WHITE PAPER

Autonomous vehicles have a lot to learn. We can help.

flex

WITH PROGRESS COMES CHANGE

As the automobile industry prepares for a future with autonomous vehicles (AVs) it must change and adapt to provide customers with a truly connected, secure and safe experience.

That experience demands a platform supported by increased connectivity and cloud infrastructure. The industry will require immense computing and processing power for all the information that AVs rely on and will continue to rely on in a future with 5G.

How do we achieve a driverless future?

One of the first autonomous devices dates to the late 19th century with the invention of a torpedo that could guide itself and make course corrections underwater[1]. Today, automobile technologies like cruise control and driver-assistance systems for blind spots or emergency braking comprise the first levels of autonomy.

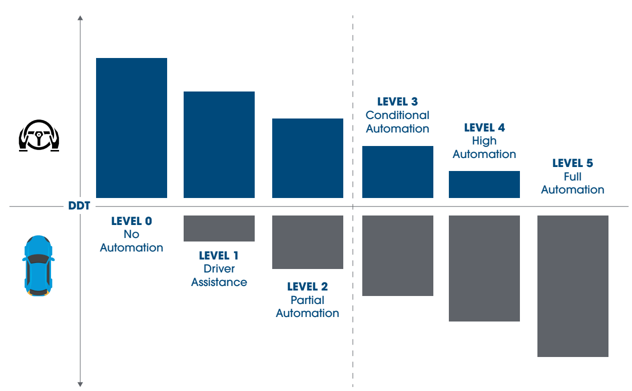
The level of automation helps determine just how dependent the vehicle is on a driver. Despite advancements in sensors, cameras and radar, we're still years away from having completely driverless vehicles on the road. The delay is primarily due to complexity of the task and the difficulty of adapting machine learning and artificial intelligence (AI) systems for AVs.

> A certain level of AI is necessary for the computing system in a vehicle to be able to not only perceive and respond like a human, but also anticipate events on the road.

Based on the number of tasks the car can do on its own, there are five levels of automation:

- **Level 0: No automation**
- **Level 1: Longitudinal control – Accelerating and/or braking**
- **Level 2: Lateral and longitudinal control – Acceleration/braking and lane changing assistance**
- **Level 3: Lateral and longitudinal control with object event detection and response (OEDR) limited to an operational design domain or driving conditions (ODD) – Driver attention required for immediate take over in case of a failure**
- **Level 4: Lateral and longitudinal control with OEDR and fallback – Infrequent driver attention required**
- **Level 5: Unlimited ODD - No driver required**

ROLES OF THE USER & AUTOMATED DRIVING SYSTEM BY LEVEL OF DRIVING AUTOMATION



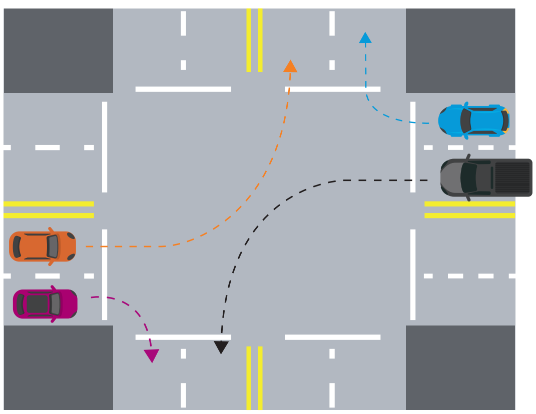
[1] https://www.wired.com/brandlab/2016/03/a-brief-history-of-autonomous-vehicle-technology/

Driving is complicated

Think of a left turn at an intersection. For a human, understanding the interaction of cars, pedestrians, bicycles and other objects on the road is complex for a beginner, but usually gets easier with experience.

Human drivers can immediately understand and process situations they encounter on roadways, but AVs take time to learn how to process new situations. This is where algorithms come into play and can help the AV with decision-making in real-time. Machine learning algorithms can help the AV interpret data and even make predictions.

The ability of an AV to handle uncertainty is a continual challenge for developers and engineers. The vehicle must be able to deal with situations like school buses, another driver breaking the rules, being cut off or someone running a red light.



- **The AV (orange car) needs to determine if the black car is going to turn left or go straight. This task becomes more difficult if the black car's turn signal is not on or if there are no traffic lights or stop signs.**
- **The blue car might begin its right turn while the AV is in the process of completing its left turn, causing a crash.**
- **If there were no pavement markings, the AV would also need to estimate where the intersection begins in addition to the other tasks.**
- **The task of estimation grows as the number of moving objects on the road increases.**

What does the AV technical stack look like?

This simultaneous managing and solving of tasks allow AVs to navigate a roadway successfully and safely. AVs require perception, mapping and planning to make decisions and get from one point to another.

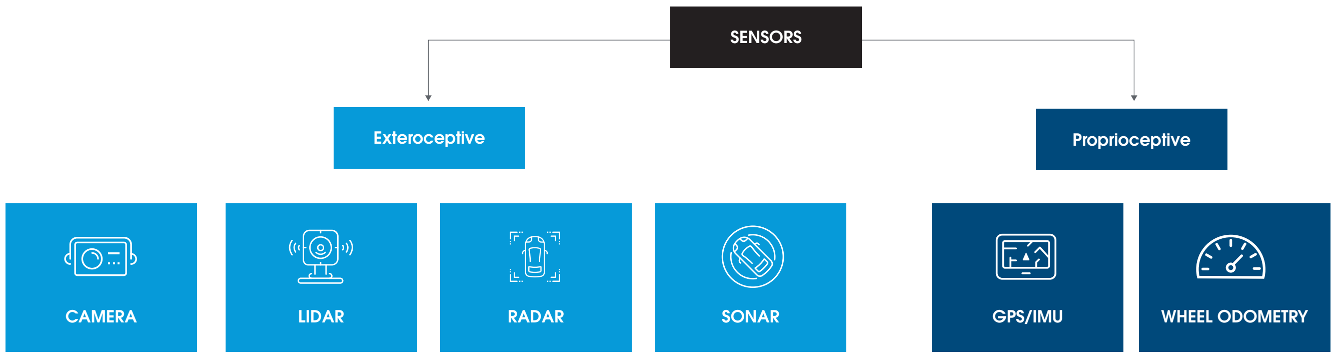
Automation is comprised of different components of technology layered together. From sensors to cameras, software and control algorithms – the AV is armed with technology to help it create a spatial understanding of the world.

The brain (or compute) of the AV is comprised of central processing units, graphics processing units, field-programmable gate array and application-specific integrated chips. It uses serial and parallel processing modules, plus information from sensors to compute actions the vehicle needs to perform. This includes anything from image processing, object detection, mapping and planning.

A safety element is another essential part of an AV. Level 4 and 5 AVs must have redundancy built into them by adding extra hardware and software to assist in case the driver or any of its sensors or compute components fail.

> Sensors help the AV interpret its surroundings and control how it's behaving in the area of operation. Exteroceptive sensors help interpret the surroundings, along with proprioceptive sensors, which measure elements like motor speed, wheel load and battery voltage.

Commonly used sensors for autonomous driving:



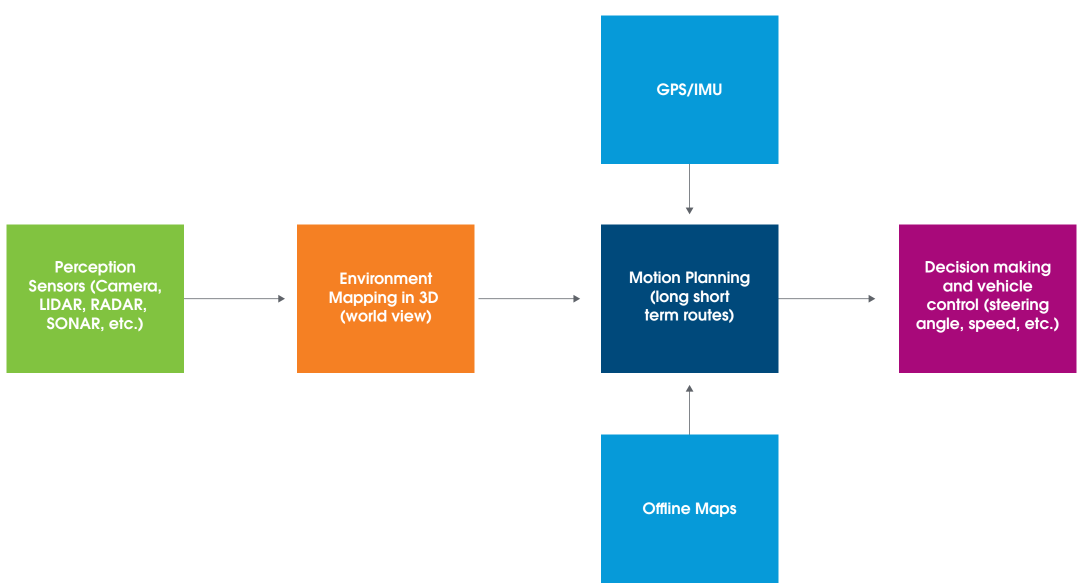
CAMERA: Once run through a deep learning algorithm, camera input helps detect and locate objects on the streets, including lane markings, intersections, signs, traffic lights, etc. Stereo cameras with an overlapping field of view and aligned image planes estimate depth.

LIDAR: With the time of flight data obtained from a light detection and ranging system, a car can detect where an object is, and how far away it is, more accurately than a camera. Some LIDAR systems can even detect object velocity, increasing their utility. LIDAR does not require external lighting to work as a camera does.

RADAR: Radio detection and ranging systems, used for superior object detection and relative speed estimation, are not affected by the environment where the AV is operated – as compared to other sensors.

SONAR: Short-range and inexpensive sound navigation and ranging sensors are primarily used when tight maneuvering is needed to park a vehicle.

GPS/IMU AND WHEEL ODOMETRY: Global positioning systems and inertial measurement units along with wheel odometry are used to measure the state (position, velocity, angular rotation rate, acceleration, heading, etc.) of the vehicle.



Harnessing the computing power necessary for AV

To supply the computing power required of AVs, the auto industry is looking to cloud data centers. The cloud is unfamiliar territory for most automakers because they've traditionally relied on microcontroller architecture and electronic control units (ECUs) inside the car. And if an additional function is needed, companies just add more ECUs.

Now consider that a single AV is expected to generate more than four terabytes of data in an hour and a half of driving.[2] It's no wonder the auto industry will need such high computing and processing capability. It will also need to make sure it has the infrastructure in place to store all of that data.

> We are uniquely positioned to help with both. Our cross-industry expertise not only enables us to develop automotive-grade solutions, but also deliver data center infrastructure and compute solutions at the cloud's edge. Our global reach and extensive group of in-house subject matter experts enables us to customize solutions to meet your unique requirements.

[2] https://newsroom.intel.com/editorials/self-driving-cars-big-meaning-behind-one-number-4-terabytes/#gs.iautoy

Partner with us to build a world of AVs

We partner with customers to create the custom sensors, system fusion models and automotive-grade servers that autonomous vehicles require. We serve more than 130 automotive customers, including traditional OEMs, tiers, new mobility and emerging brands. We re-shape industries with cloud infrastructure solutions to deliver new applications that require low latency, high volume data transfer and processing.

We can help you be 5G-ready from bumper to bumper and edge to cloud thanks to our deep experience with data center infrastructure, compute processing and global data center deployment. We can connect your vehicle to everything with automotive-grade servers, advanced sensors and in-vehicle data storage units. We tap into all our capabilities to support your mission.

Learn more about our cloud offerings.

Flex serves over 130 automotive customers, including traditional OEMs, tiers, and new mobility and emerging brands with:

- 35 automotive solutions sites across 15+ countries
- 14,000 employees
- 400 engineers
- 1 million m^2 manufacturing and services space
- 4,000+ global suppliers

Learn more about our automotive offerings.

About Flex

Flex is the Sketch-to-Scale® solutions provider that designs and builds intelligent products globally. Flex delivers innovative design, engineering, manufacturing, real-time supply chain insight and logistics services to companies of all sizes in various industries and end-markets. With unrivalled expertise across every major industry, Flex empowers leading companies to flawlessly develop and launch their next innovation at scale, from ideation, through design and development, to market – and beyond.

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