HERE HD Live Map Technical Paper

A self-healing map for reliable autonomous driving

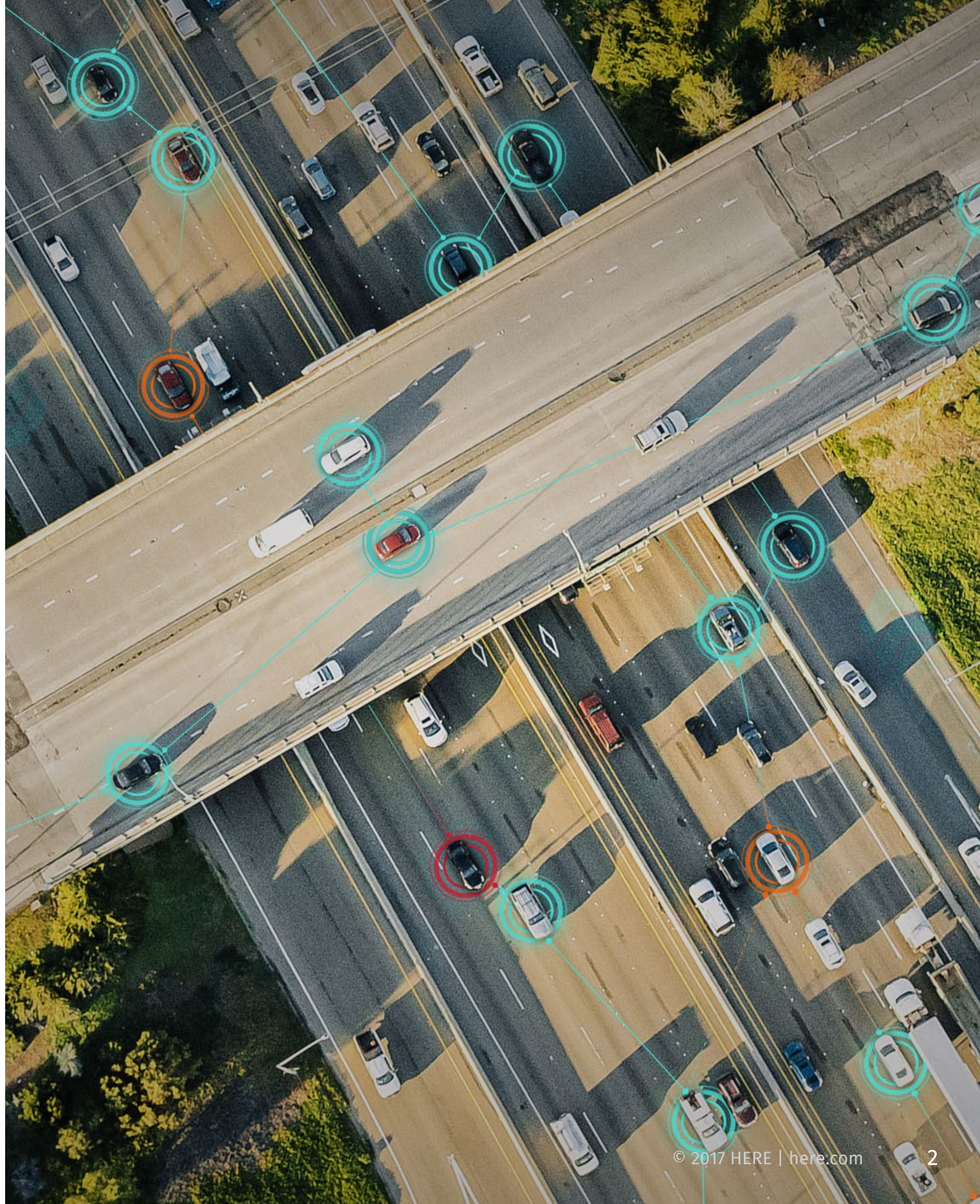
Vehicles are making more and more driving decisions without human intervention.

In order for those decisions to be safe, autonomous vehicles need reliable map information to assist them in any situation, such as knowing road layouts, what obstructions may lie ahead, and updates about local traffic laws. The data in the map is the main source of guidance for autonomous vehicles, so it has to be precise.

The world isn't static. It's constantly shifting and evolving, therefore a map that supports autonomous driving must constantly detect, verify, and update the changes that happen in the world to the map in near real-time. The only way for a map to obtain this level of freshness is to crowdsource data from the sensors of other vehicles on the road to identify changes and adapt to match the environment it's replicating - it needs the ability to self-heal.

With a 'live' map that can self-heal, vehicles have an awareness of the road environment far beyond the reach of vehicle sensors. And, with the ability to know what's further ahead, vehicles can anticipate scenarios, then make the necessary adjustments. Cars are empowered to see what drivers and sensors can't, they gain the ability to see farther ahead and around corners.

HERE HD Live Map fills the need for a new breed of vehicle intelligence. With an innovative self-healing map maintenance process never before used in the automotive industry, and multiple data sources for reliable updates, it's the foundation for a driverless future.



Precise data: the foundation of a global, reliable map

The foundation of HERE HD Live Map is sourced from high-end industrial-capture vehicles called HERE TRUE vehicles. These vehicles, which are driving roadways across the world right now, all include four cameras with 96-megapixel resolution, a 32-beam spinning Velodyne LiDAR camera, and an IMU inertial sensor unit that capture precise road data. HERE TRUE vehicles collect 700,000 3D data points at a time, which accumulates over 140 gigabytes of location data a day.

While these vehicles capture highly precise information and regularly update the map with over one million changes made per day, this type of collection process isn't fast enough for autonomous driving. For example, if an accident occurs that knocks down a guardrail and road signs, it would take too long to deploy industrial vehicles to capture and distribute the data needed to inform vehicles in the vicinity.

HERE HD Live Map provides relative map accuracy within 20 centimeters.

The layers of the intelligent map

HERE HD Live Map is a cloud-based service that is used by multiple car manufacturers today. The map comprises three layers (illustrated in Figure 1). Each layer offers an additional level of detail for accurate and relevant support to connected and autonomous vehicles.

- **Road Model:** The Road Model offers global coverage for vehicles to understand local insights beyond the range of its onboard sensors such as high-occupancy vehicle lanes, or country-specific road classification.
- **HD Lane Model:** The next layer – the HD Lane Model – provides more precise, lane-level detail such as lane direction of travel, lane type, lane boundary, and lane marking types, to help self-driving vehicles make safer and more comfortable driving decisions.
- **HD Localization Model:** The top layer helps the vehicle localize itself in the world by using roadside objects like guard rails, walls, signs and pole like objects. The vehicle identifies an object, then uses the object's location to measure backwards and calculate exactly where the vehicle is located.

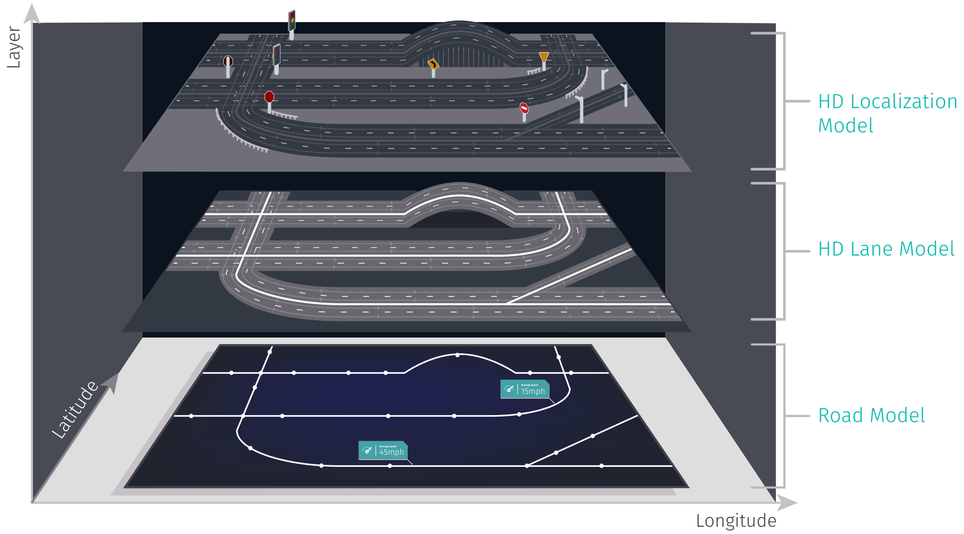


Figure **1**

Crowdsourced vehicle sensor data

As more and more connected vehicles with sophisticated sensor sets – such as cameras and radar - hit the roads, the data collected from these provides important information for the functioning of automated vehicle systems and the decisions a vehicle makes. However, this sensor data alone is not accurate enough to remove the driver from the equation completely. Vehicle sensors provide cars with the ability to 'see' the environment, similar to a human, but this is just one piece of the puzzle.

Vehicles that rely solely on sensor data have a restricted outlook of, say, 200 – 300 meters, and that's only if the view is unobstructed. If an autonomous vehicle is behind a large freight truck, for example, this distance is limited even further. Only when the truck moves will the vehicle have the ability to identify its environment, such as a lane ending. This would trigger an abrupt driving decision, like extreme braking, which could be uncomfortable for the passenger. A vehicle needs contextual awareness to fully 'understand' its environment if it's going to make safe and efficient decisions.

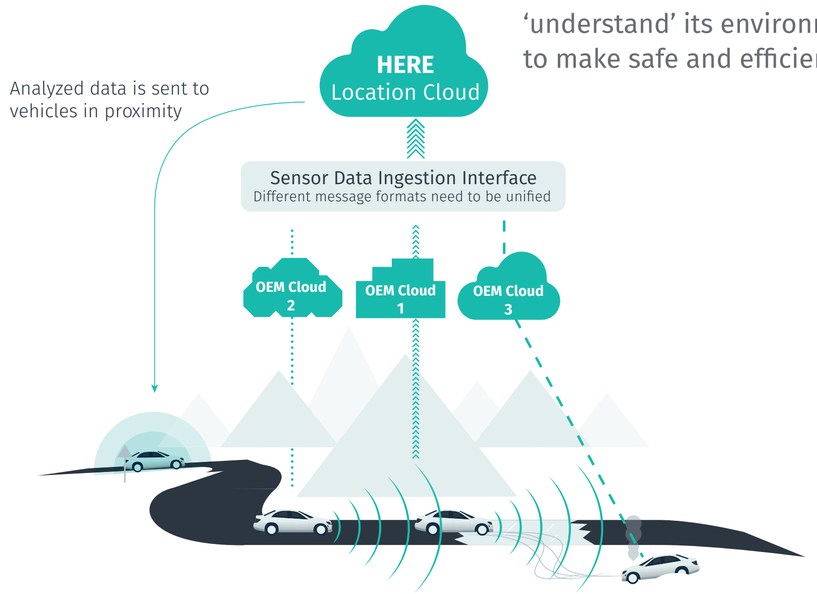


Figure **2**

Crowdsourced data is what underpins a fully-integrated, fresh, and reliable map, and provides contextual awareness to self-driving vehicles. HERE is already leveraging crowdsourced vehicle sensor data from hundreds of thousands of cars. HERE HD Live Map captures data from vehicles and turns it into trustworthy insight about new changes to the road. By extracting data from cars in the area, updates to HERE HD Live Map happen in near-real time, allowing prompt communication to nearby vehicles.

HERE has over 30+ years of experience transforming mapping technology.

Vehicle sensor data sourced from the crowd has an enormous advantage over other data points due to its quality and scale, enabling continuous map maintenance, which HERE calls self-healing. This extremely efficient and organic form of continuous map maintenance is a key factor in enabling vehicles to understand their environment in near-real time, which enables safer and more comfortable maneuvers.

In addition to industrial capture vehicles and crowdsourced vehicle sensor data, HERE uses other sources - such as satellite imagery, aerial imagery, government data, and mobile probes - to maintain and build out HERE HD Live Map. The combination of data sources provides high-quality environmental data to vehicles - such as road and lane information and roadside objects like signs and barriers - to ensure vehicles have precise positioning for lateral and longitudinal control and can make proactive driving decisions. This magnitude of data is what makes the HERE map reliable for autonomous driving globally.

Vehicle Sensor Data – Unleashing the power of the crowd

HERE is closing the loop between the vehicle and cloud to ensure sensor data can be collected from cars on the road, sent to the cloud, and then processed for valuable uses. Yet not all sensor data is the same, and not all sensor data is used the same.

Connected Vehicle Services (CVS)

The HERE Automotive Portfolio includes commercial services for vehicles that are enhanced through vehicle sensor data collected by HERE. These services, such as **HERE Hazard Warnings** are the industry's first to leverage vehicle sensor data to provide valuable services for vehicle passengers, improving safety and the overall experience.

Transforming data into a ‘live’ map

The self-healing capability of HERE HD Live Map ensures its freshness, reliability, and accuracy. The self-healing map process leverages numerous data sources and machine learning expertise HERE has.

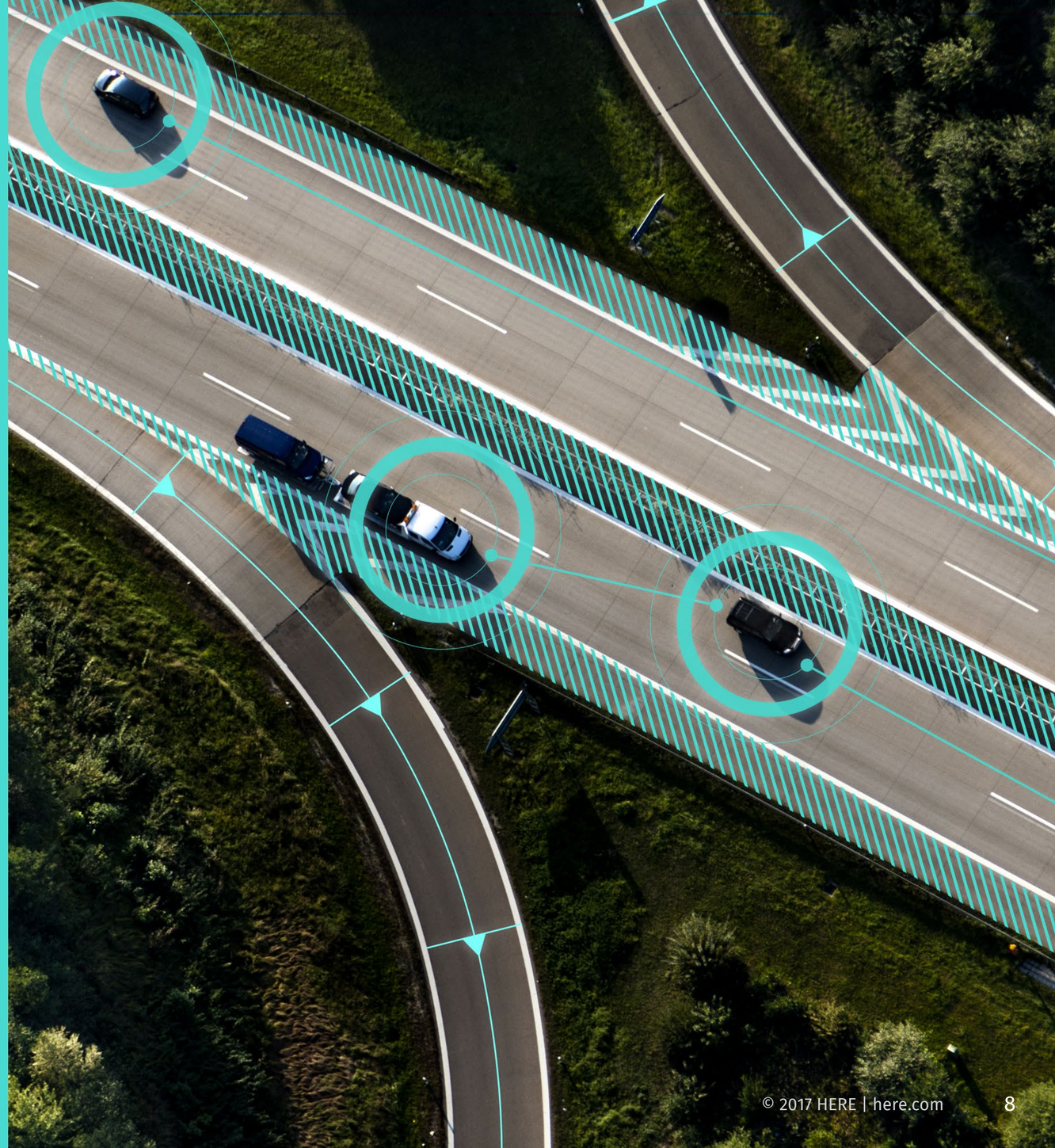
1. Observe: Data collection and ingestion
The first stage extracts data from vehicles’ sensors and collates it in the HERE cloud. The data includes ‘observations’ such as drive paths, lane markings, and curbs; and ‘points’ such as road signs and signals.

Using deep neural networks, trained by hundreds of thousands of images for each model and millions of sign detection scenarios, the system then detects and classifies the data collected. As more and more cars with sophisticated sensors appear, these ‘observations’ will increase to the hundreds of millions, so it’s imperative that data is aggregated to ensure everything is accurately reflected on the map.

SENSORIS: Pushing for an industry standard

In 2015, HERE initiated SENSORIS, a cross-industry initiative to agree on an industry standard format for collecting and processing sensor data from vehicles.

By uniting around a single data specification, the industry can make sense of vehicle data to increase trust and adoption of automated technologies.



2. Aggregate: Fusing data
Cars with different builds and sensors traveling on different parts of the road perceive objects in different ways, which creates duplications of observations with slight variations. For example, if ten cars are driving on the same road, they will provide ten locations for the same sign. HERE has developed machine learning technology that takes these many observations (as shown in Figure 3) and fuses them into one. Then, it uses the identified coordinates of the new object to localize the sign to another feature on the map to understand its spatial properties. This ensures the system doesn't collapse two adjacent signs into one.

Figure **3**

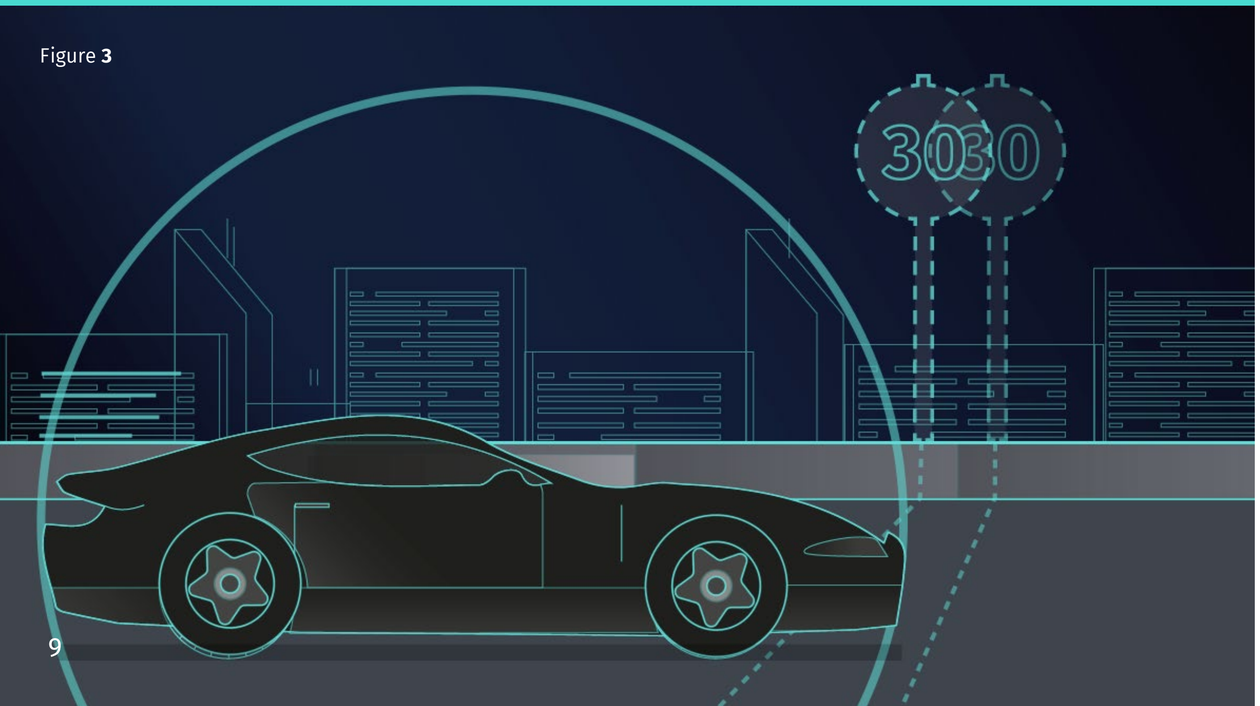


Figure **4**

3. Create: Intelligent updates
The HERE self-healing technology then uses all of these observations to create a new feature on HERE HD Live Map (as shown in Figure 4). This process isn't as simple as taking an average of all the observations. HERE has sophisticated algorithms that take into account multiple variables to determine the accurate position of the object, and then create the feature for the map. These variables might include the type of sensor the car has, which could be more robust and reliable than another car's sensors, to determine the accurate position of the object and then create the feature for the map. For certain features, ten observations may be needed, or twenty, or even a hundred. It all depends on when the algorithm starts converting the many features into one accurate feature. For example, in the US, a road sign's longevity is typically six years. If a car identifies a replacement road sign after just one year, the map software would wait for more sources to confirm before adding a new feature. However, if a car identified a replacement road sign after six years, fewer sources would be needed to update the map.

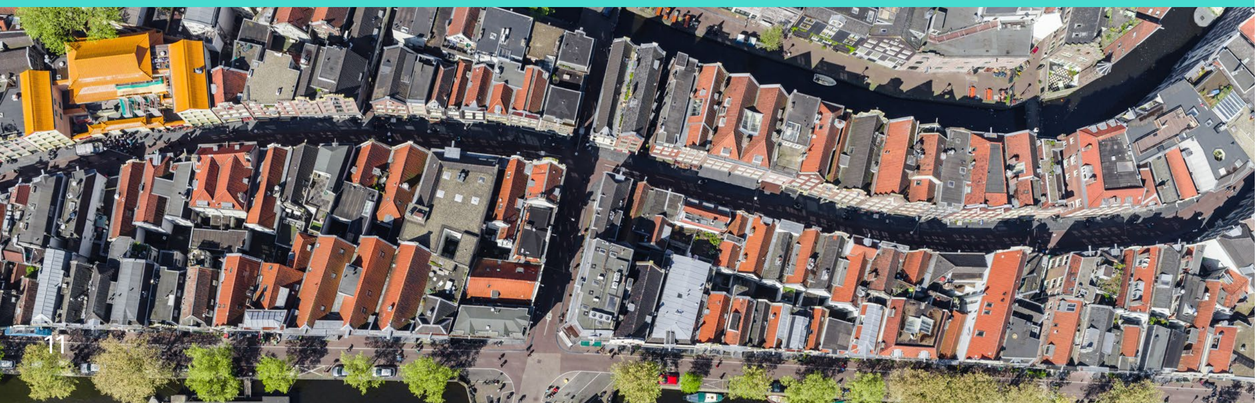
SENSORIS: Sensor data collection
As part of SENSORIS, HERE developed a **Sensor Data Ingestion Interface specification**. This specification prescribes mandatory and optional attributes within Sensor Data Messages, and is designed to accept a variety of sensor information. This includes vehicle dimensions, the driven path, and optional events and imagery along the route, such as recognized signs and obstacles.

4. Publish: Updating users
Once the feature has been aggregated, the map is updated and published in the HERE protocol buffer format as well as the Navigation Data Standard (NDS) format.

To ensure the most efficient data transmission is taking place, only the updates that occur within the specific tile for the specific layer - the Road Model, HD Lane Model, and HD Localization Model - get sent to the OEM's cloud and the vehicle. With the tiled format, over-the-air updates can be sent in a more condensed package for efficiency and optimization of data exchanges.

Once a new feature is published, there may be a specific area of a road where enhanced sensor data is needed. For example, a car might not identify a stop sign due to an obstruction. In this circumstance, HERE will request that the next vehicle in that area takes a video of the environment, then the system can better validate the data. This happens through the Sensor Data Request Interface (SDRI), a data specification format HERE created that helps the autonomous vehicle with data communication and transmission.

SENSORIS: A standardized interface
In 2016, HERE submitted SENSORIS to ERTICO-ITS Europe, the European public and private partnership for intelligent transport systems. ERTICO has agreed to evolve the design into a standardized interface specification for broad use across the automotive industry and is now the directing organization of the SENSORIS forum. HERE continues to be a part of the forum, which also includes AISIN AW, Robert Bosch, Continental, Daimler, Elektrobit, HARMAN, NavInfo, PIONEER, and other Automotive OEMs and Tier 1 suppliers.



Prepare for the autonomous future today, with HERE

While the shift from manual to autonomous driving won't happen overnight, the adoption rate will be exponential. That's why HERE is investing in a scalable process for highly accurate map-making and updating today.

The single most critical element to an autonomous future is global access to rich vehicle sensor data from all the vehicles on the road to support a safer environment for all. For this to happen, cloud data needs to be fresh and needs to be maintained with consumer fleets, not just with industrial-capture units. HERE is collaborating and aligning with OEMs to roll out extensive coverage immediately, as soon as the market need arises. Multiple OEMs are already in partnerships with HERE and provide real-time sensor data for inclusion in new services that will make driving safer and more enjoyable.

HERE is creating a global, scalable, flexible, and open solution that has the maturity to be applied to different regions, different types of sensor data, and different volumes of vehicles receiving this data. HERE HD Live Map is the foundation for a bright future of autonomous driving that everyone can access - on any road in the world.

If you would like to find out more, contact HERE today.

About HERE Technologies

HERE Technologies, the Open Location Platform company, enables people, enterprises and cities to harness the power of location. By making sense of the world through the lens of location we empower our customers to achieve better outcomes – from helping a city manage its infrastructure or an enterprise optimize its assets to guiding drivers to their destination safely. To learn more about HERE, including our new generation of cloud-based location platform services, visit http://360.here.com and www.here.com.