

# LORAN/EUROFIX/EGNOS Integration Test & Validation Programme (LOREG) - Concept and Results -

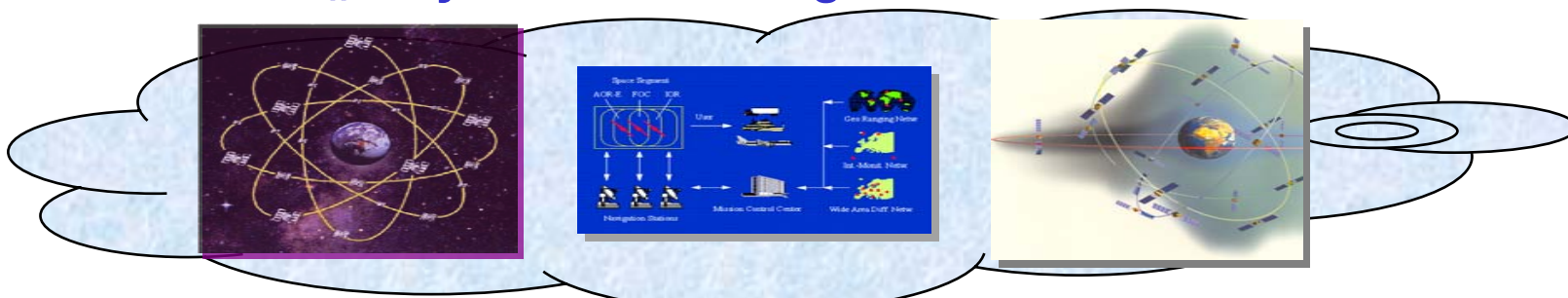
*Dr. Wolfgang Lechner  
Telematica e.K.*



## Outline

- ▶ Loran-C/Eurofix - Background Information
- ▶ NELS
- ▶ LOREG - Concept
- ▶ Extract of Results
  - Time Synchronisation
  - Positioning: Static Measurements
  - Positioning: Dynamic Measurements
  - Combined GPS/Loran-C positioning
- ▶ Conclusions

## GNSS - The „Holy Grail” of Navigation ?



## Limitations of GNSS

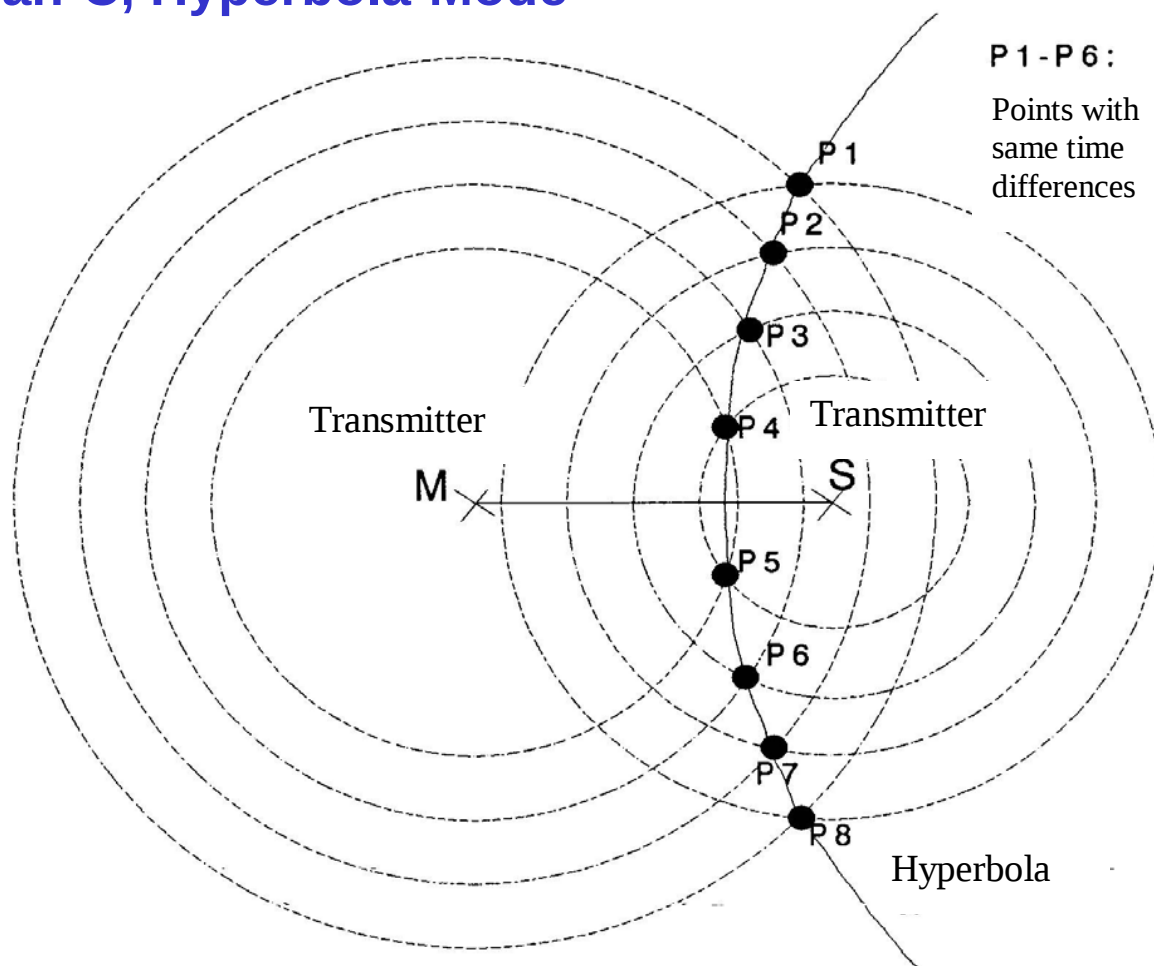
- ▶ Limited Signal Availability e.g.
  - Urban Environments
  - Vegetation Canopy
  - Mountainous Regions
  - Indoor
- ▶ Multipath-Effects
- ▶ Jamming/Spoofing
- ▶ Integrity
- ▶ System Control

## E.g. EGNOS-Visibility in Munich, Germany at 48° N

Visible  
Not Visible



## Loran-C, Hyperbola-Mode



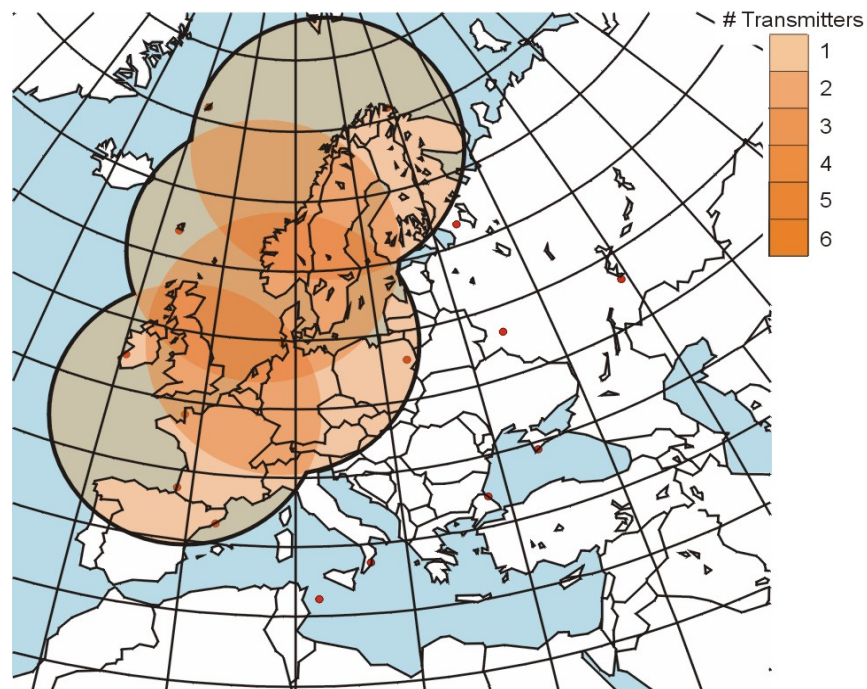
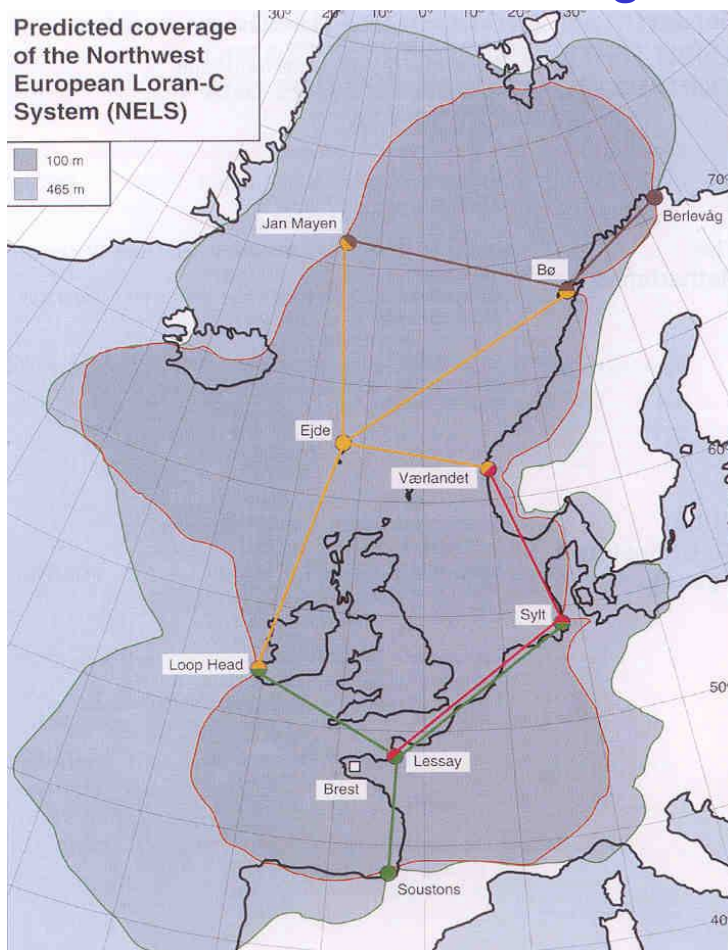
## Loran-C, TOE-Mode

|                                | Number of Satellites |              |              |              |              |              |              |
|--------------------------------|----------------------|--------------|--------------|--------------|--------------|--------------|--------------|
|                                |                      | 0            | 1            | 2            | 3            | 4            | 5+           |
| Number of Loran-C Transmitters | 0                    |              |              |              | 2D           | 3D           | 3D Integrity |
|                                | 1                    |              |              |              | 2D           | 3D           | 3D Integrity |
|                                | 2                    |              |              | 2D           | 3D           | 3D Integrity | 3D Integrity |
|                                | 3                    | 2D           | 2D           | 3D           | 3D Integrity | 3D Integrity | 3D Integrity |
|                                | 4+                   | 2D Integrity | 2D Integrity | 3D Integrity | 3D Integrity | 3D Integrity | 3D Integrity |

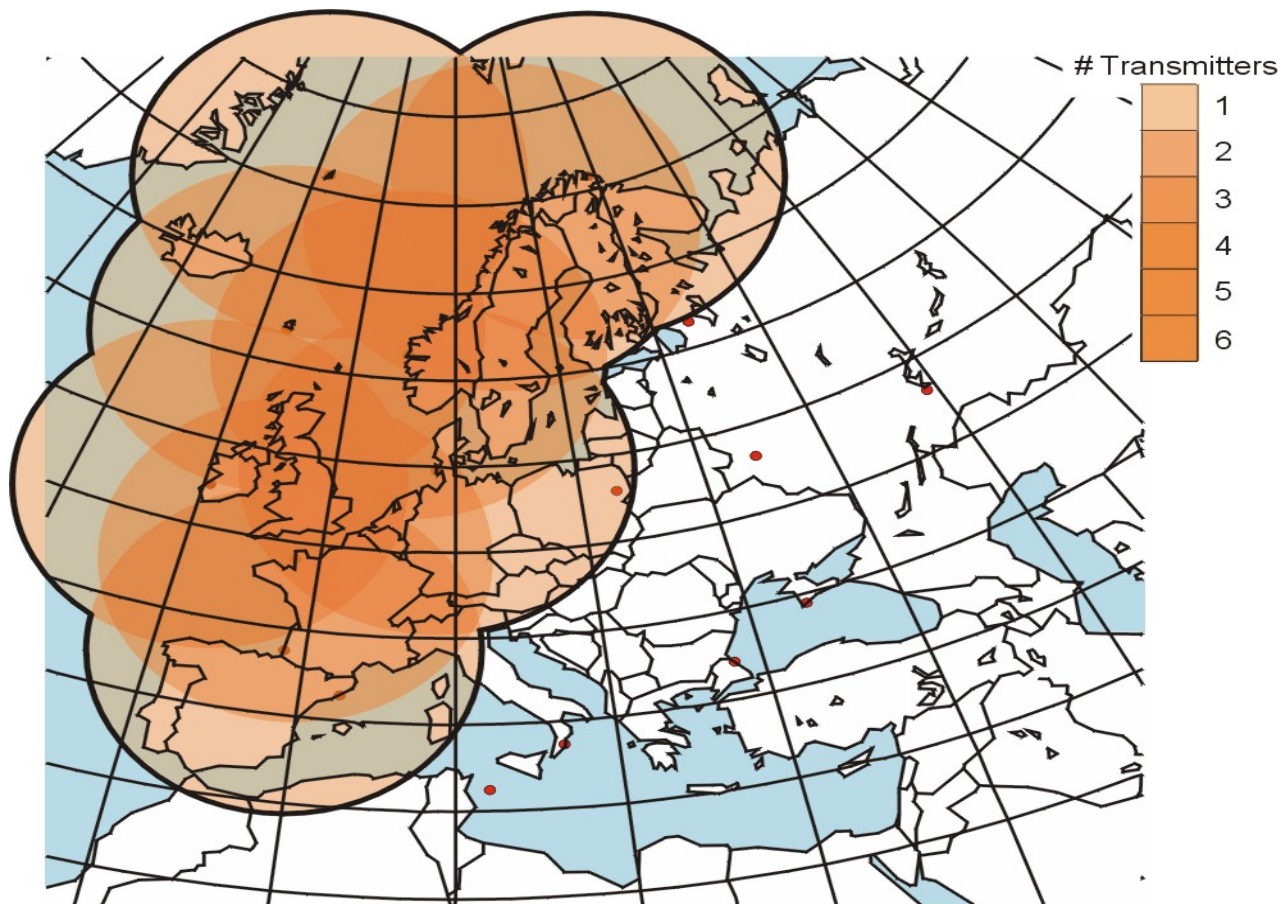
## Eurofix



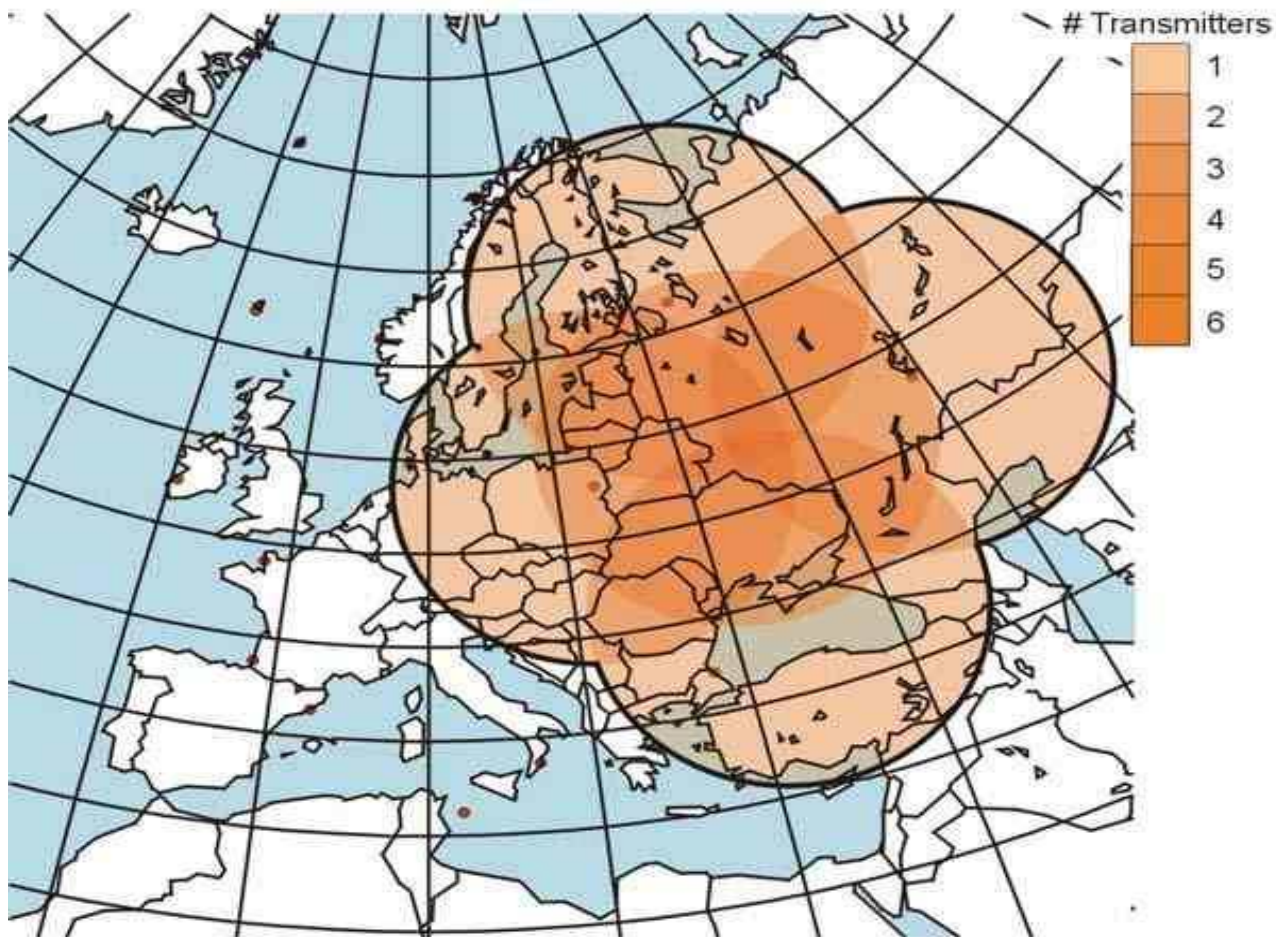
## Loran-C/Eurofix Coverage - Europe



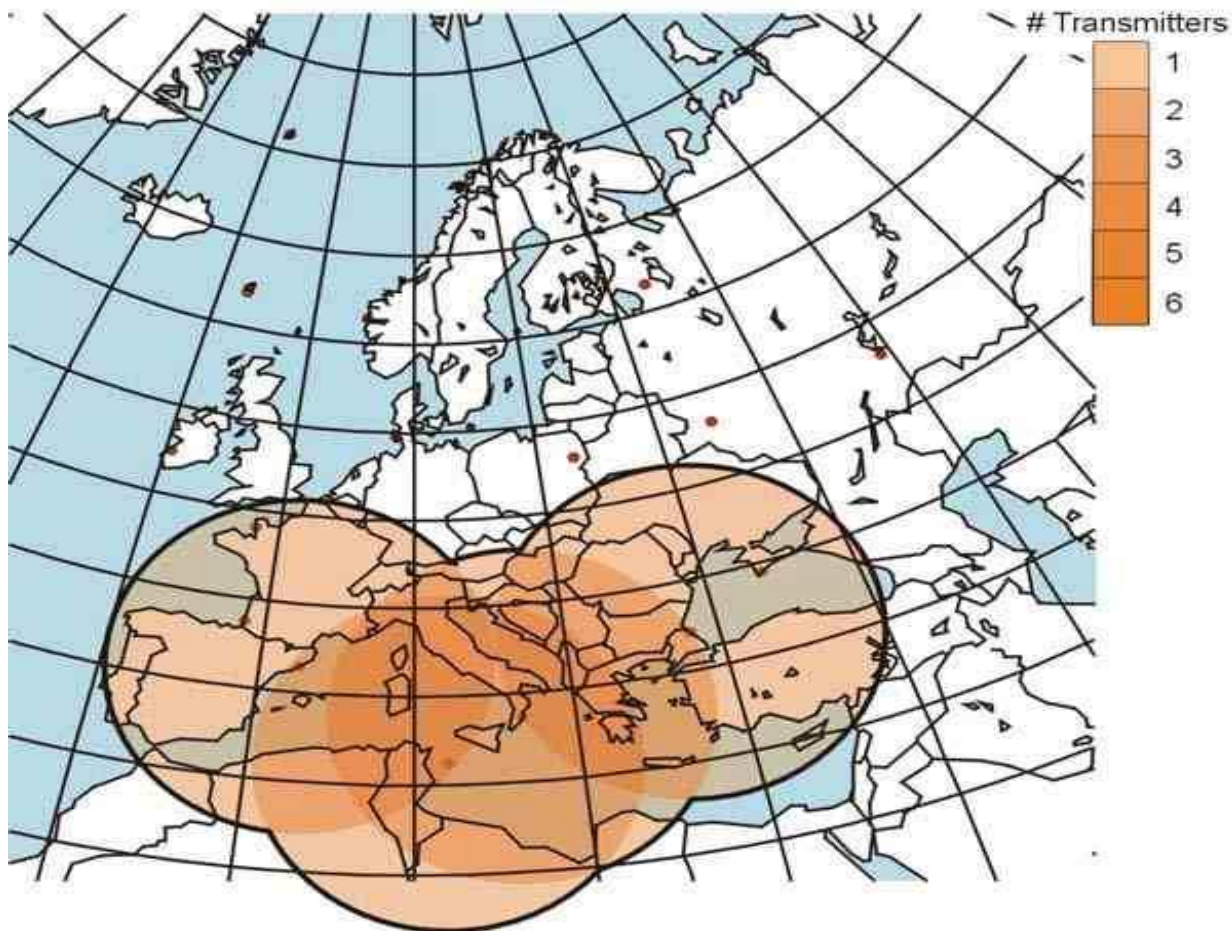
## Potential Eurofix Extension - All NELS Stations



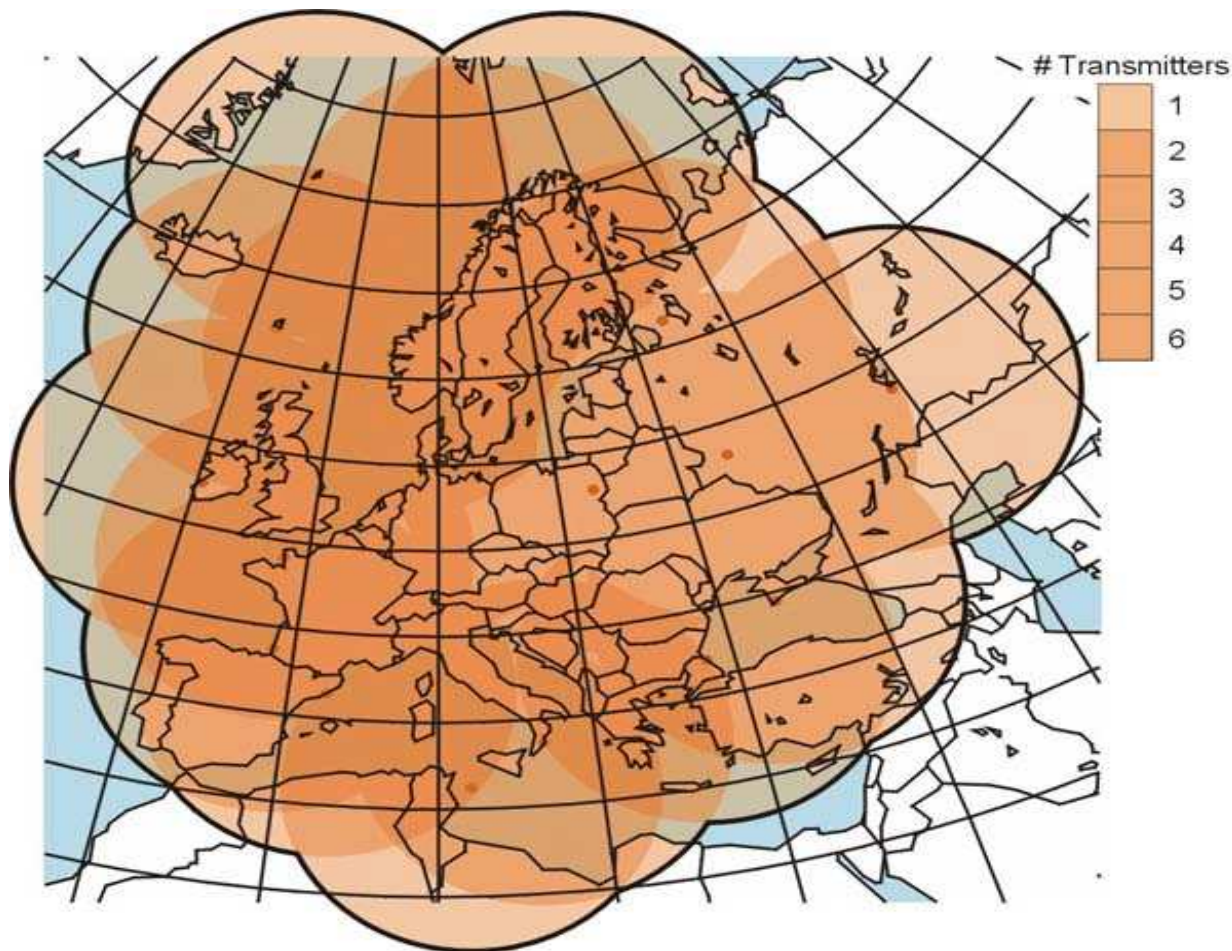
## Potential Eurofix Extension - Chayka



## Potential Eurofix Extension - SELS



## Potential Eurofix Extension – NELS, Chayka, SELS



## Global Loran-C Coverage





## NELS

### NELS members

- Denmark
- France
- Germany
- Ireland
- The Netherlands
- Norway

### NELS observers

- Austria
- Italy
- Russia
- U.K.
- USA
- AIN
- EC
- FERNS
- IALA

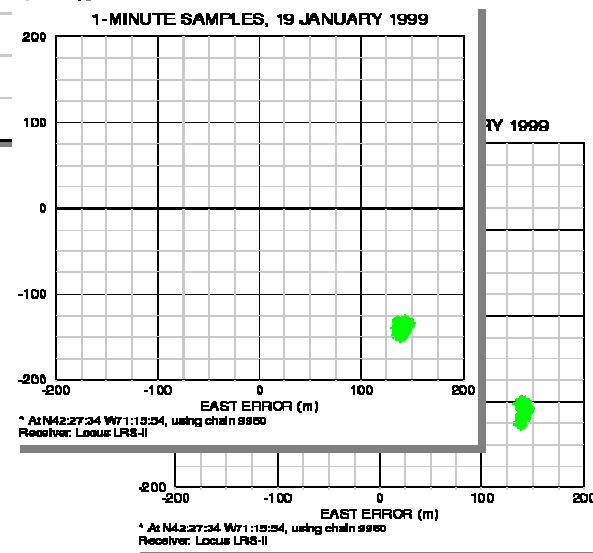
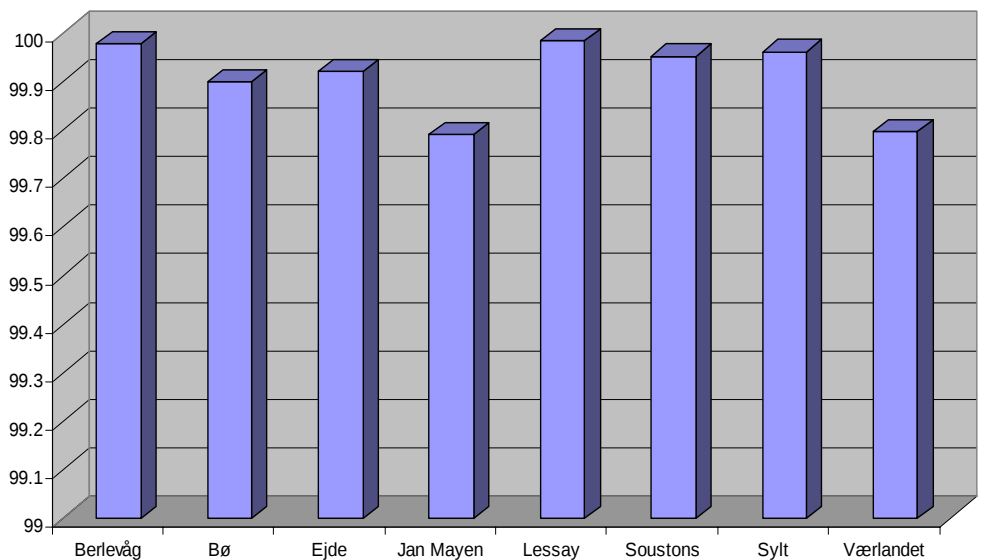
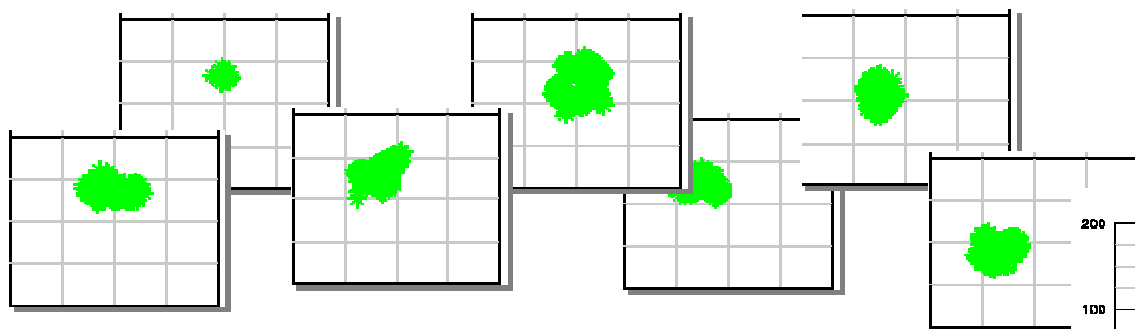
### Known interest

- Czech Republic
- Poland

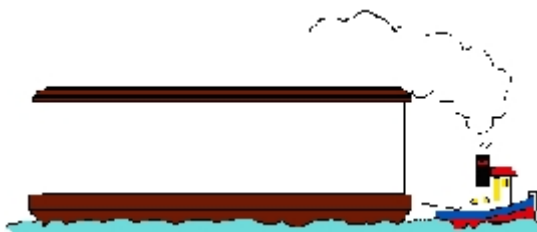
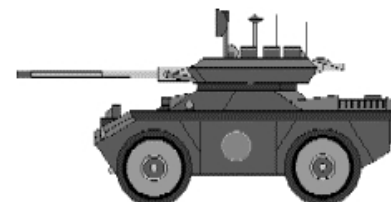
### Potential supporters

- Greece
- Hungary
- Slovakia
- Slovenia
- Switzerland

## Long Term Availability and Accuracy



## LOREG - Concept+Partners

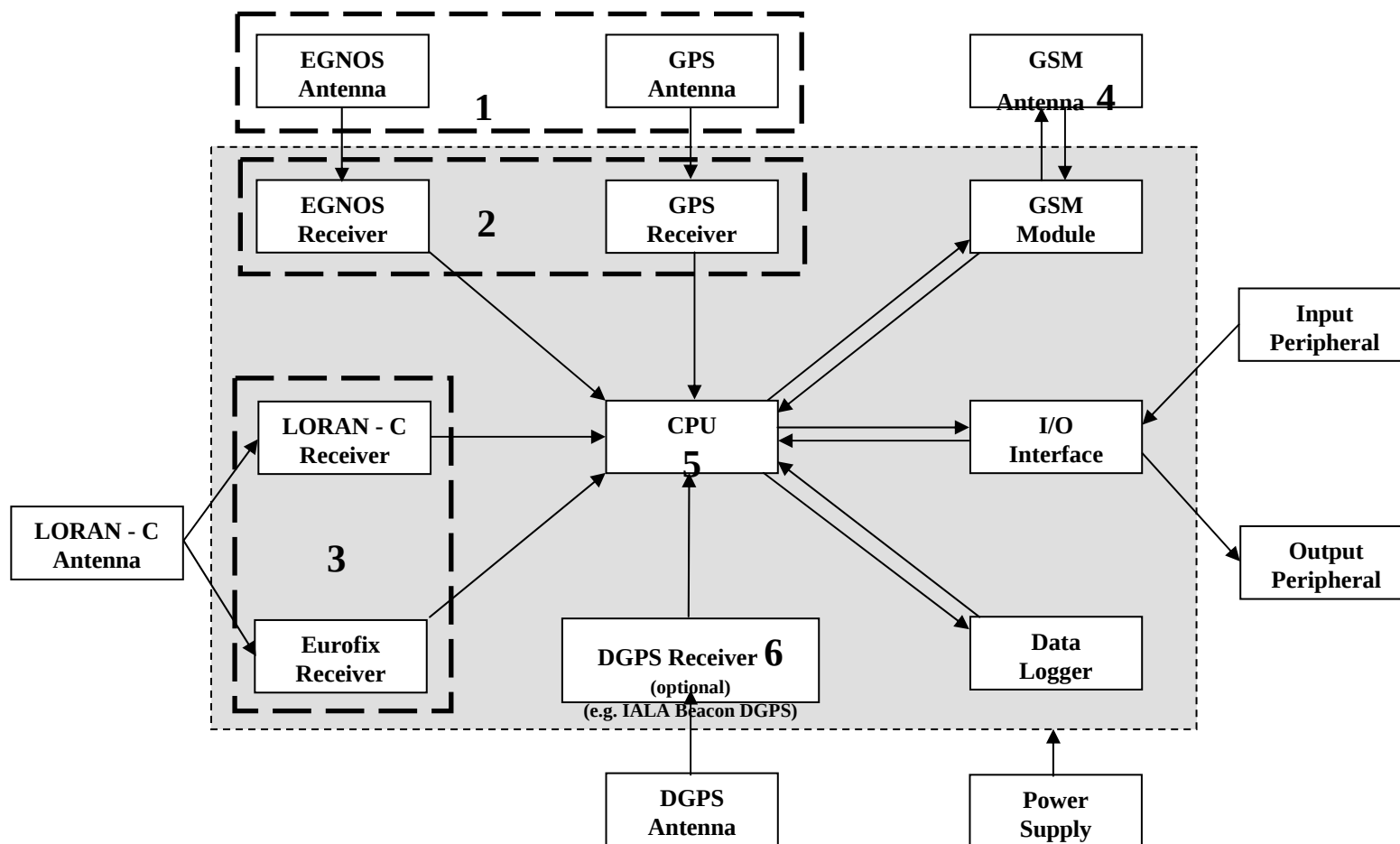




## LOREG Schedule

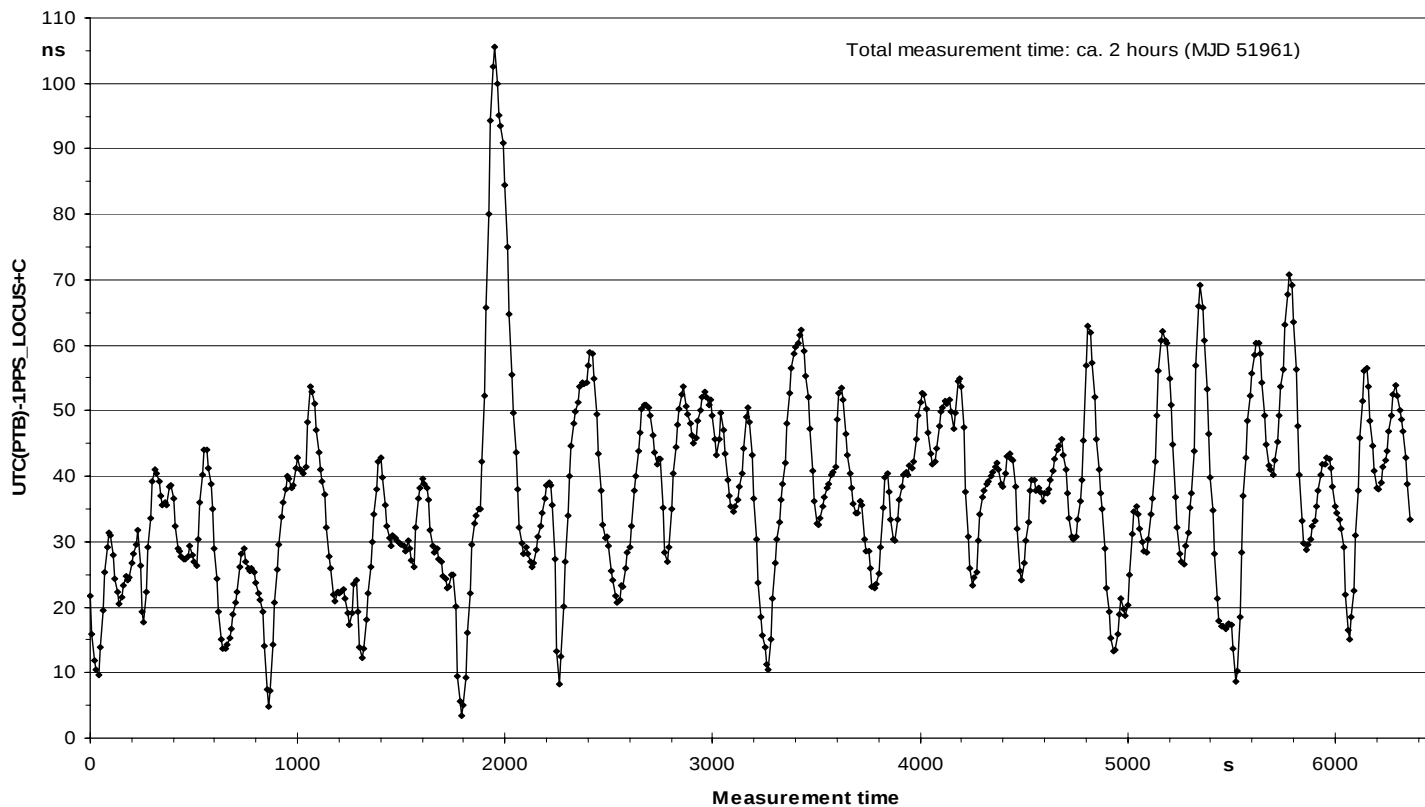
|              |                  |            |                                 |                                  |
|--------------|------------------|------------|---------------------------------|----------------------------------|
| EF 1         | Kristensen       | DLR        | IVU                             | Univ Wismar 3)                   |
| EF 2         | TUD              |            | Univ. Stuttgart                 |                                  |
| EF 3         | TU Graz          |            |                                 |                                  |
| EF 4         | Reinboth         |            | Bavarian Police 4)              | Univ. Prague                     |
| EF 5         | Univ Stuttgart   | ETHZ       |                                 |                                  |
| EF 6         | Antenna problems |            | Black Box                       |                                  |
| EF 7         |                  |            | Black Box                       |                                  |
| EF 8         |                  |            | Black Box                       |                                  |
| EF 9         |                  |            | Black Box                       |                                  |
| EF 10        | Kristensen       | Reelekttr. | NELS/CAO                        | Reelekttr. Maybe to Irish Lights |
| Satmate 1    | TUD              | Bø         |                                 |                                  |
| Satmate 2    | TU Graz          |            |                                 |                                  |
| Satmate 3    | PTB              | WSD        | TUD                             | Daimler 1) Sylt 2)               |
| Satmate 4    | SEATEX           |            | Black Box                       |                                  |
| Satmate 5    |                  |            | Black Box                       |                                  |
| Satmate 6    |                  |            | Black Box                       |                                  |
| Black Box 1  |                  |            | Seatrans                        |                                  |
| Black Box 2  |                  |            |                                 | TU Graz Datatrak                 |
| Black Box 3  |                  |            |                                 | WIFOS                            |
| Black Box 4  |                  |            | Bø/Nordtransport/Jernbaneverket |                                  |
| GeoTracker 1 |                  |            | DLR                             |                                  |
| GeoTracker 2 |                  |            | Uni Stuttgart                   |                                  |

## Black Box

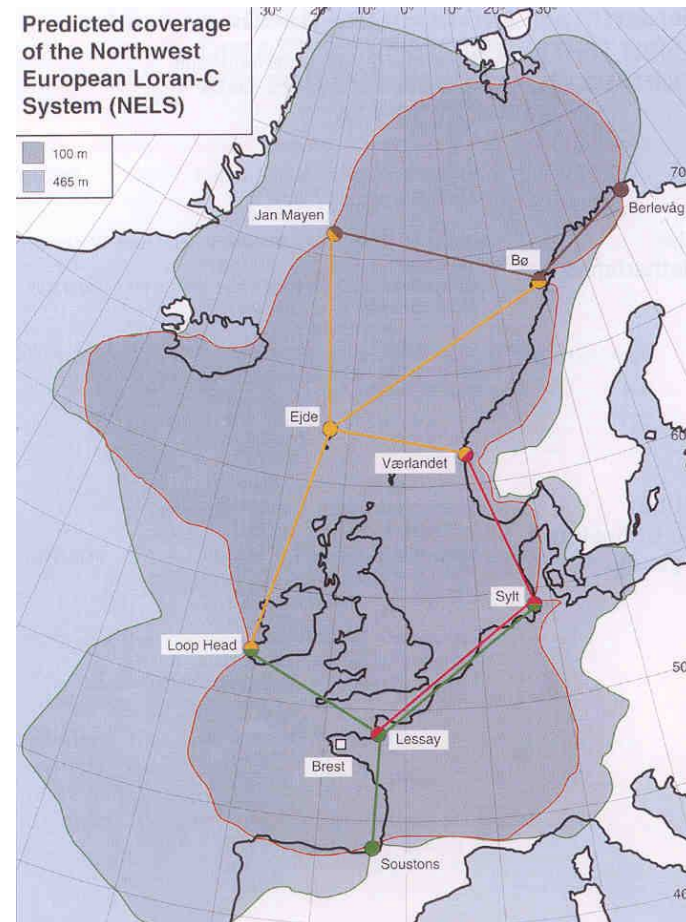


## Time Synchronisation

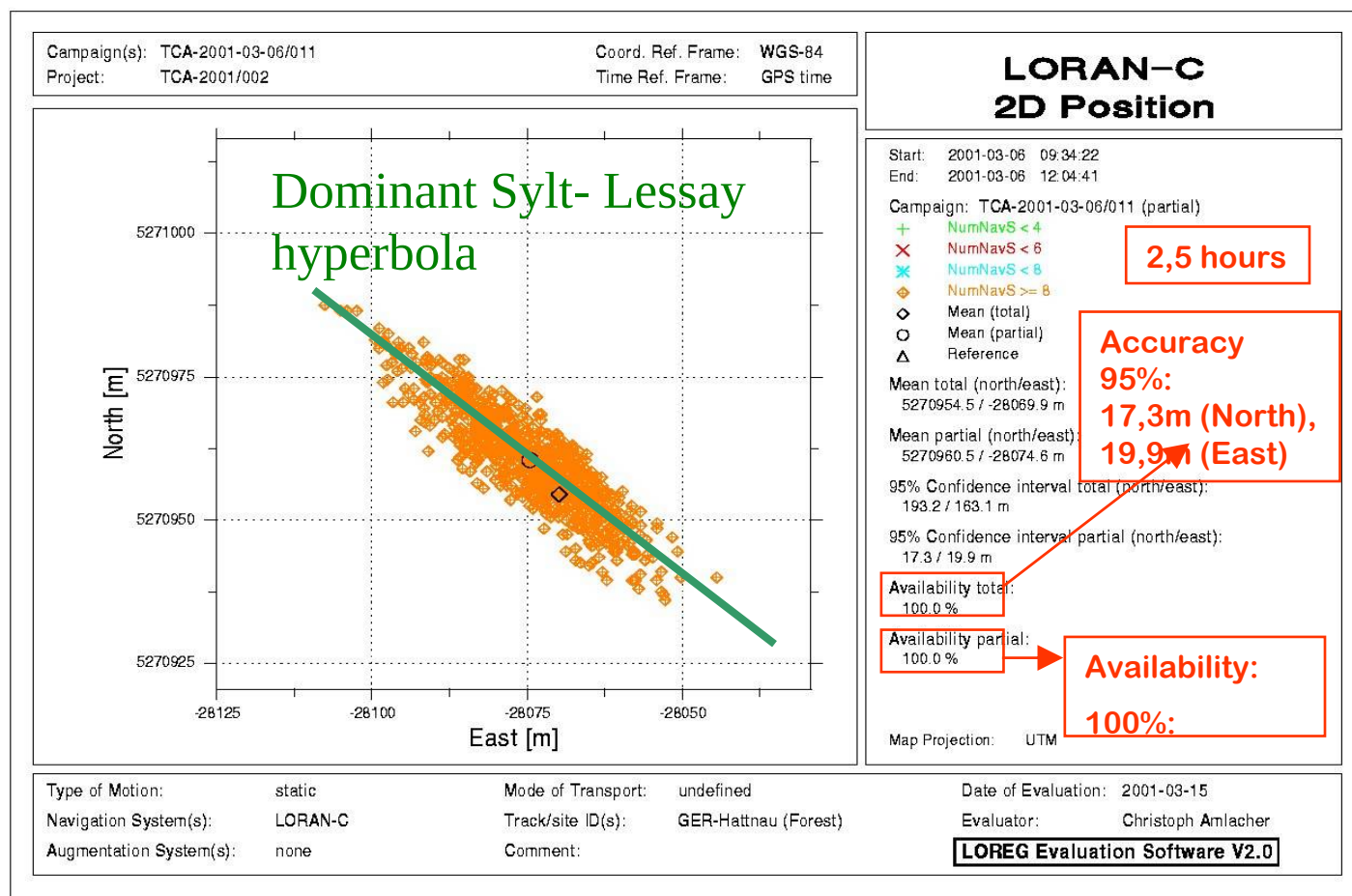
LOCUS SatMate 1000, 1PPS output B + C  
with reference to UTC(PTB), 1 measurement per 10s



## Static: Forest / Boundary of Coverage Area



## Static: Forest / Boundary of Coverage Area

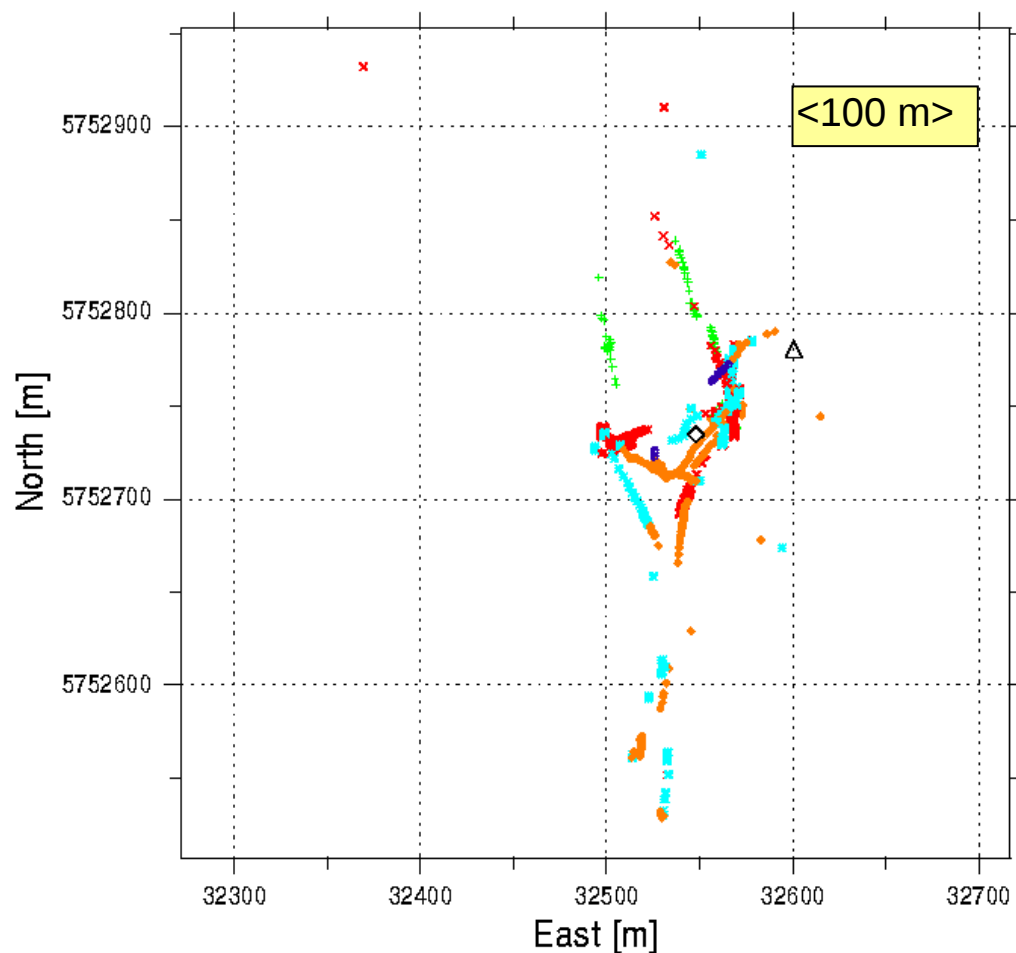


NavConvention

## Static: Extreme Urban / Center of Coverage Area

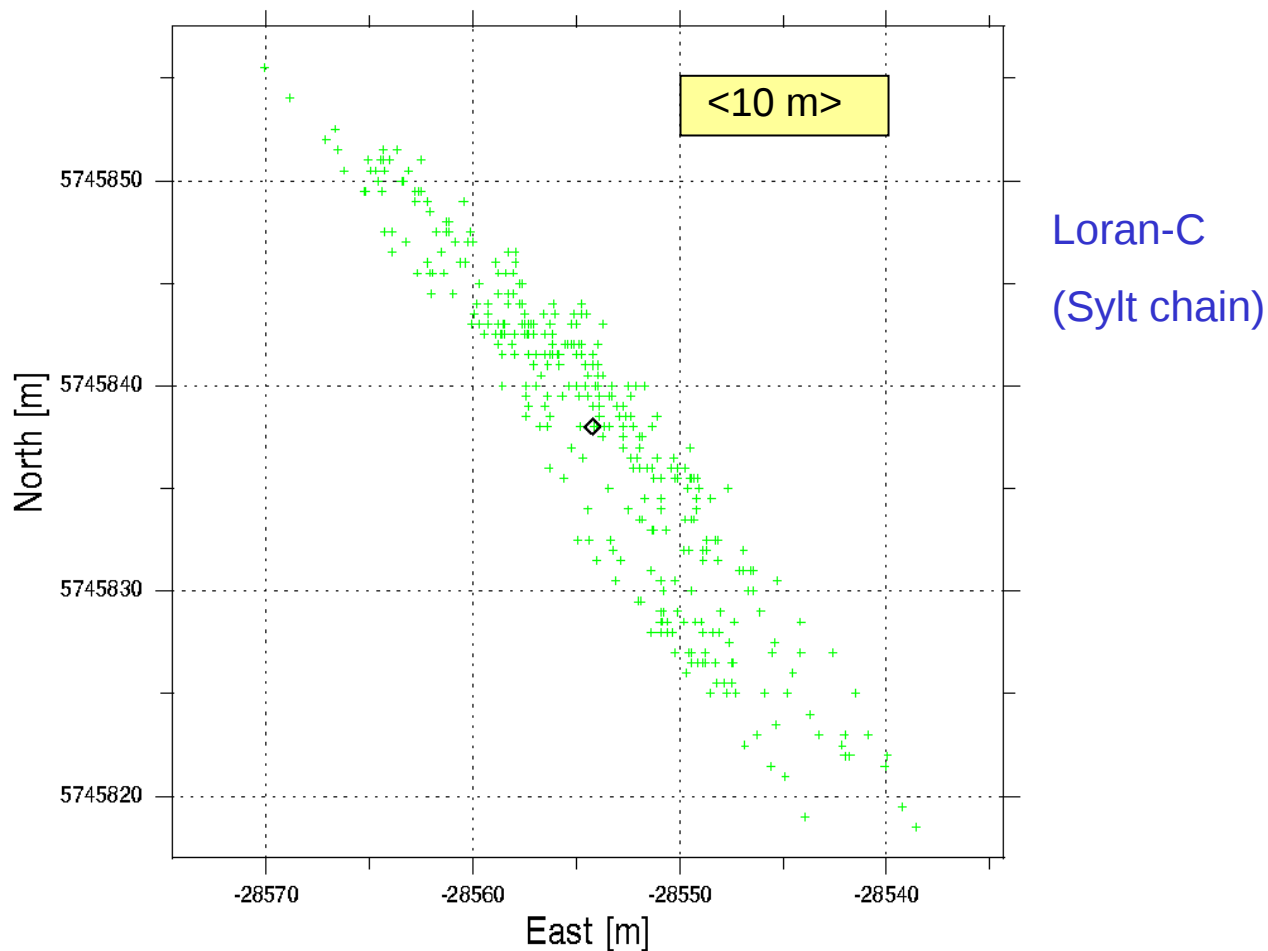


## Static: Extreme Urban / Center of Coverage Area

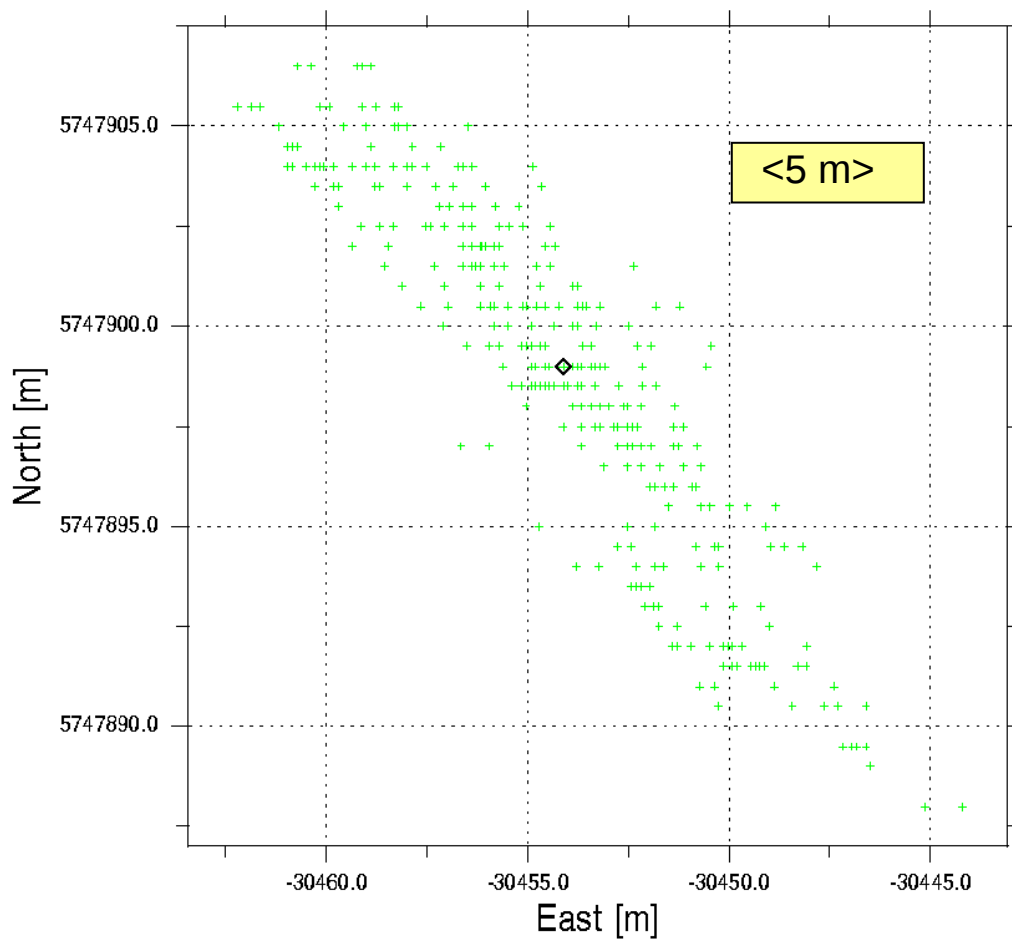


GPS

## Static: Extreme Urban / Center of Coverage Area

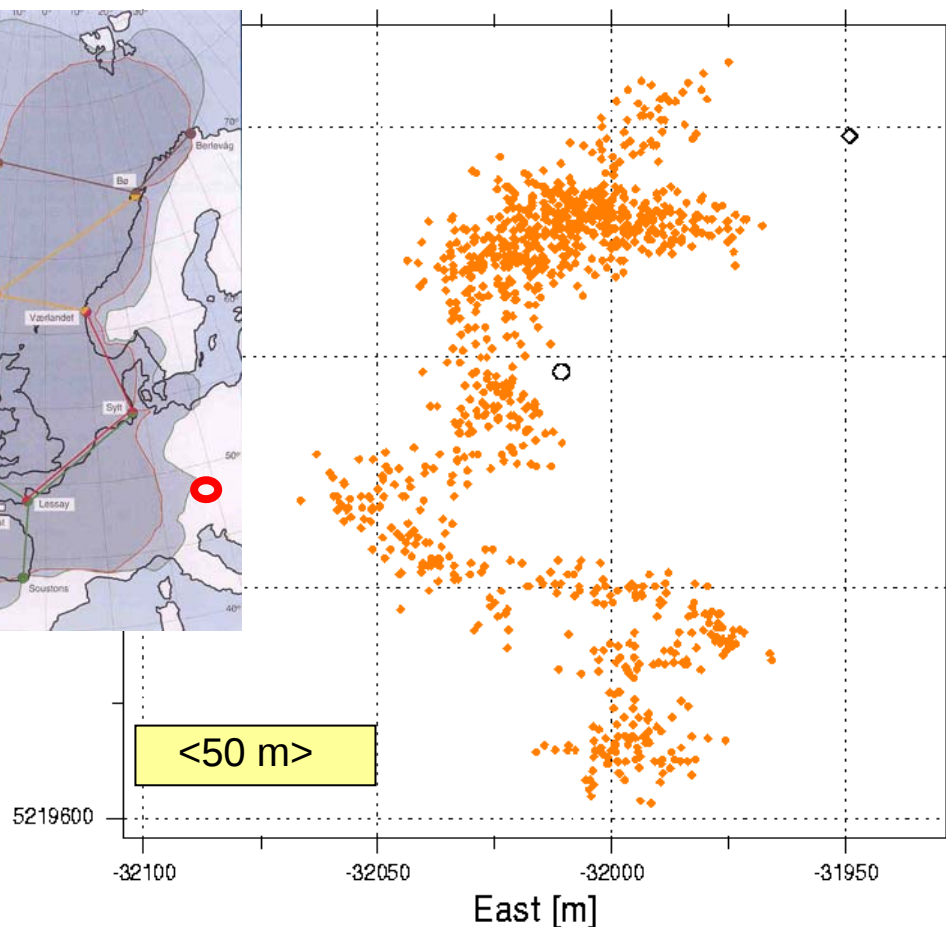
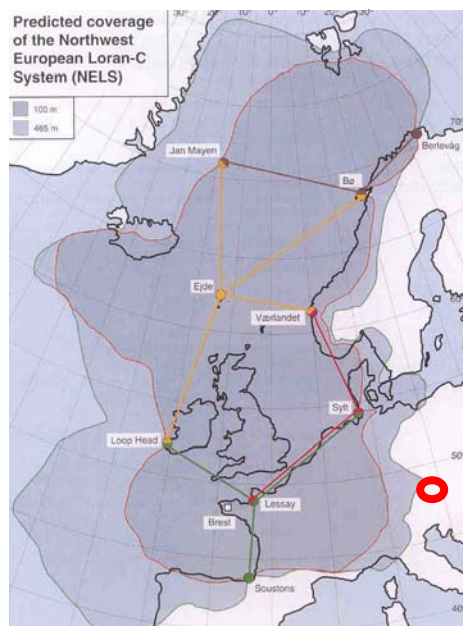


## Static: Extreme Urban / Center of Coverage Area



Loran-C  
(Sylt + Lessay chain)

## Static: Extreme Urban / Center of Coverage Area



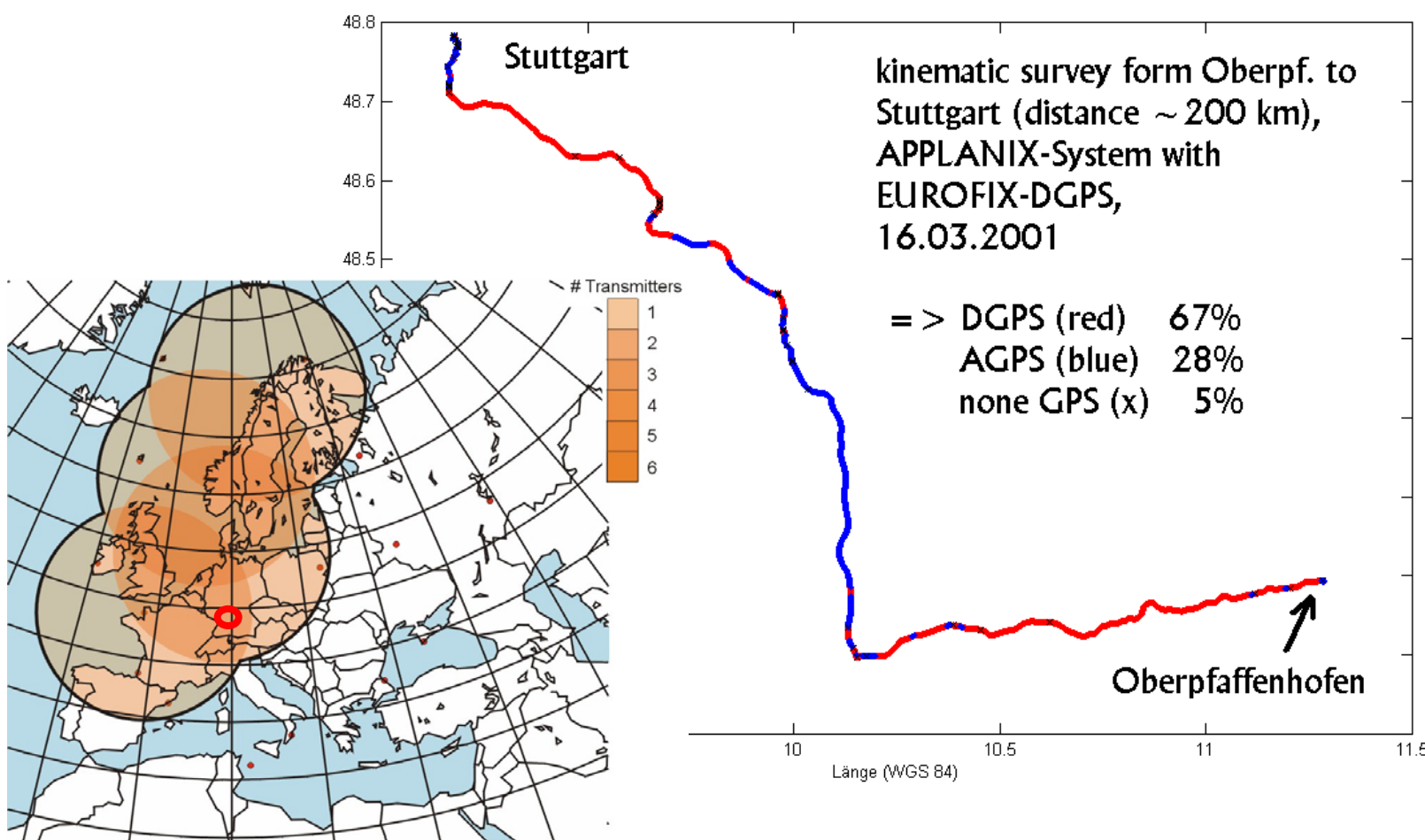
Sylt, Lessay, Chayka

Locus SatMate 1000

Locus E-Field  
antenna

Repeatable accuracy:  
81 / 38 m (95%)

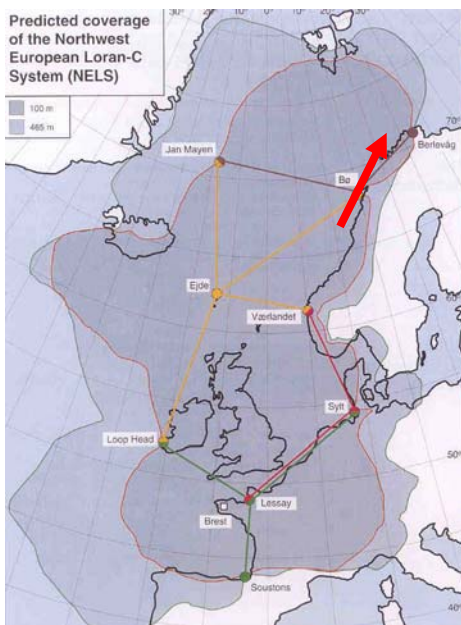
## Dynamic - Land



NavConvention

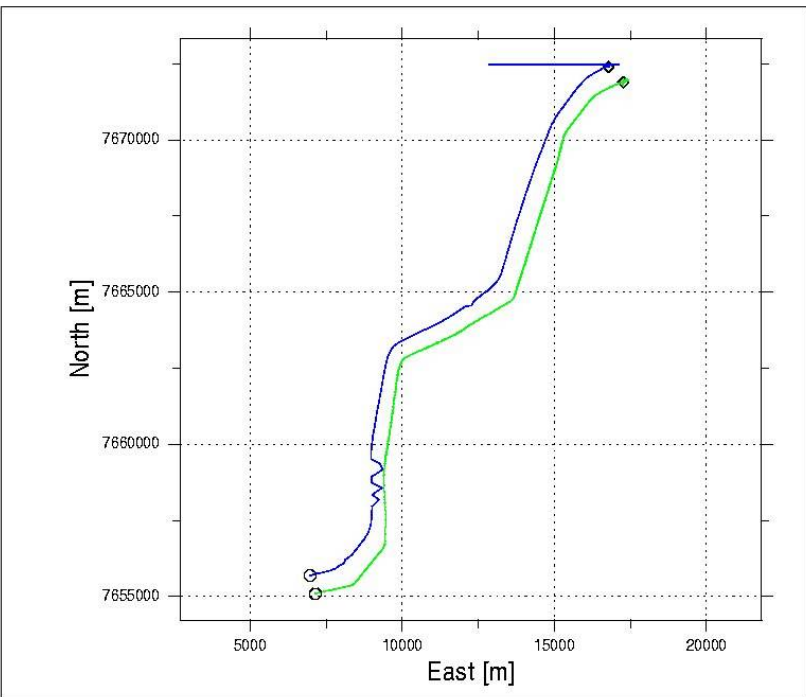
## Dynamic - Maritime

NavConvention



Campaign(s): NEL-2001-03-14/002, NEL-2001-03-14/001  
Project: NEL-2001/001

Coord. Ref. Frame: WGS-84  
Time Ref. Frame: UTC(Brest)



### LORAN-C, GPS/Eurofix 2D Position

Campaign: NEL-2001-03-14/002 (total)

Start: 2001-03-14 06:16:53  
End: 2001-03-14 12:17:36

6 hours

— LORAN-C  
◇ Start Point  
○ End Point

Availability total:  
99.9 %

Availability:  
99,9%

Continuity total:  
6.26 % (in any 10s)

Campaign: NEL-2001-03-14/001 (total)

Start: 2001-03-14 06:16:53  
End: 2001-03-14 12:16:51

— GPS/Eurofix  
◇ Start Point  
○ End Point

Availability total:  
99.9 %

Continuity total:  
99.8 % (in any 10s)

Map Projection: UTM

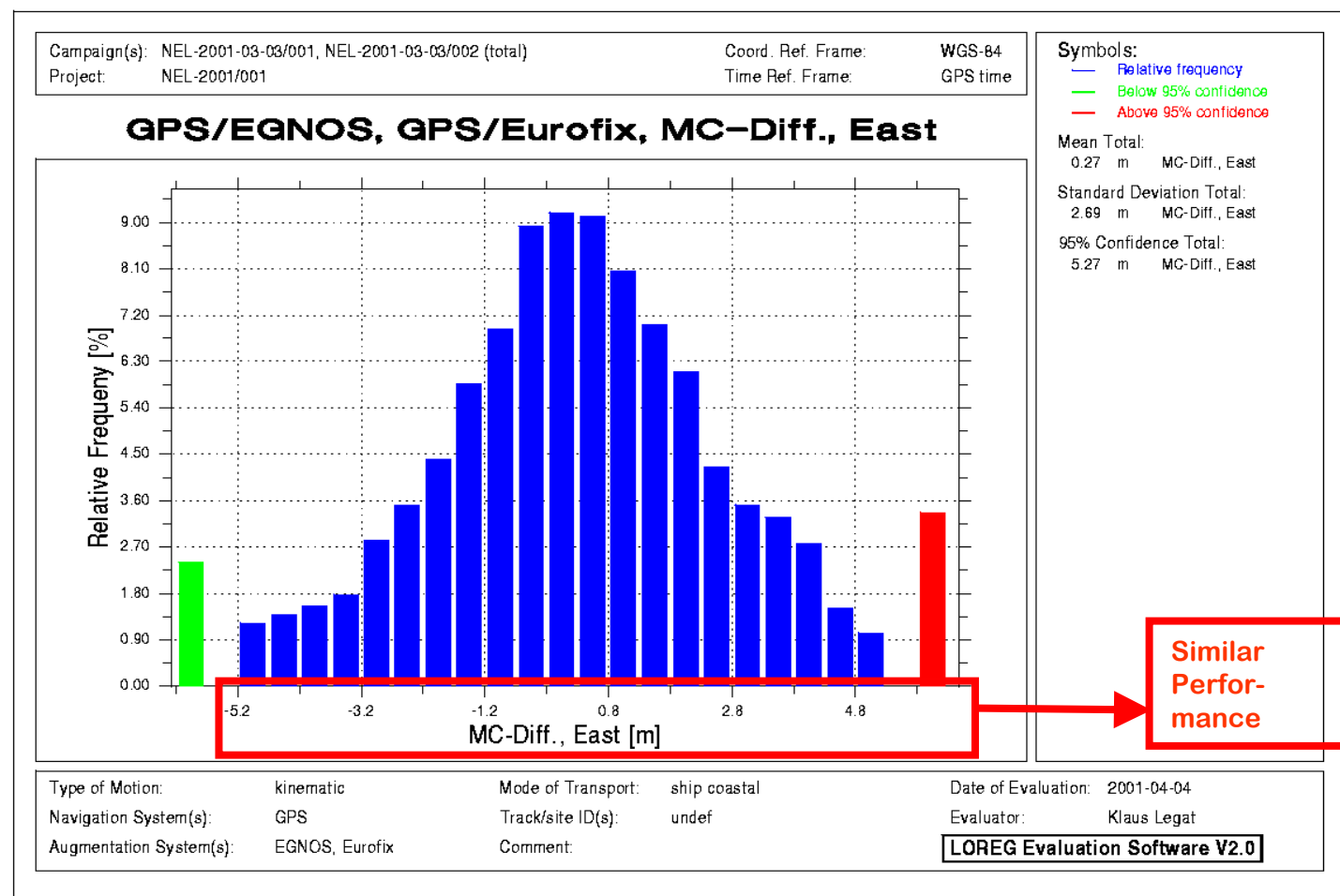
Type of Motion: kinematic  
Navigation System(s): LORAN-C, GPS  
Augmentation System(s): none, Eurofix

Mode of Transport: ship coastal  
Track/site ID(s): NOR-Bodoe - Hammerfest ( )  
Comment:

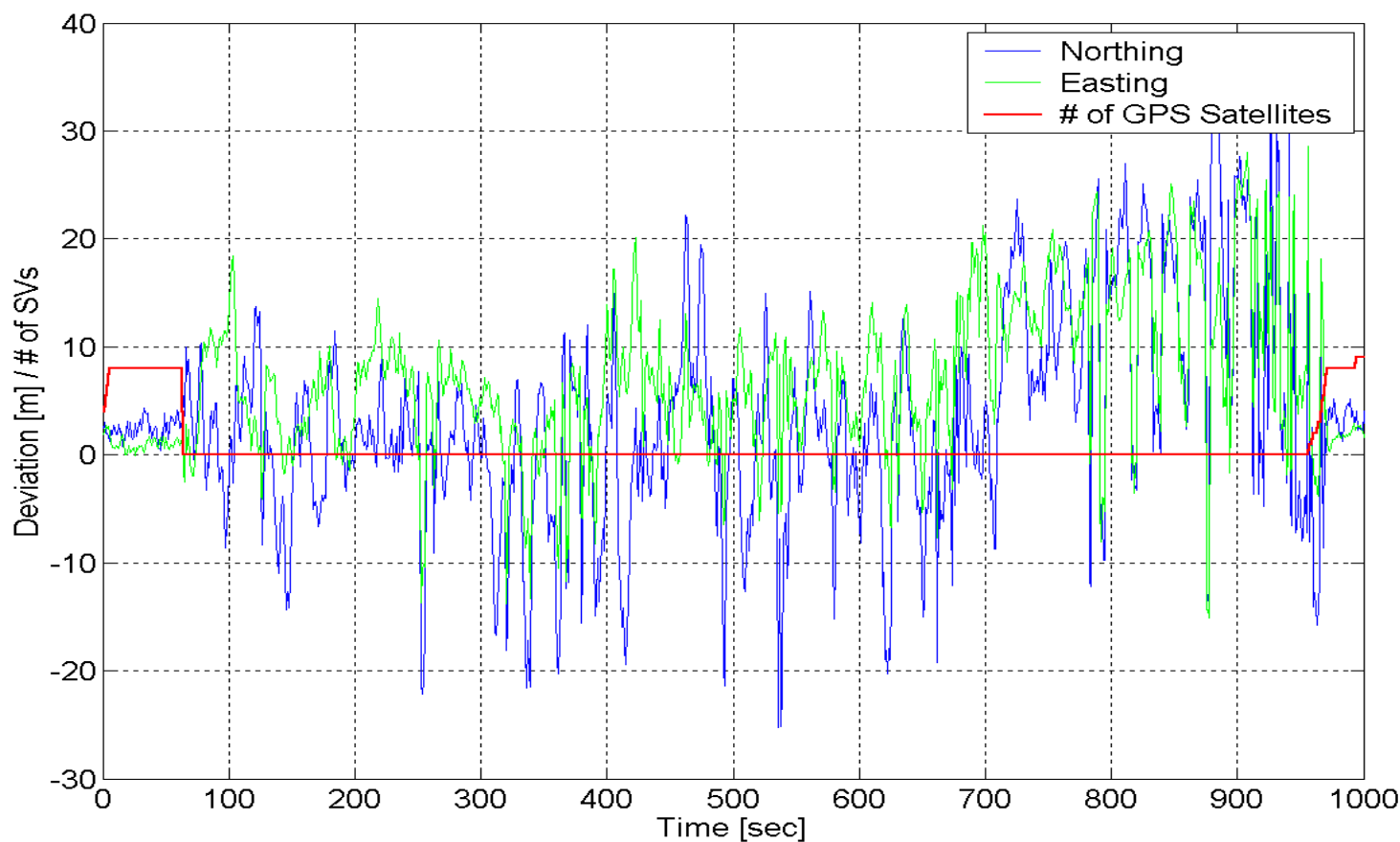
Date of Evaluation: 2001-04-03  
Evaluator: Christoph Amlacher

**LOREG Evaluation Software V2.0**

## Dynamic - Maritime

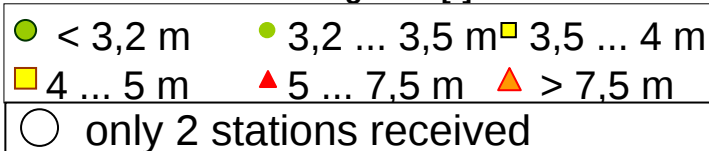
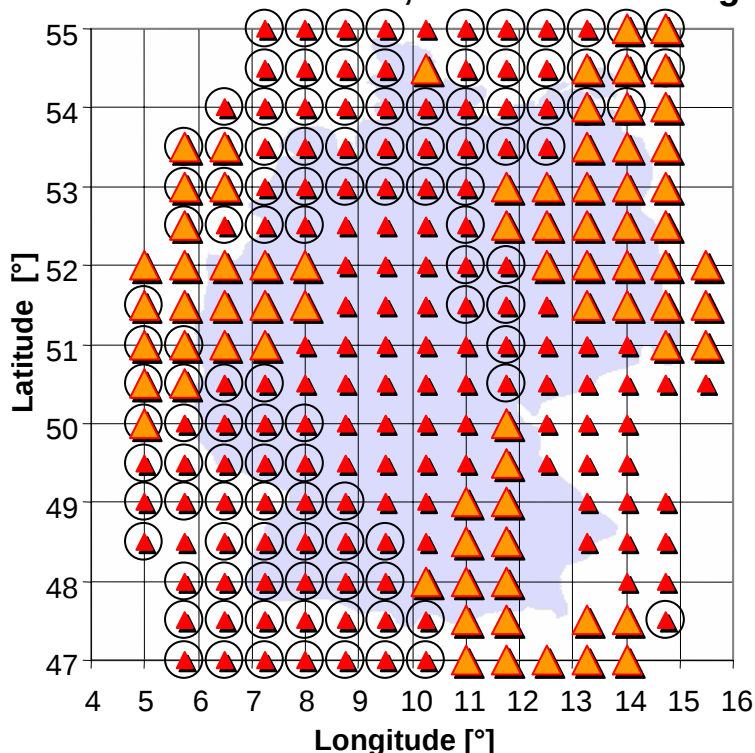


## Combined GPS/Loran-C positioning

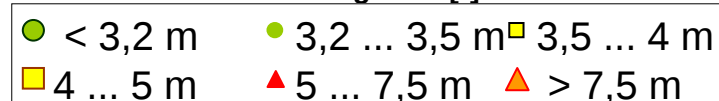
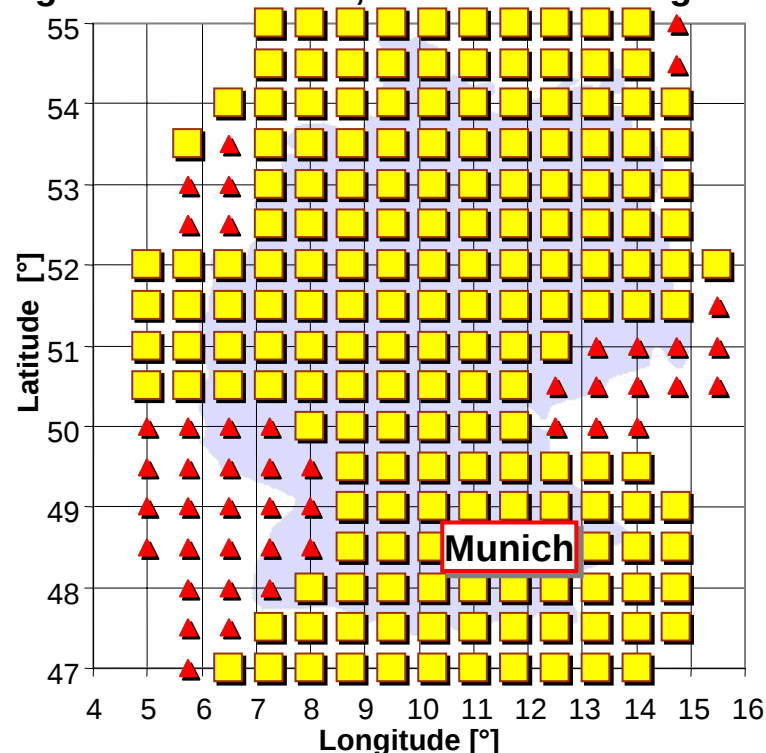


## LORAN-C 2D-Accuracy

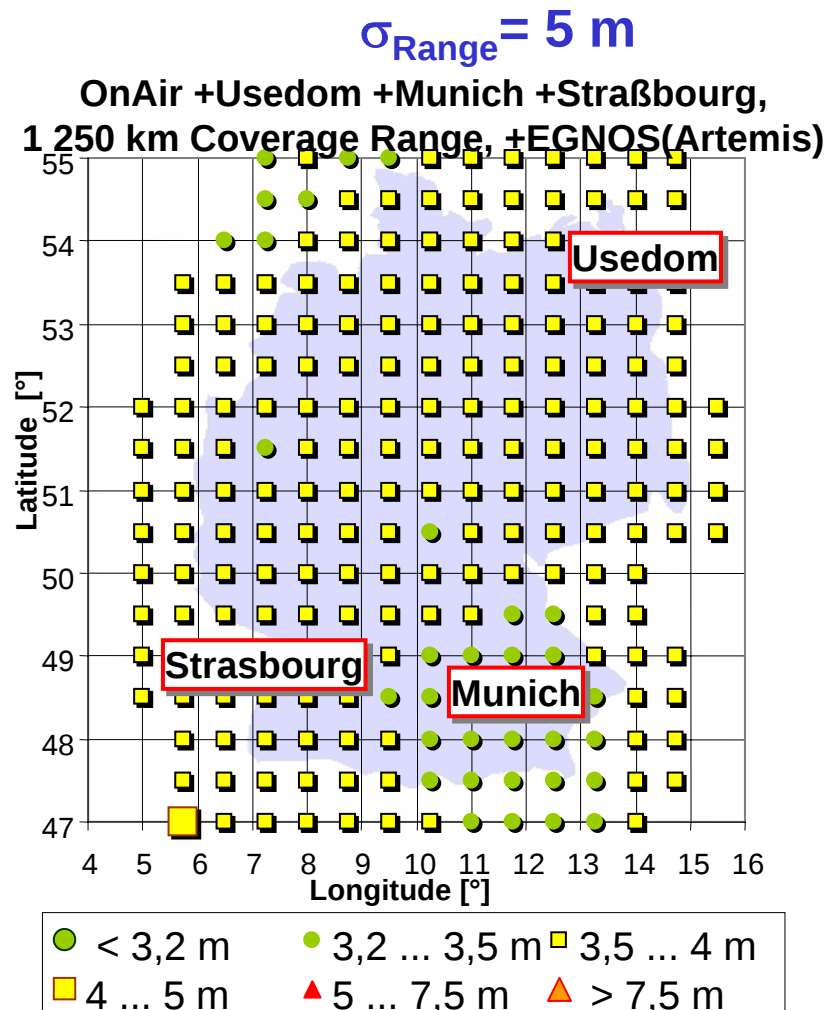
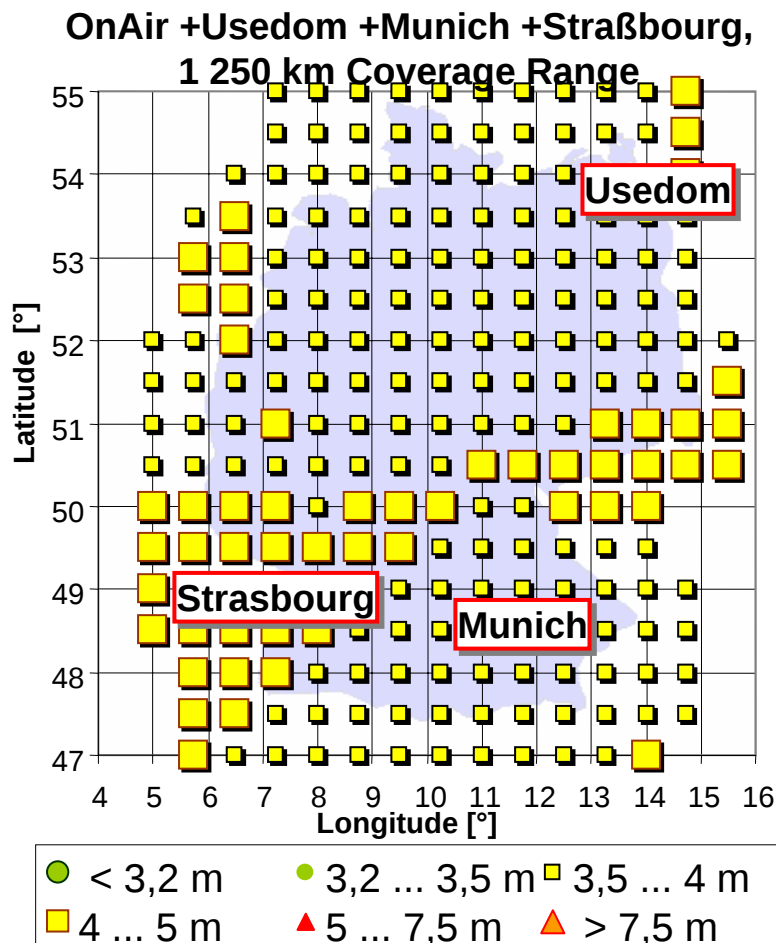
OnAir Transmitter, 1 000 km Coverage Range OnAir +Munich, 1 250 km Coverage Range



$\sigma_{\text{Range}} = 5 \text{ m}$



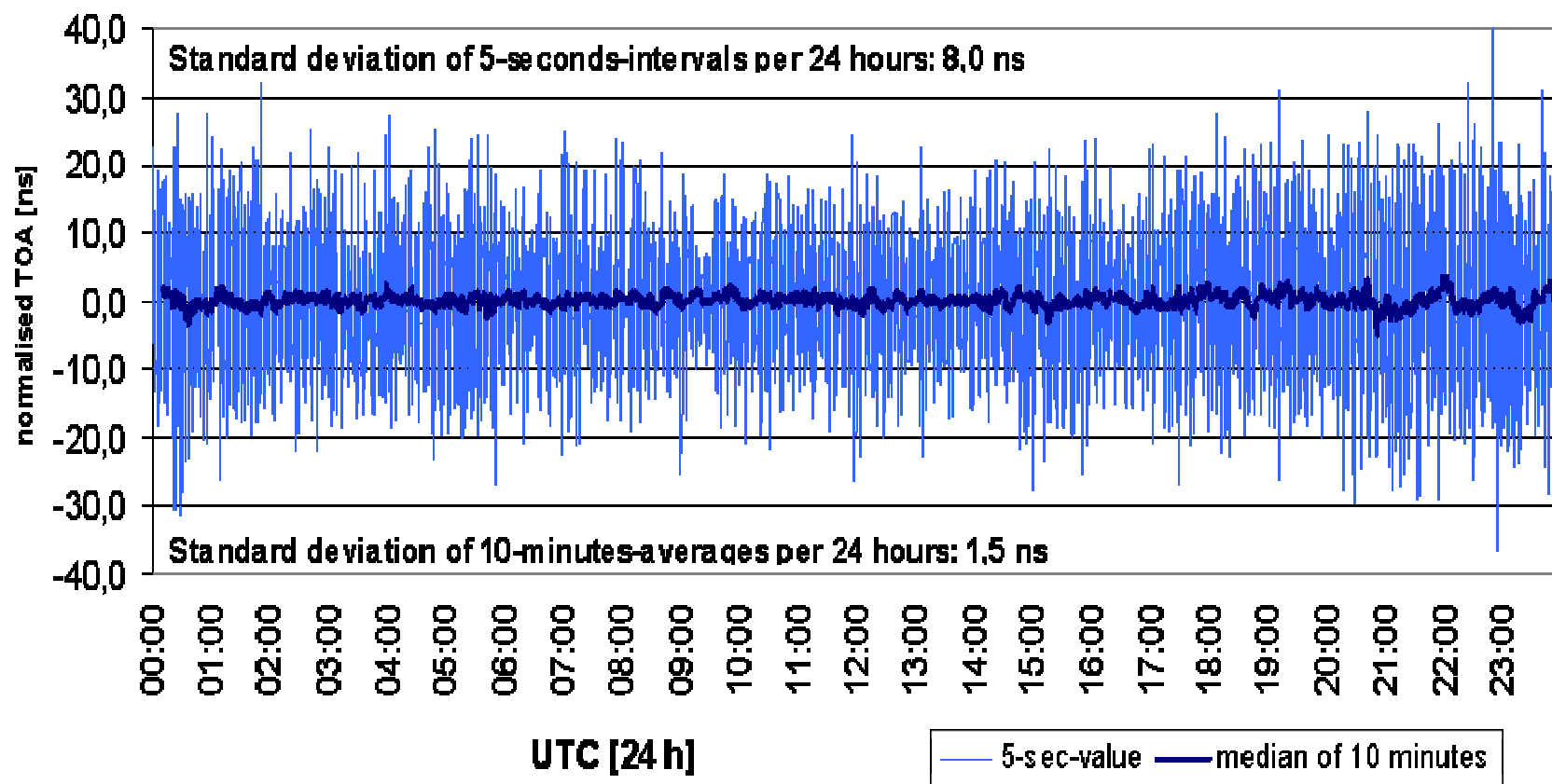
## LORAN-C 2D-Accuracy



## LORAN-C 2D-Accuracy

$\sigma_{\text{Range}} = 5 \text{ m}$

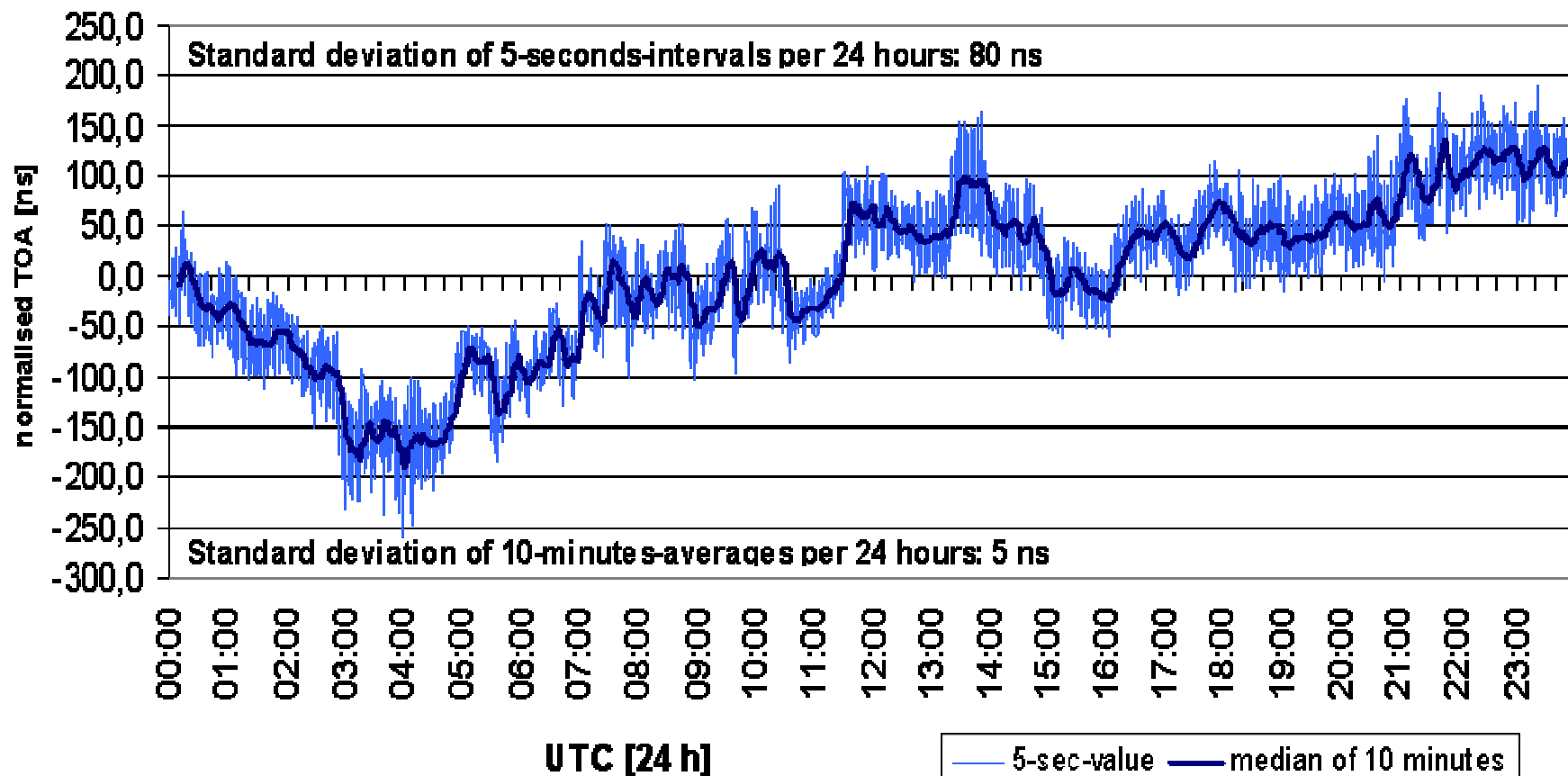
TOA (Transmitter Sylt, Receiver Neustrelitz), 30. August 2001



## LORAN-C 2D-Accuracy

$\sigma_{\text{Range}} = 5 \text{ m}$

TOA (Transmitter Slonim, Receiver Neustrelitz), 30. August 2001



## Conclusions

### ► Timing Requirements:

- $10^{-3}$ - $10^{-9}$  sec. (standard applications)
- $10^{-12}$  sec. (high-end applications)

### ► Timing Performance:

- accuracy  $\sim 70 \times 10^{-9}$  sec.

⇒ Suitable for relative synchronisation  
(comparable to GPS)

## Conclusions

### Loran-C Accuracy:

- ▶ measurements provided high repeatable accuracy (~10-20m) this will meet many requirements e.g. fleet management, navigation in coastal areas, fishery, etc.
- ▶ for the absolute accuracy the lack of ASF is a major error source (not necessary if combined with GNSS)
- ▶ First promising trials with integrated hybrid solutions

### Loran-C Availability:

- ▶ very good (often 100%), this will meet nearly all requirements

⇒ **Loran-C/Eurofix an appropriate candidate for the future integration with GNSS**



LORAN/EUROFIX/EGNOS  
Integration Test & Validation  
Programme (LOREG)

## Information + Contact



[www.telematica.de/LOREG](http://www.telematica.de/LOREG)

[telematica.wlechner@t-online.de](mailto:telematica.wlechner@t-online.de)