ESA NAVISP EL2-001 COLOSSUS

Final Presentation
MS Teams
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Context And Rationale For The Development Of The Product

Context And Rationale For The Development Of COLOSSUS

Background

GNSS performance monitoring is an established activity within safety related applications

- Analysing compliance against internationally agreed requirements
- Demonstrate system performance within system specification
- Demonstrate system performance meets user need
- Demonstrate service provider meets service level agreement

GMV had existing GNSS performance monitoring services

- GPS L1 performance
- Post-processing and reporting

Context And Rationale For The Development Of COLOSSUS

Motivation

New constellations, signals and services are becoming available and may be used for critical applications in the future

- GPS L2C / L5
- Galileo

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

COLOSSUS aims to build on existing GMV products and services to meet these new requirements

Outcome of the Project

Description of COLOSSUS

COLOSSUS Overview

COLOSSUS is a system for monitoring GNSS performance and identifying potential faults. The system provides:

- Near real-time performance and alerts
- Post-processing analysis and statistics

It enables performance monitoring at sites to verify GNSS performance against user requirements

It enables constellation performance monitoring to verify GNSS system performance against published specifications

It enables near real-time provision of GNSS status and alerts

It enables analysis and investigation of potential faults and anomalies

Description of COLOSSUS

High Level Architecture

Field Subsystem

For provision of data

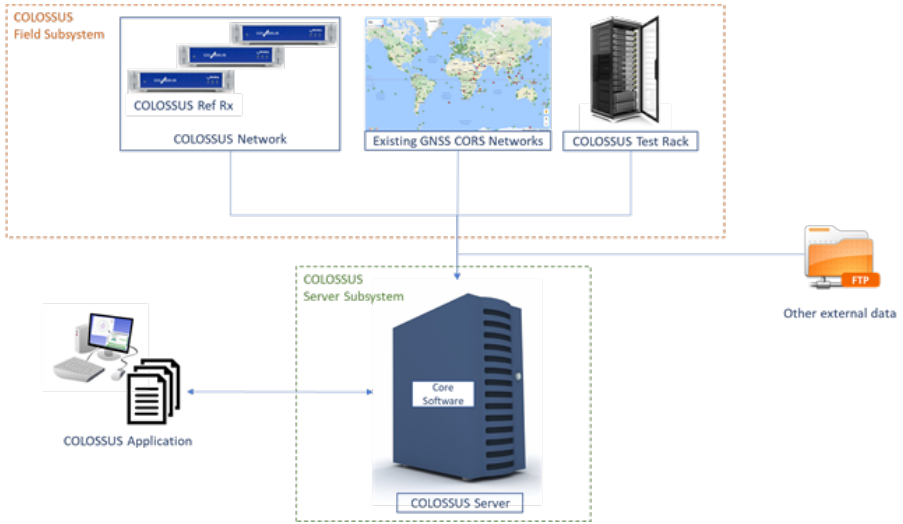
- Dedicated COLOSSUS receivers deployed
- Use of existing CORS

Server Subsystem

For data retrieval, processing , analysis

User Application

Provides interface for users to access results and generate reports

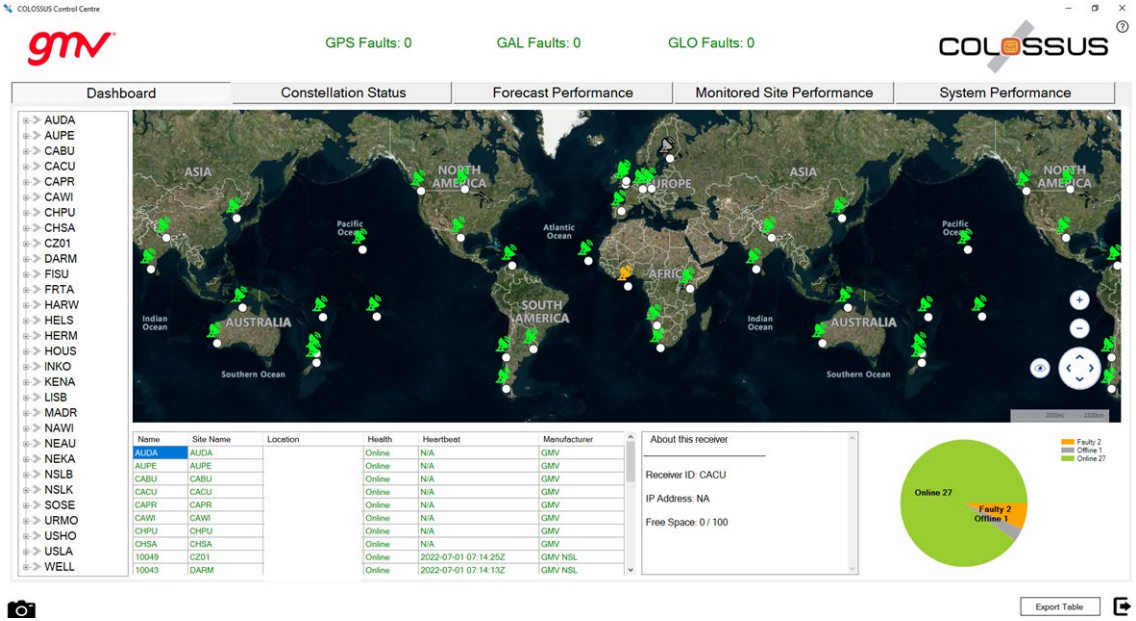


Description of COLOSSUS

Field Subsystem

Sites for Real-Time Data Provision

- Dedicated COLOSSUS Reference Receivers
- GMV Global CORS Network
- IGS Sites
- Can include other CORS



Description of COLOSSUS

Real Time Status Monitoring

COLOSSUS provides information on current GNSS status to users

- General system status (satellite status, planned outages, almanac health)
- Broadcast status (last message received, health flag, SISA)
- Monitored Status
  - Detection of alerts / faults
  - Loss of satellite signals

Informs users of issues

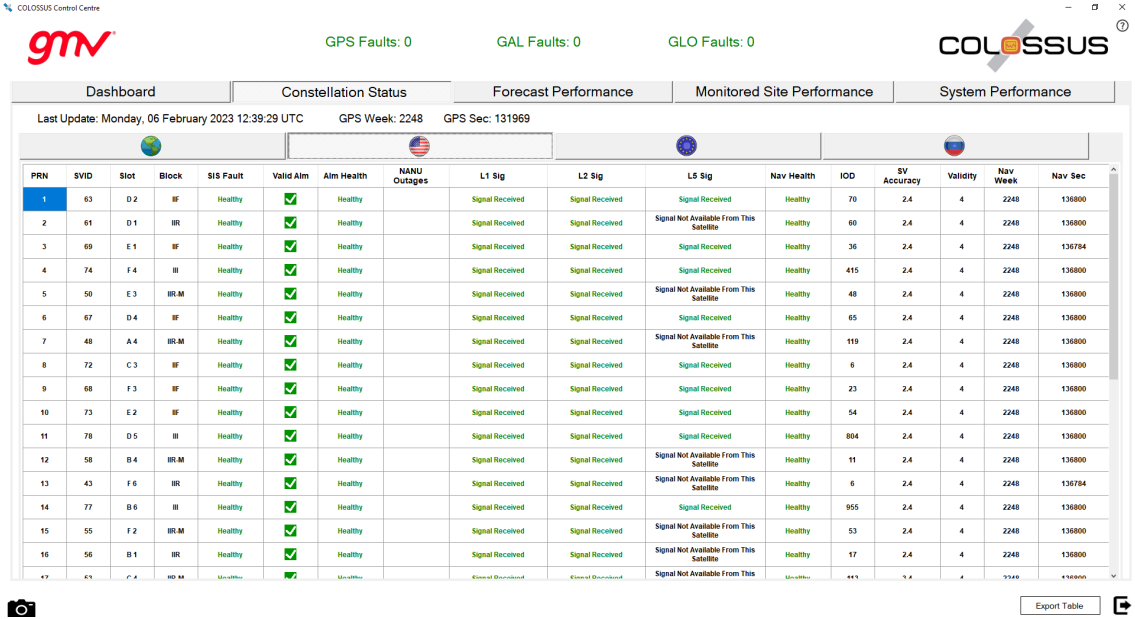
- Display status in application
- Fault alerts / issues can be disseminated in different ways (e.g. email alerts, other notifications)

Description of COLOSSUS

Real Time Monitoring

Covering GPS, Galileo and Glonass

Informs users of current status and warns of issues that may affect performance



PRN	SVID	Slot	Block	SIS Fault	Valid Alm	Alm Health	NANU Outages	L1 Sig	L2 Sig	L5 Sig	Nav Health	IOD	SV Accuracy	Validity	Nav Week	Nav Sec
1	63	D 2	IIF	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Received	Healthy	70	2.4	4	2248	136800
2	61	D 1	IIR	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Not Available From This Satellite	Healthy	60	2.4	4	2248	136800
3	69	E 1	IIF	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Received	Healthy	36	2.4	4	2248	136784
4	74	F 4	III	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Received	Healthy	415	2.4	4	2248	136800
5	50	E 3	IIR-M	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Not Available From This Satellite	Healthy	48	2.4	4	2248	136800
6	67	D 4	IIF	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Received	Healthy	65	2.4	4	2248	136800
7	48	A 4	IIR-M	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Not Available From This Satellite	Healthy	119	2.4	4	2248	136800
8	72	C 3	IIF	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Received	Healthy	6	2.4	4	2248	136800
9	68	F 3	IIF	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Received	Healthy	23	2.4	4	2248	136800
10	73	E 2	IIF	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Received	Healthy	54	2.4	4	2248	136800
11	78	D 5	III	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Received	Healthy	804	2.4	4	2248	136800
12	58	B 4	IIR-M	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Not Available From This Satellite	Healthy	11	2.4	4	2248	136800
13	43	F 6	IIR	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Not Available From This Satellite	Healthy	6	2.4	4	2248	136784
14	77	B 6	III	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Received	Healthy	955	2.4	4	2248	136800
15	55	F 2	IIR-M	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Not Available From This Satellite	Healthy	53	2.4	4	2248	136800
16	56	B 1	IIR	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Not Available From This Satellite	Healthy	17	2.4	4	2248	136800
17	53	C 4	IIR-M	Healthy	✓	Healthy		Signal Received	Signal Received	Signal Not Available From This	Healthy	113	2.4	4	2248	136800

Description of COLOSSUS

Forecast Performance

COLOSSUS generates forecast performance values for next period

- Using latest almanacs and configured settings for assumed error budget
- Using defined requirements for integrity risk, continuity
- Consider planned outages (NANUs, NAGUs)

Configuration can be changed for different users (different performance thresholds, different area, shorter time period, more frequent forecasts, single / multi constellation, etc.)

Provides users with information on expected performance

- Is it expected to meet requirements for my application?
- Are there areas where performance might be degraded?

Description of COLOSSUS

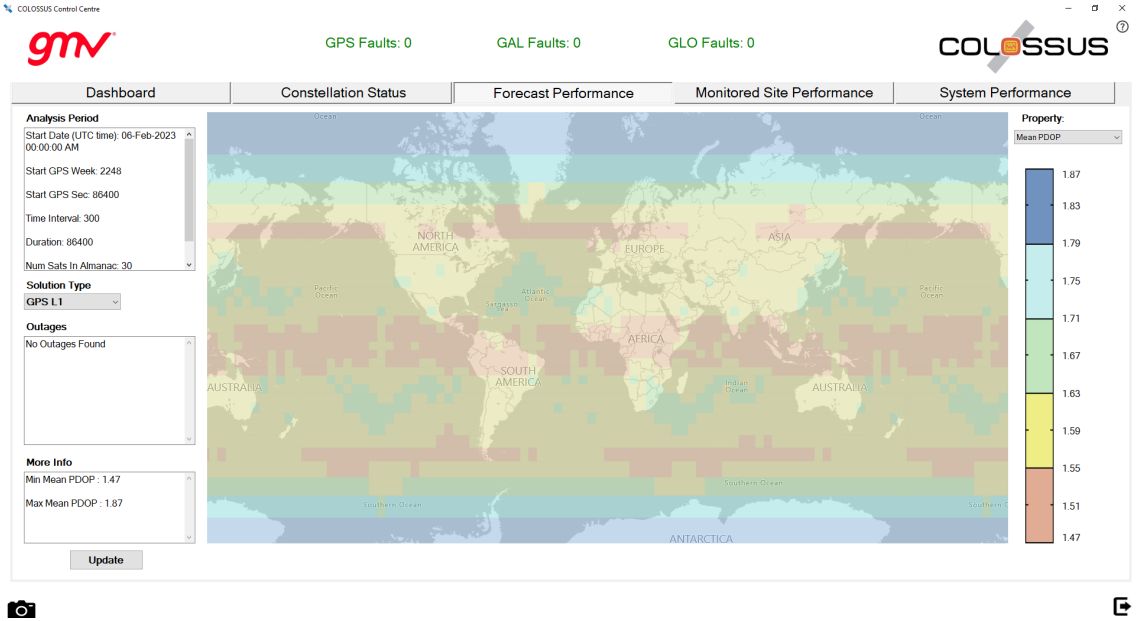
Forecast Performance

Show forecast performance metrics

- Forecast satellites in view, accuracy, DOP, HPL availability, etc.

Covering GPS, Galileo and Glonass

Gives users information on expected performance



Description of COLOSSUS

System Performance Monitoring

COLOSSUS generates monthly statistics to compare with GNSS performance specs

- Comparison with precise products
- Analysis of measurements
- Service Volume Simulations
- NANU/NAGU analysis

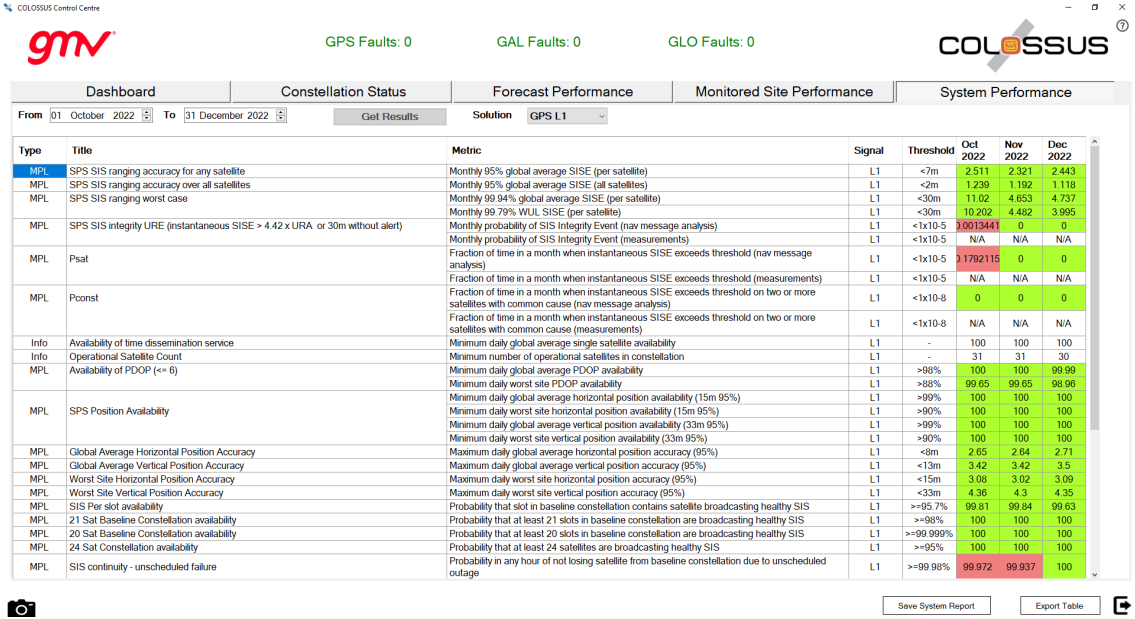
Provides information to users on whether satellite accuracy was meeting requirements and if there were any issues that may have affected performance

Description of COLOSSUS

System Performance

COLOSSUS generates monthly statistics to compare with GNSS performance specs

- For GPS, Galileo and Glonass
- SIS accuracy, integrity
- Constellation performance (DOP, accuracy, availability)



Type	Title	Metric	Signal	Threshold	Oct 2022	Nov 2022	Dec 2022
MPL	SPS SIS ranging accuracy for any satellite	Monthly 95% global average SISE (per satellite)	L1	<7m	2.511	2.321	2.443
MPL	SPS SIS ranging accuracy over all satellites	Monthly 95% global average SISE (all satellites)	L1	<2m	1.239	1.192	1.118
MPL	SPS SIS ranging worst case	Monthly 99.94% global average SISE (per satellite)	L1	<30m	11.02	4.653	4.737
		Monthly 99.79% WUL SISE (per satellite)	L1	<30m	10.202	4.482	3.995
MPL	SPS SIS integrity URE (instantaneous SISE > 4.42 x URA or 30m without alert)	Monthly probability of SIS Integrity Event (nav message analysis)	L1	<1x10-5	0.0013441	0	0
		Monthly probability of SIS Integrity Event (measurements)	L1	<1x10-5	N/A	N/A	N/A
MPL	Psat	Fraction of time in a month when instantaneous SISE exceeds threshold (nav message analysis)	L1	<1x10-5	0.1792115	0	0
		Fraction of time in a month when instantaneous SISE exceeds threshold (measurements)	L1	<1x10-5	N/A	N/A	N/A
MPL	Pconst	Fraction of time in a month when instantaneous SISE exceeds threshold on two or more satellites with common cause (nav message analysis)	L1	<1x10-8	0	0	0
		Fraction of time in a month when instantaneous SISE exceeds threshold on two or more satellites with common cause (measurements)	L1	<1x10-8	N/A	N/A	N/A
Info	Availability of time dissemination service	Minimum daily global average single satellite availability	L1	-	100	100	100
Info	Operational Satellite Count	Minimum number of operational satellites in constellation	L1	-	31	31	30
MPL	Availability of PDOP (<= 6)	Minimum daily global average PDOP availability	L1	>98%	100	100	99.99
		Minimum daily worst site PDOP availability	L1	>88%	99.65	99.65	98.96
MPL	SPS Position Availability	Minimum daily global average horizontal position availability (15m 95%)	L1	>99%	100	100	100
		Minimum daily worst site horizontal position availability (15m 95%)	L1	>90%	100	100	100
		Minimum daily global average vertical position availability (33m 95%)	L1	>99%	100	100	100
		Minimum daily worst site vertical position availability (33m 95%)	L1	>90%	100	100	100
MPL	Global Average Horizontal Position Accuracy	Maximum daily global average horizontal position accuracy (95%)	L1	<8m	2.65	2.64	2.71
MPL	Global Average Vertical Position Accuracy	Maximum daily global average vertical position accuracy (95%)	L1	<13m	3.42	3.42	3.5
MPL	Worst Site Horizontal Position Accuracy	Maximum daily worst site horizontal position accuracy (95%)	L1	<15m	3.08	3.02	3.09
MPL	Worst Site Vertical Position Accuracy	Maximum daily worst site vertical position accuracy (95%)	L1	<33m	4.36	4.3	4.35
MPL	SIS Per slot availability	Probability that slot in baseline constellation contains satellite broadcasting healthy SIS	L1	>=95.7%	99.81	99.84	99.63
MPL	21 Sat Baseline Constellation availability	Probability that at least 21 slots in baseline constellation are broadcasting healthy SIS	L1	>=98%	100	100	100
MPL	20 Sat Baseline Constellation availability	Probability that at least 20 slots in baseline constellation are broadcasting healthy SIS	L1	>=99.999%	100	100	100
MPL	24 Sat Constellation availability	Probability that at least 24 satellites are broadcasting healthy SIS	L1	>=95%	100	100	100
MPL	SIS continuity - unscheduled failure	Probability in any hour of not losing satellite from baseline constellation due to unscheduled outage	L1	>=99.98%	99.972	99.937	100

Description of COLOSSUS

Long Term Site Performance

COLOSSUS post-processes GNSS data from sites

- For different constellations and frequency combinations
- Generation of hourly and daily stats (mean, 95% error, solution availability, etc.)

Allow users to assess long term performance of GNSS at their location to understand if it meets their requirements

Provides evidence of performance for statutory monitoring and/or investigation of any issues

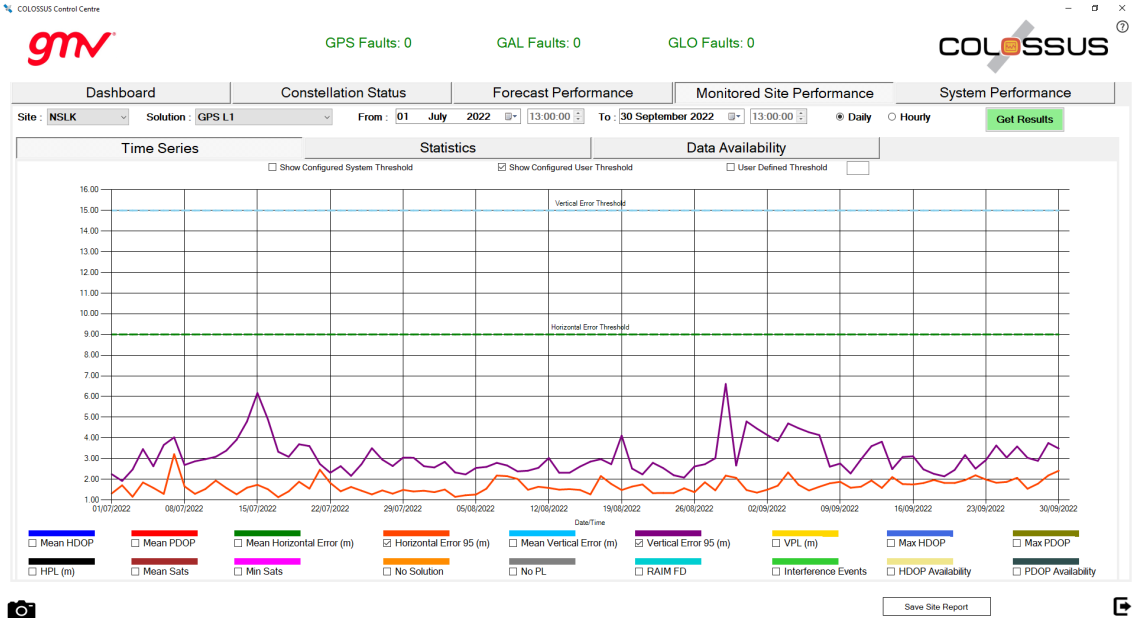
Description of COLOSSUS

Long-Term Site Performance

Monitor Long-Term Site Performance

- Generate site user performance statistics (accuracy, DOP, sat in view, integrity, etc.)
- Compare with defined thresholds

Covering GPS, Galileo and Glonass



Customer Needs Addressed

Example Use Case 1

Provision of routine monitoring for government and relevant authorities

Fulfilment of statutory obligations for monitoring

- “Has GNSS performed according to its specification?”
- -> System Performance
- “Has GNSS performance fulfilled the requirements for my application?”
- -> Long-term site performance statistics

Information and support to event / anomaly investigation

- “Were there any faults or issues with GNSS?”, “Was GNSS performing correctly at time of any reported incidents?”
- -> System Performance, site performance, real-time fault results

Customer Needs Addressed

Example Use Case 2

Provision of performance metrics to support monitoring / tracking services

Identifying possible performance / service outages in the short term

- “Will GNSS performance be suitable for my application?”
- -> Performance Forecasting

Confirming GNSS was reliable and results could be trusted

- “Has GNSS performed according to it’s specification?”
- -> System Performance

Information and support to event / anomaly investigation

- “Were there any faults or issues with GNSS?”, “Was GNSS performing correctly at time of any reported incidents?”
- -> System Performance, real-time fault results

Customer Needs Addressed

Example Use Case 3

Provision of GNSS status information to support enhancement service providers

Providing diagnostic information to support investigations of real-time issues
- “Are any reported errors / issues due to GNSS or to enhancement service?”
- -> Constellation status

Providing alerts to warn of faults / issues
- “Is there a fault that may impact the service provision or user performance?”
- -> RT fault detection and alerting

Product Opportunities

Competitive Characteristics of the Product

COLOSSUS provides the following capabilities

- **Independent monitoring of GNSS signals and systems**
  - Local, regional, continental, global monitoring
  - Multiple systems, frequencies, services

- **Monitor against KPIs from a customer specification**
  - System specification (e.g. GPS SPS)
  - User communities (e.g. ICAO)
  - Flexible to integrate application specific KPIs

Competitive Characteristics of the Product

GNSS data processing

- COLOSSUS checks real-time site performance
  - "Is GNSS performance at my location currently suitable for my needs?"
- COLOSSUS has near real-time fault detection
  - "Is there a problem that will affect my application?"
- COLOSSUS measures long term site performance
  - "Was GNSS performance suitable for my needs? Have there been any issues?"

System performance

- COLOSSUS shows real-time system status
  - "Are there any issues that may affect my application?"
- COLOSSUS checks System Performance (Orbit/clock error, DOP, service availability, etc.)
  - "Has GNSS performed as promised? Can I trust GNSS for my application?"

Path to Market

COLOSSUS has created a service that will be offered commercially in different configurations following evaluation:

- GMV hosted service, subscription based
  - Access to regular reports (e.g., monthly, quarterly)
  - Access through user application (alerts, graphics, report generation)
  - Options to host equipment (COLOSSUS receiver or other) and integrate with COLOSSUS network, or receive just system / global results

- Client hosted service with restricted rights
  - Server hosted by client, linking to 3rd party CORS networks, existing client hardware or newly deployed network

Growth Opportunities for the Company

- Development, production and maintenance of faults, failures and feared event catalogue and database covering different GNSS, signals, frequencies and geographical areas
  - To support design and validation of different services and applications
- Dual Frequency, Multi-constellation open signal monitoring for emerging applications
- Possible future enhancements
  - Monitoring of other GNSS and augmentations (BeiDou, SBAS)
  - Independent monitoring of GNSS commercial services
  - Extension to new systems and services (terrestrial, Signals of Opportunity, LEOPNT)

Working with ESA

- Thanks to the support provided by ESA and the NAVISP Element 2 programme we were able to develop and demonstrate a pre-operational COLOSSUS service utilising a global network of reference stations.

- ESA has provided technical review and guidance at different stages, including user needs and requirements, technical approach, and testing and validation of fault detection and performance monitoring capabilities

- ESA will also host a COLOSSUS receiver for an initial demonstration period in order to facilitate continued operation and demonstration of the service.

- ESA has been understanding of delays (caused by factors such as COVID), understanding the importance of completing this activity for GMV's future business opportunities

GMV would like to thank ESA for their ongoing support on this activity.

Thank you

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