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EGNOS as a component of resilient PNT and the wider e-Navigation concept

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EGNOS workshop, Copenhagen

October 2015

e-Navigation

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- e-Navigation is the IMO concept for the future of navigation
- integration of systems and provision of relevant information to the mariner and shore services
- Improve safety of life, protection of the environment & security
- exchange of information, faster, more cost-effective

*"e-Navigation is the **harmonised collection**, **integration, exchange, presentation and analysis** of maritime information **onboard and ashore** by electronic means to **enhance berth to berth navigation and related services**, for **safety and security at sea** and protection of the marine environment."*
-- International Maritime Organisation (IMO)

"improved reliability, resilience and integrity of bridge equipment and navigation information"

- IMO e-Navigation Strategy Implementation Plan (SIP)

Source: ACCSEAS

e-Navigation

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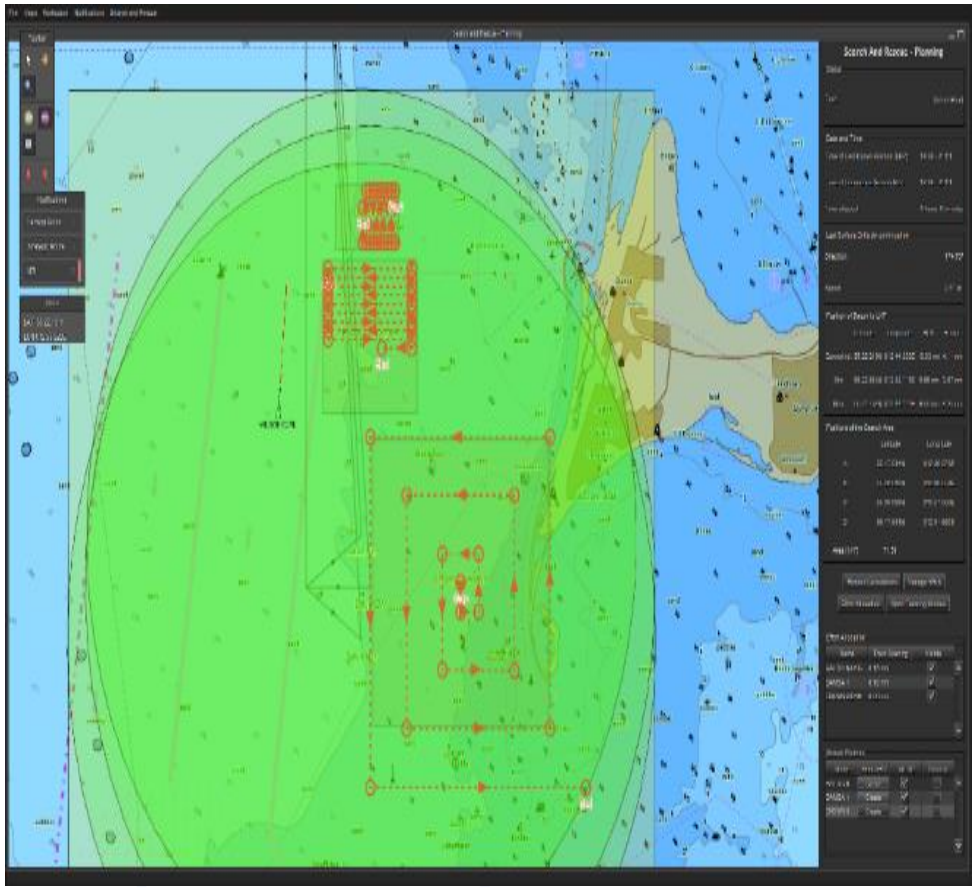

Source: ACCSEAS

Resilient PNT

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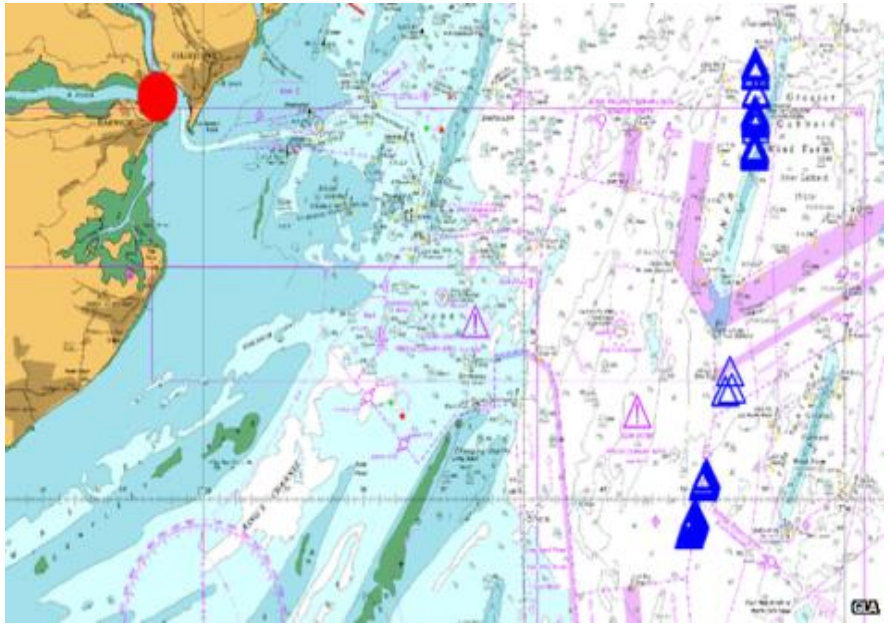
Any additional ranging signals and maritime integrity information provided will add to the mix of information that can be used for resilient PNT.

Integrity information needs to be suitable for maritime use.

New IMO receiver performance standard will permit EGNOS (SBAS) use on SOLAS vessels (expected post 2019).

IEC test standards to be completed and will need EC/ESA/GSA input.



Erroneous positions observed during GLONASS outage in April 2014

SBAS Integrity

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For SBAS to be used a component of e-Navigation the following points are of note:

SBAS have been designed for aviation.

Maritime integrity is critical and must be proven before a system can be used for safe navigation.

Maritime requirements are different to aviation, this has to be reflected in the integrity algorithms.

Maritime specific algorithms will be needed for the IMO/IEC standardisation process.

Once understood, this can be demonstrated to aid type approval and user confidence.

Source: http://www.mardep.gov.hk/en/pub_services/casualty.html

Rationale

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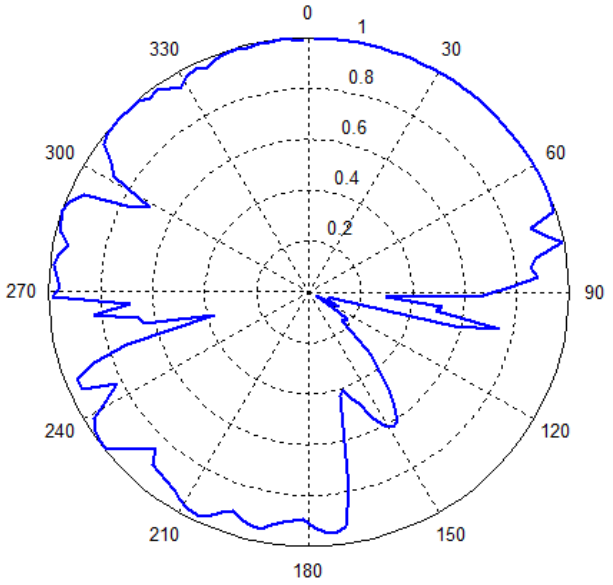
The GLAs have undertaken work to:

- understand EGNOS accuracy & availability at the extremes of the GLA service area.
- Understand the potential for EDAS/SISNet to mitigate for periods of satellite obscuration.

At no point have we considered integrity and resilience in this study.



GLA trials in 2011 showed that satellite obscuration can be a significant issue when receivers are not positioned at the top of the mast. Polar plot shows availability of data against bearing.

Maritime Performance Requirements

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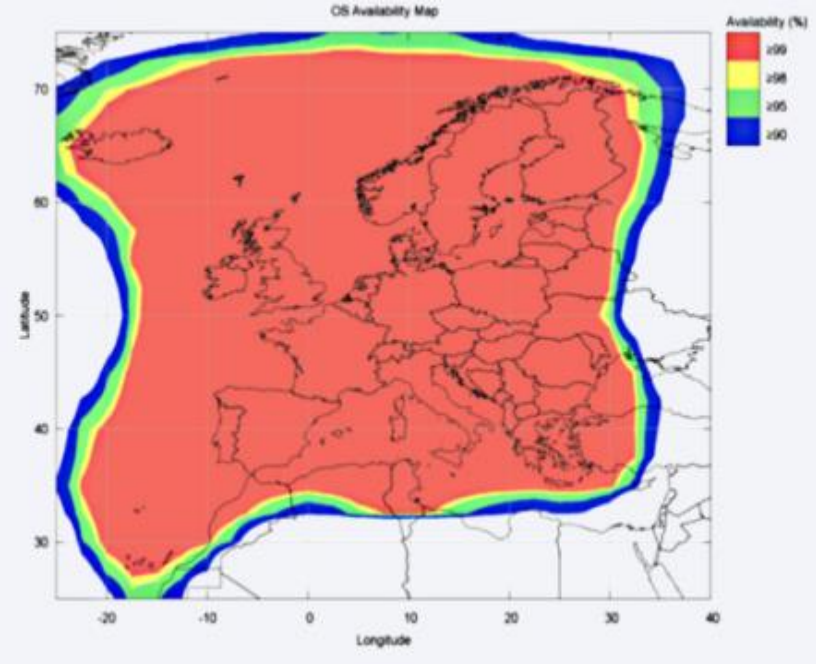
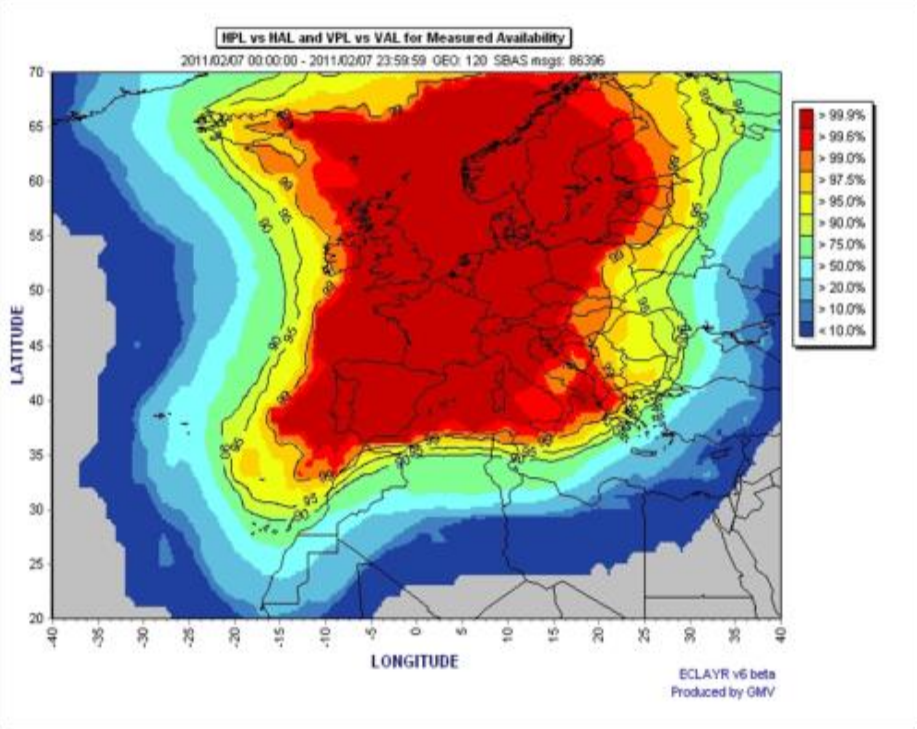
IMO Resolution A.1046 (27) details maritime requirements as:

	Accuracy (95%)	Time to Alarm	Continuity (15 min)	Availability	Update Interval
Harbour entrances, harbour approaches and coastal waters	≤ 10 m	<10 s	≥ 99.97%	> 99.8%	≤ 2 s

EGNOS Open Service Compliance Area



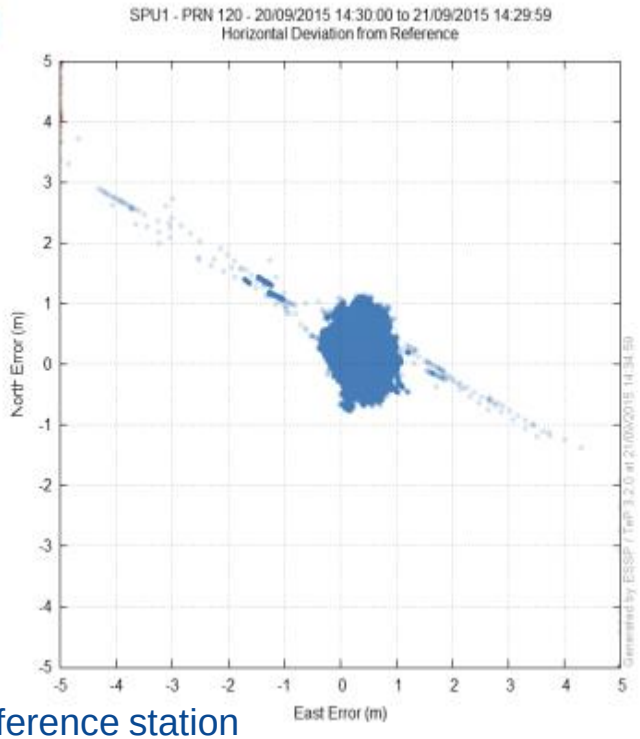


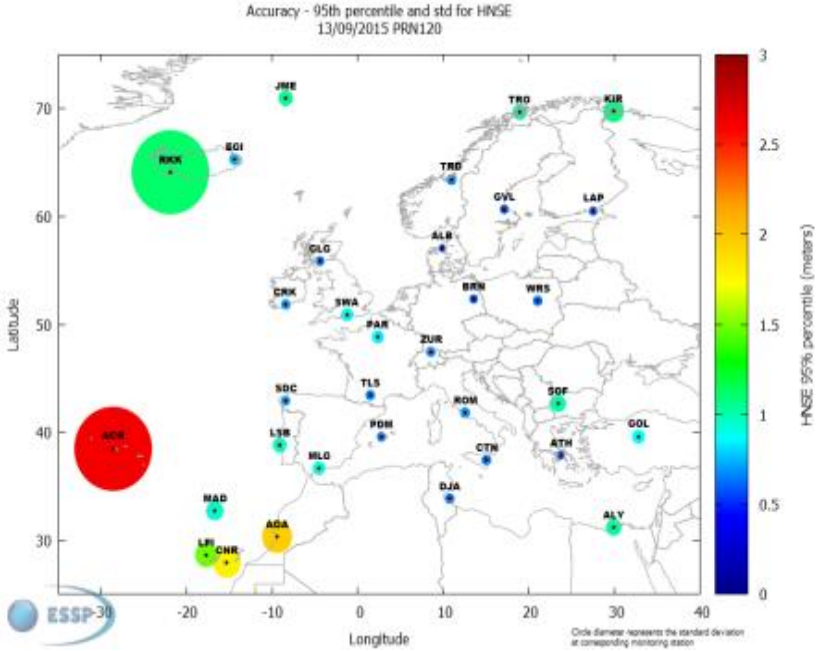
EGNOS OS Availability is defined in the present document as the percentage of time when the instantaneous HNSE is lower than 3 meters and the instantaneous VNSE is lower than 4 meters over the total number of samples with valid PA navigation solution.

Open Service

Source: EGNOS Open Service (OS) Definition Document Rev. 2.2

EGNOS Open Service Compliance Area





Madrid reference station

Accuracy	Definition	Value
Horizontal	Corresponds to a 95% confidence bound of the 2-dimensional position error[9] in the horizontal local plane for the Worst User Location	3m

Open Service

Source: EGNOS Open Service (OS) Definition Document Rev. 2.2 & ESSP website.
HNSE = Horizontal Navigation System Error

GLA' Monitoring Locations

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Esha Ness Lighthouse
Sheltand, UK
60º 29' 21.4692" N
1º 37' 38.1944" W

Cromwell Point Lighthouse
Valentia Island, Ireland
51º 56' 1.3405" N
10º 19 16.3654" W

Monitoring Setup

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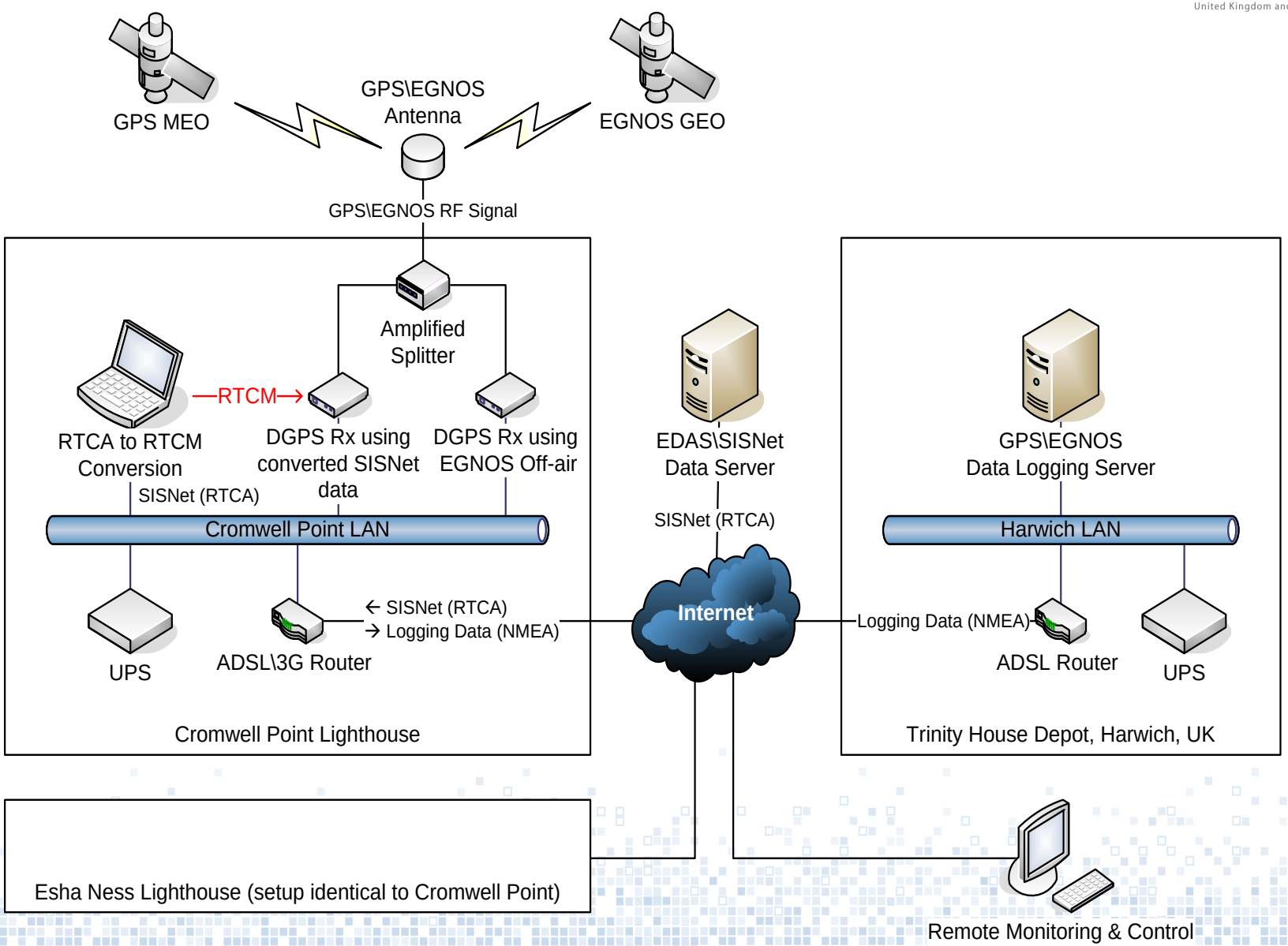

Monitoring Setup

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- Each remote monitoring station contains:
  - 1x Trimble GA530 antenna
  - 1x Amplified antenna splitter
  - 2x Trimble SPS 351 receiver
  - 1x Linux Laptop with RTCA to RTCM convertor software supplied by Alberding GmbH
  - 1x ADSL or 3G router
- Antenna positions surveyed using a dual-frequency GPS RTK receiver

Alberding software converts SISNet data to RTCM format. It uses data for EGNOS satellite PRN 120. It is not able to switch to an alternate satellite in this version.

Cromwell Point, Ireland

Performance from 1 Jan 2015 to 31 Aug 2015

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EGNOS (Off-air)				Requirement
	Min	Max	Mean / 95%	IMO Res. A.1046
No. of satellites	4	12	9.2	
HDOP	0.7	6.8	1.0	
Availability	54.3	100.0	99.98%	> 99.8%
Position error	0.0	6.0	1.61 m	≤ 10 m
Continuity	N/A	N/A	99.97%	≥ 99.97%
EDAS\SISNet				
	Min	Max	Mean / 95%	
No. of satellites	4	12	8.8	
HDOP	0.7	13.1	1.0	
Availability	4.5	100.0	99.38%	> 99.8%
Position error	0.0	17.5	1.93 m	≤ 10 m
Continuity	N/A	N/A	99.19%	≥ 99.97%

EDAS\SISNet performance driven by data communications availability at remote site

Recorded statistics calculated over 1hr time intervals

Esha Ness, Shetland, UK

Performance from 1 Jan 2015 to 31 Aug 2015

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EGNOS (Off-air)					Requirement
	Min	Max	Mean / 95%		IMO Res. A. 1046
No. of satellites	4	12	9.5		
HDOP	0.7	4.8	0.9		
Availability	64.6	100.0	99.99%		> 99.8%
Position error	0.0	32.9	1.48 m		≤ 10 m
Continuity	N/A	N/A	99.96%		≥ 99.97%
EDAS\SISNet					
	Min	Max	Mean / 95%		
No. of satellites	4	12	8.5		
HDOP	0.7	14.9	1.1		
Availability	0.7	100.0	97.46%		> 99.8%
Position error	0.0	91.7	1.79 m		≤ 10 m
Continuity	N/A	N/A	97.21%		≥ 99.97%

EDAS\SISNet performance driven by data communications availability at remote site

Recorded statistics calculated over 1hr time intervals

Cromwell Point, Ireland

Performance from 11 Aug 2015 to 11 Sep 2015

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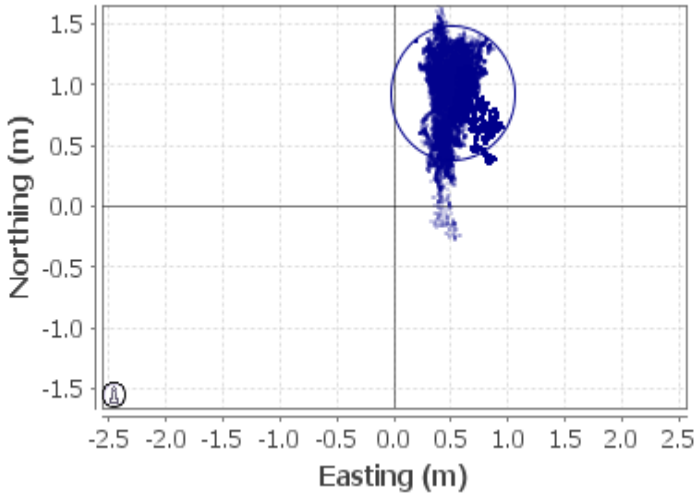
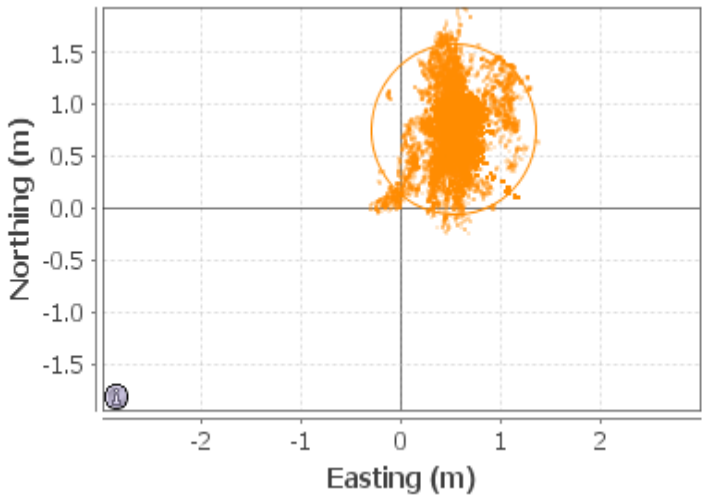
EGNOS (Off-air)



EDAS\SISNet



Approximately 1 m bias w.r.t. surveyed antenna position

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Performance from 11 Aug 2015 to 11 Sep 2015

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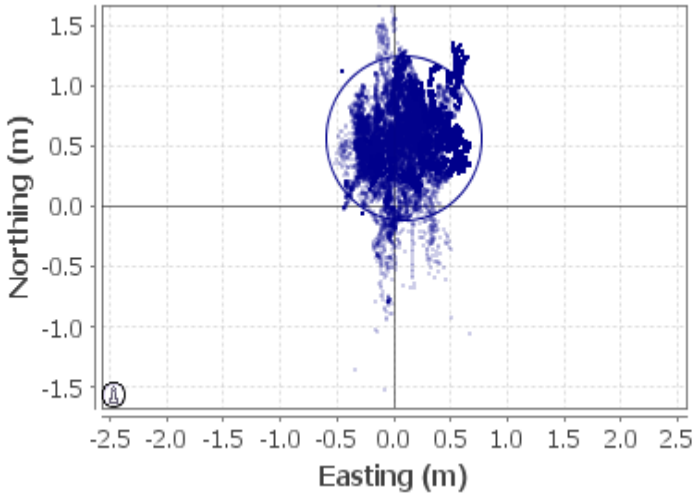
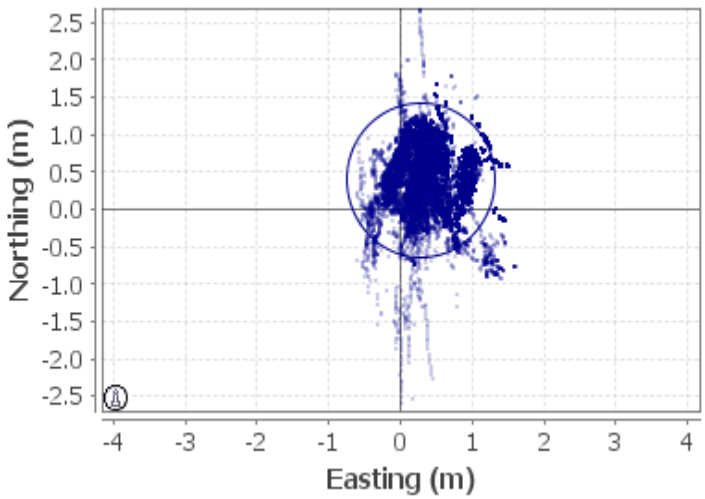
EGNOS (Off-air)



EDAS\SISNet



Approximately 0.5 m bias w.r.t. surveyed antenna position

G4 Geomagnetic Storm (17 Mar 2015)

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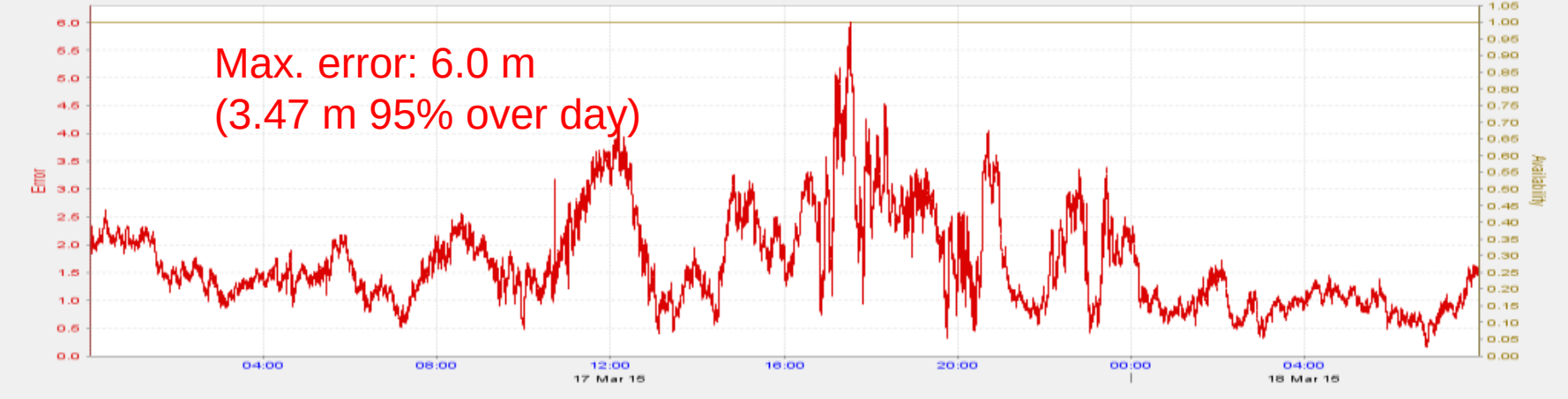
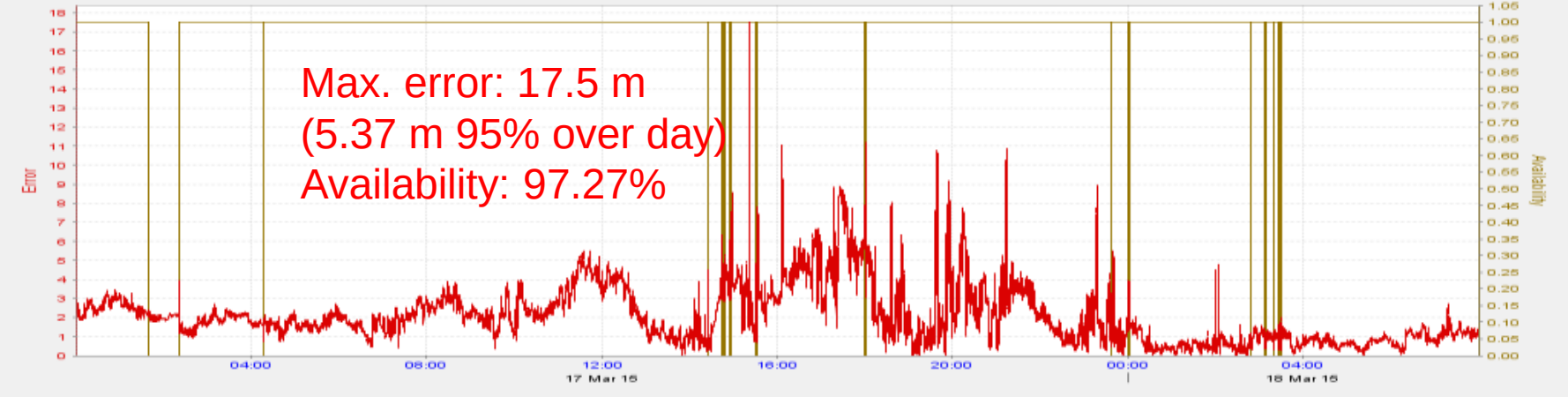
Data from Cromwell Point Station

EGNOS (Off-air)



EDAS\SISNet



EGNOS Outage on 1 Jul 2015

Data from Cromwell Point Station

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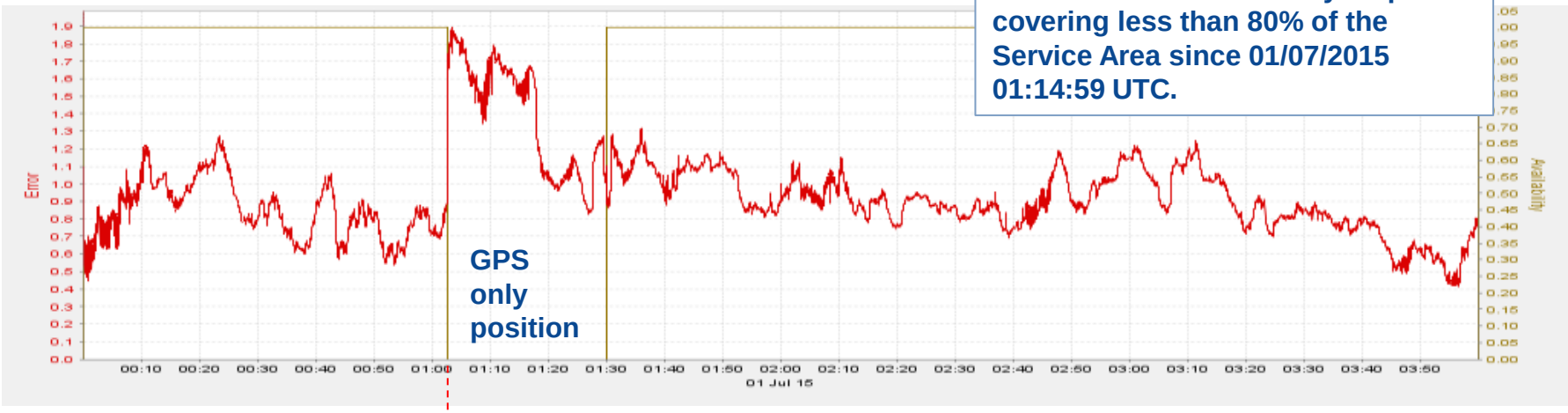
EGNOS (Off-air)

EGNOS email alert
The 99% APV-I availability map is covering less than 80% of the Service Area since 01/07/2015 01:14:59 UTC.



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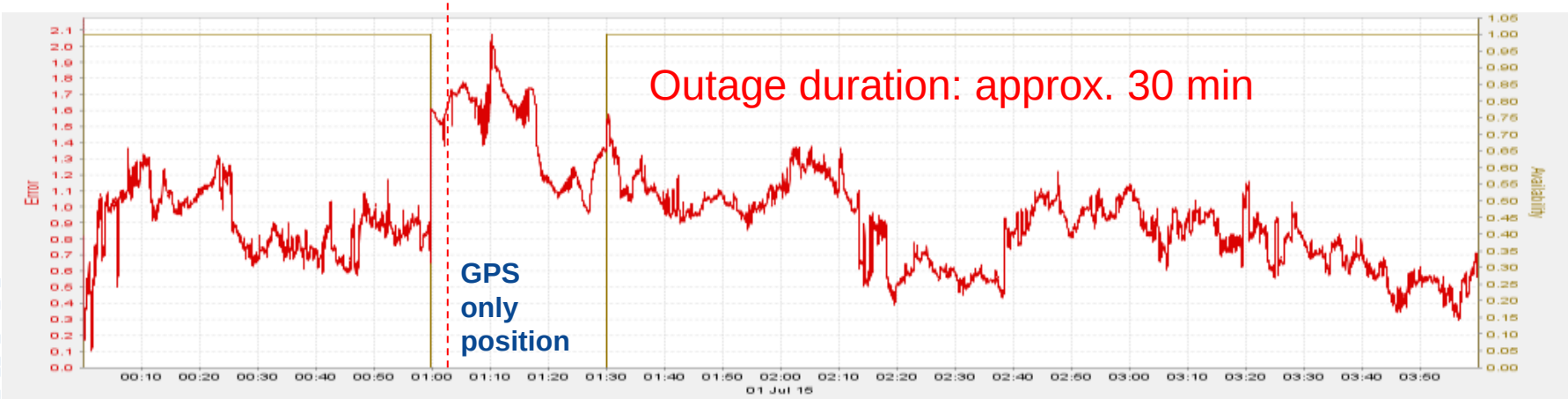
EDAS\SISNet



Conclusions

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- Based on data from two GLA monitoring stations:
  - Off-air EGNOS OS generally meets IMO accuracy, availability (and continuity) requirements for harbour operations at the extremes of GLA service area.
  - EDAS\SISNet accuracy is slightly worse than that of off-air EGNOS; peak error can be significantly higher, particularly during ionospheric events - still meets the IMO accuracy requirements.
  - EDAS\SISNet performance is driven by availability of data communications; IMO availability and continuity targets were not met at either site.
- EGNOS integrity is not considered, however must be proven to work in a maritime context both for off-air and SISNet.
- EGNOS will, in the future*, have a part to play in the mix of systems used to support Resilient PNT and e-Navigation services.

* using IMO MSC.401 approved receivers with a maritime integrity concept

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