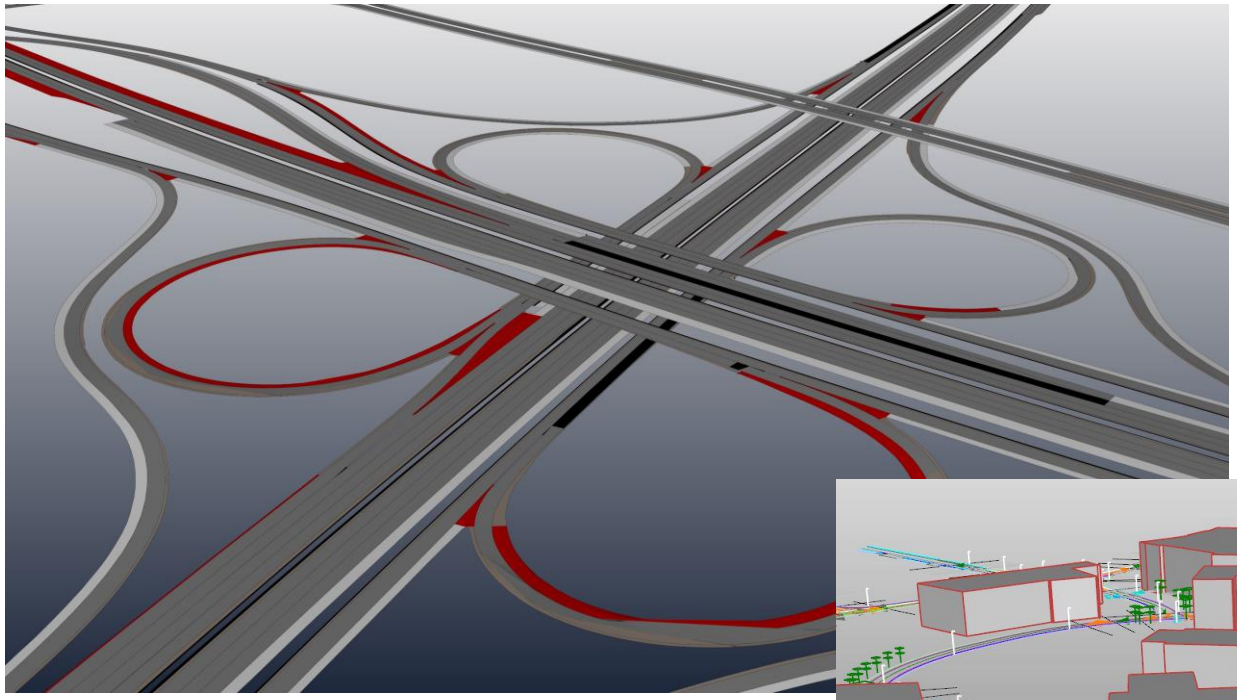
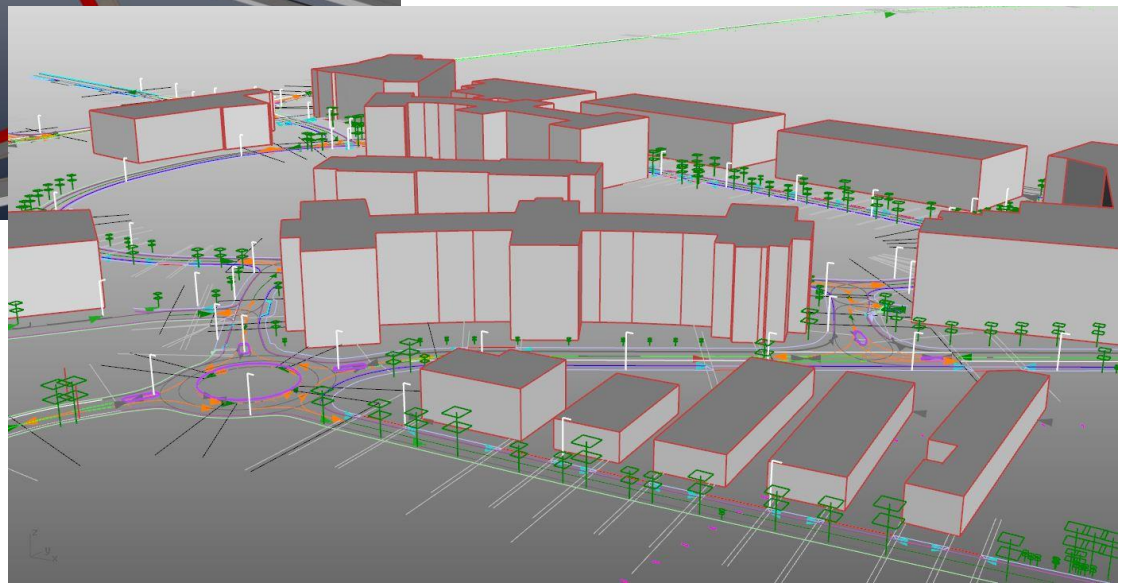




OpenDRIVE Project Experience and the Need for a Reference Implementation and Visualization

Dr.-Ing. Gunnar Gräfe, 3D Mapping Solutions GmbH

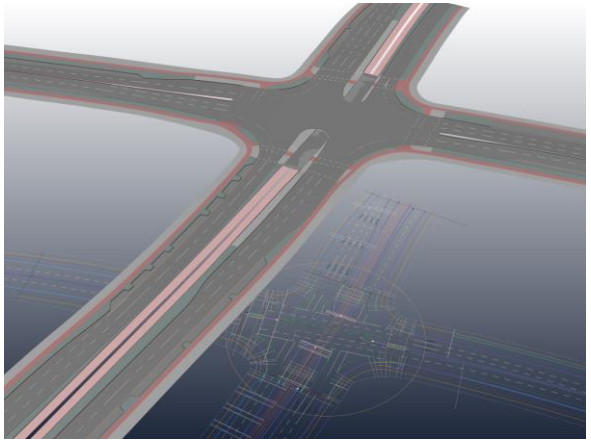
3D Mapping Solutions GmbH

The company

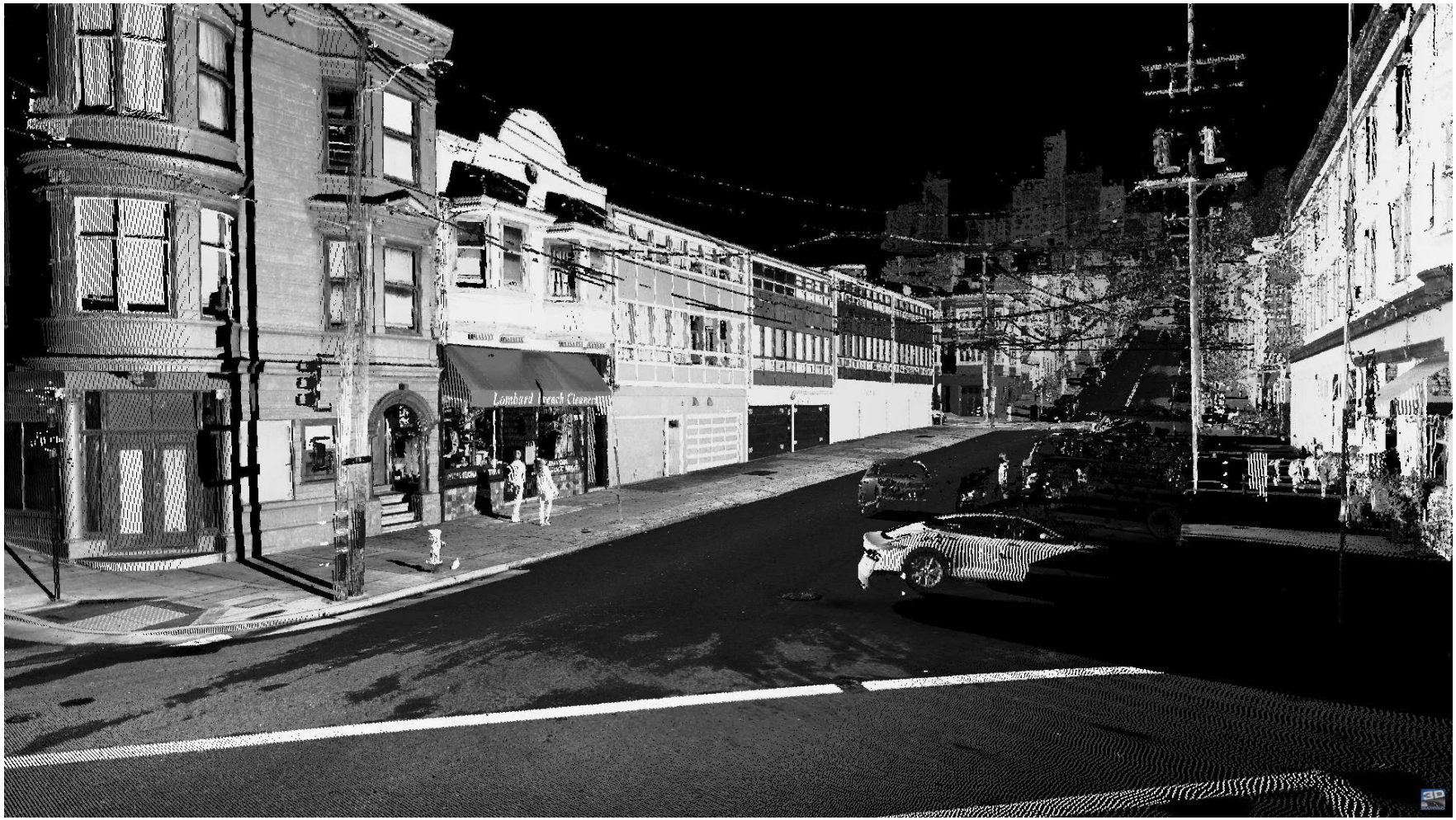
- Headquarters: Holzkirchen, near Munich, Germany
  Subsidiary: 3D Mapping Solutions Inc., Pittsburgh, PA, USA
- Founded 2007 by Dr.-Ing. Gunnar Gräfe and Dipl.-Ing. Martin Lang, both with more than 20 years experience in kinematic surveying
- 52 highly skilled employees
- Working for almost every global automobile manufacturer/supplier
- Active internationally (Europe, USA, China, Japan, Brasil, Russia, India etc.)

Worldwide survey services for Automotive Applications...

- Worldwide kinematic survey services for
  - Precise as-built digital HD Map road data production
  - Driving simulator applications and Race track simulation
  - High-end Surface models of (crg-projects)
    - race tracks
    - Proving grounds, test areas and special tracks with multiple resolutions
    - Public roads



Precise Digitalisation as a basis for digital road data production



Scanner data taken along Lombard Street in San Francisco, CA

Example for a kinematic 3D Laser Scanner Point Cloud

Laser scanner point cloud (raw data) consists of:

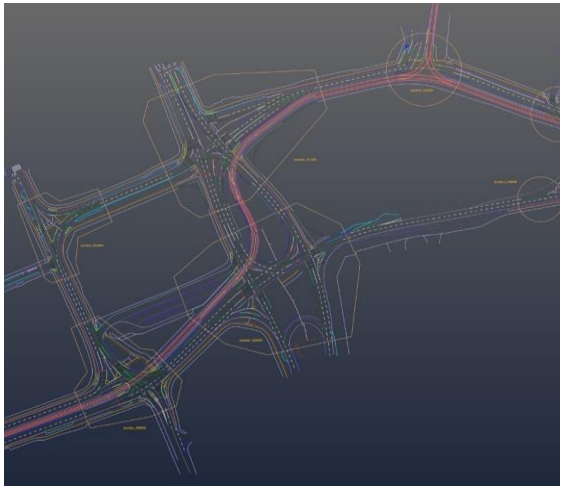
- 3D coordinates for each point
- plus reflectivity of the target surface
- All vehicle movements are fully compensated.
- 1 million points per second per scanner lead to an exact digitalisation of the road surface with a point density of more than 3000 points per square meter.

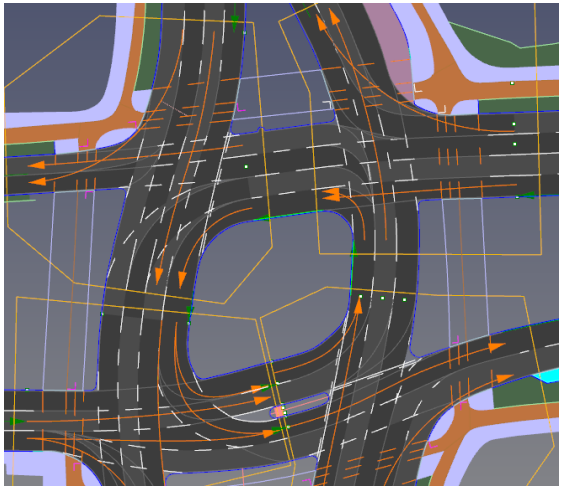
Georeferenced, digital Image Documentation

- Documentation of road corridor and road surface
- Each image exactly georeferenced, calibrated and ready for photogrammetric object survey with our software 3D Road View.
- Multiple cameras (currently up to 10) with various possibilities of mounting and combination. The camera view for all cameras is flexible and may be adjusted by project.

The data processing chain …

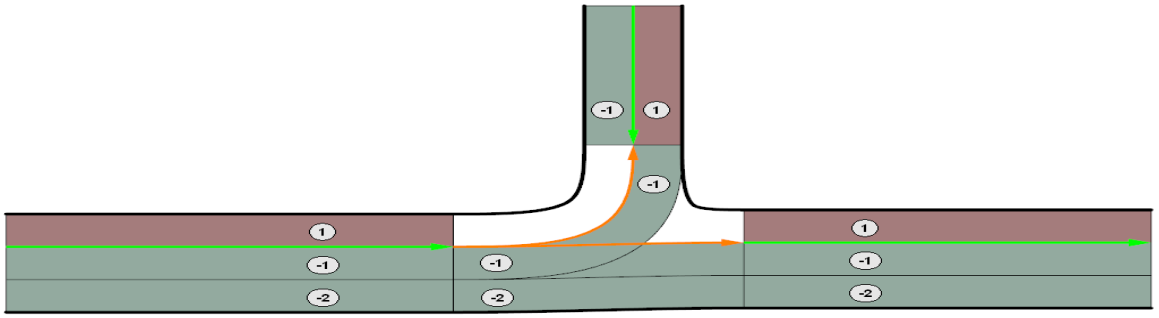
Object-extraction → **As-built plan data** → **HD Map**

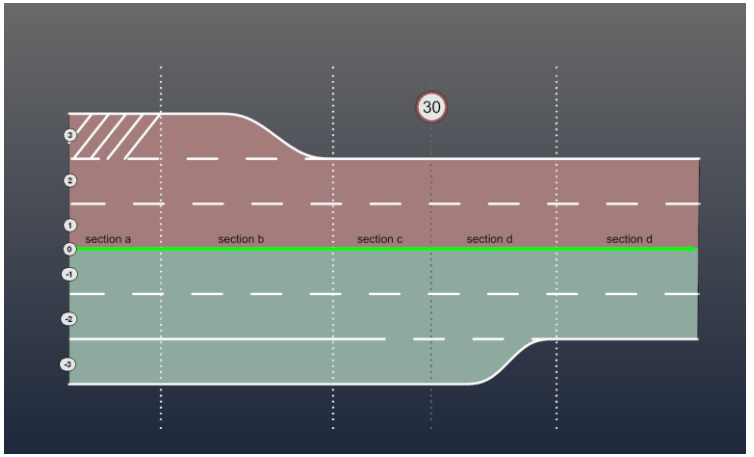




Open Drive Project Experience

- Main application is the production of highly detailed autonomous driving reference maps as in-car reference as well as basis for driving simulator testing and other simulation applications.
- Worldwide projects to generate ultra HD Maps since 2011.
- Lots of highway projects are done, but main emphasis at the moment is on inner-city HD maps as basis for simulation, testing and development.
- There is a broad bandwidth of OpenDrive interpretation.
- Every user has wishes concerning additional objects, attributes and topological features.
- A lot of effort has been necessary to keep “OpenDrive” consistent for all customers, but still there are interpretation issues.
    - Next step: ASAM OpenDrive





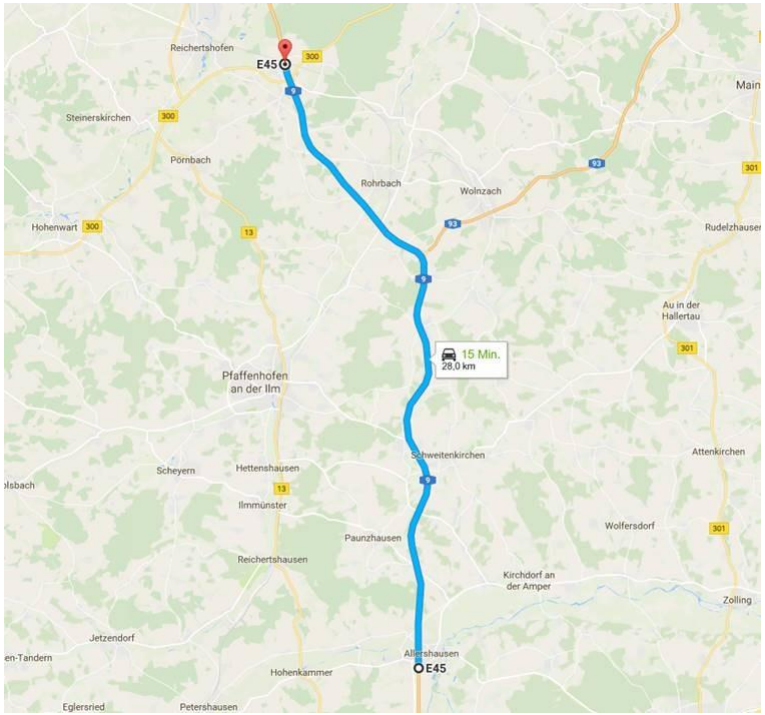
Requirements for autonomous driving high-definition reference maps

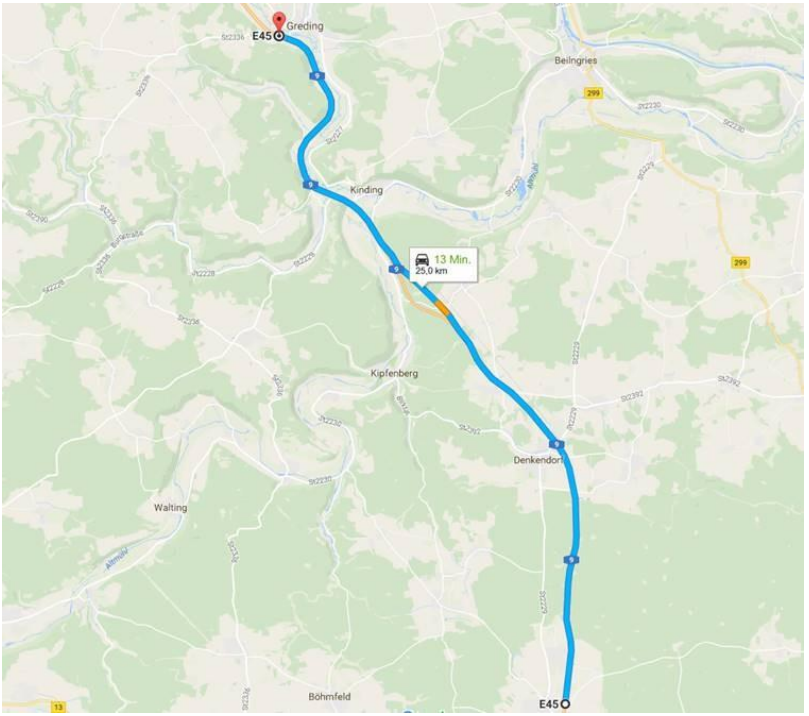
- Example: Highway as 3D Visualisation
- The high-definition reference map in the car is regarded as sensor of unlimited range.
- Most important is guaranteed relative accuracy for all 3D objects in the road corridor between 5 mm and 5 cm, depending on the object type

- Complete as-built object data, e.g. all markings, guardrails, signs, road posts, tunnels, bridges, sign bridges, fundaments, curbstones, entrances, exits, intersections including all ramps and connections, resting and parking areas etc.
- In addition to the classical „as-built“ plan, the data formats contains a complete logical road structure in a strict hierarchical order.
- In-fact the reference map data is required e.g. in driving simulator formats such as OpenDrive or IPG Road 5.

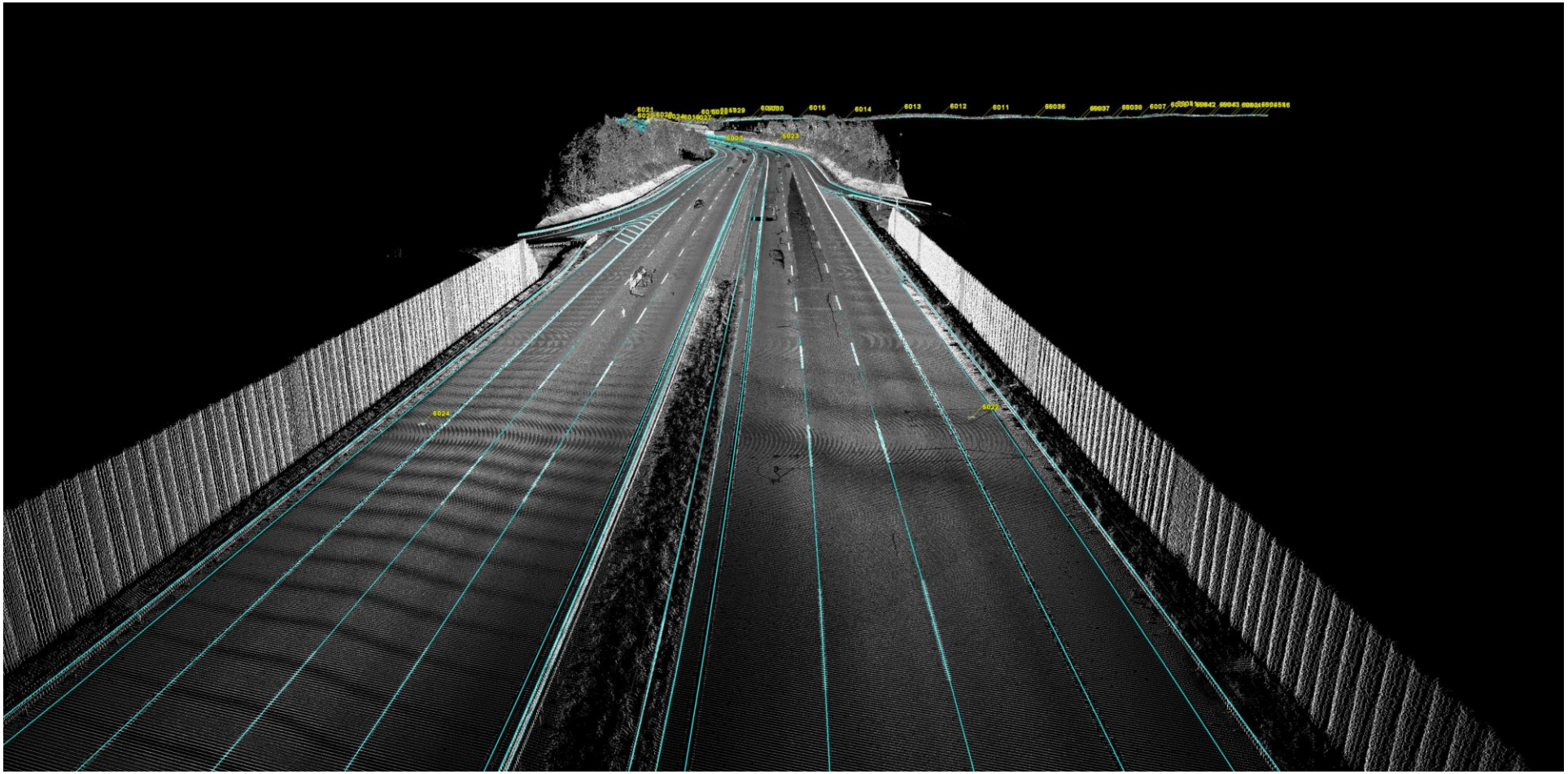
Example for autonomous driving Reference Maps
Official Map of Test Field A9

- Part 1: Highway Administration Südbayern
  - Between exit Langenbruck and exit Allershausen (approx. 27 km)
- Part 2: Highway Administration Nordbayern
  - Between exit Greding and the border between the responsibility area of Highway Administration Nordbayern und Südbayern (approx. 25 km)





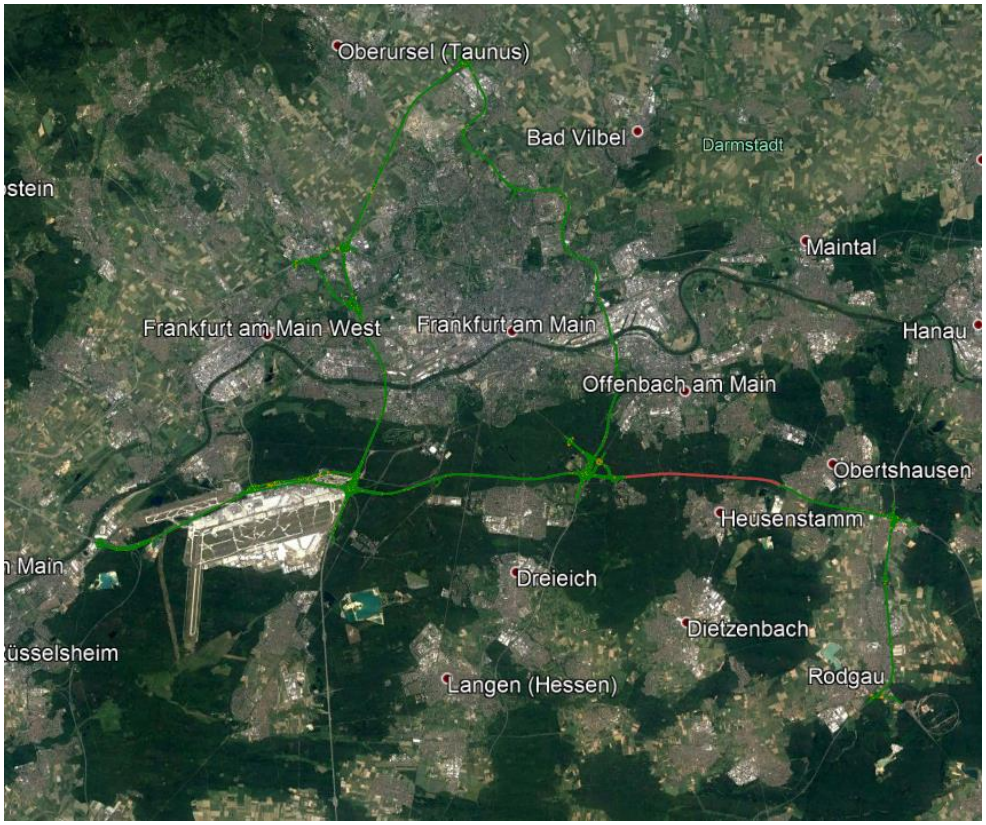
Section of the official German test field for autonomous driving along Autobahn A9



High – Definition Laser Scanner Point Cloud including extracted object data

Project Example: Ko-HAF (highway)

Project: Ko-HAF – cooperative highly autonomous driving project (funded by the Federal Ministry of Economics and Energy) www.ko-haf.de



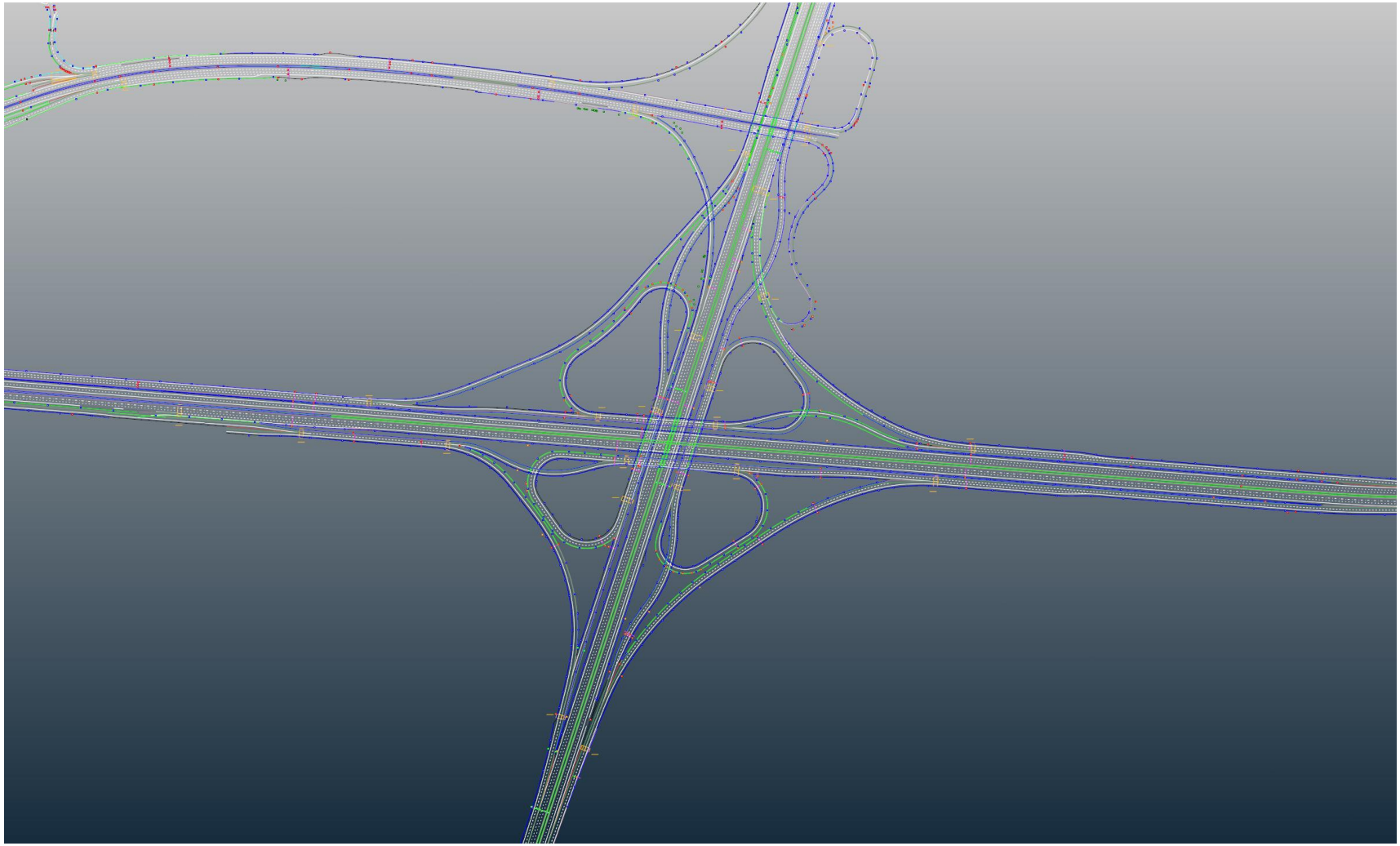
Partners

- Several OEM and TIER1
- 2016-2018

High-definition Mapping of all highways around Frankfurt

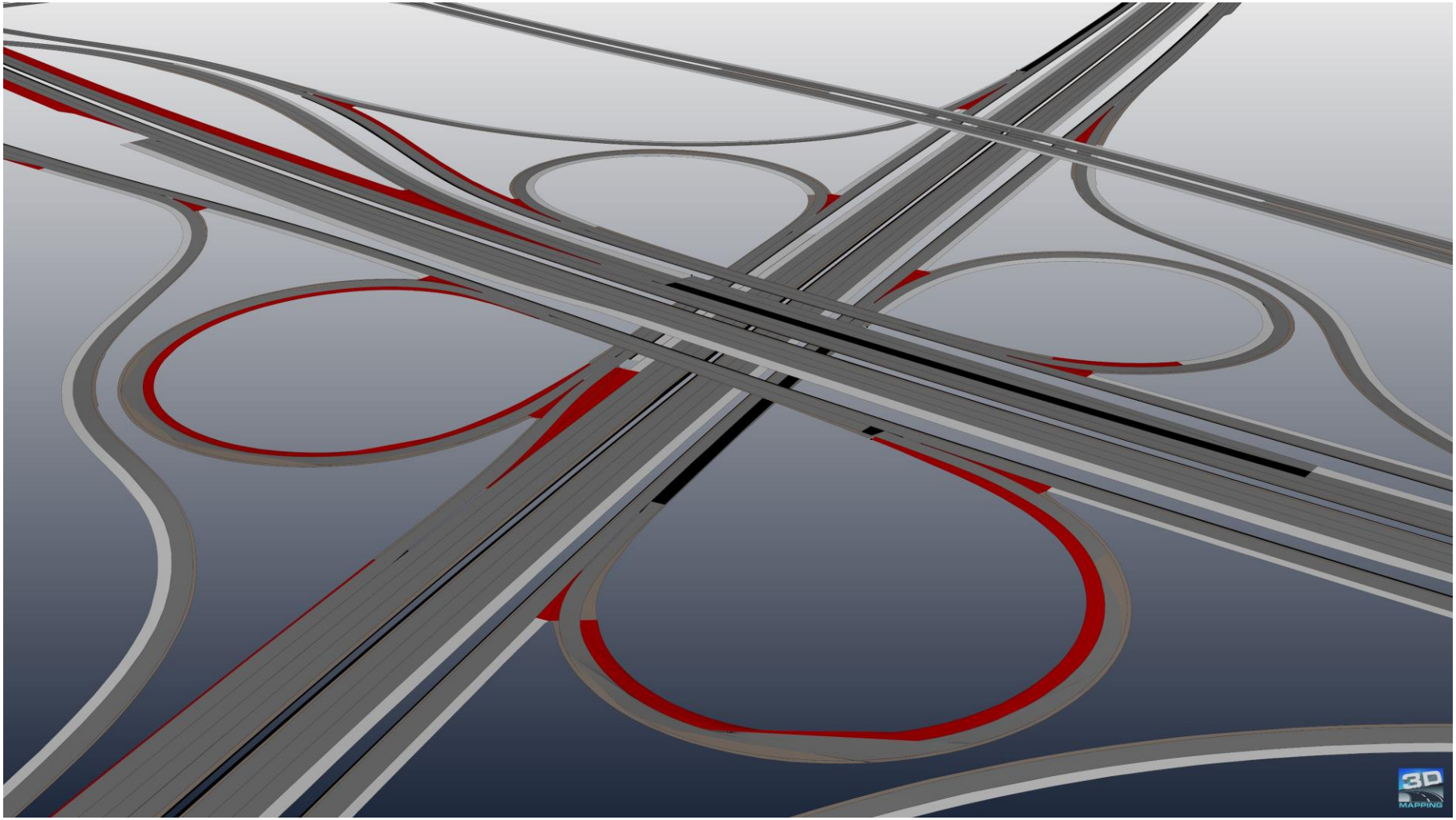
- Mapped highways displayed in green and red (left image)
  - Very complex intersections
  - Includes Frankfurt Airport highway system
  - Connection to automotive PG Dudenhofen
- HAD Map Target formats:
  - OpenDrive 1.4H

Project Example: Ko-HAF (highway)



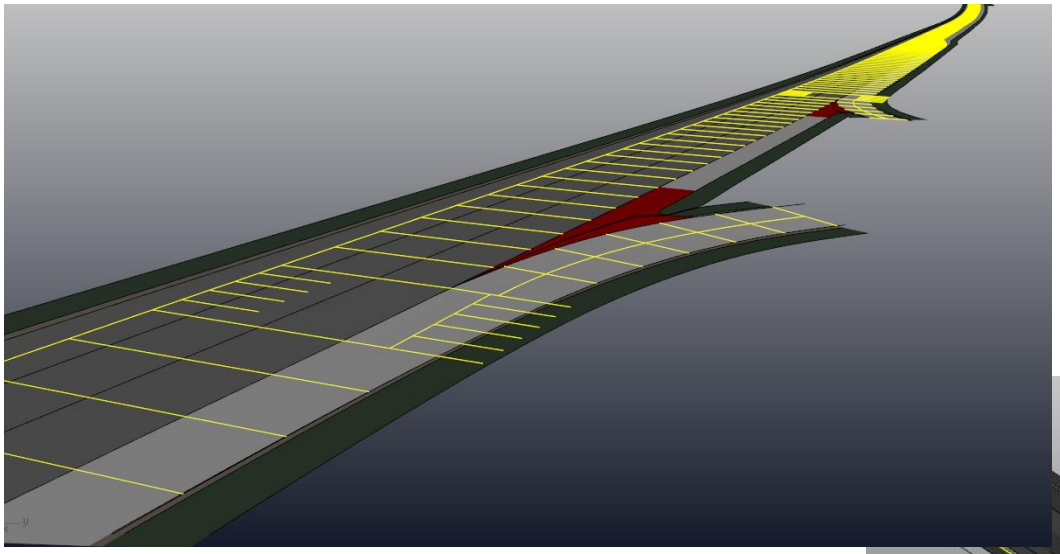
Highways represented in OpenDrive including the complete object data information

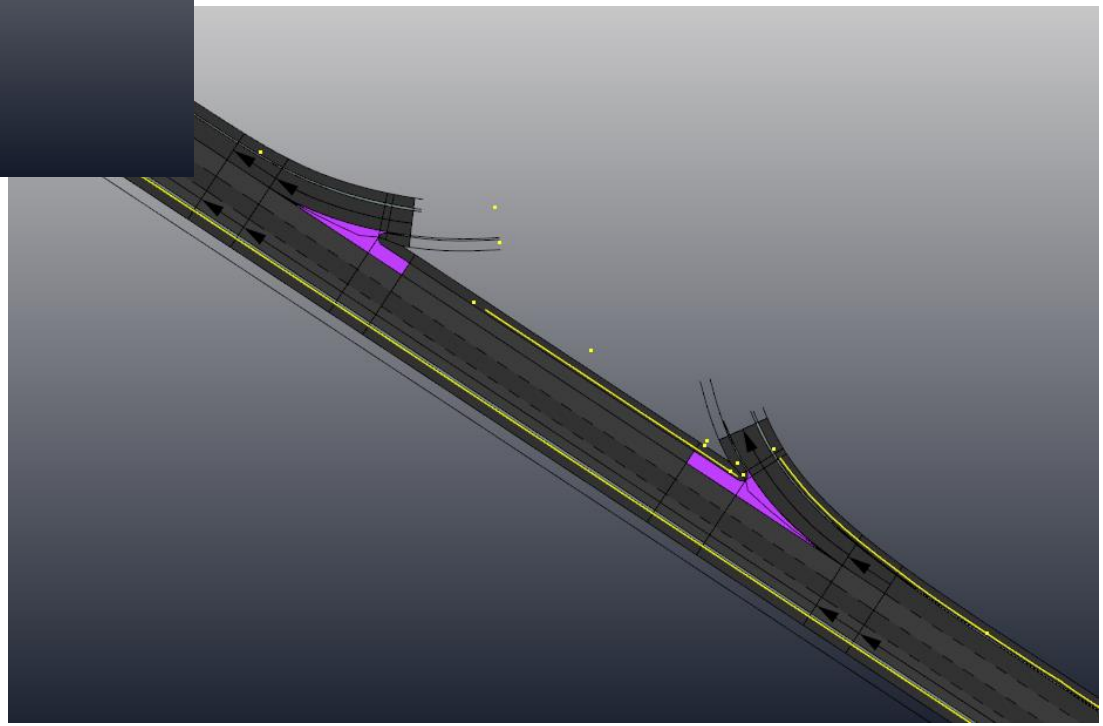
Project Example: Ko-HAF (highway)



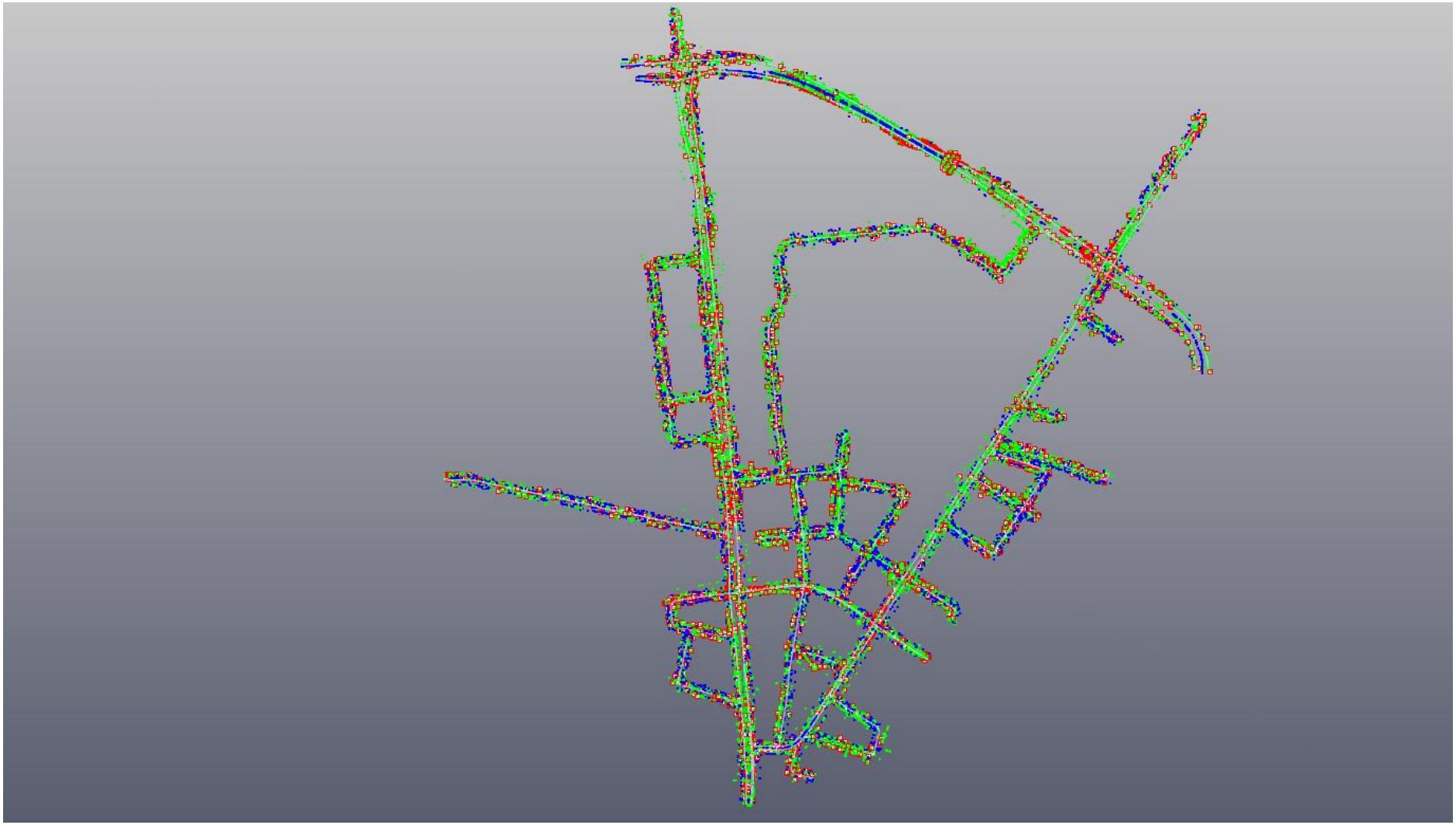
Highways represented in OpenDrive including the complete object data information

Open Drive Project Examples



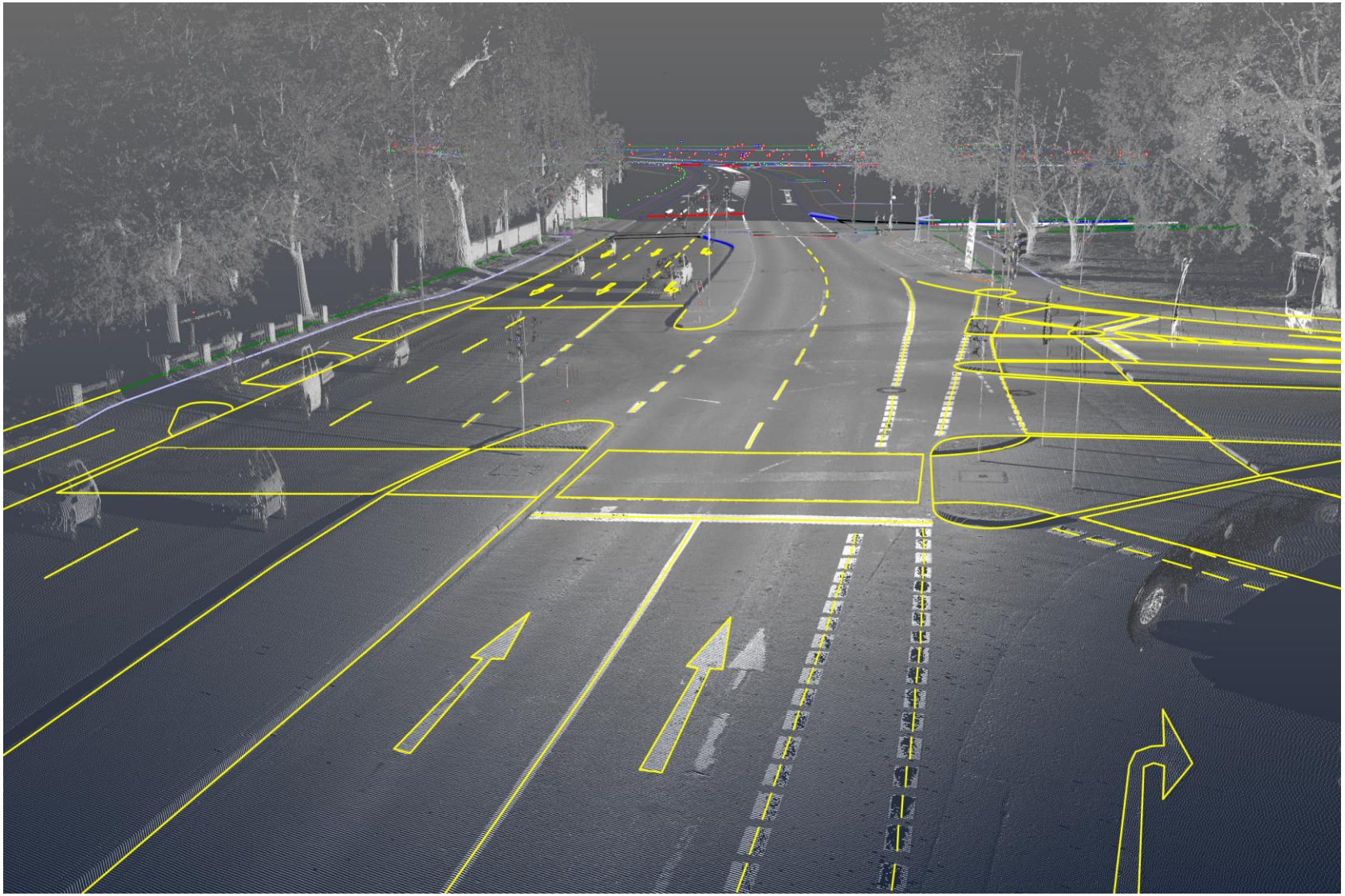


Open Drive Data Production example

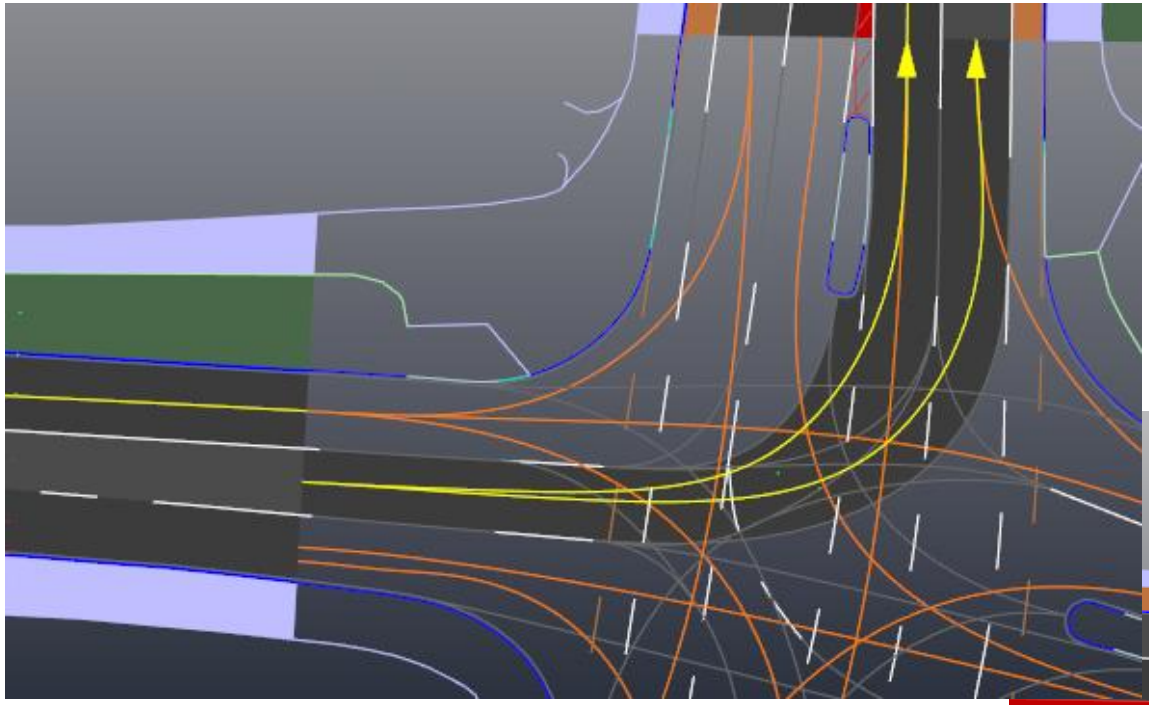


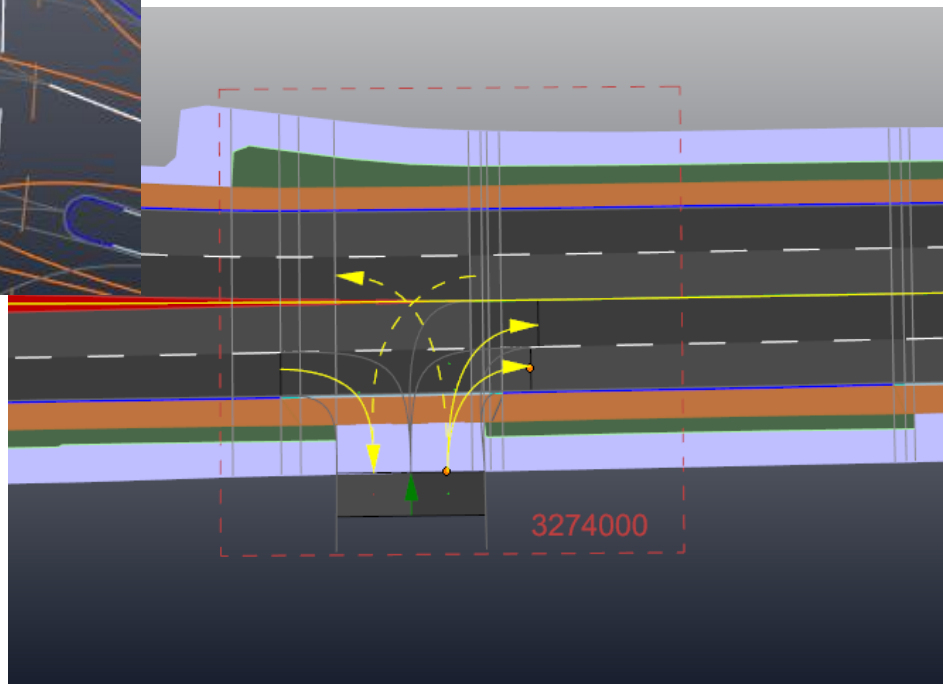
Example: inner city HAD Map data including all extracted geometry like curbs, markings, pedestrian walks etc.

Open Drive Data Production example

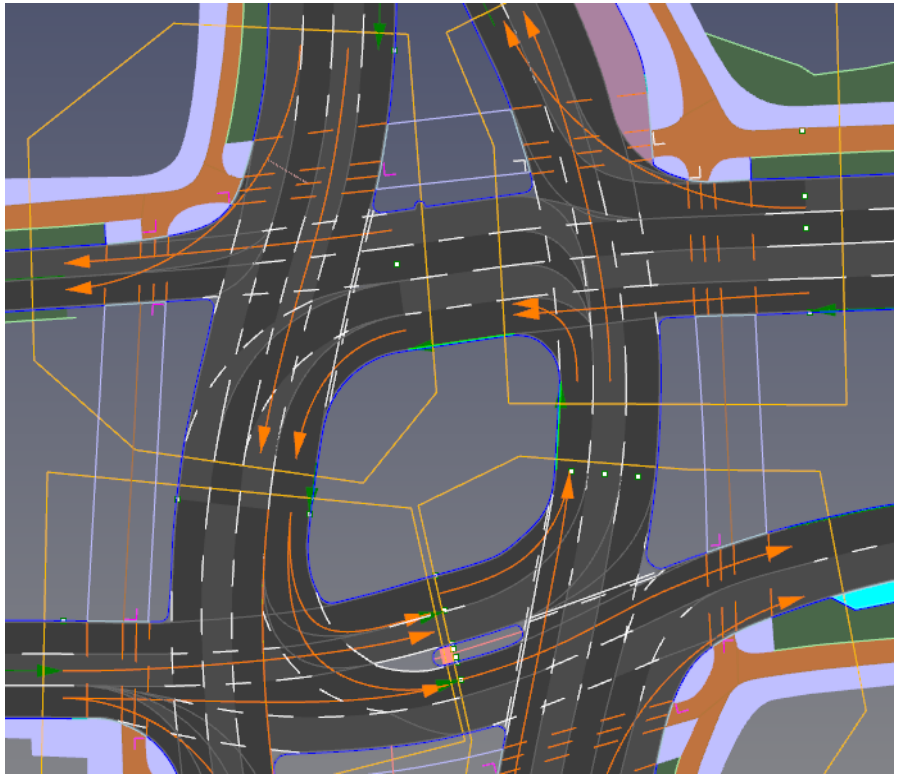


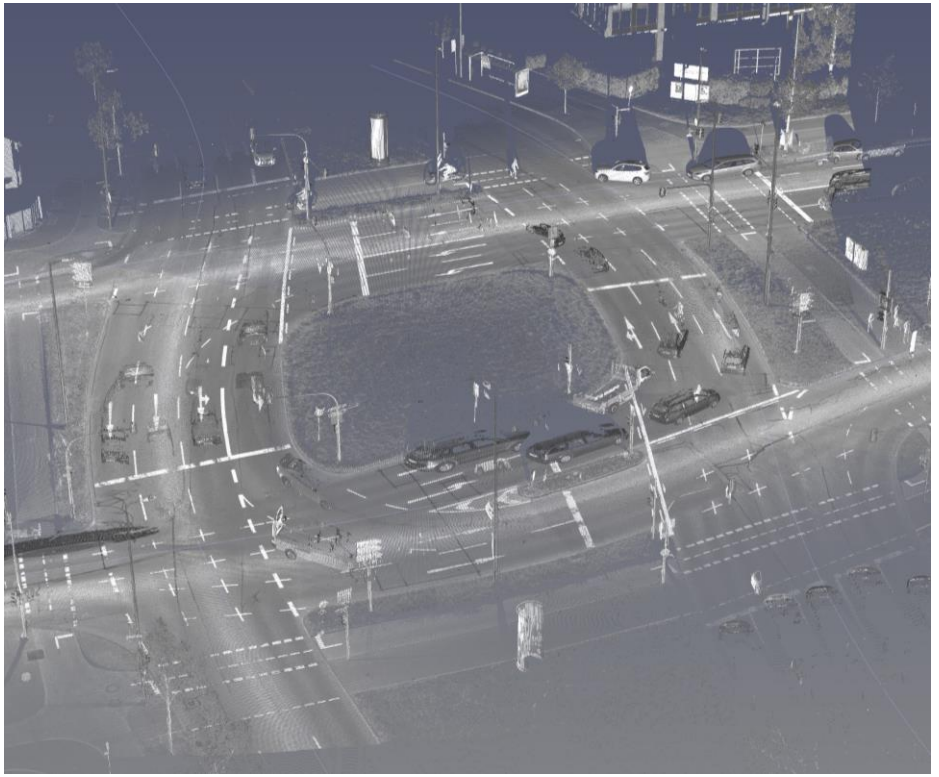
Open Drive Project Examples





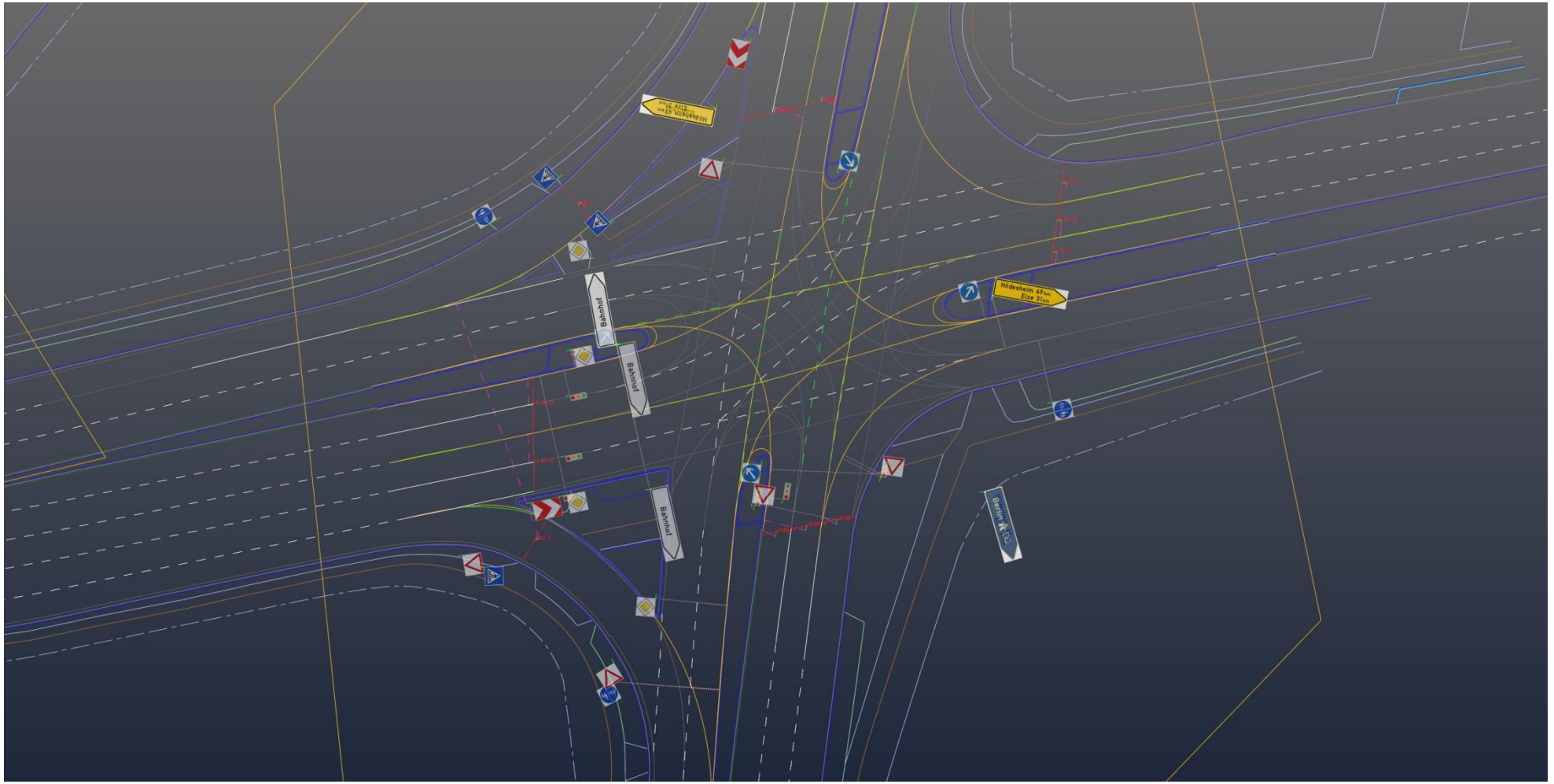
Open Drive Project Examples





Inner city project Schwabing: 15 km, 54 junctions

Open Drive Data Production example

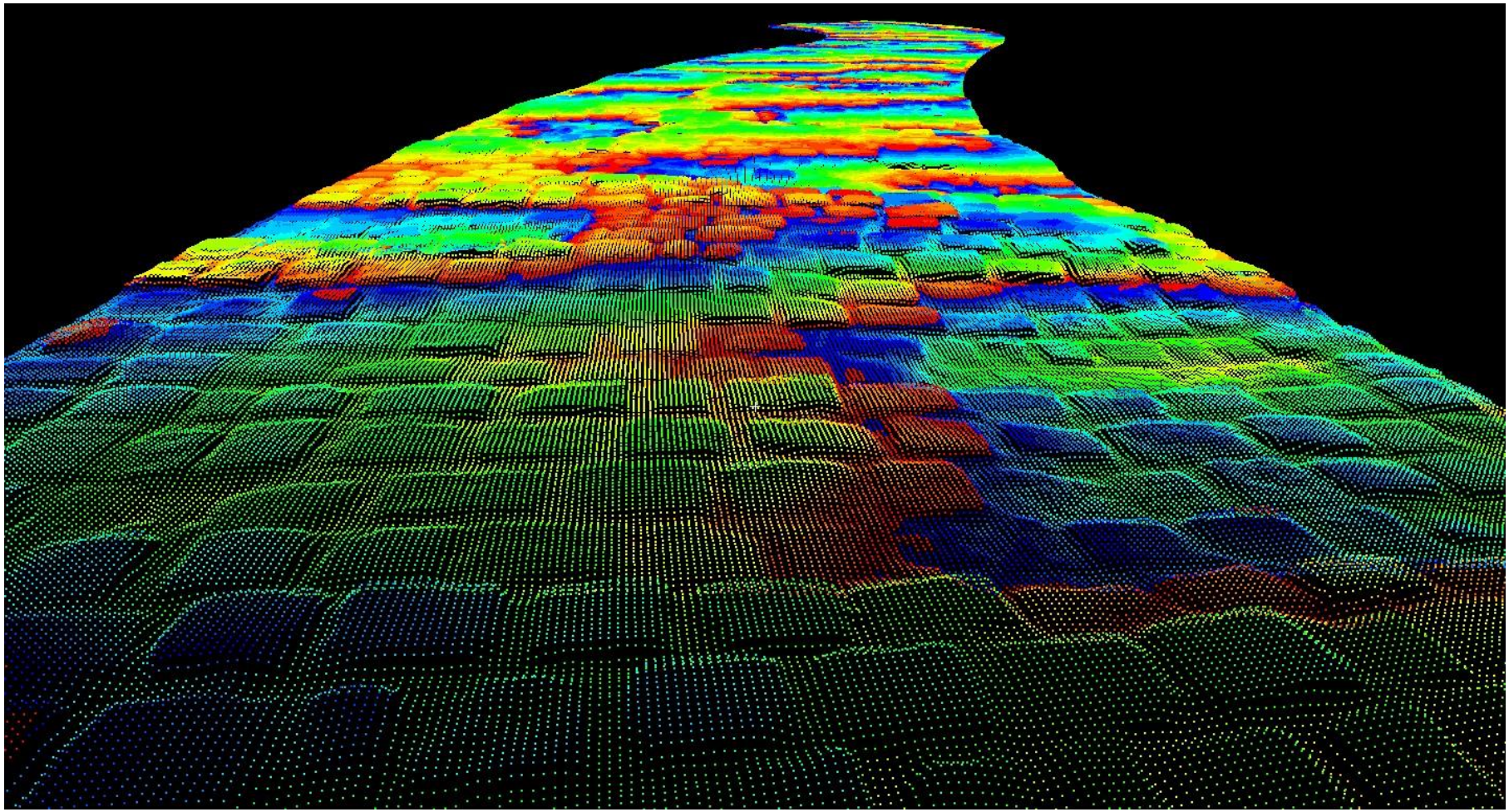


Intersection in OpenDrive including complete object information

Open Drive Data Production example

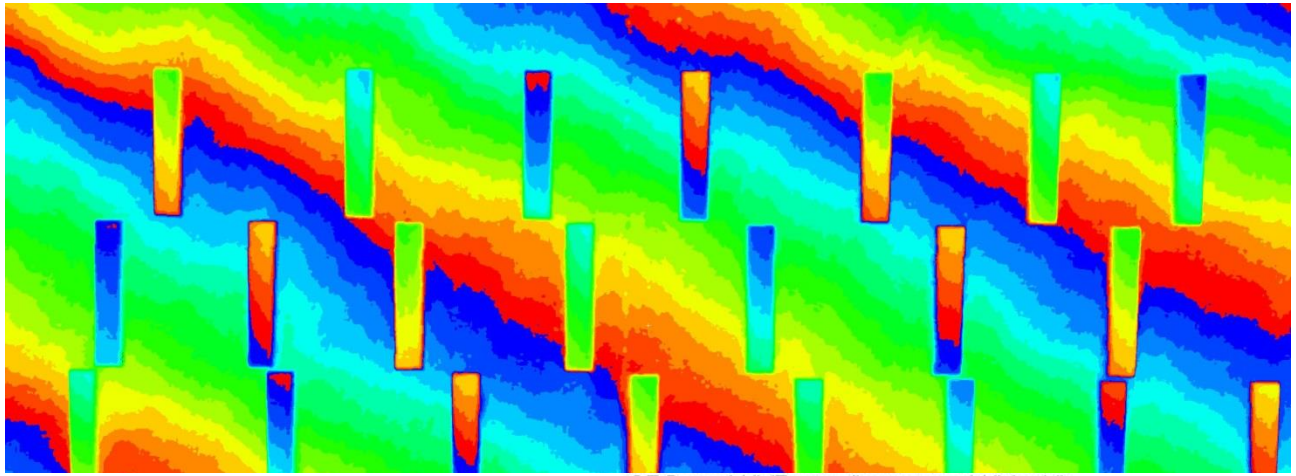
Example: inner city HAD Map data including all extracted geometry like curbs, markings, pedestrian walks etc.

High-Resolution Road Surface Model for race tracks and car test sites in OpenCRG format

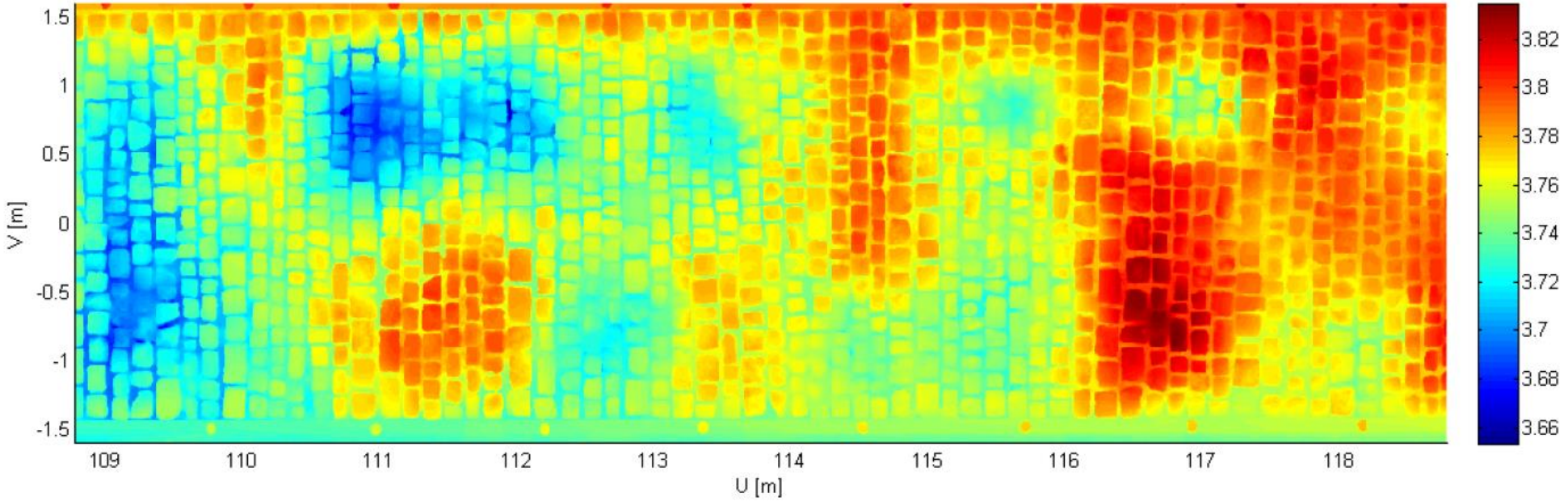


- Test track for vehicle dynamics testing
- resulting DTM with regular grid 5 x 5 mm and 0.1 mm height resolution

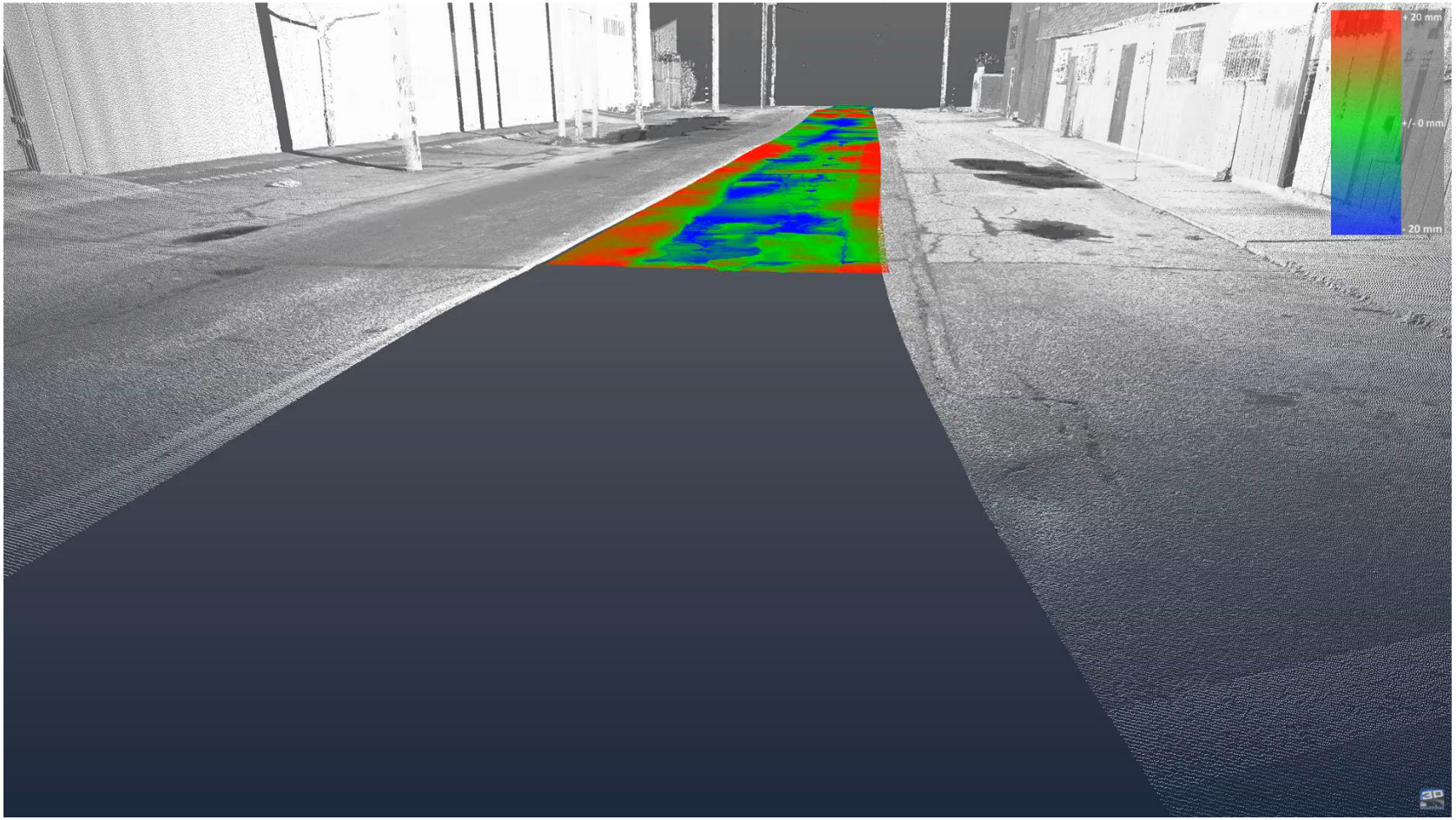
High-Resolution Road Surface Model for race tracks and car test sites in OpenCRG format



CRG road UVZ map (in uncurved UV grid)



High-Resolution Road Surface Model for race tracks and car test sites in OpenCRG format



- Test track for vehicle dynamics testing
- resulting DTM with regular grid 5 x 5 mm and 0.1 mm height resolution

Reference Implementation and Visualization

- 3D Mapping and virtualcitySYSTEMS propose a reference implementation and visualisation, so that every user and every developer can check and visualize an OpenDrive dataset.
- There have been approaches in this direction either by software manufacturers or OpenDrive users.
- What are the aims of a reference implementation and visualisation ?
    - Consistency - Are there problems with the interpretation of the OpenDrive dataset ?
    - Statistics - Which kind of data, features and attributes does the OpenDrive dataset contain ?
    - Visualisation - What you see is what you get …
    - OpenCRG and scenario visualisation might be included