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Radar Has More to Give

Radar began a long transition from fighter planes to cars in the 1990s and eventually found a secure role in blind-spot detection beginning in the early 2000s. Today, radar is applied not only to blind-spot detection and cross-traffic alert, but also to the front of the vehicle to inform automatic emergency braking and adaptive cruise control systems of obstacles in the vehicle’s path. Autoliv spinoff Veoneer expects radar penetration to grow quickly: from 6% of the world’s new vehicles in 2017 to 20% by 2022, with five radar units in each vehicle, one on each corner plus one in the front.

Radar technology has come a long way, but the technology is still far from being settled. Innovation is taking two paths. Low-definition radar for blind-spot detection is being cost reduced to make this vital safety feature affordable to more consumers. Radar sensors’ commoditization will also broaden its uses. For example, Google is developing hand gesture recognition based on radar for portable devices, technology which could be applied to the vehicle’s cockpit, driver monitors and occupant detection systems. Foot activated door openers based on radar are also being considered. With comparatively better resolution, radar could potentially substitute for ultrasonic sensors in some applications if the cost becomes low enough. Today, ultrasonics provide a very affordable and reliable solution for low-speed applications such as parking assist.

The second path of innovation underway is an effort to dramatically improve radar’s resolution and expand its range. But not only will high resolution radar chips be costly, they will also require more memory, more processing, and more sophisticated software including better algorithms and artificial intelligence.

Expanding its range and resolution will further cement radar’s role, along with lidar and cameras, as a key perception sensor in ADAS and autonomous driving systems. Radar’s ability to provide distance, height, depth and speed complements the other sensors and unlike camera and lidar, its performance is not affected by adverse weather conditions. Another advantage lies in radar’s ability to directly measure the speed of objects. Speed can be extracted from camera and lidar sensors, but not directly measured.
“Radar is going to do a lot more than it is doing today in vehicles,” said Sameer Wasson, general manager of radar and analytics processors at Texas Instruments. “Radar sensors in the market today are relatively dumb sensors used for proximity detection within the vehicle’s blind spots. But radar is transitioning to imaging technology.”

Compared with camera and lidar, radar’s ability to separate and identify objects and define where they are is the worst. Better resolution is needed. “The more resolution you have, the better the chance you have of separating those objects to do something useful with that information,” said Alan Jenkins, director of technology for Veoneer’s radar group. The range and accuracy of radar will also improve. Significant performance improvements are in the works for the chips, the signal processing and the higher level software.

**Semiconductors and Signal Processing**

Radar sensors typically include one or more integrated circuits consisting of RF transmitters, RF receivers, analog to digital conversion and a processor. The measured transition to CMOS from SiGe (silicon germanium) semiconductors is well underway. Radar devices based on CMOS are smaller, more power-efficient, more flexible, more scalable and less expensive. “The challenge in making the transition to CMOS has been on the RF side,” said Patrick Morgan, vice president and general manager of NXP’s ADAS product line. “Multiple suppliers have been working on that for years. RF CMOS is ready today and is winning the vast majority of new OEM sourcing, especially in the corner radar segment of the market.”

Today’s CMOS radar transceivers have a range well beyond 160 meters. Front-facing applications such as automatic emergency braking require a range of 250 meters and still rely on SiGe transceivers. NXP, which produces both SiGe and CMOS radar semiconductors as well as micros, says that its devices are resident in half of all automotive radar sensors produced each year.

A transition is also underway from 24 GHz radar to higher frequencies ranging from 77 GHz to 81 GHz, depending on region. “With NCAP pressure, the requirements for better forward detection of objects is increasing,” said Matthias Halsband, head of Infineon’s automated driving sensor product line. “That is creating demand for 77 GHz radar, which has better resolution and better performance. Demand for 24 GHz
is still growing, but it will peak in 2022 and not survive much beyond 2025.”

Infineon, which claims market leadership in 77 GHz radar chips, said it has shipped more than 75 million 77 GHz radar ICs based on its SiGe process. Radar sensors operating in the 77 GHz band are significantly smaller than radar operating at 24 GHz.

Ronny Bismark, product manager for driver assistance at Hella, believes that 24 GHz radar is still good for driver assistance systems, “But for autonomous driving you need the higher resolution of 77 GHz so you can classify and determine if an obstacle is in the vehicle’s path, for example a curb, a bicycle or a pedestrian.” A market leader in 24 GHz radar systems, Hella is a major supplier of blind-spot detection systems.

Hella is currently working on a compact, 77 GHz sensor based on RF CMOS technology from NXP. According to Mr. Bismark, the new product will go into series production sometime in the next couple of years, initially for forward looking ADAS applications such as intersection assist and front cross traffic alert. Hella sees future applications expanding if and when autonomous driving vehicles find traction in the market.

Impressively, TI recently began shipping a new single-chip CMOS radar device, part of a carmaker’s blind-spot detection system.

### Radar market segmented by sensor types, evolution of requirements to higher performance

<table>
<thead>
<tr>
<th>Radar Sensor Type</th>
<th>description</th>
<th>Today</th>
<th>2020+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging</td>
<td>Full MmO, mainly corner</td>
<td>-</td>
<td>8-16 / 12-16 160m</td>
</tr>
<tr>
<td>LRR-ACC</td>
<td>Multi mode ACC, no speed limits</td>
<td>4-6 / 8-12 250m</td>
<td>8-16 / 12-16 300m</td>
</tr>
<tr>
<td>Corner High</td>
<td>Multimode, for all L2+</td>
<td>-</td>
<td>3-6 / 4-8 160m</td>
</tr>
<tr>
<td>MRR-AEB</td>
<td>Basic AEB incl. ACC with lim. speed</td>
<td>2/4 (2/8) 150m</td>
<td>3/4 200m</td>
</tr>
<tr>
<td>Corner Front</td>
<td>Corner sensor for NCAP</td>
<td>2 / 4 70m</td>
<td>2-3 / 4 110m</td>
</tr>
<tr>
<td>Corner Rear</td>
<td>Rear sensor</td>
<td>2 / 4 70m</td>
<td>2-3 / 4 110m</td>
</tr>
<tr>
<td>Surround</td>
<td>Parking, free space detection</td>
<td>-</td>
<td>2-3 / 4 40m</td>
</tr>
</tbody>
</table>

1 Long-range radar – adaptive cruise control
2 Mid-range radar – automatic emergency braking

Source: Infineon
Imaging Radar
Radar developers have begun using the term “imaging radar,” to represent the idea that radar technology can progress to a point where it performs more like cameras or lidar. “If you as a human look at the data that comes out of radar, it is unintelligible. It looks like a screen of static. It undergoes Fourier transforms and a great deal of de-noising for us to understand how we should extract any sort of meaningful information from it,” explained Ben Landen, director of business development for DeepScale. DeepScale is a software company that applies deep learning to autonomous vehicle sensor outputs to create data that is actionable by the vehicle.

According to TI’s Mr. Wasson, imaging radar is anything that approaches an angular resolution of one degree, where it goes from a single function like detecting whether or not a vehicle is in the blind spot, to contributing with the other sensors to the vehicle’s perception: where are the obstacles, which are stationary and which are moving, and where is my lane?

“Others define imaging radar chips as capable of angular resolution of less than one degree. At 100 meters this guarantees a cross-range resolution of about 1.7 meters, less than a lane width,” said André Bourdoux, principal member of the technical staff at imec, a 2,000-person international research company based in Belgium that specializes in nanoelectronics and digital technologies.

“Think of the reflected radio signals after processing as a four-dimensional radar data cube—consisting of distance, speed, azimuth and elevation information. High resolution in all dimensions of the cube is needed, angular resolution being the hardest to achieve because it requires an antenna array with many antennas. MIMO (multiple-input, multiple-output) techniques are now commonplace because they make the best use of the number of physical antennas in the array. If you have a chip that has three transmitters and four receivers you can create a virtual 3 x 4 array consisting of 12 virtual antennas,” suggested Mr. Bourdoux. “Note the multiplier effect. It multiplies the improvement in the angular resolution. The trend is to use much larger numbers.”

Magna, working with the Austin, Texas, chip startup Uhnder, says it has developed state-of-the-art radar imaging that extracts data from 192 virtual antennas. “Uhnder uses 12 transmitters and 16 receivers,” said Mr. Bourdoux. The signals in the virtual antennas are processed to deliver both horizontal and vertical resolution. Developed to meet the demands of
autonomous driving, Magna’s ICON radar is scheduled for market introduction in 2019.

FMCW (frequency modulated continuous wave) radar has been employed in automotive applications for a long time. To improve resolution, developers are exploring the use of other RF modulation waveforms including PMCW (phase modulated continuous wave) and OFDM (orthogonal frequency division multiplex). “We at imec have been exploring the use of alternative waveforms,” said Mr. Bourdoux. “Radar based on these waveforms is a little difficult to design. But a strong advantage is they are very short, typically only one microsecond. It is still a continuous transmission, but the repetition is much faster. They are strong contenders for large MIMO arrays. A second advantage is you can use them to mitigate the mutual interference coming from other vehicles with radar, potentially a severe problem as radar systems proliferate.”

Interference is a big worry widely discussed at radar conferences. Hella has been looking at the issue and has some solutions in mind. The German automotive electronics industry is examining ways companies could work together to create a standard to address the problem.

**Making Sense of Sensor Outputs**

Additional advances will come by way of improved algorithms as we apply artificial intelligence and other approaches to the processing side of radar sensors.

The state of the art of radar today and for the next couple of years is still classical radar signal processing, but DeepScale is convinced that artificial intelligence can be used to extract more useful information from radar.

“We get a lot of interest in unlocking the potential of radar,” said Mr. Landen. “The OEs, the tier ones and tier twos that make the chips think we should be getting so much more out of radar, but it’s a difficult problem.” Far more investment dollars are going toward extracting more information from camera data and to creating a compact lidar that is actually producible in high volumes. Radar research is currently stuck in the mode of “it’s good enough for now,” according to Mr. Landen.

Another constraint to advancing radar signal processing in a highly cost-sensitive industry is the high cost of computer-intensive processing and memory, cautioned Veoneer’s Mr. Jenkins.
Mr. Bourdoux also expects that the application of artificial intelligence will help improve radar capability. For example, his company is working on micro-Doppler classification, which relies heavily on machine learning. “We look at how the Doppler spectrum evolves over time. When the target is deformable, like a pedestrian, you have the body, legs and arms which move differently, or a bicycle with the pedaling velocity different from the body. With Doppler analysis it is possible to differentiate a pedestrian from a bicycle, from a motorbike, from a car. It will be part of ADAS and autonomous driving solutions. The only drawback with micro-Doppler is that it is relatively slow,” Mr. Bourdoux explained.

No big breakthroughs are in store for automotive radar. The technology is evolving and will continue to do so for the foreseeable future.
Checking In with Ford’s Top E/E Brass

I spoke this month with Chuck Gray, Ford’s global director of electrical and electronic systems engineering, and Jim Buczkowski, director of electrical and electronics systems research and advanced engineering at Ford. We talked about vehicle connectivity, E/E architecture, software, standards, what Ford wants from its suppliers, and about Ford’s decision to make a full suite of driver assistance technologies standard across all the vehicles it sells in North America. Mr. Gray’s team of more than 2,000 engineers is responsible globally for electrical content and software in the vehicle. He reports to Jim Holland, vice president of vehicle component and systems engineering.

Mr. Buczkowski’s research group is focused on E/E technology for the near and distant future. Jim reports to Ken Washington, vice president of research and Ford’s CTO.

Connectivity
I asked Mr. Gray what is different in his organization since James Hackett came aboard nearly 16 months ago as Ford’s new CEO. “Jim’s passion for connectivity was music to our ears,” he said. “We work closely with another group at Ford which is responsible for the cloud and the features that are enabled by the cloud. Getting that push from the top and that commitment for 100% connectivity across Ford’s entire vehicle lineup was a real catalyst.”

Ford has lately been advocating with others for cellular V2X, which it expects will be more cost-efficient and economical than DSRC (802.11p), the technology that the U.S. DOT has been advocating for and that GM and Volkswagen have begun to implement. In July, Ford teamed up with BMW, PSA, Qualcomm, and infrastructure provider, Savari, in a live demonstration sponsored by the 5G Automotive Association (5GAA) in Paris. According to Ford, C-V2X will be ready for deployment as early as 2020.

More In-House Development
Ford took software integration in house when it developed its first Sync infotainment platform, which came to market in 2007. Over the past several years, Ford has also taken more software development in house. In 2016 the carmaker decided to build a software team within its product development
organization for both the vehicle and the cloud. So in 2017, when BlackBerry downsized as it stepped away from the smartphone business, Ford agreed to hire 400 of its engineers.

Most of the BlackBerry hires are software engineers but some are in hardware. Still working near BlackBerry headquarters in Waterloo, Ontario, Canada, they are developing integrated IVI/connectivity modules based on powerful SoCs. “We engineer a few modules ourselves within Ford and then go out to build-to-print companies for manufacturing, some of whom are existing tier ones that have decided to follow our model and work with us as a partner, like the Apple model,” said Mr. Gray.

For now, Ford’s in-house development model is focused on connectivity platforms for customer facing products. “Our goal isn’t necessarily to take over everything; it is really to be more nimble, because customer appetites change so quickly,” he added.

Hundreds of engineers are being added to the Waterloo team. Ford has been hiring software engineers all year and will hire into next year as well.

Ford has been public about its strong partnership with BlackBerry and with the BlackBerry QNX business unit. According to Mr. Gray, “QNX is a very reliable and safe operating system that is necessary for critical systems.” Ford is planning to deploy QNX software in its future domain controllers, expanding beyond infotainment to include safety related systems as well.

Apart from Waterloo, Ford has set up a central software organization with more than 100 engineers to advance software integration in increasingly complex vehicles. “Their role is to have their fingers in every vehicle, in every module,” Mr. Gray noted. “We are promoting [Classic] Autosar as a way to unify the systems and make the task easier for us and our suppliers.” Ford will eventually embrace Adaptive Autosar as well.

**ECU Integration**

Enabled by more powerful SoCs, Ford is now on a path to make the transition from distributed computing to domain computing, eventually even to centralized and end-to-end computing incorporating its own cloud. Ford will first tackle the IVI and driver assist domains and spread quickly from there to the other vehicle domains.

Ford is presently studying its path to ECU integration so it can’t yet indicate just how aggressive it will be. “The future Ford vehicle won’t have 60
ECUs,” declared Mr. Gray. Just how many depends on a study that Jim Buczkowski’s team is working on in research.

**Software as Product**

“There will definitely be fewer ECUs, whether it’s ten or twenty or five, we cannot yet say,” said Mr. Buczkowski. “The vehicle experience will be enabled by software. That is clear. So I ask suppliers, are you ready to provide Ford with software as a product? What is your core competency? We need help. We can’t do all the software ourselves. We want to assemble the best software. We want to be able to choose, to have competition. We want to be able to easily integrate software into our systems. Are suppliers ready to license or sell software? What kind of commercial arrangements will they suggest?”

The move to domain computing means that a number of Ford’s system suppliers will not receive orders for their hardware. “But they may still have some IP that is appealing. We are encouraging them to consider making that software available to be integrated into these domain computers,” said Mr. Buczkowski.

**Co-Pilot360**

Among Ford’s many innovations, Mr. Gray is especially proud of his group’s role in bringing Co-Pilot360 to market. Starting with the introduction of the 2019 Edge mid-size crossover SUV, Ford will make five driver-assist technologies standard on all its models in North America: cars, SUVs and trucks up to the F-150. The standard features include automatic emergency braking with pedestrian detection, blind spot information system with cross-traffic alert, lane keeping, automatic high beam and reverse camera assist. “My group leads these functions and will build on them as technology matures,” he said. “That will lead to more driving assistance which our customers will especially appreciate in mundane traffic situations.”

**Transportation Mobility Cloud**

Autonomic LCC, the recently acquired subsidiary of Ford Smart Mobility, will build and operate the Transportation Mobility Cloud (TMC), “the first open, cloud-based platform that connects vehicles, drivers, passengers and cities with applications,” according to Ford. TMC will help mobility providers build modern, digital transportation businesses with an industry standards approach. For more information regarding TMC and Autonomic, please visit www.autonomic.ai. ◆
The Company Profile: TTTech Auto AG

**Thumbnail Sketch**

**Headquarters:** Vienna, Austria; [www.tttech-auto.com](http://www.tttech-auto.com)

2017 Revenue: €37.5 million
2018 Revenue: €60 million plus*

**Equity:** €85 million*

**Employees:** 750*

**Revenue per Employee:** €80,000

**Ownership:** TTTech Computertechnik AG, less than 50%; Audi, less than 30%; Samsung, less than 20%

**Valuation:** Approximately €400 million

*Year end 2018 target

**Background**

TTTech Computertechnik AG, the parent company of TTTech Auto, was founded in 1998 by Professor Herman Kopetz of the Vienna University of Technology, Stefan Poledna and Georg Kopetz to commercialize safety related communications based on time-triggered technology. In 2000, the new company announced its first partnership, with Honeywell, to develop aircraft engine electronic control systems based on TTTech’s time-triggered protocol.

TTTech today mainly serves the automotive, aerospace, off-highway and industrial markets. The company is headquartered in Vienna, Austria, and has operations in Europe, the United States and Asia.

TTTech Auto Revenue by Year

<table>
<thead>
<tr>
<th>Year</th>
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<tbody>
<tr>
<td>2014</td>
<td>25</td>
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<tr>
<td>2017</td>
<td>37.3</td>
</tr>
<tr>
<td>2018</td>
<td>&gt;60</td>
</tr>
<tr>
<td>2023*</td>
<td>&gt;200</td>
</tr>
</tbody>
</table>

2014 to 2018 CAGR: 33.8%
2018 to 2023 CAGR: >20.1%

**TTTech Auto Revenue by Product**

2018 Total: €60 million

- ADAS and Autonomous Driving Safety Platforms: 75%
- Other: 25%

The vast majority of TTTech Auto’s revenue in 2018 came from dedicated engineering projects.

Other includes sales of data loggers and Ethernet gateways plus revenue from engineering work in the fields of DSPs, video acceleration and Android software.

The Hansen Report on Automotive Electronics, September 2018
[www.hansenreport.com](http://www.hansenreport.com)
**Locations**
The company (or its parent) maintains offices in:
Vienna, Austria (headquarters)
Munich, Ingolstadt and Wolfsburg, Germany
Brixen, Italy
Bucharest, Romania
Novi-Sad and Belgrade, Serbia
Banja Luka, Bosnia and Herzegovina
Tampere, Finland
Nagoya, Japan
Shanghai, China
Milpitas, California, USA
Boston, Massachusetts, USA

**Employees by Country**
Total: 505 as of Q2 2018

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<th>Country</th>
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<td>Austria</td>
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<td>Bosnia and Herzegovina</td>
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<td>China</td>
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<td>Croatia</td>
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<td>Germany</td>
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<td>Serbia</td>
<td>182</td>
</tr>
<tr>
<td>USA</td>
<td>2</td>
</tr>
</tbody>
</table>

**TTTech Auto Customers**
(Listed alphabetically)
Audi
Autoliv
BMW
Denso
Harman
Renesas
Samsung
SAIC
Volkswagen Group
ZF
Others

**Distinctions Claimed by TTTech Auto**
- Developed the world's first L3 platform to reach production (Audi A8)
- The world's leading provider of an integration platform for automated driving
- The principal partner in Audi's development of zFAS, the world's first ADAS domain computer

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The TTTech Auto Spinoff

Over the past several years as carmakers worked to develop their autonomous vehicle capabilities, TTTech experienced unprecedented interest in its safety-critical communications and computing technology. The interest from the auto industry was so great that in June 2018, TTTech Computertechnik AG decided to set up TTTech Auto, a separate legal entity that is fully focused on automotive and autonomous driving. The parent company will continue working with customers in its other three, non-automotive markets and will serve as a holding company for TTTech, providing R&D, IT, financial, legal and HR services to the new company as well as to its other subsidiaries.

To support the spinoff, Audi decided to transfer its equity investment from the parent to TTTech Auto. Samsung also invested in TTTech Auto. Audi owns not quite 30% of the company; Samsung not quite 20%. TTTech Computertechnik holds nearly 50% of the new entity, and General Electric and Infineon hold small positions. In approximately three years, TTTech Auto will likely be offered to the investment public as an IPO.
Roughly 70% of TTTech Auto’s business is based in Europe. Total revenue is expected to grow from €60 million plus in 2018 to more than €200 million by 2023, a 20% annual rate of growth. “We think that is an ambitious but absolutely doable goal which is heavily supported by the increasing number of design-in wins with our safety software platform MotionWise and project awards,” declared Stefan Poledna, member of the executive board and co-founder of TTTech Auto. Mr. Poledna is responsible for the company’s technical development, supply chain and quality management. Except for 2008, when TTTech decided to retain its highly qualified staff in the face of a global downturn in revenue, TTTech’s automotive business has been profitable every year since 2004.

Ricky Hudi, formerly Audi’s top electrical engineer, is the other co-founder of TTTech Auto. Mr. Hudi is not just lending his name to the operation. He works closely with the company and in addition to his salary will receive an equity stake. Mr. Hudi also consults to TTTech equity partner Samsung.

**Safety Computing is TTTech Auto’s Core Competence**

TTTech, the inventor of time triggered, safety-critical, by-wire communications, has a solid safety-system resume that goes back two decades to its pioneering work with the aerospace and automotive industries. TTTech technology was aboard the two Red Team vehicles from Carnegie Mellon that finished second and third in the DARPA Grand Challenge of 2005.

“We know how to make ASIL-D systems a reality. We have a strong background in fail operational systems,” declared Mr. Poledna. “You need fail operational because if the driver is out of the loop and something goes wrong you still need to proceed in a safe fashion. We know how to integrate complex, safety-related, hard, real-time systems and guarantee performance.”

Autonomous driving systems are highly complex, with multiple SoCs, multiple CPU cores, and software functions that come from different sources. Developers need to guarantee that when an obstacle becomes visible in front of the car, the vehicle can react in so many milliseconds. TTTech Auto’s safety computing platform ensures that the vehicle can respond in a guaranteed amount of time regardless of what other applications in the vehicle are doing.

**From zFAS to MotionWise**

TTTech was Audi’s primary partner in the pioneering development of Audi’s zFAS, the world’s first ADAS domain computer and the first ECU based on centralized data fusion. In 2011, when TTTech began its joint zFAS development work with Audi, ADAS features were implemented using separate ECUs that had to be coordinated. Autonomous cruise control was implemented in a separate
ECU, the parking function was a separate ECU, birdseye-view camera systems required yet another separate ECU. “With Audi we were able to do the complete sensor fusion in a single ECU and have those different functions responsible for steering, braking, suspension and powertrain sit on top of that,” said Mr. Poledna.

TTTech developed zFAS’s safety architecture and helped specify the chipsets. For the production program, TTTech took responsibility for the safety platform operating system that would involve multiple networks and multiple SoCs—from Infineon, Nvidia, Xilinx and Mobileye—along with a multi-ARM core chip and FPGA from Altera. “Everything needed to be orchestrated in order to integrate software coming from different sources and host a multitude of more than 50 different ADAS functionalities on this domain ECU,” said Mr. Poledna. “When we were starting the program there were major tier ones saying that this safety platform approach isn’t going to work. We were really breaking new ground.”

TTTech developed the basic software that orchestrates and synchronizes all the CPU cores as well as the communication with all the sensors, actuators and other ECUs. It is responsible for startup and for monitoring all the applications, detecting failures and reverting to backup strategies if necessary. The software makes sure that no data is corrupted as it is sent between different SoCs. TTTech provided the tooling, the software-in-the-loop simulation and the safety case documentation required for ASIL-D safety certification. “If you printed out the documentation we did for the safety platform and safety architecture, you would have a paper stack that is 4.2 meters high,” quipped Mr. Poledna.

For zFAS TTTech worked directly with Audi as the software and integration partner, providing the core software, the safety case for the ECU, and the complete software integration. The sensors, sensor fusion software, actuators and software algorithms were supplied in part by Audi and Volkswagen, by tier ones and by dedicated software suppliers. The zFAS hardware is delivered by Aptiv.

TTTech’s retained IP rights to the entire software it developed for this program was the foundation for its productized safety software platform, MotionWise. MotionWise debuted in the all-new Audi A8 in April 2017 and is currently deployed in more than five other Volkswagen Group models including the Porsche Cayenne, Lamborhini Urus, VW Touareg, and the Audi A7 and A6.

The majority of TTTech Auto’s revenue in 2018 is coming from engineering projects, and most of that work is related to MotionWise. “We are currently in a number of programs where we help customers integrate their software based on our MotionWise platform, getting their ECUs up and running, integrating their
We also support the safety architecture and provide the safety documentation,” said Mr. Poledna.

Mr. Poledna thinks the embrace of centralized sensor fusion as practiced by Tesla and Waymo, and now by everybody who is working toward highway pilot or automated parking, will further drive integration of ADAS ECUs. “Once you centralize sensor fusion it makes sense to also integrate the ADAS functions,” advised Mr. Poledna. Sensor fusion developers are targeting 2020 and 2021 SOPs.

TTTech Auto expects to apply the MotionWise platform to other vehicle domains and may soon be able to announce design wins in chassis and powertrain. MotionWise supports Ethernet and PCI Express as well as CAN.

Two New Products in Predevelopment
◆ Safety Copilot
TTTech Auto calls its next new product after MotionWise “Safety Copilot.” Now in research, Safety Copilot is software that safely makes the decision to switch from the main autonomous driving computer to the backup computer when something goes wrong. TTTech Auto is already running prototypes in simulation. The company is targeting 2021 for a production launch. Safety Copilot complements the MotionWise platform; together they provide an end-to-end safety solution.

◆ In-Car Compute Platform (ICCP)
Looking ahead to the challenges that developers will face as they tackle L4 and L5 autonomous driving, TTTech Auto sees the need to move beyond domain architecture to an architecture that looks more like a data center, but with the addition of stringent safety and hard, real-time requirements of the auto industry. To enable this next generation architecture, TTTech Auto is developing the In-Car Compute Platform, with which each of the vehicle’s domains can be consolidated.

The problem with domain architecture is its complexity. Having ECUs with different compute platforms, different software stacks and different tools limits software synergies as the boundaries between the domains blur. With the data center approach, the boundaries between the domains can be removed.

As high-performance SoCs with support for virtualization become available, it becomes possible to shift to a coherent cross-domain architecture. The ICCP is designed to support that architecture. ICCP leverages advanced SoCs with their powerful multicore CPUs and GPUs, and it provides external communications to
and from the vehicle. Sensors and actuators are connected to the ICCP by means of smart I/O ECUs. The ICCP and its redundant backup, as well as the smart I/O ECUs, are connected by means of Deterministic Ethernet TSNs (time sensitive networks). See figures below.
Samsung is working with TTTech on proof of concept for ICCP, which could feasibly be ready for series production in 2023.

**TTTech Auto’s Ecosystem**

<table>
<thead>
<tr>
<th>Partner</th>
<th>Date Established</th>
<th>Partnership Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infineon</td>
<td>March 2016</td>
<td>ASIL-D safety solutions in automated driving</td>
</tr>
<tr>
<td>Renesas</td>
<td>January 2017</td>
<td>Partnership to offer MotionWise and R-Car-based platform</td>
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<tr>
<td>VW/Audi</td>
<td>April 2017</td>
<td>MotionWise debuts in new Audi A8</td>
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<tr>
<td>Nvidia</td>
<td>January 2018</td>
<td>MotionWise integrated in Nvidia Drive OS</td>
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<tr>
<td>ZF</td>
<td>February 2018</td>
<td>ZF integrates MotionWise into ZF ProAI platform</td>
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<tr>
<td>SAIC</td>
<td>March 2018</td>
<td>Joint venture for autonomous driving</td>
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<tr>
<td>BMW</td>
<td>April 2018</td>
<td>Automated driving platform</td>
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<td>RT-RK</td>
<td>April 2018</td>
<td>Integrate RT-RK (51.1% owned by TTTech)</td>
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**Alliances**

◆ **TTTech Auto Joint Venture in Shanghai with SAIC**

In March 2018 TTTech announced its joint venture with SAIC to develop and integrate intelligent driving control systems based on TTTech’s MotionWise software safety platform. SAIC, China’s largest domestic carmaker, is the majority shareholder with 50.1 percent of the company. The intelligent driving central controller produced by the joint venture will be installed on an SAIC Group vehicle in 2018, China’s first domestically produced intelligent driving vehicle, according to SAIC. Autonomous parking will likely be featured on a new high-end electric vehicle based on the Roewe Wings concept car.

The joint venture will develop, manufacture and sell ADAS and automated driving ECUs and related components not only for SAIC but for other Chinese carmakers. Intent on becoming a leader in the field of intelligent driving technologies, SAIC also maintains strategic partnerships with Mobileye, Infineon, ChinaMobile, Huawei, Invista and Qualcomm.

◆ **BMW**

In June 2018, TTTech Auto announced its cooperation with BMW to bring levels 3 and 4 automated driving to highways by 2021, while also preparing for level 5. BMW and its alliance partners will apply TTTech Auto’s expertise in functional and software safety to their development of a modular, non-exclusive platform for autonomous driving. TTTech Auto is setting up a team on-site at the BMW Group Autonomous Driving Campus near Munich, Germany. BMW’s alliance partners include FCA, Aptiv, Magna, Continental, Intel and Mobileye. ◆
Features Update

Fuel Economy Still Matters
In the United States the average transaction price for a new vehicle at the end of July this year was $35,359, according to Kelly Blue Book, nearly 3% higher than it was in July 2017, largely due to American buyers’ preference for more expensive SUVs, trucks and crossovers. Cars accounted for just 31% of new car sales in July.

Even with gasoline prices among the lowest in the world and consumers’ penchant for large vehicles, fuel economy remains a priority for new car buyers in the U.S., according to the American Customer Satisfaction Index (ACSI) Automotive Report 2018. The survey found that fuel economy was the area ranked lowest in customer satisfaction. The survey also noted that car buyers think automotive technology overall is not advancing fast enough.

According to Consumer Reports magazine, the average fuel economy for all cars, SUVs and light trucks in the U.S. has increased by 12% since 2010, to 25.2 mpg, largely through technological improvements to gasoline powered internal combustion engines developed to meet CAFÉ requirements established by NHTSA. In 2016 the U.S. Environmental Protection Agency, in its review of CAFÉ targets negotiated for 2025, concluded that the auto industry could meet those future targets without increased sales of hybrid and electric vehicles, because of the progress made in conventional engine efficiency with technologies such as cylinder deactivation, turbo-boosted engines, advanced transmissions, 48-volt mild hybrid systems and advanced emissions controls.

Research by the International Council on Clean Transportation (ICCT) concluded the Obama-era standards agreed to for 2021 to 2026 “are technologically feasible at a far lower cost than anticipated in 2012,” when the standards were enacted.

Regardless of those findings, the Trump administration, with support from U.S. automakers, has proposed freezing CAFÉ requirements at the levels agreed to for 2020, a move strongly opposed by California and 12 other states. The proposal also revokes the federal waiver granted to California to set its own greenhouse gas emissions standards.

Since more rigorous emissions standards are planned in the world’s other major automotive markets, U.S. carmakers that fail to adopt the latest advancements in fuel-saving technologies could be left behind.
While the debate continues, some fuel-saving features are coming to model year 2019 trucks. For example, the 2019 Chevrolet Silverado pickup employs advanced cylinder deactivation to improve fuel economy of its V8 engine, and the 2019 RAM truck will offer a 48-volt mild hybrid system. In real world highway driving tests at speeds of 75 mph (when possible) conducted by Car and Driver, a 2018 non-hybrid Toyota Camry with automatic transmission delivered 45 mpg, scoring better than a Prius C.

**Infotainment and Connectivity**
After many years of complaints about infotainment systems being too complex, non-intuitive and less than perfect when it comes to voice recognition, there are signs that trend is reversing. The JD Power 2018 U.S. Initial Quality Study found that while it is still the most problematic feature area, infotainment problems have declined for the third consecutive year, led by fewer problems with voice recognition.

The speech interface in vehicles is going to benefit dramatically from the rapid and widespread popularity of digital assistants such as Amazon’s Alexa and Google Assistant, which have the processing power required for seamless natural language understanding available to them through their Internet connectivity. Amazon recently released the Alexa Auto Software Development Kit to simplify the integration of Alexa features into infotainment systems.

Earlier this month, BMW announced that its new Intelligent Personal Assistant based on artificial intelligence would be available in March 2019 on some models. The feature, activated with “Hey BMW,” will allow drivers to control vehicle settings for things like climate control, lighting and infotainment. It can also serve as a manual for the vehicle, sync with your calendar and provide many other Alexa-like features.

Mercedes also has its own personal assistant built into the new MBUX (Mercedes Benz User Experience) infotainment system introduced earlier this year on the new A Class. The system is based on Nuance’s Dragon Drive platform, adopting “a hybrid approach that combines embedded and cloud services to achieve the best results and to offer fallback solutions for driving in areas with zero or low network coverage,” according to Nuance.

Providing a seamless digital assistant experience in a vehicle today depends heavily on maintaining an uninterrupted Internet connection, which is not possible in many locations. Amazon researchers presented a new approach to processing natural language understanding locally, without access to the cloud, at the
Interspeech 2018 conference in early September. The research suggested that the large statistical models required for natural language processing could be shrunk dramatically, thus reducing the amount of memory and processing power required.

For more on automotive digital assistants please see the February 2018 issue of the Hansen Report.

Strategy Analytics predicts that by 2019 the majority of cars in the world will come off the assembly line with embedded connectivity, driven by the need to provide software updates over the air, as well as to collect data and link the vehicle to cloud services.

Starting with the Crown and Corolla sport models, Toyota is moving toward making a data communication module (DCM) that links to the vehicle CAN bus standard on all cars in Japan. Toyota will provide services such as live-operator support in the event of vehicle problems, maintenance updates, emergency services if airbag deployment is detected, and driving behavior metrics for insurance providers.

Connectivity penetration in China is already at 10.6%, according to China Daily, and future demand looks strong. Chang’ an Auto announced that it would stop producing “non-networked” cars by 2020. The Renault Nissan Mitsubishi alliance announced that by 2020, 90% of its vehicles will be connected to its Alliance Connected Cloud services and have access to some 35 services the carmakers plan to offer.

The Hansen Report on Automotive Electronics, September 2018

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