Strategic roadmap

WITHIN THE INITIATIVE STRATEGIC VEHICLE RESEARCH AND INNOVATION (FFI)

Electronics, software and communication

03/11/2015

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1 Purpose and Goals

This strategic roadmap describes in a general manner the FFI programme's link to Electronics, Software and Communication. This document contains challenges, research and development needs, as well as the expected results.

The aim is to identify research and innovation activities that will permit the development of safe and environmentally sound vehicles, thereby strengthening the Swedish automotive industry's competitiveness. In addition, the roadmap can be used for monitoring and evaluation, as well as to increase understanding of the FFI programme by illustrating the correlation between the funded activities and the expected effects. This document covers the period up to 2030 and makes concrete what needs to be done to enable achievement of all of the FFI programme's overall objectives, i.e. the objectives described in:

- The FFI "Overall Roadmap'
- The roadmap “FFI Road Safety and Automated Vehicles”
- Roadmap “FFI Energy and the Environment”
- Roadmap “FFI Efficient and Connected Transport Systems”

The information provided in this document is based on the combination of benchmarking, standardisation activities and applied conferences. The material has also been sent for comment to doctoral & technical specialist networks, public authorities, and middle managers in the private sector (a total of about 60 people). For this reason there are no formal references. Naturally, the data is based, where possible, on traceable facts, for example Figure 1 is based on public legislation in California, Figure 3 reflects the operations of a Swedish vehicle manufacturer, and Figure 5 reflects the situation for Swedish vehicle manufacturers.

The document describes the technologies that enable functions for the programme areas for “Energy and the Environment”, “FFI Road Safety and Automated Vehicles” and “FFI Efficient and Connected Transport Systems”. Of course, these activities do overlap somewhat. For example, if you intend only to study one Active Safety function, you will do it within the framework of the programme area “Vehicle and Road Safety”. The main focus is on how this function works in a traffic environment and part of the technical solution for this function. Additionally, the focus of Vehicle Development on the technologies that enable the function of a product to be introduced is needed, both in terms of the architectures that enable the function and the basic technologies that enable joint utilisation of the technical solution required to achieve the related functions. This symbiosis is central to effective Innovation Systems with short lead times.

This also means that this roadmap describes the technologies and knowledge structure required for areas such as “Electromobility”, “Autonomous Vehicles” and “Connected Vehicles”. Or more generally for the “Green, Safe & Connected” functionality.

The supplier structure’s expertise plays a significant role in its ability to adhere to all of the roadmaps. A specific feature of this roadmap is that one of its main aims is to pave the way for a new software-based supplier structure.

2 Background

Electronics, Software and Communication (EMK) is crucial for the development of an environmentally friendly and safe traffic system while also strengthening the competitiveness of the Swedish automotive industry. A look back gives an indication of future potential.

Environment: Since the Clean Air Act was adopted in the United States in 1970, regulated emissions of NOx and HC and CO have fallen as shown in Figure 1. The bulk of this reduction may be credited to EMK in the form of fuel injection systems, ignition systems and so on.

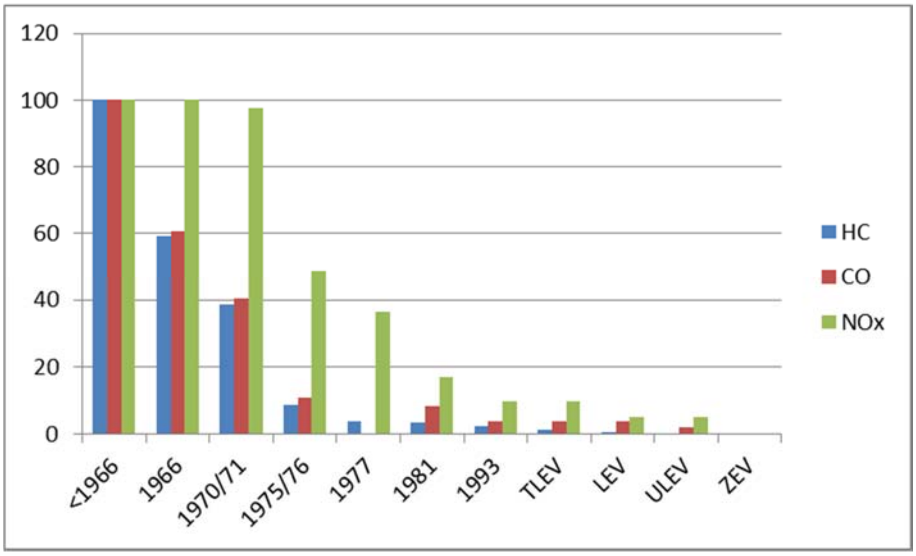

Figure 1: *Regulated "tail pipe" emissions of HC, CO and NOx in California (baseline 100% before 1966)*

California has also been a pioneer in zero emission vehicles, also resulting in reduced fuel consumption, i.e. reduction in CO_2. As an effect of their ZEV mandate (Zero Emission Vehicle mandate), over the last ten years globally we have seen the introduction of vehicles electrified to varying degrees. This includes, for example, Volvo Cars' Plug-in Hybrid with which some drivers are able to drive up to 5,000 kilometres on a tank, i.e. approximately 1 litre/100 km in fuel consumption. This type of vehicle "electrifies many miles in real world traffic".

Safety: The first major steps towards linking safety with EMK are the introduction of air bags for passive safety and anti-lock braking systems for active safety. There are now so many active safety functions in production that it is difficult to name them all, even for a specialist. Interesting in the short-term is that the EMK-based active safety systems, by their very nature are easy to retrofit if the right system is available. This will be especially important once vehicles are considered to be connected and thus easily access wirelessly. From a technical perspective, in ten years it will be fully possible to eliminate road deaths using EMK.

Competitive Swedish Automotive industry: EMK strengthens the Swedish automotive industry's core values of "Safe and Environmentally-Friendly Vehicles". Connected vehicles are a part of this development. Another effect of connected vehicles is that a number of new areas are emerging that will substantially strengthen the Swedish automotive industry's competitiveness. The automotive industry is well on its way to using the information in and around vehicles for data trading, new customer features and improved efficiency. Examples of data trading include the vehicles themselves being used as sensors for the transport infrastructure, for example where there are delays, where there are potholes, which rest areas need cleaning and so on. Examples of new customer features is the ability to detect hazards and warn other road-users. Improved efficiency can easily be envisioned growing out of a better understanding of vehicles in real traffic settings, which can lead to, for example, proactive safety.

This makes EMK crucial for "green, safe and connected" vehicles.

3 Electronics & software within the automotive industry

3.1 Approach

From a macro perspective, the automotive industry is moving toward developing products that are equally top-down optimised from a mechanical, electrical and software perspective. In a way, the automotive industry has taken the first steps toward a broad combination of traditional mechanical engineering and electronics with advanced control technology, built-in computer systems and ICT (Information and Communication Technologies).

EMK by its nature should not be seen, heard or make any noise. Nevertheless it is crucial for safe and environmentally friendly transports and for the Swedish automotive industry's competitiveness.

EMK consists of a technology platform used by several stakeholders. For example, electricity supply and operating systems are resources in the technology platform clearly used by many stakeholders. Another example is sensor information that is primarily used for one function but is also used by other stakeholders. For example, the navigation information in connected vehicles could also be used for more energy efficient and safer driving.

This document describes the sequence of events from a macroeconomic perspective as well as in slightly more detail from a system perspective.

3.2 The macroeconomic perspective - transformation of the automotive industry

The automotive industry is experiencing significant change. In simple terms, it can be said that the effects of the semiconductor industry are washing over the automotive industry. When this wave of change has passed, we will have a transport system:

- Where no-one is killed or seriously injured.
- With drive trains that are minutely controlled and that minimise environmental impact.
- With efficient coordination and use of different vehicle types.

We have also created:

- A business model, in which a large part of the automotive industry's revenues come from the use of the vehicle during its lifetime.
- A new software-based supplier structure.

To understand how quickly the wave inundating the automotive industry, a future scenario can be envisioned:

- The changes are taking place in very limited areas. Basically, huge investments in production structures are occurring that have marginal impact and that dissuade start-ups.
- Changes to basic technologies occur in small increments and at very high cost. The fundamental system solutions have also existed for a long time and they have clear interfaces with each other and with the jobs to be done.
- Because of these inflexible system solutions, major changes occur very slowly. As a rule of thumb, it can be said that major changes happen on the following cycle: research and preliminary development for 7 years; product development of first-generation products for 7 years; low volume production to build up the competence of the entire value chain for 7 years; and start of high volume production. After

approximately an additional 15 years, all products in this product series will have been replaced on the market. A significant change takes almost 40 years to achieve full market penetration.
- Basic technologies can virtually never be retrofitted.
- On the other hand, new features can increasingly be added through software. In a properly organised system, software can be easily modified wirelessly. With the help of connected vehicles and "Continuous Deployment", functions can be changed more or less instantaneously. For example, a software-based Active Safety function can be “retrofitted” to the entire vehicle fleet instantaneously. As an example, Tesla introduced the functionality for autonomous driving through a wireless software update.
- Two “clock frequencies” meet; almost 40 years vs. instantaneous.
- The result is, of course, given. When the new system structure for plug-in hybrids is available, for example, each component will individually be continuously streamlined within its interface (for example, batteries will become smaller and more efficient; the combustion engine’s job will be limited to producing electrical energy as an “Auxiliary Power Unit”). In the world of instantaneous change, the automotive industry will make every effort to ensure that existing information will create new revenue opportunities based on existing investments.
- As a result of this, perhaps the most important trend of all in the automotive industry is what is known as “Decoupled Engineering”. In principle, this means that the automotive company has three parallel product development processes: one that develops vehicles; one that develops separate subsystems; and one that develops the software-based features.
- Add to this the issue with a well organised system approach in which software can easily be retrofitted.
- It is clear that this will become partly available within the next few years. A not too daring estimate is that this will be introduced on a broad front during the 2020s.
- Within this period, the automotive industry has also built up expertise on a broad front in the field of electric drive trains throughout the value chain. From a hardware perspective, the current generation of plug-in hybrids will be the most complex vehicles developed within the foreseeable future. The focus thereafter becomes simplification within the given frameworks of the system.
- During the 2020s, the semiconductor industry will have transformed the automotive industry, resulting in a new reality characterised by no deaths in traffic accidents, minimal environmental impact from vehicle drive trains and that those who have fostered the change will have ensured a steady income from the use of the vehicles.

The above scenario clearly points to the importance of the system perspective. In the next chapter, we will return in more detail to the development of the most important elements.

Figure 2 illustrates the scenarios we have described in graphic form.

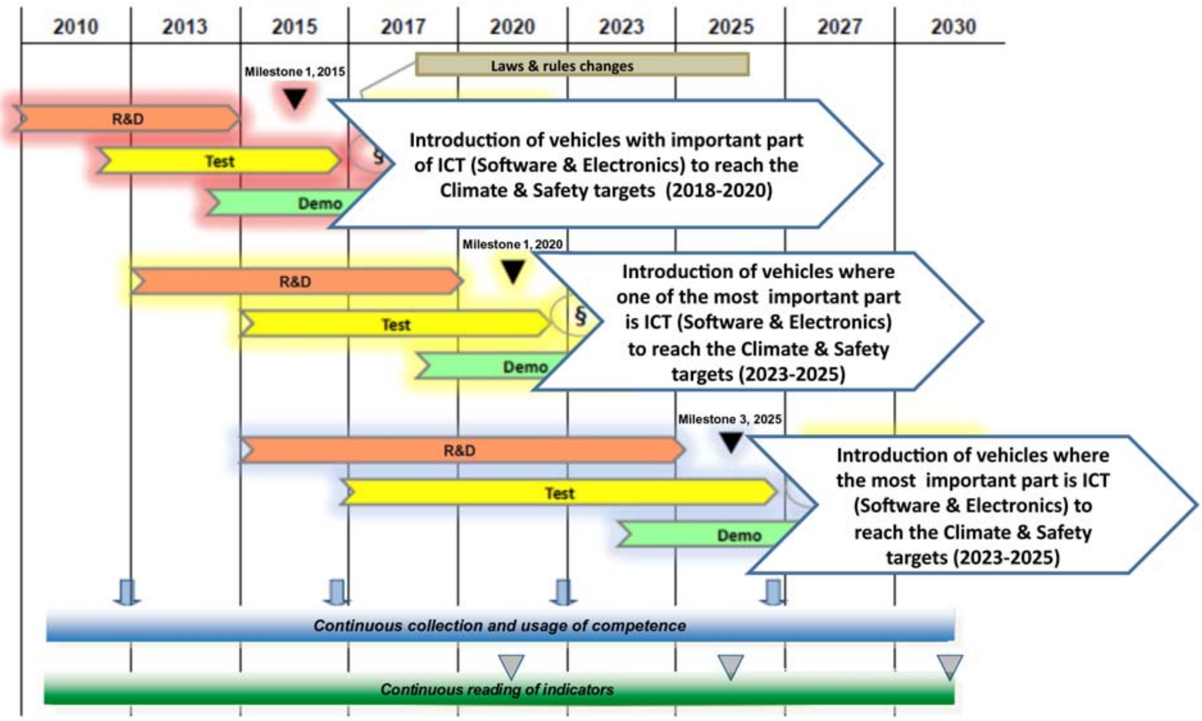

***Figure 2**: Outline - Transformation of the automotive Industry*

Another important driving force is probably Sweden's most important contribution to a global transport system: our extensive knowledge of, and love for, safety systems and care for the environment. It is extremely valuable that the automotive companies, in virtually every market noted in available documents, deliver the safest vehicles and vehicles in parity with the leading companies in the world when it comes to fuel consumption. We are leading the way. We have a tradition to defend. It started with Nils Bohlin's three-point belt (he is found in a number of Halls of Fame around the world, thanks to his work saving so many lives). We have the two basic conditions for maintaining this position: we are the global leader in safety and we are on par with world leaders with regard to EMK. The actions we have taken related to fuel consumption are also significant. Each new vehicle model that is launched must be on par with the world leaders for fuel consumption. We have delivered electric/petrol hybrid vehicles that set the stage. The changes that are now taking place narrow the gap between conventional drive trains and the plug-in hybrids and are intended to reduce total fuel consumption. If battery technology evolves as much over the next twenty years as it has done for the last twenty years, we will also have a far more conducive scenario for electric vehicles. The basic requirement for success is a willingness to achieve safe low-emission vehicles. We have already demonstrated this globally.

The Swedish automotive industry's global competitiveness also needs to be able to adapt products and solutions for developing countries, where cost must be lower and where needs are different from markets more mature technology markets. Naturally, the ambition is these products to also have low environmental impact and high safety levels for these markets too.

Another driving force is finding new income streams in a mature industry with very low margins. Everyone is very aware that more and more customer features can be realised with the help of software. This, coupled with "connected vehicles", enables completely new revenue streams. This has led vehicle manufacturers to start extensive internal efforts to obtain direct revenue from selling data, indirect revenue from improved customer functions, and indirect revenue from increased efficiency in internal processes (throughout the value chain). In addition, a completely new supplier structure can now develop in the form of companies that, with a relatively small investment, can be product suppliers. Both of these processes are already clearly evident.

Figure 3 indirectly illustrates the change underway. Up to 2012 are the actually outcomes. Years 2015 and 2020 are forecasts. Also note that the rule of thumb is that "a electronics designer at an OEM like Volvo Cars results in employment for 5-8 electronics designers throughout the supply chain".

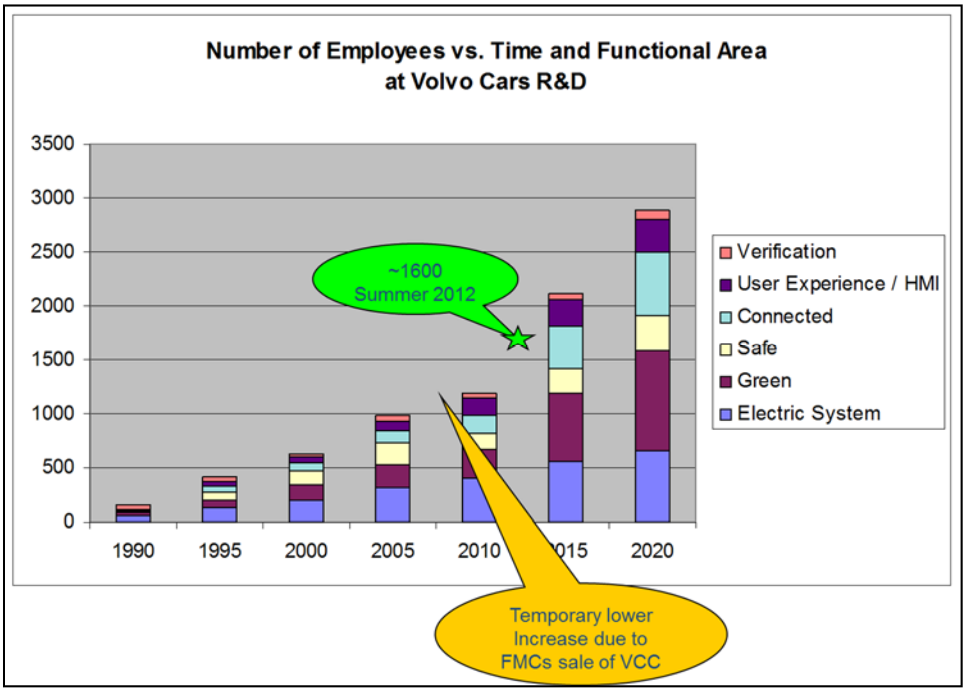

***Figure 3**: Engineers at Volvo Cars product development who have E, D, or IT qualifications vs. Time.*

3.3 System perspective - technology and processes, methods & tools

The system perspective is defined in accordance with Figure 4. The purpose of this definition is to clarify where the strongest force (or for that matter, counterforce) is in the process of change. In other words, which groupings in the structure control the change? The real power for change lies with the operations responsible for the systems **Powertrain (PT), Body&Trim (B/T), Electrical & Electronics Systems Engineering (EESE)** and **Chassis**. This is because these system owners manage existing investment in the system and are responsible for ensuring that all its interfaces work all the way to the end customer in a traffic system.

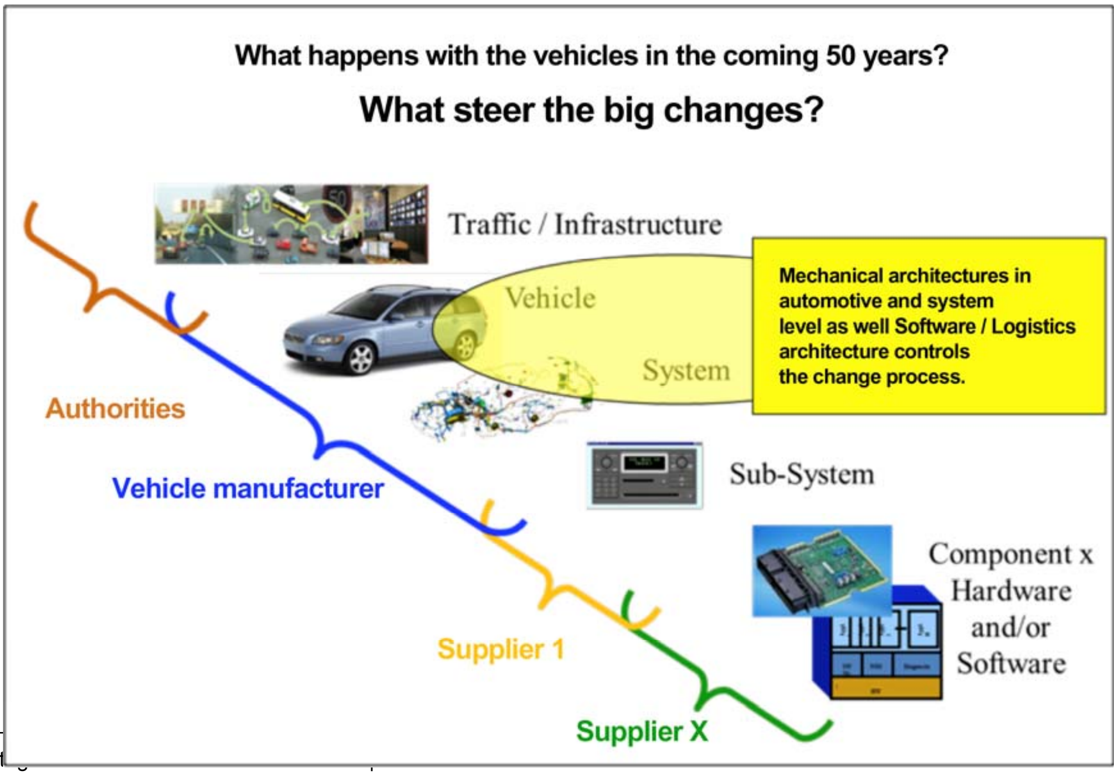

Figure 4: *Definition of the system perspective that controls the change process.*

From a traffic safety and environmental impact perspective, the PT, EESE and Chassis systems will generally have the most impact on the future. The simple explanation for this is, in part, that PT is responsible for optimisation of traditional power trains from a fuel consumption perspective and, in part, that the automotive industry has already begun to replace conventional drive trains with electrified drive trains. Chassis, in turn, is responsible for the bulk of active safety, which more and more means that the vehicles are not involved in collisions. This also means from a safety perspective that B/T does not need to do as much work improving impact protection for car bodies. EESE is responsible for the platform (hardware as well as software) that the other systems operate upon. Within passenger cars, it is worth noting that the largest department at PT in terms of number of engineers is PT's electrical department. The same is also true for Chassis. Figure 5 illustrates this (the green colour indicates engineers with E, D & IT backgrounds). It should also be noted that, for passenger cars, B/T is steadily increasing its EMK activities, e.g. it is responsible for a relatively large number of computer nodes. Most of these are relatively small, but a number are very advanced (e.g. air bags, partial shielding of full-beam headlights to avoid dazzle, blind spot sensors and so on).

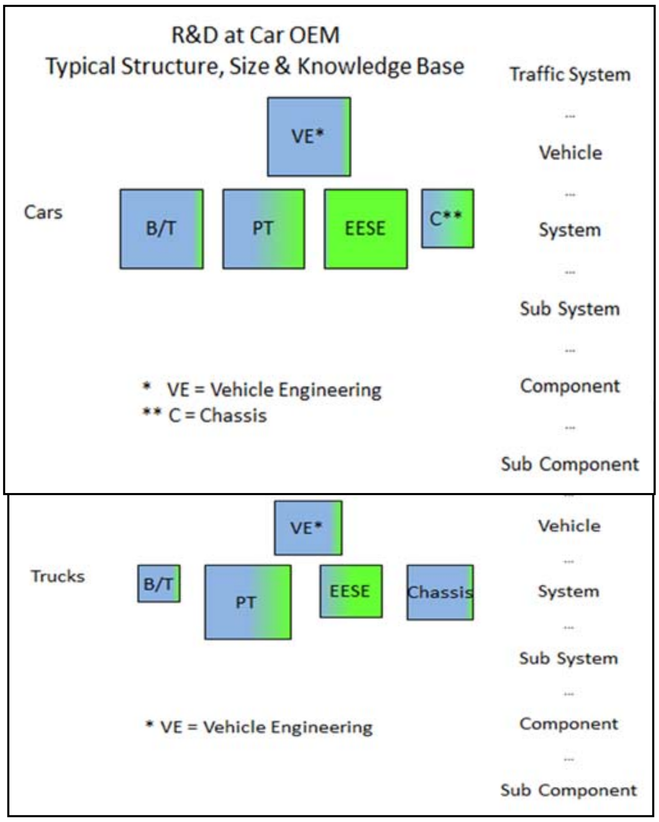

***Figure 5**: Outline of the R&D at OEMs vs. structure, size and number of engineers with E, D & IT background (green)*

In the scenario in chapter 3.2, EESE plays an important role. This system development can be described as the automotive industry going from having worked until the 1990s according to the principle that “each function has its technical hardware and software” to, during:

- during the 1990s building technical expertise in a system where multiple functions use the same technical hardware and software;
- the 2000s, consolidating the technical electrical system expertise while at the same time a number of new technologies are launched as products (e.g. sensor technologies);
- the 2010s, taking steps toward “Decoupled Engineering and introducing connected vehicles;
- the 2020s, moving the automotive industry to an innovation system that on a broad front combines mechanics, electronics and software with upgraded business models;
- the 2030s, seeing clearly visible effects in the substantial reduction of fatalities in traffic globally.

Naturally, processes, methods and tools (PMT) usually develop as technology develops. In other words, at the same time as the technology is developed for a system, the PMT are also developed for sub-systems.

Since EESE is so technically crucial to the rate of change in the automotive industry, it is important to understand how the different parts of this system developed. We have chosen the following breakdown of this system:

- Electric Architecture – On-board
- Electric Architecture – Off-board
    - Technology for “Green, Safe & Connected Functions”
    - User Experience / HMI
- Verification / Validation

A hallmark of EESE is that its operations provide expertise from several different domains (physics, chemistry, mechanics, electronics, electrical power, data & IT). Its unique competence naturally has an emphasis on electrics, data & IT while, while also requiring a high level of understanding of the other areas of expertise (more and more customer features can be achieved with the core technology from EESE). This also means that the specialist expertise of EESE is the ability to handle complexity and to understand the pace that e.g. a new technology can be migrated into the market without causing harm. These skills are crucial in driving issues during the innovation process (i.e. from idea to market). A consequence of this focus is that EESE adopts a lower profile in the case of pure knowledge (traditional basic research). It is relatively easy to understand the potential of a new technology, compared with migration into the process of innovation. For this reason, the emphasis of the EESE strategic/tactical activities lies within the FFI on TRL levels 2 to 5 (TRL = Technology Readiness Level as defined by NASA), and through interaction with service companies, institutes and academia transfer knowledge that was developed in more advanced industries to the automotive industry. The main objective of this interaction is also to supply the automotive industry with a sharply increasing proportion of engineers with E, D & IT qualifications.

4 Future Technical Development

It is worth emphasising that most of the future innovations in the automotive industry are based on efficient information management. To simplify to the extreme, it can be said that most of the hardware is already in place. For example a plug-in hybrid equipped with all active safety systems (all external sensor types included) is probably the most complex car to be developed from a mechanical perspective. Primarily, all of these sub-system/components will be made more efficient (i.e. as good as or better performance at a lower price, weight and volume). On the other hand, there is great potential for innovation through efficient information management. New innovation is created from using information that becomes available from connected safe plug-in hybrids. Vehicle ICT (Information and Communication Technologies) is thus just around the corner.

In the Appendix “The Roadmap within FFI Vehicle Development - Electronics & software at subsystem level”, the evolution of each sub-system over the next three five-year period is summarised. It also illustrates the Swedish automotive industry’s desire for positioning in the form of “Wanted Position,” “Speed of Change” and “Competence Gap”. The respective sub-areas are more generally described below. In part, their purpose and contents and, in partly, the change based on their positions in a traditional S-curve (where a mature topic is high on the S-curve, i.e. a large investment gives an incremental improvement). Finally, it also describes the expertise situation to a certain extent. A summary of the respective sub-areas’ position on the S-curve today is given in Figure 6, and Figure 7 shows the position of needed expertise. A rule of thumb is that in recent years the number of engineers with educational backgrounds in electrics, data & IT has doubled every 7 years (this can also be seen from Fig. 3).

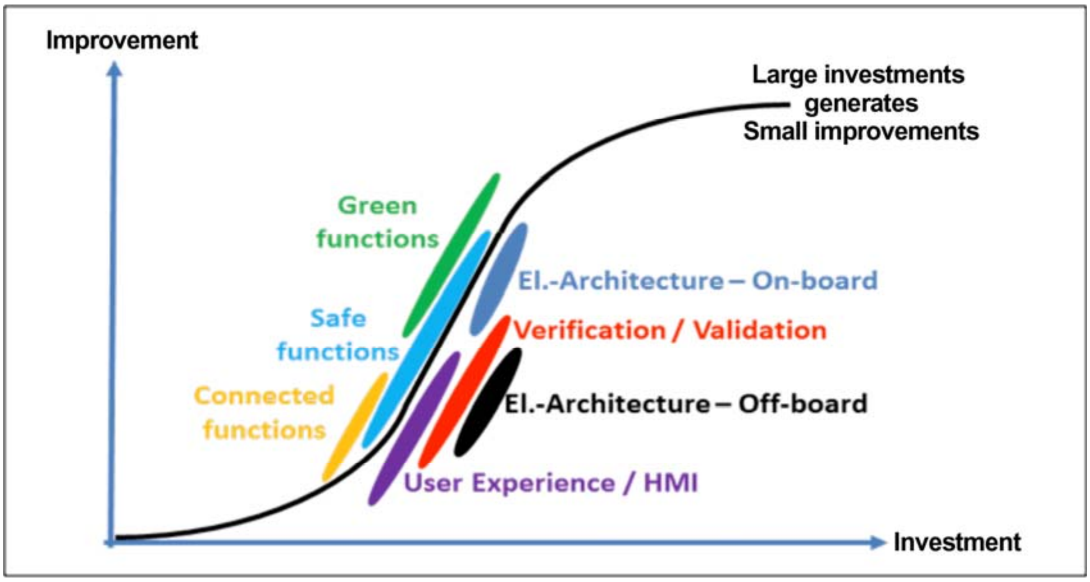

Figure 6: *Overview – "Electrical & Electronic Systems Engineering sub-areas vs. Degree of maturity*

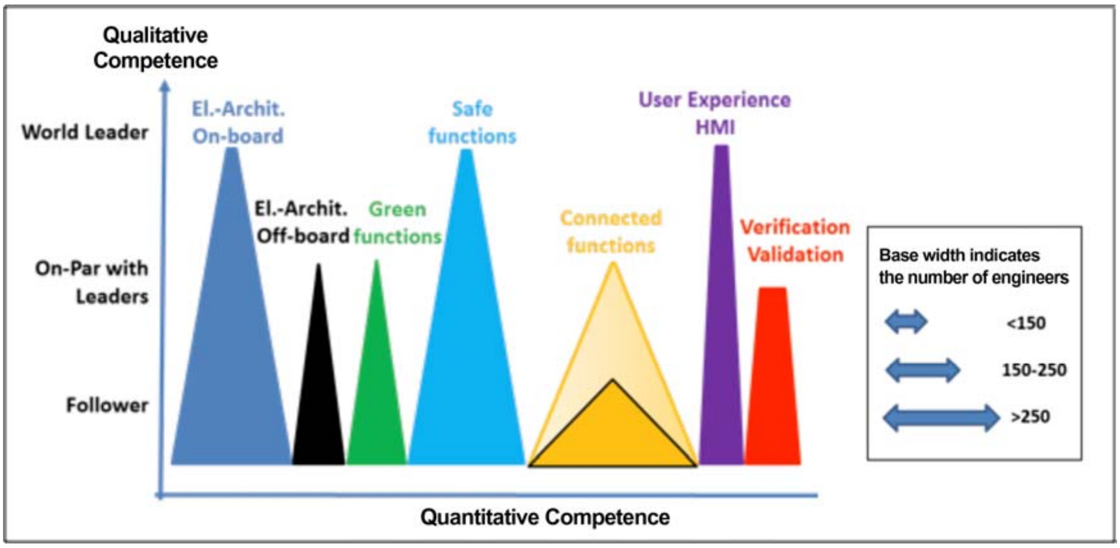

Figure 7: *Overview – EESE's access to expertise today (the rate of change is described in the text below)*
The cut off tip of the triangle indicates how much we need to strengthen qualitatively within the area.

Note that "Electric Architecture - Off-board & Connected Functions" as shown in Figure 6 is relatively immature, and that the number of engineers in Figure 7 is modest. The not too bold guess is that both of these areas will grow sharply in number. We have also used two triangles for the simple reason that we are uncertain as to where we should position ourselves for each vehicle type. The "Verification/Validation" area must match the areas where we are, or want to be, at the level of "World Leader", hence the substantially cut off tip of the triangle. As far as "Green Functions" and CO_2 are concerned, they face fierce competition. This is why we placed the tip of the pyramid at "On-Par with Leaders". The aim for new drive trains is to be "World Leader".

4.1 Architecture – On-board

Purpose: The electric architecture can be compared with a monocoque chassis. This shell bears all the mechanical loads during normal operation, while also managing the mechanical loads in the desired manner during a crash. “The self-supporting electric architecture” must bear the information loads during normal operation at the same time as it must manage information loads in the necessary manner during e.g. crash avoidance. The electric architecture must also supply the vehicle with electricity and electric power by balancing inputs at multiple levels of voltage (typically 12/24 – 48 – 300/600 V). In addition, the electric architecture must enable efficient diagnosis of itself and of the other vehicle components for service and repairs in the after-market, as well as communication with its surroundings for improvement and adaptation of the characteristics of the vehicle according to the traffic situation, transport tasks and so on.

Main Elements: The electric architecture includes the power supply, built-in computer systems, computer communication, function & system security and diagnostics. In particular, the electric architecture defines a framework for how “the self-supporting information structure” will be used to achieve customer functionality. The electric architecture includes a few components in the form of software parts (e.g. for the operating system, open source code) and as power components (the classic starter, alternator & battery and those that are needed for multiple voltage levels). Also included is a large range of versions (especially on the heavy goods vehicles side) that the electric architecture needs to manage. It also includes extensive responsibility for providing PMT to develop both the electrical system and the functions that can be achieved with the help of the electrical system. This includes PMT for both the traditional V model as the agile way of working with the end customer engaged in the development loop (i.e. “Decoupled engineering”, “Continuous Integration” and “Continuous Deployment”).

Speed of Change: In development terms, electric architecture is slightly above the centre of the S-curve. Examples of some of the major development steps include facilitation of the continuous introduction of application software in computer nodes that are ASIL rated (Automotive Safety Integrity Level) and the introduction of new communication protocols. The rate of change may be considered as medium. Electric architecture should also be made more flexible and cost efficient if it is to meet the requirements for both simpler and more complex vehicles.

Competence gap: The supply of skills occurs primarily through development of their own staff in pre-development projects, participation in the international de facto standardisation efforts, and through service companies that also take assignments from other system industries. At the present, we see no acute shortage of engineers.

4.2 Electric Architecture – Off-board

Purpose: To manage how vehicles are connected for the exchange of information with the outside world.

Main Elements: This includes wireless communications, data security, signal quality & electromagnetic compatibility, the Internet and function & system safety. This part of the electric architecture is focused on a regulatory framework for how the “self-supporting information structure” should be used to achieve customer functionality, and it includes few components in the form of software parts (e.g. for data security). As far as PMT is concerned, the focus is on exploiting the opportunities afforded by “connected vehicles” and “de-coupled SW engineering’ (i.e. the software-based applications developed separately from vehicle development).

Speed of Change: In development terms, this part of the electric architecture lies below the centre of the S-curve. Examples of major development steps include the change over to a new supplier structure for traditional infotainment features; partly the development of the respective companies’ “technical cloud platforms” and the introduction of new communication protocols. The rate of change can be considered very high.

Competence gap: The supply of expertise occurs primarily through participation in international de facto standardisation efforts and through service companies that also take assignments from other system industries. At the present, the automotive industry would benefit from increasing the number of experienced engineers.

4.3 Technology for “Green, Safe & Connected Functions”

Purpose: To develop the necessary basic technology to achieve these functions. In the case of “green functions”, this involves technologies for reducing dependency on fossil fuels in drive trains. For “safe functions” this is the primary control technology (including sensor technology) and for “connected functions” this is communication protocols and data visualisation in particular.

Main Elements: This includes many component types, including software parts, processors, batteries, power rectifiers, electrical machines, charging equipment, sensors, algorithms, actuators, optics, lighting, antennas, amplifiers, displays and so on. Each of these components need their PMT to develop. An essential end condition is that these PMT are compatible with the PMT of parent systems.

Speed of Change: In terms of development, these technologies are relatively spread along the S-curve. **“Green functions” that are provided through better use of traditional drive trains are relatively high on the S-curve; examples of this include “coasting”. The parts that are lower on the S-curve consist mainly of electric hybrid concepts and components. An example is mild-hybrid concept on 48 V. “Safe functions”** have come a long way toward more mature products. Examples are simple functions where a sensor detects something and algorithms command the actuators to act (for example “Forward Collision Warning”). That the spread goes so far down on the S-curve for “safe functions” is due to the fact that when information from sensors is combined (including sensors inside the passenger compartment and from the cloud), it is still unknown how useful active safety will be. Sensor data fusion and algorithm skills will be central. **“Connected functions” is in its infancy in the automotive industry, explaining its location down at the bottom of the S-curve. Examples of some of the major development steps is the full use of cloud services, partly for new customer functions, partly to streamline their own activities and partly e-commerce. Another example of major changes is strengthening the ability to use technology from the consumer electronics sector (e.g. Internet-based software and computer graphics). The rate of change in all three areas may be considered very high.**

Competence gap: Supplying expertise for “green & safe functions” primarily takes place through in-house pre-development projects and together with traditional supplier industries. The same applies to “connected functions”, which occurs primarily through participation in international de facto standardisation efforts and through service companies that also take assignments from other system industries and from consumer electronics companies. Within “safety functions”, it is also important to ensure the supply of knowledge from academia and institutes. At the present time, we would benefit from increasing the number of experienced engineers in all three areas at a faster rate.

4.4 User Experience (UX)/HMI

Purpose: UX/HMI deals, on a sliding scale, with activities that range from simple interaction between drivers and vehicles to how the driver and passengers experience the journey. Interaction between the driver and the vehicle is becoming increasingly multi-modal.

Main Elements: The basic modalities for easy interaction between the driver and the vehicle are visual, audio, haptic, tactile, voice, proximity, gestures and gaze and so on. These also include combinations of basic modalities and the inclusion of emotional experiences. At the heart of UX/HMI is the understanding of the impact of the modalities' characteristics and the technology needed to achieve them.

Speed of Change: The basic modalities are relatively high on the S-curve. Further down in the S-curve are the multi-modal possibilities which quickly become complex and extensive. By also adding the emotional experience, you get the the transport's UX, which is more or less new territory for the automotive industry (i.e. this component is right at the bottom of the S-curve). Examples of major challenges are effective PMTs for understanding different customer groups' preferences. The rate of change is very high.

Competence gap: The supply of expertise primarily occurs through participation in both national and international research assignments and through close interaction with academia and institutes.

4.5 Verification/Validation

Purpose: Visualisation of all customer features and their interaction with the driver can be achieved within the existing electrical system.

Main Elements: Verification/validation handle simplified MIL-SIL-HIL (Models/Software/Hardware-In-the-Loop) at higher and higher system levels. At present, the automotive industry masters MIL-SIL-HIL at sub-system level (see Figure 4) and the first set-ups at complete vehicle level are beginning to be used. The great challenges are to develop MIL-SIL-HIL all the way up to "Traffic/ Infrastructure", as shown in Figure 4, i.e. to be able to verify/validate "systems-of-system". For this reason, "verification/validation" stretches across the lower part of the S-curve. Another demanding challenge is to devise models (like mechanical/electrical/software-based systems) at all levels, as shown in Figure 4, with acceptable precision.

Speed of Change: The rate of change may be considered high.

Competence gap: The supply of skills occurs primarily through development of their own staff in pre-development projects and through service companies that also take assignments from other system industries. At the present time, we would benefit from increasing the number of experienced engineers at a faster rate.

5 A final word

The programme committee hopes that this abridged roadmap will be used jointly for strategic choices relating to research and development and that it will be valuable in following up the programme and conveying an overall picture of FFI and its importance for safe and environmentally friendly transports. The roadmap will need to be updated regularly, probably at least every two years.

The document contains examples of areas of research and development that are relevant to the FFI programme within EM. This should not, however, be interpreted as these are the only areas where the FFI can fund "strategic vehicle research and innovation activities".

6 Appendix: Roadmap within FFI Vehicle Development – Electronics & Software at Sub-system Level

	Vehicle ICT – Opportunities vs. Competence Gaps Electric Architecture – On-board				
	Main Elements	**Opportunities**	**Wanted Position**	**Speed of Change**	**Competence Gap**
2020	Concept designs	Topology, Logic design, System simulations	**World Leader**	**Average**	**Medium**
	Electric power	Establish 48 V, Battery, Convertors, Electric machines			
	Communication	Flexray, Ethernet, On-board Wi-Fi for CE			
	Electric control units, SW	SW-architecture, OS, Continuous integration, Open source			
	Functional safety	Functional architecture simplifying continuous deployment			
	System safety	ISO26262			
2025	Concept designs	Reduce number of nodes, Improved diagnostics	**World Leader**	**Average**	**Medium**
	Electric power	48 V for improved functionality			
	Communication	On-board Wi-Fi for sensors/ actuators			
	Electric control units, SW	Standard units, Continuous deployment, ”Apps in ASIL”			
	Functional safety	Well established top-down architecture			
	System safety	Utilize multiple voltages			
2030	Concept designs	In-house simulation from requirements to validation	**World Leader**	**Average**	**Medium**
	Electric power	TBD			
	Communication	Communication protocol included in SW			
	Electric control units, SW	OEM controls SW-layers, R&D an innovation system			
	Functional safety	Include cloud functions for ASIL-system			
	System safety	Utilize connection to cloud			

Vehicle ICT – Opportunities vs. Competence Gaps Electric Architecture – Off-board					
	Main Elements	**Opportunities**	**Wanted Position**	**Speed of Change**	**Competence Gap**
2020	Concept designs	V2V cloud connections on a broad scale	**Follower**	**Very High**	**Very Large**
	Integrity	Data security, Personal security			
	Communication	Establish 4G and 802.11p, Study 5G			
	Antennas	Performance and EMC-simulations			
	Functional safety	Study cloud based "ASIL-functions", Autonomous driving			
	System safety	Utilize cloud for redundant data, Autonomous driving			
2025	Concept designs	Study vehicle as a "relay station" for communication	**On-Par with Leaders**	**High**	**Large**
	Integrity	Theft protection inside/outside vehicle			
	Communication	Establish 5G and 802.11xx			
	Antennas	Strong influence on concept in early phases			
	Functional safety	Study cloud based "ASIL-functions", Autonomous driving			
	System safety	Autonomous driving			
2030	Concept designs	Establish vehicle as "relay station" for communication	**World Leader**	**Average**	**Medium**
	Integrity	TBD			
	Communication	TBD			
	Antennas	TBD			
	Functional safety	Establish cloud based "ASIL-functions", Autonomous driving			
	System safety	Autonomous driving			

Vehicle ICT – Opportunities vs. Competence Gaps User Experience (UX) / HMI					
	Main Elements	**Opportunities**	**Wanted Position**	**Speed of Change**	**Competence Gap**
2020	Interaction modalities	Gestures, Proximity, Speech, Glance	**On-Par with Leaders**	**Very High**	**Very Large**
	HMI	New primary/secondary information, Autonomous driving			
	User Experience (UX)	HMI-related			
	Displayer	Head Up Displays (HUDs), Computer graphics			
	Personalization	Driver recognition, Link CE in cloud services			
	TBD				
2025	Interaction modalities	Multimodalities (sensor fusion)	**World Leader**	**Very High**	**Very Large**
	HMI	Driver status, Continuous deployment			
	User Experience (UX)	Harmonized cross function, Autonomous driving			
	Displayer	Augmented reality in HUDs, “Soft Displays”			
	Personalization	Seamless transparency home-cell phone-car			
	TBD				
2030	Interaction modalities	Driver status – External sensors - Displays	**World Leader**	**High**	**Large**
	HMI	Adaptive HMI			
	User Experience (UX)	Innovation system for SW-based functions			
	Displayer	Advanced augmented reality			
	Personalization	Customer configure vehicle from home			
	TBD				

Vehicle ICT – Opportunities vs. Competence Gaps
Verification/Validation

Year	Main Elements	Opportunities	Wanted Position	Speed of Change	Competence Gap
2020	MIL-SIL-HIL-integration	HIL for complete vehicle	On-Par with Leaders	Very High	Very Large
	Virtual verification	Establish on system level			
	Model repository	Establish framework for complete vehicle models			
	Big data	Establish pilots within Active Safety & HMI			
	Visualization	Knowledge based engineering			
	High Level Architecture (HLA)	Study HLA			
2025	MIL-SIL-HIL-integration	MIL-HIL for complete vehicle	On-Par with Leaders	High	Large
	Virtual verification	Establish on complete vehicle level			
	Model repository	Seamless models from design to after market			
	Big data	Remote data collection in all divisions			
	Visualization	Feature decisions based on moving base simulators			
	High Level Architecture (HLA)	Connect simulators via cloud			
2030	MIL-SIL-HIL-integration	MIL-SIL-HIL for complete vehicle	On-Par with Leaders	High	Large
	Virtual verification	Established on traffic system level			
	Model repository	Dynamic models based on Big Data			
	Big data	Utilized in continuous deployment			
	Visualization	Feature decisions based on traffic simulation			
	High Level Architecture (HLA)	Visualize traffic by connecting simulators			