EXECUTIVE SUMMARY

Autonomous driving is a key trend in the automotive and personal transit space, increasing public safety, adding to driver comfort and convenience, and even opening new Mobility-as-a-Service (MaaS) business models. Every application, from active safety Advanced Driver Assistance Systems (ADAS) through to driverless robotaxis, is built on a foundation of enabling technologies including sensing and processing, with an important role for location intelligence and digital maps, including:

• Maps as a Sensor: Supplementing on-board active sensors with information from static and dynamic map layers, providing insights on road and traffic features not covered by the on-board sensors, and adding redundancy to the perception stack.
• Localization: Positioning the vehicle within the environment model relative to known points captured in the map attribution.
• Operational Design Domain (ODD) Geofencing: Defining the conditions in which an autonomous application is available to drivers/consumers, ensuring safe deployment of the application.
• Humanized Driving: Leveraging map layers on average speeds and typical drive paths to ensure that autonomous applications are comfortable and easily adopted by consumers.
• Simulation: Building a digital twin of the real world to test and validate autonomous applications before their deployment can help ensure a safer rollout.

The role that location intelligence and digital maps play varies according to the target application and the broader architecture of the technology platform. Therefore, autonomous technology suppliers require a location platform that can ingest and anonymize a variety of sensor data to build customized and purpose-built maps.
INTRODUCTION
THE STATE OF AUTONOMOUS DRIVING
For the past fifteen years, the automotive industry has been developing a range of autonomous vehicle technologies by leveraging sensors and embedded processing to build an understanding of the vehicle’s environment to support drivers in the safe and efficient execution of driving tasks, if not replacing the driver altogether.

Automakers and newcomers to the mobility space are pursuing three parallel paths to market for autonomous driving technologies, each addressing different applications and having their own expected timelines to reach maturity.

ACTIVE SAFETY ADVANCED DRIVER ASSISTANCE SYSTEMS
Active safety ADAS systems enable obstacle detection and collision avoidance by supporting the driver with either steering, acceleration, or braking tasks. Such systems are not designed to replace drivers, who always remain in complete control of the vehicle and remain responsible for any collisions and accidents that may occur. Nevertheless, active safety systems have proven effective in backing up drivers with a collision-mitigating redundancy that cannot be distracted in the way that human drivers can be. As a result, active safety ADAS systems have become the focus of quasi-regulation from safety ratings agencies such as the European New Car Assessment Program (NCAP) and The US’s Insurance Institute for Highway Safety (IIHS) and are expected to become required for new vehicle type approval in the EU shortly. The market for ADAS is therefore mature, with around 10% of vehicles on the road featuring at least one ADAS, with further growth expected as ADAS regulation expands, both in terms of the number of countries adopting ADAS mandates, and in the number of ADAS technologies covered by these mandates.

Chart 1: ADAS Market Value by System
Global Forecast, 2020 - 2027
(Source: ABI Research)
SEMI-AUTONOMOUS DRIVING
While active safety ADAS offers support in one dimension (i.e., steering or braking) to prevent collisions in extreme circumstances, semi-autonomous systems combine longitudinal and lateral assistance to add day-to-day convenience to the driver. The level of assistance provided by these comfort-oriented systems can vary significantly, as can the role that drivers are expected to play in the driving process.

Figure 1: Automated Technology Evolution
(Source: ABI Research)

Semi-autonomous features can vary from autonomous steering and speed control in highway contexts through to highly autonomous driving in complex urban environments. Similarly, semi-autonomous systems can vary according to the level of engagement required by the driver. The Society of Automotive Engineers (SAE) level system ranges from systems that require drivers to constantly supervise (SAE Level 2), through systems that require the driver to intervene as an exception when needed (SAE Level 3), to systems that can address all driving tasks within their designated Operational Design Domain (ODD), only handing back control when the driver wants control, or when the vehicle leaves the defined ODD (SAE Level 4).

The growth potential for more unsupervised semi-autonomous driving is highly dependent on changes in legislation, whereas there are no limits to the variety of features that automakers can offer, provided that the driver retains their controlling role. This has given rise to the so-called “SAE Level 2+” opportunity, which will see a rich set of semi-autonomous features brought to market under constant driver supervision.

FULLY DRIVERLESS OPERATION
The ultimate ambition for autonomous technology is the deployment of models that can address all driving tasks without the need for a driver to supervise, intervene, or even be present. Given that human error is the biggest factor in most road accidents, the potential benefit to public safety is obvious. In addition, the ability for a vehicle to complete trips without a driver being present opens up enormous new opportunities in the Mobility-as-a-Service space, with driverless vehicles expected to form the foundation of a safe, low-cost ridehailing-type mobility service in urban environments in coming years. The ability to offer a ridehailing service without the need for a costly driver will have the effect of bringing efficient shared mobility services into cost parity with personal ownership, bringing about a radical change in the nature of personal transit.
Given the scale of the advantages in terms of safety and sustainability, there is a concerted effort on the part of industry and government to bring about the necessary technological and legislative innovation to make driverless cars a reality. Nevertheless, the rollout of autonomous vehicles is expected to be slow, with today's small-scale trials expanding slowly in geographic coverage to become a prominent feature of urban transport over the next ten years.

**Location Intelligence Powers Autonomous Driving**

Every autonomous vehicle application involves a combination of enabling technologies, including sensing, processing, machine vision/artificial intelligence and location intelligence. The contributing role of location intelligence to automated driving varies according to target application, playing a role in system development, as well as at the operational/embedded level.

**ADAS**

**Maps as a Sensor**

In active safety ADAS, location intelligence and maps play an important role as an additional sensor input. A critical factor in the rapid growth of ADAS has been the widespread use of camera sensors, which combine low-cost structures from massive economies of scale with rich semantic input, providing the ideal perception layer for active safety applications. However, camera-sensors are subject to the same weaknesses as human eyes, struggling to deliver the necessary insight in bad lighting or poor weather scenarios. Therefore, many ADAS perception stacks now employ sensor fusion by augmenting camera sensors with input from other sensor modalities. Ideally, the secondary sensor should be highly orthogonal to camera sensors (i.e., not subject to the same weaknesses as camera sensors) and low cost, requirements which have driven demand for radar sensors.

Digital maps can likewise fulfil the role of a secondary ADAS sensor, satisfying the same cost and orthogonality requirements. Static map layers can give insight into factors such as upcoming road geometry and speed restrictions, helping to improve the efficiency of adaptive cruise control systems. Dynamic map layers can give insight into the non-static elements of the road environment.
This can range from the status of digital signage/variable speed signs to the location of road hazards based on aggregated sensor data. Furthermore, some features of the road and traffic situation cannot be visually identified by a camera sensor, such as the upcoming road curvature or changes in elevation.

The extent to which dynamic map layers can be used as a sensor in safety critical systems depends first on the capabilities of the map platform (time to reflect reality, resolution, depth of attribution), and secondly on the embedded communication capabilities of the connected vehicle, with low latency and trust being essential ingredients to the use of dynamic map data in real-time, mission critical applications. Nevertheless, dynamic layers detailing road hazards (such as static obstacles, broken down vehicles, etc.) over a kilometer down the road can be ingested over typically available LTE/Uu radio interfaces and used to make navigation safer and more convenient for the driver.

**INTELLIGENT SPEED ASSISTANCE (ISA)**

An important example of maps as a sensor is the forthcoming Intelligent Speed Assist (ISA) mandate in the EU, in which an adaptive speed limit is set according to the local speed restrictions that apply to the current road section. While many vehicles have featured road signs recognition (RSR) as part of their vision based-ADAS systems, the quality requirements for ISA under the next set of new vehicle type approval requirements will outstrip those of legacy optional RSR systems. In particular, ISA will need to account for all of the variations in signage design across EU member states, and must remain available even when visibility is poor, signs are damaged or even occluded. Furthermore, the ISA must correctly identify implicit speed limits, as some speed restrictions are implied by the broader context (e.g., a residential area), rather than by explicit signage. Critically, the ISA system must remain operational throughout the considerable lifecycle of the vehicle, which can easily be over ten years. A dynamic map layer, detailing the speed restrictions on different road sections, will be an essential complementary “sensor” to the dominant camera sensor, improving the accuracy and reliability of the ISA.

**SEMI-AUTONOMOUS HUMANIZED DRIVING**

In semi-autonomous applications, the role of location intelligence in providing an additional sensor input becomes even more important. In addition to the static and dynamic layers mentioned above, comfort-oriented semi-autonomous applications benefit from purpose-built map layers featuring rich semantic attribution, particularly in relation to driving behavior. Understanding the average speed which manually-driven vehicles typically take along certain stretches of road can be key to delivering a semi-autonomous driving experience that is smooth and acceptable to the end-user, particularly if the upper speed restriction, while legal, would feel unsafe to passengers. Capturing these rich semantic details can also serve to improve the performance of low-resolution sensors, such as radar, matching information on the nature of objects in the scene with the corresponding radar response.

**LOCALIZATION**

An important role of maps in semi-autonomous driving applications is relative positioning, enabling the vehicle to use on board sensors to position the vehicle relative to known objects in the scene. In order to keep a vehicle within the lane of travel, decimeter levels of accuracy are required. Leveraging a fresh and detailed map—a digital twin of the real world to position the vehicle relatively—allows for semi-autonomous applications to be deployed without the need for expensive and unscalable absolute positioning technologies.
OPERATIONAL DESIGN DOMAIN GEOFENCING
Semi-autonomous applications are designed and verified according to a predefined operational design domain so the road types and driving conditions under which the set of autonomous features can be safely performed. Digital maps can be used to define geofenced areas in which the autonomous features are available to the consumer, preventing the driver from activating the semi-autonomous systems in contexts that would not be safe. In some cases, the factors that would dictate the ODD can be captured in static map layers, such as road type (interurban vs. multi-lane highway) or curvature. However, in many cases, dynamic map layers would be required to reflect non-static factors that dictate the safe delivery of an autonomous feature, such as the weather, time of day, traffic condition, or presence of road hazards.

There are many barriers to the effective deployment of a semi-autonomous vehicle, chief among which is the potential for misuse, with every accident caused by inappropriate activation of the semi-autonomous system, exposing the Original Equipment Manufacturers’ (OEMs’) brand. Therefore, the ability to precisely calibrate, even dynamically, the ODD of a semi-autonomous system will be essential to easing consumers into the habit of sharing driving tasks with an autonomous technology platform.

A purpose-built digital map will therefore accelerate the deployment of SAE L2+ applications. Firstly, the map can function as a sensor, delivering insights on the road geometry not typically captured by the active sensors, and providing redundancy in circumstances which compromise the performance of the active sensors. Secondly, a semantically-rich map can enrich the input from low resolution sensors, transforming a simple radar reflection into information on the location of a road sign, traffic lights, or other items of street furniture. Thirdly, relative positioning can deliver significant cost savings compared to absolute positioning alternatives. Finally, the ability to geofence gives automakers control over how their SAE L2+ applications are deployed and used in vehicles bearing their brand.

DRIVERLESS
In driverless applications, location intelligence will continue to be leveraged as a quasi-sensor, enabling robust perception in scenarios that would see the OEM or fleet operator taking full responsibility in the event of an accident. Similarly, accurate localization will be essential in performing safe maneuvers in complex urban environments featuring multiple road users, pedestrianized zones, intersections, and designated crossings. Geofencing will continue to be relevant to autonomous vehicle deployments in the driverless age, with the first deployments of driverless vehicles confined to very specific areas of a city and “grounded” in extreme weather situations, such as snow. Building a map to dynamically define this ODD according to the capabilities of the driverless vehicle platform will ensure that driverless modes are only made available to MaaS consumers when appropriate for their journey.

SIMULATION AND PROTOTYPING
Overtime, robotaxi fleet operators will look to expand this ODD, as technology refinements and enabling legislation allows for driverless vehicles to operate in a larger a geography and in a broader set of circumstances. In practice, a robotaxi fleet operator operating within a certain zone will identify key areas in which demand for trips is high, and use simulation software services to prototype, test, and validate their autonomous platform for that target zone. Location intelligence plays a key role here. While testing autonomous platforms on randomly simulated streets can be useful, it is clearly more valuable to test against a digital twin of a zone in which there is a profitable business case for expansion. Leveraging location intelligence to test and validate a driverless vehicle in an accurate simulation of the target deployment zone where it will operate will increase the likelihood of a safe and successful expansion.
LOCATION PLATFORM REQUIREMENTS FOR AUTONOMOUS DRIVING

In order to leverage location intelligence to support autonomous technology deployments, automakers and newcomers to the AV space need a location platform that can fulfill a set of stringent requirements.

CUSTOMIZED MAP CREATION

As discussed in Section 3, there is a broad spectrum of paths to market for autonomous vehicle technologies, with the role that maps and location intelligence have to play in the application varying in each deployment. Therefore, autonomous vehicle developers require a platform that can create customized maps featuring the necessary attribution and time to reflect reality, which will ultimately combine a high-quality base map and curation process with datasets and attribution ingested specifically for the target application.

For example, every OEM deploying a semi-autonomous system will have their own unique ODD, requiring a customized map that captures the factors that dictate where it is safe to activate some or all of the semi-autonomous features. Given that each semi-autonomous system has its own architecture and set of capabilities, deployers of these systems cannot rely on off the shelf map offerings, and must opt for platforms that can create a map with characteristics that perfectly aligns with the system needs.

Once this map has been created, automakers can then apply their own unique business logic, for example, a navigation option that prioritizes routes that make maximum use of routes on which autonomous operation is safe, depending on the consumer preferences.

In the driverless vehicle space, most of the short-term opportunity is in off-road or off-public highway scenarios. In these contexts, the ability to create a unique and purpose-built, or “private” map, is even more important, with fleet operators requiring a platform that can build the required map from scratch. In the longer term, on-road driverless applications, such as long-haul freight and robotaxis, will also require customized map creation.
Case Study: HERE and Ford BlueCruise

Ford uses a mixture of HERE’s map content, dynamic map layers, and location intelligence services to create a unique map that underpins its BlueCruise hands-free semi-autonomous system. This customized map provides a key input into the Ford cloud, helping to assess whether or not hands-free operation can be safely made available on different stretches of road. This map also plays an operational role, serving as a virtual sensor in the sensor-fusion process that enables Active Drive Assist.

AV SENSOR DATA INGESTION

Creating unique maps requires the ingestion of data from multiple sources, with one of the best data sources being connected, sensor-equipped vehicles already on the road. By aggregating data generated by their models (or fleet vehicles in the case of MaaS deployments), automakers can convert the experience of models already shipped into a key competitive differentiator. While there can be advantages in sharing sensor data between different OEM brands to build a critical mass on insight, in many cases OEMs prefer to retain the distinct competitive advantage that these connected car datasets can generate.

Therefore, autonomous vehicle technology developers require a location platform that can ingest connected car sensor data sets, while allowing them to retain control over the competitive advantage, captured in unique attribution and map layers, created by these data sets.

While the ultimate incarnation of this sensor data ingestion process will see semantically rich Autonomous Vehicle (AV) sensor data sets ingested on an ongoing basis to continually update the autonomous driving map, it is important to recognize the low hanging fruit opportunities available with today’s commonly available sensors and connectivity technologies. A location platform featuring a high-quality map with rich attribution can transform datasets from relatively humble sensors with location context to provide valuable insights.

Case Study: HERE, Audi, and NIRA

Audi has leveraged HERE’s 3D model of the road network to add location context to friction sensor data aggregated and anonymized from Audi models on the road. Combined with data from NIRA cloud relating to current and historical weather trends, Audi can provide their drivers with advanced warning of poor driving conditions through the embedded Human-Machine Interface (HMI).

ROBUST ANONYMIZATION

Without a doubt, the sensor data crowdsourcing paradigm is an enormous automotive opportunity, not only for the role it will play in providing a fresh and detailed location foundation for autonomous driving, but also for the broader monetization opportunities opening up for automakers. However, taking full advantage of this paradigm requires automakers to tread carefully with respect to driver privacy, both to protect the integrity of their brand in the eyes of consumers and, more importantly, to remain compliant with a myriad of varying privacy regulations across the different markets that the automaker serves.
This can prove surprisingly difficult, since as little as four journey data points could be used to identify 95% of people. Therefore, autonomous technology developers looking to take advantage of datasets from their vehicles need a location platform with robust anonymization capabilities, able to guarantee compliance with a complex set of privacy regulations, which will prove critical to scaling AV deployments globally. The optimal anonymization technique will vary from one use-case to another and also according to the types of data being used. Therefore, the AV supplier will also need to identify a location platform that is flexible and able to support a variety of anonymization methods.

**Case Study: HERE and A High-Volume OEM**

A large OEM has leveraged HERE’s anonymizer pipeline to enable real-time anonymization of sensor data and meta data. This enables the automaker to translate their connected car installed base into a competitive advantage, using these data to assess their AV use-case deployment strategies.

**VISUALIZATION**

In driverless deployment scenarios, visualization can be a powerful tool in building a business case for deployment and in assessing the performance of the MaaS service enabled by the robotaxi. By ingesting and visualizing probe data, a robotaxi fleet operator can assess the scale of potential demand, the extent to which it is served by existing transit options, thereby building a business case for the driverless deployment. Furthermore, visualization can be leveraged to identify hotspots for driverless vehicle faults, near misses, or frequent teleoperator interventions.

4.5. ACCESS TO A RICH DATA MARKETPLACE

Not all of the attribution, location intelligence services, and dynamic map layers required to deploy autonomous vehicles can be crowdsourced from vehicles in the AV fleet. Therefore, autonomous technology developers need access to a location platform that can match its own rich attribution with access to a healthy data marketplace featuring providers of key data and location-based services, such as weather, traffic, digital signage, road hazards, etc.

While it is possible to make contracts or licensing agreements with the many separate content and location service suppliers, engaging with each provider on an individual basis can be a time-consuming process, particularly for applications which require the ingestion of a diverse set of datasets. A single, streamlined marketplace can reduce the friction between AV technology deployers and suppliers of key enabling datasets.

**Case Study: HERE and tomorrow.io**

Tomorrow.io is a leading provider of hyperlocal weather information services, air quality assessment, and weather forecast modelling. Semi-autonomous vehicle developers with a weather-contingent ODD can access tomorrow.io’s hyperlocal weather data sets to better anticipate the availability of the semi-autonomous features throughout the driver’s journey. Using data from tomorrow.io and hundreds of other providers on the HERE Marketplace, autonomous technology developers can enrich their solutions faster and eliminate some of the barriers of bringing in third-party data.
SUMMARY

In conclusion, digital maps and location content are relevant across the full spectrum of autonomous driving, helping to make ADAS and semi-autonomous applications safer and more reliable, and playing a critical enabling role in future highly automated applications. The attribution and time to reflect reality required from autonomous vehicle maps varies significantly by application, meaning that no single off-the-shelf solution can be relied upon by the autonomous vehicle technology market. Rather, autonomous vehicle technology developers and deployers need a location platform capable of curating maps that are purpose built for the target application and sit as needed within a broader AV platform/architecture, which will vary from one automaker to the next.
About HERE Technologies

HERE, the leading location data and technology platform, moves people, businesses and cities forward by harnessing the power of location. By leveraging our open platform, we empower our customers to achieve better outcomes – from helping a city manage its infrastructure or a business optimize its assets to guiding drivers to their destination safely. To learn more about HERE, please visit https://www.here.com/solutions/automated-driving.

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