

# Crowd-sourced platform for GNSS anomaly identification, isolation and attribution analysis (COLOSSUS)

COLOSSUS



- Michael Pattinson  
NSL



# Overview

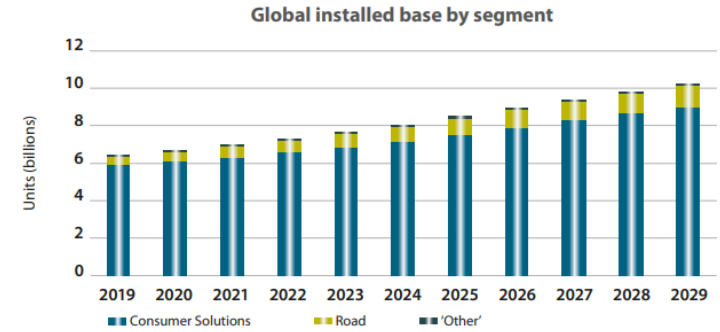
- NAVISP Element 2 project
- Motivation
- Main Objectives
- NSL Description
- Description of the market
- System Overview
- Results
- Future plans



# GNSS and Resilience

- Billions of GNSS devices used around the World
  - Vast majority are consumer devices
  - Performance of GNSS ok, occasional faults tolerated
- Much smaller number of devices used for other critical applications
  - Safety (Aviation, Maritime, Train Control, RPAS)
  - Governmental (Road pricing, offender monitoring)
  - Critical Infrastructure (Telecoms, power grids)
  - However, GNSS performance and faults critical for these applications

£5B in 5 days



Source: GNSS Market Report, Issue 6, copyright © European GNSS Agency, 2019



# Motivation for COLOSSUS

- GNSS performance monitoring is an established activity
  - With safety related applications
  - Analysing compliance against internationally agreed requirements
  - Performance reports are currently used to:
    1. Demonstrate system performance within system specification
    2. Demonstrate system performance meets user need
    3. Demonstrate service provider meets service level agreement
  
- New applications are emerging that will require not only performance monitoring BUT also diagnostics when performance is out of tolerance
  - Evidence of failure to comply
  - Incident investigation
  
- There is currently no product/service/infrastructure that provides fault and failure reporting and analysis for user applications.



# COLOSSUS Main Objectives

- Utilise multi-GNSS, multi-frequency RINEX data from existing commercial and scientific continuously operating reference station (CORS) networks, as well as from dedicated COLOSSUS receivers.
- Continuously process GNSS data to persistently monitor performance across all GNSS constellations and all GNSS frequencies in order to identify, isolate and attribute GNSS faults and failures.
- Provide near real-time detection, warning and alerting of faults that impact user performance.
- Build up a database of probabilities of occurrences of anomalies and the associated consequential impact of faults, failures and events in order to understand what “trust” to place in GNSS and in doing so support the development of next generation GNSS applications.



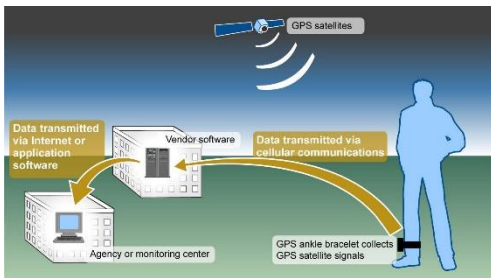
# COLOSSUS Consortium

- NSL is sole company in COLOSSUS
- NSL is a UK based high-tech small-to-medium sized enterprise.
- NSL specialize in the use of satellite navigation through shaping the use of Global Navigation Satellite Systems (GNSS) within **critical applications** such as those that:
  - directly affect the **safety** of citizens
  - are key in terms of national **security**
  - affect the way **business** is conducted.
- NSL develop and deliver GNSS-based services, systems, solutions, and intellectual property ensuring positioning and navigation is accurate and reliable, safe and secure, resilient and robust.

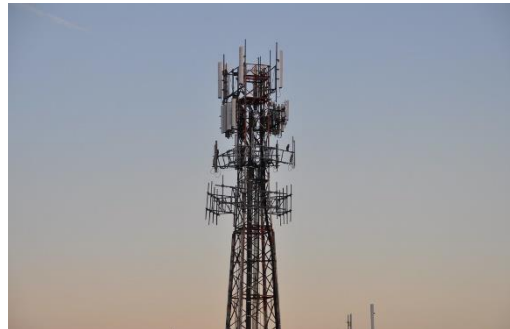


# Description of the Market

- Regulated markets require GNSS assurance



Source: GAO analysis of National Institute of Justice and Center for Criminal Justice Technology information; An Explosion (clip art) | GAO-18-10



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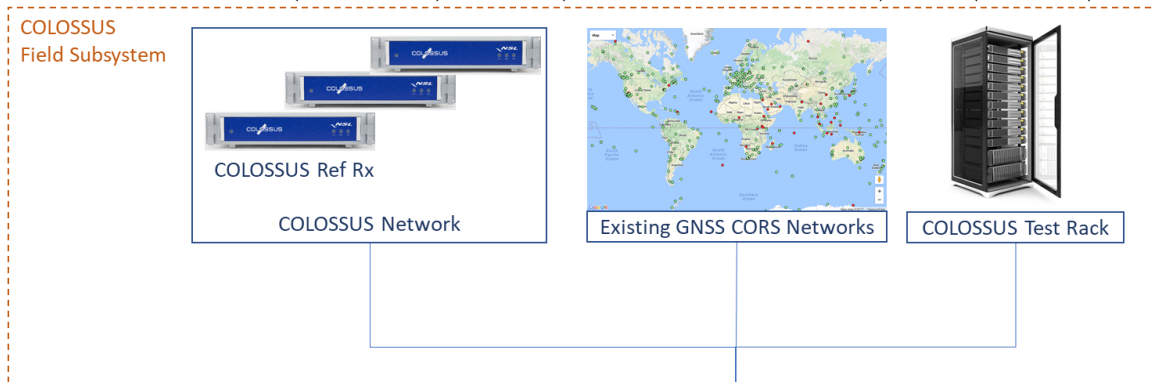
# Overview of COLOSSUS

Provision of data for processing and analysis

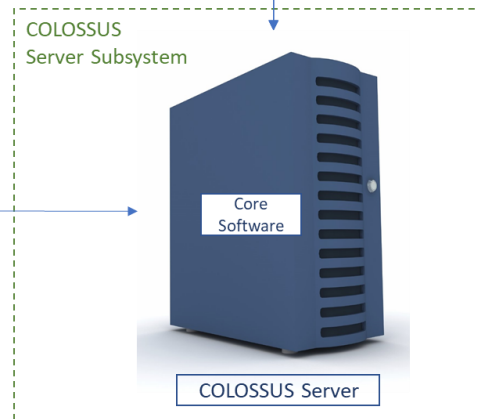
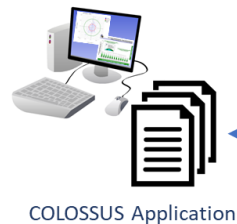
GNSS obs and nav  
(real-time)

GNSS obs and nav  
(real-time and off-line)

GNSS obs and nav  
(off-line)



Viewing results, generating reports



Other external data

Reference information

- Data processing and analysis
- Real-time and post-processing



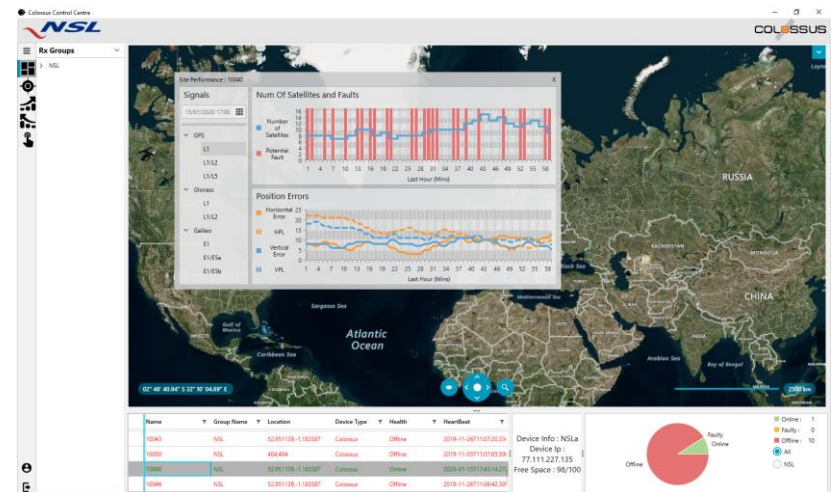
# Expected Results

- Two main areas of results
  - Near real-time performance monitoring
    - Monitoring and reporting constellation status
    - Detection and alerting of potential faults
  - Off-line performance assessment
    - Validation of system performance
    - Validation of user / application performance
    - Fault / anomaly investigation



# Near Real-Time Site Monitoring

- Purpose is to continuously monitor in near real-time the performance as measured at the monitoring sites
  - Position errors
  - Satellites in view
  - DOP
  - Interference
  - Potential faults / breaches
- Near real-time data processing from sites
- Alert sites of identified faults



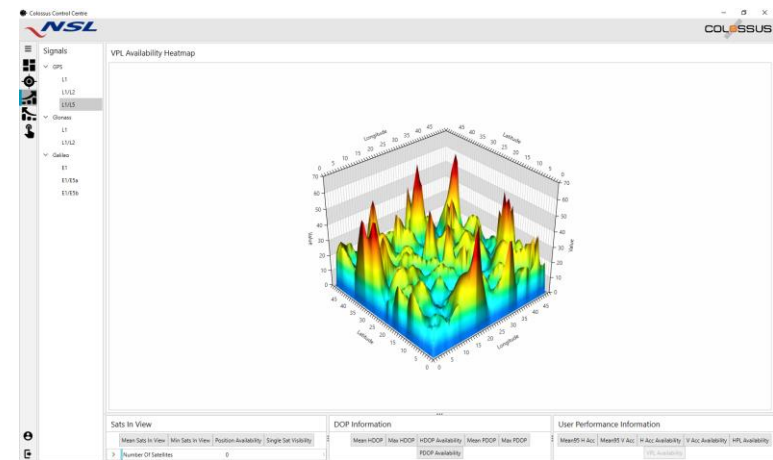
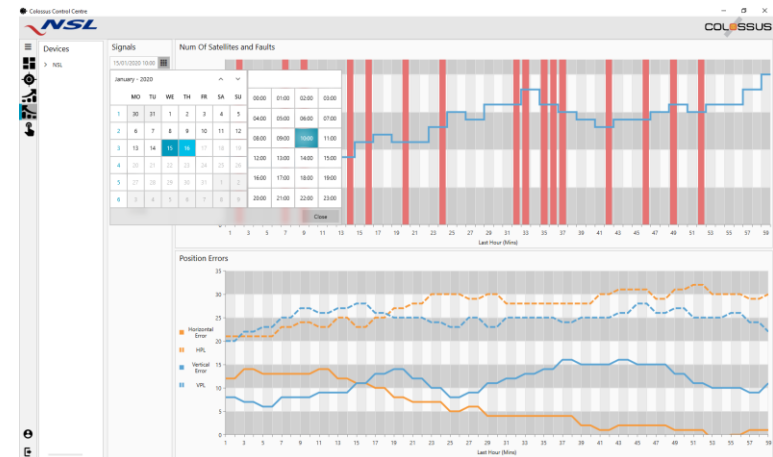
# Near Real-Time Constellation Monitoring

- Purpose is to continuously monitor in near real-time the status of the GNSS constellations and signals
  - Constellation status (operational satellites)
  - Current health status
  - NANUs, NAGUs
  - Latest navigation message data
  - Signal availability
  - Fault status
- Information from broadcast navigation messages, almanacs and system data, and near real-time data processing
- Alert users of identified faults

PRN	SV ID	Slot	Block	Epoch	Fault	Valid Status	Almanac Health	NANO Date	U1 Sig	U2 Sig	U3 Sig	Body Health	IODEC	SV Accuracy	Validity	New Week	Non-See
1	83	02	IF			✓	Healthy	N/A	✓	✓	✓	Healthy	56	2	4	2008	23400
2	61	01	IR			✓	Healthy	N/A	✓	✓	✓	Healthy	55	2	4	2008	23400
3	89	01	IF			✓	Healthy	N/A	✓	✓	✓	Healthy	62	2	4	2008	23400
4	74	A6	IR			✓	Healthy	N/A	✓	✓	✓	Healthy	167	2	4	2008	341072
5	30	03	IR-M			✓	Healthy	N/A	✓	✓	✓	Healthy	66	2	4	2008	23400
6	67	04	IF			✓	Healthy	N/A	✓	✓	✓	Healthy	7	2	4	2008	341004
7	48	A4	IR-M			✓	Healthy	N/A	✓	✓	✓	Healthy	5	2	4	2008	23400
8	72	C3	IF			✓	Healthy	N/A	✓	✓	✓	Healthy	138	2	4	2008	23400
9	68	F3	IF			✓	Healthy	N/A	✓	✓	✓	Healthy	11	2	4	2008	23400
10	75	02	IF			✓	Healthy	N/A	✓	✓	✓	Healthy	56	2	4	2008	23400
11	46	05	IR-M			✓	Healthy	N/A	✓	✓	✓	Healthy	75	2	4	2008	23400
12	58	B4	IR-M			✓	Healthy	N/A	✓	✓	✓	Healthy	12	2	4	2008	23400
13	42	F6	IR			✓	Healthy	N/A	✓	✓	✓	Healthy	34	2	4	2008	23400
14	41	F9	IR			✓	Healthy	N/A	✓	✓	✓	Healthy	65	2	4	2008	23400
15	70	F2	IR-M			✓	Healthy	N/A	✓	✓	✓	Healthy	60	2	4	2008	23400
16	56	B1	IR			✓	Healthy	N/A	✓	✓	✓	Healthy	51	2	4	2008	23400
17	53	C4	IR-M			✓	Healthy	N/A	✓	✓	✓	Healthy	54	2	4	2008	23400
18	0					✗	Unhealthy	N/A	✗	✗	✗	Unhealthy	42	2	4	2008	23400
19	59	C5	IR			✓	Healthy	N/A	✓	✓	✓	Healthy	34	2	4	2008	23400
20	51	B4	IR			✓	Healthy	N/A	✓	✓	✓	Healthy	25	2	4	2008	23400
21	45	03	IF			✓	Healthy	N/A	✓	✓	✓	Healthy	10	2	4	2008	341004
22	47	06	IR			✓	Healthy	N/A	✓	✓	✓	Healthy	56	2	4	2008	23400
23	65	B4	IR			✓	Healthy	N/A	✓	✓	✓	Healthy	1	2	4	2008	341004
24	63	A7	IF			✓	Healthy	N/A	✓	✓	✓	Healthy	78	2	4	2008	23400
25	62	02	IF			✓	Healthy	N/A	✓	✓	✓	Healthy	10	2	4	2008	341004

# Off-Line Performance Validation

- Measure and report on performance
  - Number of satellites, availability, continuity
  - DOP
  - SIS errors
  - User accuracy
  - Other broadcast products (TGD, iono model)
- Check compliance against system specification
- Check compliance against user specification
  - Different for different user groups, applications



# Off-Line Fault / Anomaly Investigation

- Real-time monitoring will identify and coarsely attribute potential faults
  - Coarse identification of 'system' faults
  - Affect user level performance
- Off-line / post-processing can perform additional processing and investigation to analyse potential faults in more detail
  - Use of additional data e.g. precise orbit/clock, precise iono
  - Larger monitoring network, e.g. CORS sites without real-time data
  - Additional processing and checks
  - Different thresholds

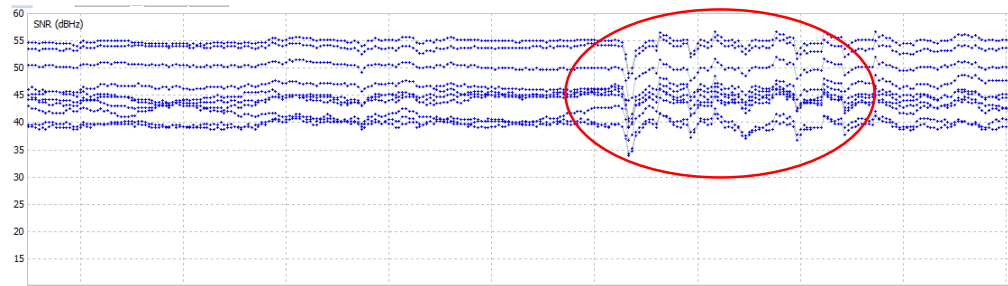


# Latest COLOSSUS Results

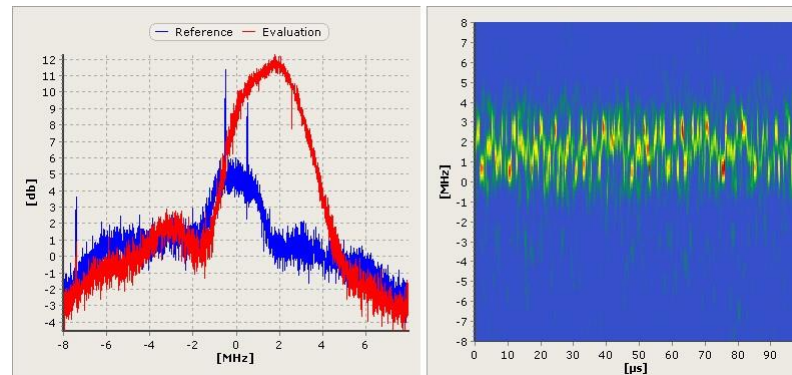
- Currently finishing development and testing
- Processing starting to be automated
  - Continuous near real-time GNSS data processing
  - Scheduled post-processing
- Faults are relatively rare so do not expect to regularly detect multiple faults
- However ...

# Example Interference Event

- At NSL detected drop in C/N0 across all GPS L1 signals on 20/10/19 at approx 13:30



- Matches with detected interference event





# Conclusions on Example Interference Event

- COLOSSUS Receiver and RINEX data processing detected possible interference event at NSL
  - Some impact on GNSS tracking
- Interference characterisation capability of COLOSSUS Rx allowed identification of other similar events
- Network of receivers (existing NSL Detector units) enabled identification of common interference across regional area
  - Seen on other days too
- Possible cause?
  - Short duration events (few seconds) but repeat every 15 minutes or so over few hour period
  - Seen over a wide area but power level not excessively high
  - Power level different at different locations and changes



# Future Plans for COLOSSUS

- Q1 2020
  - Deployment of COLOSSUS Reference Receivers
  - Development and test of server side core processing
- Q2/Q3 2020
  - Acceptance and Validation of COLOSSUS system
  - Initial operations
- Q4 2020
  - Start of services
- Future enhancements
  - Monitor additional constellations and signals
  - Monitor augmentation and commercial services



# Benefits from NAVISP activity

- NSL has gained the following benefits from NAVISP2 funding for COLOSSUS
  - Increase in man power
    - Funding allowed growth of team to deliver COLOSSUS
  - Technical input / review
    - Oversight from technical experts provides valuable feedback
  - International visibility
    - ESA website, NAVISP industry day
    - Host sites keen to collaborate on an ESA project



# Further Information on COLOSSUS

- NAVISP website: [navisp.esa.int/project/details/7/show](https://navisp.esa.int/project/details/7/show)
- GPS world article: [www.gpsworld.com/esa-to-use-cors-networks-for-global-error-mapping/](https://www.gpsworld.com/esa-to-use-cors-networks-for-global-error-mapping/)
- NSL website: [www.nsl.eu.com/](https://www.nsl.eu.com/)

Thank you!

