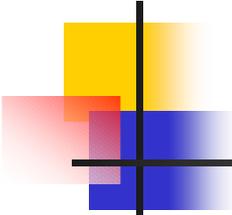


"Loran-C and Galileo, a European navigation solution"

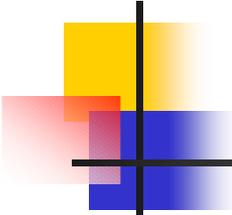
*Gerard Offermans, Durk van Willigen,
Arthur Helwig, Edward Breeuwer, Reelektronika bv
Jean-Pierre Vincent, Alcatel Space Industries*

International Loran Association Conference
12-15 November 2000, Washington, DC.



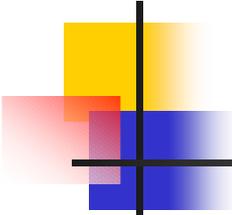
Overview

- Galileo overview
- European navigation projects
 - Galileo related
 - Loran-C/Eurofix related
 - Integration related
- GNSS and Loran-C integrated positioning
- The most challenging environment...



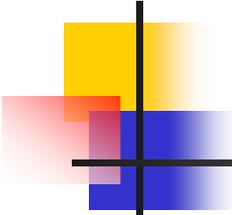
Galileo Overview - 1

- A European Union initiative
- Following a strategy defined in the early 90s and endorsed in 1994
- Concerns a new multimodal transport infrastructure
- Under European civil control
- Offering Positioning/Timing and navigation related services
- For public, commercial, safety of life, security and governmental applications
- Final Operational Capability by end 2008



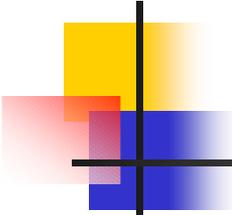
Galileo Overview - 2

- 4 navigation services
 1. OAS: Open Access Service
 1. provides free of charge for mass market application
 2. CAS 1: Controlled Access Service level 1
 1. provides improved service for professional markets (e.g. improved accuracy and integrity)
 3. CAS 2: Controlled Access Service level 2
 1. provides high integrity service for safety critical (SAS) or strategic applications (GAS).
- 1. Search and Rescue service



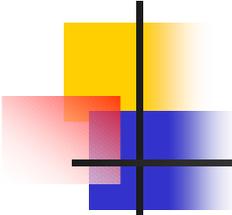
Galileo Overview - 3

- Open Access Service
 - Similar to the future and modernised GPS SPS
 - Accuracy better than 10 m world-wide and an availability of 99%
 - Dual frequency in L-band
- Controlled Access Service
 - Better accuracy performance than OAS
 - Guaranteed service levels (Integrity)
 - Restricted access
 - Dual frequency in L-band



Galileo Overview - 4

- Galileo Integrity concept
 - Integrity on Galileo provided through a subset of the MEO satellites
 - Integrity available in Controlled Access Services (CAS 1 & CAS 2)
 - Integrity on GPS/Glonass provided through EGNOS Geostationary Satellites
 - Local integrity and differential corrections may be provided to enhance performance



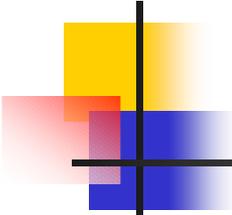
European Navigation projects

- Galileo related projects

- GALA **Galileo Architecture Definition**
- GALILEOSAT Definition of space and associated ground infrastructure
- INTEG **Integration of EGNOS into Galileo**
- GEMINUS Service Definition
- SAGA **Standardisation of Galileo**
- SARGAL **SAR mission on Galileo**

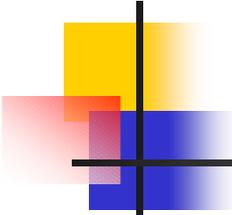
- Web site

- <http://www.Galileo-pgm.org>
- <http://www.geminus-project.org>



European Navigation projects

- Loran-C/Eurofix related
 - EFP **E**urofix **F**easibility **P**hase, installation of Eurofix on 4 NELS Loran-C transmitters
<http://www.nels.org>
<http://www.reelektronika.nl>
 - Disc-II Loran-C/Eurofix receiver concept development
 - EUROLOG Miniaturisation of Loran-C/Eurofix receivers
 - TACIS **T**echnical **A**ssistance for **CIS** countries - Establishment of a joint Loran-C/Chayka navigation system in southern Europe



European Navigation projects

- Integrated Navigation

- LOREG

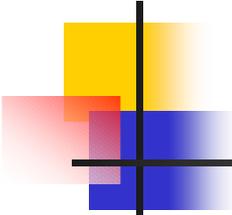
LORAN/Eurofix/**E**GNOS Test & Validation Programme

<http://www.telematica.de/loreg/>

- GLORIA

GNSS & **L**Oran-C for **R**oad and **Ra**il **A**pplications

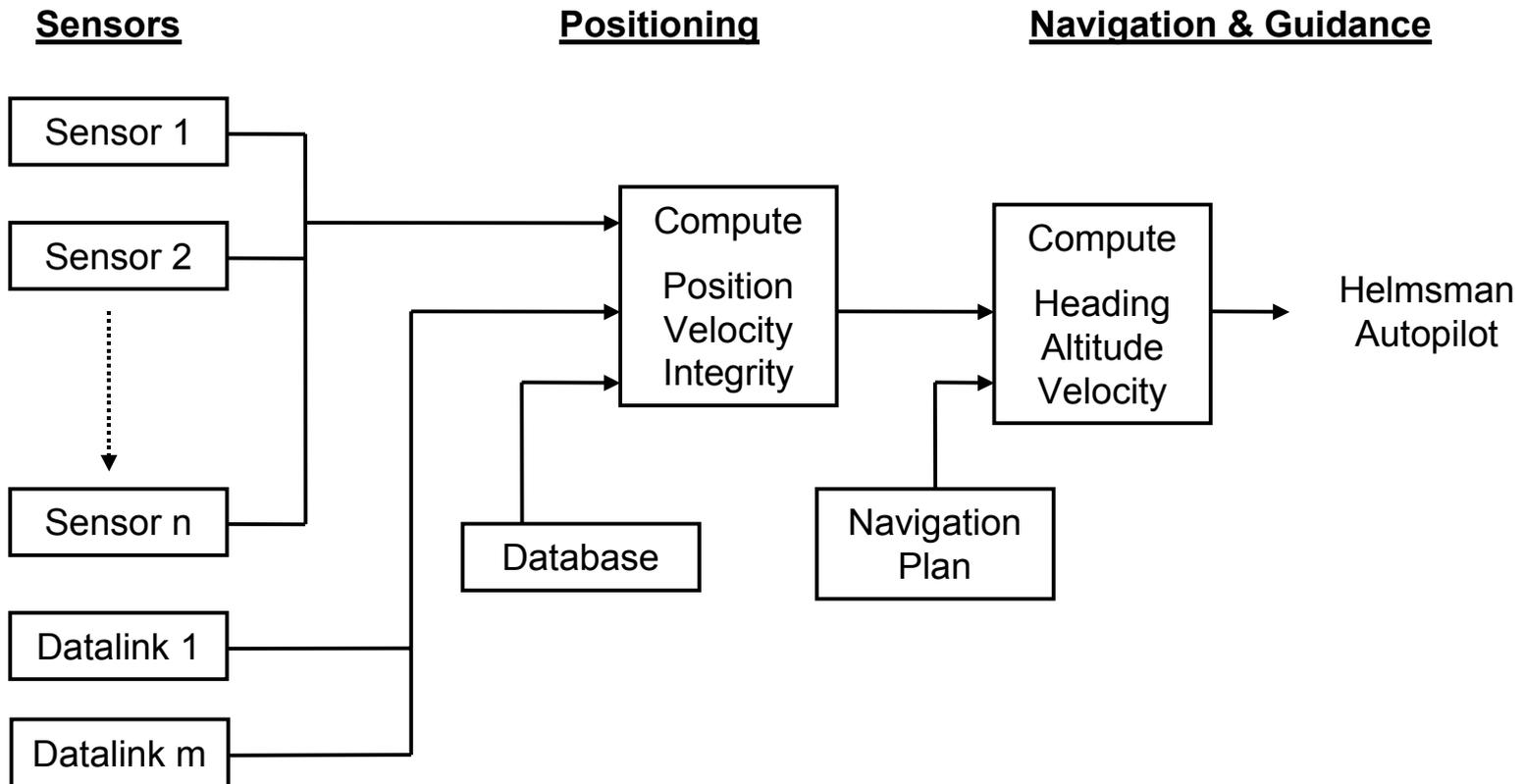
<http://www.eu-gloria.org/>

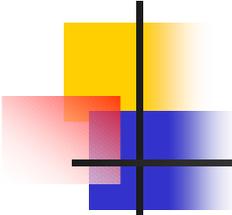


GNSS and Loran-C integrated positioning

- Sole means of navigation for all modes of transportation using only one system is abandoned
- Integration of sensors to improve:
 - Positioning Availability
 - Positioning Integrity
 - Positioning Accuracy
- For safe navigation the different sensors should be dissimilar
- Integrated navigation systems provide cost-effective guidance and control of all modes of transportation
- Navigation goes from SIS to SIB

Integrated Navigation concept





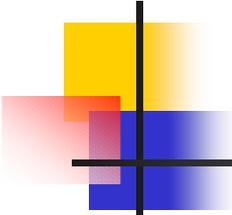
GNSS and Loran-C system characteristics

GNSS

- Ultra-High Frequency, low power
- Satellite based
- Line of sight propagation
- Global coverage

Loran-C

- Low Frequency, high power
- Ground based
- Groundwave and Skywave propagation
- No global coverage



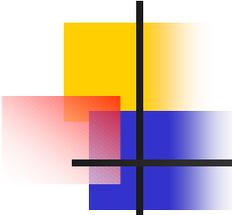
GNSS and Loran-C accuracy & integrity

GNSS

- Good absolute accuracy (if no obstructions)
- Multipath propagation and shadowing limit accuracy in urban environment
- GPS has poor internal integrity
- Galileo baseline provides integrity in CAS-1 & CAS-2

Loran-C

- Low absolute accuracy due to unknown Additional Secondary Factor
- Good repeatable accuracy
- Internal integrity provided by blink



GNSS and Loran-C integrated positioning

- Improving positioning availability
 - Use GNSS when available
 - Calibrate Loran-C ranges based on (D)GNSS position fix
 - Use calibrated Loran-C ranges in integrated solution in case GNSS is partly or temporary unavailable

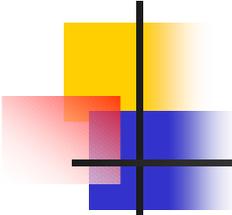
GNSS and Loran-C integrated positioning

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

¹ Loran-C is not suitable for altitude determination.

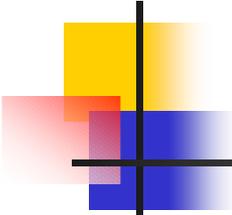
² 3D or 2D + Integrity.

From “The Potential of Hybrid GPS/LORAN-C Receivers”, dr. D. Kügler, ILA '97



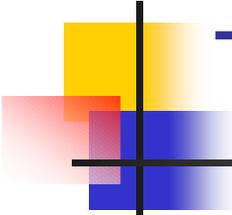
GNSS and Loran-C integrated positioning

- Improving positioning accuracy
 - GNSS differential corrections provided by Eurofix
 - Use of ionospheric models for GNSS positioning, EGNOS and RAAS provide accurate measured data for calibrating models
 - Calibrate Loran-C ranges based on GNSS position fix
 - Use calibrated Loran-C ranges in integrated solution in case GNSS is partly or temporary unavailable
 - Soft degradation of accuracy



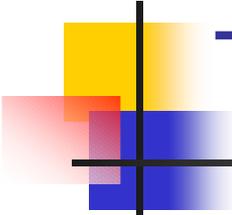
GNSS and Loran-C integrated positioning

- Improving positioning integrity
 - External GPS/Glonass/Galileo integrity provided through Eurofix datalink
 - Receiver internal integrity provided through RAIM
 - GNSS blunder detection through use of ASF corrected Loran-C ranges (models)
- Note: Calibration of Loran-C ranges using GNSS fixes has to be carefully executed to prevent a single point failure structure!



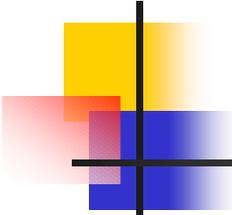
The most challenging environment...

- Urban environment
 - Satellite signals are blocked or suffer from severe multipath effects
 - Availability of satellite-only system is significantly reduced
 - Loran-C E-field signals are highly attenuated
 - Loran-C H-field signals are still available at sufficient signal strength
 - Steel building constructions may cause Loran phase disturbances however



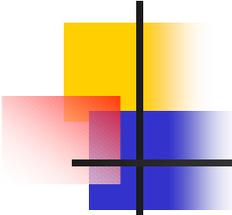
The most challenging environment...

- Railway environment
 - Railway applications require high positioning robustness and integrity
 - GNSS outages due to interference or shadowing can be overcome by Loran integration
 - The (electrified) railway environment may cause large interferences in the 100 kHz spectrum
 - New H-field antenna design and Loran signal processing is required to overcome this



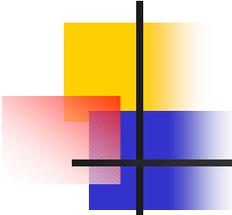
GLORIA objectives

- Test the integrated system under typical situations of road and rail applications
- Develop and optimise receivers integrating GNSS, LORAN-C and Eurofix signals focussing on the complementary attributes
- Identify market opportunities, assess the potential and develop implementation strategies for the most promising applications, with special emphasis on safety critical applications
- Investigate the possible improvements of the Galileo system implementation mainly considering best benefits resulting from combinations with terrestrial position determination



Conclusions

- December 2000: EU Transport Council
Decision on Galileo Development Phase
- EC supports many projects developing Satellite, Terrestrial and Integrated Navigation systems
- From a technical/economical point of view integration of Galileo with Loran-C is considered beneficial
- Please follow presentations on GNSS/Loran integration in coming two years



More information

- **GNSS/Loran integration**

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