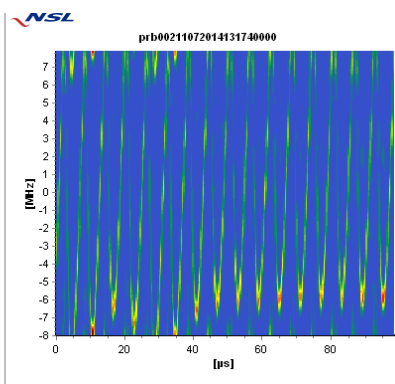
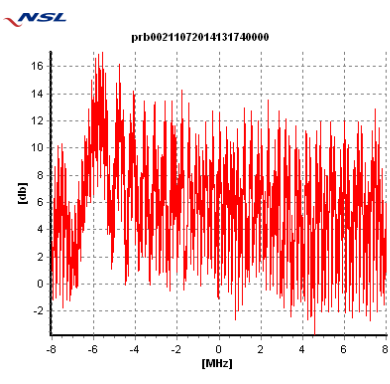
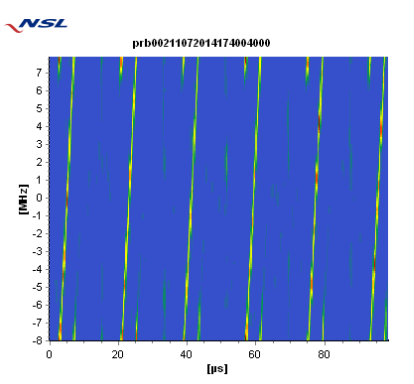
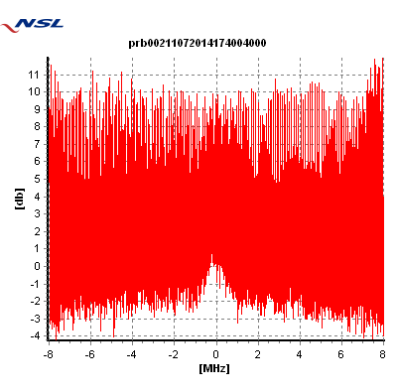
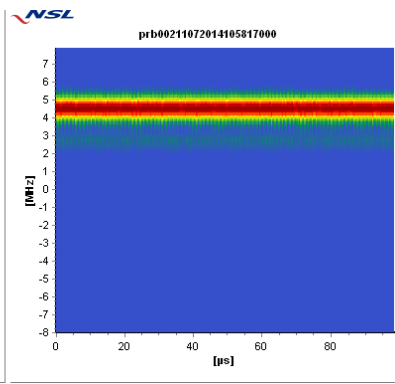
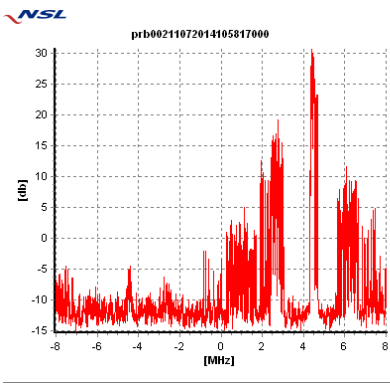
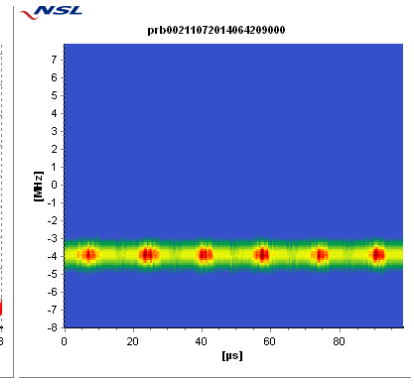
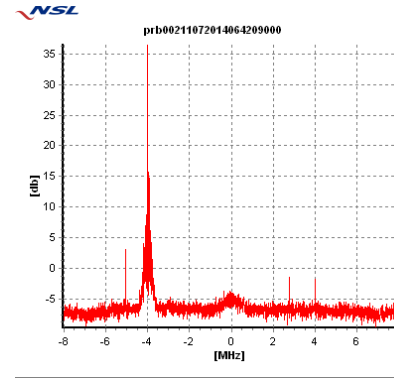
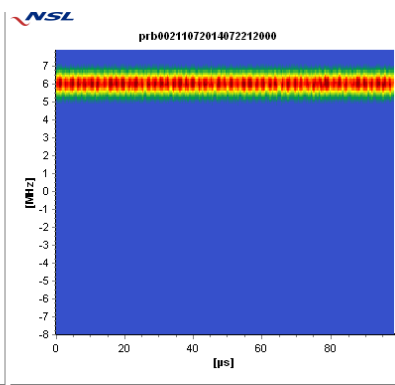
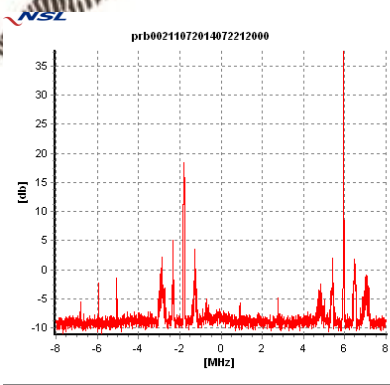
# Extract of “June 2014” Jammers

Multiple jammers of same type OR the same jammer?





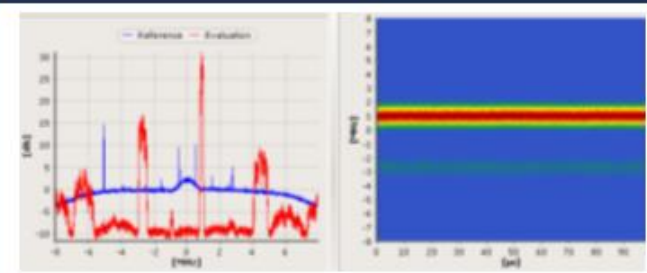
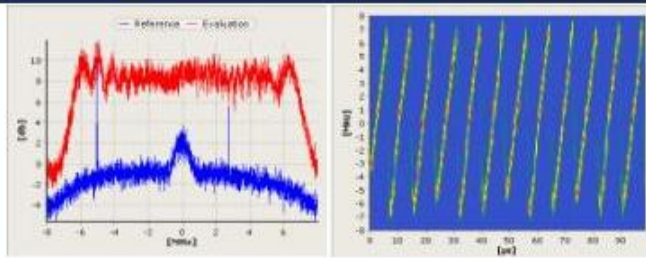
# Examples: Friday, 11<sup>th</sup> July 2014



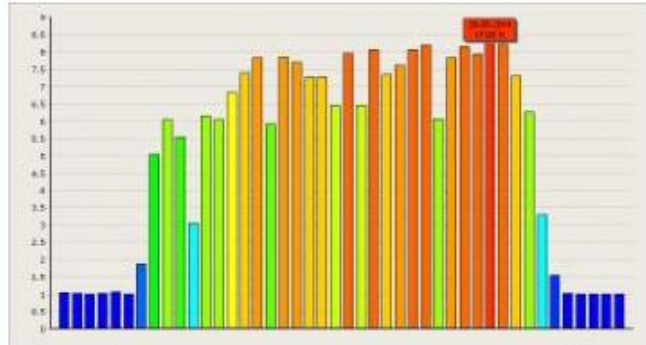


# DETECTOR Impact Assessment #1

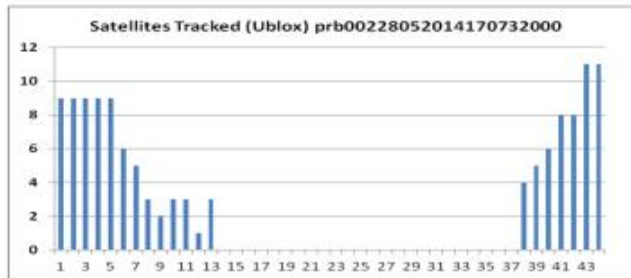
Spectrum/  
Spectrogram



Power



Number of  
Satellites tracked

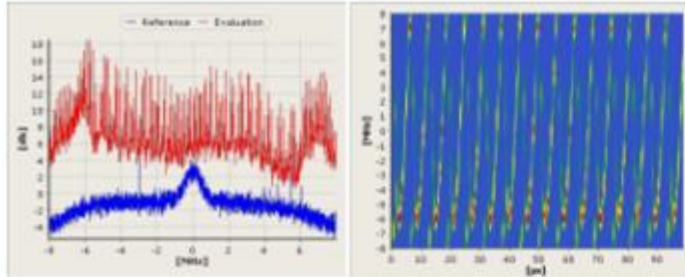


**DETECTOR** includes a commercial GNSS receiver within the probe which enables DETECTOR To be used to assess the impact of the threat on the receiver.

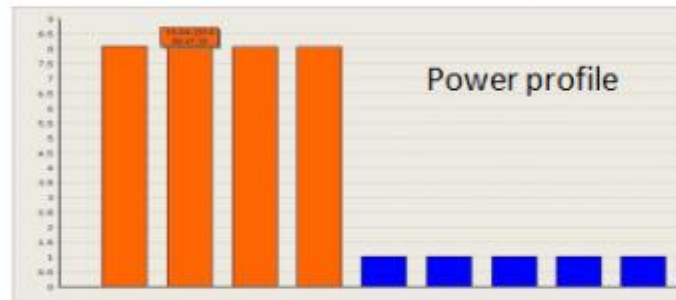


# DETECTOR Impact Assessment #2

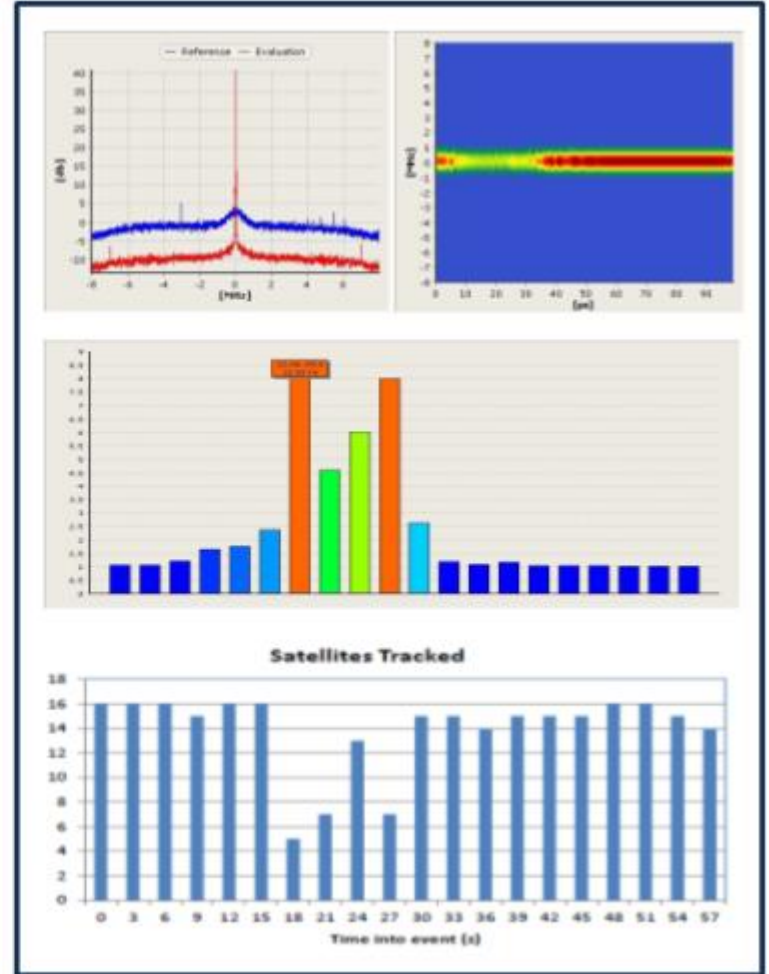
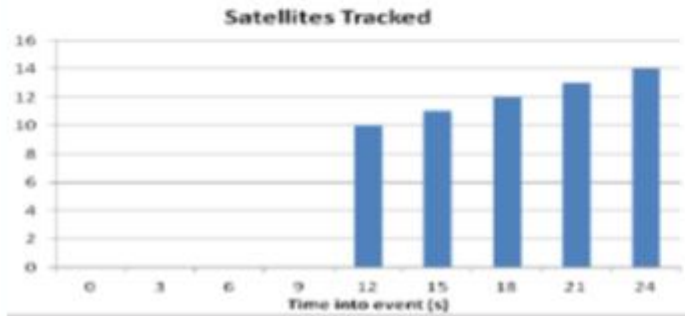
Spectrum/  
Spectrogram



Power



Number of  
Satellites tracked

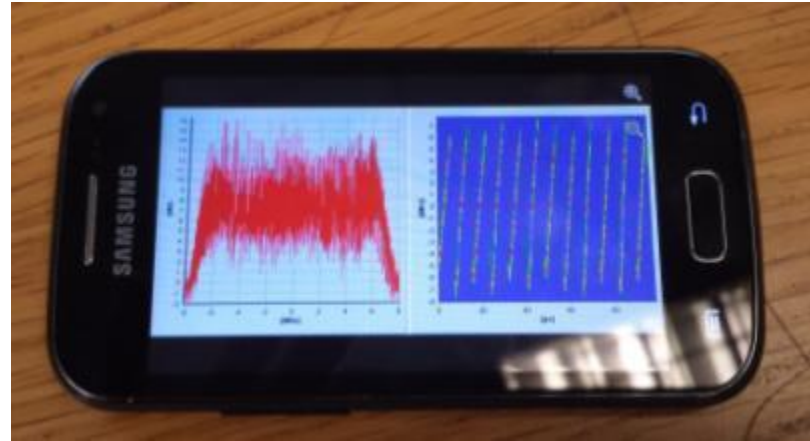
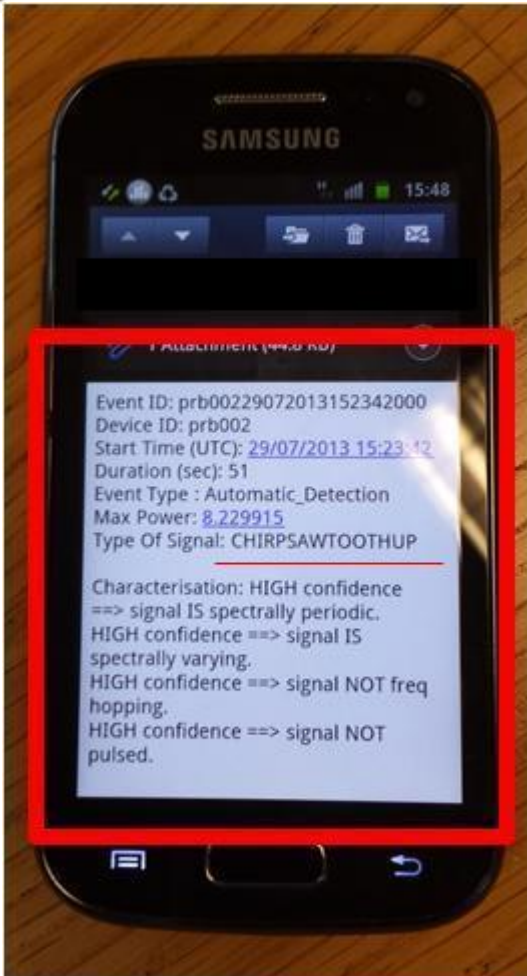


**DETECTOR** includes a commercial GNSS receiver within the probe which enables DETECTOR To be used to assess the impact of the threat on the receiver.





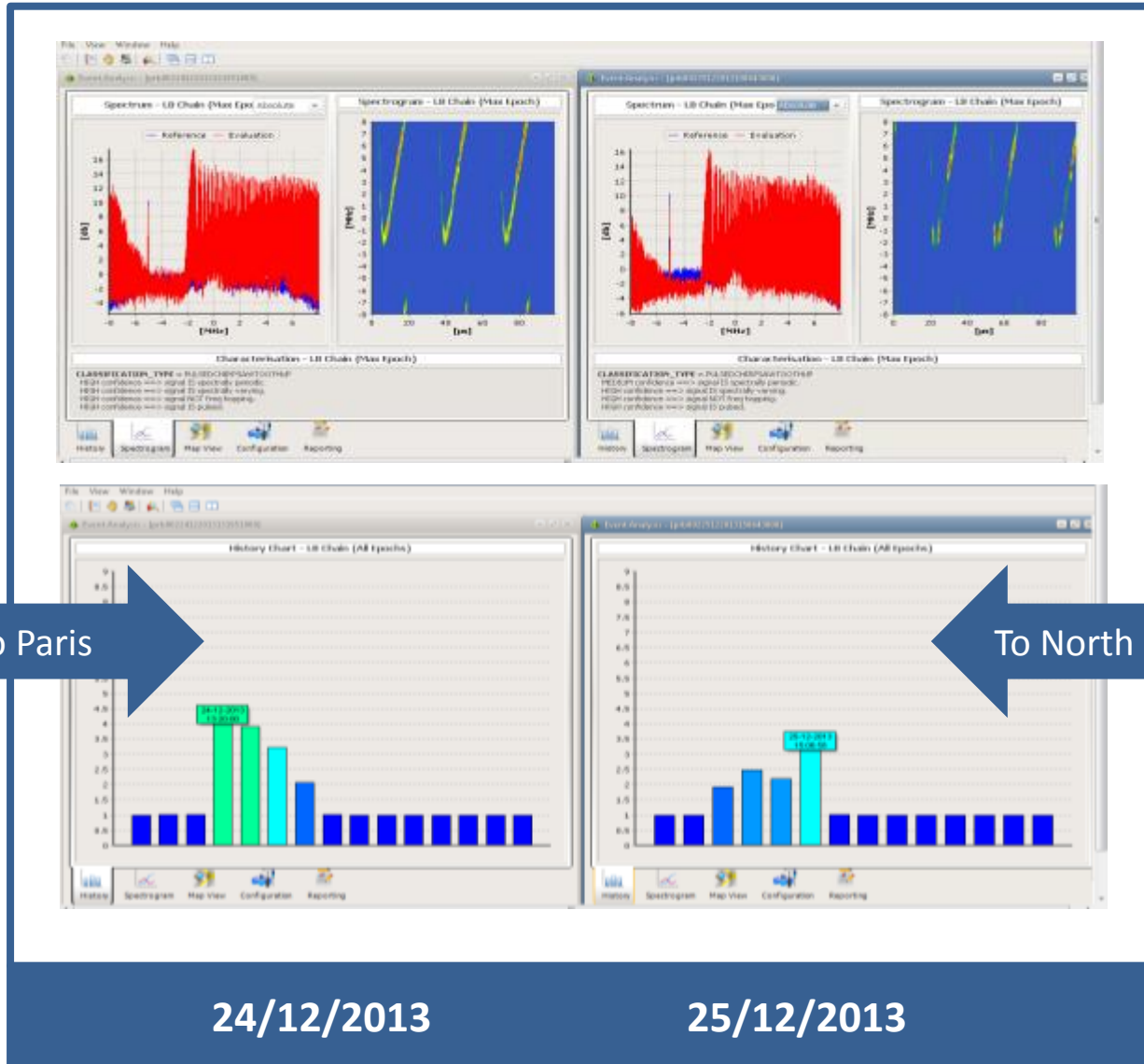
# DETECTOR Alerting services



- A demonstrator situational awareness tool has been developed based on the DETECTOR back-office
- Alert messages are automatically generated based on “**DETECTION**” events
- Messages can be dispatched via SMS or EMAIL to pre-defined user group recipients
- Messages contain essential “**DETECTION**” and “**CHARACTERISATION**” information as well as the interference signature



# Direction of “Jammer” Travel



To Paris

To North Pole

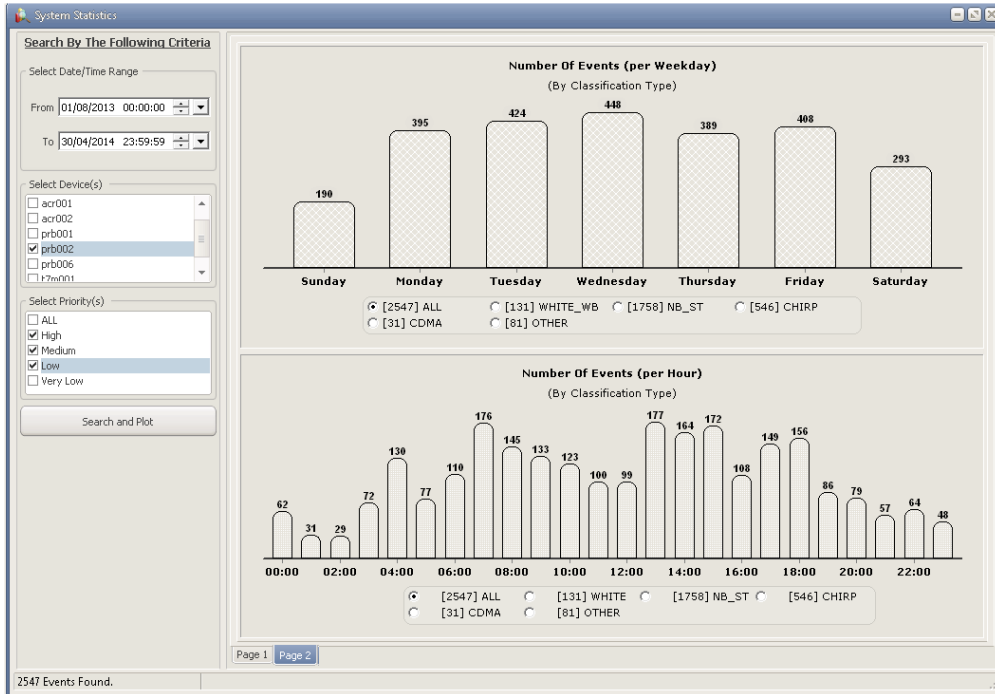
24/12/2013

25/12/2013

DETECTOR can determine direction of travel of the vehicle through monitoring power profile within the frequency band.



# DETECTOR Statistics #1



## 9-months statistics [2547]

- Day of week
- Time of day



## 9-months statistics [2547]

- Duration
- Power
- Type of interference
- Priority level

“Day of week” and “time of day” analysis produces a correlation with days/hours of human activity.

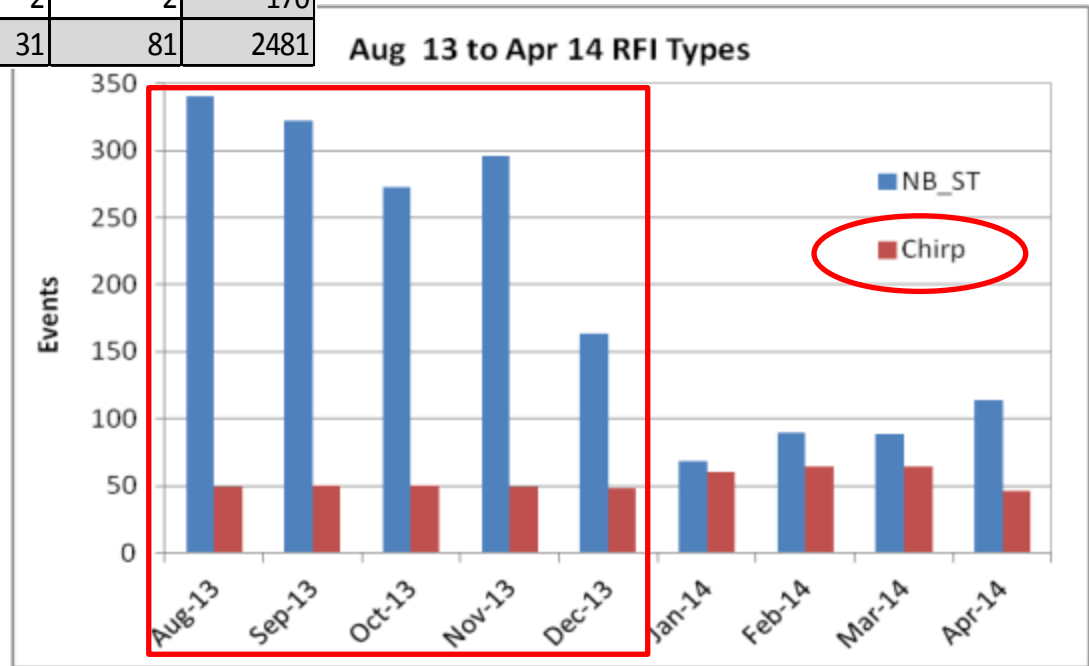


# DETECTOR Statistics #2

	White WB	NB_ST	Chirp	CDMA	Other	Total
Aug-13	31	341	49	13	13	447
Sep-13	19	323	50	4	16	412
Oct-13	28	273	50	1	7	359
Nov-13	27	296	49	4	17	393
Dec-13	14	164	48	4	12	242
Jan-14	2	68	60	1	10	141
Feb-14	1	90	64	1	1	157
Mar-14	3	89	64	1	3	160
Apr-14	6	114	46	2	2	170
9 Months	131	1758	480	31	81	2481

9-months statistics  
•Event types per month

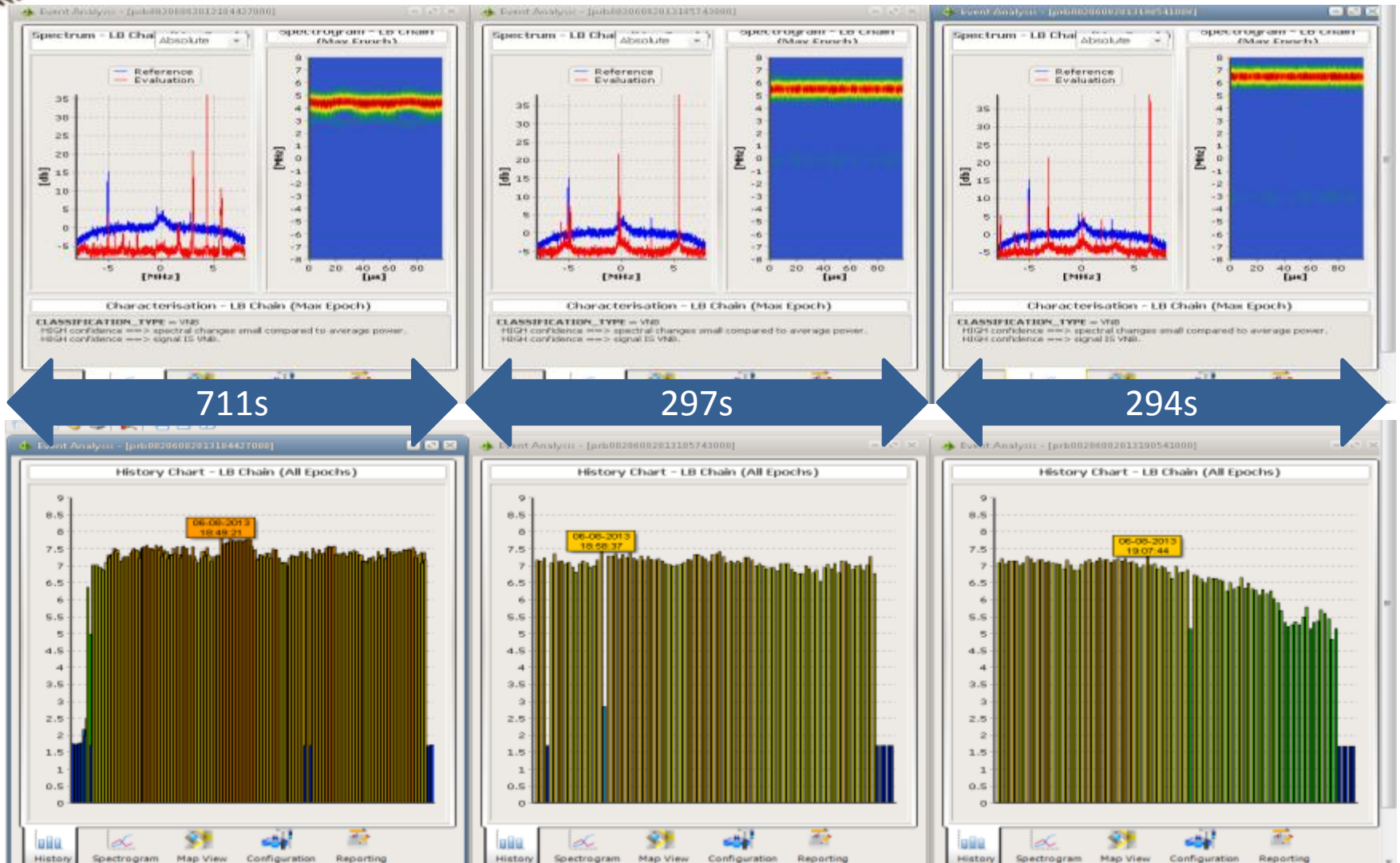
9-months statistics  
•Narrow band ST drop  
•Chirp stays constant





# DETECTOR Discoveries #1

This event resulted in loss of satellites and loss of lock of the COTS GNSS receiver

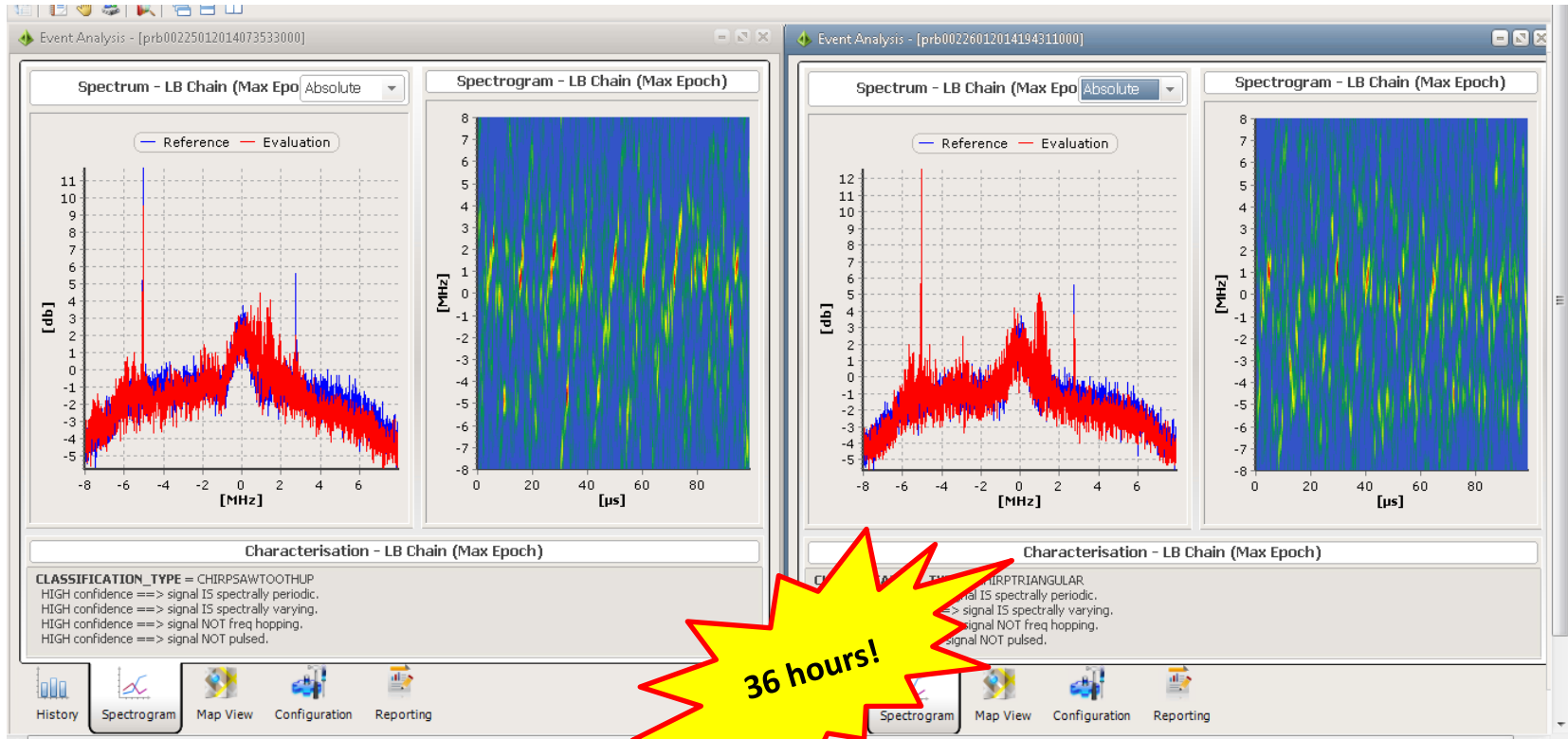


**22 minute event!** Unintentional interference that sweeps across L1 frequency.



# DETECTOR Discoveries #2

DETECTOR has experienced a long duration jamming event



START=25/01/2014, 07:35:33

FINISH= 26/01/2014, 19:43:11

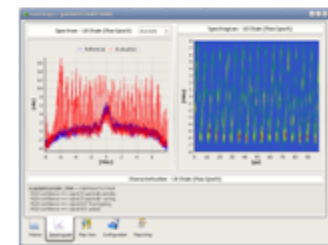
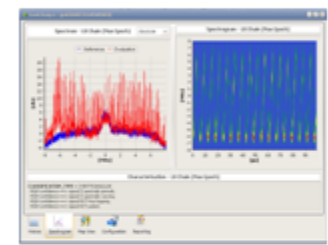
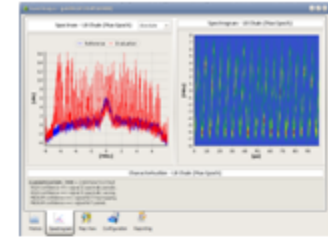
A persistent “stationary” low power jammer. Located in the vicinity of the **DETECTOR** probe.



# DETECTOR Discoveries #3

Pattern recognition and trending identifies persistent jammers

Priority	Duration (sec)	Event Type	Class Type	Max Power
High	19953	Automatic_Detection	CHIRPSAWTOOTHUP	4.3027
High	20793	Automatic_Detection	CHIRPTRIANGULAR	4.8393
High	20751	Automatic_Detection	CHIRPSAWTOOTHUP	4.1393
High	20349	Automatic_Detection	LSSEDCHIRPSAWTOOTH	4.6952
High	21741	Automatic_Detection	CHIRPSAWTOOTHUP	4.2070
High	20385	Automatic_Detection	CHIRPSAWTOOTHUP	3.9897
High	20247	Automatic_Detection	CHIRPTRIANGULAR	4.2926
High	19809	Automatic_Detection	ULSEDCHIRPTRIANGULAR	3.8852
High	20868	Automatic_Detection	CHIRPSAWTOOTHUP	3.7906
High	21390	Automatic_Detection	CHIRPSAWTOOTHUP	4.7529
High	21696	Automatic_Detection	LSSEDCHIRPSAWTOOTH	3.4368
High	20980	Automatic_Detection	LSSEDCHIRPSAWTOOTH	3.1295
High	21246	Automatic_Detection	CHIRPSAWTOOTHUP	4.4012
High	21396	Automatic_Detection	LSSEDCHIRPSAWTOOTH	3.8307
High	20949	Automatic_Detection	CHIRPTRIANGULAR	2.6683
High	20895	Automatic_Detection	CHIRPSAWTOOTHUP	2.6915
High	21444	Automatic_Detection	CHIRPSAWTOOTHUP	3.9889
High	21582	Automatic_Detection	CHIRPSAWTOOTHUP	3.4402
High	21711	Automatic_Detection	CHIRPSAWTOOTHUP	2.9138
High	21459	Automatic_Detection	LSSEDCHIRPSAWTOOTH	4.6854
High	21993	Automatic_Detection	ULSEDCHIRPTRIANGULAR	3.8837
High	47395	Automatic_Detection	CHIRPSAWTOOTHUP	2.3868
High	18802	Automatic_Detection	CHIRPSAWTOOTHUP	2.5626



Same jammer, 23 events (7 May – 11 July)  
Each event, 20000 seconds duration!!

Is the driver aware it is a jammer?

6 hours!



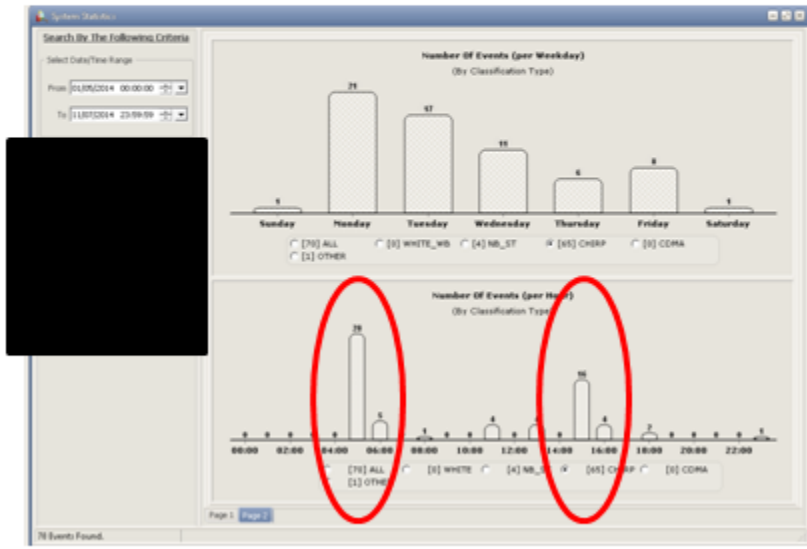
# DETECTOR Discoveries #4

Characterisation PLUS Time/day analysis as a diagnostics tool



Events dominated by Jammers

Highly predictable behaviour



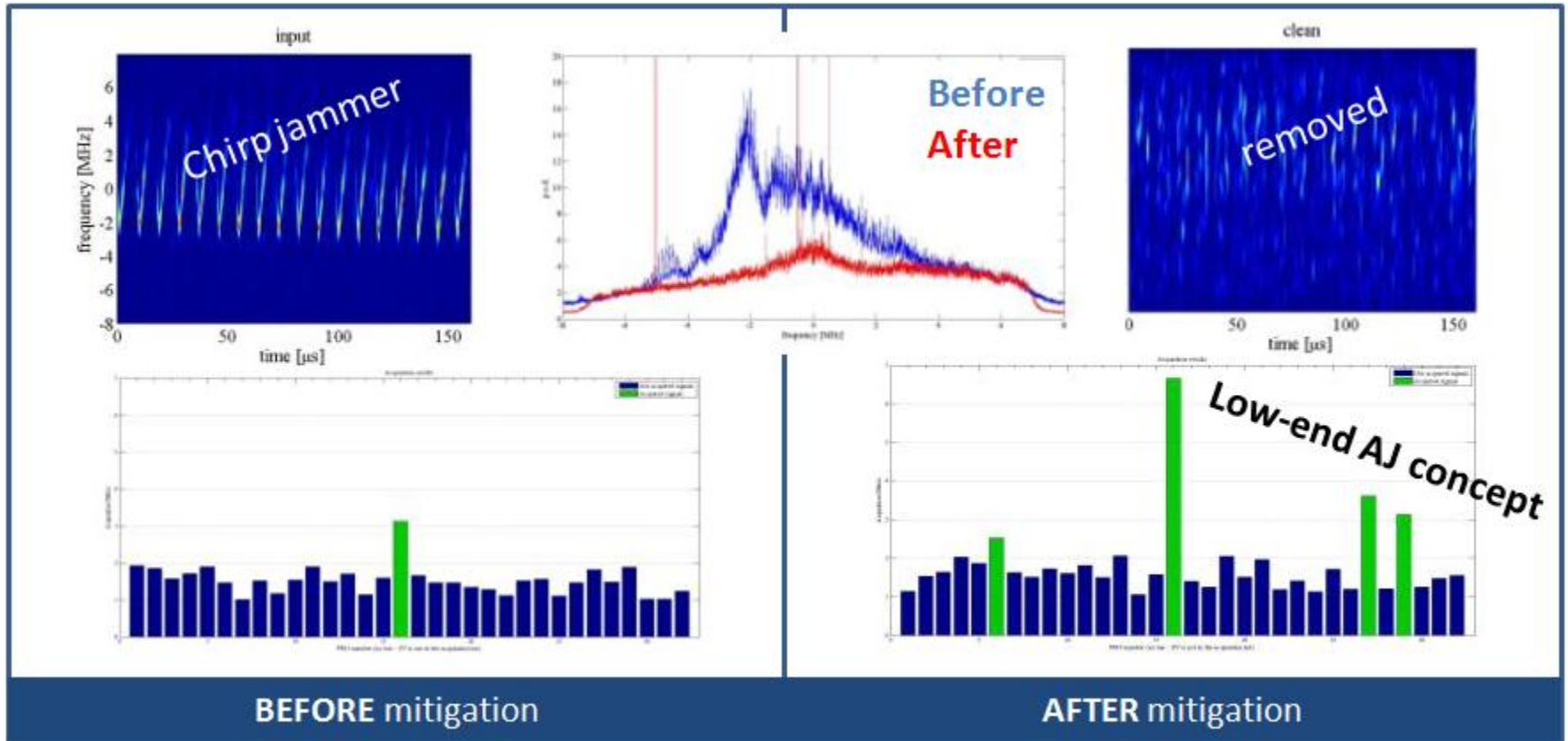
Optimise deployment of "enforcement resources"





# DETECTOR Mitigation

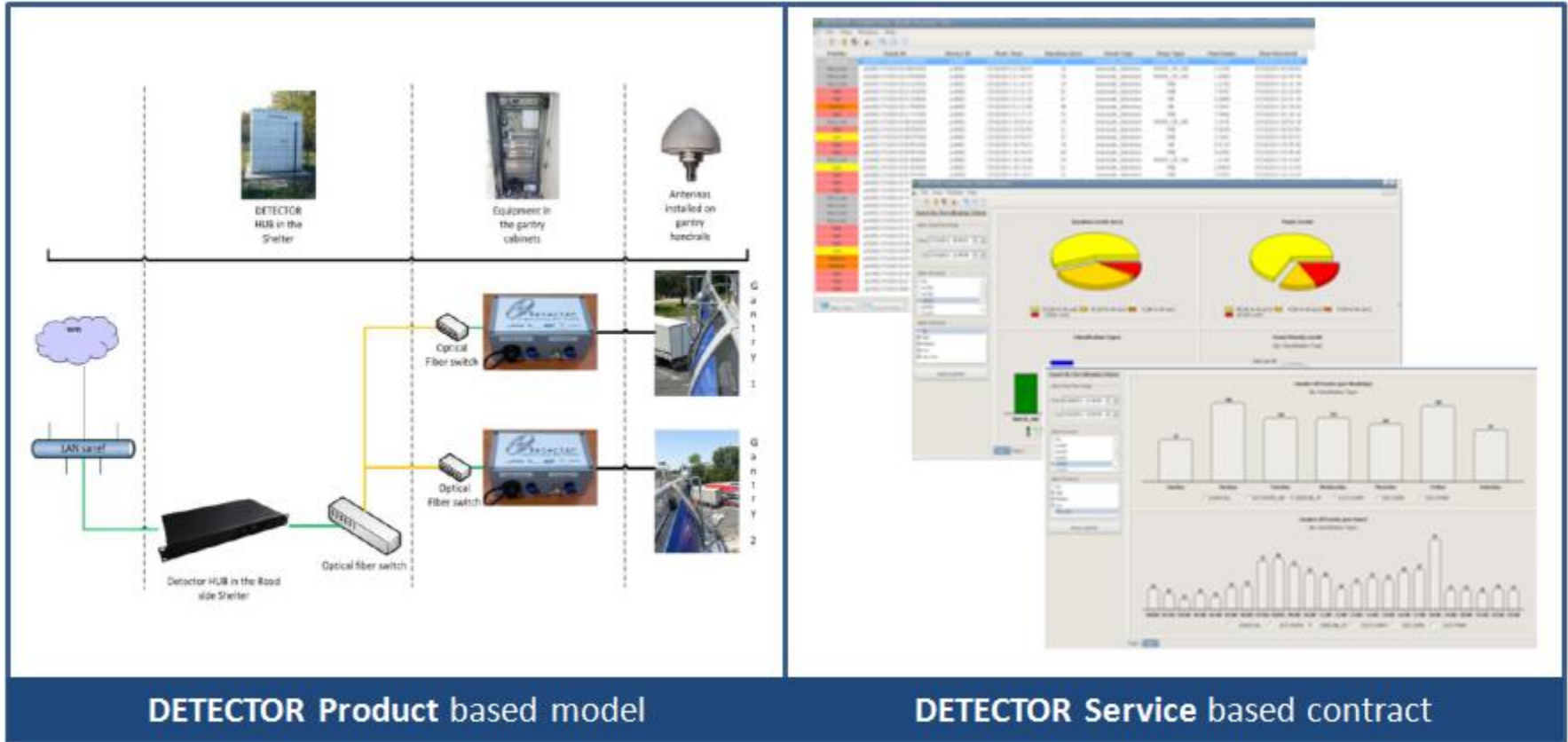
RF event database provides test samples for developing mitigation



**DETECTOR** is enabling the development of countermeasures to GNSS interferences and jamming. New techniques are being developed to **cancel the presence of the interference within received signals.**



# DETECTOR Business model



**DETECTOR** has two principal routes to business: Product and Service.  
**Product provides autonomy and security.**  
**Service offers access to the wider “ecosystem”.**



# Portable DETECTOR

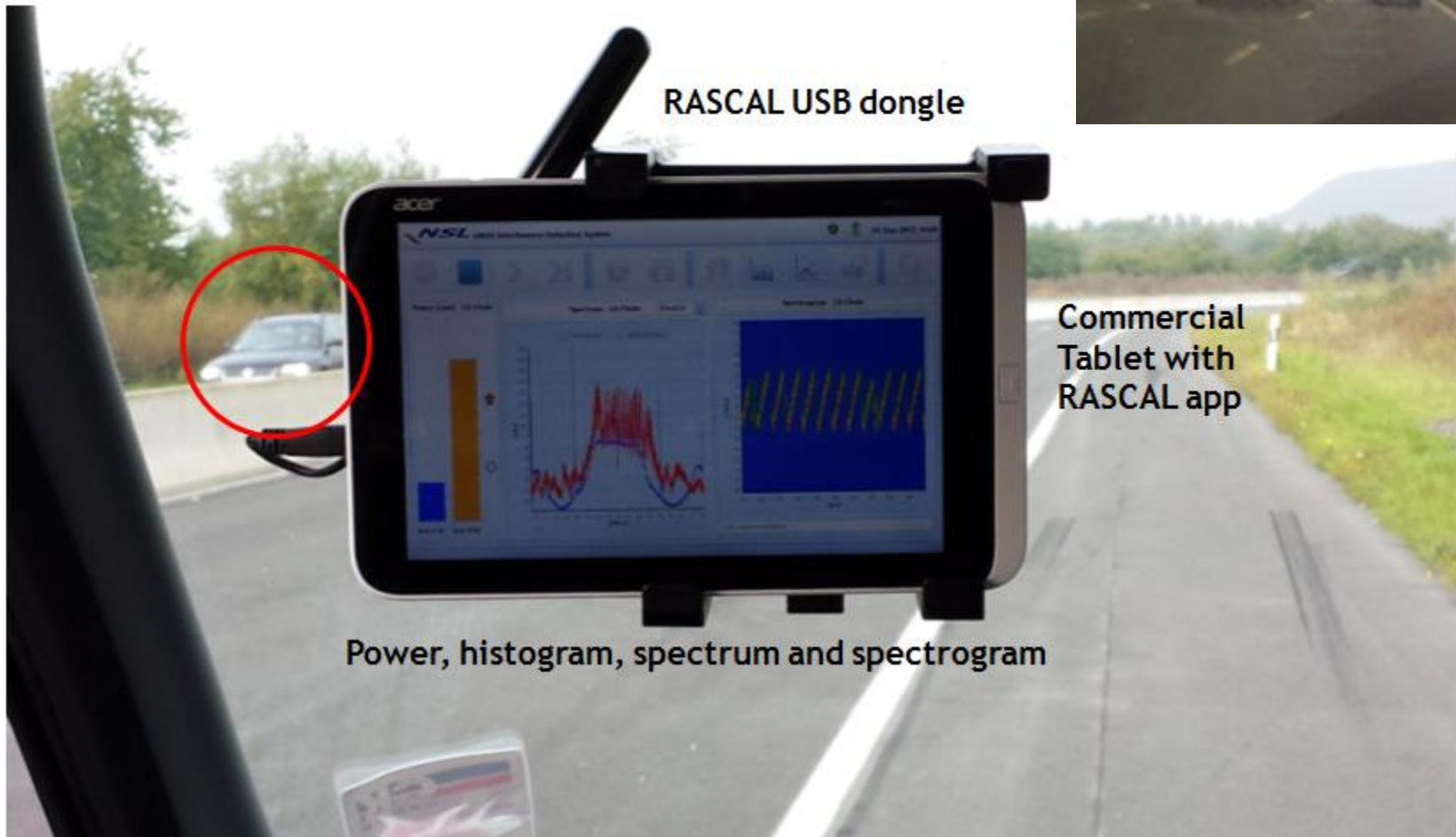
Records video  
of event



RASCAL USB dongle

Commercial  
Tablet with  
RASCAL app

Power, histogram, spectrum and spectrogram





# DETECTOR Message format

DETECTOR - Control Centre - [Events Received - 103]

File View Window Help

Priority	Event ID	Device ID	Start Time	Duration (sec)	Event Type	Class Type	Max Power	Time Received
Very Low	prb00217102013215190000	prb002	17/10/2013 21:51:50	15	Automatic_Detection	WHITE_OR_WB	1.5704	17/10/2013 22:51:50
Very Low	prb00117102013215001000	prb001	17/10/2013 21:50:01	15	Automatic_Detection	WHITE_OR_WB	1.2184	17/10/2013 22:50:03
Very Low	prb00217102013214449000	prb002	17/10/2013 21:44:49	15	Automatic_Detection	WHITE_OR_WB	1.6905	17/10/2013 22:44:49
Very Low	prb00117102013213137000	prb001	17/10/2013 21:31:37	15	Automatic_Detection	VNB	1.2318	17/10/2013 22:31:39
High	prb00217102013212133000	prb002	17/10/2013 21:21:33	51	Automatic_Detection	VNB	7.5397	17/10/2013 22:22:09
High	prb00117102013212130000	prb001	17/10/2013 21:21:30	27	Automatic_Detection	NB	6.0888	17/10/2013 22:21:44
Medium	prb00217102013211750000	prb002	17/10/2013 21:17:50	45	Automatic_Detection	NB	4.2847	17/10/2013 22:18:20
High	prb00117102013211717000	prb001	17/10/2013 21:17:17	72	Automatic_Detection	VNB	7.9966	17/10/2013 22:18:16
Very Low	prb00117102013195316000	prb001	17/10/2013 19:53:16	15	Automatic_Detection	WHITE_OR_WB	1.2476	17/10/2013 20:53:18
High	prb00217102013195250000	prb002	17/10/2013 19:52:50	21	Automatic_Detection	VNB	5.0830	17/10/2013 20:52:56
Low	prb00117102013195237000	prb001	17/10/2013 19:52:37	27	Automatic_Detection	VNB	2.2261	17/10/2013 20:52:51
High	prb00117102013184441000	prb001	17/10/2013 18:44:41	78	Automatic_Detection	NB	8.5119	17/10/2013 19:45:46
High	prb00217102013184447000	prb002	17/10/2013 18:44:47	69	Automatic_Detection	VNB	8.6992	17/10/2013 19:45:40
Very Low	prb00217102013181358000	prb002	17/10/2013 18:13:58	15	Automatic_Detection	WHITE_OR_WB	1.4194	17/10/2013 19:13:57
Low	prb00117102013181322000	prb001	17/10/2013 18:13:22	21	Automatic_Detection	VNB	2.8909	17/10/2013 19:13:29
High	prb00217102013181321000	prb002	17/10/2013 18:13:21	21	Automatic_Detection	VNB	7.6701	17/10/2013 19:13:26
High	prb00217102013174333000	prb002	17/10/2013 17:43:33	78	Automatic_Detection	CHRPTRIANGULAR	8.6420	17/10/2013 18:44:35
High	prb00117102013174325000	prb001	17/10/2013 17:43:25	63	Automatic_Detection	CHIRPSAWTOOTHUP	8.5583	17/10/2013 18:44:14
Very Low	prb00117102013174301000	prb001	17/10/2013 17:43:01	15	Automatic_Detection	WHITE_OR_WB	1.2801	17/10/2013 18:43:03
Very Low	prb00217102013173311000	prb002	17/10/2013 17:33:11	15	Automatic_Detection	WHITE_OR_WB	1.5581	17/10/2013 18:33:10
Very Low	prb00117102013172453000	prb001	17/10/2013 17:24:53	18	Automatic_Detection	NB	1.5913	17/10/2013 18:24:56
Very Low	prb00217102013172452000	prb002	17/10/2013 17:24:52	18	Automatic_Detection	NB	1.5052	17/10/2013 18:24:54
High	prb00217102013172151000	prb002	17/10/2013 17:21:51	63	Automatic_Detection	VNB	8.1388	17/10/2013 18:22:38
High	prb00117102013172138000	prb001	17/10/2013 17:21:38	60	Automatic_Detection	NB	8.7145	17/10/2013 18:22:24
High	prb00117102013165829000	prb001	17/10/2013 16:58:29	21	Automatic_Detection	NB	7.1847	17/10/2013 17:58:39
Low	prb00217102013165838000	prb002	17/10/2013 16:58:38	15	Automatic_Detection	VNB	2.9983	17/10/2013 17:58:37
Medium	prb00117102013164944000	prb001	17/10/2013 16:49:44	33	Automatic_Detection	ST	3.1782	17/10/2013 17:50:04
Medium	prb00217102013164949000	prb002	17/10/2013 16:49:49	24	Automatic_Detection	VNB	4.8734	17/10/2013 17:49:57
High	acr00217102013135022694	acr002	17/10/2013 13:50:22	9886	User_Initiated	WHITE_OR_WB	8.3652	17/10/2013 17:40:10
High	acr00217102013121153892	acr002	17/10/2013 12:11:53	6169	User_Initiated	CHIRPSAWTOOTHUP	7.3210	17/10/2013 17:28:21
High	acr00217102013091652574	acr002	17/10/2013 09:16:52	12054	User_Initiated	CHRPTRIANGULAR	7.5856	17/10/2013 17:18:34

Filter Data Export Data

## DETECTOR event message content

- Priority
- ID
- Device
- System
- Frequency
- Bandwidth
- Location
- Time
- Duration
- Type
- Classification
- Power levels
- Time received
- Confidence

DETECTOR promotes standardisation of RFI reporting so that events can be exchanged between Governments and key stakeholders.



# Detector

Fingerprinting GNSS Threats

**ICG Workshop on GNSS Spectrum Protection and Interference Detection and Mitigation**  
**ITU, Geneva, Switzerland**  
**14-15 July 2014**

**thank you**

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Deploy systems

Detect Interference

Characterise the threat



# Tracking the “Fingerprints”

DETECTOR can identify the same jammer as it appears on multiple passes

