

# ADVANCED INTEGRATED EMBEDDED PLATFORMS FOR ADVANCED TCAS, SITUATION AWARENESS AND (SEMI-) AUTONOMOUS PILOTING

*Mirko Jakovljevic, Jacques Gatard, TTTech Computertechnik AG, Vienna, Austria*

## Abstract

The experiences from the aerospace Integrated Modular Avionics (IMA) domain can be very useful to define a framework and architectural patterns for advanced integrated modular systems for cross-industry applications, as they also become more integrated. The trend towards more integration results in a noteworthy influence of rapidly advancing high-volume industries such as automotive on the product roadmaps of semiconductor manufacturers. They can provide an ecosystem of modules and components, designed under consideration of safety design assurance processes causing lower system lifecycle risks and costs.

In this work, TTTech as an automotive ADAS (Advanced Driver Assistance Systems) [1] and a rotorcraft IMA [2] component supplier examines the viability of the latest automotive developments for rotorcraft TCAS, situation awareness and autonomous flying architectures.

This paper proposes the framework for scalable embedded platforms in advanced integrated systems, which can include commercially available COTS computing/DSP hardware and at the same time:

- Enable tight hard real-time control function coupling with a priori defined interfaces and separation of temporal and functional behavior as well as Full isolation, and partitioning of hosted distributed functions per design,

by using a blend of commercial system integration capabilities and standard avionics networks.

In early stages, the results of the proposed approach can be used for the improvement of the situation awareness and/or collision avoidance and can be simply extended to automatic obstacle protection or any semi-autonomous operation capabilities with full situational awareness. Later a similar approach, assuming further automotive industry system safety advances could support the seamless integration of cross-industry equipment with excellent service

history in safety applications for other aerospace applications.

This paper discusses three interrelated topics which jointly enable new functionality at competitive costs, potentially interesting for rotorcraft avoidance and other aerospace applications (airport taxiing):

- 1) A unified framework for the definition of generic and open embedded platforms for fully integrated modular architectures, which can be virtualized for different cross-industry applications, integrating time-critical and soft-time functions in both open and closed systems, based on AFDX®/ARINC 664 [3], SAE AS6802 [4] and IEEE TSN. [5]
- 2) Latest advances in automotive electronics, system integration and safety assurance processes for autonomous driving. [1, 6, 7]
- 3) Integration of commercial ADAS ([1] embedded platforms in such a framework, and close alignment with trajectory and envelope control functions.

## Generic integrated architectures and distributed IMA

The main driver is the need for convergence of capabilities on one integrated architecture to reduce hardware costs and simplify the physical system.

IMA systems require a robustly partitioned Ethernet networking infrastructure, as described in ARINC 664 [3], and an L-TTA computing model, which is sufficient for closed architectures in aircraft applications.

In open systems or systems which extend the integration of fast hard real-time functions or strictly deterministic jitterless functions, a different set of architecture patterns is required. Such an approach requires platform capabilities similar to an “embedded cloud” computer.

An embedded cloud should provide the full capability to host hard real-time functions, and any other functions without clearly defined resource use profile. Such functions shall not be able to influence the operation of time-, safety- and mission-critical functions hosted in the system. Such an embedded cloud represents a special class of integrated Ethernet-based architectures equivalent to Distributed IMA in DO-297.

In order to operate properly, the “embedded cloud” platform shall support TTA and L-TTA models of computation with asynchronous and synchronous networking capability.

Automotive industry [1], railway [8] space [9] and IoT [10] are currently moving into the direction of Distributed IMA when designing integrated modular architectures with functions of different criticality, using Ethernet networks, albeit with different topology and cost structure.

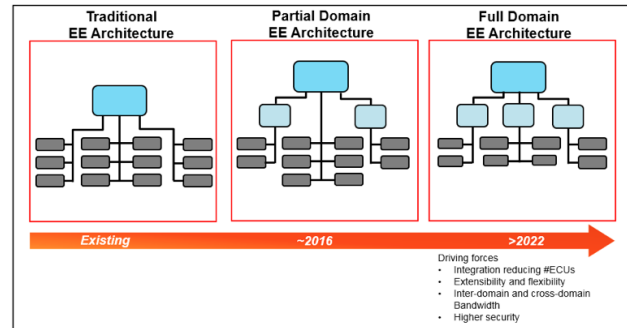
### ***Increasing safety requirements and design assurance in the automotive industry***

With the adaptation of IEC 61508, and the issuance of ISO 26262 in 2011, the automotive industry has defined a set of design practices for safety-relevant electronic systems and components. Semiconductor companies started developing safety-relevant MCUs in mid-2000. Since then, the introduction of autonomous and piloted driving has accelerated the spreading of safety assurance processes in the industry. This development will accelerate even more until 2020-2025, and is going to pose new challenges in terms of the design of safe and secure, open and closed networked systems and embedded platforms for the automotive industry. This supports further development of the ecosystem and the pool of components which are viable for the design of critical aerospace and defense systems, but at a very competitive price.

The trend toward piloted systems demonstrated by Tesla and Audi [6] has an effect on how automakers design the vehicles electronic architecture.

Industry experts consider the need for redundant fail-operational architecture, and some sort of centralized (maybe distributed) resources similar to IMA approach, which can be safe and highly available [11].

The architecture needs to be redundant, and has several function-oriented central “brains” (Fig 1), which will control all the actuators and sensors via simpler low-cost fieldbuses or Ethernet. Such central controllers will have the processing power of a supercomputer and will be integrated by gigabit deterministic Ethernet with time-driven hard real-time communications.



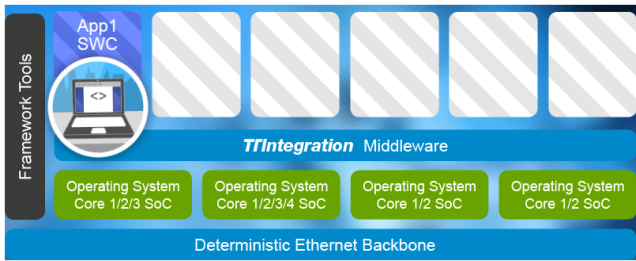
**Figure 1. Automotive architectures – from CAN networks with gateways to full domain electronic architecture [12]**

### ***Automotive ADAS: Integration for rotorcraft systems?***

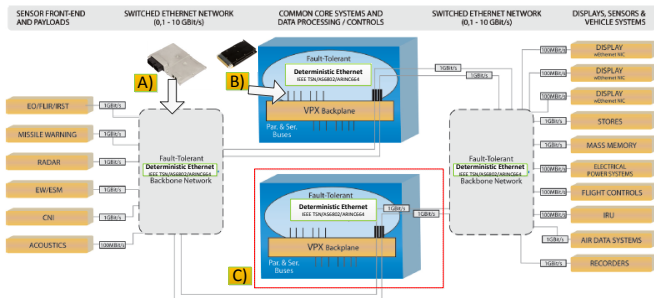
An autonomously driving car in an unconstrained area has to avoid obstacles and possess full environmental awareness. This requires a quantum leap in terms of technology, system engineering and design methodology.

The required embedded platforms should have significant processing power with tens of hundreds of CPU cores to capture all sensor data, enable deterministic processing as well as separation of functions. Typically, an automotive ADAS platform will host up to 50 software functions, working deterministically in parallel.

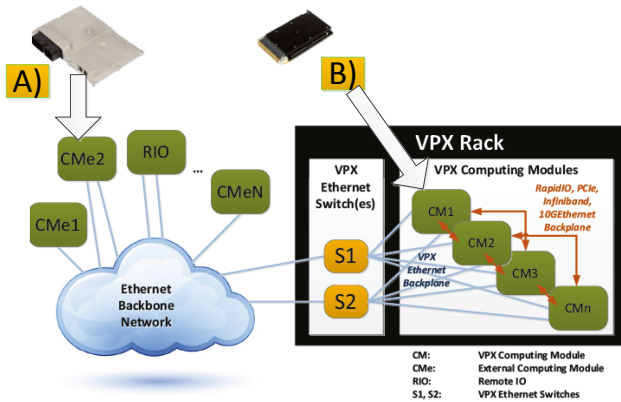
The image shows how such a system [1] ensembles very closely all aspects of IMA architectures (Figure 2) on one integrated unit, and how it can be extended to a fully integrated system (Figure 3) as one of the common core components. In Figure 4, a logical view of the system integration for ADAS as an LRU or LRM is presented.



**Figure 2. Internal ADAS architecture with capability of full integration as a common IMA component**



**Figure 3. Integrated architecture with different variants for ADAS embedded platform integration**



**Figure 4. Logical View: Integrated architecture with different variants for ADAS embedded platform integration**

## The prototyping platform

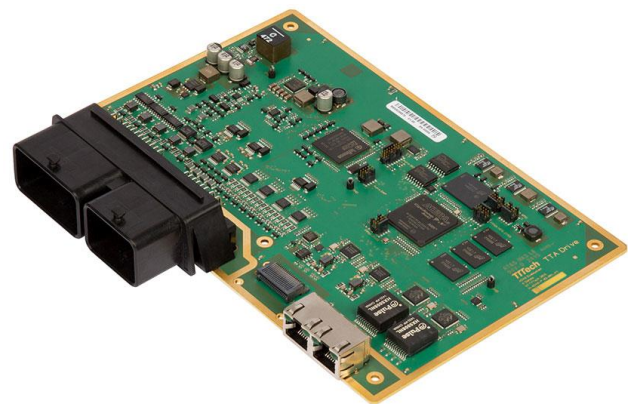
The TTA Drive is designed as a platform for sensor fusion in critical systems. It enables customers to quickly and simply integrate different application modules at an early stage of series development. This integration process is supported by a software named TTIntegration and a tool-set specifically developed for TTA-Drive (Fig. 5). This software package is

located and running as a middleware between CPU-level and the integrated applications. It provides each application with CPU-time and memory needed but at the same time separates hardware from applications. Therefore the origin of data and data usage are strictly decoupled (location transparency). Further benefits include simultaneous support of various safety levels while ensuring “Freedom from Interference” and ease of software integration. In comparison to ARINC653 API, this middleware simplifies the interactions to the bare minimum, and minimizes the overhead for fast calculations. For critical functions it also integrates VxWorks RTOS.

TTA-Drive architecture offers a clean separation of components dedicated for a mixed criticality levels for automotive applications ASIL B to ASIL D, which can be compared with DAL C to DAL B(+) systems for partly fail-operational systems. TTA-Drive provides strict time and space partitioning for distributed applications, but offers a better control of hard real-time processes essential for fast concurrent computing.

With adaptations, the platform could be upgraded to host DAL A applications and support fail-operational behavior. The approach which is deployed can be compared to an IMA or distributed IMA architectural approach.

As such, it meets the integration and sensor fusion requirements for a generic set of autonomous driving requirements, with the exact control of resource sharing for networking and computing components.



**Figure 5. TTA-Drive LRU for automotive applications and ADAS prototyping**

In prototyping use, the TTA Drive platform is easily extended with external building blocks e.g. for image processing. An external Deterministic Ethernet switch can also be used to integrate additional TTA Drive modules for simulating a fail-operational setup.

TTA-Drive architecture is designed to be expandable in the further step with the set of latest developments in high-performance computing, with Infineon, NVidia, MobileEye, ARM or Intel multicores and DSPs.

The middleware of the platform and its capability to tightly control simultaneous execution of different software components on heterogeneous cores deterministically, and with full decoupling of function, executing core and sensor source, is the key to reuse. The principles which are used do not differ significantly from aerospace data coupling and SW/HW integration considerations which support the implementation of DO-178 DAL A software. To be functionally viable, the design of the unit is based on aerospace experiences from TTech (flight controls, Boeing 787 power system platforms, etc.)

Therefore the TTA-Drive platform has a scalable architecture that can be configured flexibly to fit customer requirements for building a series production ECU / LRU / LRMs, without the need to modify application software on different platforms and systems.

### ***Co-Simulation***

Typically semiconductor providers ensure they support specific RTOS and provide development tools, but for design of complex ADAS systems this is not enough.

Due to provided co-simulation for TTA-Drive which is used in series automotive project a remarkable amount of time can be saved during the development process. Each supplier tests and integrates applications individually into their respective execution boundaries set up by the platform integrator. For functional testing all applications are then integrated by the platform integrator and can immediately run together on shared resources. Thanks to the overall concept, violations by software timing, deadlocks, and bugs are detected very early in the design and integration process. Based on our past aerospace experiences the methodology for integration of complex functions

and distributed systems, this can reduce the integration effort for upto an order of magnitude. In IMA architectures, this represents a huge gain and the key to competitiveness when applied and reused on different platforms.

### **Use cases**

This ADAS component can be integrated into an existing system as an external stand-alone automotive COTS component (e.g. as a CMe component) or as a dedicated CMI module in a 3/6U VPX- or CPCI-based rack, or fully integrated as a part of common core avionics architecture. The prerequisite is the availability of Deterministic Ethernet networking capability integrated into ADAS. The functions integrated in an ADAS can be adapted for rotorcraft applications and specific needs. In rotorcraft applications, such approach goes well beyond TCAS tasks, and offers increased environmental awareness, or special operation modes with fully autonomous flying functions with 360° degree environmental assessment could be added.

For cars, the information supplied by all sensors—including the signals from the 3D cameras, the laser scanner (LIDAR) and the radar and ultrasonic sensors—is permanently fed into and processed by this module. With its tremendous computing power, ADAS is capable of continuously comparing the data from the vehicle sensor systems with the model of the road space and its surroundings. With current R&D agendas, this capability can be initiated after 2018, and fully developed after 2025.

For rotorcraft, this equivalent capability can be reused to allow early visual, optical or electromagnetic, “threat detection”, recognize and identify all flying and ground objects, determine their relative position and speed, relative to the rotorcraft and propose the best trajectory to avoid obstacles, much faster than the pilot response.

### **Automotive ADAS operation**

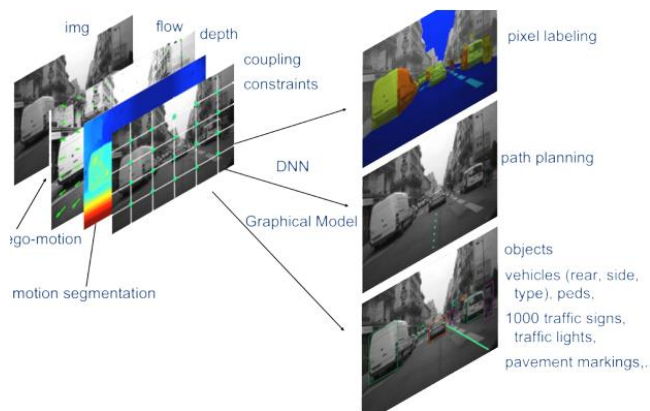
An autonomously driving car in an unconstrained area has to avoid obstacles and possess full environmental awareness. Operation of automotive systems and recognition surrounding are based on orchestrated fusion of several sensors at once. This redundancy and different sensor

capabilities can help to dynamically assess the position of other objects in the environment in real time.

### **Sensor Types: Optical**

Advanced optical sensors and cameras provide data for pattern recognition to manycores, which extract useful information. External manycore CPUs such as NVIDIA TEGRA can be used to conduct additional supercomputing pattern recognition, calculations, while special safety CPUs can make decisions based on those data. For critical applications physically separated CPUs are used to ensure separation.

With preprocessing, such system can recognize different objects or determine the distance on their own, even without stereo vision. It has enough processing power to conduct pattern recognition and run neural network calculations on its own. Tesla car uses MobileEye sensor with as a central element for semi-autonomous driving. This unit can conduct all pre-processing and object patter recognitions with neural network calculations, and path planning which tells the car where is is safe to go forward. The solutions such as MobileEye (Fig. 6) can do it all at low cost but focus on application specific capabilities. Therefore for the rotorcraft industry, more viable path could be the use of existing IR sensors and cameras, with selective use of automotive solutions focusing on specific tasks.



**Figure 6. Mobile Eye Q4 solution can replace multiple SoC and optical sensors**

### **Sensor Types: Radar**

For rotorcraft, radars may be more complex than for the road vehicles which work in a constrained environment and typically work at distances of upto 200m against moving objects. Rotorcraft systems have capable radar systems which can be integrated with other incoming data and most probably do not require additional hardware.

### **Sensor Types: Lidar**

LIDARs can be used for the detection in case visual means are not sufficient or precise enough. Lidars for automotive applications and smaller volumes (200-500USD price range) can use optical phased arrays and scan the environment as a pulse phase array at distances of upto 150m [13]. More expensive lidars with moving parts can scan upto several kilometres around the vehicle, but such units are too expensive for automotive applications. In rotorcraft and unmanned applications several LIDAR system has been reported [14] which can reliably detect all power lines on the aircraft path. A combination of existing rotorcraft LIDAR systems and low cost automotive LIDARs could be used to offer full 360° coverage in 3D.

Similar application can be integrated using TTA-Drive and profit from available automotive hardware.

### **Sensor Types: Ultrasound**

It is only interesting for smaller distances such as 0.5-5m, in extreme cases upto 20m. typically they are used for close proximity detection for parking or slow driving.

## **Conclusion**

On rotorcraft, the proposed solution could integrate the standard avionics Ethernet-based architecture and the supplementary system for improved situation awareness, traffic collision avoidance, and it can be upgraded to support autonomous/unmanned operations. It provides options which are based on radar, lidar and optical recognition of its environment.

The reuse of standardized automotive components which are designed for deterministic real-time processing could provide these added



functionalities at a guaranteed safety level and at the automotive price. The rapid pace of such developments can lead to very powerful semi-autonomous flying/driving capability on a single computing unit for safety-critical applications before 2025. TTA-Drive allows the prototyping and integration of those functions on heterogeneous computing and distributed infrastructure.

In addition this platform can be an integral and natural part of the rotorcraft integrated architecture due to airworthy system integration capabilities.

Rotorcraft industry can profit from automotive developments and can work on more advanced semi-autonomous algorithms specialized for 3D operations in a less constraining environment, but the core hardware and principles could be very similar to methods developed by the automotive industry.

## References

- [1] "Audi piloted driving", <https://youtu.be/Z7QXAebLmd0>
- [2] "TTEthernet Avionics Backbone a Technology Breakthrough for S-97 Raider", Avionics Magazine, July 20, 2015, [http://www.aviationtoday.com/av/topstories/TTEthernet-Avionics-Backbone-a-Technology-Breakthrough-for-S-97-Raider\\_85578.html](http://www.aviationtoday.com/av/topstories/TTEthernet-Avionics-Backbone-a-Technology-Breakthrough-for-S-97-Raider_85578.html)
- [3] ARINC 664, "664P7-1 Aircraft Data Network, Part 7, Avionics Full-Duplex Switched Ethernet Network", [http://store.aviation-ia.com/cf/store/catalog\\_detail.cfm?item\\_id=1270](http://store.aviation-ia.com/cf/store/catalog_detail.cfm?item_id=1270), accessed Aug 2014
- [4] SAE AS6802 Standard, <http://standards.sae.org/as6802/>
- [5] IEEE TSN, <http://www.ieee802.org/1/pages/tsn.html>
- [6] "Delphi selected to build Audi's autopilot computer", March 31, 2015, [http://www.automotive-eetimes.com/en/delphi-selected-to-build-audi-s-autopilot-computer.html?cmp\\_id=7&news\\_id=222904180](http://www.automotive-eetimes.com/en/delphi-selected-to-build-audi-s-autopilot-computer.html?cmp_id=7&news_id=222904180)
- [7] "Renesas Electronics and TTech to Collaborate on New ADAS-ECU Development Platform with High Computing Performance and State of the Art Functional Safety", Advanced Driver Assistance System (ADAS) Renesas Home Page, 6<sup>th</sup> January 2016, <http://am.renesas.com/applications/automotive/adas/index.jsp>
- [8] "MITRAC Train Control", Bombardier, <http://www.bombardier.com/content/dam/Websites/bombardiercom/supporting-documents/BT/Bombardier-Transportation-MITRAC-Game-changing-Electronics.pdf>
- [9] "ASICs Support Orion's Onboard Data Network", 1st Aug 2014, <http://www.techbriefs.com/component/content/article/ntb/features/application-briefs/20298>
- [10] "It's about time: the evolving time-sensitive networking standard for the Industrial IoT", Design World, 11th Jan 2016, [http://www.designworldonline.com/its-about-time-the-evolving-time-sensitive-networking-standard-for-the-industrial-iot/#\\_42nd](http://www.designworldonline.com/its-about-time-the-evolving-time-sensitive-networking-standard-for-the-industrial-iot/#_42nd)
- [11] ADAS- <http://www.greencarcongress.com/2016/01/audi-to-use-gen-2-zfas-controller-in-production-e-tron-quattro-piloted-driving-moving-to-domain-cont.html>
- [12] James Scobie and Mark Stachew, "Electronic control system partitioning in the autonomous vehicle", Automotive EETimes Europe, October 29, 2015 <http://www.automotive-eetimes.com/content/electronic-control-system-partitioning-autonomous-vehicle>
- [13] Quanergy Announces \$250 Solid-State LIDAR for Cars, Robots, and More, <http://spectrum.ieee.org/cars-that-think/transportation/sensors/quanergy-solid-state-lidar>, 7<sup>th</sup> Jan 2016
- [14] Roberto Sabatini, Alessandro Gardi, Mark A. Richardson, LIDAR Obstacle Warning and Avoidance System for Unmanned Aircraft, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:8, No:4, 2014

