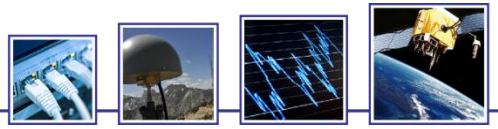


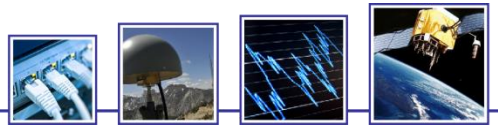
EDAS-based DGPS service with pre-broadcast integrity monitoring

Tamás Horváth

Alberding GmbH

EGNOS Service Provision Workshop 2016, 27-28 September 2016, Warsaw, Poland

Outline



Motivation

EGNOS for maritime navigation

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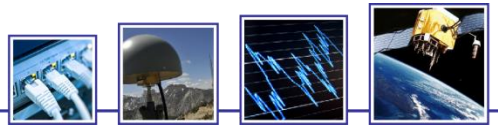
Pre-Broadcast Monitoring

EGNOS-VRS test campaign 2016

Hybrid approach

Maritime DGNSS modernisation



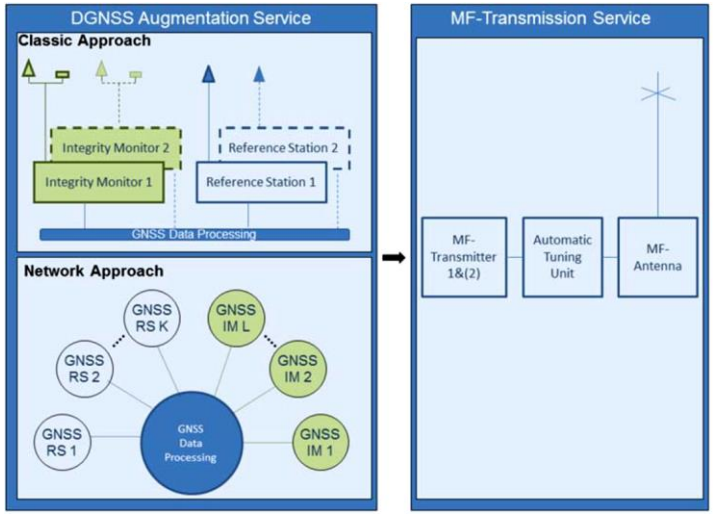
- More than 300 IALA DGNSS stations operating worldwide
- Some of the European IALA radio beacon networks are becoming obsolete (no spare parts available)
- IALA DGNSS re-capitalisation:

Classic approach
(correction generation at the transmission site)

- Hardware Reference Stations and Integrity Monitors (RSIM)
- Software RSIM

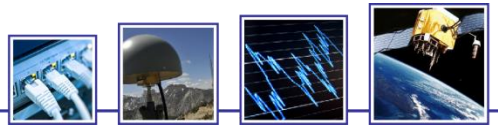
Service-based approach
(correction generation at a central server)

- Virtual Reference Stations (VRS)
- **SBAS integration**
- Need of a backup system at the transmission site



IALA Guideline No. 1112

EGNOS for maritime navigation



- SBAS is designed primarily for aviation use.
- EGNOS or EGNOS-VRS corrections could be used for maritime navigation if the maritime requirements are met.
- EGNOS-VRS positioning accuracy and availability performance assessed in 2014-2015 trials.
- Integrity information provided by SBAS systems is aviation centric. Integrity monitoring in acordance with maritime integrity concept has to be performed.
- 2016 July-August: new EGNOS-VRS test campaign focusing on integrity monitoring and extending the analysis period.

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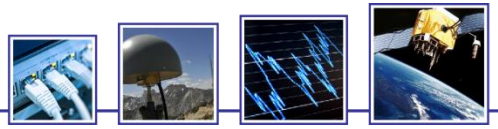
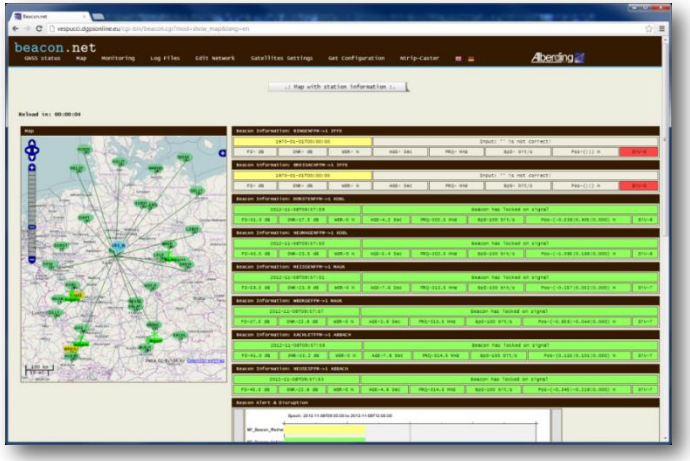
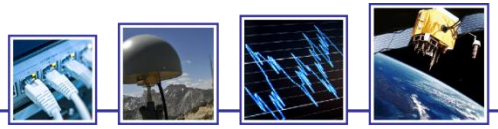


- GNSS software suite designed for the operation of maritime and inland waterway DGNSS services
- Runs on a central server, implements multiple DGNSS correction approaches:
  - Own DGNSS network approach (VRS)
  - DGNSS corrections from an existing network
  - Single DGNSS reference stations
  - EDAS/EGNOS SIS (EGNOS VRS)
- Scalable, modular software that allows for a flexible system architecture

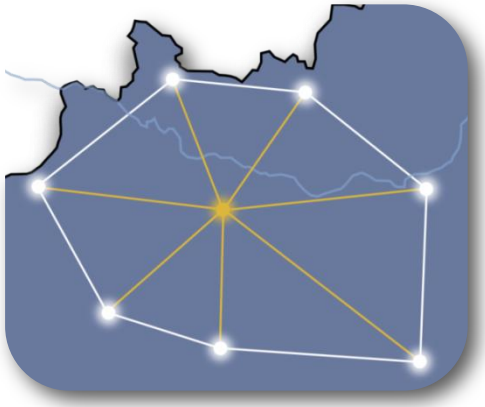


Alberding Beacon.net modules



- **GNSS raw data input**
  - IALA beacon stations
  - AIS DGPS base stations
  - Other GNSS reference stations
  - EGNOS RTCA from SiS or EDAS
- **VRS server**
  - Network DGNSS processing
  - Generation of virtual corrections
  - Supports EGNOS-VRS
- **Integrity monitoring**
  - Pre-broadcast monitoring (SV and position domains)
  - Far field monitoring (position and signal quality)
- **Data transmission**
  - IALA radio beacons, AIS, Ntrip (GPRS, WLAN)
  - RTCM 2.x, 3.x, AIS Type #17, etc.

beacon.net



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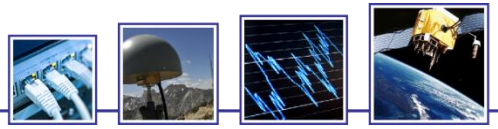
Beacon.net pre-broadcast monitoring



Pseudorange domain

PRC/RRC check

- During correction generation at the reference station side.
- If user-defined thresholds exceeded for an SV:
  PRC and RRC fields immediately set to **”do-not-use”** values in RTCM output.

PRC/RRC residual check

- At the monitoring station side.
- If user-defined thresholds exceeded for an SV for a pre-set period of time:
  PRC and RRC fields set to **”do-not-use”** values in RTCM output.

Output Information

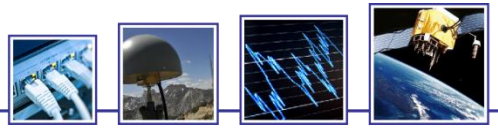
Output	Monitoring-Status (PBM)	Connection-Status	Last Error PRC/RRC [s]	Last Residual Error PRC/RRC [s]	Last Horizontal Error [m]
ALBA_101-FAERDER_VRS-IM		ALBA_101			0.26
DARE0-EARLS_HILL_STIRLING_VRS-IM		DARE0			0.09
DARE0-POINT_LYNAS_VRS-IM		DARE0			0.34
MLGA_1701-MALAGA_VRS-IM		MLGA_1701			0.23
OBE40-OBERASBACH_VRS-IM		OBE40			0.03
ONSA0-GOTEBORG1_VRS-IM		ONSA0			0.18
ONSA0-GOTEBORG2_VRS-IM		ONSA0			0.18
SCOA0-MACHICACO_VRS-IM		SCOA0			0.52
TLSA_3102-CAP_FERRET_VRS-IM		TLSA_3102			0.45
WTZR0-REGENSBURG_GRASS_VRS-IM		WTZR0			0.68

Monitored Output: DARE0-EARLS_HILL_STIRLING_VRS-IM

Monitor Data	Correction Data
DARE0	EARLS_HILL_STIRLING_VRS

Correction Data		
Max PRC (≤ 10000)	60	m
Max RRC (≤ 4)	2	m/s
Monitor/Raw Data		
Max PRC Residual (≤ 150)	10	m
Max PRC Residual Delay (10 ≤ delay ≤ 65)	10	s
Max RRC Residual (≤ 10)	2	m/s
Max RRC Residual Delay (10 ≤ delay ≤ 65)	10	s
DGNSS Solution		
Max Positon Difference (≤ 100)	10	m
Max Positon Difference Delay (5 ≤ delay ≤ 100)	10	s

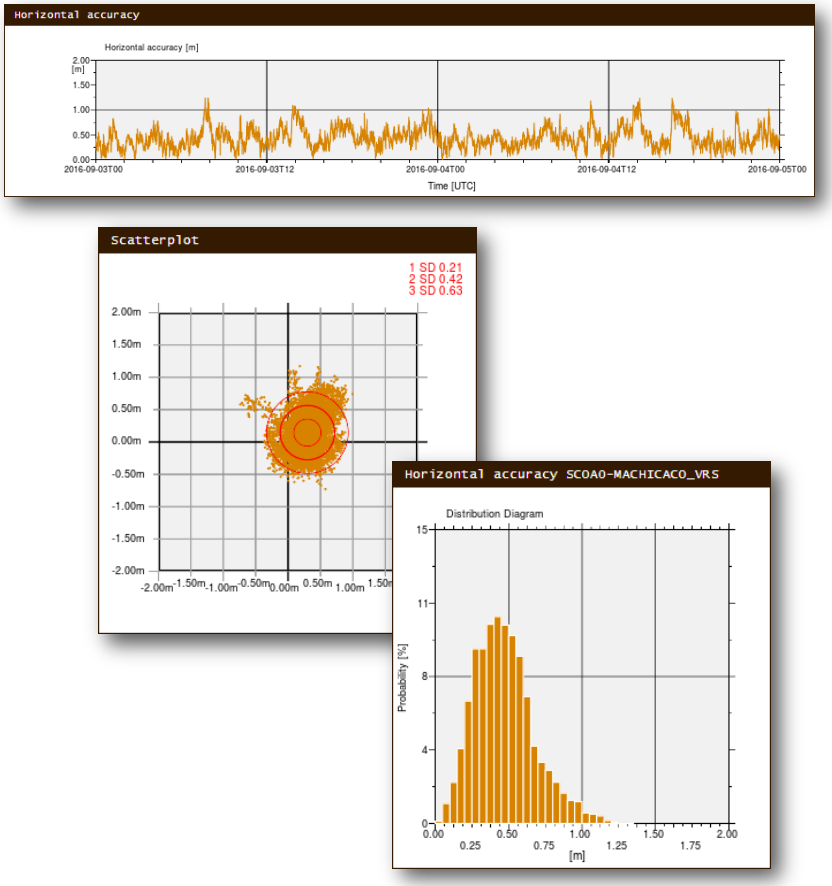
Beacon.net pre-broadcast monitoring



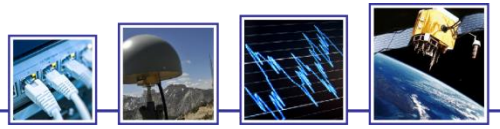
Position domain

Horizontal position error check

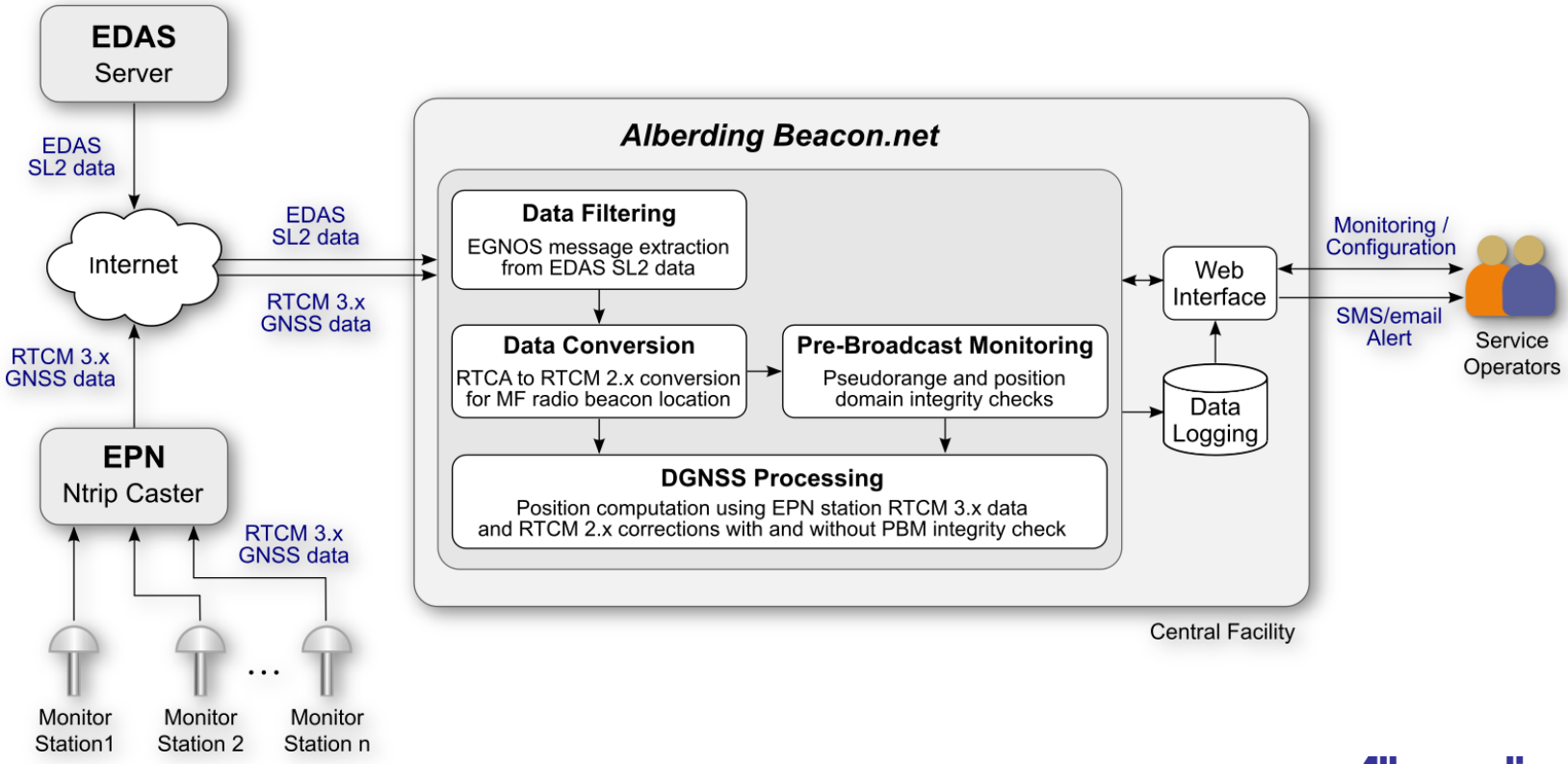
- At the monitoring station side.
- If the computed DGNSS position error exceeds a user-defined threshold for a pre-set period of time:
  Reference station set to **”not working”** status in RTCM header.
- If the monitoring station is unavailable or no DGNSS position could be computed for a pre-set period of time:
  Reference station set to **”not monitored”** status in RTCM header.



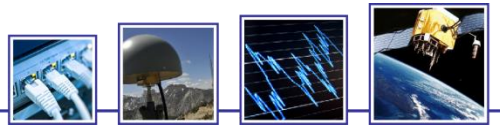
EGNOS-VRS test architecture

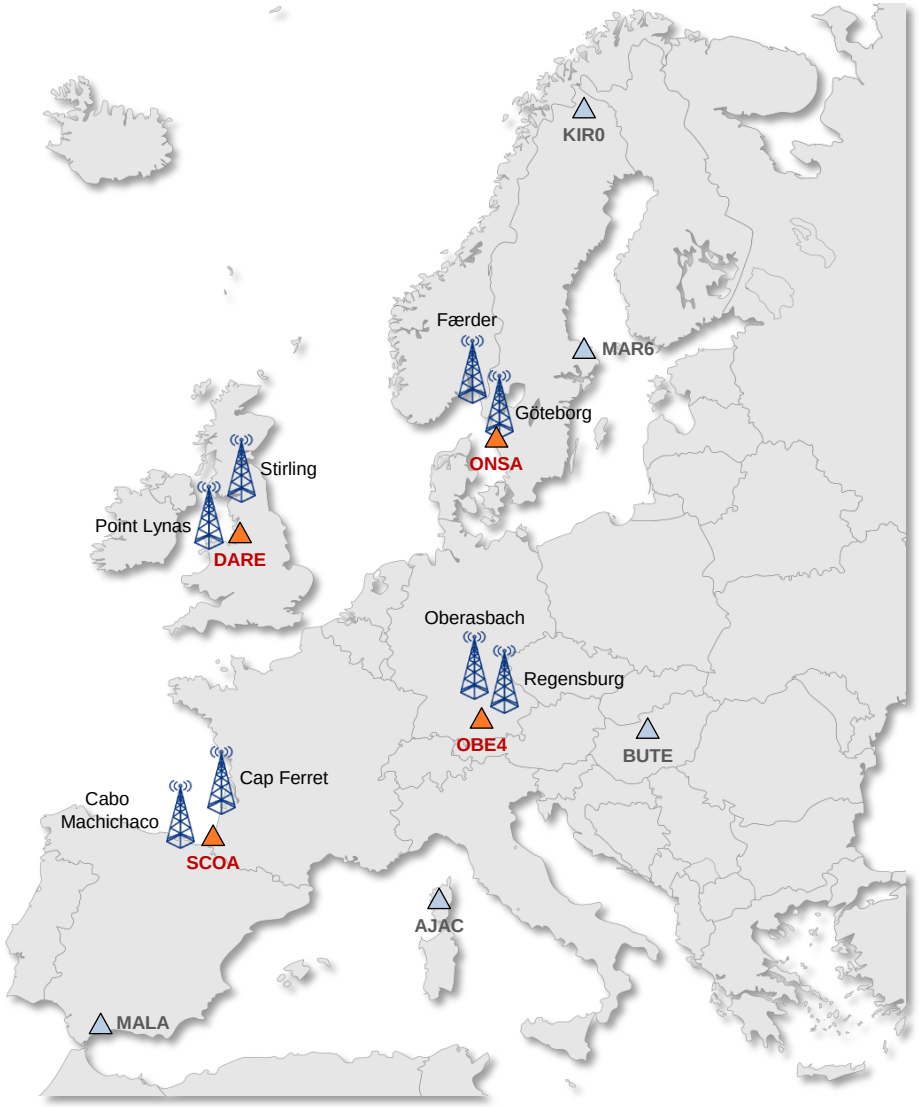


- EDAS RTCA data conversion to RTCM 2.x corrections (EGNOS-VRS) referenced to IALA beacon locations
- Integrity check (Pre-Broadcast Monitoring) using raw data from an independent network of monitoring stations



EGNOS-VRS test campaign 2016



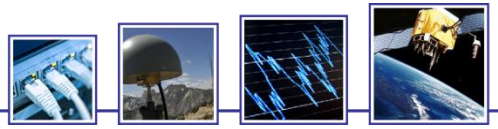


Time period: 2 July – 13 August (6 weeks)

Locations:

Rover station	EDAS-VRS location	Distance [km]	
ONSA	Göteborg	25	Maritime
ONSA	Færder	200	
DARE	Point Lynas	110	
DARE	Stirling	316	
SCOA	Cabo Machichaco	86	
SCOA	Cap Ferret	135	
OBE4	Regensburg Grass	100	Inland
OBE4	Oberasbach	150	

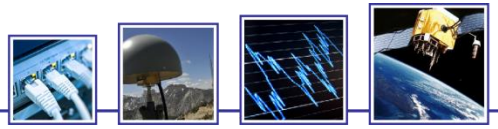
EDAS-VRS PBM settings

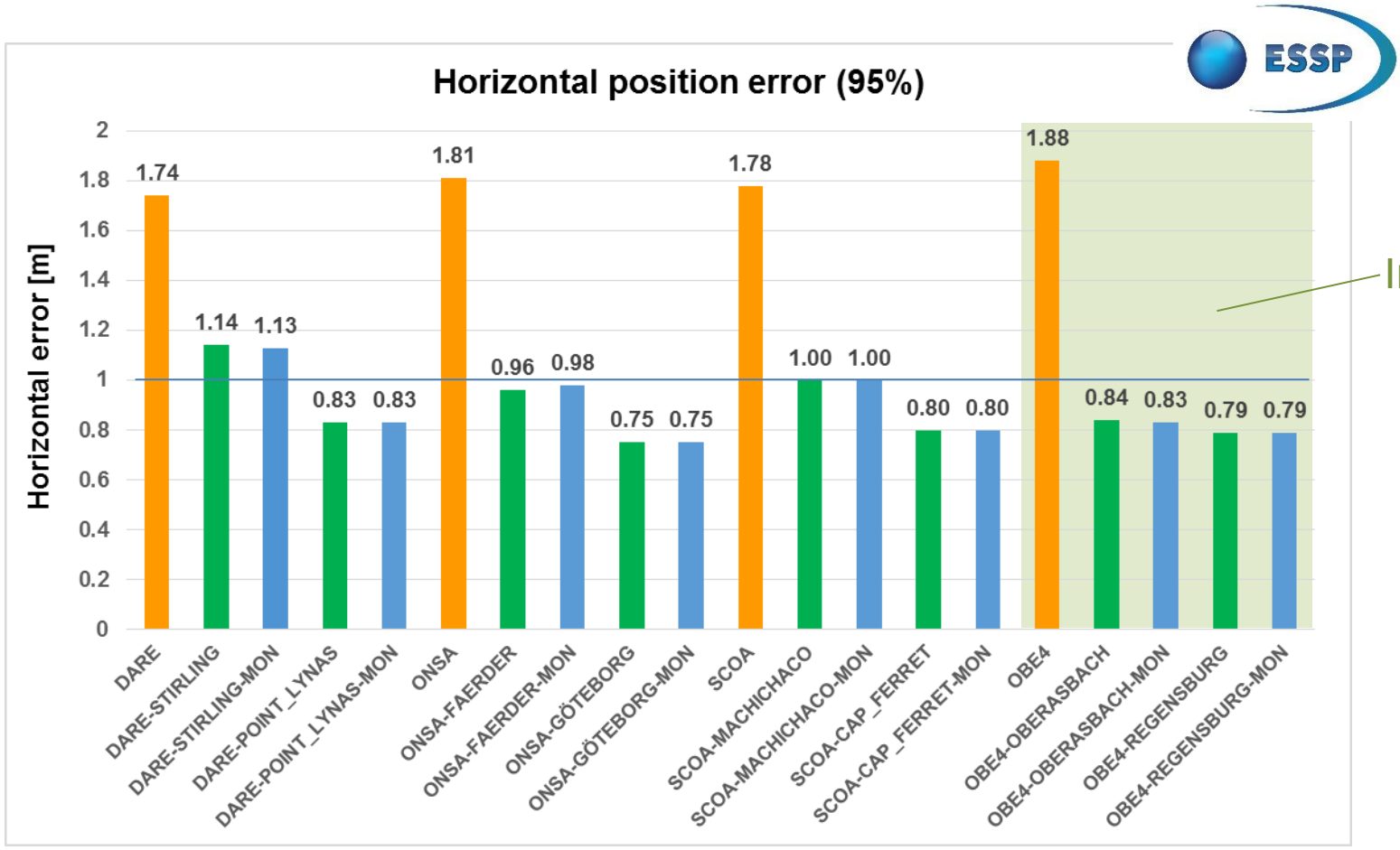


Parameter	Coastal	Inland
Max PRC [m]	60	40
Max RRC [m/s]	2	0.5
Max PRC Residual [m]	10	5
Max RRC Residual [m/s]	2	1
Max Horizontal Position Error [m]	10	2
Alert Interval [s]	10	10

Thresholds defined are based on the ranges proposed by IALA (Guideline No. 1112) and also on the Alberding know-how (considering other PBM implementations in Europe).

EDAS-VRS horizontal accuracy

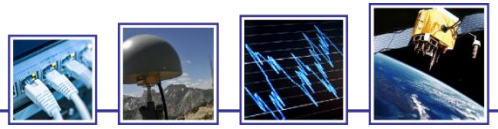


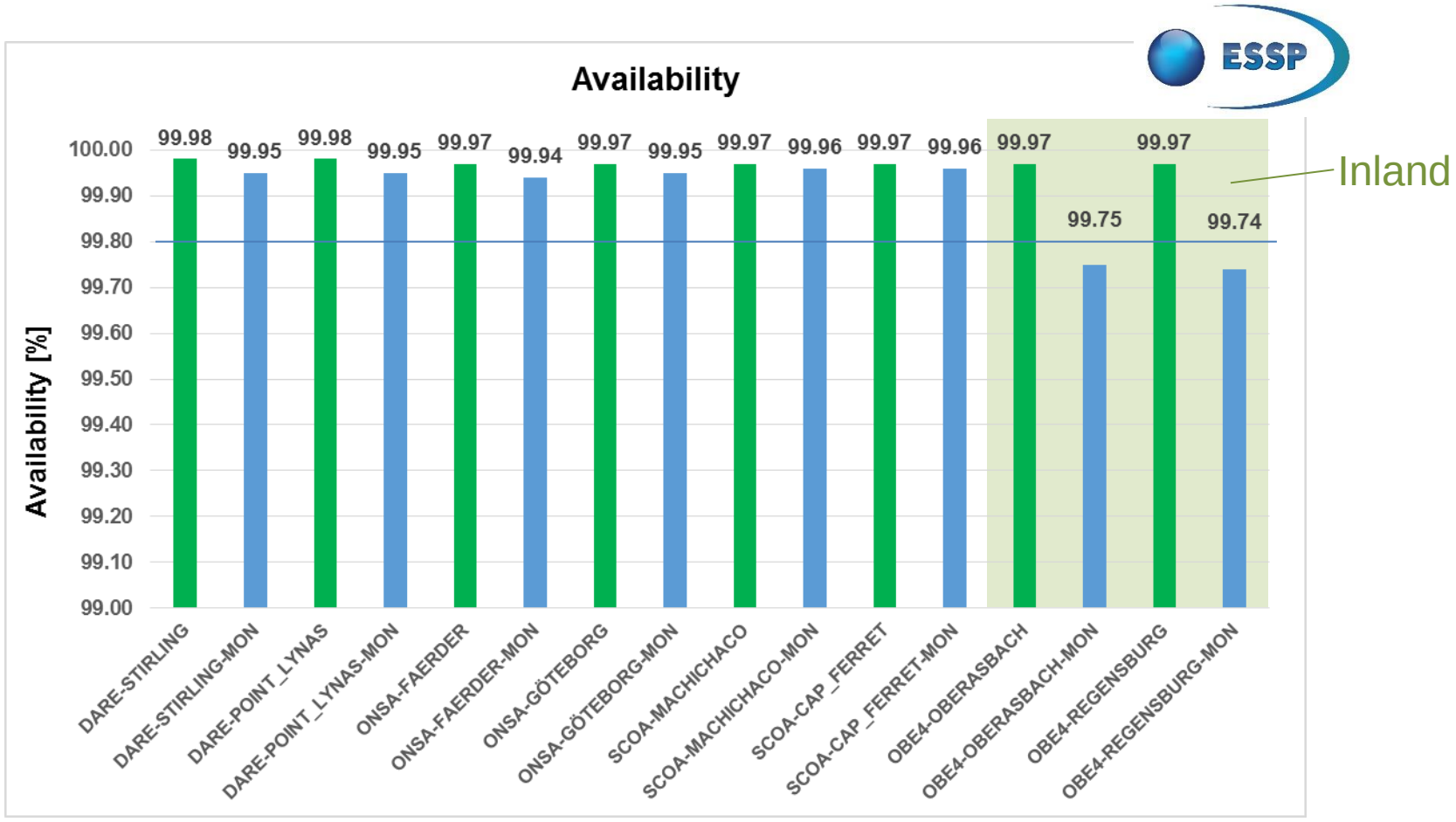


Statistical values computed by ESSP

Absolute GNSS
EDAS-based VRS
EDAS-based VRS with PBM

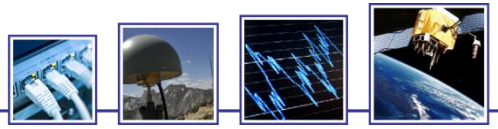
EDAS-VRS availability

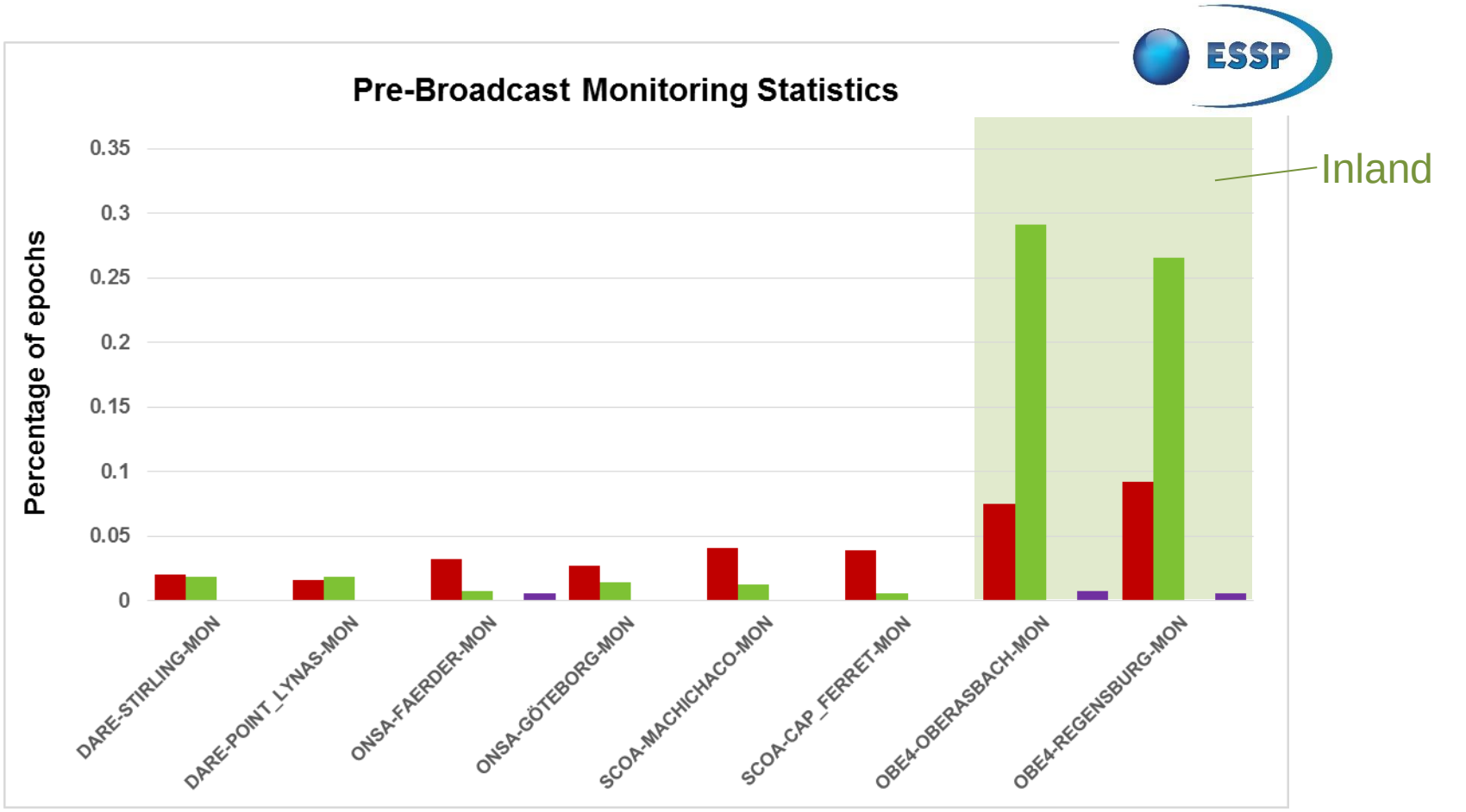




Statistical values computed by ESSP

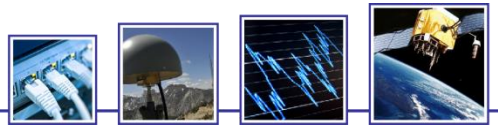
EDAS-VRS PBM statistics





Statistical values computed by ESSP

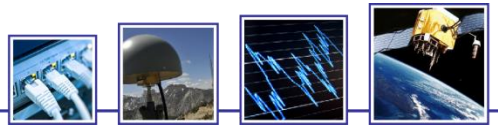
Test campaign conclusions



- EGNOS-VRS **Horizontal Position Error** (95%) was **below 1 m** on all baselines < 300 km (with and without PBM)
- EGNOS-VRS based DGNSS position solution **availability** with PBM
  - using **coastal** settings was **above 99.9%**
  - using **inland waterway** settings was above **99.7%**

  (as long as rover GNSS data was available)
- To achieve 99.8% availability highly **reliable communication lines** are required and a **local backup** receiver at the transmission site is recommended.
- **Integrity thresholds** shall be carefully defined (especially the position error threshold) since it may impact the availability performance.
- **Pseudorange domain** integrity failures affected **< 0.01%** of all epochs. This illustrates the quality of the EGNOS-Based VRS corrections.

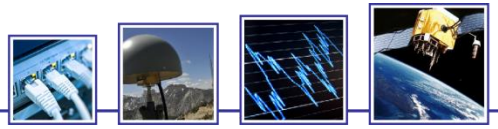
Test campaign conclusions



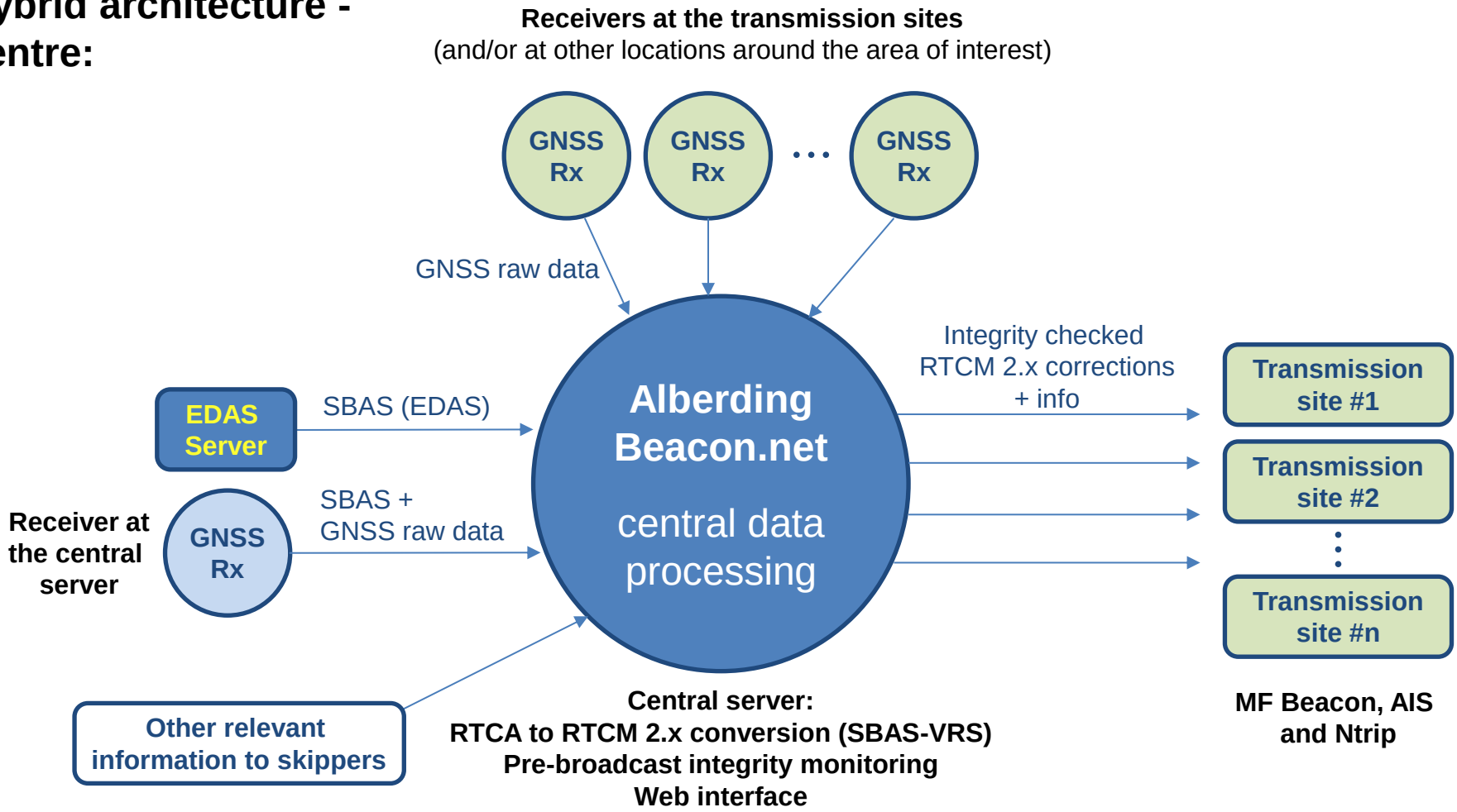
- EDAS could be used as part of a cost-effective solution (providing some room for the rationalization of the infrastructure), in line with the IALA recommendations and the accuracy (10 meters 95% for general navigation and even 1 meter for ports), availability (99.8%) and integrity requirements.

- For more details read:
  J. Morán, E. Lacarra, J. Vázquez, M.A. Sánchez, F. Cantos and T. Horváth (2016) "EDAS for a DGPS maritime service: EGNOS-based VRS performance with pre-broadcast integrity monitoring." Proceedings of the ION GNSS+ 2016 Conference, 12-16 September 2016, Portland, Oregon, U.S.A.

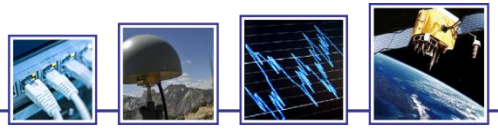
Alberding recommended solution



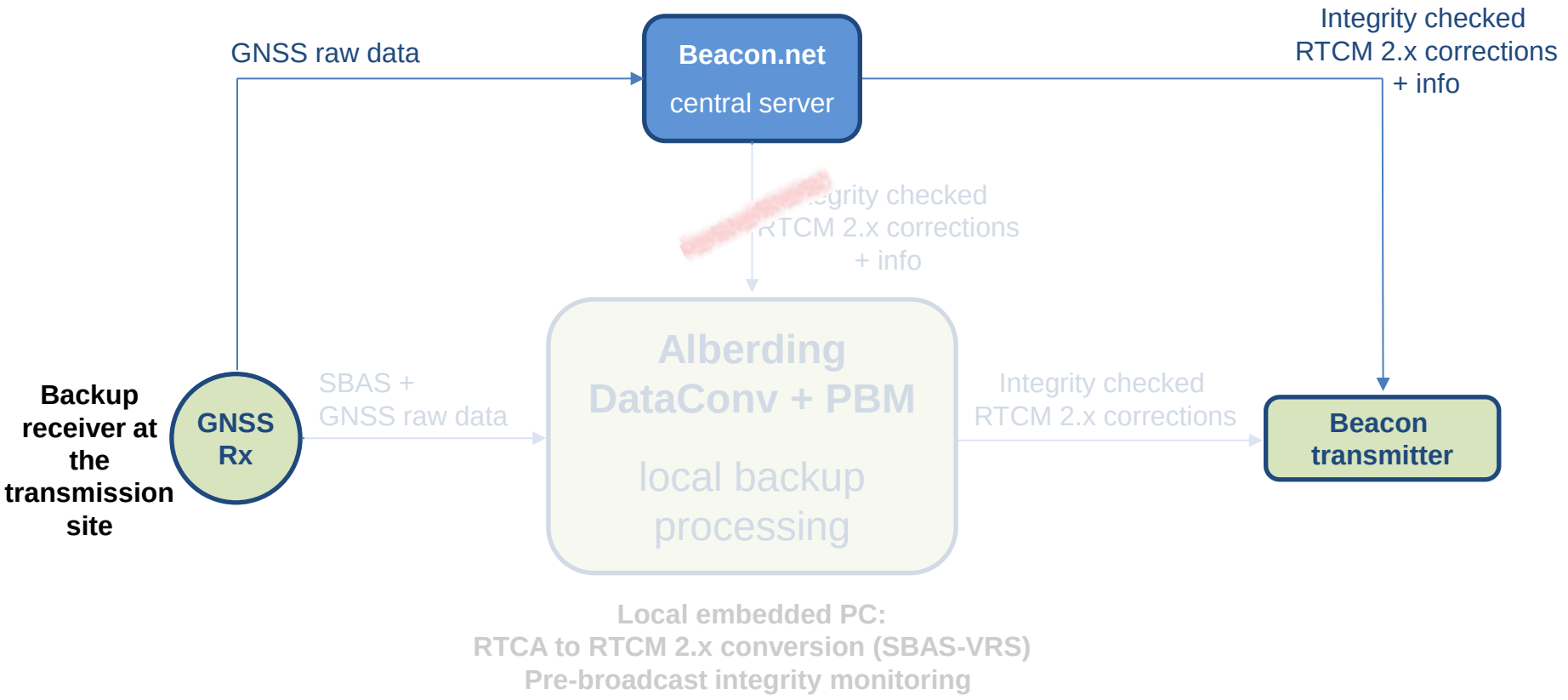
Hybrid architecture - centre:



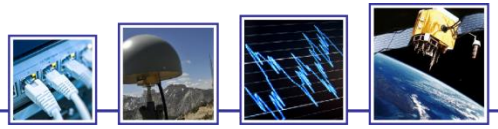
Alberding recommended solution



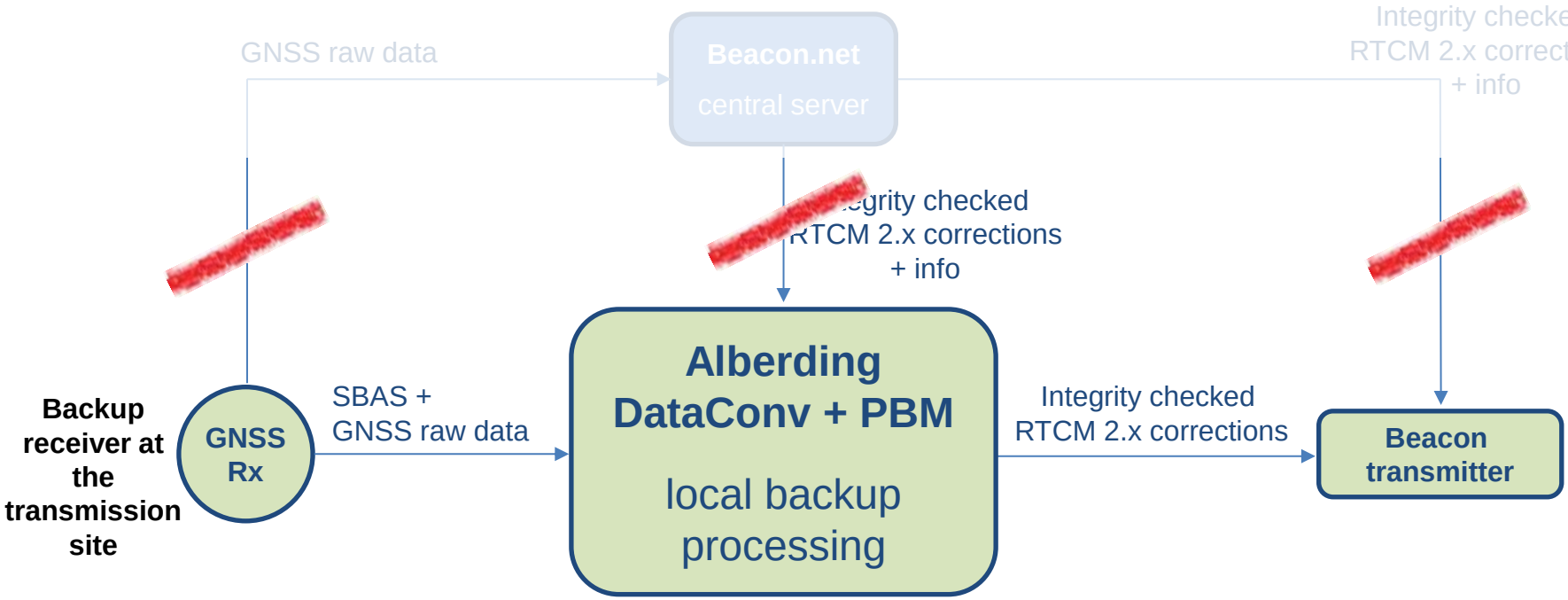
Hybrid architecture - transmission site:



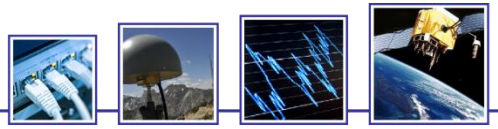
Alberding recommended solution



Hybrid architecture - transmission site:



Local embedded PC:
RTCA to RTCM 2.x conversion (SBAS-VRS)
Pre-broadcast integrity monitoring



Thank you for your attention!

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