

White Paper

# **The Benefits of a Common Map Data Standard for Autonomous Driving**

*By Philip Hubertus*

*with contributions by Martin Schleicher, Fabian Klebert, Georg Horn, and Dr. Markus Junker*

**Navigation Data Standard e. V.**



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# The Benefits of a Common Map Data Standard for Autonomous Driving

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We have spoken to companies and start-ups that have built self-driving vehicle system prototypes. The results they showed off were super promising. Even with relatively simple sensor hardware, many of them were able to achieve good results in a relatively short development time. Soon they were out there, letting go of the steering wheel, taking their foot of the pedal, and cruising along highways hands-free. Yet, none of them had access to a high-definition map, which supports automated driving use cases. Since getting evaluation access to map data for highly automated driving (HAD) from the big mapping companies is not easy, they simply focused on what they could get easy access to, in this case, self-captured data from sensors. The more sophisticated start-ups were combining data from different kinds of sensors, like cameras, ultrasonic sensors, radar, and lidar. They trained and improved their AI models on recorded data sets from their test drives – with promising results.

But is sensor data really enough to fulfill the needs of a self-driving car? Can sensor data alone power a vehicle that is at least as safe and comfortable as a human chauffeur-driven car?



1 - A vehicle with SAE level 2 - Partly Automated Driving - features enabled

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The Benefits of a Common Map Data Standard for Autonomous Driving

In order to make safe, reliable, and comfortable automated driving a reality, carmakers must see maps as a necessary reference for the sensors that enables self-driving cars. We, the NDS association believe, maps should serve as a common location reference, the common canvas on which vehicle and infrastructure sensor data are combined to paint a realistic picture of the world. The map helps the car understand the world around it. And the map also includes the data that vehicle and infrastructure sensors cannot provide. An example of such non-detectable data are rules of the road that are not posted on a sign.



*2 - A vehicle with SAE level 2 - Partly Automated Driving - features enabled on the German Autobahn*

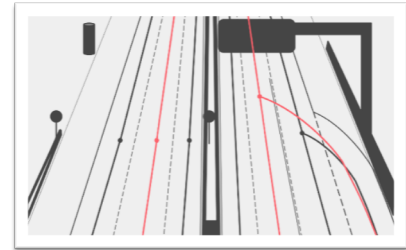
Human drivers make decisions based on experience, intuition and their own knowledge of the rules and tactics you need behind the wheel. A self-driving car aiming to provide a ride at least as safe and comfortable as a human chauffeur-driven car needs that and more. Every millisecond, a self-driving car needs to obtain, evaluate and make decisions based on its environment. And that environment can change rapidly. The map that fills this role must be a high definition (HD) map, one that enables vehicles to combine what the sensors see with the information from the HD map to precisely locate and position the vehicle on the road and in the lane. With this precise vehicle positioning, the maneuvers of the vehicle will match the safety and comfort level its passengers expect.

Let's break this down:

- A map for automated driving needs to include local knowledge of the **rules of the road**. This is information that sensors often cannot collect themselves. Basic driving rules, for example, are not generally posted for sensors to “read”, which means that a self-driving car relying on sensors alone would not be able to understand and follow the rules. For example, a sensor only based self-driving car will encounter situations where it will not be able to detect the right-of-way rule for an intersection. Is it then safe to assume the default right-of-way rules apply? Since sensors cannot expect to see such rules clearly displayed all the time for each unique roadway or intersection, this information needs to come from the map, where these rules are attributed to the specific roads and the lanes they apply to.
- A map for automated driving needs to **enhance sensor functionality** for **contextual awareness** of the environment. With the map as a reference, a self-driving car can better understand exactly where it is and compare what it “sees” with its sensors to what is coded as attributes into the map data. For example, is the car currently driving on two-lane, one-way road, or is the left lane actually intended for oncoming traffic? Is the object detected ahead by sensors simply a highway sign or an overpass – or could it something else? If it is not coded in map data, this would send a red flag to the vehicle that the seemingly harmless object could actually be a physical barrier that, if approached at full speed, could prove fatal.
- A map for automated driving needs to enable the planning of vehicle control maneuvers **beyond sensor visibility**. This enables self-driving cars to slow down before a sharp curve, an intersection, or a reduced speed zone, thereby making the ride comfortable and safe for the passengers. This is an essential capability, particularly under conditions with lower sensor visibility, e.g. due to weather, poor lighting or bad road markings.
- A map for automated driving needs to allow the **precise positioning** of a vehicle on the road. Understanding where exactly the vehicle is in relation to the road lanes further supports all of the three above-mentioned elements. It is critical to leave very little room for interpretation on this. For example, whether a car is driving on the highway or on a parallel street – or perhaps even a road running underneath on a lower level street or in a tunnel – can make an enormous difference with regard to speed limits, lane direction and more. By being able to match the vehicle to the exact lane it is driving in, and by having additional data points to improve positional accuracy, the behavior of a car operating in automated driving mode will be much more comfortable and safer.

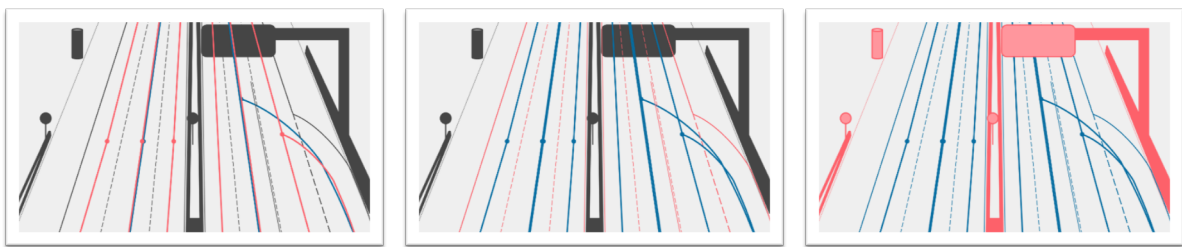
You may wonder whether the standard navigation maps of today are not enough already. Let's look at the differences of a map for navigation and one for automated driving.

Today's standard definition maps include road topology and the link network, in which the centerlines of roads are coded. Sometimes there is a centerline for each direction of traffic, but in many cases, only one centerline is coded for both directions. Clearly, such imprecise and inconsistent information is insufficient for automated driving.



3 - Road segment with coded centerlines shown in red

For automated driving, the data needs to be much more detailed, with lane geometries, lane groups and lane relations. The next level of detail is the exact lane markings, including their type and color. After that, comes the localization objects that allow the positioning of the vehicle by including guardrails, signs, lampposts, medians, gantries, walls and more.



4 - Road segment with coded lane centerlines, coded lane markings, coded localization objects shown in red

The common canvas that unites all of this information is an HD map. This highly detailed map includes this information and even more, like permanent speed limits, temporary construction zones or detoured routes. With this level of detail, an HD map can precisely locate and geo-reference all this data and, along with the vehicle's sensor data, share it with others on the road.

By continually comparing the real-time data collected by its sensors with the road and environmental data stored in the HD map data, vehicles can determine their position independently of navigation signals, enabling precise positioning that is accurate down to less than 15 cm laterally and 50 cm longitudinally. The more data collected and shared using a common referencing system, the more the car can benefit from the data in return.

And there is one additional factor that cannot be underemphasized:

*This map needs to have a fast feedback loop with as many participants as possible contributing to it with their sensor data.*

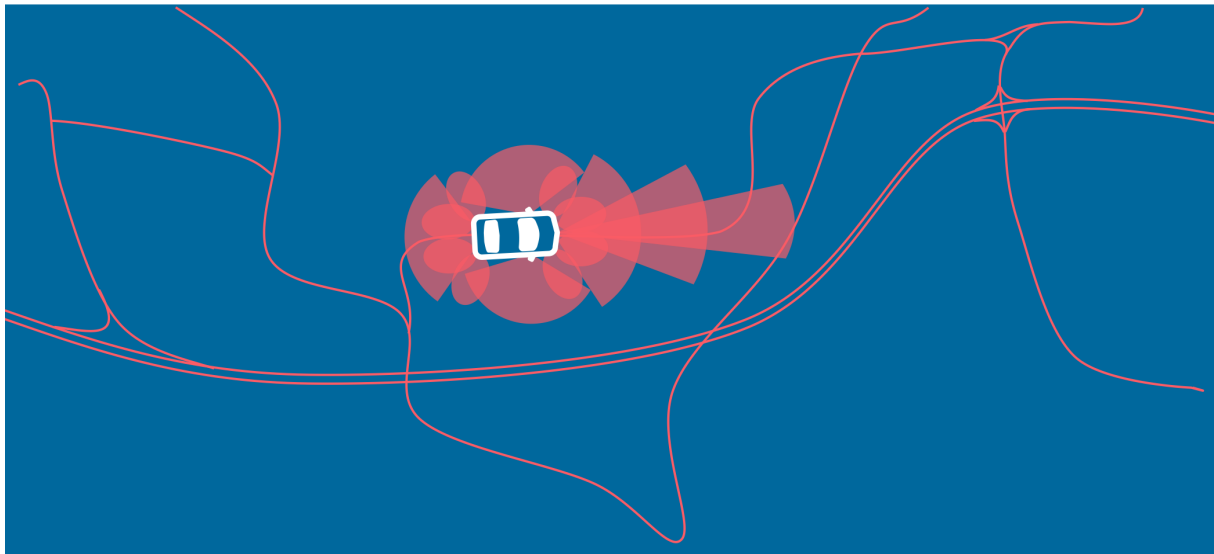
In our diverse, global economy, no single OEM, supplier or system vendor has enough vehicles in the field equipped with sensor technology to serve all relevant markets entirely themselves. Automated driving functionalities require high-quality, precise maps that are always up-to-date. And this needs to be barrier-free, meaning that when you drive your German car across the border to France, there should still be consistent data available. Updating such a map by using only your own brand's vehicle sensor data is simply not enough to reach the quality and update frequency required to maintain accurate maps. For example, an OEM with a large number of vehicles in the United States, may not have a significant volume in Germany or China. Not only would it be unfeasible to expect the same coverage across the world's different markets, it is also inefficient and impractical. Collaboration, data sharing, and using common data standards is a win-win for everyone, but for that to work, we need to speak the same "language" with a common infrastructure, a common standard.

The advantages of a common standard for navigation map data are numerous. To name a few, a common map data standard:

- offers data compatibility.  
*"Speaking the same language" ensures there is less room for translation error when transforming and interpreting data that describes the real world. This is essential to collect and compare sensor data with the map that serves as the location reference to increase the safety and comfort level of an automated vehicle.*
- provides ease of access, reducing development costs.  
*When developers collaborate, they save valuable time and money. By pooling resources, no one has to start from scratch to develop their own systems, because they can pull from the extensive expertise and experience of a global network of partners working toward the same goal.*
- increases the data quality, and thereby the safety, reliability and practicality of automated vehicles.  
*When cars speak the same language and share their data indiscriminately, every car can have the most accurate, up-to-the-minute information about its environment, allowing it to react to situations more quickly, reliably and safely.*
- improves the consistency of data and the speed of the feedback loop increases.  
*This leaves less room for errors when processing and using data. As a vehicle sensors' process data and compares them to the reference map, a common definition help to speed up the feedback loop that transfers detected differences back to a system that updates the map in near real-time.*



- increases general road safety for all road users.  
*When cars can communicate with each other regardless of make, model or origin, accidents can be prevented, our roads become safer and everyone benefits, whether you are a driver, passenger, cyclist or pedestrian.*
- presents legal certainty with respect to IP, contributed to and owned by the standard's members.
- supports the sharing of domain knowledge, resulting for example in the full inclusion of broad market requirements.



5 – A common map data standard increases the data quality and thereby the safety and reliability of automated vehicles

The Navigation Data Standard (NDS) is the worldwide standard for map data in automotive eco-systems. Today, map data in NDS format is used in vehicles of over 30 automotive brands globally since many years. This includes Acura, Aston Martin Lagonda, Audi, Bentley, BMW, BMW Motorrad, Chrysler, Citroën, DS, Ferrari, Fiat, Hyundai, Jeep, Kia, Lamborghini, LEVC, Mercedes-Benz, Mercedes-Benz Trucks, MG Motors, MINI, Nissan, Opel, Peugeot, Porsche, Renault, Seat, Skoda, Smart, Subaru, Toyota, Volkswagen and Volvo.

The NDS association has 38 members: industry leading OEMs, system and solution vendors, and map data suppliers. The advantage of a consortium like NDS is that it creates broad consensus in the industry on the best path forward, supported by the best engineers and experts available from multiple companies. Standardization consortia may not be known for their fast pace. However, market-driving associations by like-minded companies – as is the case with NDS – have demonstrated themselves to have the right speed for the market.

The members of the NDS Association have defined the data specification for an HD map to support automated vehicles. Established map data providers, as well as newcomers, are offering their high definition maps in NDS, and a number of OEMs are using the standard to develop and test automated vehicles today.

For HAD, the NDS map data format offers four specific building blocks that layer the data and references it to each other:

1. The **NDS Lane Building Block** contains advanced lane information for HAD and enhanced navigation functionality. It represents an attribute layer for highly detailed lane geometry and provides the data for precise guidance instructions and advanced lane guidance functionality, since navigation systems for HAD need detailed information on road topology and road geometry.

Usually, roads are digitized as a single polyline for each roadway independent of the number of lanes. For HAD, it is insufficient to encode the number of lanes and the connections between lanes only. The following information is also important:

- Geometry of lanes and lane boundaries, such as physical lane dividers
- Road markings, such as arrows
- Possibilities of changing lanes
- Associated lanes, such as lanes in opposite directions

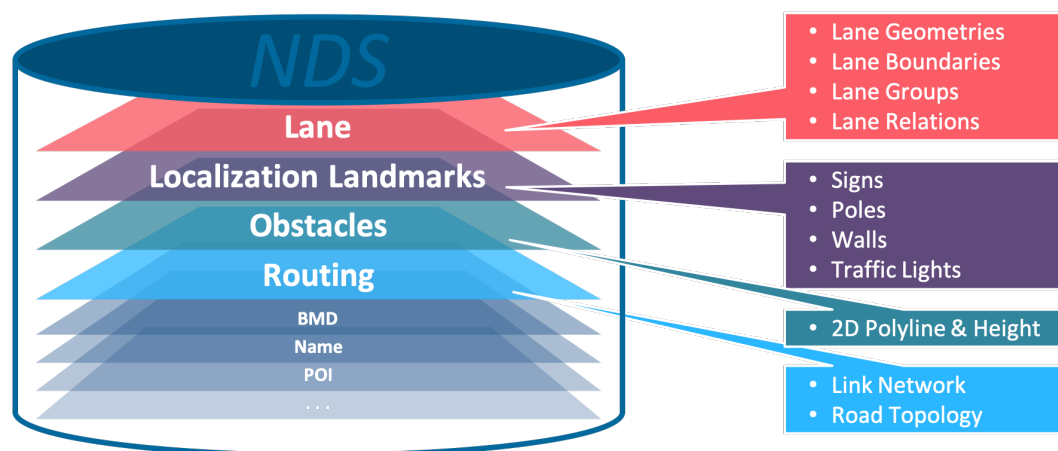
Lane properties that contain the information required by navigation systems for HAD may be described by attribute groups that combine lane attributes with validity ranges.

2. The **NDS Obstacle Building Block** provides data structures that allow the modeling of obstacles along the road edges. Obstacles are generic, stationary objects that reside along the road and can be used for positioning, for example, guardrails, walls, fences, or small hills near the road.
3. The **Localization Landmark Building Block** provides data structures that allow the modeling of landmarks that can be used for positioning. Localization landmarks represent real-world objects, such as signs, traffic lights, road markings, road-side equipment like posts and poles, or perpendicular walls. If the sensors of a vehicle detect localization landmarks along the road, the system can use these to determine the vehicle's position.  
For each localization landmark, a bounding box with an absolute geographic position and height values, or a center line is defined. To model relations between routing



features and localization landmarks, feature references between the base links and road geometry lines and the landmarks are defined. This information enables the application to validate the localization landmark's position in relation to the assumed current car position.

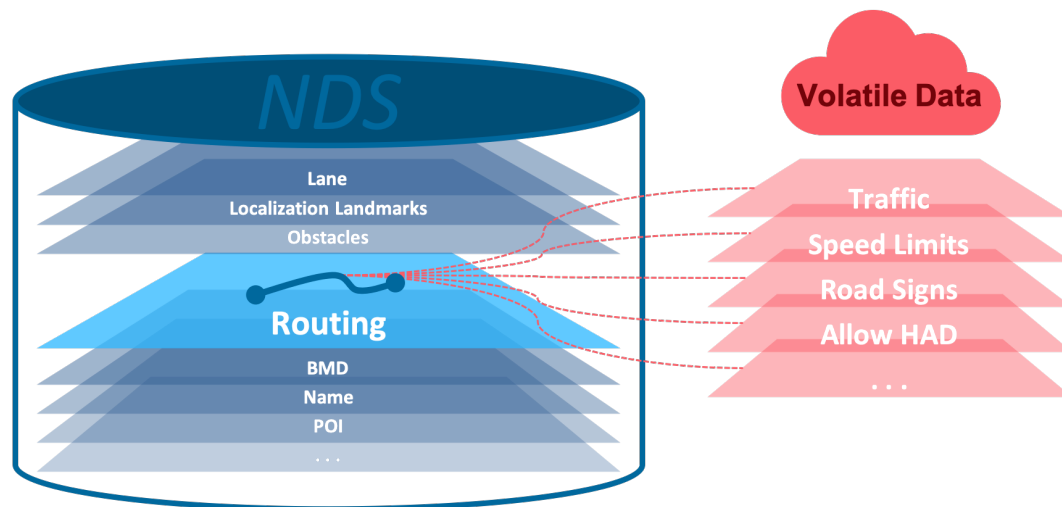
4. The **Routing Building Block** provides the underlying link network for the other building blocks. Applications need this link information to enable car positioning.



6 - Illustration of NDS database building blocks with selected attribute lists

In addition to storing this data as a full on-board database, the data relevant for automated driving can be consumed tile-based, via an application programming interface (API). The collected and shared sensor data that is highly dynamic and changes often can be referenced to the map data and then offered via APIs. Automated vehicles can consume this data as they need it. For HAD, you must think of traffic data, hazard warnings, dynamic speed limits and road signs, and safety flags that indicate whether a road segment is safe and accessible.

As part of the NDS data specification, the members have defined how volatile location IDs can be used to support use cases where data with an extremely high frequency of changes is combined with map data that doesn't need the same high frequency of updates. This is to ensure NDS enables data transfer bandwidth and costs to be used as efficiently as possible.



7 - Illustration of NDS database with reference from routing building block to volatile data layers

The currently latest version of NDS is version 2.5 and its specification includes data format definitions for the above. Nevertheless, the NDS format is evolving to a new generation of specifications that is focused on enabling a combination of embedded and streamable data. This is specifically targeted at even better supporting highly and full automated driving with map data. It is also addressing the fact that navigation is shifting from pure offline and embedded models to hybrid models. Map data that is not changing often, for example the digital terrain model or icons and country meta data, remains embedded, while map data attributes that change more frequently are streamed to the vehicle on demand. Hybrid also means, features like search, route calculation and traffic-related recalculations, as well as other high data and computational features, can move to servers. This includes cloud-connected dynamic data services derived from infrastructure and vehicle sensors. On the server side, NDS is used to ensure data integrity and a seamless user experience in case a data connection is not possible.

While NDS spec 2.5 will continue to be maintained as NDS.Classic, the new evolution of NDS is called NDS.Live.

NDS.Live comes highly modularized to scale across usage scenarios in the car, in the edge network (5G), and in the cloud. With its focus on HAD, functional safety, and seamless map data distribution. NDS.Live widens the scope of the format to better include online electronic horizon services and dynamic map management to generate a truly distributed map experience for NDS developers and OEMs.

The NDS Association drafted a first version of NDS.Live in May 2019. Further specification work will continue to migrate current NDS features, as well as add new functionality, for

example, to improve HAD support in urban scenarios and to integrate lessons learned into the new architecture. The target of the version 1.0 release of NDS.Live is in 2020.

The NDS association members invite companies to join the association and the shared patent pool of the Navigation Data Standard, which is THE worldwide standard for map data in automotive eco-systems. Together we will define the format specification of the digital map and its interfaces.

Learn more about NDS at [www.nds-association.org](http://www.nds-association.org) and feel free to contact Martin Schleicher, NDS Association Chairman, [martin.schleicher@nds-association.org](mailto:martin.schleicher@nds-association.org) or Dr. Markus Junker, NDS Association Administration, [markus.junker@nds-association.org](mailto:markus.junker@nds-association.org)

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## About NDS

NDS, short for Navigation Data Standard, is the worldwide standard for map data in automotive eco-systems.

NDS maps work worldwide and are globally adopted. NDS members and map coverage include North America, EMEA, APAC, including China, South Korea, and Japan. NDS offers a well-defined spec for how to store map data and it allows flexibility for customized user experiences. The NDS specification covers the data model, storage format, interfaces, and protocols. NDS is for in-vehicle navigation and for ADAS and e-horizon safety systems. It is for mobile companion apps, connected car cloud solutions, and for automated driving. It evolves with the market needs as NDS is for the automotive industry, by the automotive industry.

The NDS association has 38 members: Automotive OEMs, system and solution vendors, and map data suppliers.

The advantage of a consortium like NDS is that it creates broad consensus in our industry on the best path forward, made by the best engineers and expert available from multiple companies. Standardization consortia may not be known for a fast pace. However, market driving associations by like-minded companies - as it is the case with NDS - demonstrated to have the right speed for the market.