Holistic HMI Architecture for Adaptive and Predictive Car Interiors

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Abstract
With the fast-ongoing evolution towards C.A.R.E. vehicles (Connected, Automated, Ride-Sharing, Electrified) interior arrangements are deeply transformed. Both seats and surfaces as part of the interior are becoming populated with actuators and sensors in order to make them truly adaptive and predictive to the various situations encountered while driving. This evolution leads to the perception of the full interior as an extensive "Human Machine Interaction (HMI)" system providing customized comfort, safety, smart and enjoyable life-on-board in all situations. The main benefit for the car users is utilizing the driving time for productive activities in continuity with their occupations outside of the car. This paper explains the end-to-end architecture ("Cockpit Intelligence Platform" – CIP) views of Faurecia for such holistic interior HMI solutions. Faurecia is a worldwide leader in car interiors which has created an extensive partnership network in the last years in order to meet these new challenges. Faurecia demonstrated its concrete solutions and innovations through prototypes and demonstrators at the Frankfurt Motor Show 2017, Las Vegas CES 2018 and recently at the Paris Motor Show, where the company attracted a considerable attention from the automotive community.

1. Introduction

It is obvious that humankind is developing at an exponential rate. One example: the number of human beings populating the earth. Each generation includes as many individuals as the sum of all those who lived before it, since millennia. This is not a fact of nature, as other species do not undergo the same curve, but it is clearly the result of humans' capability to understand, develop, and hopefully manage their environment and its resources.

In the last 100 years, significant developments in the world, starting with the transportation revolution (the invention of combustion engines), followed by the Information revolution (stemming from fundamental discoveries in physics such as the transistor and the LASER), have been powerfully fueling extremely large and radical evolutions not only of the products at our disposal, but more fundamentally of our lifestyles.

We have come now to the point where these two revolutions (Transportation and Information) are merging and giving birth to probably even further reaching transformations with countless consequences. New types of vehicles such as semiautonomous or fully autonomous cars are rapidly brought on the market. In parallel, virtuality increases as well, making it possible to realize remotely what was previously requiring a physical move, e.g.: teleconferencing, online shopping, working, studying, entertainment, etc.

Some researchers depict the evolution phase we are in as the VUCA, which means a Versatile, Uncertain, Complex and Ambiguous world. Automotive products are spectacularly impacted by this move. As a consequence of the general VUCA context, they become radically (**Fig. 1**):

- **Connected**, meaning that all data and information we use in other contexts are made available in the car as well;
- **Autonomous**, meaning that the car becomes a robot, relieving the driver from the task of driving under increasingly stricter conditions (jams, regulations, controls…)
- **Ride-Sharing**, meaning that cars are seen less as possessed goods, more as a commodity that can be obtained when needed, and payed use-by-use;
- **Electrified**, pointing a radical change in the propulsion principle itself, evidently fueled by environmental concerns. It has enormous consequences such as a drastic simplification of the motoring technology and the possibility of far simpler and better car interior designs.

Fig. 1 - C.A.R.E. vehicles and their benefits

A particular consequence of these changes is the proliferation of new actors in the field of mobility, following the Tesla model. Lots of them embark on the electrical propulsion mode (Tesla, Rivian, Lucid…), some on the pure mobility service (such as Uber or Didi Chuxing), and others come from the “virtual world” (Google, Apple or Baidu).

This pushes traditional players to rapidly and deeply reconsider their traditional technology, competency basis and their business models. For example, the German automotive industry that traditionally focused on horse-powered combustion engines, is now reengineering itself into breakthrough electric propulsion engines.

2. Evolution of automobiles architectures

At the level of car architectures and technology, these changes have far-reaching consequences.

Overall, automotive products will gradually be limited to the assembly of three "macro" components:

- **The chassis** (including engine), populated with sensors and intelligent software enabling them to direct themselves in an autonomous manner, even in complex situations;
- **The cockpit** (meaning the complete interior of the car), increasingly becoming a "moving lounge"
- **The cloud**, establishing the link with the external world and enabling a full continuity of activities in or out of the car;

Parrot-Faurecia view is that this macro-partitioning should be reflected in the long run by the electronic architecture through four technical platforms (**Fig. 2**):

- A cloud intelligence and service platform
- A connectivity platform
- A cockpit controller platform
- A chassis controller platform

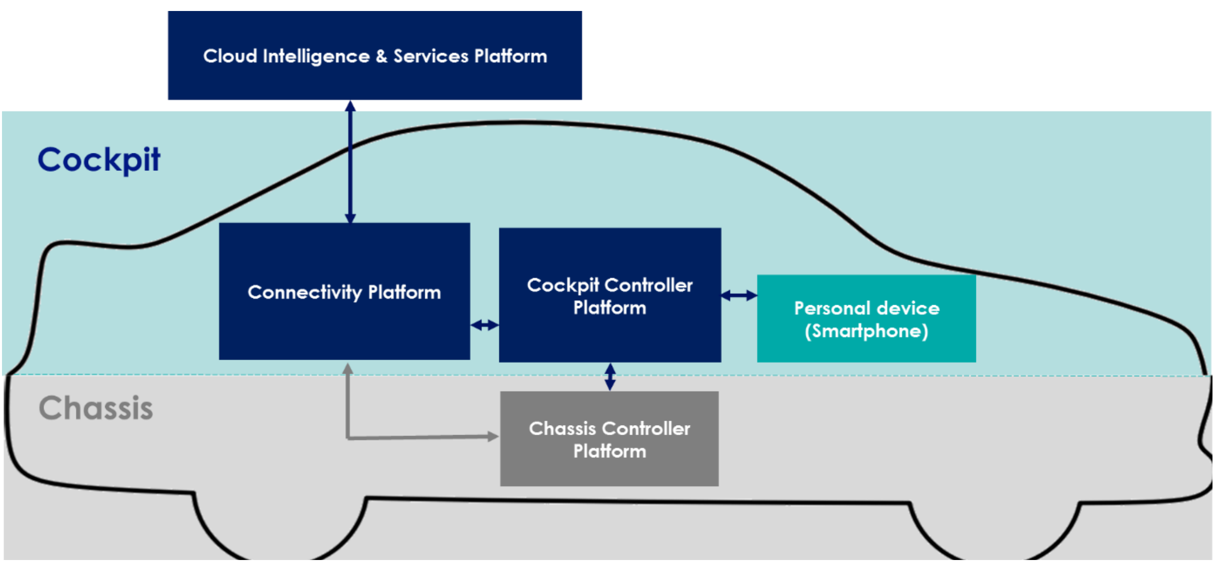

Fig. 2 – *Parrot-Faurecia view on the macro-partitioning of automotive products*

Each of the three macro components will follow specific logical development routes:

- The chassis is becoming a robot; Artificial Intelligence and highly sophisticated real-time short-loop control and supervision algorithms are clearly keys to this domain. The chassis will need to interact with its environment and therefore will have the ability to communicate. The 5G standard currently in deployment represents a much larger step than previous 2G/3G/4G mainly because it includes standards for "Internet-of-Things" (IoT) objects in general and Vehicle-to-Things" (VtoX) protocols and capabilities. It is also clear that chassis will undergo stricter approbation procedures, drastically narrowing-down the number of vendors of their key modules, particularly, the Autonomous Drive Controller.

- The cockpit is evolving along two fundamental lines: it becomes "another living room or office", and it is the element of diversification and identity of the car. Comfort, communication devices like large displays, outstanding sound and lighting systems, full continuity with pre and post-car activities through connectivity, aesthetics & materials quality are the key directions for connected/autonomous cars interiors. Shared vehicles will introduce the additional requirement of personalization: different people using the same car in specific time slots and situations, or several persons involved in different activities with specific preferences sharing the same trip. This creates the "bubble" topic as one of the major technical challenges for example, in the audio, entertainment and thermal comfort domains.

- Finally, cloud servers are obviously key-enablers of car-customization in different contexts: the continuity of activities for individual car occupants, fleet management for professionals, rental car companies, cities, geographically localized ecosystems (Google, Yandex, Baidu…). But progressively, through big data, cloud servers will also enable a higher level of service than what an "isolated vehicle" could deliver.

3. Use cases

In such disruptive contexts, it is clear that for traditional car makers and their suppliers a big challenge will be establishing a legacy. Legacy refers to technical architectures which were adequate in previous generations but no longer valid or optimal when cars become autonomous connected robots. This can be the case for organizations as well, which have been aligned and fine-tuned on previous generation architectures and parts breakdowns.

Furthermore, totally new technology competencies are taking over the lead, having their own specialists and methods, especially linked to software in the car industry. This is destabilizing and frightening existing technical organizations.

In this context, the temptation to proceed "incrementally" for evolving architectures and organizations is very understandable. Unfortunately, it is associated with a major risk of developing obsolete solutions with huge efforts and investments.

As an example, I was recently in a taxi somewhere in northern Europe. The car, produced by a recognized leading innovator in electric vehicles, had a huge display and a nice map of the country on its dashboard. Still the taxi driver was using his smartphone, probably 20 times smaller, less comfortable to use and 100 times cheaper than his car, to navigate.

As painful as it could be, it is essential to remember that architectures and organizations are solutions for offering relevant use cases to customers, not self-justifying realities. And, as a matter of fact, with the transition from cars to C.A.R.E vehicles, totally new use cases are emerging, e.g.:

- In-car office;
- In-car cinema;
- Individual audio bubbles;
- Personalized climate comfort;
- Versatile cockpits, where seats for example can be rearranged from autonomous to driving modes;
- Individual customization;
- Occupants health monitoring

This is the reason why Faurecia has followed a logic starting with use-cases and then focusing on cockpit architectures for reengineering its capabilities and organization, deciding its alliances and acquisitions and creating user-friendly next-generations cockpits.

At Faurecia everything starts from a system-level "Cockpit-of-the-Future" activity which is imagining, exploring, representing and testing the new use cases of years 2020-2030, driven by the C.A.R.E megatrends.

4. Technical challenges

Looking into such use cases, Parrot-Faurecia has tackled several key technical challenges:

- The mere assembly of elementary functional "components" no longer does the trick. Two main factors are at play:
  - On the one hand, use cases cannot be handled by single isolated technical components anymore (e.g. a car radio, a seat, a button…). Managing use cases involves a complete chain going all the way down from the user interface (sensors, actuators), through control and

intelligence modules, connectivity channels (4G LTE, 5G, V2X…) up to cloud-based software and services, thus creating end-to-end services.
    - On the other hand, individual sophisticated services alongside one another (for audio, lighting, infotainment, health, thermal, safety, etc.) will never make for a consistent, unified and useable system. Cockpits of the future also imply proper holistic, transversal and user-friendly Human Machine Interface solutions.

- New use cases require traditional "static" components to "come to life". For instance, seats can now provide massage, heating and cooling, or move every which way. Door trim components are able to display images, generate light, deliver haptic feedback, become tactile and vibrate to generate high-quality audio and music. In a nutshell, all traditional mechanical components of car cockpits are becoming smart, adaptive, and even predictive.

- Software cannot be a "nice-to-have" element added as an afterthought on top of mechanical- and trim-based cockpits. Software is actually the lifeblood of next-generation vehicle interiors.

- Service continuity with the outside world is no longer optional. As driving is losing relevance, vehicle occupants get the opportunity to earn back time. Being in a vehicle is no longer a daily hassle. It is a new space, an extension of their living room or their office where they can relax, be entertained or productive – hence the need for relevant and up-to-date infotainment and content.

- Unprecedented technical issues arise as a result: running open ecosystems (e.g. Google, Yandex or Baidu) along with highly secure software modules on the same electronic platforms creates a whole range of cybersecurity concerns.

The resulting macro electronic architecture of vehicles is Parrot-Faurecia frame of reference (called the "Cockpit Intelligence Platform – CIP") and involves four domains (**Fig. 3**).

1. a **cockpit domain controller ("CIP-Core")**, associated with **cockpit domain sensors and actuators**, short-loop ECUs **("CIP Sense & Act");**
2. an **(Autonomous) chassis domain controller**, associated with **chassis-domain sensors and actuators**, short-loop ECUs *(Not in Faurecia's perimeter)*
3. a **connectivity unit ("CIP-Connect");**
4. a **cloud platform ("CIP-Cloud").**

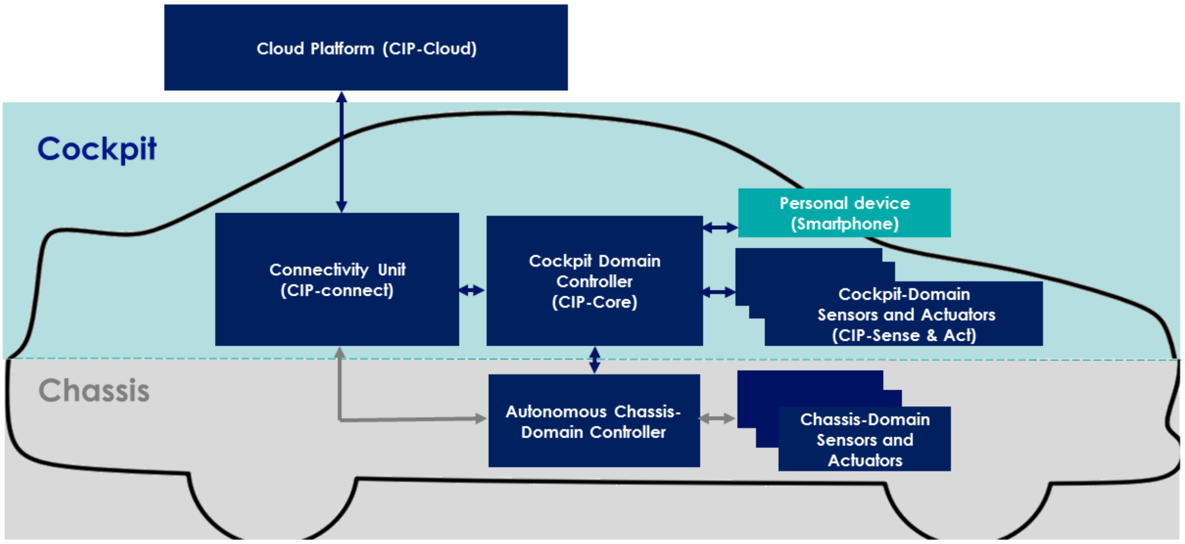

Fig 3 – *Parrot-Faurecia frame-of-reference for next-generation vehicle electronic architectures*

As Faurecia is focusing on car interiors, we will now dive deeper on items 1, 3 and 4.

The cockpit domain controller (CIP-Core) is an evolution and a fusion of several traditional cockpit ECUs:

- The **instrument cluster:** its main purpose is to provide the driver with any information relevant to driving, to the vehicle status and/or. Over the last few years, this ECU has shifted from mechanical and analog user interfaces (pointers and gauges) to multi-purpose freely programmable digital displays
- The **In-Vehicle Infotainment (IVI) unit**, stemming from the car radio and enhanced over the years by multimedia, navigation and connectivity with nomadic devices (such as smartphones)
- The **HVAC control unit**: what was originally a purely mechanical heating system has turned into a smart and programmable comfort interface over time
- **Specific body functions** like seats position adjustments, health and wellness controls

Given the development of programmable technology solutions (essentially large programmable touchscreens), the automotive industry is increasingly taking the focus off driving itself to redirect it to other activities linked to entertainment, communication and information. The emergence of autonomous vehicles will completely relief the driver from the hassle of driving in certain situations (levels 3 "eyes off" and 4 "mind off" of driving automation). Depending on the level of automation along the trip, the vehicle will thereby seamlessly shift from a traditional driving environment to an actual "office on wheels" tailored to the user preferences and habits.

The underlying technical solutions require the combined development of several innovation streams:

- Large displays integrate once dissociated functions into one surface (IVI + HVAC, and even the instrument Cluster);
- Powerful "Systems-On-Chips" (SOCs) run multiple functional domains on one CPU/GPU;
- Software partitioning and virtualization enable to run multiple operating systems (e.g. Android and ASIL-certified real-time OS) independently on the same platform;
- Over-The-Air (OTA) updates go increasingly deeper in the software layers (middleware, firmware) even within the lifetime of a vehicle;
- Cybersecurity is paramount at all levels of the chain: software modules, networks, factories, cloud, etc.

The connectivity unit (CIP-Connect) is the key node where data transfer, control and distribution occur, from the vehicle to the outside world and vice-versa. It is mainly made up of two blocks:

- A **reception unit** to demodulate or modulate data from several standards. Traditional broadcast standards such as analog and digital radio will not disappear overnight. However, 2-way channels are increasingly gaining ground. 4G LTE and soon 5G cover a wider scope than mere telephony: Internet access, traffic information, MoD or even VoD – richer and better content for a complete infotainment suite. This unit will also include short distance wireless technology standards such as Wi-Fi and Bluetooth;
- A **data analysis unit** to interpret data and route it to the proper endpoint. This connectivity gateway plays a fundamental role in safety and security as it stands where in-car networks and external data networks meet.

The cloud platform (CIP-Cloud) provides the car with up-to-date applications, data, and algorithms:

- As of now, Android-based IVI systems already use cloud servers to offer seamless customization tailored to the preferences of the end-users and car makers:
    - **Geographically relevant** content and ecosystems (Google in Europe, North and South America, Yandex in Russia, Alibaba and Baidu in China…)
    - **Specific re-skinning and app store** (for shared vehicles platforms across brands for example)
    - **Scalable** (integrating new popular apps that were not available at production start)

- In the coming years, thanks to the collection of end-users preferences and habits combined with cloud-based big data analysis and artificial intelligence, car functions will display new and smarter behaviors delivering a better interior user experience

5. New business challenges and models

The extremely deep transformations covered in this paper naturally have consequences on the business models and the role of the different actors in the value chain. We do not claim to draw up an exhaustive list of the different possible configurations, as they will result from a complex mix of:

- Actual technology choices
- Legacy situations for traditional OEMs
- Greenfield approaches of new entrants
- Emergence of new technical actors
- Expansion of existing Tier-1s in new territories

Faced with this complex and uncertain future, Parrot-Faurecia strategy focuses on adequate answers to two overwhelming challenges:

1. Creating "agnostic" banks of software service modules that can be integrated in a controlled, cost-effective and rapid manner across different specific vehicle software environments
2. Developing system modeling tools bridging the gap between the description of user experiences and holistic systems able to consistently orchestrate said experiences

It should be highlighted that these new business models will be executed along two holistic axes: with services being the "vertical" axis and the overall system, including the Human-Machine interfaces the "horizontal" one.

The first axis is **the end-to-end service axis**, represented in red on **Fig. 4**. As explained above, emerging in-car services require a "vertical chain" of technical modules running all the way from the cloud down to the end-user in the vehicle. It is essential to have a dual expertise in physical components (actuators, sensors, displays, loudspeakers, etc.) and virtual components (software short-loop algorithms, AI-based control algorithms, big data, etc.) to be able to deliver specific services actuating physical vehicle parts (seats, lighting or audio). Combining mechanical and electronic know-how is a key underlying trend explaining recent M&A moves among major automotive Tier-1s.

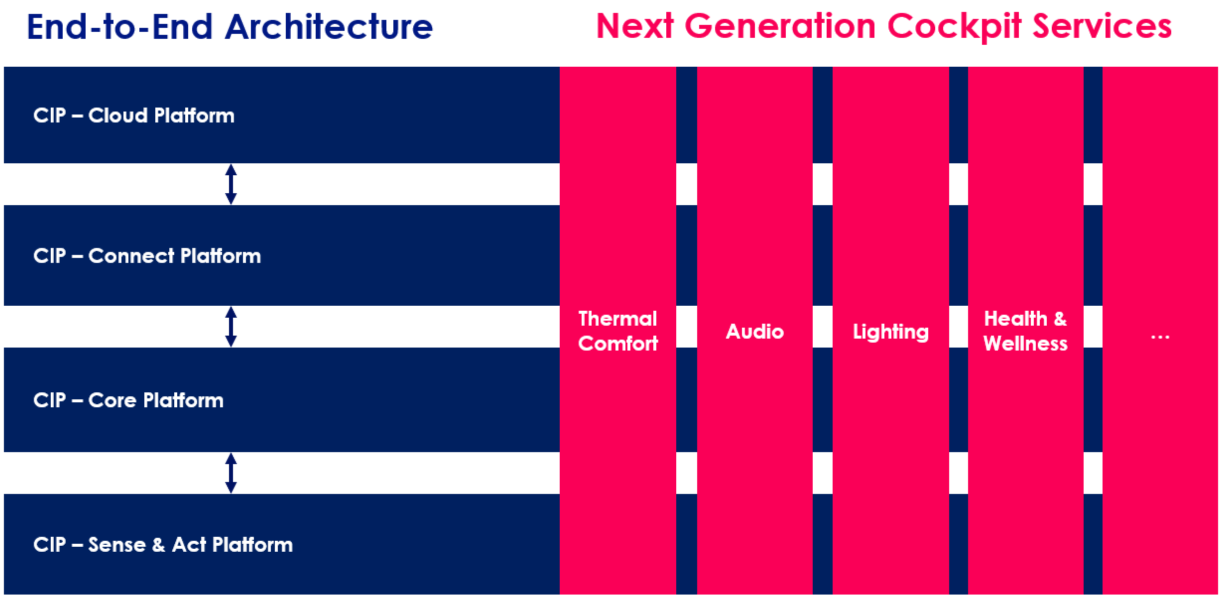

Fig. 4 - *"Vertical" end-to-end service axis*

The second axis is the overall system including the **Human-Machine Interface dimension**. All "vertical services" need to be combined together. The sheer number of new services and the speed at which they are developed create unprecedented challenges when it comes to the usability and appeal of global vehicle systems such as:

- **Fast and reliable combination of services** into a complete car scenario, enabled by Service-Oriented Architectures in particular
- Creating and assessing **user-friendly and attractive interfaces** to manage the underlying service complexity
- **Authoring**: as programmable displays are taking up increasingly larger interior surfaces, graphic design and HMI logic will end up becoming core elements of the car makers brand DNA
- **Scalability**: as new services will pop up all along the decade-long lifecycle of most vehicles, HMI will have to keep up with those evolutions.

Fig. 5 is showing how the "vertical" services are implemented onto the "horizontal" platform structure.

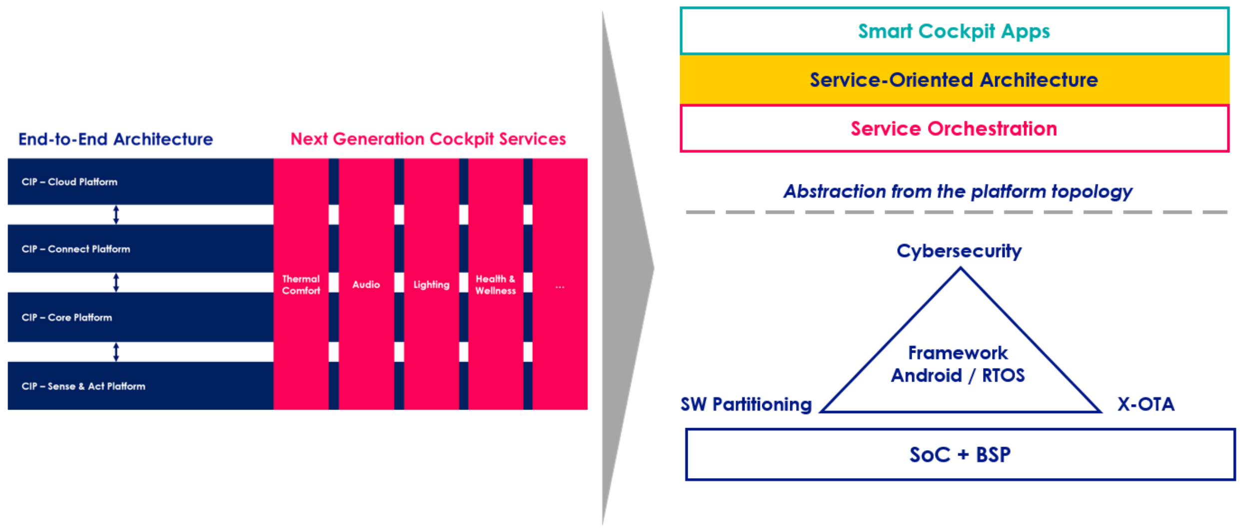

Fig. 5 – "*Vertical" services implementation on the "horizontal" topology & HMI axis*

6. Summary

Over the last decades, technical breakthroughs in the automotive and communication industries have converged to such a degree that it is now possible to come up with brand new vehicles, similar only in shape to the former generations of automobiles. Thanks to mobile robots, getting into a vehicle is no longer focused on driving but is rather another situation in the continuum of daily activities.

In practice, such changes entail to fundamentally reengineer the set of technical skills and practices required to conceive new car interiors. Acknowledging the need to start from the user experiences enabled by autonomous, connected, shared and electrified vehicles, Faurecia is redesigning its engineering capabilities to offer end-to-end services supported by a complete "Cockpit Intelligence Platform": from the cloud to physical car interior components – its traditional know-how and business.

The need to address those challenges has also dictated a fair number of the acquisitions, alliances and technical reorientations that have been recently reported in the automotive industry. Parrot-Faurecia is a clear first-mover going in this direction.

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