Prototype intelligent telematics devices

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Involved partners / Version control

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3D	Three-dimensional
Abb.	Description of Abbreviation
°c	Celsius
CATIA	Computer Aided Three-Dimensional Interactive Application
CREAM	Customer-driven Rail-freight services on a European mega-corridor based on Advanced business and operating Models (FP 6 project)
CSD	Circuit Switched Data
DB	Deutsche Bahn
EGNOS	European Geostationary Navigation Overlay Service
EMC	Electromagnetic compatibility
FDMA	Frequency Division Multiple Access
Hz	Hertz
IABG	Industrieanlagen-Betriebsgesellschaft
g	Gravitional force
GLONASS	Globalnaya navigatsionnaya sputnikovaya sistema
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
kbps	Kilobit per second
kg	Kilogramme
km	Kilometre
LED	Light-emitting diode
m	Metre
M2M	Machine-to-Maschine
m/s	Metre per second
Mhz	Megahertz

MSAS	Multi-functional Satellite Augmentation System
PCB	Printed Circuit Board (electronic board)
SBAS	Satellite-based augmentation system
SMS	Short Message Service
tkm	tonne-kilometre
UIC	International Union of Railways
v	Velocity
W	Watt
WAAS	Wide Area Augmentation System
WPAN	Wireless Personal Area Network

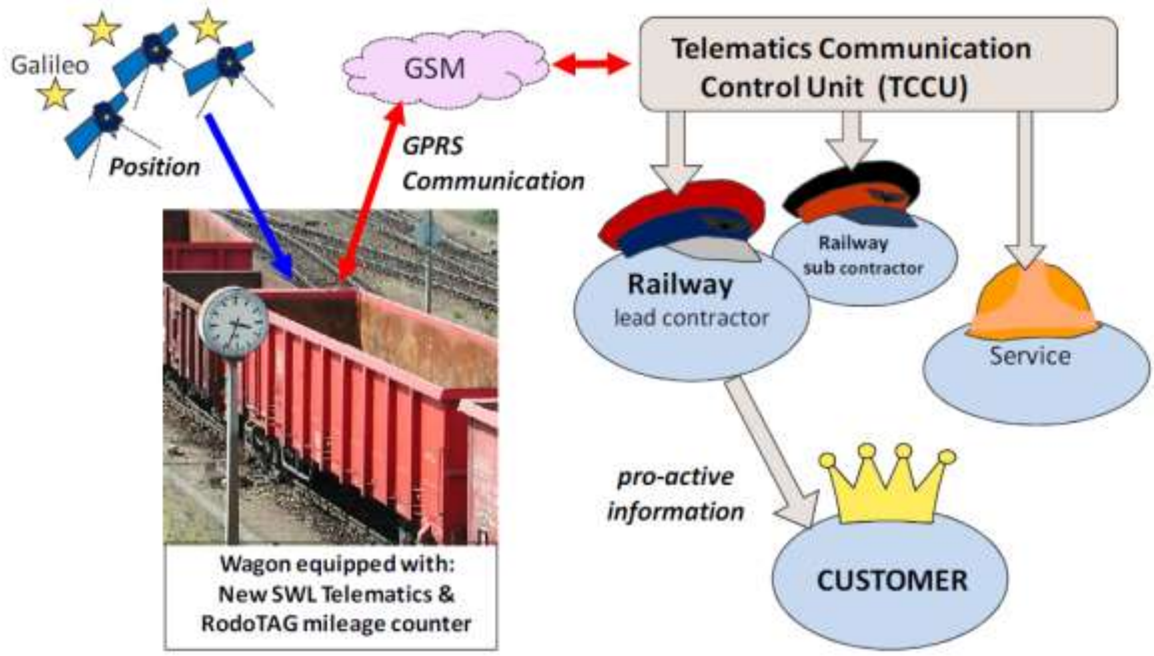
1 Background and objectives

1.1 Telematics information needs in rail freight transport

Unlike road transport, load tracking and tracing is still not widely used in single wagonload traffic. ViWaS seeks to accelerate the introduction of communication technology in rail freight. With on-board communication technology freight operators improve the dispatching of wagons and the rescheduling processes in case of disturbances. Based on reliable and "on-line" telematics data, the dispatchers will be able to inform their customers about changes in the transport schedule earlier than today. This pro-active customer information will increase the reliability and thus satisfy the stakeholders.

The project addresses particularly more competitiveness through an efficient organisation of transport processes. Cost-efficient and intelligent telematics based information services enable real-time wagon tracking (better quality) and automatically depicted wagon mileage information (cost reduction). A first step to quality improvement is the implementation of some kind of quality measurement. The telematics data service will automatically generate the information which is necessary for a reliable quality recording.

Figure 1: ViWaS telematics at a glance



Source: Eureka

The usual economic life cycle of freight wagons still foresees a rigid time schedule of six years, which does not represent the actual wear. The reason for this is the lack of mileage information of wagons. Since the accident of Viareggio, the railway authorities are requesting documentation of wagon mileage. This has to be seen as an additional effort that railway operators have to perform from now on. This applies especially to SWL traffic, because the large number of different RUs involved will cause problems to document all movements. A small electronic mile-counter with a radio link to the telematics device could overtake the RU's responsibility of wheel-set individual mileage counting.

1.2 Development objectives

The benefit of single wagon telematics is in general not questioned by RU's, but many potential users. They fear that the costs of such technology would exceed its benefits. The development within ViWaS will be consequently focused on a significant increase of benefits of the use of telematics and a massive reduction of the cost of ownership for such systems.

The goal of WP7 Task 3 is the development of an intelligent wagon telematics system on basis of the existing NavMaster technology. This includes the following activities:

1. Development of an intelligent wagon telematics system with the following design goals: Small, lightweight, cost reduction for hardware / communication by more than 50%
   a) Definition of a general concept to fulfil the requirements
   b) Design, construction and test of a new housing
   c) Design, development and test of the core telematics PCB
2. Prepare the system to use Galileo positioning (as soon as Galileo is in operation)
3. Integration of a GPS mileage counting function
4. Integration of a Sensor PCB with a three-axis shock recording mechanism
5. Integration of a radio interface to a RodoTAG mileage counter or another radio sensor
6. Development of a telematics installation and servicing procedure without the need for expensive railway workshop visits. The goal is a quick installation by the customer or a field service
   a) Definition of an installation concept to fulfil the requirements
   b) Design, construction and test of different mounting kits
7. Evaluate options for a low-cost and simple load detection sensor with radio interface to be integrated in the new telematics system

Figure 2: Relevant KPIs for WP7.3

KPI	Definition	Measure (compared to initial situation)	Target
Telematic costs	Change in hardware components and new HW-production schemes	Cost of the current NavMaster Generation	- Overall 50% cost cut
	New installation schemes to cut costs of installation and make (in the best case) a workshop visit needless	Current installation scheme compared to the new installation scheme in terms of opportunity costs	
Information flow	Information quantity in terms of information frequency and number of different information types	Information frequency, amount of max. number of information proceeds within the telematics device of the old and the new generation.	Increase in frequency
		Number of information types, amount of max. number of information proceed within the telematics device of the old and the new generation	Increase in information types
	Information quality, ensure a more stable information flow	Amount of time where localisation data with the current NavMaster System is unavailable. Currently the telematic does not send location data in case there is no GPS reception. Increase the number of localisation information by using Galileo and GSM cell tracking.	Decrease the amount of time where no location information is send

Source: Eureka

2 Development of intelligent wagon telematics

2.1 General concept of the new telematics

Based on the long term experiences with the NavMaster telematics Eureka defined a list of requirements for the system design. The general requirements were defined with the WP7 task definitions: Small, lightweight and cost reducing. The following list shows the selection of main requirements for the new development:

- Max. weight of electronics and battery must not exceed 1.5 kg.
- A battery change by the customer itself must to be possible, without any warranty related consequences (e.g. damaged seals).
- For a future design, the integration of a smaller internal battery has to be foreseen. A change performed by the customer is not required.
- The housing must be waterproof according to IP68 or better, and has to withstand very strong hits according to IK8 standard.
- The system must be able to operate in a temperature range of -40 to 85°C.
- A mass production must be feasible at low cost per unit.
- The GPS receiver and antenna should have a high sensitivity to enable navigation even under unfavourable conditions.
- The GPS antenna should be mountable in different directions inside the housing.
- The GSM receiver and antenna should have a high sensitivity to enable navigation even under unfavourable conditions.
- All components have to be supplied by companies that a known for high quality and long term availability of their products.
- An 868 MHz WPAN communication PCB should be stackable on top of the main PCB to enable a wireless communication to smart sensors.
- The integration of a Bluetooth communication module should be considered.

An analysis of the requirements resulted in a completely new system concept which is based on the following main ideas:

a) The separation of electronics and (main) battery in two housings,
b) Use of identical housings for electronics and battery,
c) Design of a flat long housing for maximum stability and water tightness,
d) G Design, construction and test of a new housing.

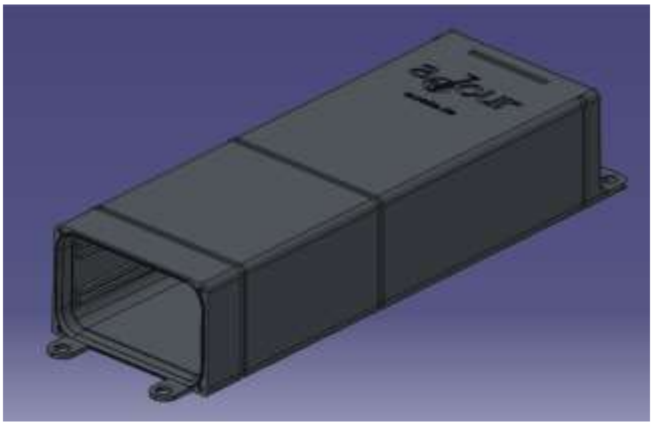
2.2 Design, construction and test of a new housing

As a first step, the most optimised housing size ratio was evaluated. For the various wagon types and wagon constructions, it was clear that a universal mounting concept will require different sizes and device proportions.

The requirement of a battery change by the user leads into an extended discussion of warranty issues due to possible damages of housing seals. As a result, having a complete extra housing for the battery was identified as the best solution. This construction idea was additionally beneficial as a flexible size ratio could be realised. A cable connection between battery and electronics housing allows both boxes to be arranged in different orientations.

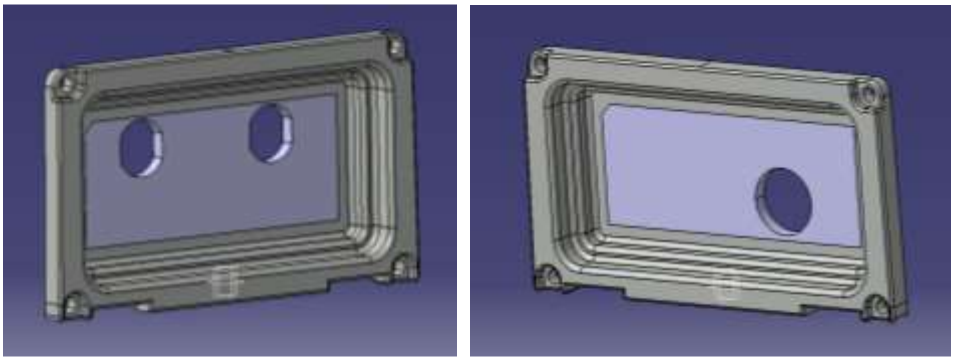
The decision on which side of the housing a lid opening is placed was based on the experience that the shortest possible cover gasket length is the best. This construction results in a stable and extreme watertight housing design. The disadvantage of such a sack-type housing is the difficult production process, which required several modifications of the production form until a high quality result could be produced.

Figure 3: New telematics housing without front lid (CATIA drawing)



Source: Eureka

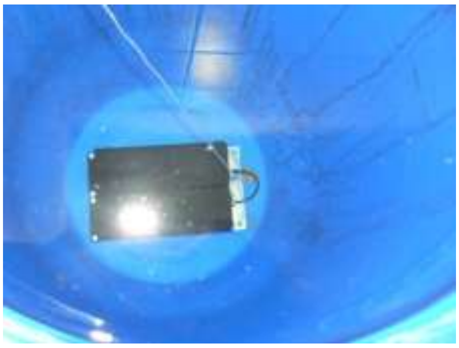
Figure 4: Front side of battery and electronics housing (CATIA drawing)



Source: Eureka

Intensive tests were performed to ensure IP68 water tightness for the whole temperature range of -40°C to +85°C.

Figure 5: Telematics housings in a 1.2 m deep water basin



Source: Eureka

Condensation of humid air inside the housing is a very critical reason for corrosion of the electronics. Therefore, the sealing was designed to be gas tight, even over temperature range. This was verified by air pressure tests according to DIN 60068 2-2 in a climate chamber.

Figure 6: Housings with pressure transducer in the climate chamber.

Source: Eureka

The compliance of the housing to an IK8 impact energy level according to EN 62262 was tested with a drop test bench. The falling mass had a weight of 1.1 kg and a falling height of 1 m. This in a speed of v = 4.43m/s and an impact energy of W= 9.81 Joule.

Figure 7: Falling mass and housing probe under the vertical test rig

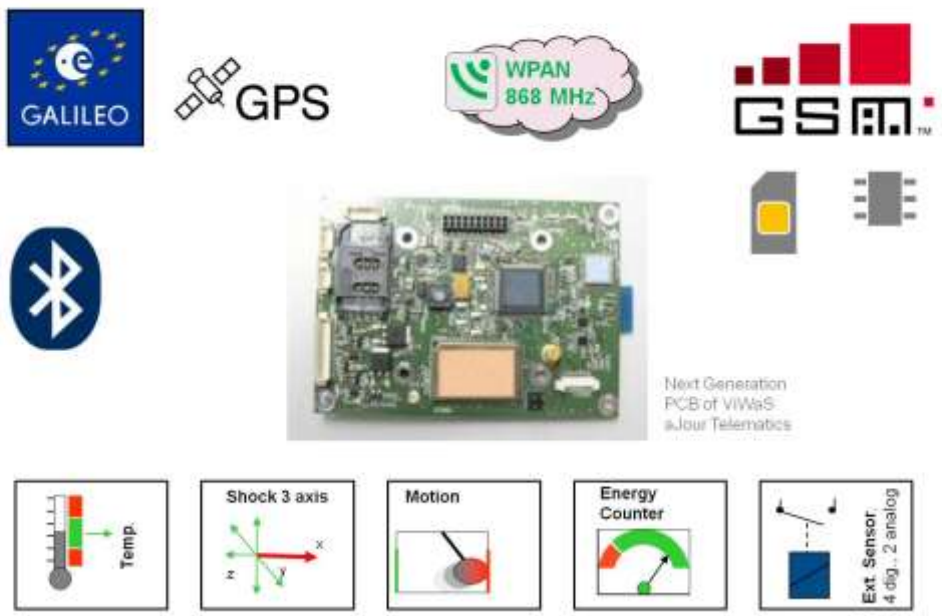
Source: Eureka

2.3 Design, development and test of the telematics PCB

The telematics electronics consist of the following main components:

a) Main PCB with all standard functions of the telematics
b) GPS Antenna
c) GSM Antenna
d) Auxiliary WPAN 868 MHz data communication PCB
e) Auxiliary WPAN and digital/analogue IO PCB

Figure 8: Functionality of new ViWaS telematics



Source: Eureka

The main PCB contains a new ultra-compact GSM module. This module was suited to the needs of M2M manufacturers of small GSM communication devices with a focus on high reliability and very low power consumption. The selected component offers quad band GPRS operation and offers therefore worldwide communication. A pin compatible dual band version could also be selected for use in GSM 900 and 1800 countries.

GSM-Module specification:

- GSM Quad-Band: 850 / 900 / 1800 / 1900 MHz or GSM Dual-Band: 900 / 1800 MHz
- 3GPP release 99
- GPRS multi-slot Class 10
- Compliant to GSM phase 2/2+
- Output power: Class 4 (2W) and Class 1 (1W)
- GPRS Class 10 DL: max. 85.6 kbps, UL: max. 42.8 kbps Mobile Station Class B
- Internet Services TCP server/client, UDP, HTTP, FTP, SMTP, POP3, Ping
- CSD data transmission up to 14.4 kbps, V.110, non-transparent
- USSD support
- SMS text and PDU mode, cell broadcast

Many tests had to be performed to find the best type of GSM antenna. Specific EMC problems had to be located and eliminated at the cabling to the antenna and also at the antenna backplane. The high frequency design for the GSM showed significant influences in the GPS signal sensitivity. Many modifications and test cycles were necessary to achieve a good RF design that fulfils the EMC standards.

The ViWaS telematics PCB is very small sized and is equipped with a low power multi-GNSS (GPS, GLONASS, Galileo, QZSS and SBAS) circuit. The compact component has an exceptional performance and combines a high level of integration capability with flexible connectivity options in a miniature package.

GPS specification:

Receiver type:	56-channel engine
GNSS Signals:	GPS/QZSS L1 C/A, GLONASS L1 FDMA,
Correction SBAS:	WAAS, EGNOS, MSAS
Navigation rate:	up to 10 Hz
Accuracy GPS:	2.5 m
Accuracy GLONASS	4.0 m

With the new GSM and GPS modules, a significant cost reduction of the main cost driving components could be achieved. These two components are moreover the main energy consuming components of the whole electronics. The innovative design of these circuits allows a significantly reduced energy consumption of the ViWaS generation telematics.

2.4 Prepare the system to use Galileo positioning

The new PCB contains a GPS circuit, which is able to receive and navigate on Galileo satellite signals. Galileo is the global navigation satellite system (GNSS) that is ~~currently~~ still being created by the European Union and the European Space Agency.

Due to many delays and losses of the first two Galileo satellites the Galileo service will not be available for civil purposes before end of 2016. The full completion of the 30-satellite Galileo system (24 operational and 6 active spares) is expected by 2020.

Therefore, test of the Galileo navigation with the new ViWaS telematics is planned to be performed after the ViWaS project end in late 2016.

2.5 Integration of a GPS mileage counting function

The firmware of the telematics was enhanced by a function that calculates the distance travelled between each GPS position received. This algorithm uses a simple distance calculation between the current location and the last measured position.

The accuracy of this km-based calculation is quite poor as tracks are not straight and turns between both positions are not included. The accuracy of the algorithm is therefore dependent on the distance between the positions measured by GPS and the number of turns between. Reducing the interval between GPS measurements is not a feasible strategy, as this increase the power consumption.

The pilot will test with a GPS interval of one hour. The GPS results will be compared with the results of the RodoTAG mileage sensor.

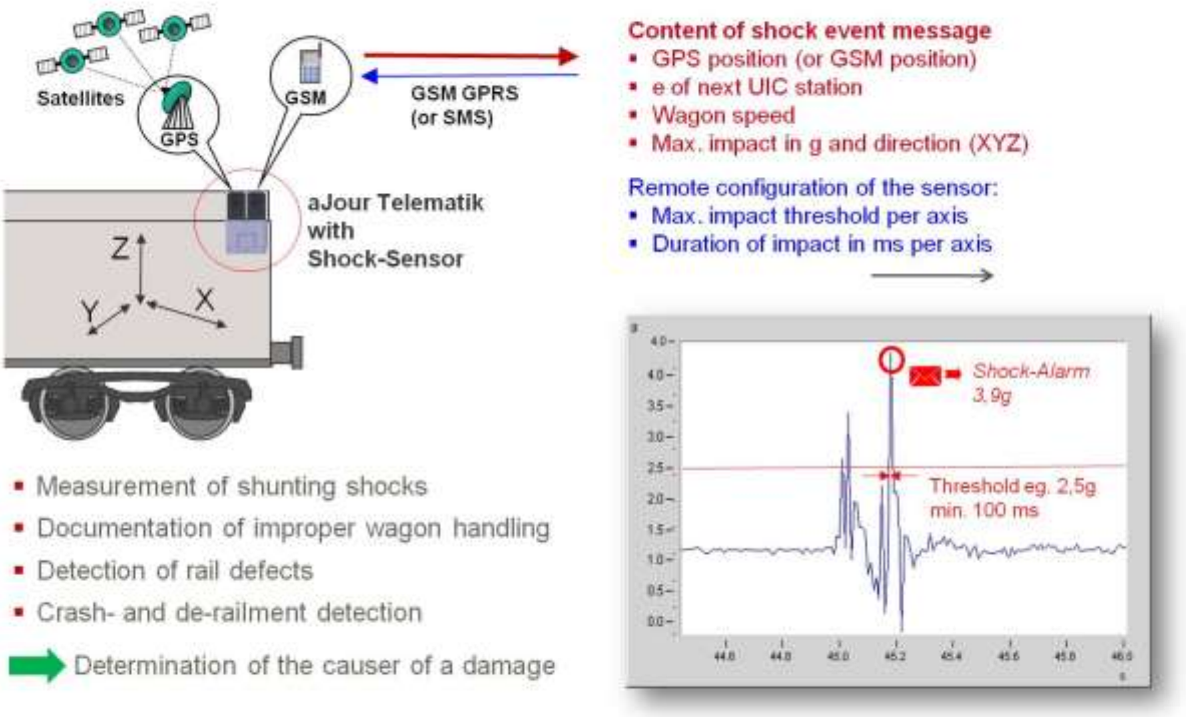
2.6 Integration of a Sensor PCB with a 3-axis shock recording

The interviews with potential users of telematics applications show that there are many different sensor requirements:

- Lateral shock detection (> max. shunting shock of 2.4 g)
- 3D shock detection with selectable thresholds
- digital inputs (e.g. door switches)
- 2 digital outputs (e.g. LED or relays)
- 2 analogue inputs (e.g. voltage or current)
- 2 sensor supply voltages

As the above given requirements are relevant for specific configurations, the development team decided to create a separate optional sensor PCB as an extension for the main PCB. The most difficult sensor was the development of a configurable 3D shock sensor. The following graph shows the principle and the parameters of the sensor:

Figure 9: 3 Axis shock detection with configurable thresholds



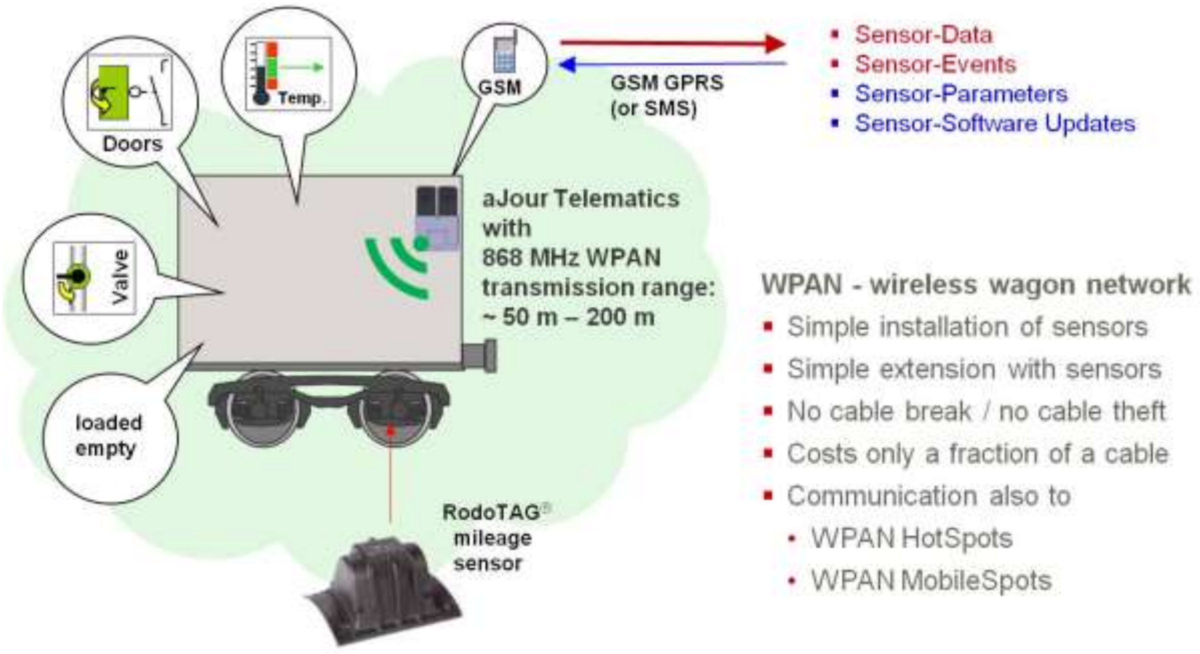
Source: Eureka

2.7 Integration of a radio interface to a RodoTAG mileage counter

In the previous EU funded project CREAM Eureka developed a wireless data radio based on the public 868 MHz frequency. This WPAN (Wireless Private Area Network) was mainly used to transmit mileage data from the RodoTAG smart sensors for mileage counting to hotspots, installed in railway yards. Additional tests showed that this technology offers a reliable communication around freight cars.

Based on these experiences a small WPAN module was developed that can be plugged on the main PCB of the ViWaS telematics. This data radio interface receives the data of up to 16 wireless smart sensors.

Figure 10: Telematics receives data from various smart sensors



Source: Eureka

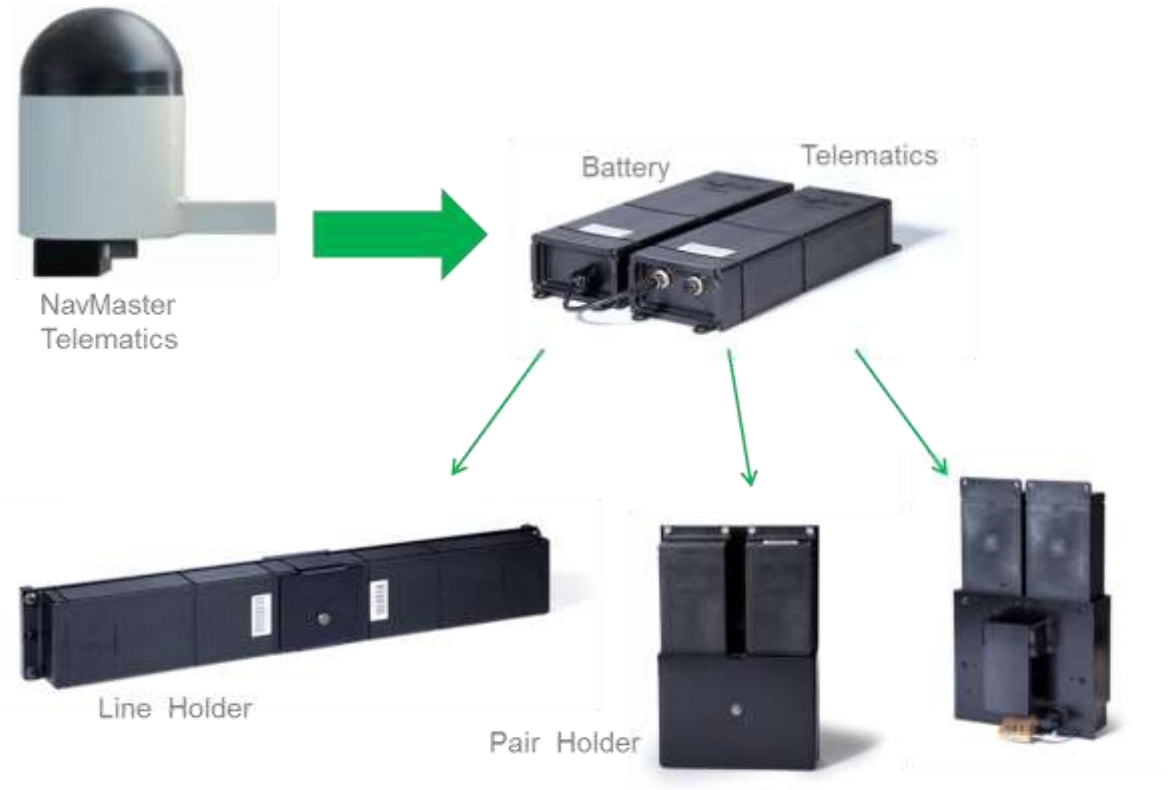
Figure 11: WPAN radio communication PCB

Source: Eureka

2.8 Development of simple installation and servicing procedure

The previous NavMaster design had an integrated steel boom which allowed a direct welding to the wagon. This concept was identified as very inflexible. With the new ViWaS telematics design many different holders could be constructed, tailored to the construction of the wagon type.

Figure 12: Modular telematics housing with different mounting holders



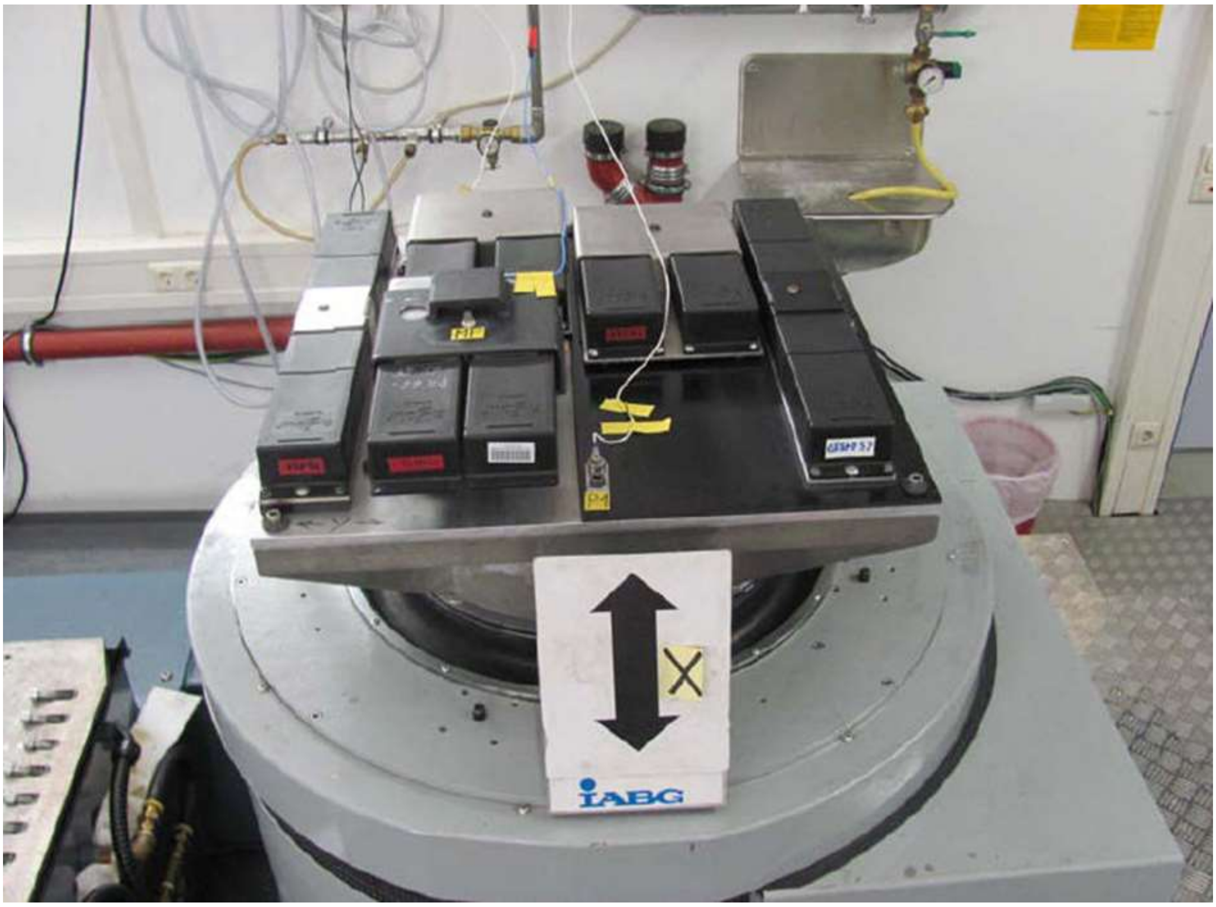
Source: Eureka

The following holders were constructed:

a) Holder "Line" was designed to mount the telematics on elongated vertical or horizontal structures.
b) Holder „Pair" mounts both housings side by side
It has a very strong steel base plate and cover and offers the best theft protection of all holders.
c) Holder "Bracket" holds both housings side by side. The hook on the rear side allows simple hanging the telematics in the signal bracket, which are located next to the buffers of each wagon. The front side of the holder has a bracket for use of end-of-train signals. The construction of the holder is strong enough to hang a French lamp signal in the bracket. As the device is only secured by a number lock, the users should be careful operating it in areas with a high probability of theft.

Telematics units which are mounted on the outside of a wagon have to withstand severe mechanical stress like shock, vibration and stone impact. Those environments are simulated and tested according to EN 61373 Category 1 and Class B.

Figure 13: Telematics mounted with different holders and different mounting methods on a shock and vibration test rig



Source: Eureka

The shock and vibration tests were conducted at a certified environmental test center at IABG Munich. The telematics units were in functional operation during the tests.

All three different holders were welded and screwed to the base plate of the test rig. Additionally, tests were performed with holders mounted by adhesive bonding tape and magnets. All tested mounting configurations fulfilled the test requirements. The internal components of the telematics and batteries showed no damages and no operational abnormalities during the test.

2.9 Documentation of prototype delivery

A small set of prototype devices have been built and are currently in practical tests.

a) Delivery of two telematics with holder „Pair“ and RodoTAG to DB Schenker Rail: Installation March 2014 at the DB Service Centre in Mannheim;
b) Delivery of three telematics with holder „Bracket“ to DB Schenker Rail: Installation April 2014 on different wagon types at the DB Service Centre Magdeburg;
c) Delivery of one telematics with holder „Line“ to Wascosa: Installation January 2015 at the SBB Service Centre Muttenz.

2.10 Outlook to training/demonstration

The training, setup and test results of the demonstration will be reported within WP9 and WP10.

2.11 Evaluation of load detection sensors

Several shippers, railway undertakers, wagon keepers and maintenance service suppliers were interviewed regarding benefits and consequences if a reliable load sensing technology would be available for freight cars.

The interviewed insiders expressed high interest in answering their daily questions:

1. Is the wagon still loaded? Yes/No
   -> When can the wagon be dispatched for the next transport?
2. What is the weight of the load?
3. How can the shipper’s personnel load wagons up to the max. allowed wagon capacity?
4. Is the max. axle loads exceeded?
5. Is the load on the wagon unequally distributed (left/right and front/back)?
6. How can tkm be calculated?

Summary of the evaluation:

Today, most of the freight cars in railway operation do not use the full load capacity as there is no existing cost-effective possibility to measure the load especially during the filling-up process e.g. in the area of bulk freight. If the wagon would be overloaded and afterwards moved by a train, all wheel sets have to be exchanged for a costly inspection in a workshop. Thus, the freight car will normally not be filled to its maximum payload.

The dispatching processes could be optimised if wagons transmit their load status. Such information would enable the dispatchers to re-dispatch the wagon in short time after unloading. Shorter standstill times and higher wagon efficiency would be the result.

The evaluation identified two positive business cases from the received answers:

a) Empty/Loaded information for optimising the dispatching (mainly railway undertakers),

b) Weight measurement and overload indication (all parties expressed highest interest).