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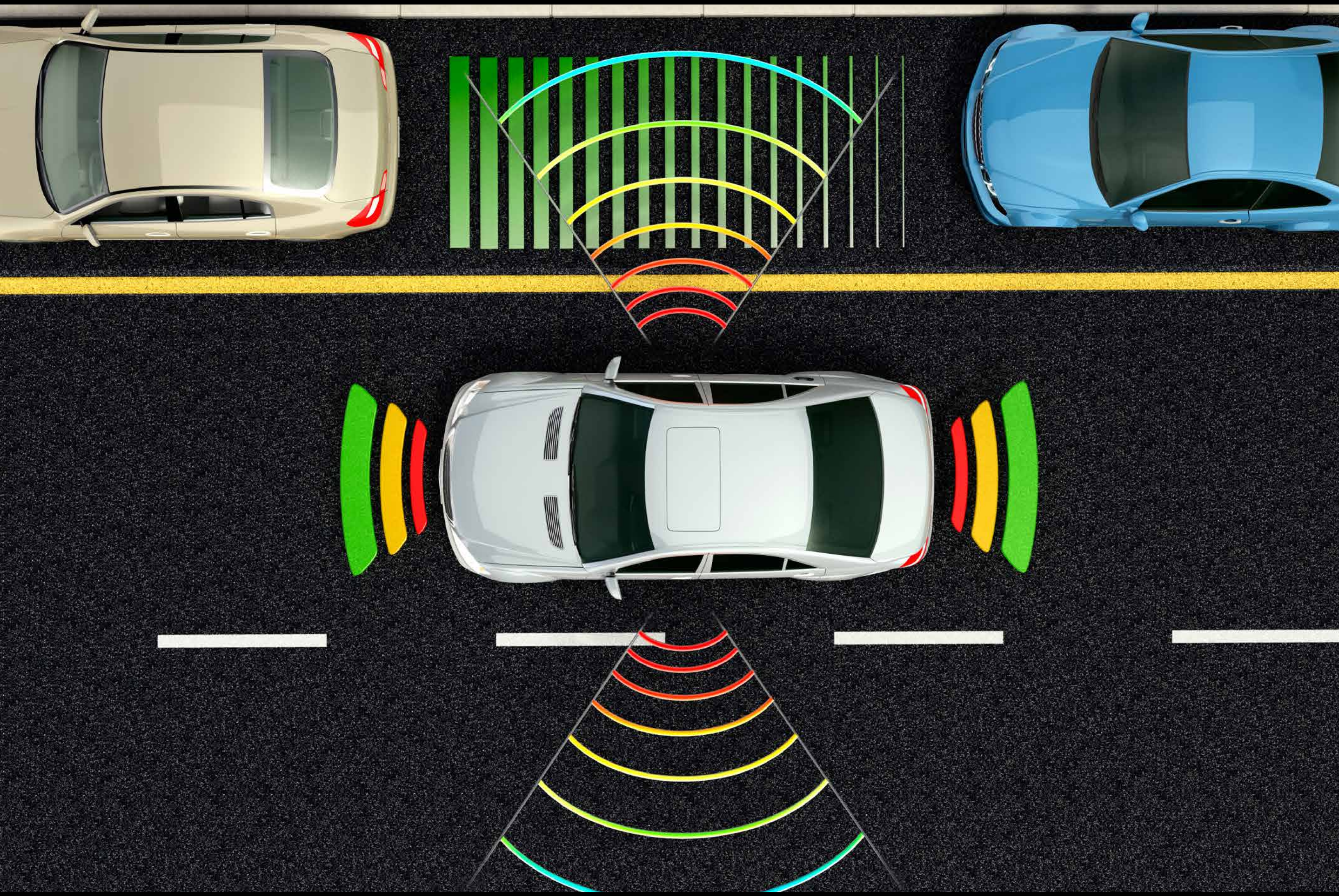
AUTONOMOUS DRIVING: AN EYE ON THE ROAD AHEAD



AGENTS OF CHANGE™

EXECUTIVE SUMMARY

The day when drivers can completely surrender control of their cars to autonomous driving systems, at any speed, for any distance, on any type of road, could arrive as early as 2020 by some projections. Many hurdles remain to be crossed between now and then: Laws and regulations must be written. Industry standards must be established. Consumers must be educated and persuaded. And marketers, who for decades have built car brands on the thrills of control, handling, and performance, will have to find new buzzwords to define a new driving–or non-driving–experience.

Technological advancement toward autonomous driving, however, is accelerating faster than the legal framework or market forces that will govern it. The hardware footprint required to house complex autonomous systems is shrinking, while processing speeds and capacity are expanding. Advanced driver assistance systems (ADAS) are already a reality, with features like pedestrian detection, adaptive cruise control, collision avoidance, lane correction, and automated parking becoming increasingly commonplace.

Still, the technology behind driverless cars is not without its challenges—increasing complexity, safety, and security chief among them. This white paper will look at the current state of autonomous driving, its various stages, and the key technological challenges car manufacturers must address to get in the game.

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FROM ADAPTIVE CRUISE CONTROL TO FULL AUTOMATION: THE ROADMAP

While serious public discussion and consumer awareness of autonomous driving have increased considerably in just the past few years, automotive engineers and university scientists have been working on it for over a decade. In 2004, the U.S. Defense Advanced Research Projects Agency (DARPA) launched a series of driverless car races that enabled builders to showcase their concepts over long and arduous courses.

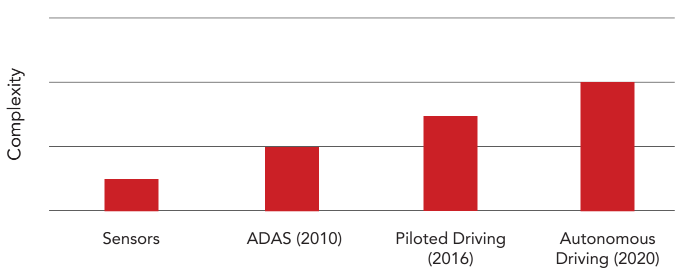

Figure 1: Key development milestones for autonomous driving technology

Over time, the technology that will eventually take autonomous driving mainstream has been continually refined and its footprint reduced, to the point that it has become commercially viable as ADAS deployed in cars on the road today. ADAS include intelligent systems aimed at proactively helping drivers avoid accidents, improve driving efficiency, and reduce driver fatigue. Figure 2 illustrates some of the currently available ADAS functions.

Longitudinal and Lateral Control	Collision Avoidance	Vehicle and Driver Monitoring
Speed control	Rear-end collision avoidance	Tachograph to record speed, distance, and driver activity
Adaptive cruise control	Obstacle and pedestrian detection	Alerting systems
Road and lane departure avoidance	Intersection collision warning	Vehicle diagnostics
Lane change and merge assistance		Driver drowsiness detection
Parking assistance		
Blind spot detection		

Figure 2: Sample ADAS functions

The sensing technologies behind ADAS include laser-based lidar, ultrasonic and motion-based sensing, cameras, and communications between vehicles and from vehicle to the Internet. Data acquired by the sensing systems are then interpreted and cross-analyzed with other pertinent data, resulting in a particular action by one or more of the respective electronic control units (ECUs), as illustrated in Figure 3.

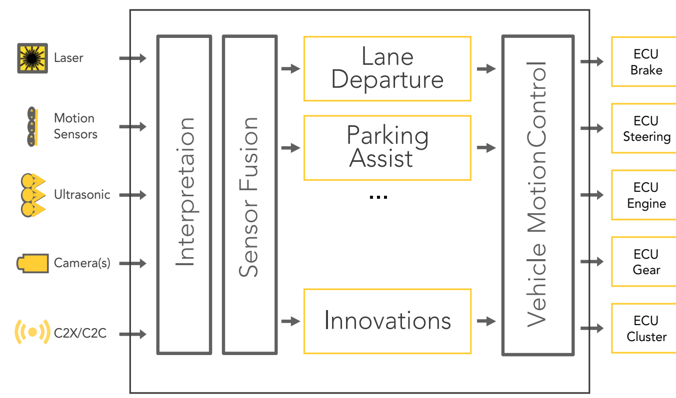

Figure 3: Conceptual design of ADAS systems

In 2013, the U.S. National Highway Transportation Safety Administration (NHTSA) issued its first policy statement on automated vehicles, in which it defined four levels of automation:

Level 1 – Function-specific automation: Specific control functions are automated, such as cruise control, lane guidance, and automated parallel parking. Drivers are fully engaged and responsible for overall vehicle control (hands on the steering wheel and foot on the pedal at all times).

Level 2 – Combined function automation: Multiple and integrated control functions are automated, such as adaptive cruise control with lane centering. Drivers are responsible for monitoring the roadway and are expected to be available for control at all times, but under certain conditions can disengage from vehicle operation (hands off the steering wheel and foot off pedal simultaneously).

Level 3 – Limited self-driving automation: Drivers can cede all safety-critical functions under certain conditions and rely on the vehicle to monitor for changes in those conditions that will require transition back to driver control. Drivers are not expected to constantly monitor the roadway.

Level 4 – Full self-driving automation: Vehicles can perform all driving functions and monitor roadway conditions for an entire trip, and so may operate with occupants who cannot drive and without human occupants.

Autonomous driving, self-driving, driverless cars, piloted driving—these terms are tossed about interchangeably and for the most part mean the same thing, with a couple of distinctions. Piloted driving generally refers to automation options available to the driver in certain circumstances (Level 3 in the NHTSA's definitions). For example, in stop-and-go traffic, a driver can switch on a system that senses the movement of cars ahead and behind, and the car automatically speeds up, slows down, or brakes with the flow of traffic. When the congestion ends and traffic returns to normal speeds, the car alerts the driver, who then takes over the wheel and the pedals. Piloted driving is seen as the next step—and a big one—on the path to fully autonomous driving.

The go-to-market roadmap for piloted driving is taking shape based on road classes. The evolution will likely begin with highways, where driving conditions are generally more predictable. As the technology becomes more sophisticated, the roadmap will eventually lead to urban roads and then to the inner city, with more complex building structures, traffic lights, pedestrians, cyclists, left turns, and other demands that call for more precise safety functionality. In a recent announcement, General Motors shared its plan to incorporate the GM "Super Cruise" semi-automated technology in a 2017 Cadillac model. With the driver's hands and feet off the steering wheel and pedals, respectively, this feature will automatically keep a vehicle in a specific, properly equipped freeway lane, making necessary steering and speed adjustments in bumper-to-bumper traffic or long highway trips.

Virtually all of the world's major automakers are working on and testing automated vehicles, but it is a technology company that seems to have captured the spotlight and sped up the race. Google has reportedly logged some 700,000 miles of autonomous driving and recently demonstrated a prototype of its own self-driving car. Unlike the car companies, who are gradually introducing ADAS options into existing vehicles, Google has created its driverless prototype from the ground up. And while the vision of autonomous driving generally assumes some form of driver engagement—for example, optional automation that a driver can switch on or off—Google's car has eliminated the steering wheel and pedals completely. This simplifies the experience for, for example, people with disabilities. Google has stated, however, that it does not intend to go head-to-head with the car companies in mass production for the consumer market.

WHAT'S DRIVING IT: SAFETY FIRST

Human error is reportedly the cause of 90% of all accidents. Safety is the primary impetus behind the push to autonomous driving. Advocates believe the number of accidents, injuries, and fatalities could drop dramatically when the risk of human error is removed by networks of sensors, cameras, radar, lidar, GPS receivers, and sophisticated ECUs. Computers, it is reasoned, react more quickly than humans and make better judgments based on thousands of instantaneous calculations. Moreover, they don't get groggy behind the wheel and their minds don't wander.

Safety will become an even more critical factor in the future, as the number of vehicles on the road is likely to increase with autonomous driving. People with disabilities or previously limited mobility will now have access to road travel, and others may be more inclined to use their cars for trips which they might previously have taken by plane or train. And even though autonomous vehicles are expected to improve the utilization of the capacity of the roads by allowing more vehicles to run faster and more closely spaced, the increase in the number of vehicles on the road may produce a net increase in the load on the road infrastructure, and the resulting capacity and safety issues must be addressed.

It is essential for ADAS developers as well as the automakers themselves to work closely with providers of embedded technology solutions, such as Wind River®, to address issues of reliability and security at the earliest stages of system specification and design.

THE CONNECTED CAR: BETTER SAFETY THROUGH SITUATIONAL AWARENESS

A major advancement in autonomous driving and safety is expected to come from cars' ability to communicate with each other. Promoted by the NHTSA, among others, vehicle-to-vehicle (V2V) communications will enable cars to increase each other's situational awareness by sharing information about their location, speed, and direction and communicating warnings related to forward collisions, blind spot and lane changes, and control loss for crash avoidance.

V2V data and communication standards have been developed by the Intelligent Transportation Systems Joint Program Office (ITS JPO) of the U.S. Department of Transportation Research and Innovative Technology Administration (RITA). The standards include the Society of Automotive Engineers (SAE) J2735 Dedicated Short Range Communications (DSRC) Basic Safety Message and a standard communications platform communicating in the 5.9 GHz band of the radio spectrum.

HELPING CAR MANUFACTURERS GET THERE

Automotive designers face a number of challenges. They have to find ways to build multiple systems and components into the very limited confines of a car. They also must meet stringent, prescriptive certification standards such as ISO 26262, the international standard governing safety-critical electronics in automobiles. And given the intensifying competition to be first to market with piloted and eventually fully autonomous driving, they have to deliver high-performance, reliable products under tight timelines.

And technology is not 100% infallible. A high-end car might have as many as 100 different ECUs managing both safety-critical and non-safety-critical functions. The more complex systems become, the higher the risk that functions will interfere with each other or that one or more systems will fail. The other major cause for concern is security against network-borne threats. Connected cars, employing V2V communications and telematics, will be able to alert each other to road hazards or impending collisions. However, as cars become more dependent on wireless connectivity, both within the vehicles and externally, they become more vulnerable to outside interference, whether accidental or with malicious intent.

One way to reduce the time, complexity, and costs of developing systems while accelerating the testing and certification process is through the use of virtualization technology. Commercial multi-core processors and virtualization software now allow for time and space separation of functions, optimized for safety-critical designs. Virtualization, either on a single core or a multi-core device, allows different applications to run in safe and secure partitions, separated from each other and controlled by a partitioning hypervisor. Applying embedded virtualization to ADAS in automobiles is an effective way to drive ECU consolidation, which allows car manufacturers to reduce size, weight, power, complexity, and costs of the systems.

Commodity multi-core computer processors make it easier for ADAS designers to combine multiple applications on a single processor instead of using several different proprietary circuits. Eliminating multiple custom boards also greatly simplifies maintenance.

ENSURING SECURITY

Partitioning also helps reduce vulnerability to external threats, whether from an ill-timed software update or a malicious attack. Each partition can run its own small firewall rather than relying on one main firewall, in which a breach could give an intruder access to the whole system. If one application is compromised, the intrusion is limited to one partition where it can easily be detected and disinfected, saving considerable time and money and reducing safety risks. This also stops intrusions from spreading across system components, particularly from malware. Importantly, it prevents hackers from accessing the network stack to launch other attacks or take remote control of the vehicle.

Powerful intrusion detection and prevention systems are essential to the safety of self-driving automobiles. Software security controls need to be introduced at the OS level, take advantage of the hardware security capabilities now entering the market, and extend up through the device stack to continuously maintain the trusted computing base. Building security in at the OS level makes it easier for ADAS designers and developers to configure systems to mitigate threats and ensure their platforms are safe. Figure 4 shows common guidance for ensuring software security in the automobile.

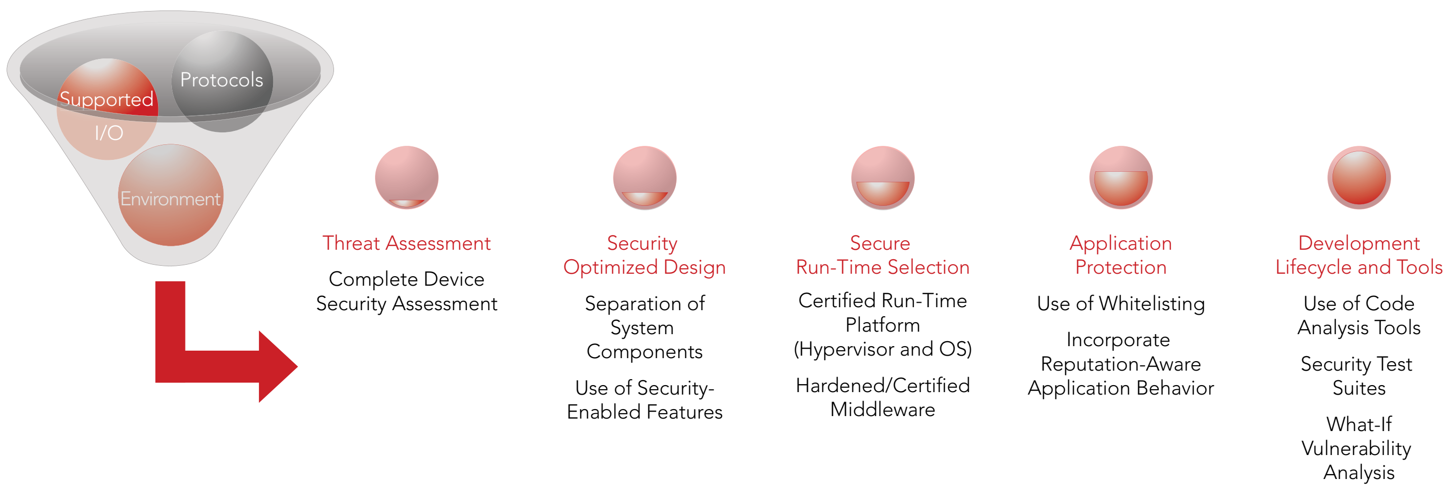

Figure 4: Steps to enhance automotive embedded security

Wind River has a vast reservoir of experience and long-standing partnerships with developers of automated systems for aviation, aerospace, and rail transit that require compliance with strict safety standards. For example, Wind River technology is used in Northrop Grumman's X-47B, the first unmanned, autonomous air system operating from an aircraft carrier. Today we are actively working with ADAS developers and carmakers to bring this experience to bear on the automotive industry and help assure that cars operate safely as they become increasingly automated.

TRAINS, PLANES, AND AUTOMOBILES

Automakers stand to benefit significantly from lessons learned in aerospace and aviation, as well as rail transportation, where performance, reliability, safety, and security are non-negotiable imperatives. Airplanes have long been highly automated, and rail systems are increasingly interconnected. Both are entrusted with the safety of millions of passengers every day. And both are reliant on sophisticated embedded systems that communicate with each other and with centralized control systems. Lots of experience and technological know-how developed for unmanned aerial vehicles, such as drones, can be leveraged for autonomous driving.

THE RIGHT DEVELOPMENT PARTNER

In the effort to reduce complexity, control costs, streamline development, enforce security, and deliver a product that performs to expectations, it is not simply a matter of finding the right technology platform, but also the right technology partner. Solutions must be backed by solid service and support that will minimize the testing required to assure timely certifications.

With over a hundred automotive projects per year, Wind River delivers a winning combination of in-depth industry expertise, proven automotive software integration and lifecycle management services, and a leading-edge software portfolio.

Wind River provides the operating systems and software that deliver the underlying intelligence—including safety and security functionality—that enables ADAS to perform safely and reliably every time. The VxWorks® real-time operating system (RTOS) delivers the uncompromising deterministic performance and low latency required for automotive safety-critical applications. Together with Safety Profile for VxWorks and Virtualization Profile for VxWorks, the RTOS offers the ability to create robust partitioning within one or multiple operating systems on single core or multi-core processors. VxWorks has been deployed in a variety of safety- and security-critical applications, from spacecraft to unmanned aircraft to automotive safety systems.

The modular architecture of VxWorks, in which the OS kernel is separated from applications, protocols, and other packages, allows software components to be upgraded, added, or removed in a targeted fashion without impacting the rest of the system. This modular design helps reduce the amount of testing required compared to monolithic system software architectures, where the entire system needs to be retested every time a new piece of software is added. Knowing that functions that have already been tested will not be impacted when new, non-overlapping features are added also helps ensure a more predictable and robust software integration process.

In addition, the majority of automotive original equipment manufacturers (OEMs) leverage Wind River Diab Compiler, a best-in-class development tool used in numerous projects for automotive functional safety. Developed using an Automotive SPICE (Software Process Improvement and Capability Determination) Level 2 process, Diab Compiler enables the creation of high-quality, standards-compliant object code that helps boost application performance and reduce memory footprint. Diab Compiler ISO 26262 Qualification Kit offers a model-based environment to simplify tool qualification for ISO 26262 and other safety standards.

The Wind River Professional Services team has proven expertise in secure and safe automotive software solutions, and hundreds of automotive experts worldwide to help manage complexity and increase predictability in automotive software development.

Much of the time and effort in a development project is spent on preparation, testing, and documentation for safety certification. Wind River participation in a project significantly streamlines the certification process, as our technology has already undergone rigorous testing and has proven to meet international safety standards.

CONCLUSION

The era of autonomous driving is dawning. As consumers become more accustomed to ADAS and active safety features, their expectations for autonomous driving will keep getting higher. Advocates say it will save lives, reduce fuel consumption, emissions, and costs, and make road travel accessible to people with disabilities or diminished faculties. It long ago stopped being a question of "if" and has now become a question of "when"—and of equal importance, "who." Automakers and developers who can solve the challenges of complexity, security, and time-to-market will have a clear competitive advantage in this race.