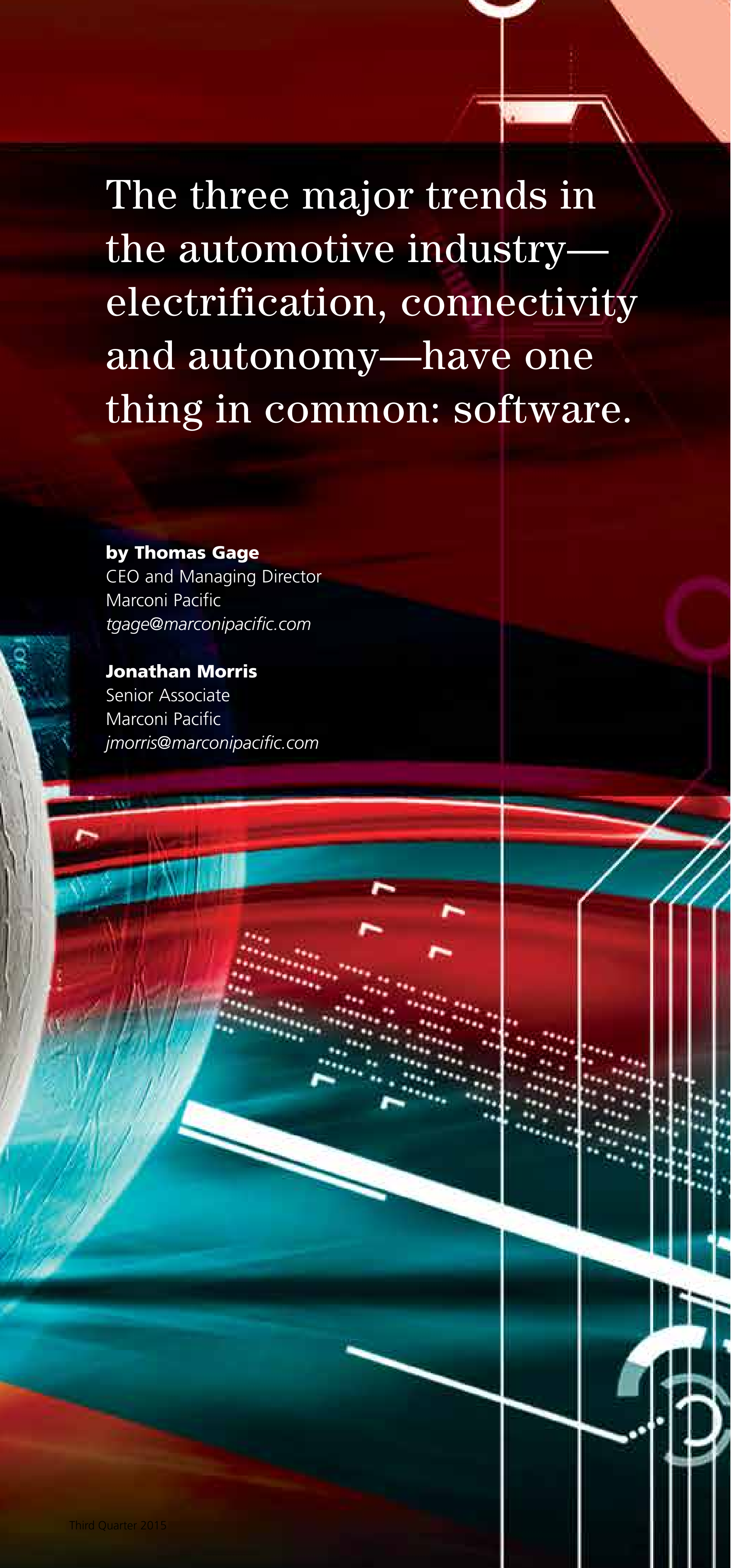
The Coming Revolution in Vehicle Technology and its BIG Implications



The three major trends in the automotive industry—electrification, connectivity and autonomy—have one thing in common: software.

by Thomas Gage
CEO and Managing Director
Marconi Pacific
tgage@marconipacific.com

Jonathan Morris
Senior Associate
Marconi Pacific
jmorris@marconipacific.com

We are on the threshold of a radical change in vehicle technology. No, it's not automation, although that will come very soon. Instead, change is being driven by the underlying technology for automation that is already here and advancing rapidly; that is, crash avoidance technology delivered by advanced driver assistance systems, or ADAS for short.

ADAS makes safety and marketing sense. Whether it is Daimler, Toyota, Ford, Nissan, GM, another vehicle OEM or even Google, none are going to put vehicles on the road that can steer, brake or accelerate autonomously without having confidence that the technology will work. ADAS promises to first reduce accidents and assist drivers as a "copilot" before eventually taking over for them on some and eventually their entire journey as an "autopilot."

As for how quickly the impacts of this technology will be felt, the adoption curves for any new technology look very similar to one another. For example, the first commercial mobile-phone network went live in the United States in 1983 in the Baltimore-Washington metropolitan area. At the time, phones cost about $3,000 and subscribers were scarce. Even several years later, coverage was unavailable in most of the country outside of dense urban areas. Today there are more mobile-phone subscriptions than there are people in the United States, and more than 300,000 mobile-phone towers connect the entire country. Low-end smartphones cost about $150.

Vehicle technology is moving forward at a similar pace. And, because transportation is so fundamental to how we live, the disruptive effects are likely to be astoundingly large.

The ADAS systems of today and autonomous driving systems of tomorrow will rely on software to make sense of a slew of data from sensors, cameras, the Internet, infrastructure and other vehicles.

THREE VEHICLES, ONE REVOLUTION

The development of automation and ADAS is not the first trend to upend the auto industry status quo. International competition and liberalized trade forever altered the automotive OEM landscape, eroding the U.S. sales market share of the Big Three automakers from 72 percent to 45 percent in the last 20 years. And while vehicle technology has advanced enormously, the basics of driving have not changed much in the last 40 years.

Now, every day in California's South Bay, you can commonly see three vehicles representing three world-changing trends in the automotive industry: a sleek Tesla Model S rolling quietly past, a late-model sedan with an Uber "U" in the back window picking up a passenger and a heavily modified Lexus SUV with a spinning lidar on the roof, driving itself down the street while a Google employee (or an employee from an auto OEM in one of their vehicles in other parts of the world) collects data. These daily sights represent three technology-driven trends that are simultaneously arriving to significantly disrupt the automotive status quo: electrification, connectivity and autonomy. Each trend is moving at a different pace, but all three have one thing in common: It's all about the software!

SOFTWARE: REFINING TODAY, REVOLUTIONIZING TOMORROW

Since 2004, the costs of electronics in an average vehicle have doubled from 20 to 40 percent. Today's luxury vehicles commonly contain 100 microprocessors and run 100 million lines of software code, controlling everything from engine timing to infotainment systems. We are now at an inflection point where software, sensors and processors are delivering entirely new areas of vehicle functionality, and not simply transitioning conventional functions from mechanical to electronic control. Both the ADAS systems of today and the autonomous driving systems of tomorrow will rely completely on software to make

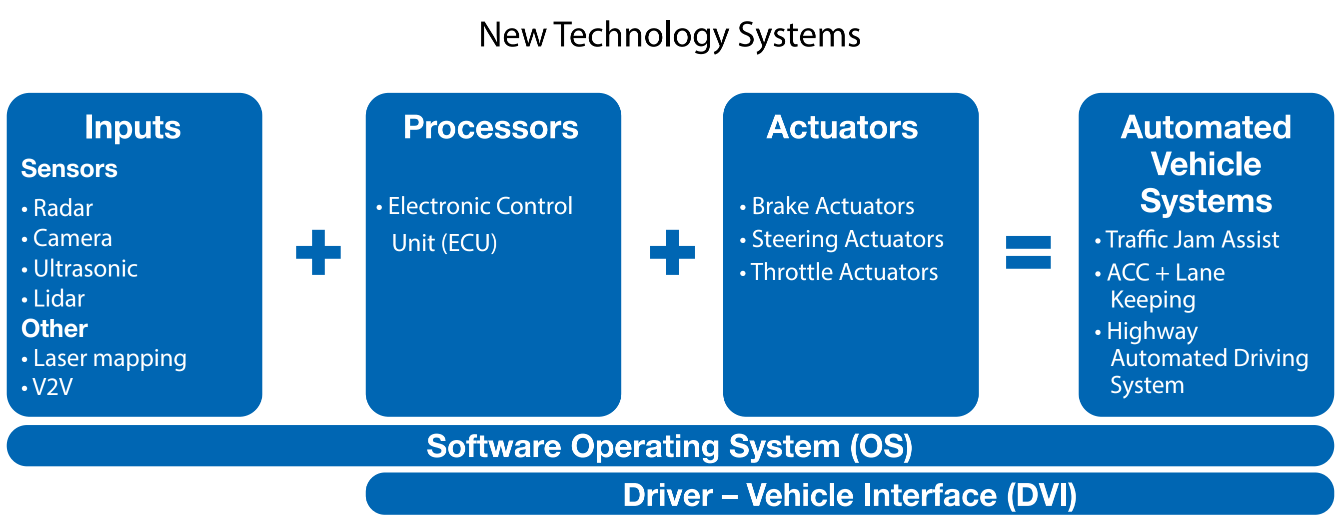


Figure 1 – The basic ADAS architecture starts with a set of sensors that provide data on driving conditions to an ECU.

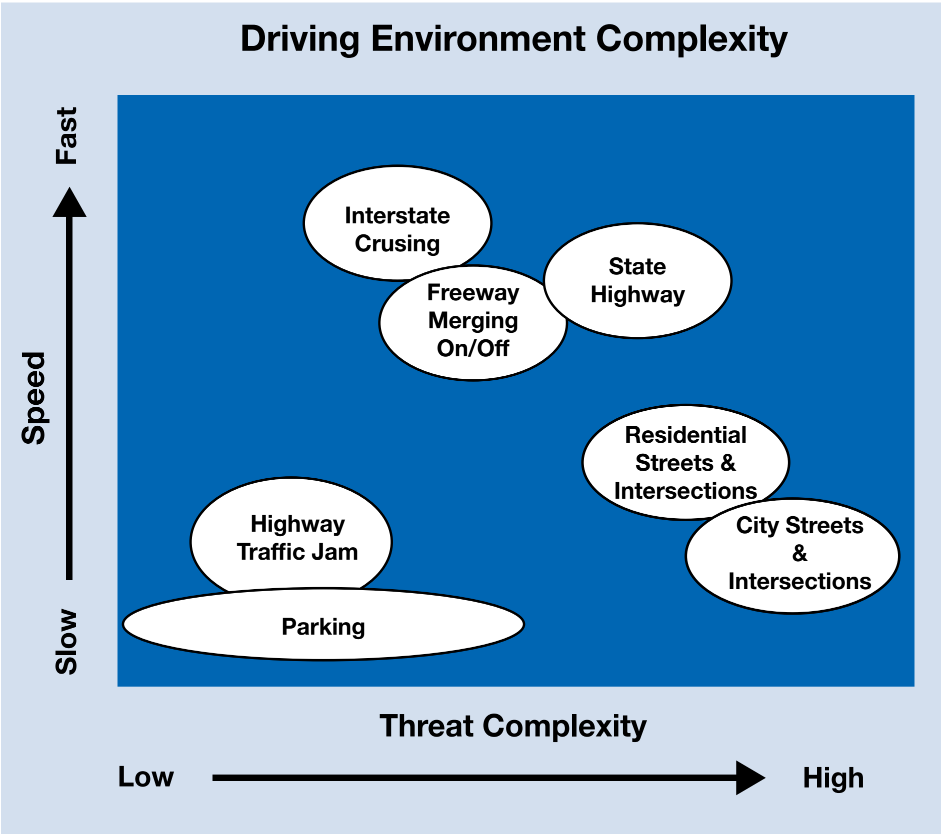


Figure 2 – ADAS software algorithms must account for road types, speed and threat complexity.

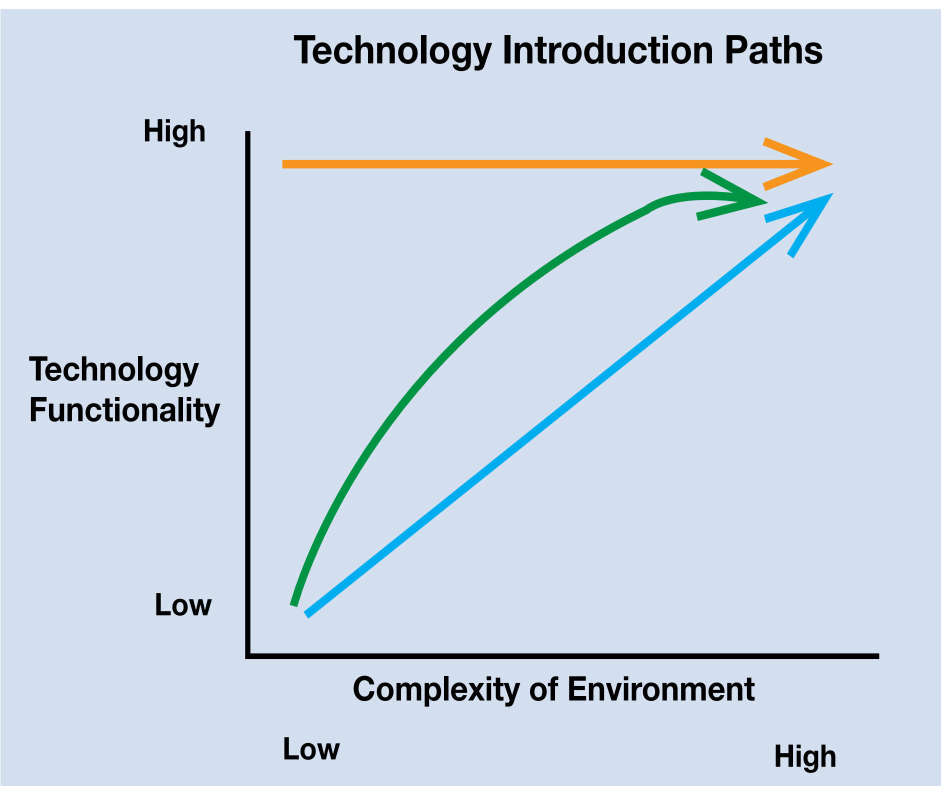


Figure 3 – Simpler systems like "traffic jam assist" will roll out first, followed by systems able to operate the vehicle.

sense of a slew of data from sensors, cameras, the Internet, infrastructure and other vehicles.

The increasing complexity of vehicles has already shifted the automotive value chain. The trends of electrification, connectivity and automation will only accelerate this shift in value toward those companies that create electronics and software, and away from OEMs that fail to innovate.

This shift will have two effects. First, software will become a critical market differentiator, pressuring OEMs to shorten product cycles and provide support and updates for legacy systems. To meet consumer demands for current technology, OEMs are now forced to significantly modify or introduce new models after only three or four years, while previous product cycles averaged five to eight years. This leaves OEMs with many challenges including rapid innovation, complex QA testing, higher development costs, less time to amortize R&D and the need for new sales and vehicle-ownership models.

Second, the shift to software allows new entrants to innovate in an industry with notoriously high barriers to entry. After decades of the same players dominating the industry, Google, Apple, Tesla and Uber are all poised to remake the automotive landscape through software, a thought that would have seemed highly unlikely even five years ago.

In a typical ADAS-equipped vehicle (Figure 1), applications such as forward collision avoidance (FCA) are enabled by a set of sensors that provide data on the external driving environment to an electronic control unit (ECU). This unit then uses software to determine whether a threat is present and operates brake actuators (or potentially, other countermeasures) to mitigate the threat.

The sensors available today for driver assistance applications are the hardware foundation for autonomous vehicles. But tomorrow's sensors will necessarily be smaller, faster and cheaper. For example, Continental AG's sensors and processors can transmit

The software algorithms that will let vehicles drive themselves more efficiently and safely than human drivers in complex environments remain the biggest challenge.

and recalculate algorithms needed to understand the driving environment every 10 to 60 milliseconds, while the human brain can pass a message from a sensory neuron to a motor neuron in only a few milliseconds.

But the real gap between the ADAS systems of today and the fully autonomous systems of tomorrow is seen in software. Regardless of how fast inputs can be processed, the software algorithms that will allow vehicles to drive themselves more efficiently and safely than human drivers in complex driving environments remain the biggest challenge. Complexity is defined by both the number of threats, characterized by the types of threats that a driver can encounter on different road types (for example, pedestrians, vehicles traveling at a right angle to your vehicle, bicyclists) and the speed at which the vehicle is driving (see Figure 2).

As they race to improve their software, vehicle OEMs and their suppliers are introducing their technology to the market in three distinct ways. OEMs such as BMW, Daimler and Nissan have already begun to sell moderate-functionality ADAS systems designed to operate in simple driving environments such as interstates. Without needing to account for traffic signals, turns or multidirectional traffic, these vehicles automatically steer, brake and accelerate in lower-speed situations using systems like “traffic jam assist” (a trajectory represented by the blue line in Figure 3). Eventually, systems will operate at higher speeds or in more-complex urban settings, and offer additional functionality such as the ability to merge, change lanes or negotiate an intersection. A subset of these OEMs, such as Volvo and Ford, are introducing moderate-functioning systems for defined geographic areas (typically geo-fenced), such as a particular stretch of an interstate between two cities, to take advantage of laser scan mapping data. Over time, system functionality will increase and the number and complexity of geographic areas available to the system will expand (green line in Figure 3). Finally, Google’s approach has been to develop a highly functioning, fully autonomous vehicle from the outset (in geo-fenced areas and for low-speed city or campus driving), then test and refine its capabilities in increasingly complex environments (in orange on Figure 3).

CONSUMER ADOPTION AND DIFFUSION

While OEMs are choosing different strategies to bring ADAS and vehicle autonomy to market, ADAS-equipped vehicles of increasing capability have already been introduced nearly every year since 2010 and continue to roll out annually. In 2013, fully 29 percent of passenger vehicle models offered optional forward-collision warning, and of those, 12 percent had autonomous braking. This year’s Mercedes entry-level premium CLA sedans come standard with a forward-collision prevention system, and Volvo has made its City Safety braking system standard on its XC60 since 2010. Now that the early generations of this technology are available, how fast will consumers adopt it?

To understand the adoption of ADAS-enabled and autonomous vehicles, it is instructive to look at adoption rates of other technologies. As a general trend, modern technologies such as the cell phone, Internet and PC have been adopted at a much faster rate than older technologies such as the VCR or TV. Cars have conventionally been one of the slower technologies to be adopted. This is largely due to their high relative cost as compared with consumer electronics, and to the need for highways to be constructed. In contrast, the smartphone is considered to be the fastest-adopted technology in history, on track to reach saturation in a decade. Mobile phones (largely what we today call “feature phones”) took 20 years to reach saturation and conventional landlines took a century (largely because of the need to build out the landline networks).

ADAS-equipped and autonomous vehicles likely will be adopted at rates slightly slower than other modern technology due to vehicle costs, but they will still be adopted much faster than conventional automobiles were. As with the uptake of other new technologies, we expect a wave of first movers and early adopters to drive early sales of ADAS-equipped vehicles, followed by gradual adoption by the majority of consumers once the safety benefits have been proven (see Figure 4). Importantly, the current additional cost of a typical ADAS suite of equipment is only about $3,000 (declining at about 7 to 9

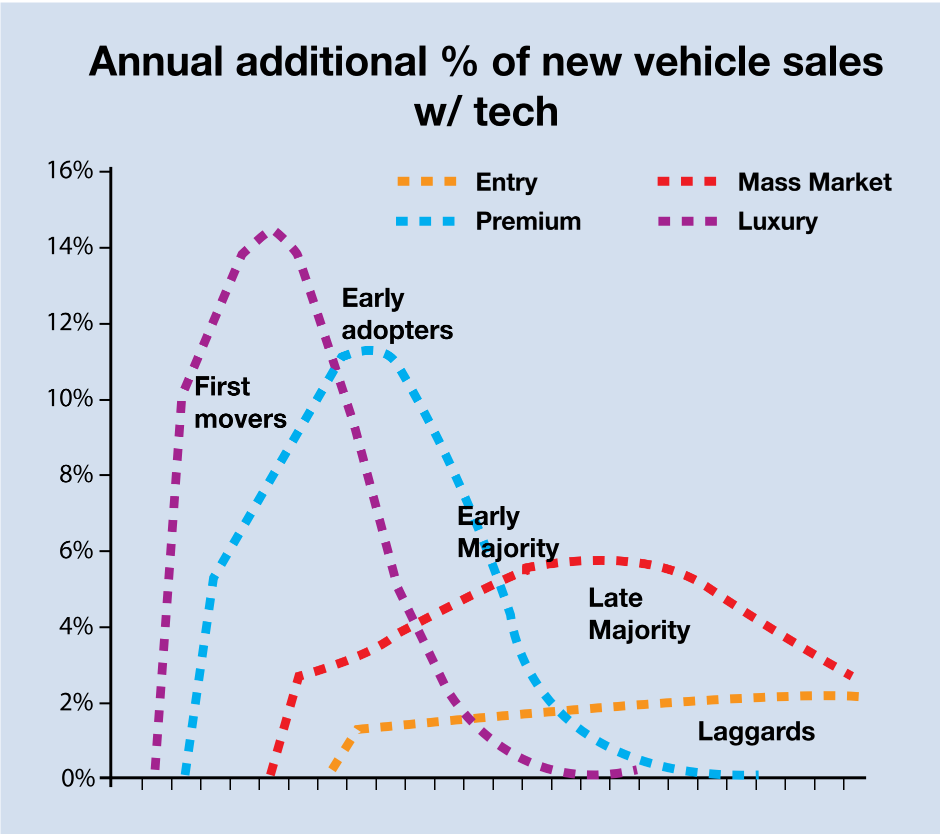


Figure 4 – Additional sales for ADAS and autonomous vehicle (AV) technology will pick up as consumers see the safety and convenience benefits.

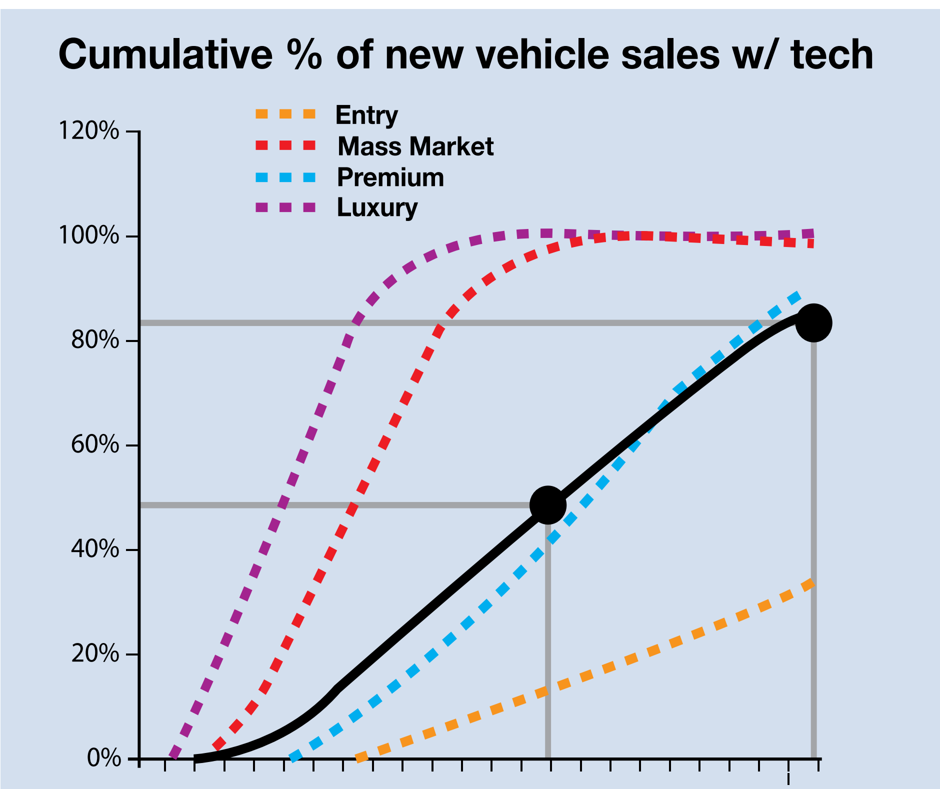


Figure 5 – Cumulative sales for ADAS/AV technology could approach 85 percent of total car sales by 2035, according to one model.

percent per year), or about 10 percent of the cost of the average vehicle sold in the United States of $33,560. For luxury vehicles, the ADAS equipment cost represents only 2 to 3 percent of the vehicle sale price on average.

Marconi Pacific consumer research into ADAS and autonomy indicates that consumers will be initially drawn to the safety and convenience of this technology. Safety will be a large motivator for families as they begin to hear that ADAS-equipped vehicles avoided crashes that might have injured or killed the vehicle's occupants. But the big driver (pun intended!) will be time recapture. Being able to cruise along a freeway (and soon enough, other road types) while paying limited attention to the road will be a significant accelerator of demand.

Marconi Pacific has built a diffusion model to better understand the pace of introduction of the technology and the uptake by consumers. The model is scenario based, with numerous inputs. A few key factors are annual vehicle sales, ADAS technology introduction dates and fleet turnover forecasts. The results are striking. In one run of the model, by 2035 more than 50 percent of vehicles and 85 percent of new-vehicle sales across all segments had one generation or another of ADAS-equipped or autonomous vehicles (see Figure 5). Of course, different levels of ADAS and of autonomy will have different impacts on society, including different levels of total annual crash reduction, different impacts on traffic congestion and different impacts on shared-vehicle, Uber-like services.

AUTO ECOSYSTEM IMPLICATIONS

The automotive sector and adjacent industries form a large ecosystem with pervasive reach across the global economy; in the United States, transportation represents just under 10 percent of GDP. As innovation in the form of electrification, connectivity and automation disrupts the status quo, the effects will be felt not just by OEMs,

Xilinx All Programmable Devices: De Facto Standard Platforms for ADAS and Beyond

by Mike Santarini
Publisher, *Xcell Journal*
Xilinx, Inc.
mike.santarini@xilinx.com

Xilinx Inc. has a rich history in the automotive market, but over the last four years and with the commercial launch of the Zynq®-7000 All Programmable SoC in 2011, the company has quickly become the platform provider of choice in the burgeoning market for advanced driver assistance systems (ADAS). Companies such as Mercedes-Benz, BMW, Nissan, VW, Honda, Ford, Chrysler, Toyota, Mazda, Acura, Subaru and Audi are among the many OEMs that have placed Xilinx® FPGAs and Zynq SoCs at the heart of their most advanced ADAS systems. And with the new Zynq UltraScale+™ SoCs, Xilinx is sure to play a leadership role in the next phases of automotive electronic innovation: autonomous driving, vehicle-to-vehicle communication and vehicle-to-infrastructure communication.

The basic goal of an ADAS technology is to make drivers more aware of their environment so they can drive safely while enjoying the driving experience. Around 10 years ago, luxury OEMs began to offer the first ADAS systems in the form of backup radar/lidar sensor-based products that would simply beep if they detected an object behind the vehicle. Over time, these systems advanced to multisensor versions that fused radar with cameras and even lidar, to not only give drivers a view of what's behind them but also detect if something is coming up from the side.

In subsequent years, the ADAS sensor arrays morphed from doing one task at the back of a vehicle into networked sensor arrays that see 360 degrees around and even inside an automobile, with each sensor performing a number of tasks. Today's high-end automobiles can include ADAS products with not only highly advanced rear-camera systems, but fusion-sensor systems that simultaneously perform multiple tasks such as blind-spot and lane-departure warning, pedestrian and sign detection, automated cruise control, forward-collision warning and even drowsy-driver detection and warning. The latter system monitors the driver's eyes to detect eye patterns that may indicate he or she is falling asleep at the wheel and needs a sonic alert or even a puff of smelling salts to snap to.

What's more, over the last five years, an increasing number of features once offered only in premium vehicle lines are quickly becoming standard in even economy lines. In short, OEMs are leveraging ADAS as competitive selling points for their vehicles.

Today, OEMs are moving above and beyond the ADAS warning features and are starting to network ADAS into the controls of the vehicle to actively and momentarily take charge. Adaptive cruise control, intelligent speed control, lane-keep assist, collision avoidance and even automated parking are available in many models. And these remarkable technologies represent the first steps in the automotive industry's race to offer consumers fully autonomous, self-driving vehicles in which the driver is essentially the copilot. What's more, these technologies will also be leveraged heavily to facilitate vehicle-to-vehicle and vehicle-to-infrastructure (V2X) communications designed to enable governments to build smart infrastructure—streets, traffic signals and so on—to streamline traffic flow in real time, making transportation safer, more efficient and economical, and better for the environment.

Xilinx's All Programmable devices and especially the multi-award-winning Zynq SoC are at the heart of today's most sophisticated ADAS systems and are quickly replacing much less versatile ASSPs. The combination of the Zynq SoC's ARM® processors and FPGA logic on the same device has enabled OEMs to build highly sophisticated, All Programmable ADAS platforms that can scale with automotive product lines and be upgraded with new enhancements to suit demanding and ever-evolving customer requirements.

Automotive OEMs leverage the Zynq SoC in many platform configurations. The device serves as a multisensor, multifeature driver assist platform, a high-resolution video and graphics platform, a vehicle networking and connectivity platform, and an image-processing and recognition platform. In these applications, customers implement algorithms for their design's most complex and compute-intensive functions in the logic portion of the Zynq SoC and implement serial processing functions in the onboard ARM processing system. They leverage the Zynq SoC's high-speed I/O to link to sensors and create highly reliable connections to automotive networks. Customers also leverage IP from Xilinx and from members of the Xilinx Alliance Program, as well as Xilinx's Vivado® Design Suite and the new SDSoC™ development environments, to quickly develop ADAS platforms.

Xilinx's new Zynq Ultrascale+ SoC is destined to enable these same OEMs to bring autonomous vehicles to the mass market. With 64-bit application processors, real-time processors, on-chip memory and FPGA logic on the same device, the UltraScale+ version of the Zynq SoC will allow OEMs to create ever-more-sophisticated fusion systems with a programmable platform that can't be matched by any other silicon architecture.

For more information on Xilinx's role in the rapidly advancing ADAS market, visit http://www.xilinx.com/applications/automotive.html.

but also by numerous other sectors and businesses that have previously been structured around conventional personal vehicles (see Figure 6).

Automakers have many opportunities as the race to deliver advanced functionality accelerates. These include more luxury vehicles and features, more telematics/infotainment and new “driving” experiences. But there are also risks regarding competitive timing, technology capability (hardware and software), complex sourcing, technical selling capability of dealers and brand differentiation. Automotive OEM, component and aftermarket suppliers also are likely to have increased product liability risks as their technologies assume direct responsibility for more of the driving.

Auto parts and component suppliers and adjacent industries have their own opportunities and risks. Chip makers and security companies have significant opportunities to enable and secure this new functionality. Telematics content and platform providers, as well as telecom network operators, have opportunities in areas such as mapping, car sharing, parking apps, infotainment, vehicle-to-X communication and vehicle-to-Web integration.

Traditional vehicle hardware suppliers are likely to be price-squeezed as value moves to software and infotainment. Auto insurance companies will need to develop new business models as crashes diminish in both frequency and severity, with corresponding reductions in premiums. Property developers, garages, transportation engineering and construction firms, and transit agencies (to name a few industries) must all consider how transportation will change as vehicles become safer, perhaps owned less by individual families and ultimately are fully automated.

The three technology-driven trends that are simultaneously arriving to significantly disrupt the automotive status quo—electrification, connectivity and autonomy—are here today. Companies that move quickly to take advantage of the opportunities are likely to succeed. Laggards—well, history has shown what usually happens to them.

REFERENCES

1. Wards Auto, “U.S. Total Vehicle Sales Market Share by Company, 1961-2014”
2. Gapper, John, “Software Is Steering the Auto Industry,” *Financial Times*, Feb. 18, 2015
3. Kuchinskas, Susan, “Crash Course: Training the Brain of a Driverless Car,” *Scientific American*, April 11, 2013
4. IIHS Status Report, Vol. 48, No. 3, April 25, 2013

Ecosystem Implications of Driver-Assisted and Autonomous Vehicles

Industry Sector	Opportunity	Risk	Action Time Frame
• Vehicle OEMs	High	High	Now
• Traditional OEM suppliers	Medium	Medium	Now
• Tech OEM suppliers	High	Low	Now
• Motor Insurance Carriers	Low	High	Now
• Telecom Carriers	Medium	Low	Now
• Telecom platform providers	High	Medium	Now
• Security solutions	High	Low	Now
• Transportation agencies	Medium	High	Soon
• Auto – Repair/body shop/gas	Low	High	Later
• Auto dealerships	Medium	High	Now
• Big-data analytics	High	Low	Now

Figure 6 – ADAS and autonomy will have a major impact on many ancillary industries besides just automotive.