



EGNOS SIS performance based on IMO Res. A.1046

IALA ENG8 2018



European
Global Navigation
Satellite Systems
Agency



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- SBAS Guidelines for Shipborne Receiver
- Integrity concept in the maritime domain using EGNOS SiS
- EGNOS 1046 service performance
- Maritime GNSS campaign in Norway coast
- Summary & Conclusions

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SBAS Receiver Guidelines

- SBAS Guidelines proposes the use of the following Message Types to fulfil IMO Res A.1046 performance requirements:
 - **Accuracy-related messages:**
 - Decode and apply fast corrections information (broadcast through **Message Types 2 to 5** and **24** corresponding to satellites selected by **Message Type 1**).
 - Decode and apply long-term satellite error corrections (broadcast through **Message Types 24 and 25**).
 - Decode and apply ionospheric corrections (broadcast through **Message Type 26** for ionospheric grid points defined by **Message Type 18**).
 - Apply **tropospheric error** corrections.
 - Use the SBAS satellite ranging function if available (broadcast through **Message Type 9**).

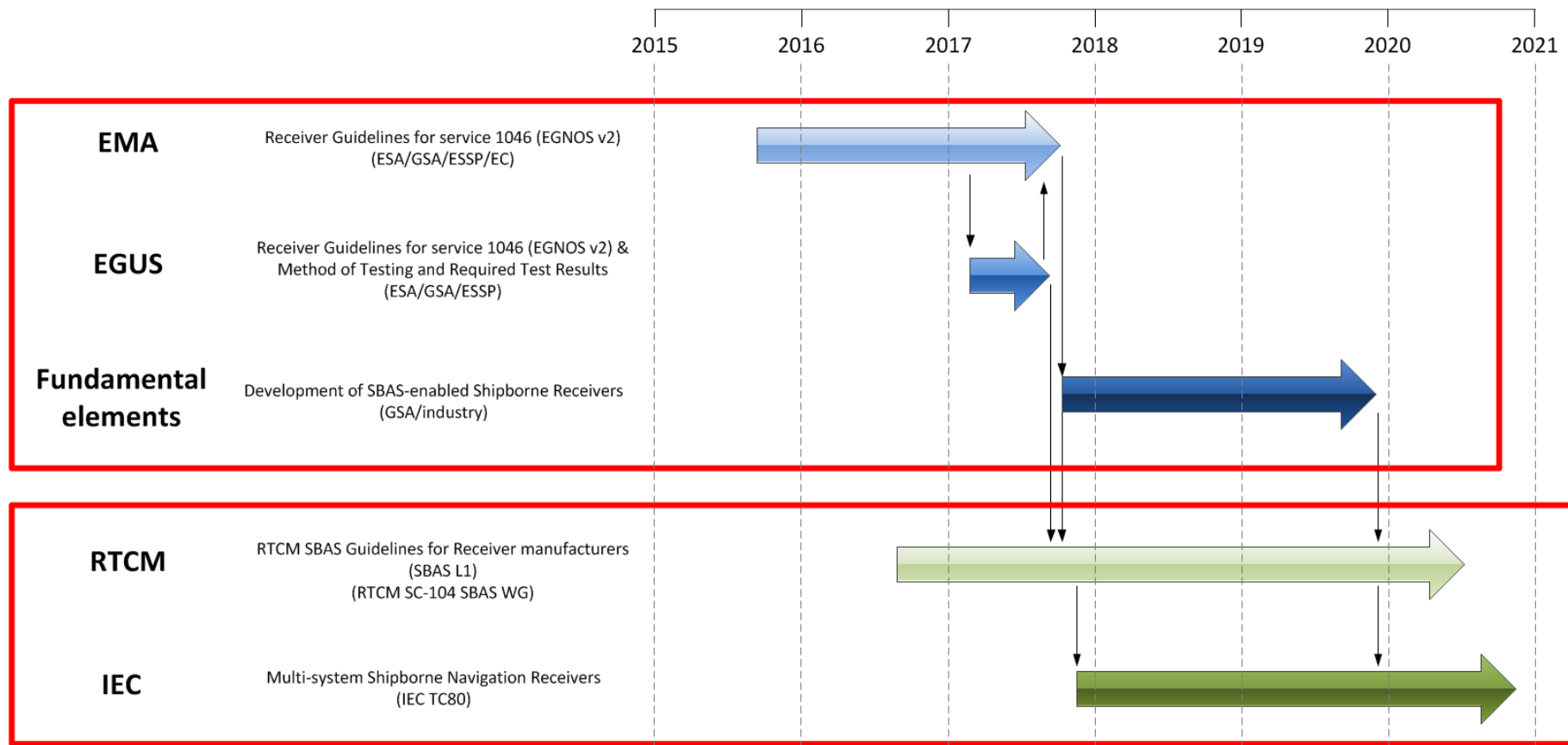
SBAS Receiver Guidelines

- **Consider major warnings broadcast by the system (Integrity-related messages):**
 - Information on the availability of the service by the system through **Message Type 0**.
 - Satellite alerts in **Message Types 2 to 6 and 24**.
 - Ionospheric alerts in **Message Type 26**.
- **Other recommended messages:**
 - Time-out intervals for the validity of the messages computed from **Message Type 7** information.
 - Almanac data from SBAS satellites broadcast through **Message Type 17**.
- **Optional messages:**
 - Degradation factors provided in **Message Type 10**.
 - **Message Types 27 and 28** to compute satellites' sigma values.

SBAS Receiver Guidelines

- **Proposed Test for manufacturers:**
 - Static accuracy
 - Static accuracy with angular movement of the antenna
 - Dynamic accuracy
 - Static availability
 - Static continuity
 - SBAS Navigation warnings and status indications
 - Use of SBAS messages
 - SBAS data input
 - Sensitivity and dynamic range
 - SBAS GEO switching

SBAS Receiver Guidelines



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Integrity concept in the maritime domain using EGNOS SiS

- EGNOS integrity concept at system level in the maritime domain has to consider at least the following:
 - The receipt of a Message type 0 will result in the cessation of the use of EGNOS for all safety applications.
 - The use of a satellite in the position solution will depend on the status indicated in the last UDREI received for a satellite:
 - If UDREI=14 or UDREI=15, the satellite is not to be used in the position solution.
 - If UDREI=12 or UDREI=13, the satellite is not to be used in the position solution because SBAS designate satellites with UDREI=12 or 13 when they are subjected to certain failure conditions. This point is to be confirmed.
 - If UDREI<12, the satellite is to be used in the position solution.

Integrity concept in the maritime domain using EGNOS SiS

- EGNOS integrity concept at system level in the maritime domain has to consider at least the following:
 - The selection of a set of IGPs to correct the ionospheric delay will be done following RTCA MOPS DO-229.
 - If $GIVEI=15$ or $GIVD=63.875\text{m}$, the IGP is not to be used for the computation of the ionospheric error.
 - The use of EGNOS safety of life will be restricted to maritime users within the EGNOS maritime service area. This area will have to be specified in a Service Definition Document (SDD).

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IMO Res A.1046 (27) Operational Requirements

Maritime operational requirements on IMO A.1046 (27)

| | Horizontal Accuracy 95% | Signal availability | Service continuity (over 15min) | Position update rate | Integrity warnings ¹ | System coverage |
|--|----------------------------|---------------------|------------------------------------|----------------------|---------------------------------|-----------------------|
| Ocean waters | 100m | 99.8% | - | 2s | MSI as soon as practicable | Adequate ² |
| Harbour entrances, harbour approaches and coastal waters | 10m | 99.8% | 99.97% | 2s | 10s | Adequate ² |

¹Generation of integrity warnings in cases of system malfunctions, non-availability or discontinuities.

²Taking into account the radio frequency environment, the coverage of the system should be adequate to provide position-fixing throughout this phase of navigation.

Scenario configuration

- Configuration:
 - PA algorithms as defined in MOPS DO-229
 - No alarm limits used
 - Elevation angle mask: **7.5°**
 - Receiver model: in line with **Draft Guidelines for Manufacturers for the Implementation of SBAS in Shipborne Receivers**
 - **MT used:** 0, 1, 2-5, 6, 7, 9, 10, 17, 18, 24, 25, 26, 27
 - No local effects: **only SiS SBAS messages** used (no pseudorange analysis)
- Data:
 - 26 months period: from **1-May-2016** to **30-June-2018**

EGNOS 1046 Performance parameters

Signal availability

- **Signal Availability**

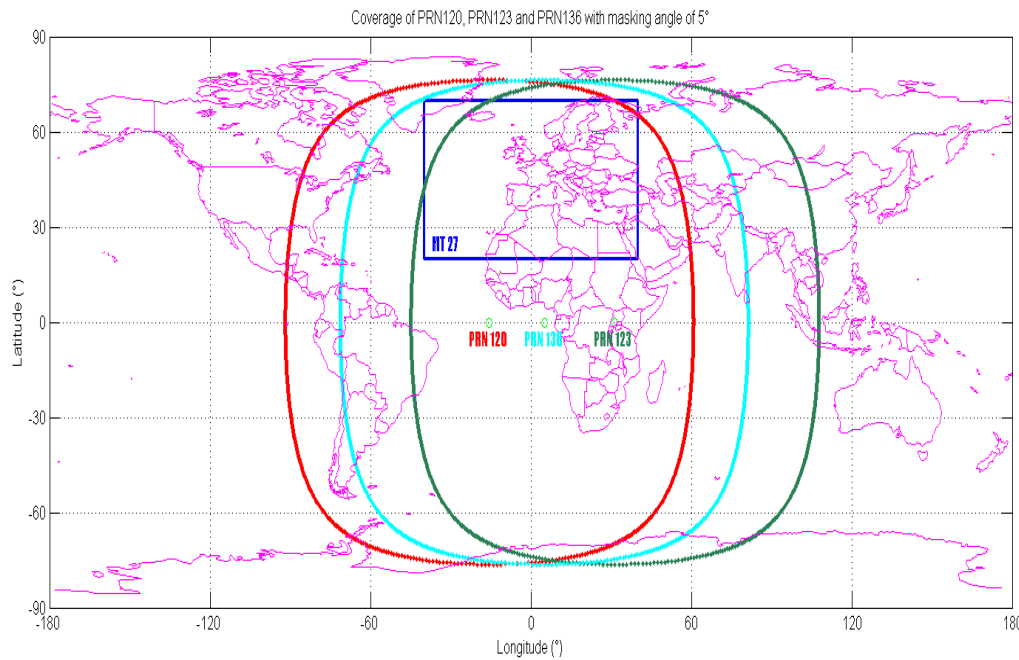
- Signal availability is given, if the radio reception of the signal is ensured in the specified system coverage and if **the signal is provided according to its specification.**
- EGNOS Signal availability is the **percentage of time** the EGNOS SiS is provided according to RTCA messages.
- EGNOS signal unavailability happens when there is a **simultaneous SiS outage** in both EGNOS GEOs.

EGNOS 1046 Performance parameters

Signal availability

- **Signal Availability**

- EGNOS receivers are capable of instantaneous **GEO switching** without impacting the user.



Broadcast at least one EGNOS
GEO satellite
(PRN120 or 123/136):

100%



EGNOS 1046 Performance parameters

Position update rate

- **Position Update Rate**

- Receivers using, at least, Message Type 1, 2, 3, 4, 5, 6, 7, 10, 18, 24, 25 and 26 are capable of an update rate of 1s of the computed position.

The compliance to this parameter shall be demonstrated by the receiver/equipment manufacturers.



EGNOS 1046 Performance parameters

Integrity warnings

- **Integrity Warnings**

- EGNOS provides timely integrity alarms in less than 6s after the trigger event to GPS satellites at pseudorange level and ionospheric corrections.



EGNOS 1046 Performance parameters

Horizontal Accuracy 95%

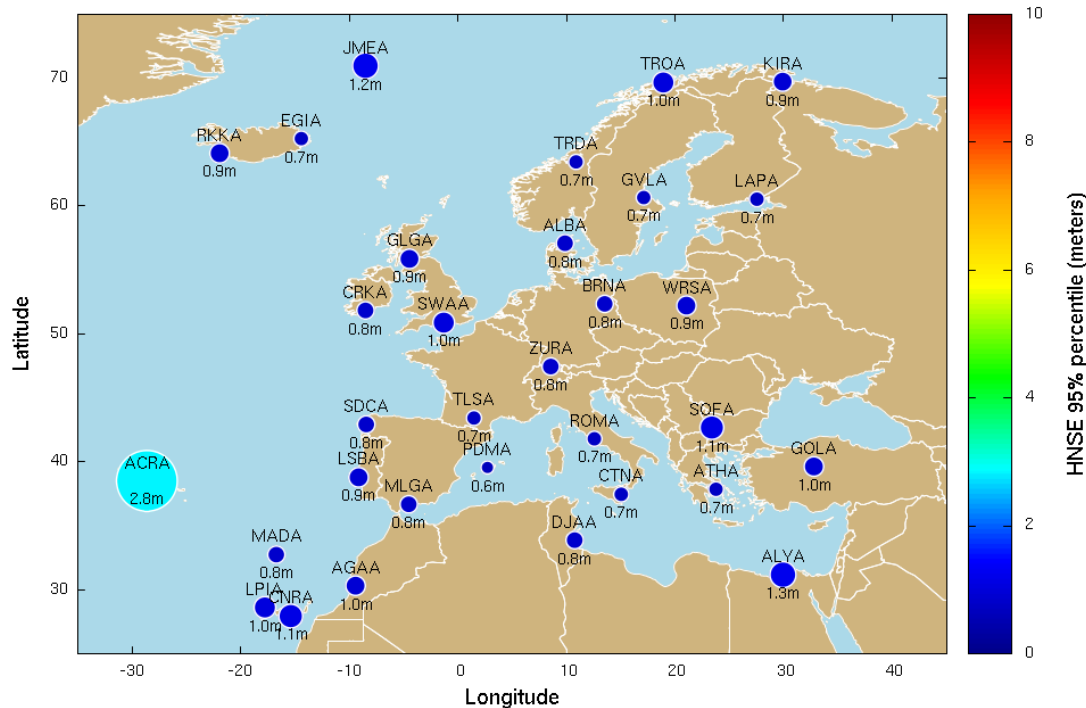
- **Horizontal accuracy error/probability**
 - Horizontal Accuracy 95% is the 95% percentile of the Horizontal Position Error (HPE) distribution. HPE is the 2D radial error of the instantaneous position respect to the true position.

EGNOS 1046 Performance parameters

Horizontal Accuracy 95%

- Horizontal accuracy error/probability

Accuracy - 95th percentile for HNSE
01.05.2016 - 30.06.2018



Horizontal Accuracy 95%:

< 3m



EGNOS 1046 Performance parameters

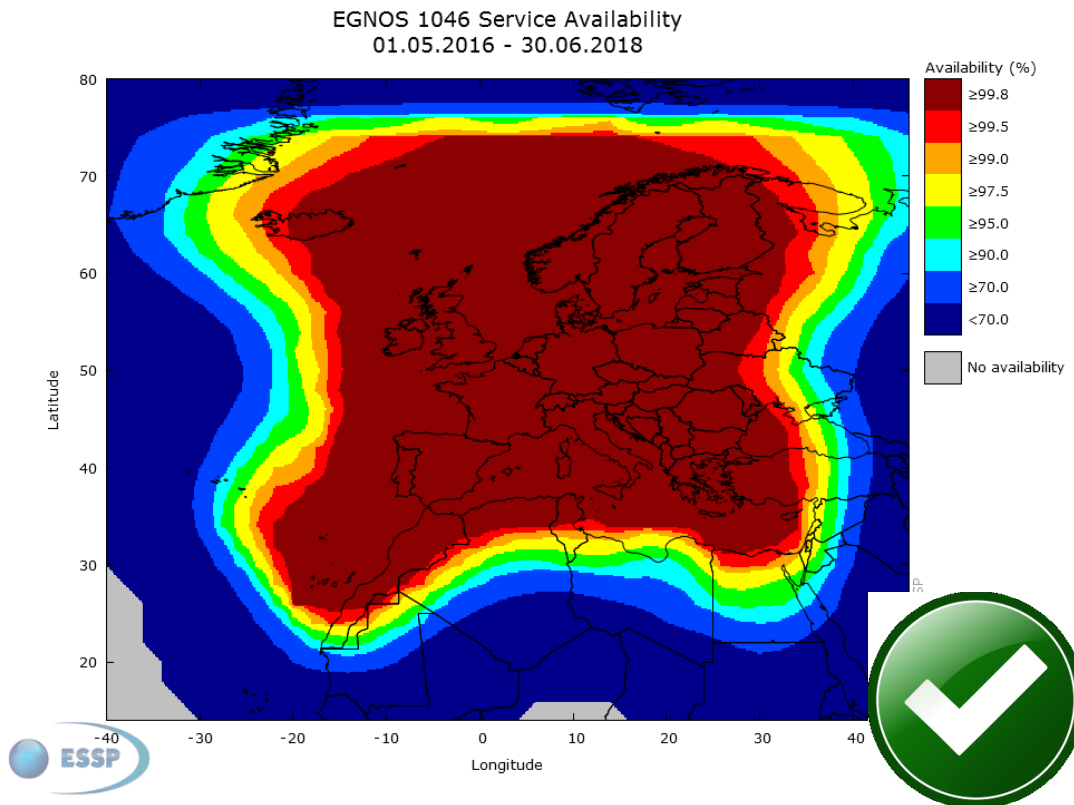
Service Availability

- **Service Availability (additional parameter)**
 - The Service Availability is the percentage of time a user is able to compute a position based on EGNOS.
 - By analogy with Signal Availability requirement and taking into account the IALA Guidelines 1112 on the interpretation of this parameter, a requirement of 99.8% of the time for the Service Availability will assure a very high performance for EGNOS 1046 users.

EGNOS 1046 Performance parameters

Service Availability

- Service Availability (additional parameter)



EGNOS 1046 Performance parameters

Service Continuity

- **Service Continuity**

- The Service Continuity is the probability that a lack of position-fixing event will start during the Continuity Time Interval (CTI). The CTI is 15 min.
- Service Continuity is calculated using combined GEOs as the GEO switching is done immediately by EGNOS receivers.
- Service Continuity is mathematically calculated as:
 - $\text{Service Continuity} = 1 - \text{CTI}/\text{MTBF}$
 - CTI is 15 min. MTBF is the “Mean Time Between Failures” over a period of two years.

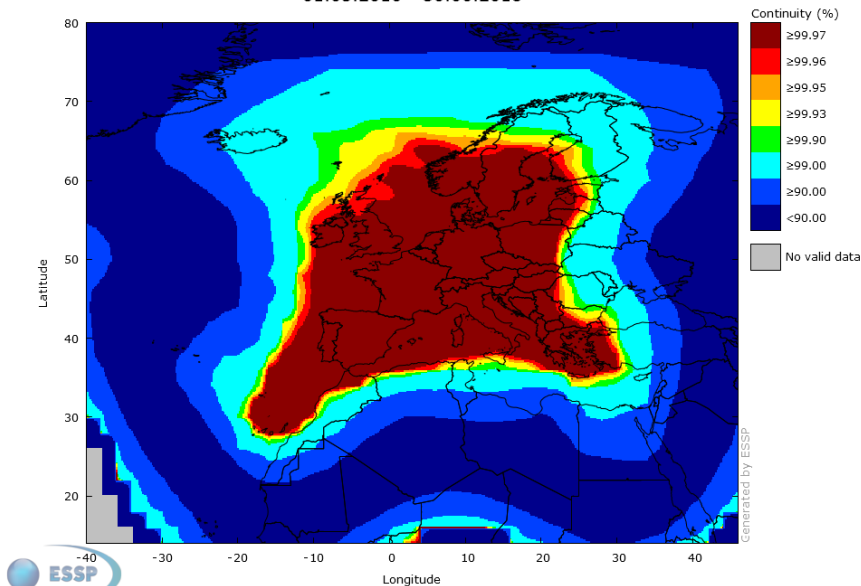
EGNOS 1046 Performance parameters

Service Continuity

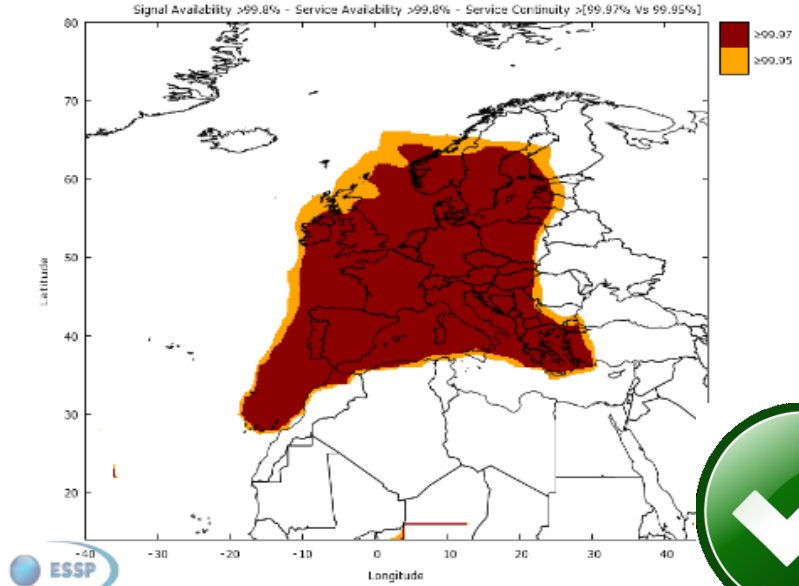
- **Service Continuity**

- The Service Continuity requirement is only for harbour entrances, harbour approaches and coastal waters surrounding Europe.

EGNOS 1046 Service Continuity
01.05.2016 - 30.06.2018



EGNOS 1046 Service Coverage
01.05.2016 - 30.06.2018



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Maritime SBAS Service: EGNOS 1046

Service Coverage

- **Service Coverage**

- Service coverage is a designated geographical area where the coverage of the system should be adequate to provide position-fixing throughout a phase of navigation.

**OCEAN
WATERS**

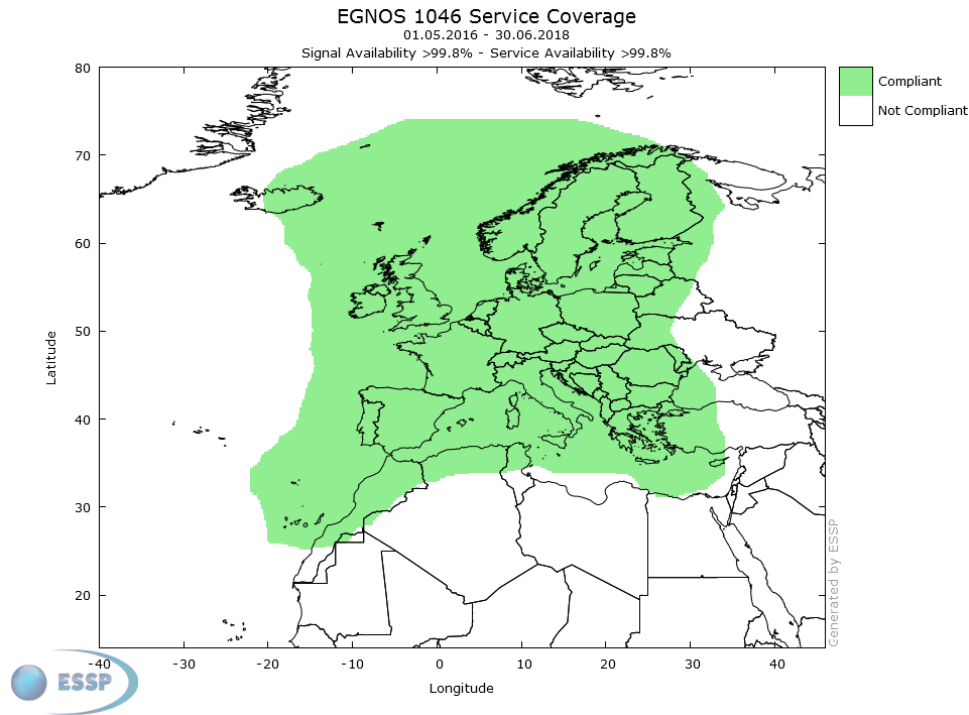
**Signal Availability
Service Availability
Horizontal Accuracy 95%
Position update rate**

**Time To Alarm
Service Continuity**

**HARBOUR
ENTRANCES,
HARBOUR
APPROACHES
AND
COASTAL
WATERS**

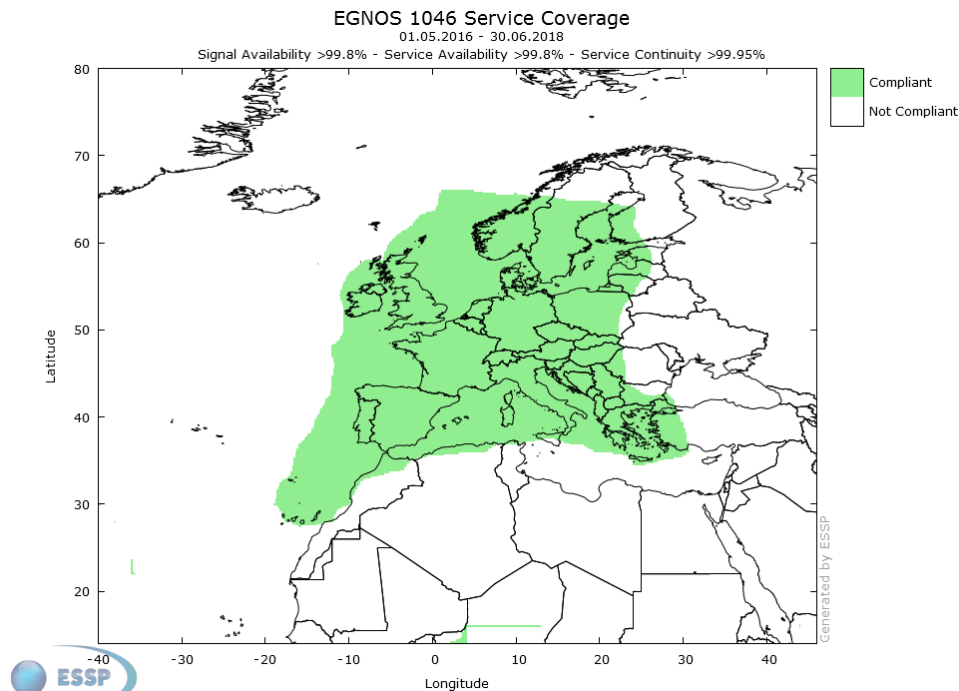
Maritime SBAS Service: EGNOS 1046 Service Coverage

- Service Coverage
 - Service coverage for **ocean waters**:



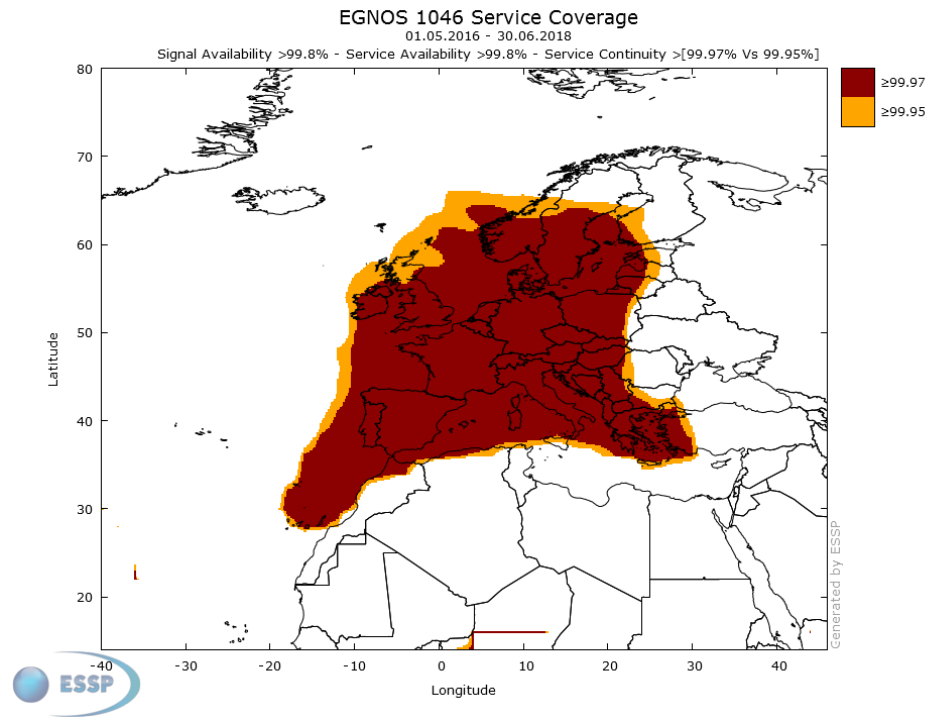
Maritime SBAS Service: EGNOS 1046 Service Coverage

- **Service Coverage**
 - Service coverage for **harbour entrances, harbour approaches and coastal waters:**



Maritime SBAS Service: EGNOS 1046 Service Coverage

- Service Coverage
 - Service Continuity >99.97% vs. with Service Continuity >99.95%



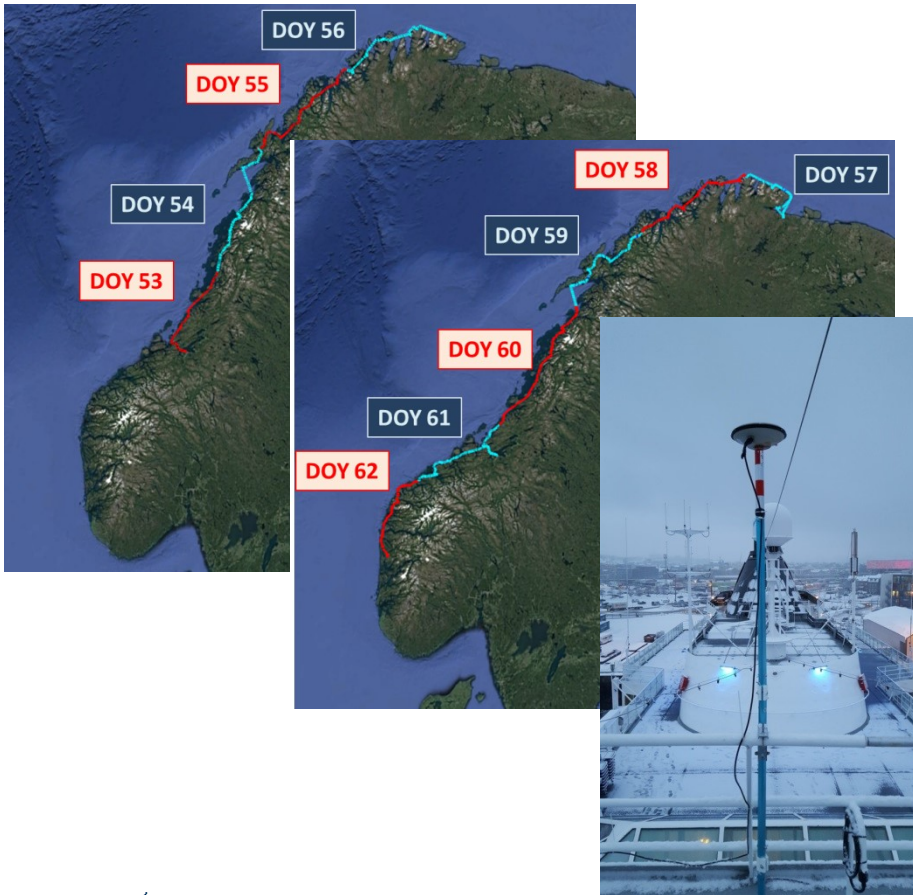
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Maritime GNSS campaign in Norway coast

- Route:
 - In the northbound, the vessel departed from Trondheim to Kirkenes.
 - The southbound was from Kirkenes to Bergen.
- Dates:
 - Departure from Trondheim: 22/02/2018
 - Arrival to and departure from Kirkenes: 26/02/2018
 - Arrival to Bergen: 03/03/2018
- Vessel: MS Finnmarken (more information in <https://www.hurtigruten.co.uk/our-ships/ms-finnmarken/>)

Maritime GNSS campaign in Norway coast

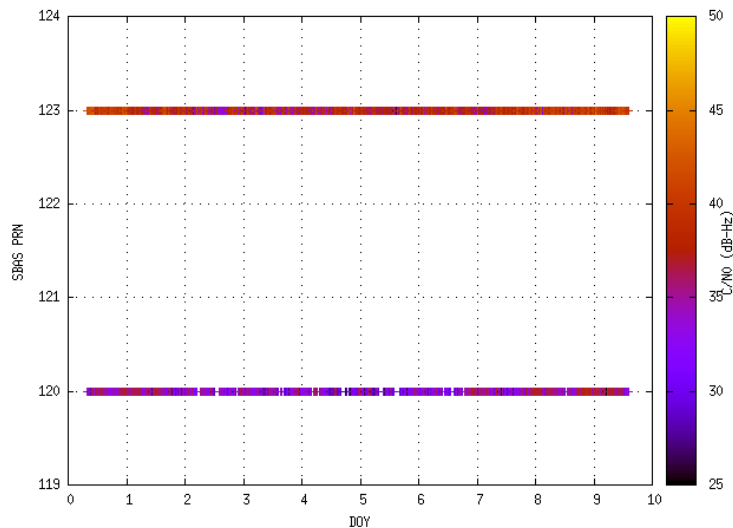


- GNSS multi-frequency Receiver with the following capability:
 - GPS L1/L2/L5
 - SBAS
- GNSS Antenna L1/L2/L5
- L1 RF Recorder



Maritime GNSS campaign in Norway coast

- EGNOS SIS availability
 - Broadcast at least one EGNOS GEO satellite: **100%**
 - At receiver level → % time SBAS PRN is tracked by the receiver

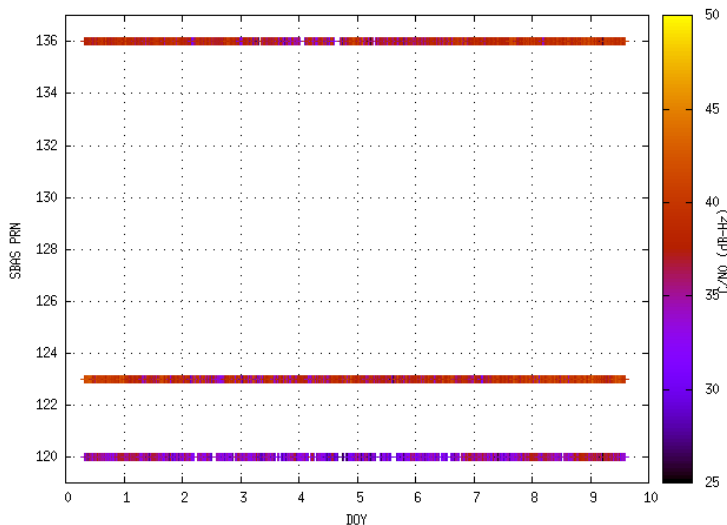


PRN123 tracked: 96.78%

PRN120 tracked: 73.34%

Maritime GNSS campaign in Norway coast

- EGNOS SIS availability
 - Broadcast at least one EGNOS GEO satellite: **100%**
 - At receiver level → % time SBAS PRN is tracked by the receiver



PRN136 tracked: 93.02%

PRN123 tracked: 96.78%

PRN120 tracked: 73.34%

Broadcast at least one
EGNOS GEO satellite

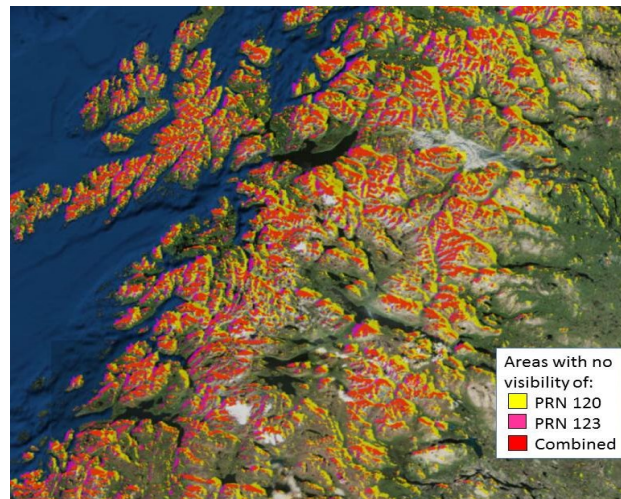
PRN120 or 123: 98.89%

PRN123 or 136: 99.34%

New Operational EGNOS GEO
satellite (PRN136 replaced
PRN120) improves the EGNOS SIS
visibility in this area.

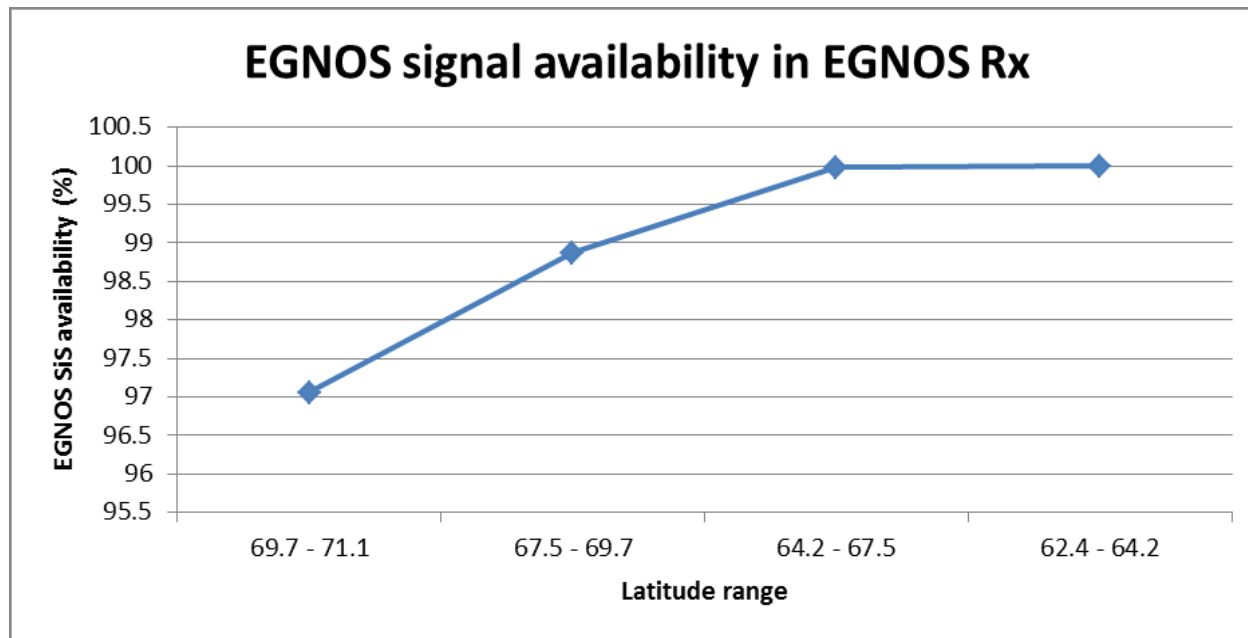
Maritime GNSS campaign in Norway coast

- EGNOS SIS availability
 - Broadcast at least one EGNOS GEO satellite: **100%**
 - At receiver level → % time SBAS PRN is tracked by the receiver
 - PRN120 or 123: 98.89% PRN123 or 136: 99.34%
 - The lack of EGNOS signal at the receiver → the orography



Maritime GNSS campaign in Norway coast

- EGNOS SIS availability



EGNOS signal in space availability in function of latitude obtained from EGNOS Rx

Maritime GNSS campaign in Norway coast

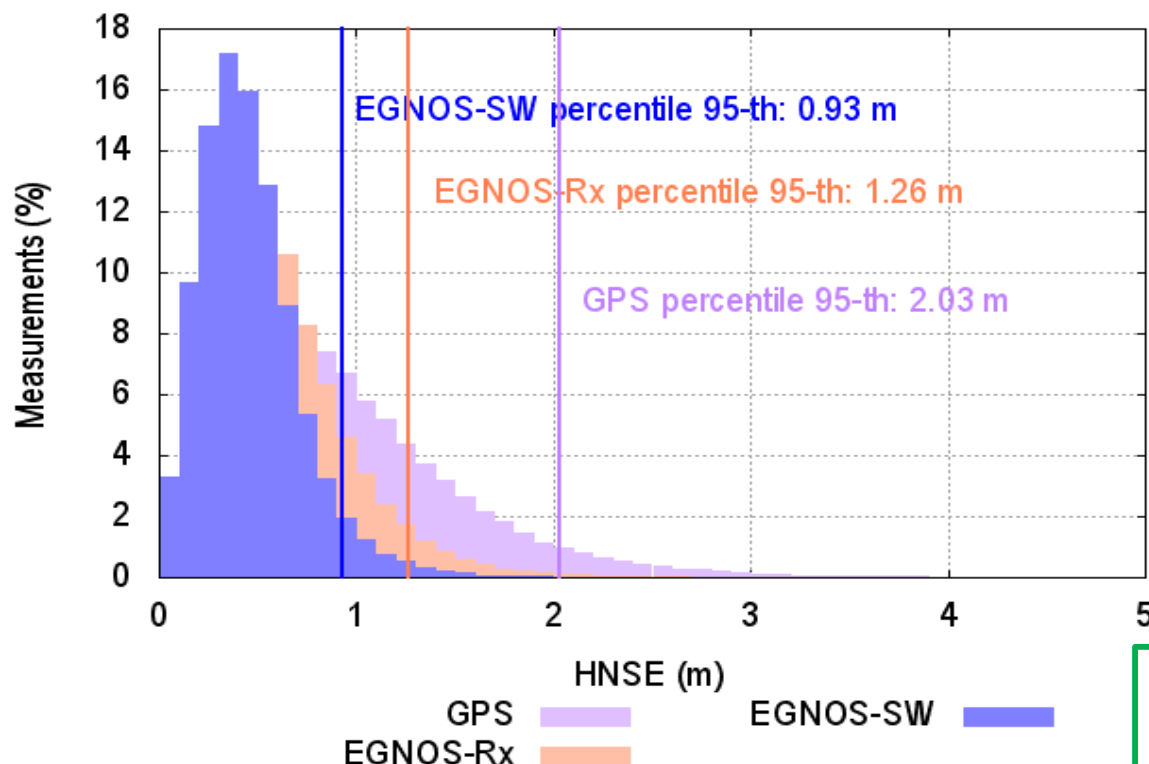
- EGNOS SIS accuracy

| DOY | EGNOS Rx | EGNOS SW | GPS |
|-----|----------|----------|------|
| 53 | 1.24 | 1.14 | 2.08 |
| 54 | 1.21 | 0.95 | 2.00 |
| 55 | 1.41 | 1.03 | 2.09 |
| 56 | 1.30 | 0.92 | 1.87 |
| 57 | 1.23 | 0.97 | 1.87 |
| 58 | 1.44 | 0.96 | 2.00 |
| 59 | 1.23 | 0.89 | 2.05 |
| 60 | 1.18 | 0.89 | 2.05 |
| 61 | 1.14 | 0.80 | 2.36 |
| 62 | 1.11 | 0.76 | 1.87 |

- **EGNOS SW:** compliant with SBAS Guidelines for Shipborne Receiver
- **EGNOS Rx:** commercial receiver compatible with SBAS
- **GPS:** GPS standalone receiver

Maritime GNSS campaign in Norway coast

- EGNOS SIS accuracy



- EGNOS SW:** compliant with SBAS Guidelines for Shipborne Receiver.
- EGNOS Rx:** commercial receiver compatible with SBAS
- GPS:** GPS standalone receiver

Accuracy with EGNOS is increased with respect to GPS

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Summary & Conclusions

- Guidelines for Manufacturers for the Implementation of SBAS in Shipborne Receivers including Methods of Testing and Required Test Results was developed.
- Integrity concept for the use of EGNOS v2 in maritime defined and presented in EMRF and RTCM.
- The EGNOS Service Coverage areas over Europe for “harbour entrances/approaches” and “ocean waters” meeting the requirements of in IMO Resolution A.1046 (27) were presented.

Summary & Conclusions

- A GNSS campaign was done in Norway coast:
 - The **EGNOS signal in space availability** was 100% during the whole period. Some lack of EGNOS signal at receiver due to orography.
 - EGNOS provides **better accuracy** performance than GPS Standalone.
 - Accuracy figures are degraded between 30% and 50% in GPS standalone.
- The work presented in this paper are intended to support the integration of SBAS in the standardization process for maritime navigation and radiocommunication equipment and systems IEC 61108.



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Corporate Video

THANK YOU!

BACK-UP slides

- Horizontal accuracy error/probability

| Station | H. Accuracy 95% (m) | Station | H. Accuracy 95% (m) | Station | H. Accuracy 95% (m) |
|-------------|------------------------|-----------------|------------------------|-------------------|------------------------|
| Aalborg | 0.8 | Sofia | 1.1 | Palma de Mallorca | 0.6 |
| Berlin | 0.8 | Gävle | 0.7 | Reykjavik | 0.9 |
| Catania | 0.7 | Toulouse | 0.7 | Roma | 0.7 |
| Cork | 0.8 | Trondheim | 0.7 | Lappeenranta | 0.7 |
| Warsaw | 0.9 | Tromsø | 1.0 | Santiago de C. | 0.8 |
| Djerba | 0.8 | Zürich | 0.8 | Longyearbyen | 2.1 |
| Egilsstadir | 0.7 | Jan Mayen | 1.2 | Abu Simbel | 2.5 |
| Glasgow | 0.9 | Athens | 0.7 | Alexandria | 1.2 |
| Lisbon | 0.9 | Agadir | 0.9 | Golbasi | 0.9 |
| Swanwick | 1.0 | Canary Island | 1.1 | Kirkenes | 0.9 |
| Madeira | 0.8 | La Palma Island | 1.0 | | |
| Málaga | 0.8 | Azores | 2.8 | | |

BACK-UP slides

- EGNOS availability at Receiver

| DOY | EGNOS SiS tracked (PRN 120 or 123) | EGNOS PVT solution | EGNOS PVT vs EGNOS SiS tracked |
|-----|------------------------------------|--------------------|--------------------------------|
| 54 | 86077 | 85883 | 99.77% |
| 55 | 84913 | 84708 | 99.76% |
| 56 | 84063 | 83446 | 99.27% |
| 57 | 85681 | 85657 | 99.97% |
| 58 | 83854 | 83119 | 99.12% |
| 59 | 85422 | 85084 | 99.60% |
| 60 | 86382 | 86380 | 100.00% |
| 61 | 86400 | 86398 | 100.00% |