# Technology and Computing Requirements for Self-Driving Cars

## Moving beyond horsepower to deliver a new era of driving safety and convenience

Consumers now expect their connected digital lifestyles to extend into the car and their inside and outside worlds to be aligned. It is an expectation that is both heightened and accelerated by the Internet of Things.


Automakers have responded, integrating new capabilities into the driving experience thanks to the advent and proliferation of innovative in-vehicle infotainment (IVI) technology. Today, capabilities like email, Facebook*, streaming music, and many other features and applications have become increasingly common, even in entry-level makes and models. As a result, the technology that makes these functions possible has transitioned from being a source of competitive differentiation for automakers into a standard feature found in virtually every car.

At the same time, growing traffic challenges and congestion, an explosion in first-time drivers, and an overall shift in priorities have sharpened the focus on safety. This development, in combination with the near ubiquity of IVI, is motivating the industry to pivot and concentrate its research and development efforts on delivering production-ready, advanced safety functions and capabilities made possible by today's technology.

Automakers are beginning to deliver improved driving safety and convenience through the development of next-generation advanced driver assistance systems (ADAS). Cars will become much safer and more efficient as they grow increasingly aware of and react to the surrounding driving environment and conditions. Real success will mean the democratization of ADAS in which the technology is available in entry-level to premium vehicles, for first-time drivers to seniors, in passenger and commercial vehicles, and everywhere in between. And sooner than we ever thought, ADAS technology will deliver self-driving capabilities to production automobiles.

### The growing need for compute

Accelerating the delivery of next-generation, ADAS-enabled functionality should be the immediate focus of automakers. And, as they begin to introduce these new safety features, automakers must also be thinking ahead to lay the groundwork for self-driving cars. Indeed, they are finding that they must rethink a great many things about the car, including how the driver interacts with today's increasingly "intelligent" car and how that car is designed and built. This will mean securing new technology partners, developing a new supply chain strategy, and perhaps most importantly, equipping the car with significantly greater computing power.

### The evolution of the car: Why it matters

As cars grow more intelligent and more aware of their surroundings, consumers will expect increasingly sophisticated safety, security and convenience features and functions. These can only be delivered through the development of next-generation ADAS technology.

Successfully realizing the enormous opportunities of these automotive innovations has the potential to not only change driving—but also to transform society.

- **Prevent the majority of all traffic accidents**—Approximately 90 percent of accidents are driver error[1]
- **Lower the death rate for children under the age of 12**—Traffic accidents are the leading cause of death among children[2]
- **Decrease overall traffic deaths**—About 1.3 million people a year are killed in car accidents[3]
- **Reduce the number injured in car accidents**—Roughly 50 million are seriously injured in car accidents[3]
- **Reclaim lost productivity**—American drivers spent 5.5 billion hours in their cars in 2011[4]
- **Save money**—Traffic congestion costs drivers $121 billion in wasted time and fuel a year, or about $818 each[4]

The automakers that lead the way will quickly distinguish themselves from their competition, winning both customer loyalty and market share. And because these innovations have the potential to dramatically save time, money, and lives, the first to implement these next-generation ADAS technologies could inspire a change in thinking capable of transforming society.

## How the car is changing

Intel describes the trajectory of change in the automobile as a three-step process: "Inform, Assist, Assume." Here's how it works:

### Inform

This step began with the introduction of both IVI and first-generation ADAS technologies. With the mobile phone revolution, the car's in-vehicle technologies became the focus of differentiation for automakers. Drivers wanted a way to seamlessly meld their connected lifestyle with their car. Along the way, the car grew ever more connected, extending and amplifying our digital lives. In addition to enhanced IVI functionality, automakers also introduced new safety features enabled by first-generation ADAS technologies, helping make driving safer. Meanwhile, all this change led automakers into new fields and disciplines more in line with the development of consumer electronics than automobiles.

### Assist

As drivers have come to expect their car to perform the functions of a digital device, new demands have emerged. Moving beyond IVI, ADAS technology now delivers new capabilities that actively "assist" the driver. These new capabilities, ranging from lane departure warning, adaptive cruise control, and emergency braking, are just the most recent examples of how computing power is transforming what cars can do, making driving safer and more convenient. Once primarily a mechanical device, the vehicle is quickly evolving into a supercomputer on wheels.

As a result, after years of advancement, today's automotive computing systems have now plateaued in their ability to deliver increasing levels of safety and convenience. The challenge is as the level of functionality increases, so does the level of required computer processing, and today's automotive computing suppliers are finding it difficult to deliver semiconductor technology able to meet these new requirements. Offering the next generation of safety functionality will require the next generation of ADAS technology, which can only be cost-effectively delivered through the use of the most advanced semiconductor technology available.

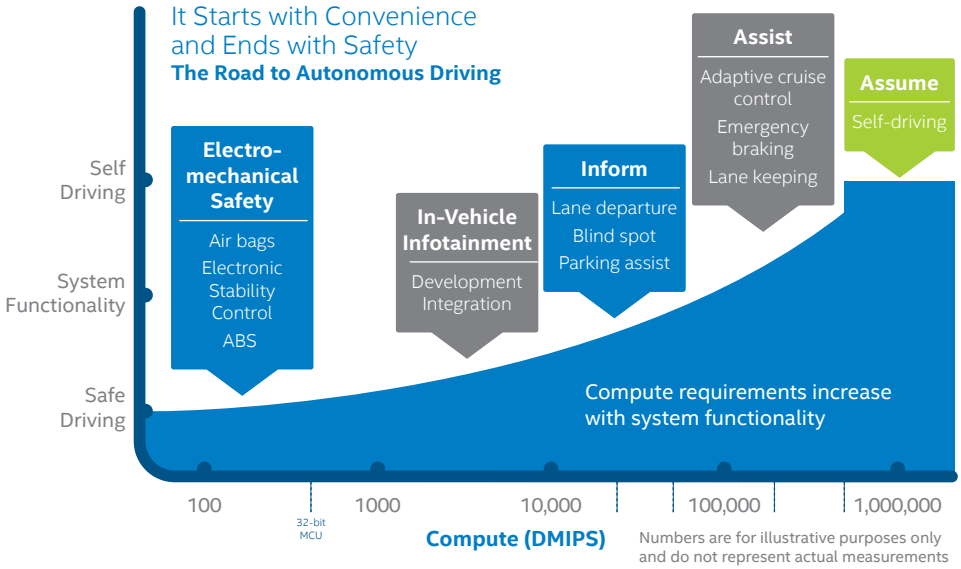
### Assume

Next-generation ADAS technology promises to deliver unprecedented levels of safety and convenience. The car will truly become a platform with multiple ADAS technologies aggregated into a single system, one that is able to communicate, collaborate, and ultimately fulfill the human driving functions in almost all driving situations (e.g., parking, city driving, freeway driving). But as noted above, these new capabilities will require automakers to find suppliers able to deliver automotive computing solutions that provide performance more akin to today's datacenter servers than the smartphone-based technologies used to date.

## Making the most of emerging opportunities

### Sensors, cameras, and more

To enable next-generation ADAS—and ultimately realize the promise of self-driving vehicles—cars will need numerous sensors to gather the necessary information about the driver's constantly changing surroundings and the ability to "fuse" the data (~1gb/sec) from these various sensors in order to make safe decisions. The sensors will be part of a larger constellation of technologies that include light detection and ranging (lidar), radar, advanced camera technologies, and GPS, among others.




**Reliability, security, and speed**
The burden of many operational decisions that were once the domain of the driver is increasingly being shifted to the vehicle. At the same time, we are moving from an immersive user interface that draws a driver into the driving experience, to an assistive user interface that anticipates a driver's needs and assists in making driving safer. Ultimately, the interface will assume control of the car to ensure the driver and the car's occupants remain safe. The car's ability to manage these changes, and the enormous amount of data enabling critical driving decisions, is paramount. Reliability, security, and real-time decision making are non-negotiable necessities for the next generation of car technology, as a fraction of a second can mean the difference between life and death.

**The car must compute to compete**
With the development and deployment of next-generation ADAS technologies—and self-driving vehicles in the not too distant future—it is important to look at how the collective set of systems within the car can deliver a better experience versus approaching the car as a handful of independent technologies.

Over the past few years, automakers have largely relied on a vehicle's IVI system to enable and deliver automotive innovation. Some in the industry suggest these systems are sufficient to satisfy the compute requirements that enable next-generation ADAS technology. But the reality is that current IVI systems do not offer the requisite processing abilities. And while IVI will continue to play an important role in the vehicle's ecosystem, *tomorrow's cars will require a level of computing not currently available in any of today's automobiles*, though already widely used in advanced computers.

## Enabling ADAS and self-driving cars: The top 5 requirements

**1. Greater computing power**
In order to fully realize the opportunities of next-generation ADAS technology, the car will require more computing muscle. Put another way, the intelligent car will need a bigger "brain," meaning new hardware and new software.

Approximately 1 GB of data will need to be processed each second in the car's real-time operating system. This data will need to be analyzed quickly enough that the vehicle can react to changes in its surroundings in less than a second. Consider that the car's brain will demand new levels of compute to figure out when, how hard, and how fast to brake based on analysis of a range of variables, from the vehicle's speed to the road conditions to surrounding traffic. It will successfully gauge the flow of traffic to merge onto a freeway and account for the unpredictable behavior of pedestrians, bicyclists, and other cars while in the city. And that is just the beginning.

**2. A reliable supply chain**
Just as the brain of the car is changing so too must the supply chain automakers rely on to source, build, deliver, and service the vehicle. Collaboration will be more critical than ever. To meet these new demands, many automakers are already working with new partners and engaging with current partners in new ways. Specifically, semiconductor companies delivering leading-edge silicon promise to be important players. As the entire supply chain evolves, those who collaborate with these leading technology companies and help lead the change will be in the best position to compete and succeed.

**3. A centralized approach**
Currently, new technologies added to the car often come with their own computer and software. Such a situation has spawned a distributed-computing approach that accommodates this growing ecosystem

**The economic impact of the self-driving car[5]**
Morgan Stanley estimates that self-driving vehicles could deliver the following:

- $1.3 trillion in annual savings to the U.S. economy
- $507 billion in annual productivity gains
- $158 billion in annual fuel cost savings
- $488 billion in annual accident cost reduction savings
- $11 billion in annual savings from reducing congestion
- $138 billion in annual productivity savings from less congestion

of embedded control units (ECUs). But with each new addition, the complexity and cost increase, as do the challenges for the automaker to manage so many disparate systems. As the industry moves toward offering more advanced driving experiences to consumers, such a strategy will no longer be supportable and automakers will see many benefits in returning to a more centralized model to enable self-driving cars.

**4. A small, low-power solution**
While the processors in tomorrow's cars must deliver increasing computing power, they also must do so as efficiently as possible. Automakers have determined that all of this computing muscle needs to be located in the safest location in the car—under the driver's seat. In order to meet this requirement, while keeping passengers comfortable, they will have to use semiconductors, which both provide very high processing capabilities and use very little power.

**5. Security and privacy**
Consumers have an expectation of privacy and security in their cars. Vehicles with next-generation ADAS (and ultimately self-driving capabilities) will largely rely upon data that is generated from sources within the vehicle, and thus are less vulnerable to threats that can arise when data is transmitted externally. However, given that a car's IVI system regularly gets data from external sources (e.g., the Web, CDs, and other sources), it is imperative that it ensure that the data is free from any malicious intent. This is especially important as the IVI system will also function as the vehicle's user interface (UI).

For self-driving vehicles, it remains critical that the growing volumes of data transmitted to, from, and within the vehicle are safe. The vehicle will need to rely on its data and the source of that data to make quick, accurate decisions—and to prevent, identify, and isolate malicious threats. This underscores the need to move the automobile's compute architecture from a decentralized approach with numerous discrete technologies to one that relies on a more homogeneous system. The automotive industry's ability to respond to these requirements will help determine how quickly technological advancements can be rolled out to consumers. Technology companies with established track records of addressing these challenges are critical partners in helping enable auto industry success.

## The future is waiting

The gathering momentum of next-generation ADAS technology will revolutionize both the automobile itself and the auto industry. A handful of automakers have already committed to introducing self-driving vehicles as early as 2020.

But they cannot do it alone. Collaboration will be the engine that drives the transformation as car makers nurture relationships with the right technology companies that bring track records of experience addressing these key challenges from compute to security. Together with these technology partners, the most competitive automakers will lead the way in defining the future of the industry—and the driving experience.

## Shaping the future of the automobile through technology innovation

From in-vehicle infotainment to autonomous driving, Intel is using its proven expertise and R&D in computing technology, automotive systems, and consumer electronics to help automotive industry partners accelerate the evolution of connected, intelligent vehicles.

## Learn more

For more about Intel automotive solutions, visit **intel.com/automotive**.

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