EPoSS Strategic Research Agenda on Smart Systems Integration

Chapter: Smart Systems for Transport & Mobility

Riccardo Groppo, 9th September 2013
Topics

• The EPoSS SRA
• Overview on transport and mobility
• Example subsector: Automotive
• New challenges in packaging/interconnection technologies
• Conclusions
Smart Systems are autonomous or collaborative systems. They bring together sensing, actuation, informatics and communications. They detect / evaluate / predict / respond to help users or other systems perform a role. They are truly interactive systems.
SRA Methodology

1. The IRISS structured survey of 93 contributors:

2. Stakeholder workshop for data validation and condensation.

3. Ten structured expert discussion workshops seeded by the data from Step 2.

4. Outcomes from expert workshops prepared by specialist chapter authors.
Country spread of contributors

- Germany: 31
- France: 14
- Spain: 9
- Italy: 6
- The Netherlands: 6
- Norway: 6
- United Kingdom: 4
- Finland: 3
- Switzerland: 3
- Sweden: 2
- Austria: 2
- Belgium: 2
- Ireland: 1
- Poland: 1
- Greece: 1
- Portugal: 1
- Romania: 1
SRA Content and its Multiple Roles

- A clear statement of technology and market categories
- A record of questions, barriers, difficulties and opportunities
- A checklist with *timescales and forecasts* for researchers and strategists in SMEs, Large Companies and RTOs
- A discussion paper to support dialogues with government, funding and regulatory bodies
- *Above all, a reference document upon which to base action*
## SRA Format: Scale

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Overview: Transport & Mobility
Introduction

• The Transport & Mobility SRA chapter comprises an overview, then details of 4 subsectors
  – Automotive
  – Mass Transit
  – Navigation
  – Infrastructure & Signaling

• Today I will show you excerpts from the overview and one of the subsectors

• Please feel free to comment at any point, as we are seeking guidance and validation from as many people as possible
Overview

All forms of transport and their necessary infrastructure are continually demanding increasing levels of safety, efficiency and environmental performance.

Smart Systems, with their in-built knowledge base, offer reduced operator distraction and error, and optimisation of vehicle control, navigation and logistics potentially across multiple modes of transportation.

Profile

63 Smart Systems providers representing the Transport & Mobility supply chain from research through to market servers were predominantly engaged in the automotive sector (illustrated left).

Instruments such as the EU Green Car Initiative have attracted the attention of Smart Systems providers and users. This activity needs to migrate to other aspects of transportation.
Growth prospects: Organisations

Of the 63 Smart Systems providers surveyed, the great majority forecast employment growth, with a significant proportion of companies predicting headcount increasing by more than 50% by 2016 (illustrated left). There were no predictions of reductions in headcount.

A similar picture emerged for growth in financial terms.

Growth prospects: Whole sector

The Transport sector in EU27 is immense in value (>640 Bn€). The sector represents ~22% of worldwide production and R&D investments are ~5% of turnover (>26 Bn€). Currently Smart Systems account for possibly ~1% of this, but could rise to ~10% (>60 Bn€) by 2020 by greater adoption of sensor networks in the automotive subsector, smart devices for navigation, and seamless multimode transportation.
Drivers and barriers

The survey of 63 Smart Systems providers to the Transport & Mobility sector rated “Increased Functionality” as the most important driver compared to, in descending order, Reduced Cost, Increased Reliability, New Markets, Global Competitiveness, Simplicity in Use, and legislative drives to compel the use of new devices or techniques.

The most obstructive difficulty reported was “Fragmented supply chain”, responses indicating also that some 30% of public research bodies had no opinion about supply chain matters.

Accordingly, action should be considered to:

- Encourage researchers to gain better understanding of the Smart Systems supply chain to achieve a better match between research approaches and manufacturing capability.
The sector and its subsectors

There is a sort of “red wire” which links Mobility and the other aspects of transportation, including Mass transit, Navigation and Infrastructure & Signalling. In fact they share some global trends such as:

- Improved connectivity (e.g. IoT)
- System availability, exceptional quality standard and improved safety levels
- Eco-sustainability and progressive shift towards “electrification”

With particular respect to the “electrification, as it is very often confused with EV technology only, it is worthy to notice that it will be pervasive through the massive introduction of e-actuators and x-by-wire technology on a very wide range of applications. In fact, in the coming years several millions of vehicles, ranging from 2 wheels up to busses, trucks and agricultural machines, will feature a wide range of e-systems which will be “smart” by nature.

“Young man, that’s the thing: you have it. Keep at it. Electric cars must keep near to power stations. The storage battery is too heavy. Steam cars don’t do either for they have to keep a boiler and a fire. Your car is self contained – carries its own power plant – no fire, no boiler, no smoke and no steam”.

Thomas A. Edison to Henry Ford, Aug. 1896
References

"The automobile industry pocket guide" - ACEA, Sept. 2012
"European Roadmap - Electrification of Road Transport" 2nd Edition ERTRAC, June 2012
"Research and Innovation Roadmaps" ERTRAC, Sept. 2011
"Future Powertrain and Technology Trend Electrification" R. Bulander, Robert BOSCH
"Application of Hybrid Technologies into Heavy Duty Trucks", Glenn Ellis, Hino Motors Sales USA Inc. - SAE 2012 Hybrid Vehicle Technologies Symposium
"ERTRAC Research and Innovation Roadmaps", Sept. 2011
"Future Trends in Integrated Safety and Driver Support" - Dr. Erik Coelingh, Chalmers University, SSDS May 2012
"Automotive Interiors Becoming Smarter", A. Eppinger - Group Vice President Technology Management, Johnson Controls, SAE 2012
"Logistics and the Internet of Things", Prof. Dr. M. ten Hompel - IoT International Forum Nov. 2011
"IHS Topical Report: Advanced Driver Assist Systems: Gaining Momentum and Increasing Awareness, Q3 2011"
http://www.darpa.org
Example Subsector: Automotive
Overview

Smart systems affect every aspect of the automotive sector. A great number of sensors, actuators and processors are already in place in today’s cars, so there is a ready opportunity to install “smartness”.

The long term vision of autonomous vehicles rests with building a reliable set of images to describe precisely both the internal and external “state-of-functions”. A huge amount of information must be processed in real time in order to provide a coherent picture. At the same time the vehicle will be integrated into the Transport & Mobility infrastructure and thus will interact into a much larger eco-system.

Opportunities for Smart Systems

• Much intelligence is integrated already, in all vehicles, but is particularly at the heart of the EV
• Optimise driver decision making and navigation.
• Health and Usage monitoring
• Real-time sensor fusion and virtual sensor creation
• Smart “shells” the design and implementation of an intelligent environment for occupants

Hurdles to be overcome

• Re-inventing architectures – simplifying, localising in actuators, distributing. Trade-off from local to remote.
• Real time processing performance and a multi-core platform
• Affordable solutions for safety relevant applications
• Consumer Electronics and Cyberspace interact with Automotive

Courtesy of Magneti Marelli – Selespeed (Robotized gear-box Control Unit)
Applications

According to some in depth analysis ("Smart Connectivity: Connected Automotive Systems" B. Bihr, President Bosch Engineering GmbH, June 2012) there will be about 7 Bn connected people and about 1 Bn licensed connected vehicles worldwide by 2015. Moreover, due to the capability of HEV/EV to manage electrical energy on-board, it will become natural to consider the vehicle as a user/producer of electrical energy. As a result the vehicle will interact in the Internet of Things (IoT) and Internet of Energy (IoE). Hence, there will be important opportunities for Smart Systems both in consolidated (e.g. pwt, chassis, body,..) and new domains:

- *Smart cluster for driver assistance*
- *Safety*
- *Optimise range, performance, comfort*
- *Smart e-actuators*

Source: Strategy Analytics Data Jan 2013
Introduction of three classes of Smart Systems

The three classes below do not necessarily succeed each other in time: the nomenclature “generation” indicates increasing levels of “smartness” and autonomy.

**1st generation** Smart Systems include sensing and/or actuation as well as signal processing to enable actions.

Currently there is wide application of algorithms in automotive emissions, fuel injection and combustion. Further applications are appearing continuously.

**2nd generation** Smart Systems become predictive and self-learning.

Huge production volumes bring spreads in the aging of key components. Systems must learn, and react for clean combustion and acceptable performance.

**3rd generation** Smart Systems simulate human perception/cognition.

Co-operative rather than self-organised systems are expected.

Evolutionary (self-reconfiguring and healing) hardware is already under development.
Subsector forecast

Electronic systems are already 40% of the value of a car and will represent up to 75% in Hybrid and Fully Electric Vehicles.

In 2012, the global market for automotive electronics systems was worth $189 billion, a rise of 11.2% over 2010, despite challenging economic conditions in many parts of the globe.

The value of the world-wide market for automotive electronic controllers (ECUs) stood at $51.1B in 2011. This market is expected to continue to grow, due to high-value of vehicles (inc. hybrids), with demand now expected to increase to $263 billion by 2016.

Advanced Driver Assistance Systems and HEV/EV are the major growth drivers, especially in established production areas.

<table>
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<th>Key indicators: Automotive</th>
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<td>Growth characteristic for the sector</td>
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<td>2010 value (EU27 + EFTA) for the sector</td>
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<tr>
<td>2010 Smart Systems value (as % of total sector)</td>
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<td>2020 Smart Systems value (as % of total sector)</td>
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The indicators above are shaded to reflect uncertainty

Sensors are inextricably linked to Smart Systems. The total automotive sensor market in 2011 was $15.4 billion, where Europe remains the largest automotive sensor market, with an expected value of $6.3 billion in 2019.
Subsectors as a whole

• The previous slides showed only Automotive. Similar sets have been developed for:
  – Mass Transit
  – Navigation
  – Infrastructure & Signaling
New challenges in packaging/interconnection technologies
**ADAS: gaining momentum and increasing awareness**

- Momentum behind automotive and road safety continues to propel the industry forward. Governments are calling for standard installation of safety and driver assistance systems, the industry is constantly innovating and improving its products and practices, and consumers seem to be taking a more active interest in the technologies that can protect vehicle occupants should critical situations arise. Together, safety technologies are beginning to play a much greater role in shaping the automotive landscape.

- ADAS technologies employ sensors (e.g. camera, radar, laser, ultrasound, ..) around the vehicle to gather data on the surroundings and then pass on vital information to the driver so that informed and intentional decisions can be made.

- ADAS are systems or devices intended to help drivers operate vehicles more safely by integrating sensors with on-board systems for alerting the driver to hazardous conditions or by facilitating specific tasks such as parking. Some sensors are visible to drivers while many more are embedded within the vehicle and its systems.

- Actions taken by these systems began as simple passive alerts or reproducing information for the driver. Today, active intervention is quite common for the latest generation of ADAS.

- This trend will continue and many applications of the future of ADAS and automotive safety include semi- or fully-autonomous vehicles as well as intelligent infrastructure to support these vehicles.

- This will expand the reach of ADAS from single vehicle based systems to networked safety systems drawing on the same sensors to new implementations of these systems based on vehicle-to-vehicle communications and wireless infrastructure.
ADAS: challenges on technologies

• According to Strategy Analytics and others OEM/Tier1 supplier, ADAS will represent one the major driver, especially in established production areas. The CAAGR over 2012-2017 will be above 25%.

• Hence **the challenge is to develop more advanced systems** (e.g. processing capability, mechatronic integration, ..) **with lower costs.** This will support the massive adoption of ADAS also on mid-class vehicle segments (i.e. **ADAS democratisation**).

• With particular respect to packaging/interconnections topics there is the need to integrate in an effective manner RF sub-systems and embedded processor for compact sensing modules (e.g. RADAR, ..). Several solutions have been proposed by major silicon supplier (e.g. eWLB, RCP, ..) but a **system approach must be followed**, taking into account both the interaction with the PCB (e.g. manufacturability, yield, cost of complex multilayer substrate) and the **electrical performance** (e.g. signal integrity).

• The **improved processing capability will increase the power dissipation** of the processor, thus **efficient package from the thermal viewpoint** will be required as well.

Note (*) MMIC: Monolithic Microwave Integrated Circuits
Improving vehicle dynamics and stability: torque vectoring and smart wheel system

- The increasing request for improved vehicle dynamics and stability is supporting the development of active torque vectoring systems, where current implementations are based on in-line “electrical drives” architecture.

- The smart wheel concept aims to integrate braking, suspension function thus creating a true “smart systems” and offering additional features in vehicle stability.

- There are several challenges in the packaging/interconnections domain:
  - true mechatronic integration around the e-motor and sensing elements
  - high operating temperature and vibration levels
  - co-existence of power and logic devices
  - large passives
  - possible adoption of wide band-gap materials
  - advanced cooling techniques (e.g. phase change materials)
  - safety relevant applications (e.g. fail silent units)
  - low cost
Conclusions
Conclusions

• We can assume that the **next generation of vehicles** (mid/high value segment) will see a **wider adoption of smart systems** because the **complexity of interconnections** and the **“cost” of transmission along the networked nodes** are becoming a real issue and no longer manageable with centralised architecture.

• There will be the **co-existence between high hierarchy supervisor units**, dealing with the whole vehicle management (e.g. powertrain, chassis, energy, infotainment, ..) and **several smart nodes** able to perform local processing and functions.

• Smart node will be able to diagnose themselves and enter into safe state in case of fault.

• **Packaging and interconnection** will play a major role in the **further miniaturization of mechatronic units** while meeting the demanding **quality, availability, performance and cost** constraints required in the automotive domain.

• The final two slides invite discussion regarding the EU position in Smart Systems and suggested Research Priorities across all the subsectors.
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<th>Sub-sector</th>
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<th>Weaknesses</th>
<th>Opportunities</th>
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| **Sector as a whole**          | • EU global players have the necessary muscle to develop Smart Systems and to establish their acceptance and appeal | • Smart Systems value chain not clearly defined and recognised            | • Smart Systems need a new class of “applications aware” multidisciplinary engineering teams | • Reliability issues not fully explored regarding autonomous Smart systems  
• “Cyber attack” of Smart vehicles and transportation systems |
| **Automotive**                 | • Innovative small companies and >6000 sensor producers  
• Well established supply chains | • Incremental development based upon improving previous models can hold back revolutionary Smart Systems | • Electrification brings new spaces for Smart Systems  
• CO₂ reduction is a further driver, with Smart Systems will bring higher efficiency and cleaner operation | |
| **Mass Transit**               | • Huge installed infrastructure with “Smart” ticketing and some driverless systems already accepted by the travelling public | • The timescales of long-term infrastructure investment can fail to recognise and intercept with future technologies such as Smart Systems | • Resilient multimodal seamless Passenger-centric and goods-centric. travel.  
• Retro-fit new technology into existing infrastructures | |
| **Navigation**                 | • Good GSM and other infrastructure                                       | • Basic display and Human Machine Interfaces are produced outside the EU  | • Smart Systems to automatically gather and update geopositioning information | |
| **Infrastructure & Signalling**| • An already well regulated transport system to build upon                  | • Legacy systems need to interface with Smart Systems                    | • Use Smart Systems to optimise existing infrastructure at relatively low cost – more capacity on existing routes | • Regions of the world having a “clean sheet” for infrastructure could develop Smart Systems free from “legacy” constraints |
### Smart Systems for Transport & Mobility: EU Research priorities

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<th>Mid-term actions</th>
<th>Longer term actions</th>
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| **Sector as a whole**       | • Unified semantics for sensor systems around the Transport & Mobility sector and the wider Internet of Things  
• Scale up Erasmus Mundus to create a new class of “applications aware” multidisciplinary engineering teams                                                                                       | • Integration of sensors, actuators and power electronics into components  
• Optimized integrated power electronics including advanced thermal management and cooling strategies  
• Standardisation for integrating the Smart vehicle into developing infrastructures                                                                                       | • Reliability issues not fully explored regarding autonomous Smart systems  
• Cyber security  
• Introduce Systems Level Design as a curriculum subject                                                                                                                                                  |
| **Automotive**              | • Innovative comprehensive battery management systems (BMS) and standardization of BMS components and interfaces  
• Optimized integrated power electronics including advanced thermal management and cooling strategies  
• Integrated electrified accessories in order to improve energy efficiency  
• Advanced electrical/thermal monitoring systems  
• Develop Devices for Automated and Cooperative Driving  
• Generate new procedures to ensure that Smart Systems are “Automotive Grade”                                                                                                                                  | • Provide Interfaces for Integration into Transport System Networks; Enable multi-modality  
• Optimized integrated power electronics including advanced thermal management and cooling strategies  
• Standardisation for integrating the Smart vehicle into developing infrastructures                                                                                                                                  | • Fundamentally revised E/E- and Software Architecture: Integration, Simplification, Flexibility                                                                                                                  |
| **Mass Transit**            | • Identify the key points at which Smart Systems could provide significant benefits in existing and future Mass Transit systems, and quantify those benefits                                                                 | • Exploit ADAS for safety                                                                                                                                                                                   | • Establish a mechanism for long-term infrastructure developments to intercept with rapidly developing Smart Systems technologies                                                                                     |
| **Navigation**              | • Secure linking of personal nomadic systems to vehicle systems, mass transit systems                                                                                                                                 | • Enable fully automated driving for defined situations/applications                                                                                                                                       |                                                                                                                                                                                                                 |
| **Infrastructure & Signalling** | • Research the technical capacity in the existing infrastructure for the installation of smart upgrades, and determine new strategies accordingly                                                                 | • Enable Car2X Infrastructure  
• Provide devices and communication protocols for bi-directional charging of EV                                                                                                                                  | • The integration or upgrading of older vehicles that do not have Smart System capabilities, and formulating an upgrading process for Smart vehicles                                                                 |
Acknowledgement

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