Galileo for Security and Safety of Railway Transport

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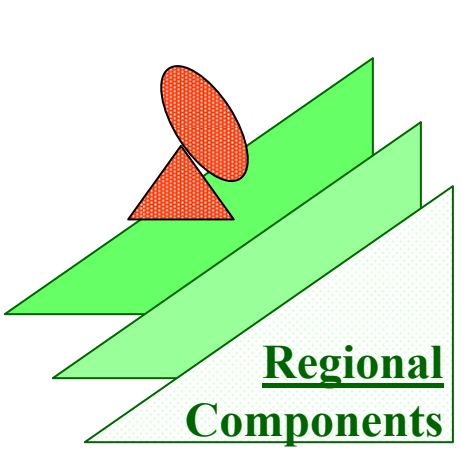
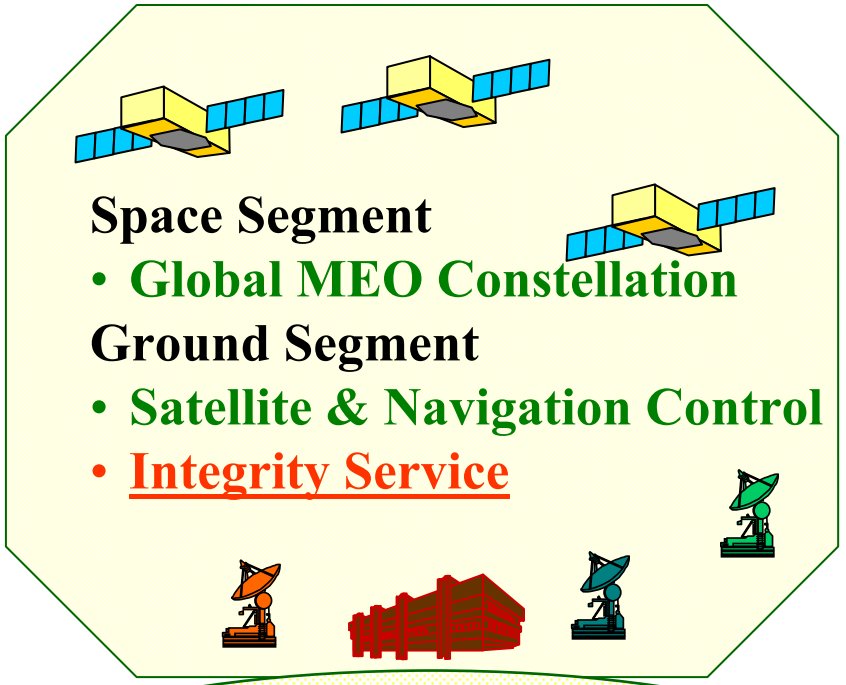
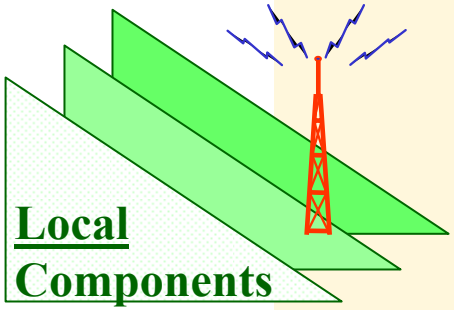
5. Example of application in Czech Republic (AZD Praha s.r.o.)

Motivation for safe and secure satellite navigation system

Galileo system







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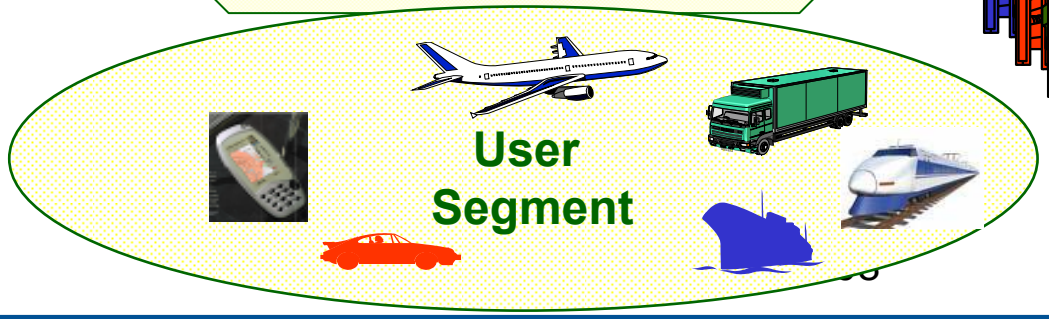
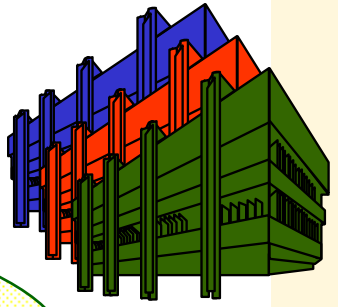


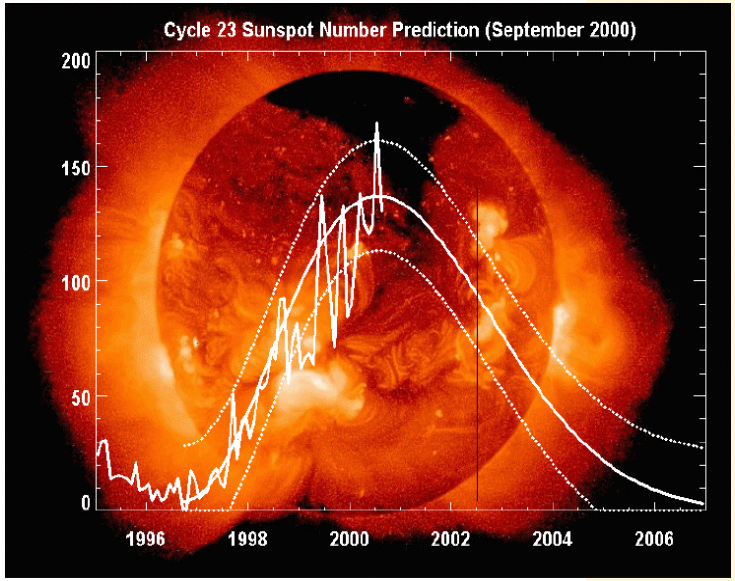


Service
Centres

Motivation for safe and secure satellite navigation system

Satellite navigation system threats

- Atmospheric anomalies
  - Two atmospheric layers have a significant influence on violation of constant signal speed precondition: ionosphere, troposphere
- Influence of ionosphere
  - The ionosphere, consists of gases that have been ionized by solar radiation that produces clouds of free electrons that act as a dispersive medium for GPS signals.
  - Worst-case influence: 45m (on 1 measurement)



source: E.D.Kaplan: Understanding GPS principles and applications

Motivation for safe and secure satellite navigation system

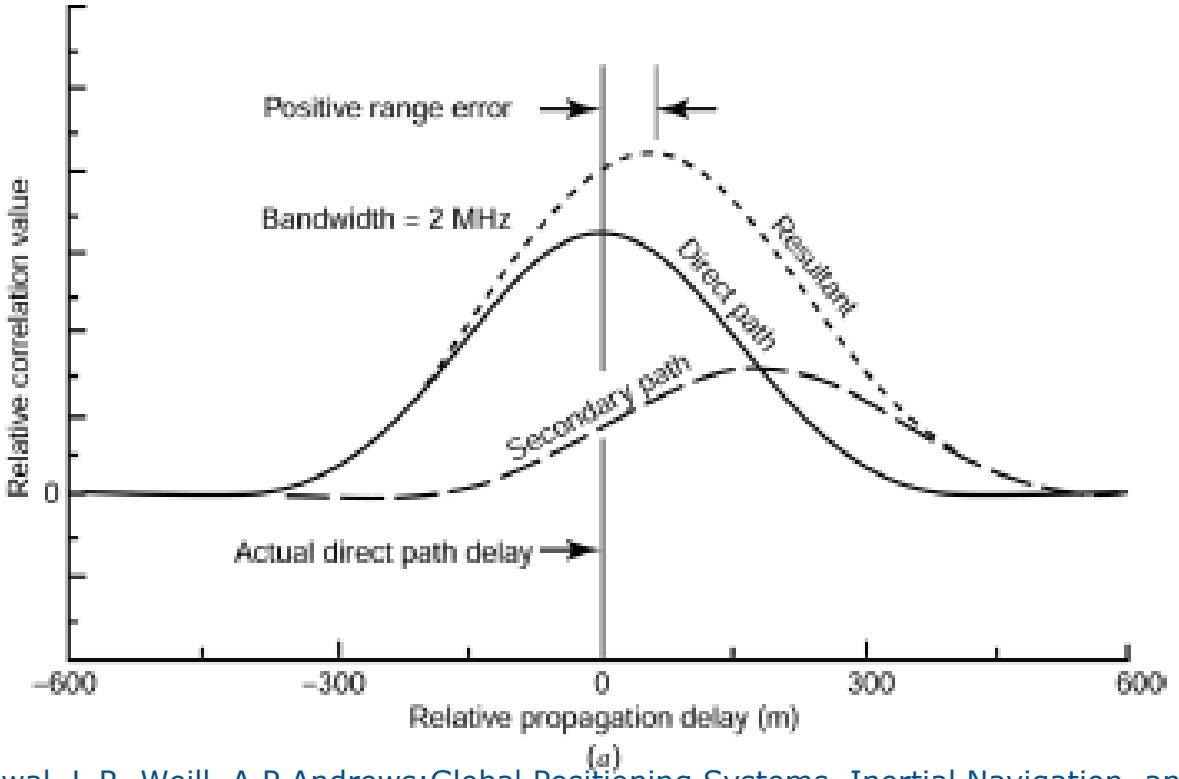
Satellite navigation system threats - 2

- Troposphere
  - Lower part of the atmosphere composed of dry gases and water vapor, which lengthen the propagation path due to refraction.
  - Worst-case influence: 25m
- Multipath problem
  - Objects in the vicinity of a receiver antenna can easily reflect GPS signals, resulting in one or more secondary propagation paths. Secondary-path signals, which are superimposed on the desired direct-path signal, always have a longer propagation time and can significantly distort the amplitude and phase of the direct-path signal.
  - Worst-case influence on position error: 100m

source: E.D.Kaplan: Understanding GPS principles and applications

Motivation for safe and secure satellite navigation system

Satellite navigation system threats - 3



source: M.S.Grewal, L.R. Weill, A.P.Andrews:Global Positioning Systems, Inertial Navigation, and Integration

Motivation for safe and secure satellite navigation system

Satellite navigation system threats - 4

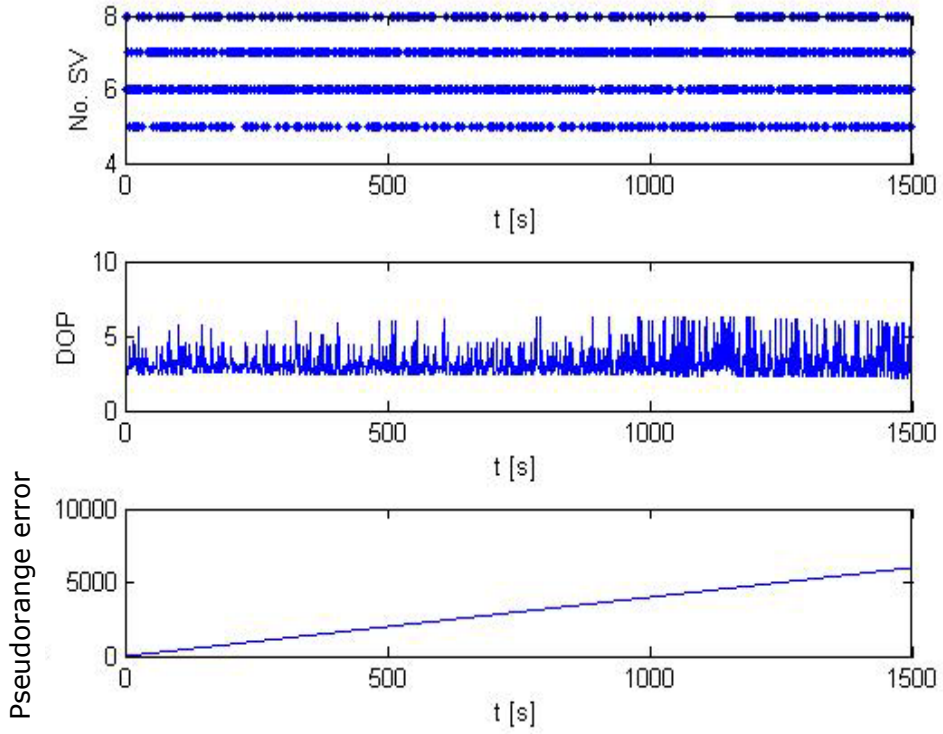
- Navigation system anomalies
  - en.wiktionary.org: An irregularity or disproportion; Something that is strange or unusual; Any event, big or small, out of the ordinary
  - Most dangerous for any safety system, position error could be unbounded

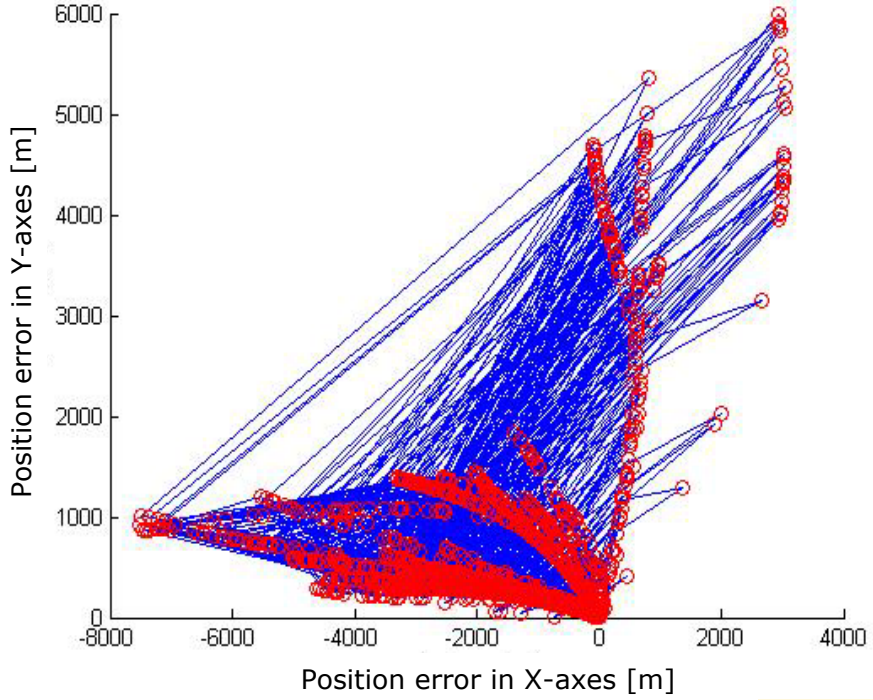
Time of occurrence	Duration [s]	Description
28.07.01 22:07	6660	Drift of pseudo range of satellite PRN22
11.06.03 19:31	2890	Linear growth of satellite PRN5 clock error of satellite
26.05.03 16:00	5669	Linear growth of satellite PRN27 clock error
01.01.04 18:00	7200	Satellite PRN23 clock error exponentially dropped
08.03.04 13:24	90	Unstable measure of Doppler frequency on satellite PRN11
29.08.04 00:41	3052	Increase of pseudo range error of, 50 minutes before planned satellite PRN27 maintenance

Motivation for safe and secure satellite navigation system

Satellite navigation system threats - 5

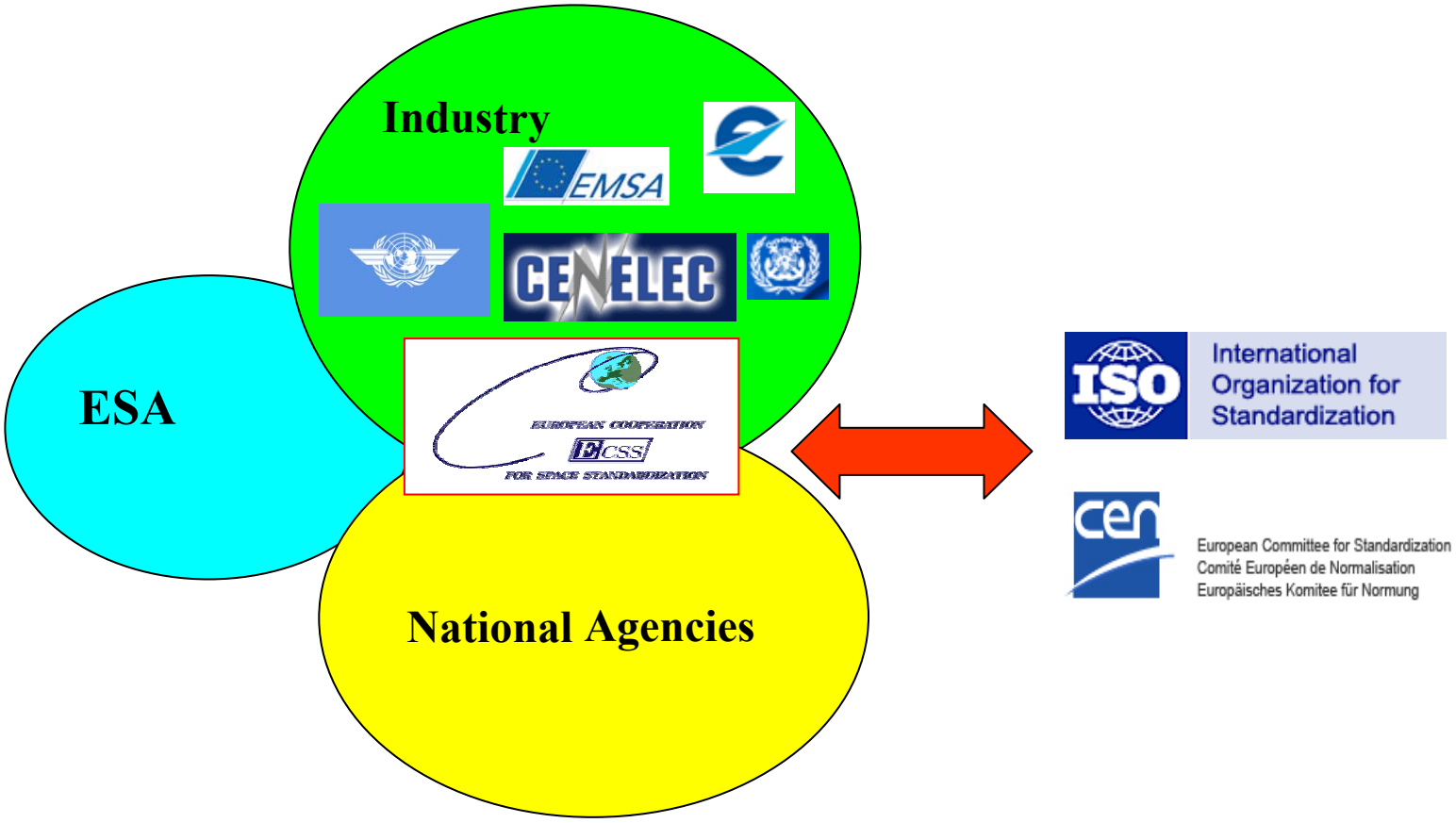
- Anomaly consequence simulation





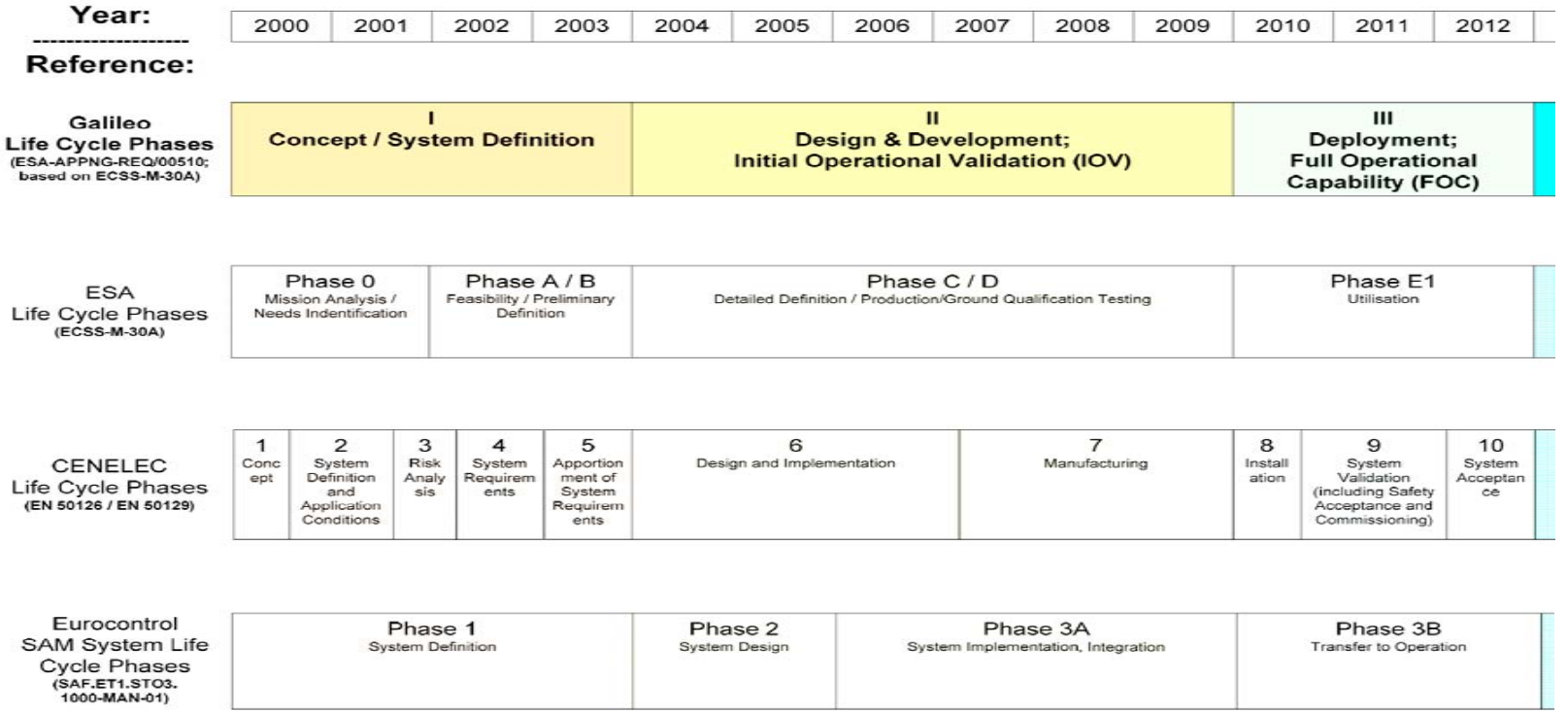
Motivation for safe and secure satellite navigation system

Standards



Motivation for safe and secure satellite navigation system

Standards



source: GALCERT project

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Galileo navigation system properties

Safety Of Life service

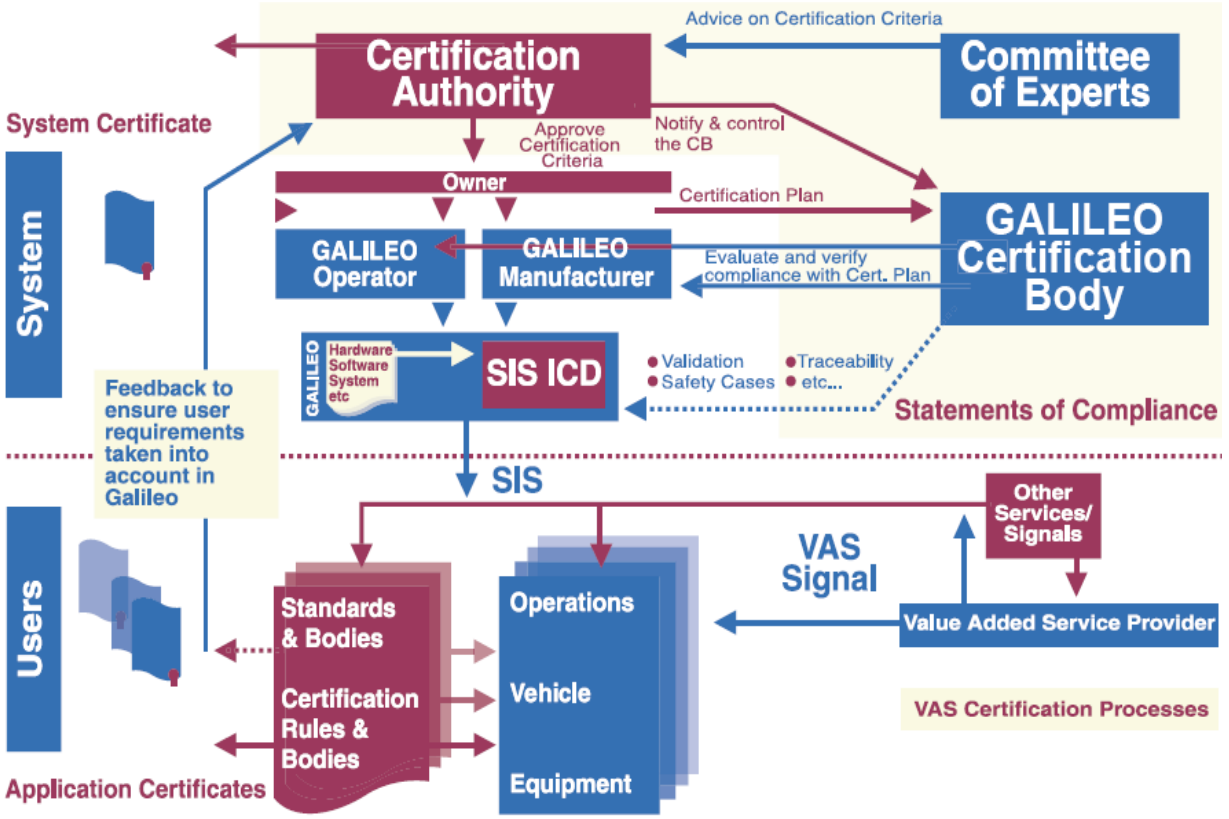
- Service guarantee (still is an issue?)
- integrity information at global level (EGNOS support)
- separated in frequency to improve robustness to interference
- permit correction of errors induced by ionospheric effects by differentiation of the ranging measurements made at each frequency

		Safety-Of-Life Service	
Type of Receiver	Carriers	Three Frequencies[12]	
	Computes Integrity	Yes	
	Ionospheric correction	Based on dual-frequency measurements	
Coverage		Global	
		Critical level	Non-critical level
Accuracy (95%)		H: 4 m V: 8 m	H: 220 m
Integrity	Alarm Limit	H: 12 V 20 m	H: 556 m
	Time-To-Alarm	6 seconds[13]	10 seconds
	Integrity risk	3.5×10^{-7} / 150 s	10^{-7}/hour
Continuity Risk		10^{-5}/15 s	10^{-4}/hour – 10^{-8}/hour
Certification/Liability		Yes	
Availability of integrity		99.5%	
Availability of accuracy		99.8 %	

Source: Galileo HLD v3.23

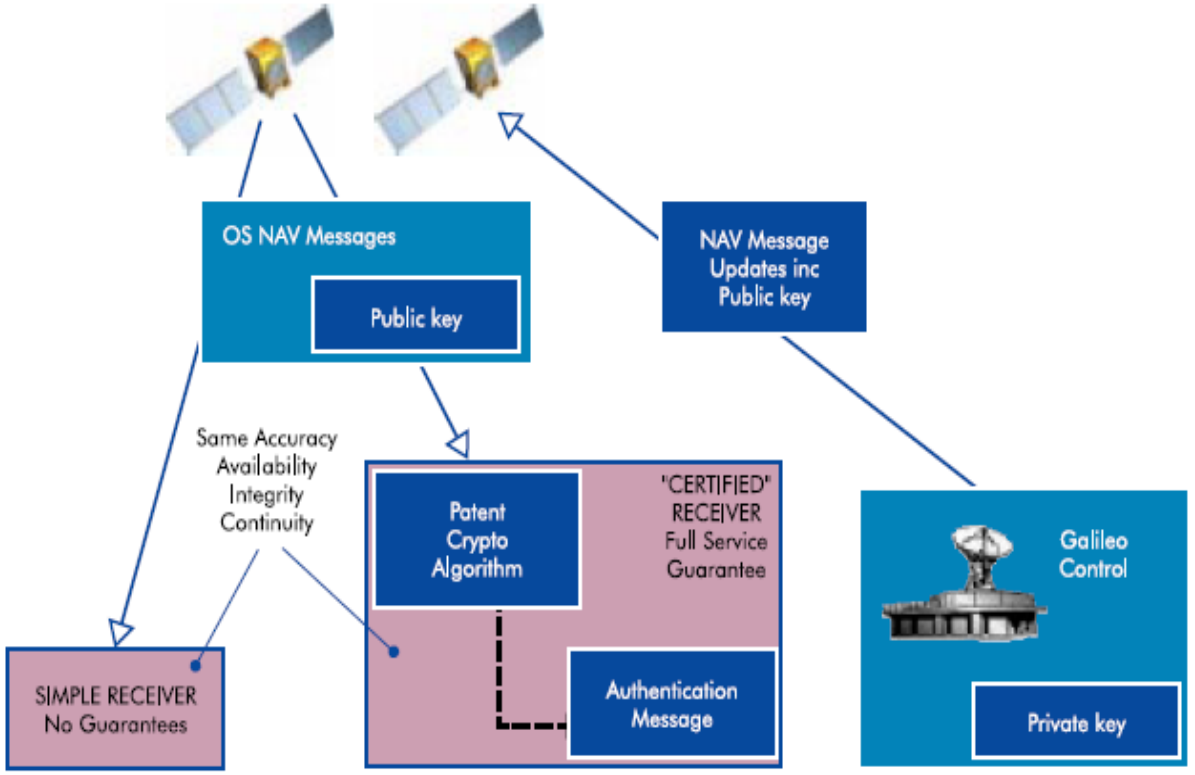
Galileo navigation system properties

Galileo safety architecture - authentication



Galileo navigation system properties

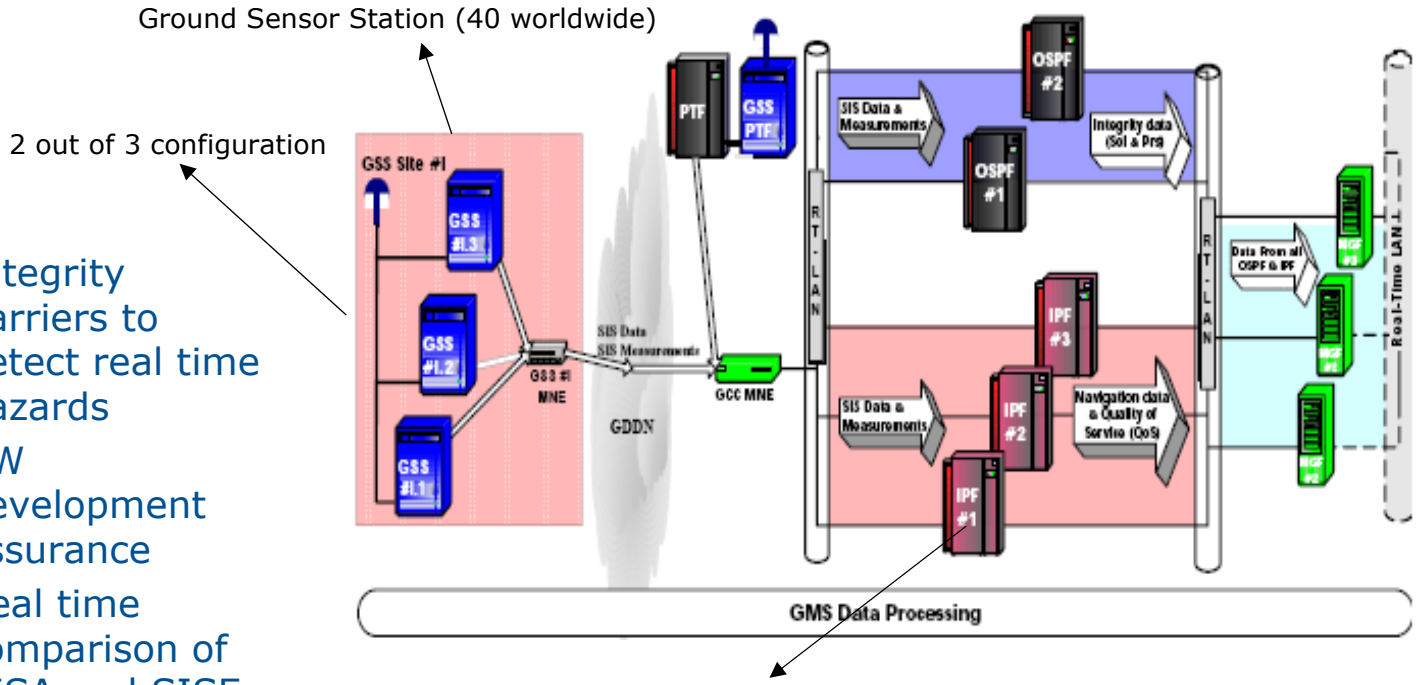
Galileo safety architecture - authentication



Galileo navigation system properties

Galileo safety architecture – ground segment

- Integrity barriers to detect real time hazards
- SW development assurance
- Real time comparison of SISA and SISE parameters

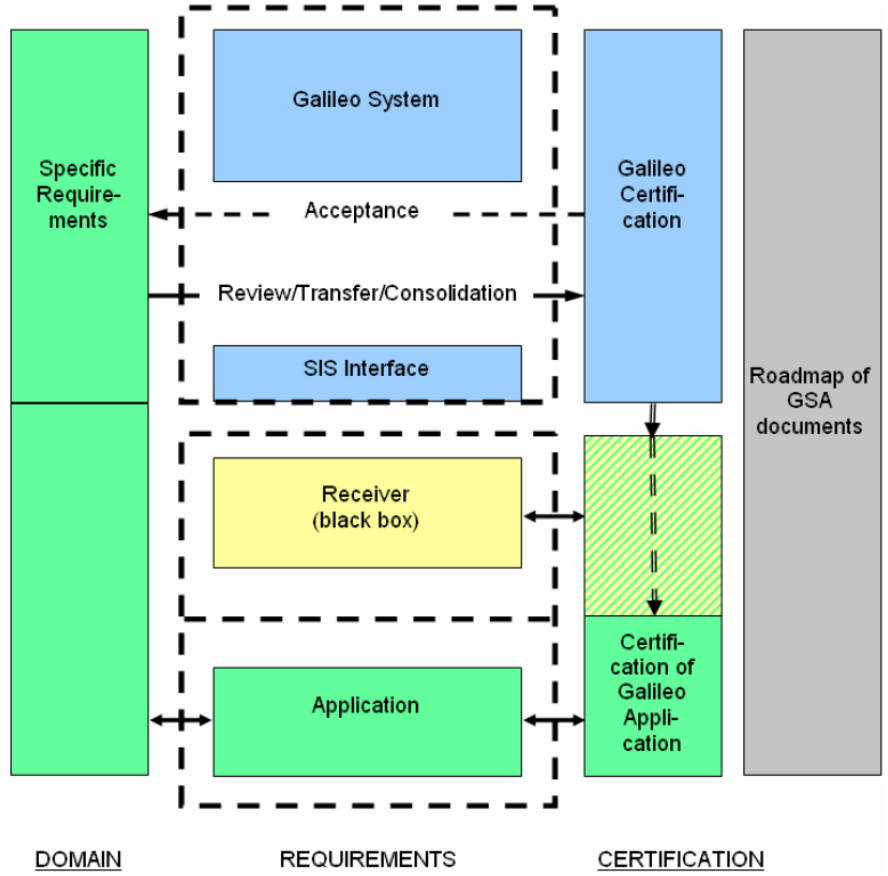


Source: European Space Agency, Thales Alenia Space

Galileo navigation system properties

Certification

- "Certification is a process by which a mandated body will independently assess the compliance of the system with standards identified by a regulating authority"
- Certification **will not overlap traditional certification schemes** used by different user communities to certify specific applications
- The whole life cycle of the system will be covered, including system design, implementation and operation phases during which quality assurance shall be provided



source: GALCERT project; funded by GSA, managed by GZVB

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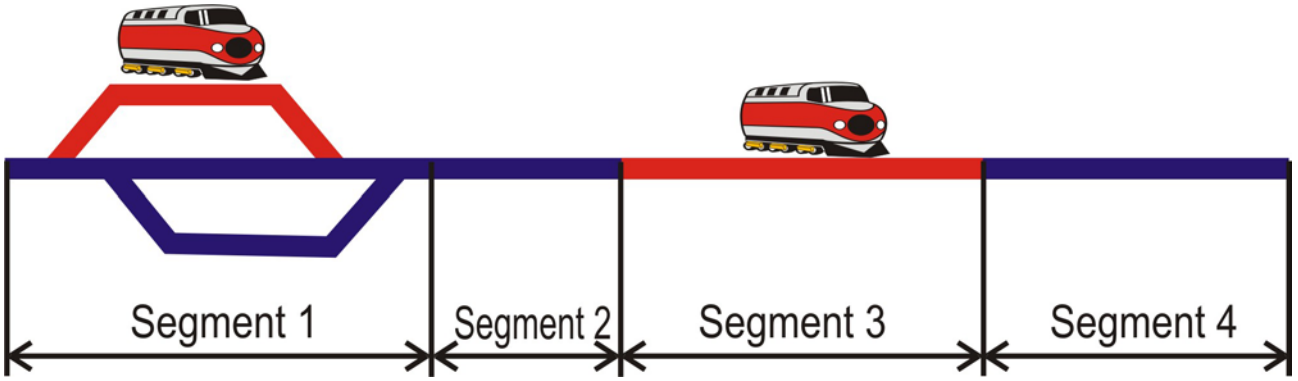
Advantages of safe satellite navigation for railways

- Train location is key information for rail transport control
- Track circuits – classical concept
  - Train position within track segment
  - Trackside wires needed – not cost effective
  - Fixed block – low efficiency of using line
  - ATO is hardly applicable without additional technology



Advantages of safe satellite navigation for railways

- New concept – employing satellite navigation to the safety systems
  - Track – independent mean of absolute train positioning (allowing centralized maintenance and service operations)
  - More flexible system of train positioning
    - Radio-based train control system
  - Low density lines
    - Cost effective solution
    - Effort in improving safety
    - Position information can be also used for telematic applications such as ATO systems

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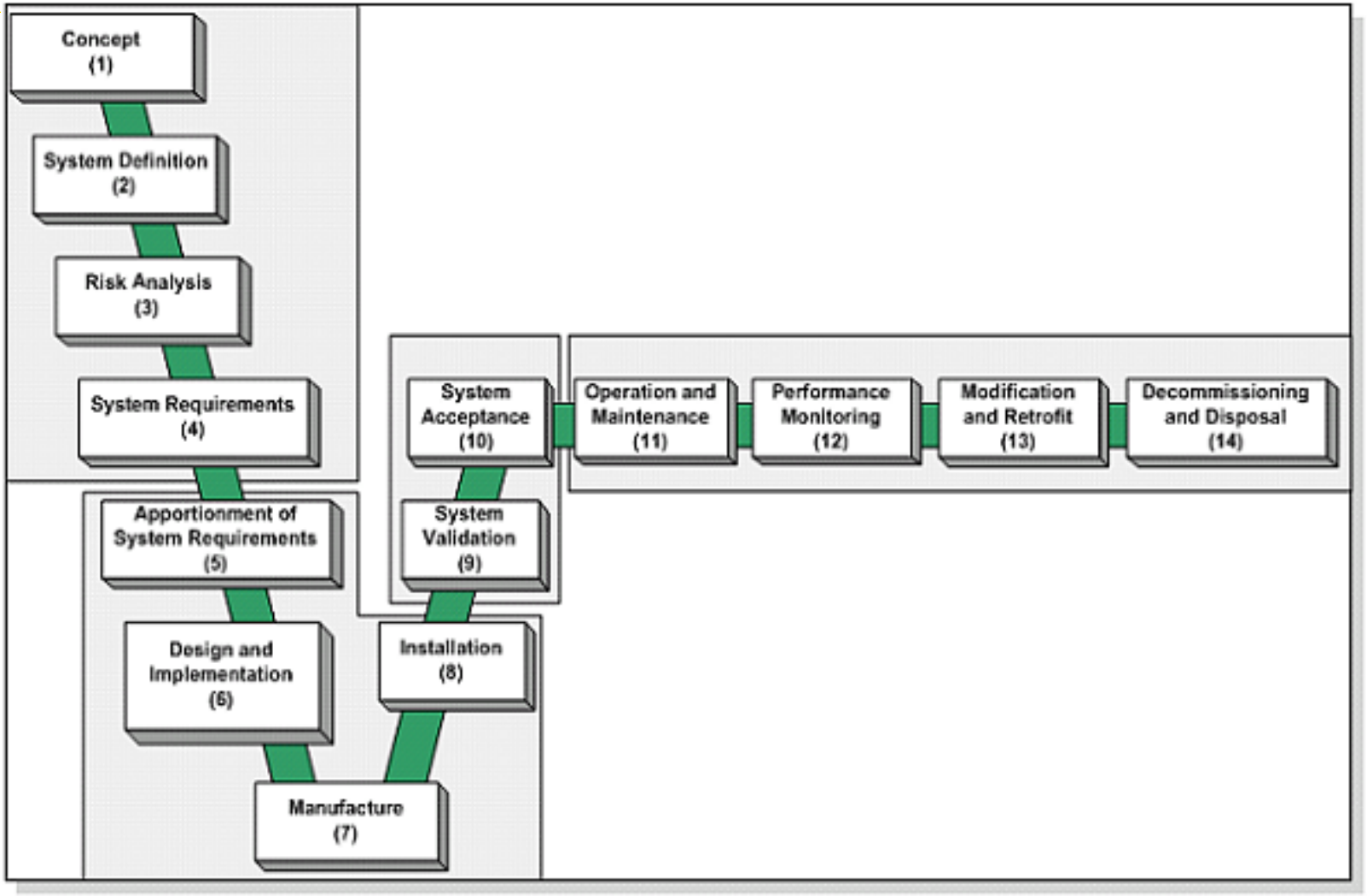
Introduction of new safety – related products in railways

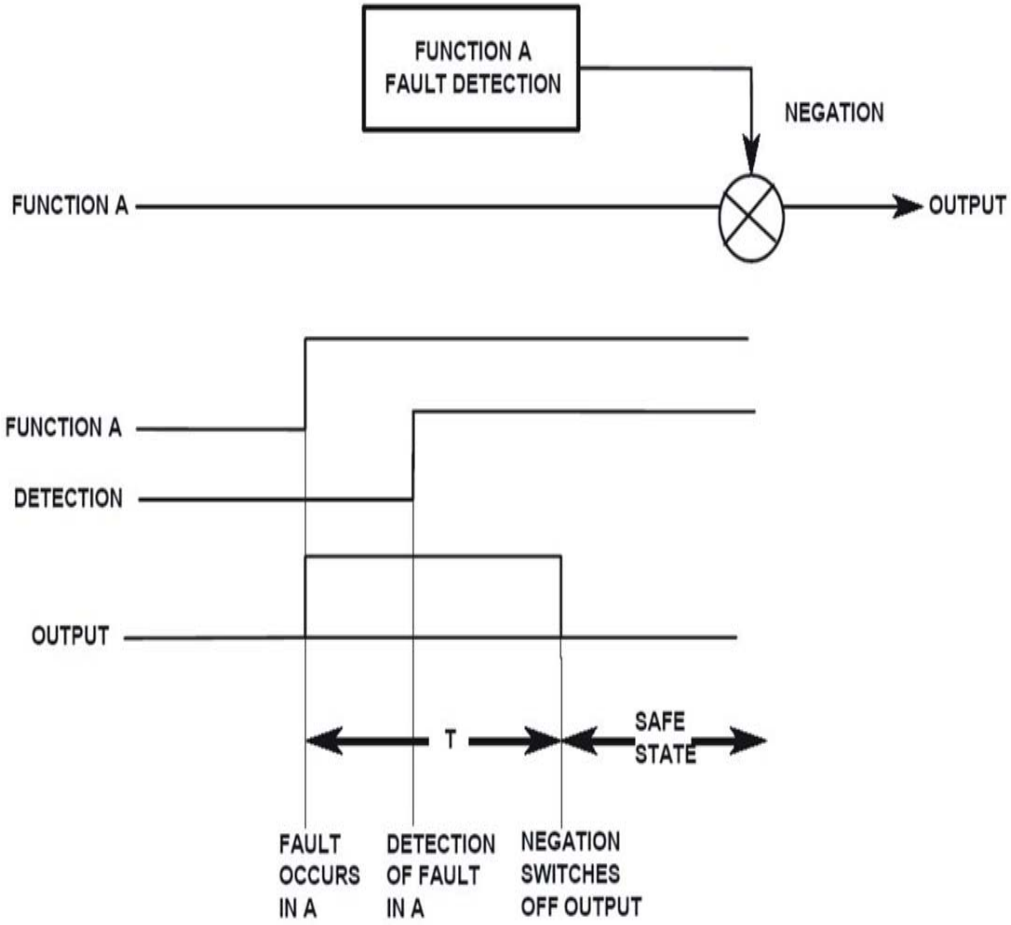


Introduction of new safety – related products in railways

- "V" lifecycle
  - It's a cyclic process without sharp borders from the phase start/stop point of view
  - Responsibility is divided equally among Suppliers (Galileo), Operators, Contractors and Approval authorities
- GALILEO certification without its safety approval according to CENELEC 5012x standards
  - Quantification of the system parameters does not mean its compliance with any safety integrity level (SIL)

Introduction of new safety – related products in railways

- CENELEC standards requirements (some of)
  - "It is necessary to ensure that SIL 3 and SIL 4 systems remain safe in the event of any kind of single random hardware fault which is recognized as possible."
  - For the purposes of safety approval it is needed to detect all failures in the time interval that is shorter than possibility of next failure appearance.
- Role of the SIL0 devices
  - The device reaches the SIL according to weakest part of the whole system



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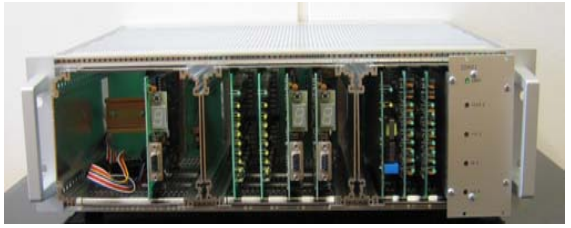
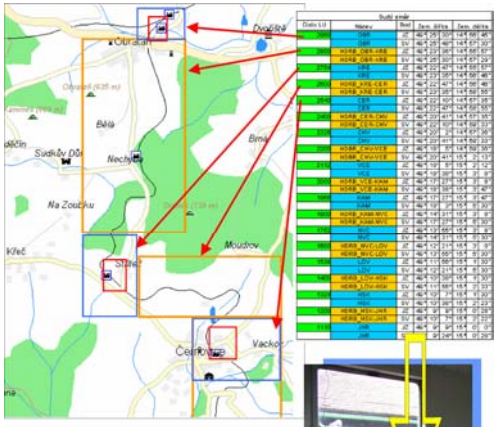
First applications

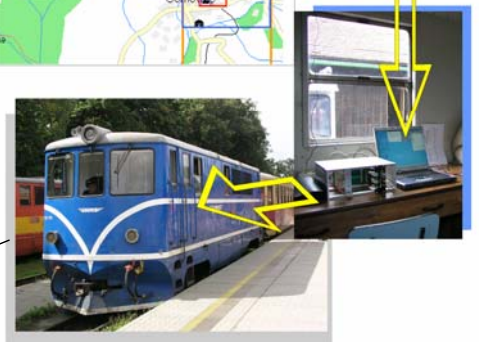
Project of the Ministry of Transport of the Czech Republic, "Czech Republic participation in the project Galileo" – AZD Praha s.r.o. contribution

Simulation of usage GNSS as a part of complex safety related control system for low density line



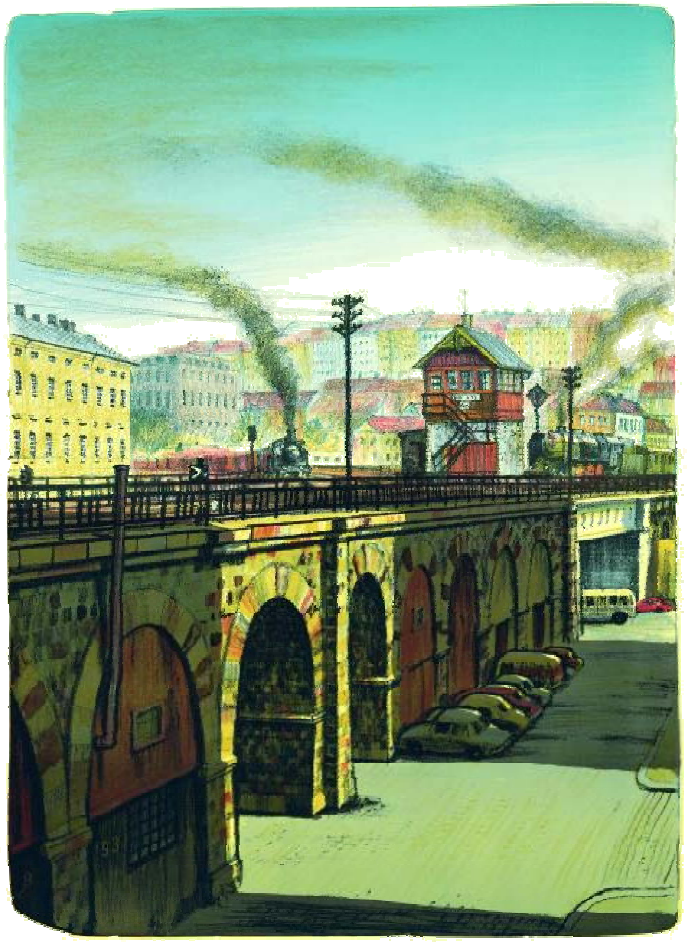
Developed prototype with new DMI





Testbed held in JHMD lines

Discussion



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