Special Vehicles
past, present and future

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Some customers of the automotive industry demand cars for very special purposes. Various requirements can be fulfilled by using standard automotive know how or after sales solutions. Others need a dedicated development in special departments. A very special challenge is the provision of police cars. They need high end technology to fulfill the tasks of the police. This paper will give an insight to these features and will show the necessities during the development of the police cars providing historic current and future perspectives. It should become clearer why there is a need for in-car-networks and in particular the advantages of dedicated networks like CiA 447.

Special cars – special functions for special purposes

Ever since the invention of cars there is also the need for special cars.

At a certain age each of us completed a driving license in a first special car: The *driving school car*. It contains a number of special mechanical parts like mirrors and pedals but also electrical parts like a "bell" for signaling that the teacher is pressing a pedal. Today there is not yet the need for a dedicated in-car network but modern technology could provide much more features.

Other special cars are those for *handicapped people*. In the past the required solutions for enabling handicapped people to drive a car were mainly based on mechanical solutions. Nowadays smarter solutions are provided e.g. a remote control device mounted onto the steering wheel to handle several car functions.

The times are past where a *taxi* system consist of solely a taxa meter, a roof sign and a radio based on speech communications. These autonomous functions (nearly) don't need any in-car information. Nowadays the car manufacturers provide a calibrated speed signal for the calculation of the price or support (special) navigational systems. Taxi "hot spots" can be sent to drivers, communication is speechless and the status of a car can be instantly downloaded via remote access of the car owner.

These taxi-specific systems use electrical car components (e.g. communications systems, antennas) as well as information provided by the car communications network.

"Bad guys" trigger the need for high tech police cars

The police's "customers" use high end technology either to avert traffic regulations or to commit a crime. In the past it was perceived that the police lacked technology upgrades. At least for the work in the police cars, there had to be a new approach. The public authorities had to react so that police work could become more efficient.

In the past three years the public authorities in Germany have been observed in trying to strengthen their activities with regard to the application of new technologies.

The PTI [15] updated their requirements [1] and asked the OEM's to harmonize the handling with just one single HMI [10] device. Why? And what does this mean?

Police cars – high tech on our roads!?

Comparatively, the highest requirements of all special cars are demanded by police cars. Currently the technological evolution of normal cars is much quicker compared to police cars. But there is an urgent need to include more "high tech" for police cars.

Historically they were equipped with only one radio, a light bar with a horn and some mechanical parts. Over time several functions were added (e.g. accident monitor, keyless engine-run, multi radio operation etc.). There seems to be no obvious concept since all these functions

were added on demand as isolated applications. Current police cars already have roughly 20 electrical based special functions.

Figure 1: ~20 functions in a police car

Nearly all of these functions are provided by components offered by a limited number of different companies for the after sales market. These companies are sometimes very small but they provide smart solutions. Unfortunately the components and functions of the different companies rarely interact between each other.

There are dedicated buttons or switches for each function. Finally all these remain as isolated applications. The synergetic potential can obviously not be lifted this way!

In a first step some OEM's [14] like VW offered access to their car functions via the in car network (CAN). The resulting effect of this solution is naturally limited since this approach *hinders* the basic functions of the car.

For a number of use cases there is one dedicated large ECU [7] with a number of analog I/O interfaces. This ECU behaves as a kind of firewall to the series cars' architecture.

Unfortunately the flexibility of this architectural approach is quite limited. Each time when a connected component

has to be changed, the central ECU has to be adapted too. As a consequence connecting many different components with after sales components is currently avoided. They remain as isolated functions.

Hence a blue light bar presently is connected to a dedicated light bar commander.

It is even worse that each of the different radio systems (up to 4 in one police car!) use separate control units. There is little space for the integration and in an alarm situation it might be difficult for policemen to recognize which requirements are needed in certain situations.

It should be obvious that innovations can only be integrated with a new universal architectural approach. Synergetic potential should be lifted to fulfill future requirements.

1 + 1 = far more than 2

The idea: Let's have a more detailed look at recent developments of brake systems. In the past there was an innovation called ABS [2] which made the car safer in an emergency brake situation. An isolated sensor with a controller prevented each wheel not locking-up anymore.

In the next step the database was broadened by connecting the same brake-sensor-signals via a CAN [4] system. The results included; an ESC [8], an ASR [3] a hill holder function and more resulting from the use of the synergetic potential. This evolution continues and has not ended yet.

The same approach should be used in the development of police cars.

The key point is to interconnect the data of all isolated applications. This leads to a broad database where function A could use the data of function B and the result could be used by establishing a new function C.

As mentioned before the series car communication and their systems shall not be influenced at all. Therefore in 2012 Volkswagen decided to keep the "firewall" ECU called MFG [11] and to add a dedicated special network. CANopen CiA 447 seemed to be the solution. We need to fix this together…

CiA 447 – How to handle this challenge

On the way to CiA 447 two very different tasks had to be completed – identification and realization.

The first task was to identify whether or not there is a need of the introduction of the CiA 447 network at all.

Hence Volkswagen took a handful of well-educated engineers. They made a functional analysis and it became clear that by following the current approach (isolated functions) the upcoming needs of the market cannot be fulfilled. They analyzed the database of the existing isolated functions and by this they got a clear picture of the synergetic potential.

They became aware that this would allow the creation of new functions for which only a few architectural changes had to be added. With this knowledge from a technical perspective management made the decision to introduce the CANopen CiA 447 and to introduce the architectural changes.

With this decision the second task was started – the realization. Several questions had to be answered:

Technology

> Is the CiA 447 already fit for the future?

> What does it mean for the partners to make their products CiA 447 proof?

Partners

> What is the benefit of the after sales partners to cooperate in the future?

Functionality

> Which features do customers need in the near and far future?

> What can be offered with the new database?

> Is it possible to use the existing in car structure (network) and how?

Components

> What would be the architecture?

Handling

> How can we handle all these new functions?

Technology – Evolution or Revolution?

In October 2011 Volkswagen announced at a meeting of the "CANopen TF police" to introduce the CiA 447 from the next Golf on. Starting with this car each device in the Volkswagen police cars would communicate via CiA 447. Other special cars would follow.

The partners in the consortium communicated an immediate response. The OEM's mentioned all the problems which could possibly occur whereas the after sales partners perceived substantial chances and were ready for this step.

With hindsight it can today be said that both parties were absolutely right.

The experience gained since the startup project "SFA" [16] revealed that some innovations work perfectly from the first minute on while other already well-known functions were not able to be integrated into the new architecture at all.

It was clear that a necessary step to make the SFA successful would be to harmonize the CiA 447 data matrix. A data analysis completed with key partners (blue light bars, radio, video) and missing signals provided to the next release (V2.0) of the CiA 447. The goal was to minimize the company specific data. Only those signals which were needed for company-unique functions were allowed to differ from the standard. Those signals which mean the same function but in different devices from different companies (e.g. blue light in the roof bar) would be harmonized. This allows the interaction of different devices and also the replacement of those devices offered by different companies, e.g. the blue light bars.

The fulfillment of a multi-supplier strategy is a fundamental key to the acceptance of the SFA system by customers. Even within the relatively small police car market customers have very special and widely diverging demands. Thus each partner included the CiA 447 protocol.

During the development it became clear that the stability of the whole system benefits from the CiA 447. In the past when a device had a problem with its active/sleep modes it strived to remain active even in demanded sleep mode.

By the introduction of the standard software and the usage of the network management it makes it easy to identify specify problem areas. When such a problem is fixed the solution will be available for each CiA 447 participant.

The new technology in the context of police cars is surely a revolution. In respect of the well-known usage possibilities in other similar applications it might well be an evolution.

Partners – Dreamwork or teamwork?

The idea of making the big step to CiA 447 might have sounded like dreamwork. A standardization in very small markets? Would this mean that only the big companies can afford this?

Surely not!

In the course of this project it was seen that within each company the respective products quality increased. The engineers no longer had to focus on very special solutions for quite a small number of customers but they could focus on the development and improvement of their functions. The harmonization of standards opens the market. They have a wider database which might (and already do) lead to new functions. Also they can now offer their products to a wider range of potential customers.

The answer is easy – Teamwork!

Functionality – The future started two years ago!

In the very beginning of the SFA-project Volkswagen started discussions with customers regarding their needs. The commonly known functions served as the basis of the discussion. In the course of these discussions some things became clear and were settled:

- Development has to take place closely coupled to customers.
- Due to the new broad database there might be some features available which customers never thought about before.
- Police cars should no longer be seen isolated but it has to be a part of the whole police apparatus.

Subsequent to this clarification several workshops between police representatives and Volkswagen have been performed. In these workshops the layout of the known functions has been defined as well as the necessity and time to market of the new ideas. Furthermore it was agreed that also the control room / headquarter has to keep track with the new functions.

Compared to the common approach it can be said that the introduction of the CiA 447 defines a new generation. It allows the sustainable functional expendability of special cars for years to come.

Components – Can the complexity be handled at all?

It became clear that the firewall to the basic car should be kept. The special car domain shall be decoupled from the basic car domain.

The first approach was to attach those special car components which communicate to the CiA 447. A dedicated sub-domain was created.

Figure 2: Exemplary architecture with CiA 447

It is clear that just by connecting the components via CiA 447 a police car won't behave as it should. The components still don't know anything about each other.

Since the OEM's still would remain responsible for the integration they have to understand each function in detail, their own and those of the partners. With having this detailed knowledge it should

be possible to develop those higher functions which just can be realized by use the mentioned synergies. Consequently Volkswagen decided to develop the higher functions on their own. The partners remain responsible for their devices and can sell them also in the future and the integrator is able to fulfill future market needs. This appears to be the only way to handle the complexity of the upcoming market needs.

Handling – Listen to the customers!

With this architectural decision the only question was how all these new functions can be handled. The so far approach of allowing an arbitrary number of handling devices would not have been future-proof. From the start of this project on Volkswagen spoke and listened to their customers. The policemen as well as the police advisory board told that the complexity of the handling devices in the car more and more becomes dangerous in certain situations. If one has to search for the right button in a stressful situation faulty handlings can occur. So there was an urgent need to reduce the complexity.

In this time the PTI provided a recommendation of how the handling in police cars should function in future generations. In detail they proposed that there should be one central handling device and a number of additional hard keys for immediate direct access to some functions. Volkswagen fully agreed to this recommendation.

They agreed to cooperate with selected police departments and developed a system which allows the centralized handling of each special car function.

The key was the utilization of the series multimedia systems touch control panel. Based on the MIB [12] they developed a solution to use this without changing anything in the MIB. By this they benefit from the development for millions of cars and utilized it for their special cars customers.

The smart integration is enabled by one central ECU (the SFA) which is responsible for all new functions, the control of each external function and the interface to the touch control panel. Also a panel with 10 hard keys was implemented.

So the discussion result with individual customers and customer forums was the definition of <u>where</u> the handling in the future police car has to be done.
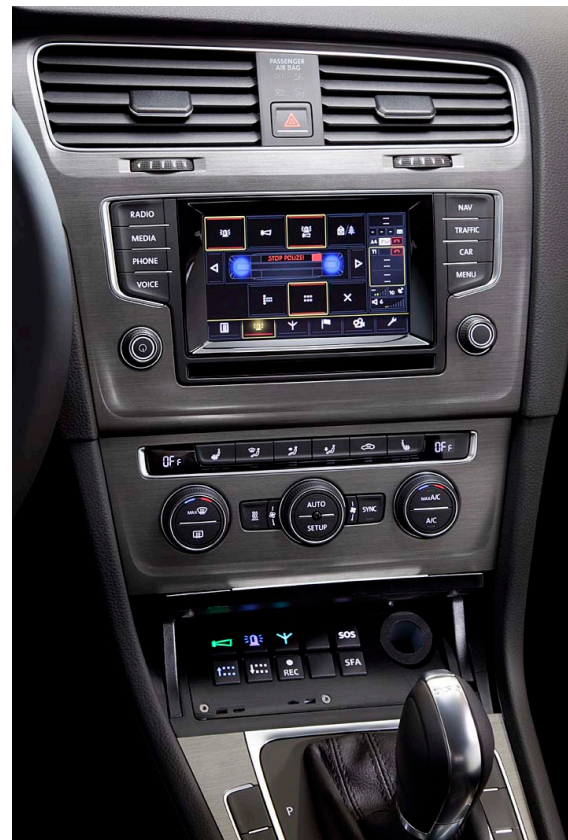

Figure 3: The hard keys and touch panel handling

Another question was <u>how</u> the user interface should appear. Together with the policemen the surface and levels were designed and some rules where agreed:
- There shall be an area which always shows the current status of the special functions.
- The most important functions shall be started on the top level. Each top level shall be entered by just one touch.
- The biggest space on the panel shall serve for the handling of the functions.
- The handling shall be intuitive.
- Wherever it makes sense icons shall be used instead of texts.

Figure 4: The roof bar level of the SFA

With these rules Volkswagen and its partners designed the system.

Some examples of the customers influence:

- The screen for the radios shows exactly what the policemen know from the "old" radio systems.
- Icons where used wherever it makes sense. Commonly known icons are used.
- Main function buttons are big.

With the introduction of the CiA 447 standard in the special cars and the consequent realization of customer's wishes Volkswagen follows the assumption that Dr. Martin Winterkorn summarized on the IAA 2013 in a very comprehensive way. It is translated as follows:

"This is why Volkswagen remains what it is for a long time now. A company that listens to people very thoroughly… designing ideas with a big heart and most of all – passion!"

Summary

In the past it was hardly possible to add more functions to highly equipped special cars. Presently the CiA 447 standard allows the special car world to enter a new dimension.

The utilization of the CiA 447 opens a new door. By using this standard it becomes possible to enable the connection of available data.

Together with smart ideas like the SFA system which fulfills the customer's needs special cars will be fit for tomorrow.

In future generations there could be the focus on communication with the environment. Ideas like the car-to-car communication or even car-to-environment is almost ready to be introduced to series (special) cars.

The CiA 447 and upcoming innovations make police work substantially safer.

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As the head of the electric development department of the Volkswagen R GmbH Dr. Martin Döring is responsible for the electric/electronic in the Volkswagen special cars, the "R"-, the "R-Line"- and the exclusive- and unique cars, too.

Before this he was responsible for the development of FlexRay and also the start-stop system in the new Golf. He made his study of communication engineering and his doctor's degree on safety theory and traffic systems and is with Volkswagen now for 14 years.

References

[1] Fortschreibung der technischen Richt-linie, Funkstreifenwagen, „Anforderungen an digital vernetzte Kraft-fahrzeuge", Polizeiinspektion Spezialeinheiten Nord-bayern, TEK, 2011

Glossar

[2] ABS, anti-lock braking system

[3] ASR, anti-slipping regulation

[4] CAN, Controller Area Network, event triggered bus system

[5] CiA DS 301, CANopen application layer and communication profile

[6] CiA DSP 302, Framework for CANopen managers and programmable CANopen devices

[7] ECU, electronic control unit

[8] ESC, electronic stability control

[9] FlexRay, deterministic and fault tolerant bus system

[10] HMI, Human Machine Interface, Interface for the allowing the user to interact with a technical system.

[11] MFG, multi functions ECU

[12] MIB, Modularer Infotainment Baukasten, Volkswagens multimedia system in series cars.

[13] MOST, Media Oriented Systems Transport, a multimedia bus system

[14] OEM, Original Equipment Manufacturer, car manufacturer

[15] PTI, Polizeitechnisches Institut

[16] SFA, Sonderfahrzeugassistent from Volkswagen, a new system to control each special function in a special car.