中華民國 內政部 地政司
Dept of Land Administration, M. O. I.

HD MAPC | High Definition Maps Center

Piloting Autonomous Vehicles with HD Maps: Current Progress and Unsettled Problems

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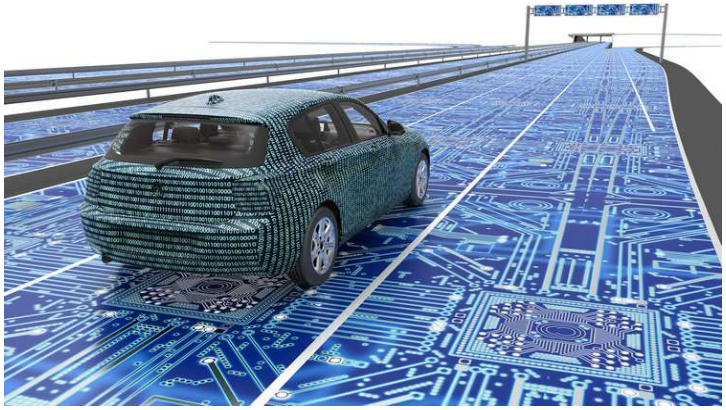
NATIONAL CHENG KUNG UNIVERSITY 1931
窮理致知

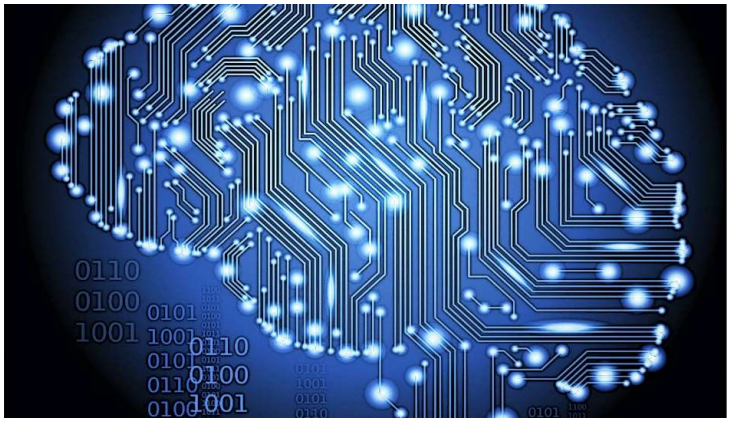
OpenDrive

AUTOWARE.AI

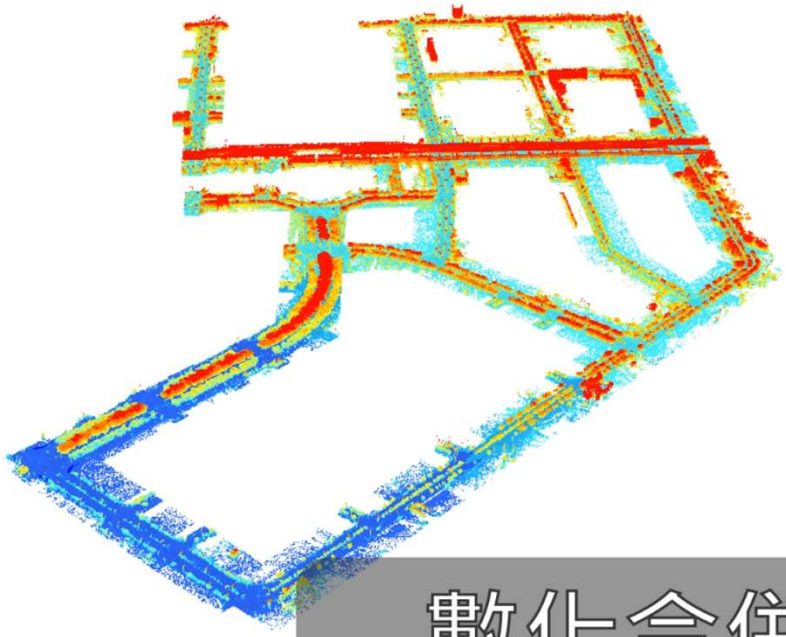
Outline

- Background
- What are HD Maps
- Who use HD Maps
- Recent Progress
- Unsettled issues of HD maps production
- MOI’ s solutions
- Concluding remarks





Together, we are mapping the future



數化合併成果展示

Background

- **Timeline of location based applications**

(Source: Carnegie Mellon)

- Self-driving
- Mobile Mapping

Finder LBSs
- Restaurants
- Gas stations
- ATMs ...

Phone supporting Java location API

GPS-capable phones

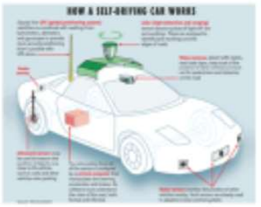
Phones with MEMS sensors

Smart home appliances

Wearables

LEO navigation signals

Now



(Source: the economist)

1996 2000 2005 2010 2015

US FCC passes E911mandate

3G networks

Commercial WiFi fingerprinting systems

RFID

Google Maps

Location-enabled social networks

Indoor LBS

Drones

LPWAN

AR/ VR

5G

(Source: iStockphoto/a-image)

(Li, et al., 2021)

Background

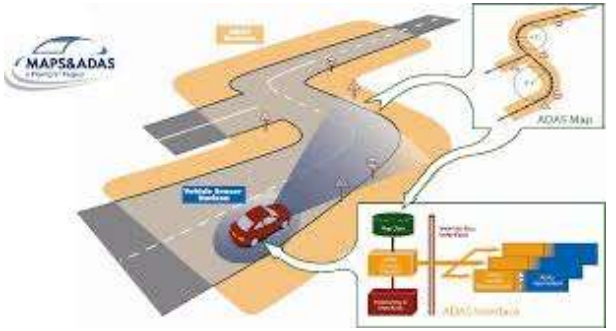
- **Evolution of electronic map**

Autonomous Vehicle
from 2012


HD MAPS
High definition map
(accuracy : 0.01-0.2m)

ADAS
Early 21st century


ADAS MAPS
Slop, curvature, gradient, traffic signs, speed restriction, lane at junction
(accuracy : 0.2-1m)



Navigation system
End of the 20st century

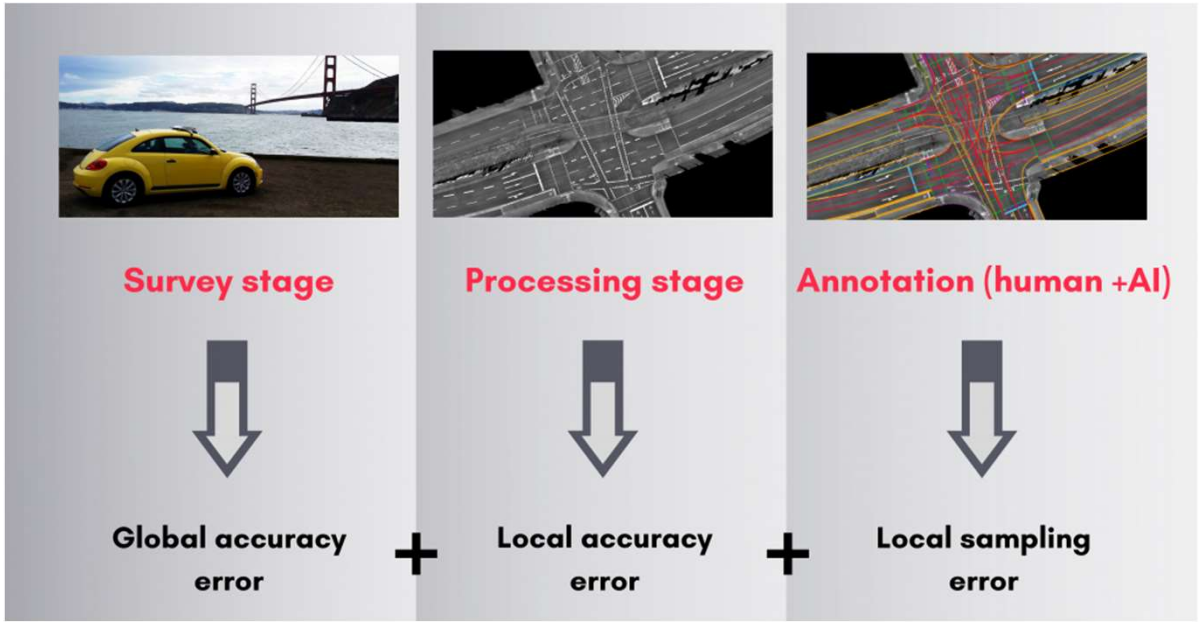

Electronic navigation map
GNSS, GIS
(accuracy : 5-10m)

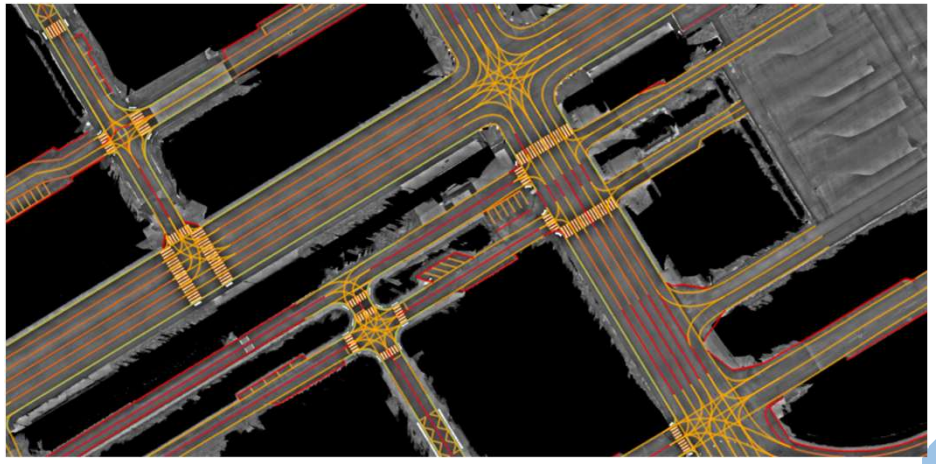
What are HD maps

- **The requirements of HD maps services**
  - **Challenges ahead (Book, 2021)**
    - Lack of common and standardized architecture
    - Sensor and map error estimates
    - Lack of infrastructure and/or government support
    - Multi-sensor (fusion) data use and validity
    - Verification and ground truth
    - Lack of data sharing
    - Data processing along the development chain
    - Ground truth/validation of quality/accuracy

What are HD maps

- **Accuracy requirements**

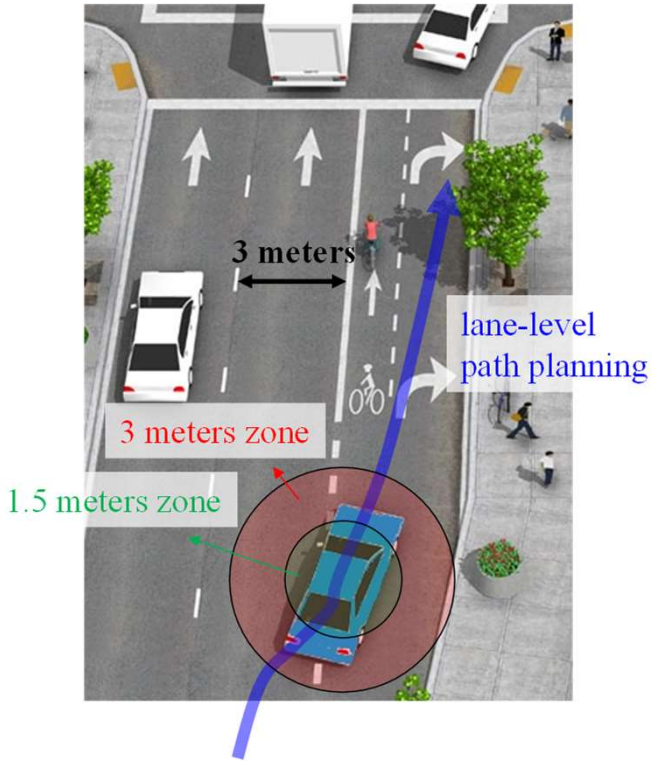


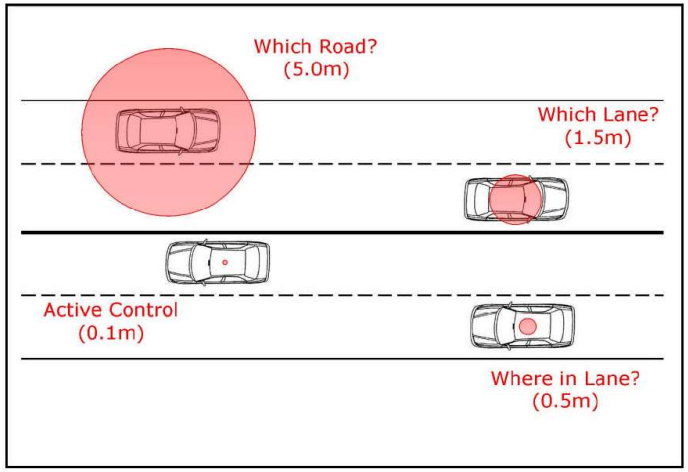


(Dahlström, 2021)

What are HD maps

- **Accuracy requirements**





- ***HD maps absolute accuracy (Localization support)***

Taiwan: Horizontal: 20 cm, 3D: 30 cm

Japan: Horizontal: 25 cm, 3D: 35cm

Korea: Horizontal: 25cm, 3D: 35cm

- ***HD maps relative accuracy (Labeling/Perception support)***

Taiwan 1~2 cm (1st class), 4-10 cm (3rd class)

(1st class PCD) (2.5k-10Kpts/m^2) (Mapping grade)

(3rd class PCD) (0.1K-0.4Kpts/m^2) (Navigation grade)

Japan : 1~5 cm

Others: 1~10 cm

	Total Error Budget (map + vehicle) [meters 2sigma]	Map Error [meters 2sigma]	Vehicle Positioning Error [meters 2sigma]
WHICHLANE	1.5	0.5	1.0
WHEREINLANE	0.5	0.2	0.3

(CAMP, 2004)

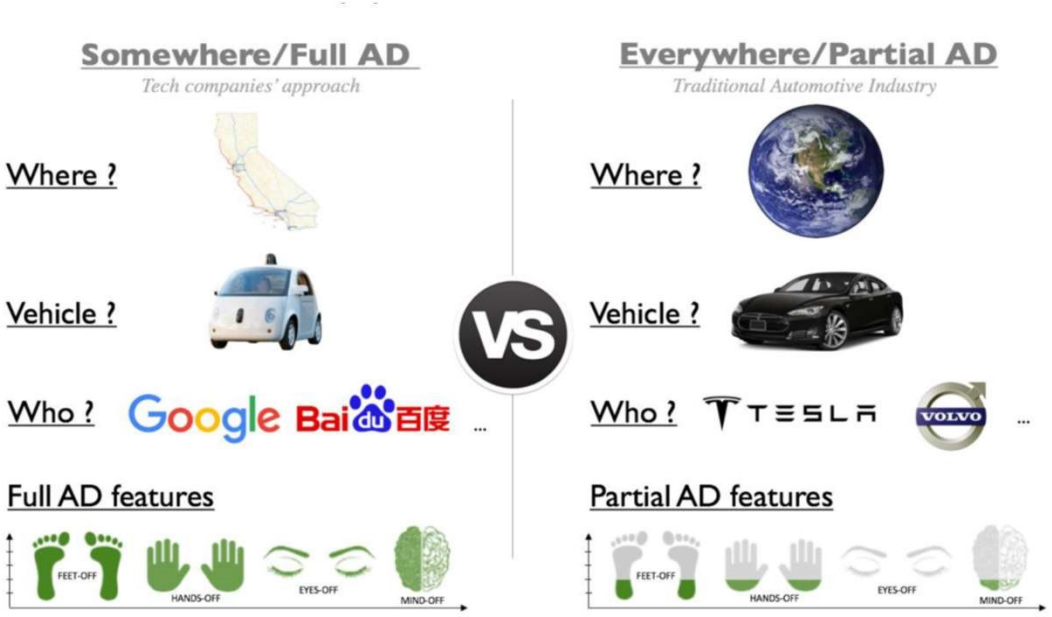
Who needs HD maps

- **Autonomous vehicles and HD maps**
  - ➢Different levels of self-driving have different content and accuracy requirements for the map

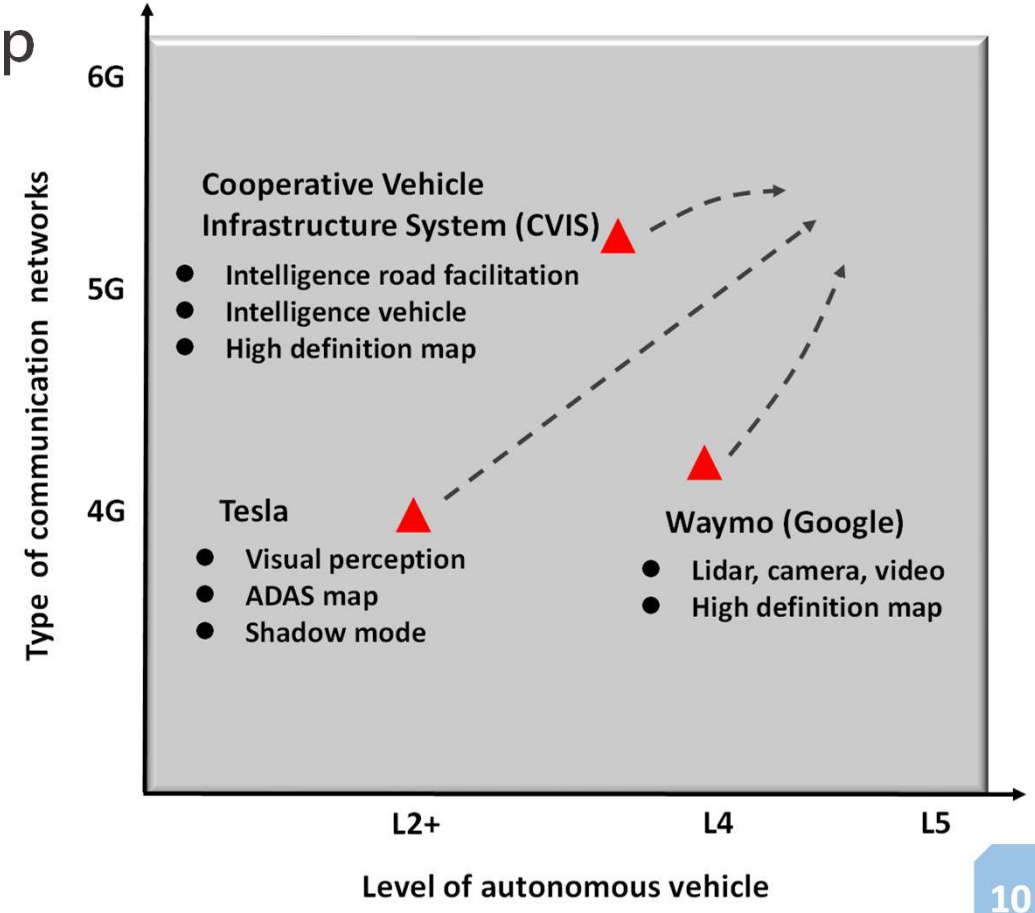
Level	Title	Map	Accuracy of map	Typical conditions
Driver scenario				
1 (DA)	Driver Assistance	ADAS map	Submeter level	Optional
2 (PA)	Partial Automation	ADAS map	Submeter level	Optional
Automatic driving system (“system”) scenario		ADAS map + HD map	Submeter level Centimeter level	Required
3 (CA)	Conditional Automation			
4 (HA)	High Automation	ADAS map + HD map	Submeter level Centimeter level	Required
5 (FA)	Full Automation	HD map	Centimeter level	Required (update automatically)

Who needs HD maps

- **Autonomous vehicles and HD maps**
  - ➢Different AV technology roadmap



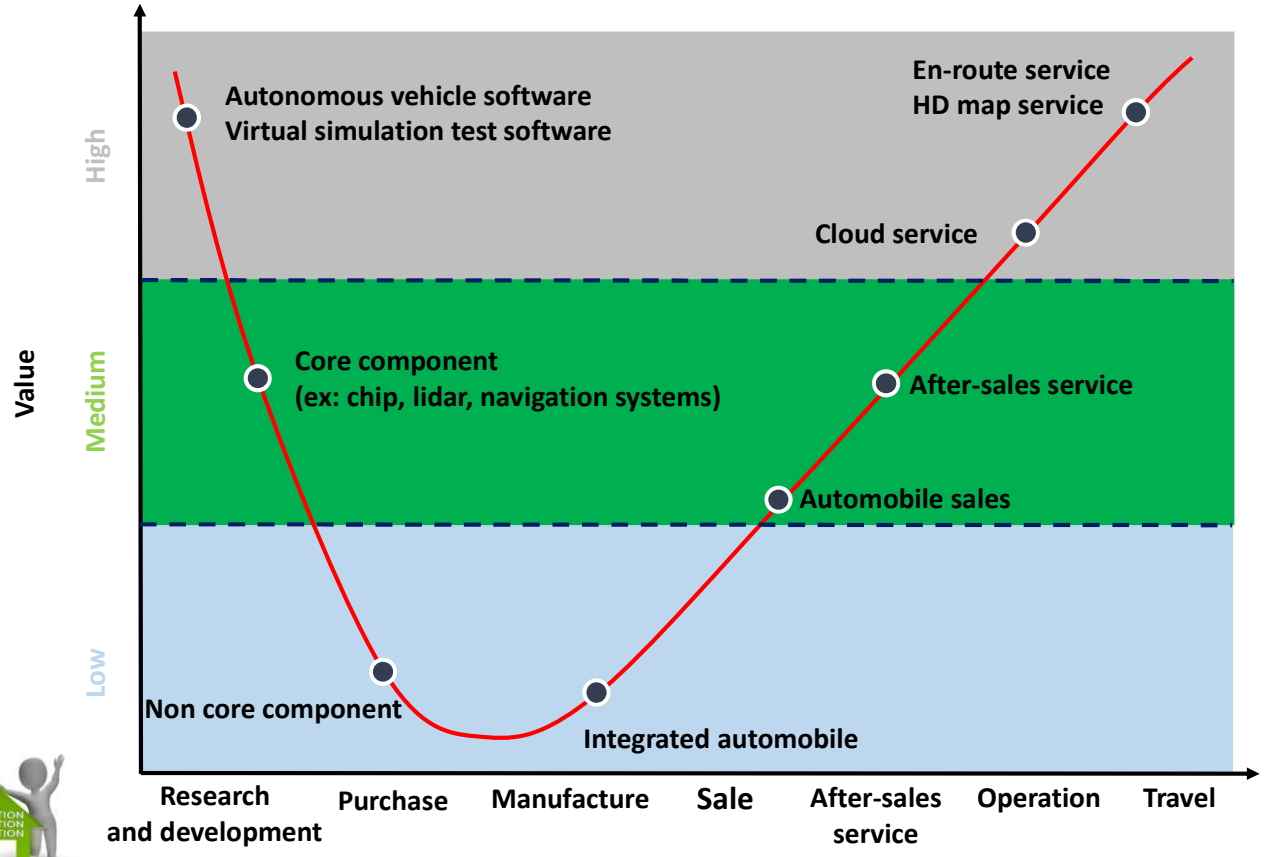
(Heng, 2020)



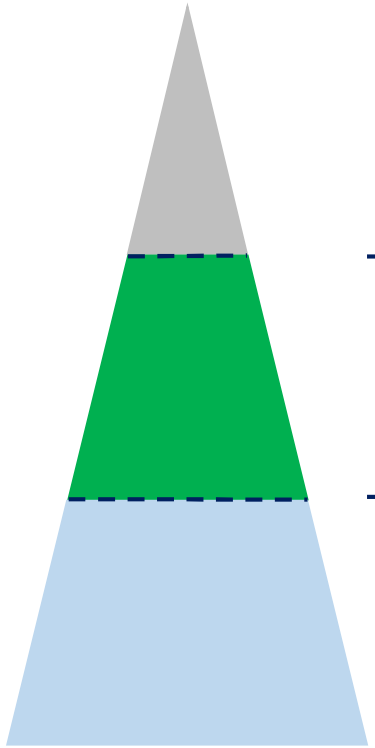
Who needs HD maps

- **Autonomous vehicles and HD maps**

The Smiling curve of automobile industry chain



Value distribution of automobile industry chain



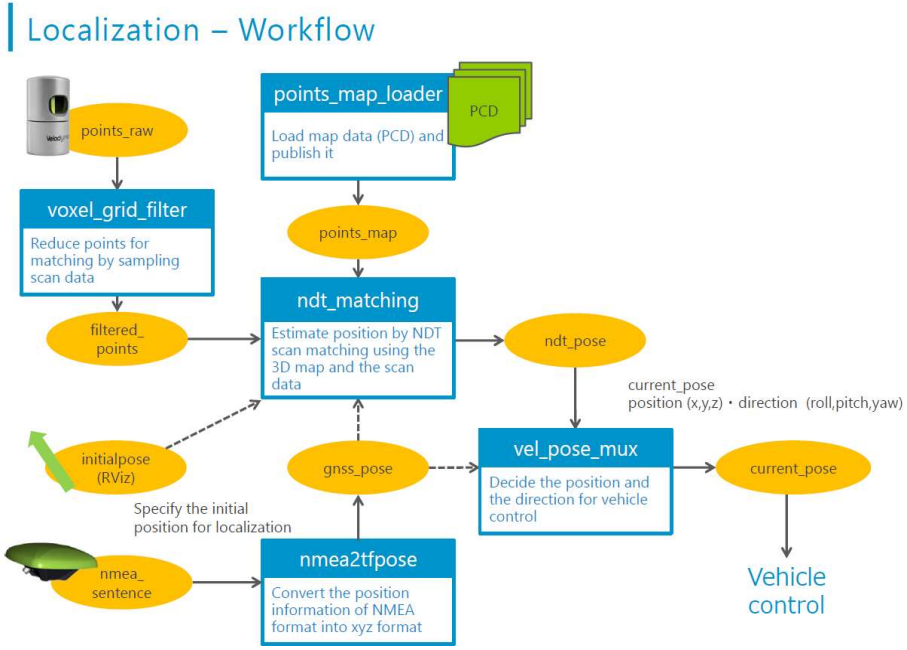
- En-route service
- HD map service
- Autonomous vehicle software
- Virtual simulation test software
- Cloud service

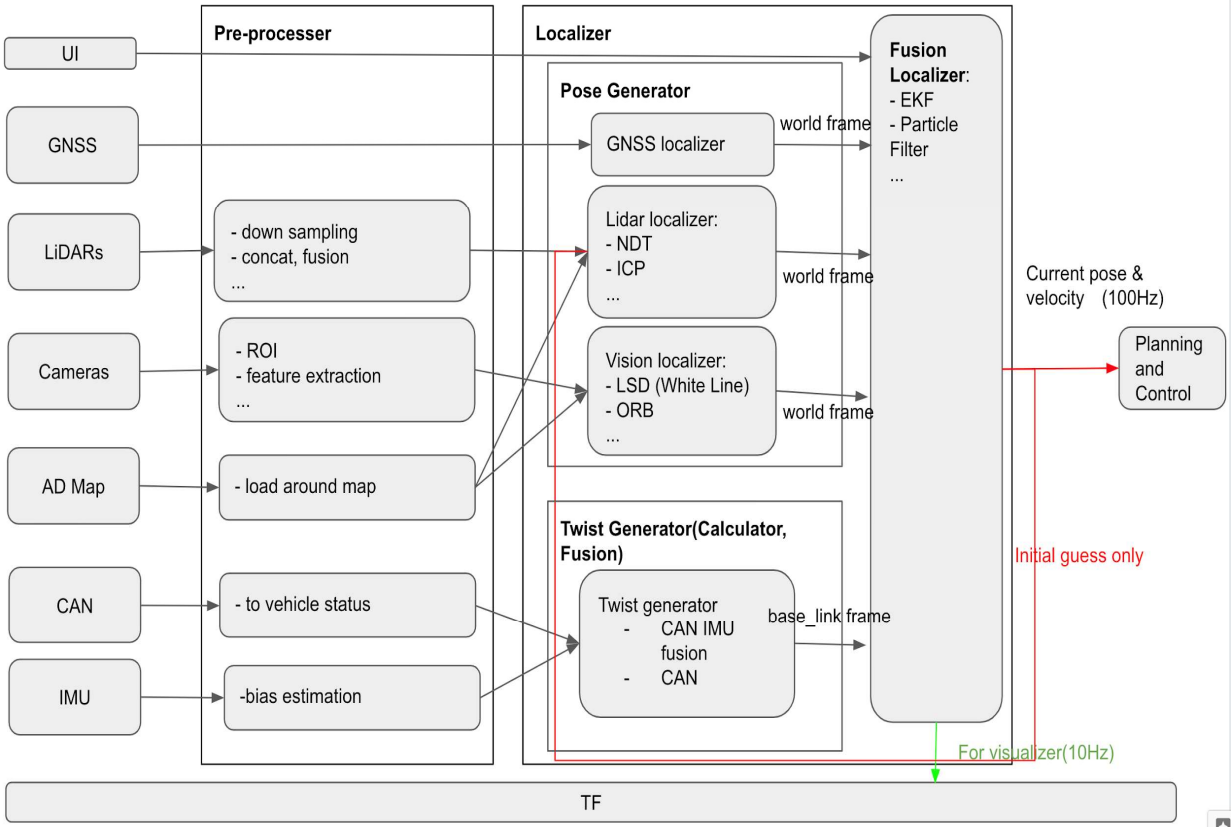
- Core component (ex: chip, lidar navigation systems)
- After-sales service
- Automobile sales

- Integrated automobile
- Non core component

Who needs HD maps

- **Do AVs need HD Maps?**
  - ➢ Autoware (Level 4)

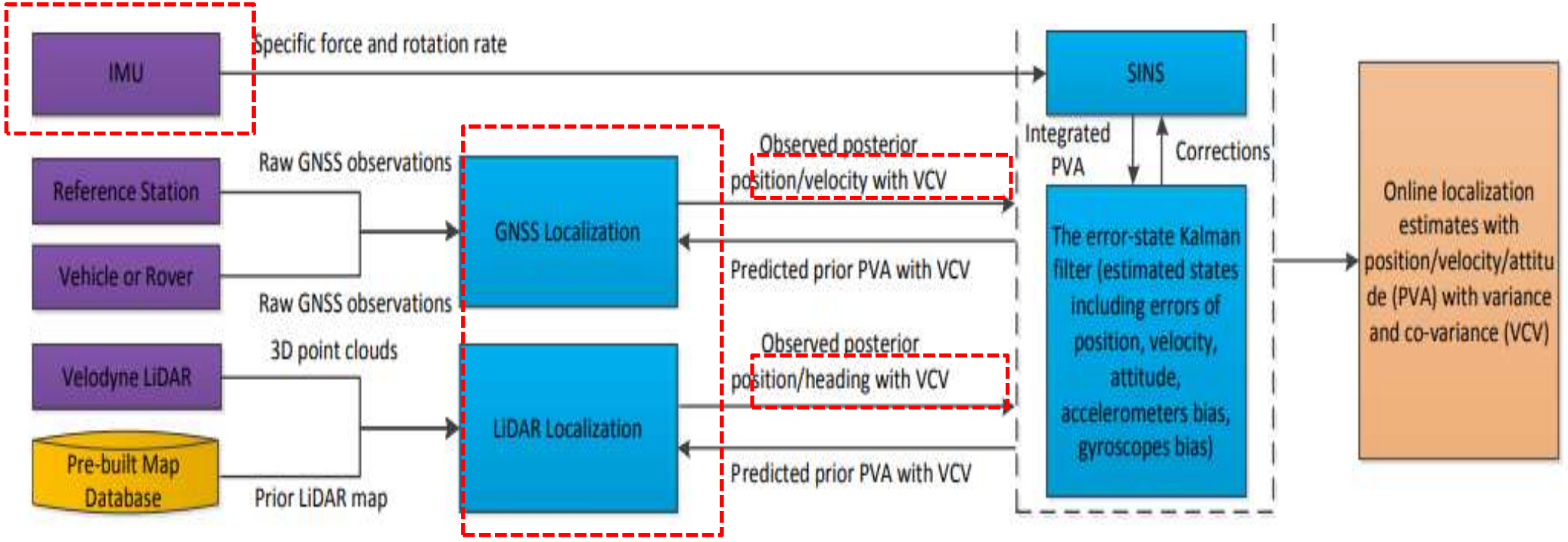




The current Autoware depends only on LiDAR (ndt_matching). Other inputs such as GNSS, CAN, and IMU are used to guess initial search position in ndt_matching algorithm. It is difficult to scale up scenarios which Autoware can drive.

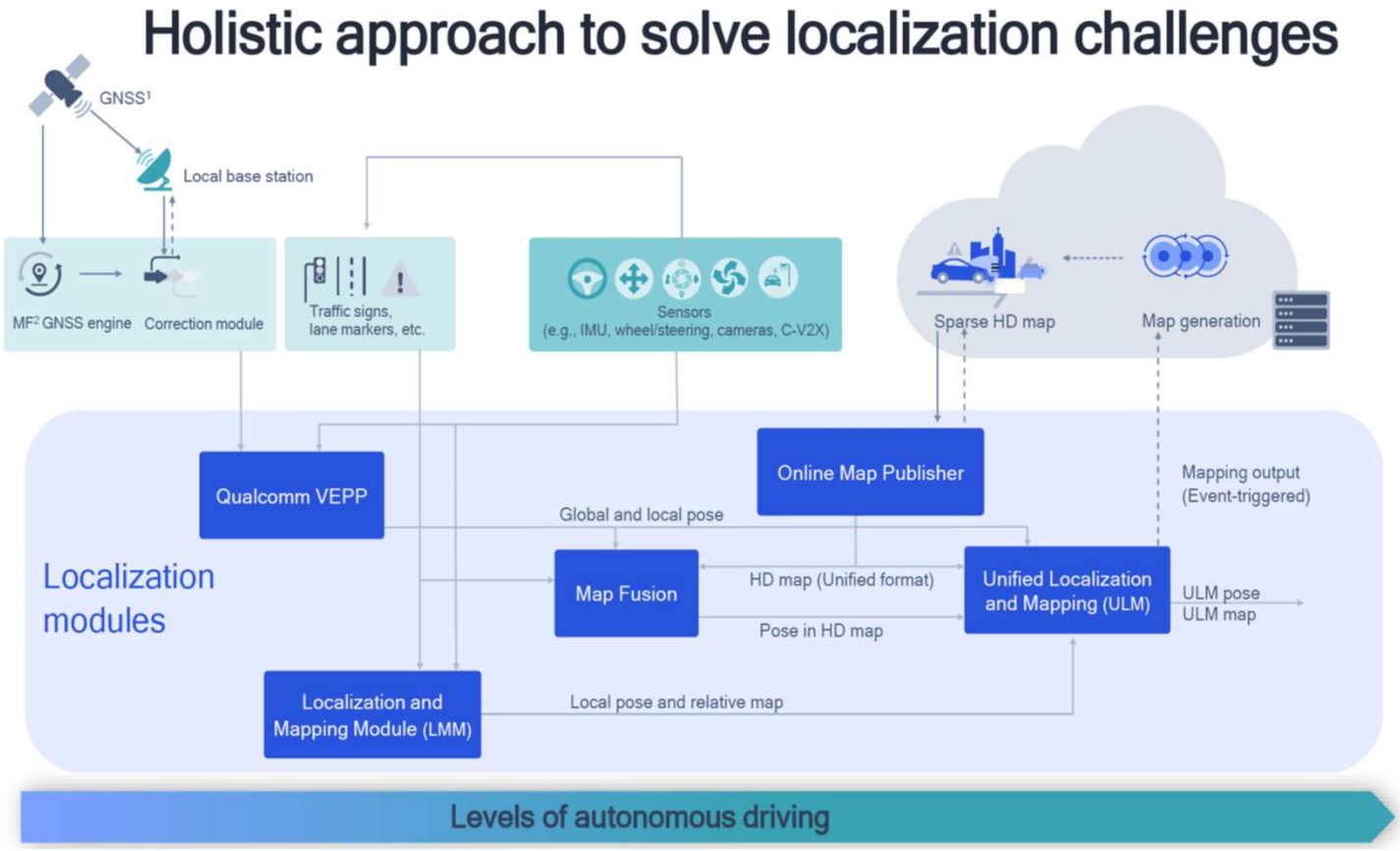
Who needs HD maps

- **Do AVs need HD Maps?**
  - Apollo (Level 4)



Who needs HD maps

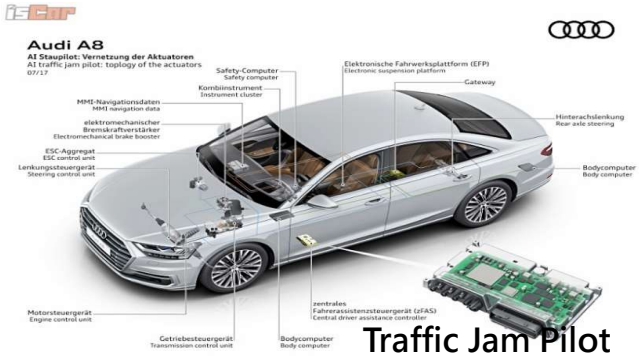
- **Do AVs need HD Maps?**
  - Qualcomm (Level 3)



(Ahuja, 2021)

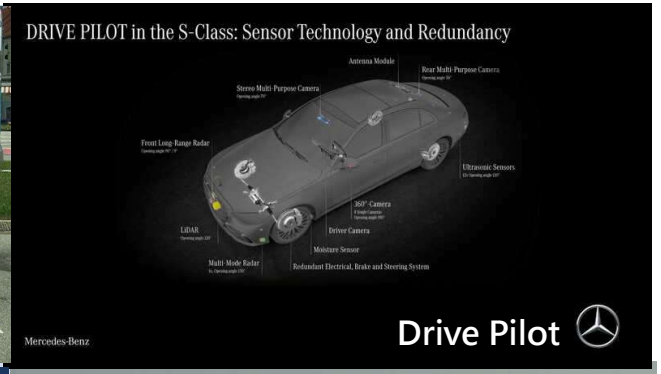
Who needs HD maps

- **HD maps piloted AVs from Tier 1 car makers (Level 3)**



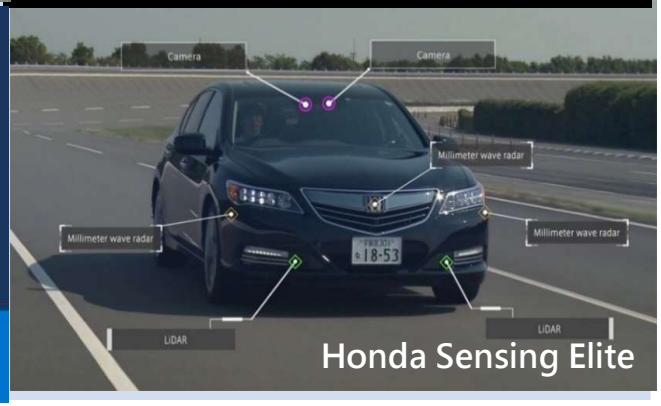
Traffic Jam Pilot

Copilot



Drive Pilot

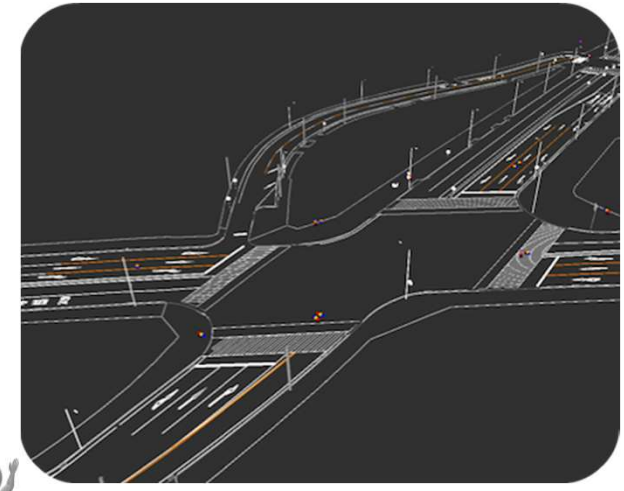
Ride Pilot

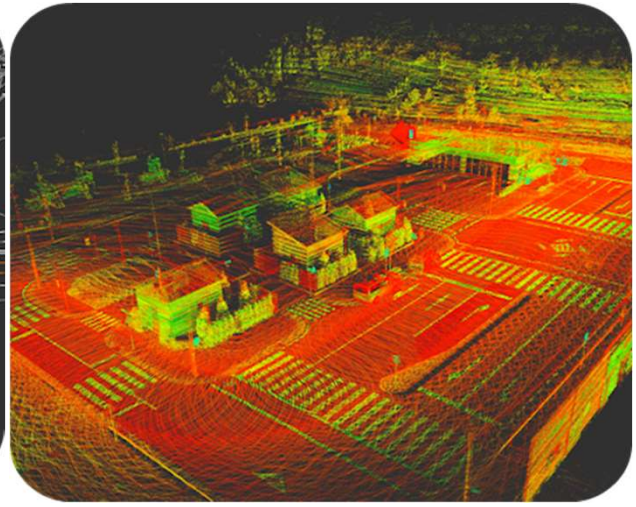


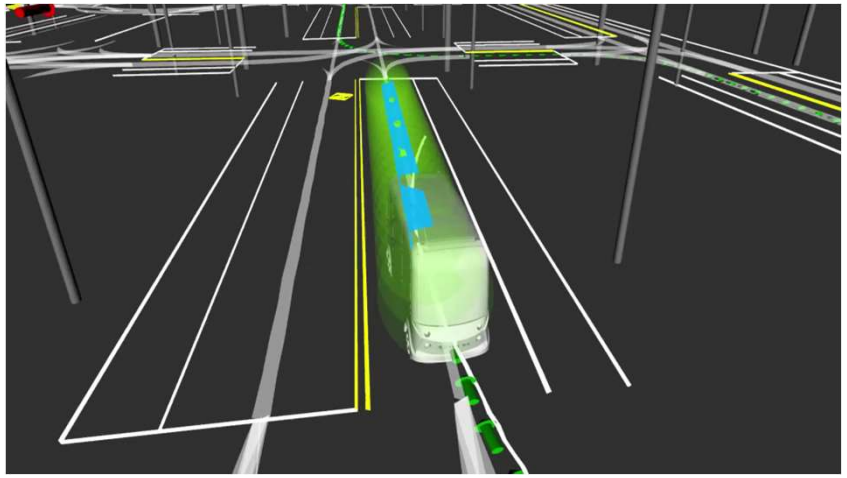
Honda Sensing Elite

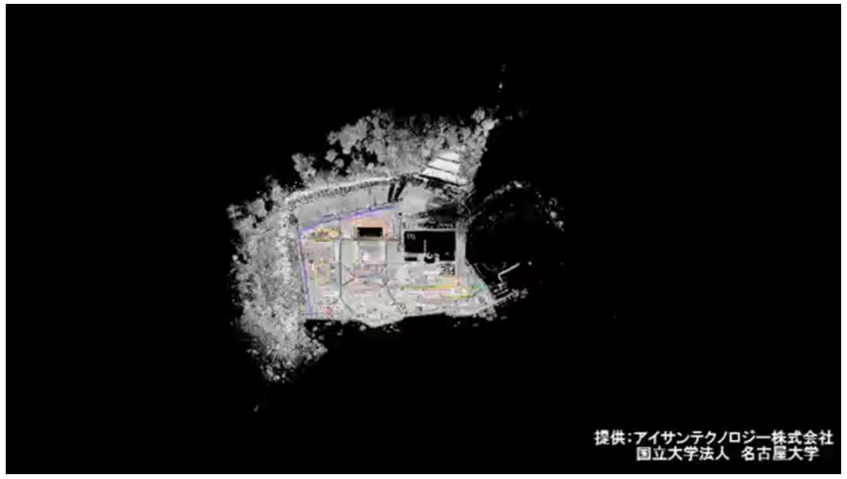
Recent progress

- **Autoware' s approach**
  - Point cloud layer for localization
  - Vector map layer for perception and route planning
    - Asian Vector Map for autoware.ai
    - Lanelet2 for autoware.auto (now)
    - OpenDRIVE for autoware.auto (future)





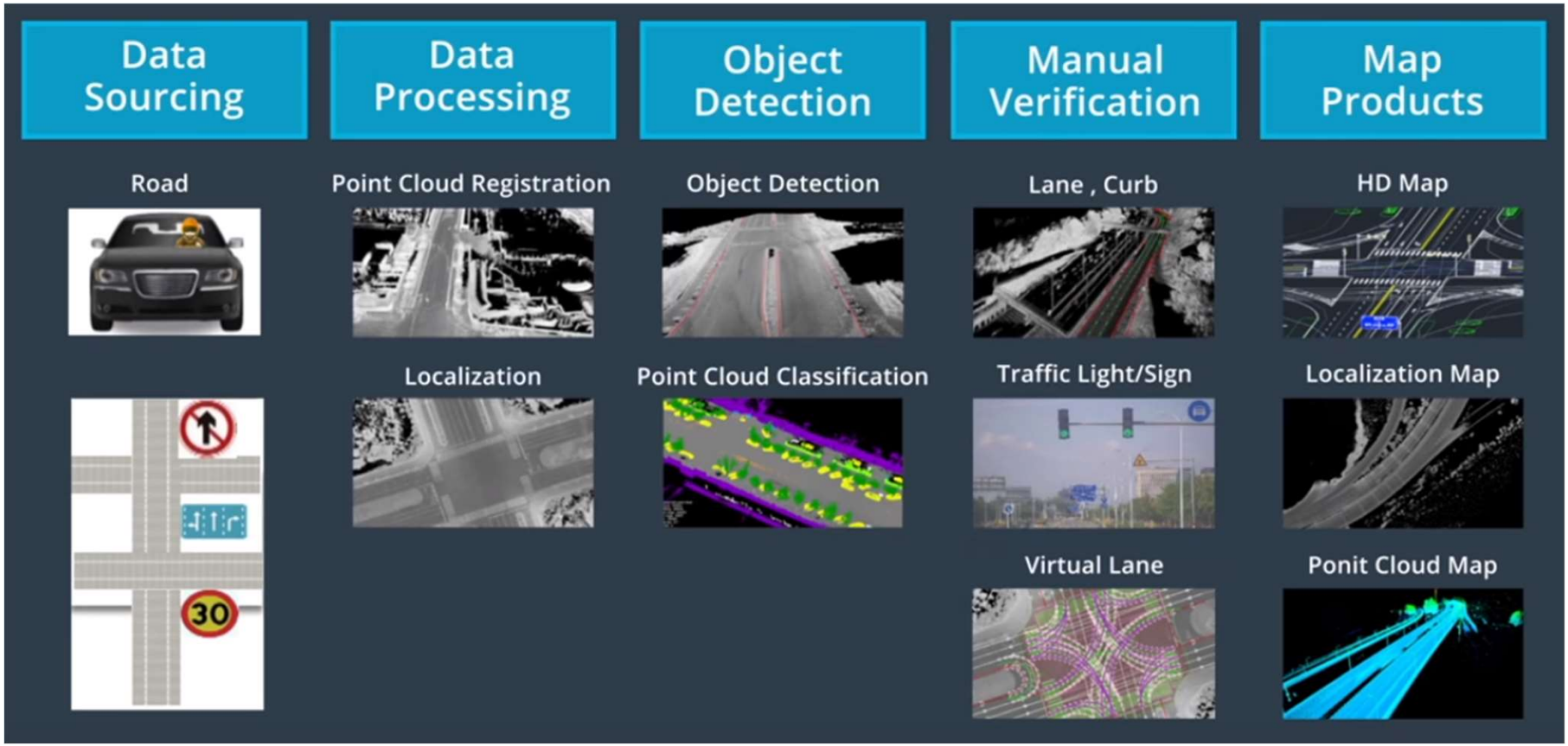




(Courtesy of Nagoya University)

Recent progress

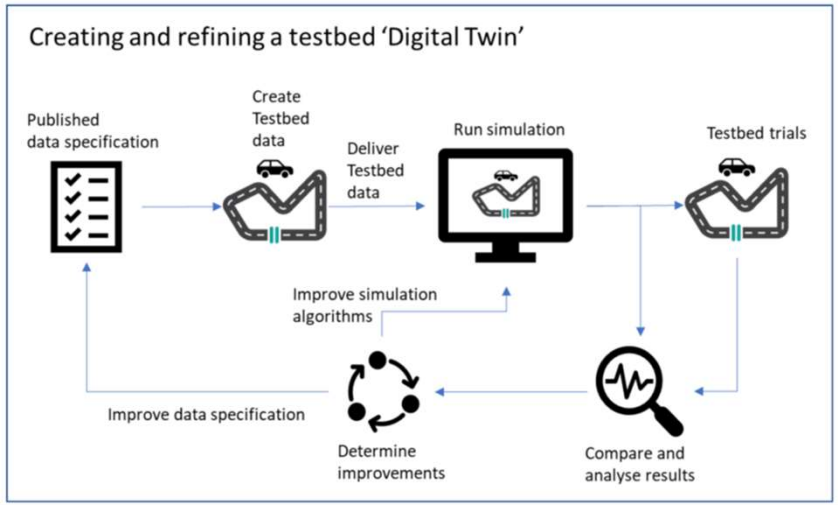
- **Apollo's approach**



http://road2ai.info/2018/08/11/Apollo_02/

Recent progress

- **UK's recommended Geodata (HD Maps)format for autonomous driving applications (Ordnance Survey)**



Format	Purpose
LAS 1.2 or LAZ (compressed form of LAS)	Point cloud data capture for identification, extraction and modelling of terrain and key features
OBJ	Good for representing the terrain and 3D objects such as buildings
OpenDRIVE	Good for describing track-based road networks
ESRI shapefile	A portable format good at representing a wide range of specific key features and their attributes

(Zenzic, 2020)

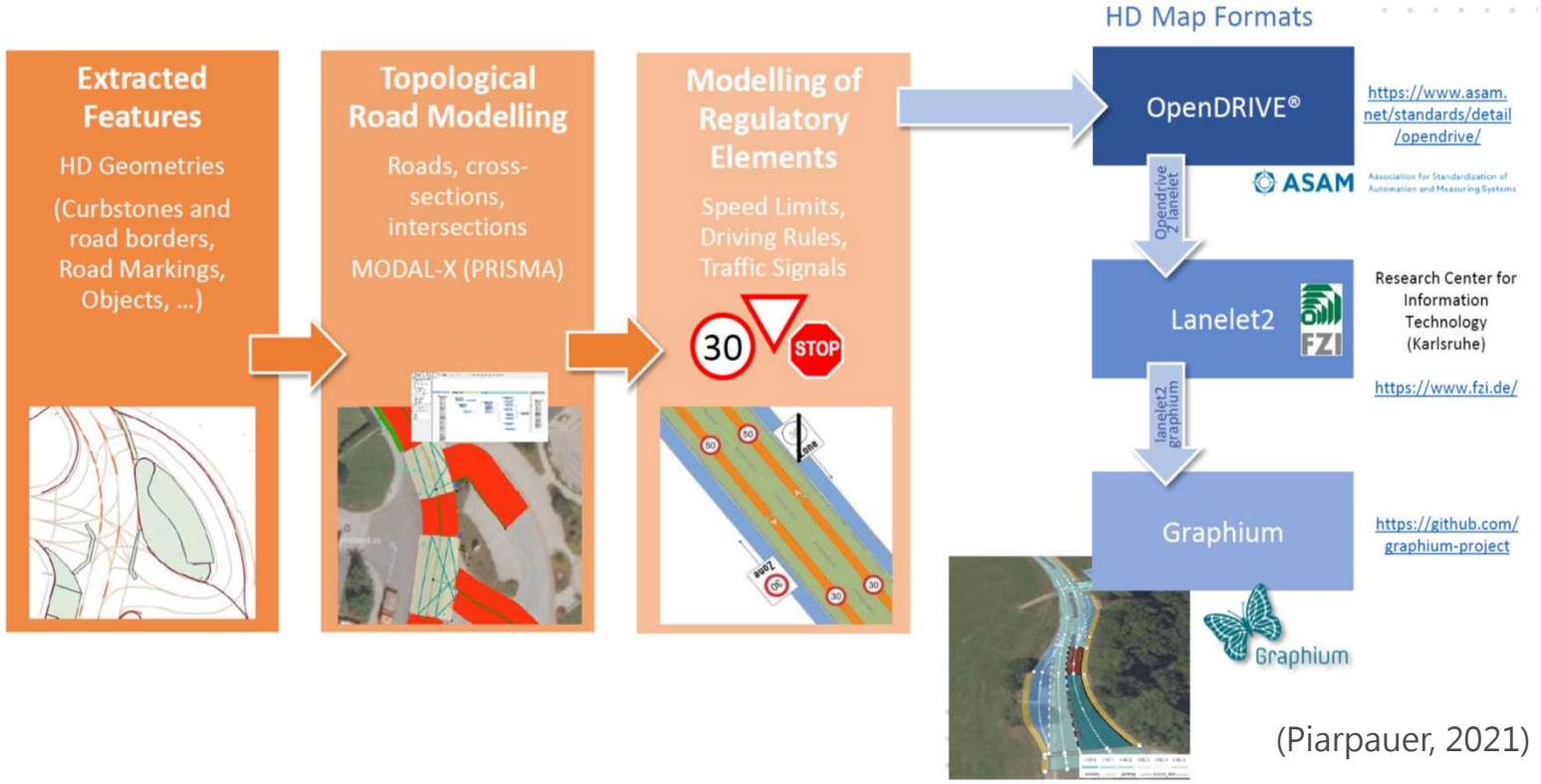
Recent progress

- **SHOW project (European Union's Horizon 2020 program)**
  - 8 test sites in EU join this project

Site/format	Lanelet2	OpenDRIVE	Others
Salzburg	o (current)	o (current)	
Madrid	o (current)	o (current)	
Karlsruhe	o (current)	o(future support)	
Brno		o(Apollo)	o
Rouen		o(Apollo)	o
Graz			o
Tampere			o
Aachen			o

Recent progress

- **Digibus® Austria project (AIT funded project)**
  - ➢Austrian flagship project for automated driving
  - ➢OpenDRIVE to Lanelet2 conversion



(Piarpauer, 2021)

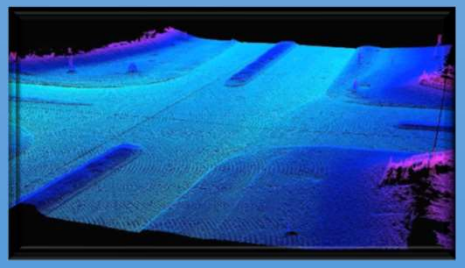
Recent progress

- **Taiwan HD maps (For level 4 or up)**

MOI(Standardization/establishment of base map)

End user (Applications)

(Certified point clouds,LAS)



(Certified vector maps, SHP)

Taiwan HD maps
OpenDrive+extension

- Open format
- Common base map
- Local extension
- Interoperability
- Quality assurance
- Support to end user format conversion

OpenDrive

Map maker
Autonomous vehicles

- OpenDrive
  - Variants
- Autoware
- NDS
- DMP
- Lanelets
- Others
- Conversion to be done by end user

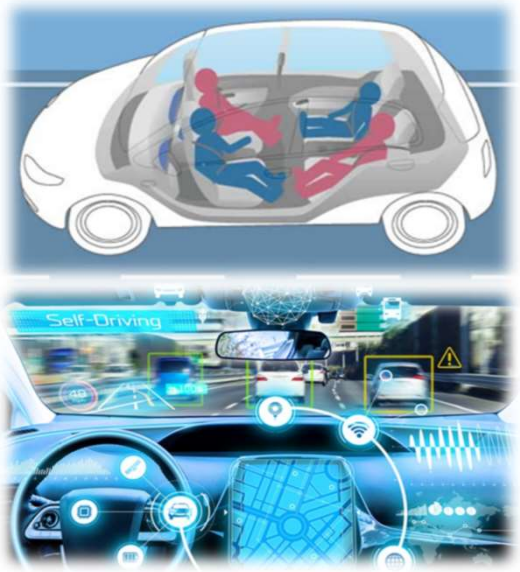
Recent progress

- **Taiwan HD maps alliance**

Government

Institutions

Geospatial industry



Other industry partners

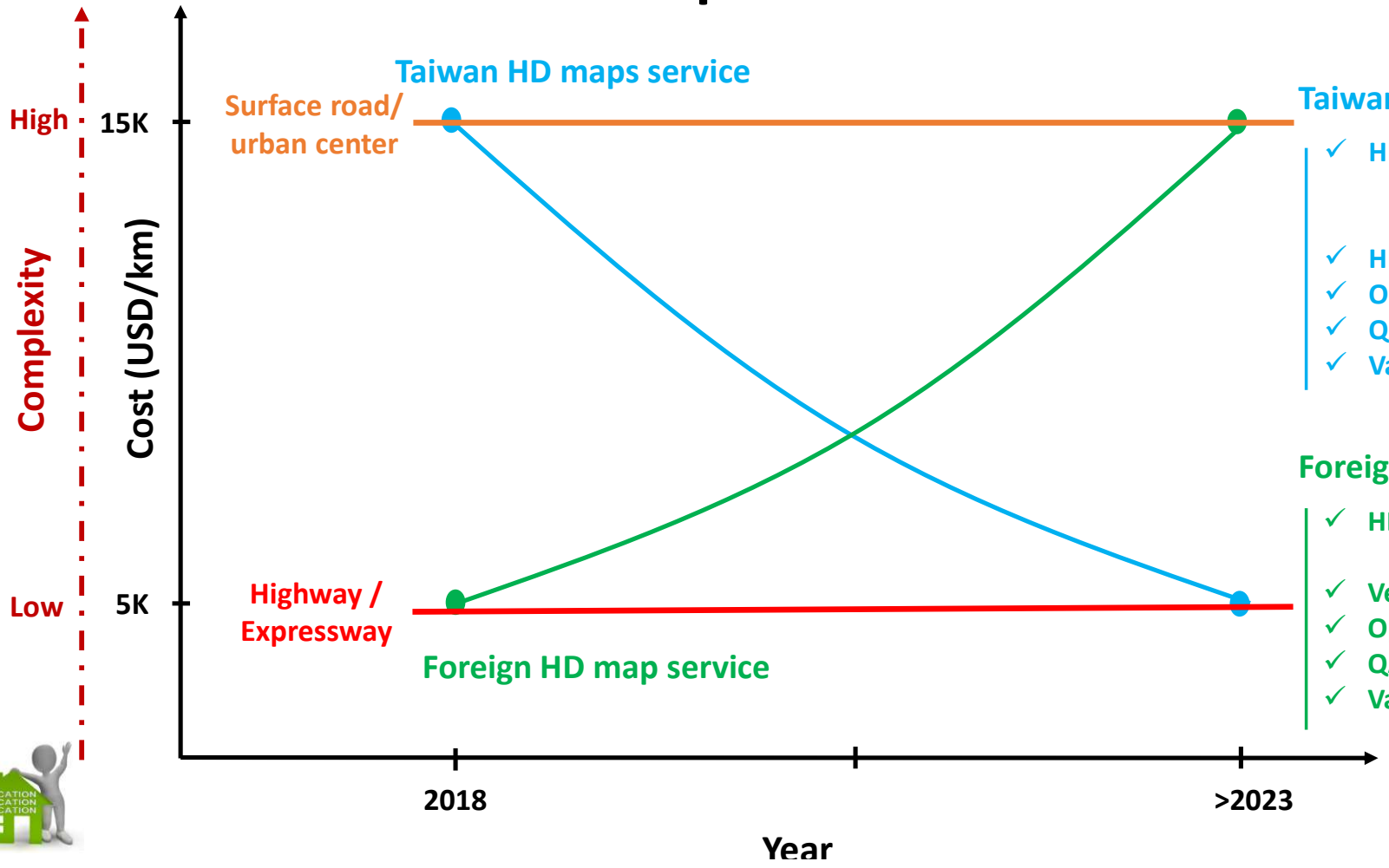
ZATiTECH wistron THINKTRON
ZENRIN Japan Asia Group KOKUSAI KOGYO TURING 台灣智慧駕駛股份有限公司
LILEE SYSTEMS MIH NovAtel METI Civil Maps
MSC Software FOXCONN 鴻海科技集團 AIROHA Airoha Technology Corp.

Unsettled issues on HD Maps for AD

- **Four primary issues to be answered (Book, 2021)**
  - Initial map creation—economics and feasibility of scaling HD map creation worldwide
  - Bend the production curve
  - Map change detection and updates—how changes in map content are detected and how a map is updated
  - Map safety levels—how map content is validated in order to contribute to system safety
- **Extended issues to be exploited answered (Book, 2021)**
  - Standardization
  - Cloud and data processing
  - Privacy and security
  - Crowd sourcing
  - Regulatory and infrastructure support

MOI's solutions

- **Production cost comparison**



Taiwan

- ✓ HD PCD Map (Standard)
  - Mapping grade (2500 pts/m2)
  - Navigation grade (100-400 pts/m2)
- ✓ HD Vector map (Standard)
- ✓ OpenDRIVE + Lanelet2 (Standard)
- ✓ QA / QC (External)
- ✓ Validation (Standard)

Foreign service

- ✓ HD *.pcd (Optional)
  - Navigation grade (100 pts/m2)
- ✓ Vector map (Standard)
- ✓ OpenDRIVE + Lanelet2 (Optional)
- ✓ QA / QC (Internal)
- ✓ Validation (Optional)

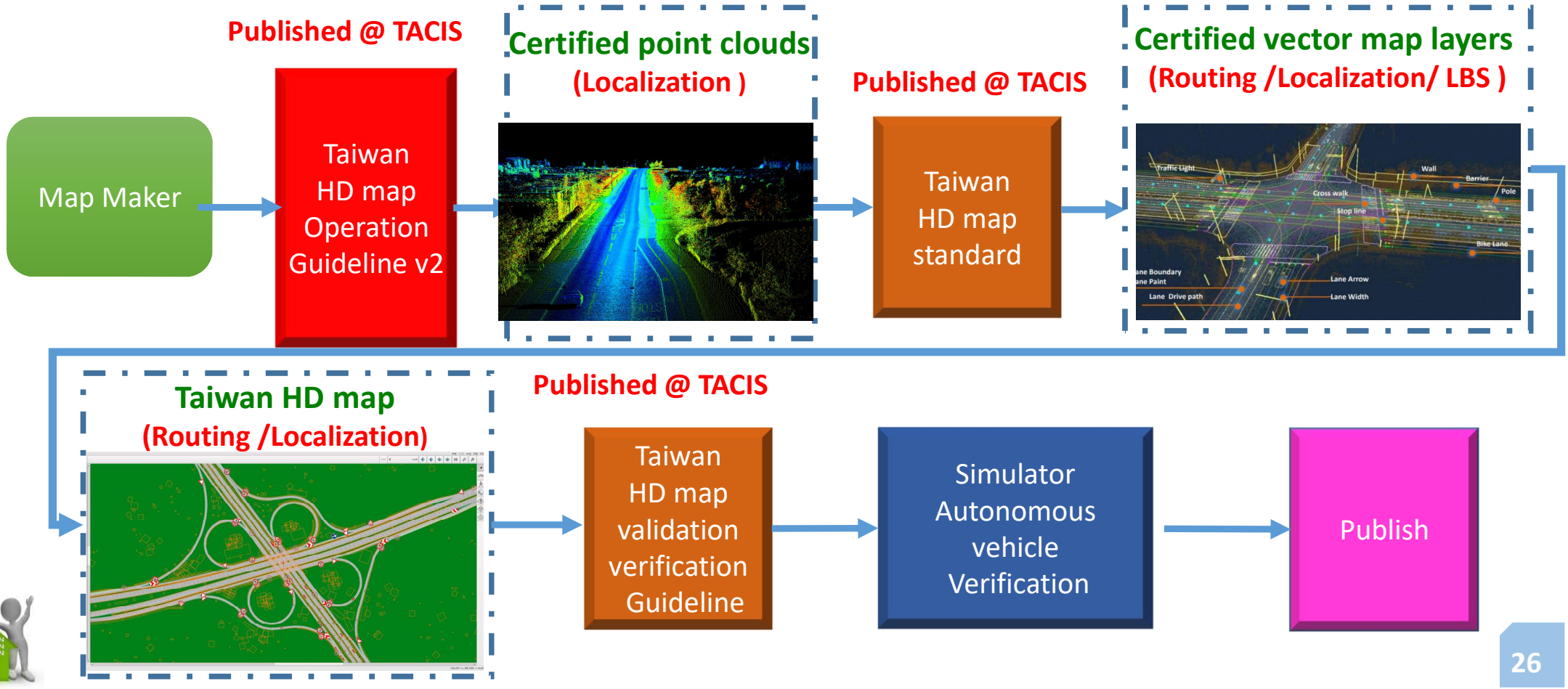
MOI’s solutions

- **Publishing related technical guidelines and standards**

Technical documents	Time	Activities
HD Maps Operation Guidelines v2	2019.10.17	Published @ Taiwan Association of Information and Communication Standards (TAICS)
Verification and Validation Guideline	2020.05.22	Reviewed @ (TMC#11, TAICS)
	2020.06.05	Published @ TAICS
HD Maps Data Content and Format Standards v1.1	2020.03.16	Published @ TAICS
	2020.06.12	Updated and published @ HD Maps Research Center
Operation and verification Guideline for HD maps Updating –Permanent Static Data	2021.10.21	Published @ TAICS
Standard and test specification for Intelligent driving care sensing data format	2021.10.21	Published @ TAICS

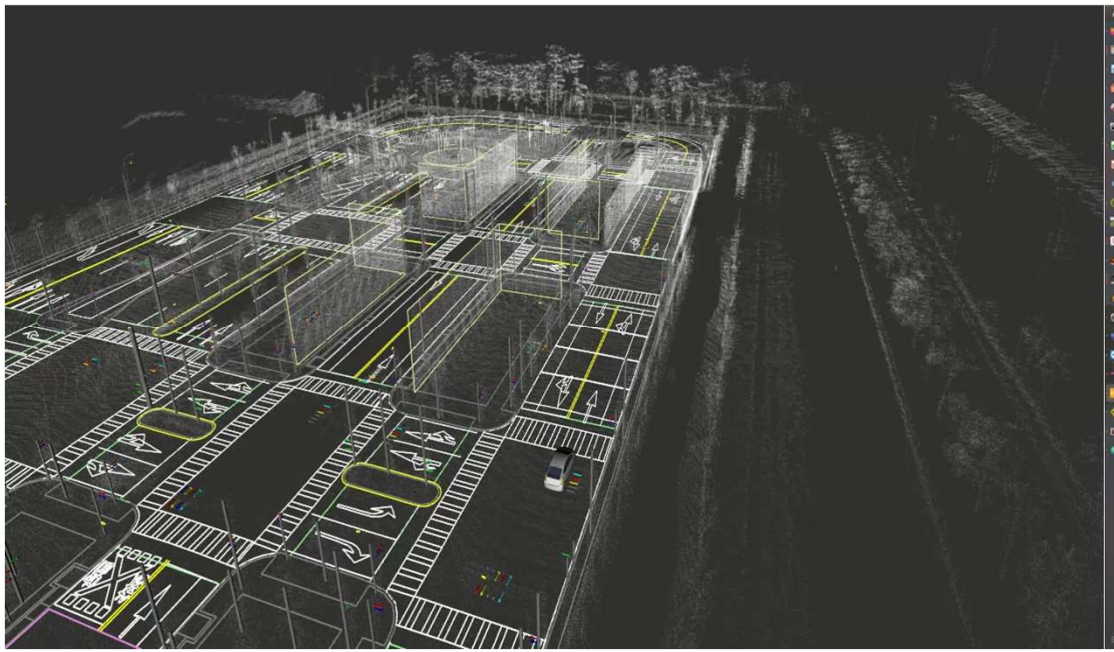
MOI’s solutions

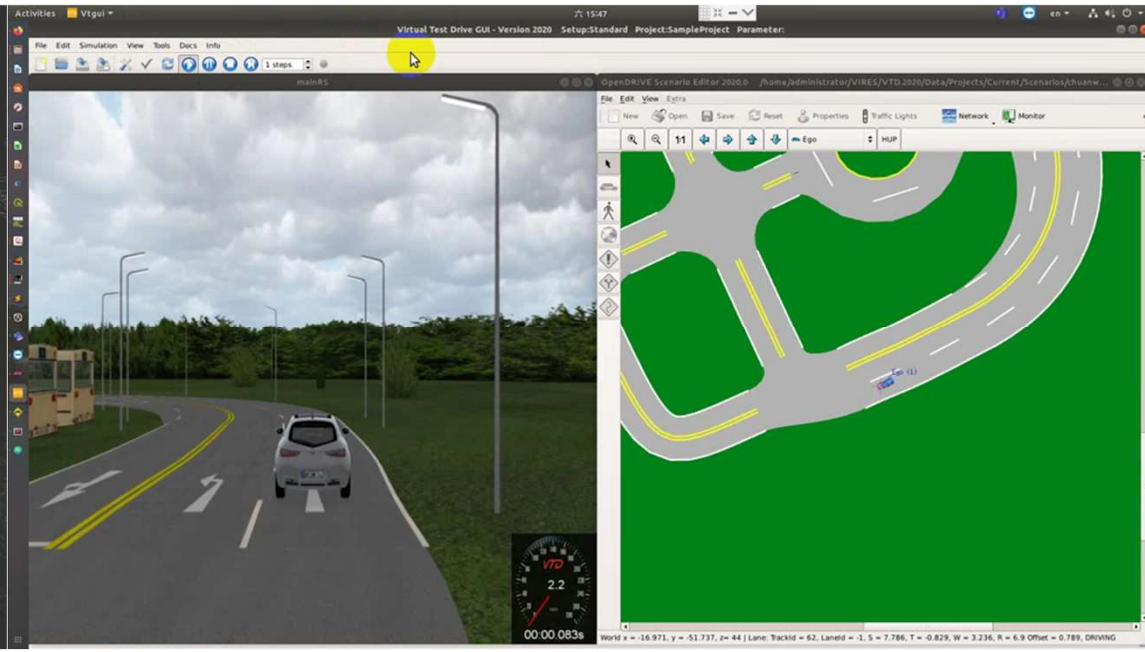
- **MOI’s recommended steps for HD maps production**



MOI’s solutions

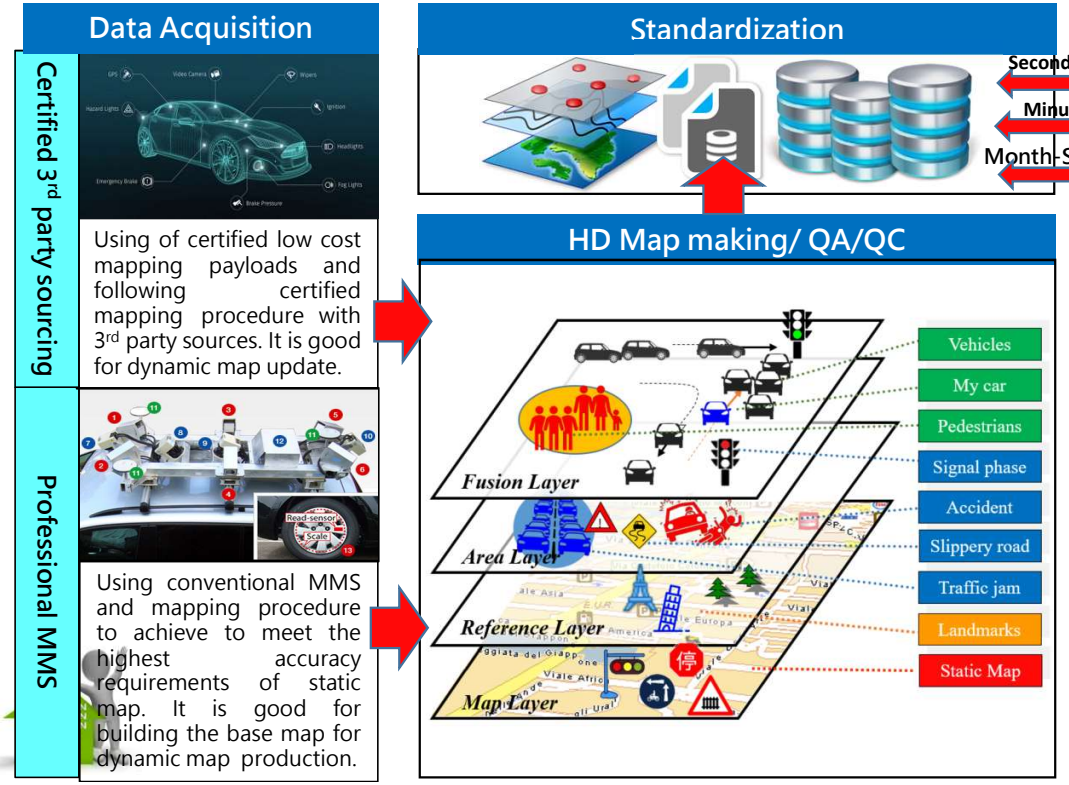
- **HD maps verification with simulator or real ADV**



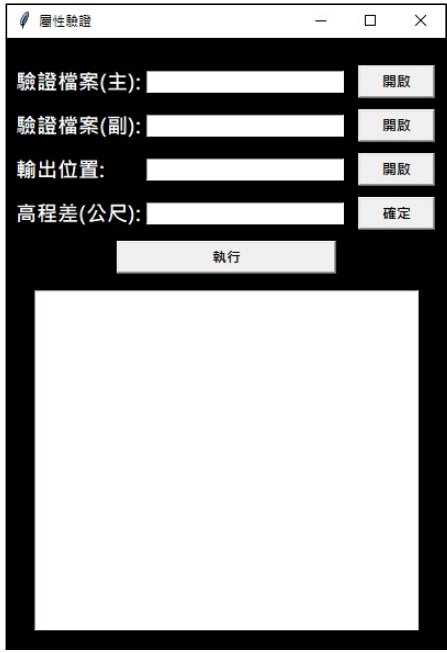


MOI's solutions

- **Flexible and fresh data acquisition and mapping service**
  - Professional MMS for base map and low frequency update
  - 3rd party sourcing for rapid/ near real time map update



Automated verification tool

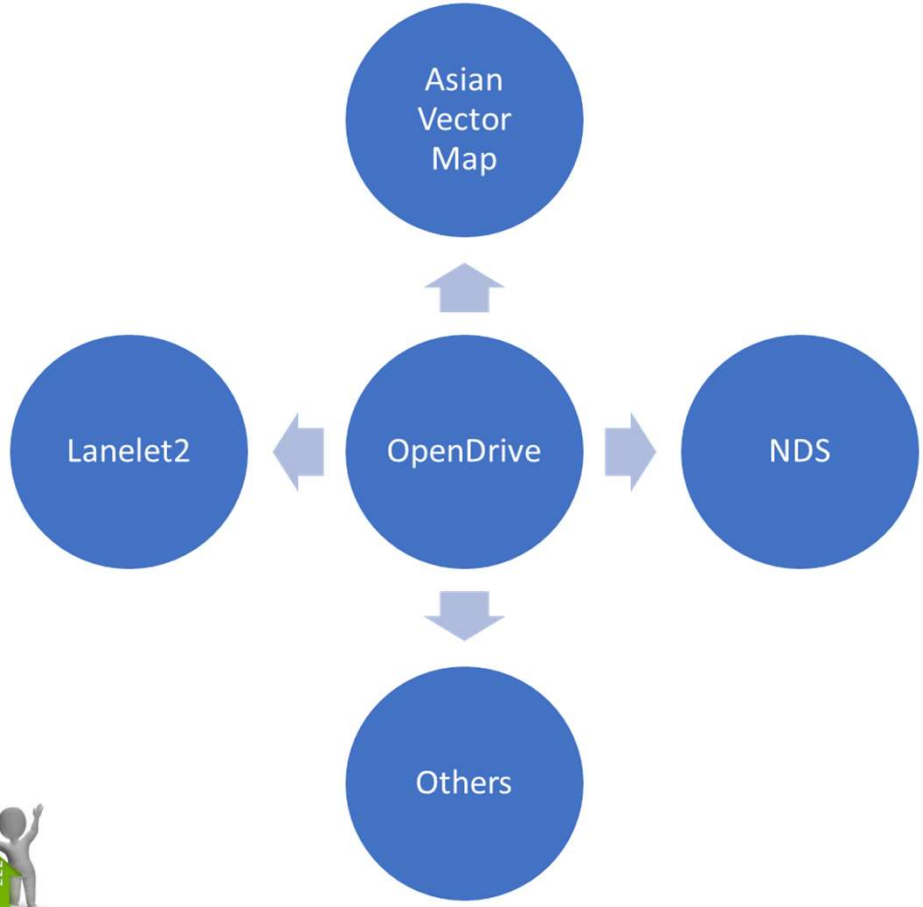


MOI’ s solutions

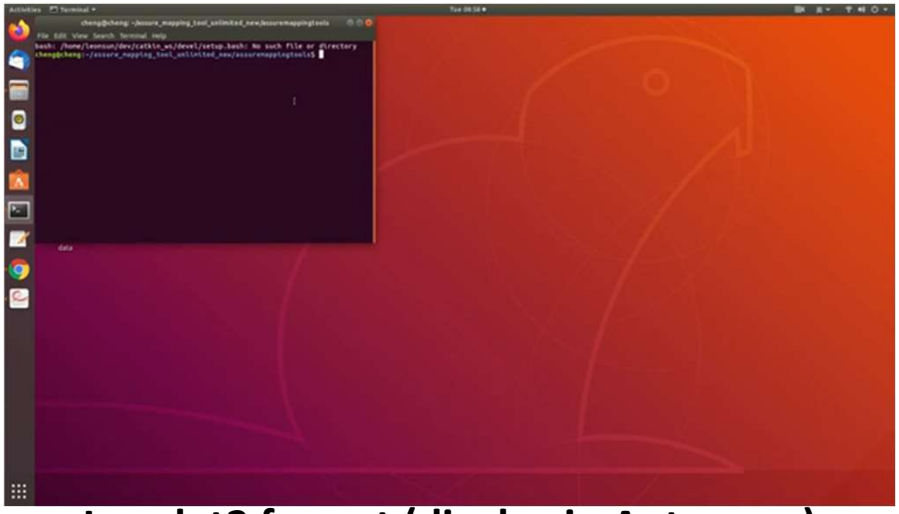
- **3rd party sourcing map updating- change detection and update**

MOI’s solutions

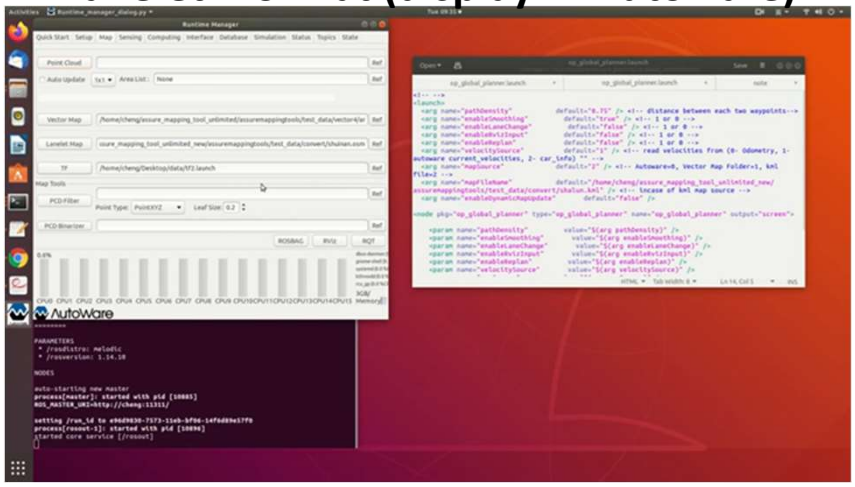
- **Automated format conversion**



MOI’S Format conversion tool

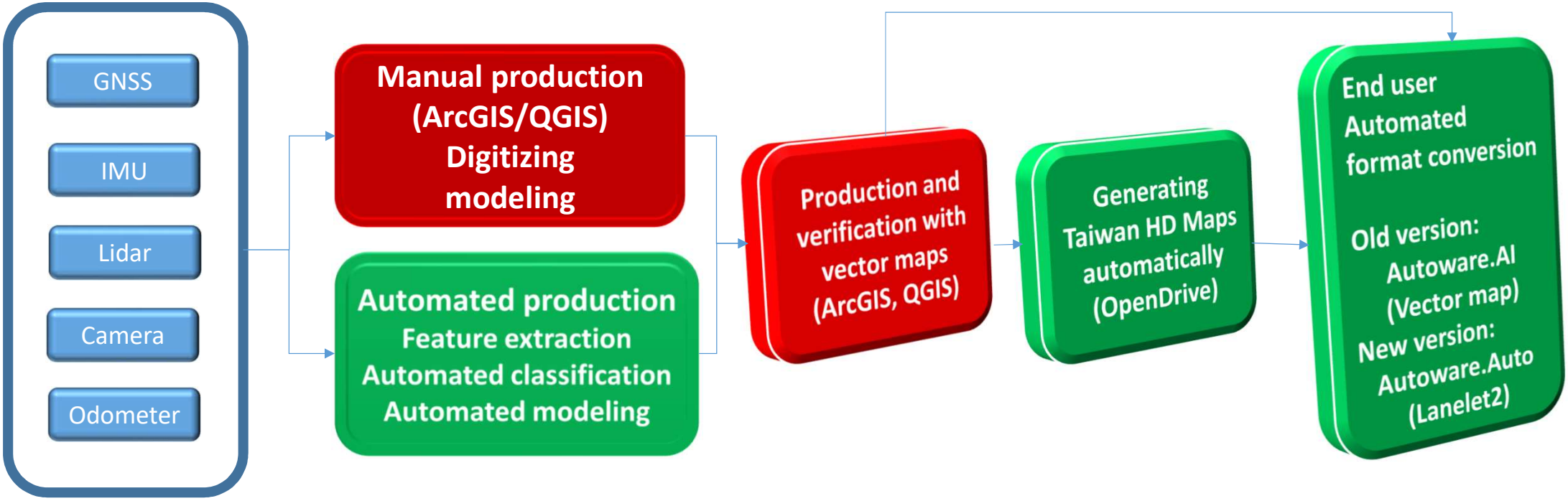


Lanelet2 format (display in Autoware)



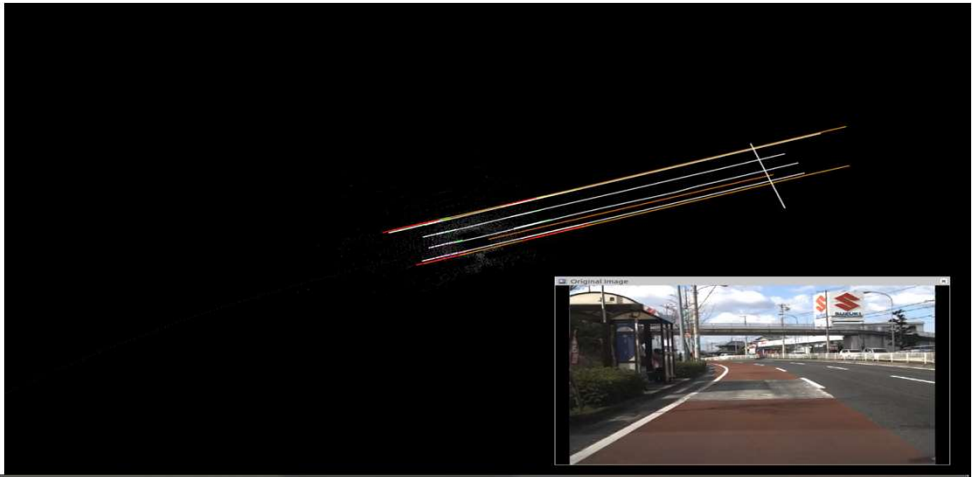
MOI’s solutions

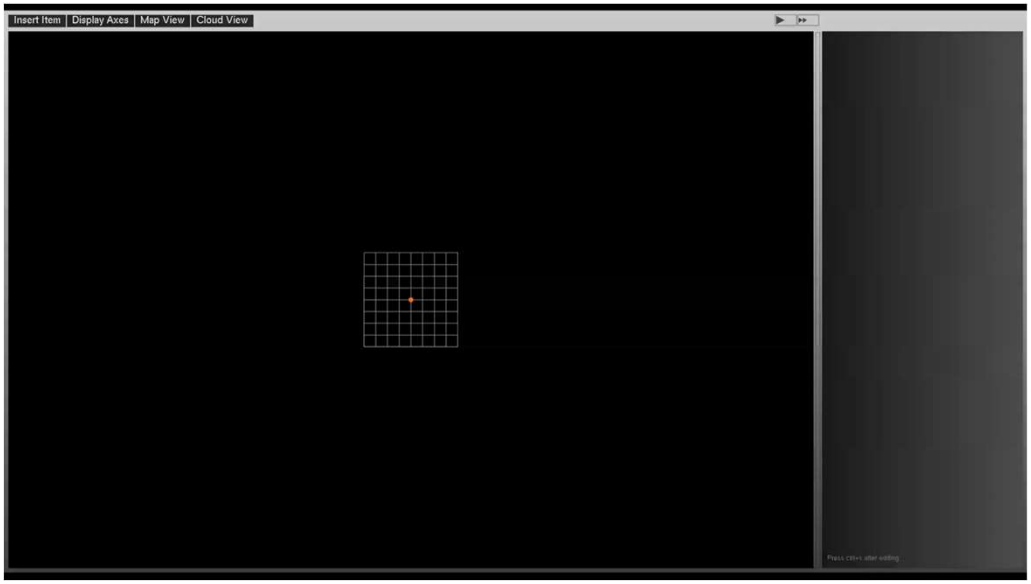
- **Automated Map Production**

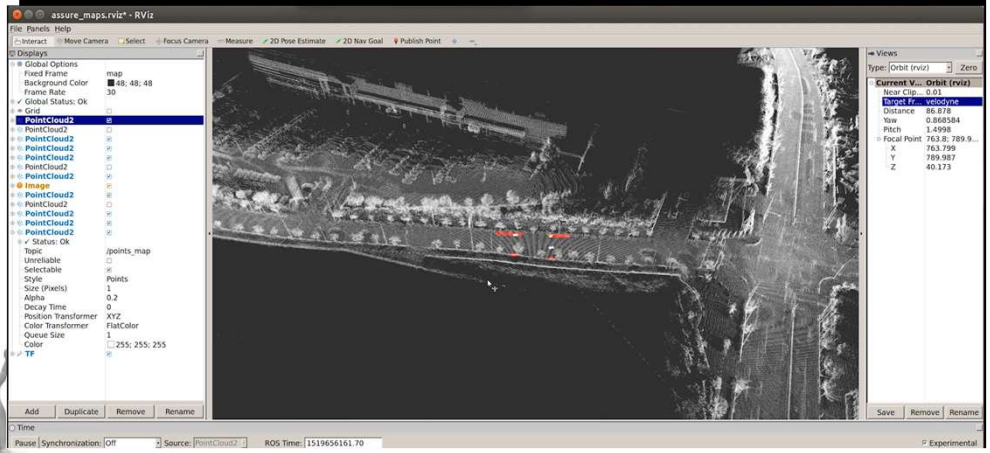


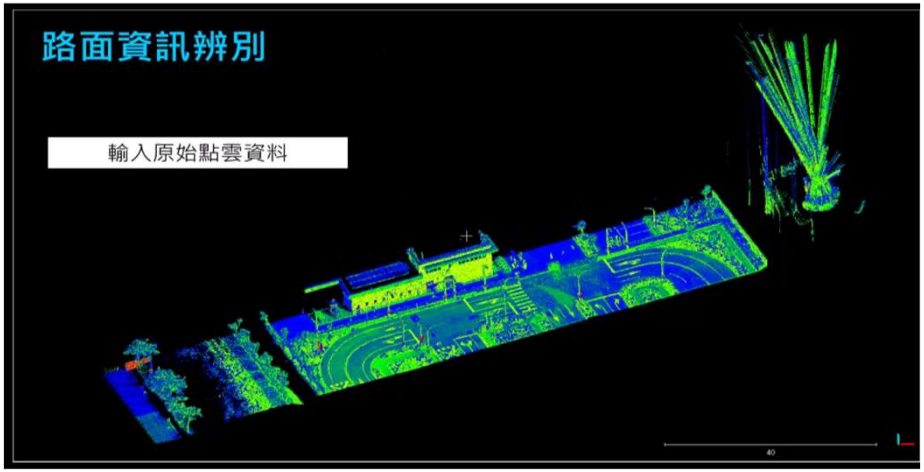
MOI’s solutions

- **Automated map production**









MOI’s solutions

- **Digital twin for AD simulation and future LBS applications**

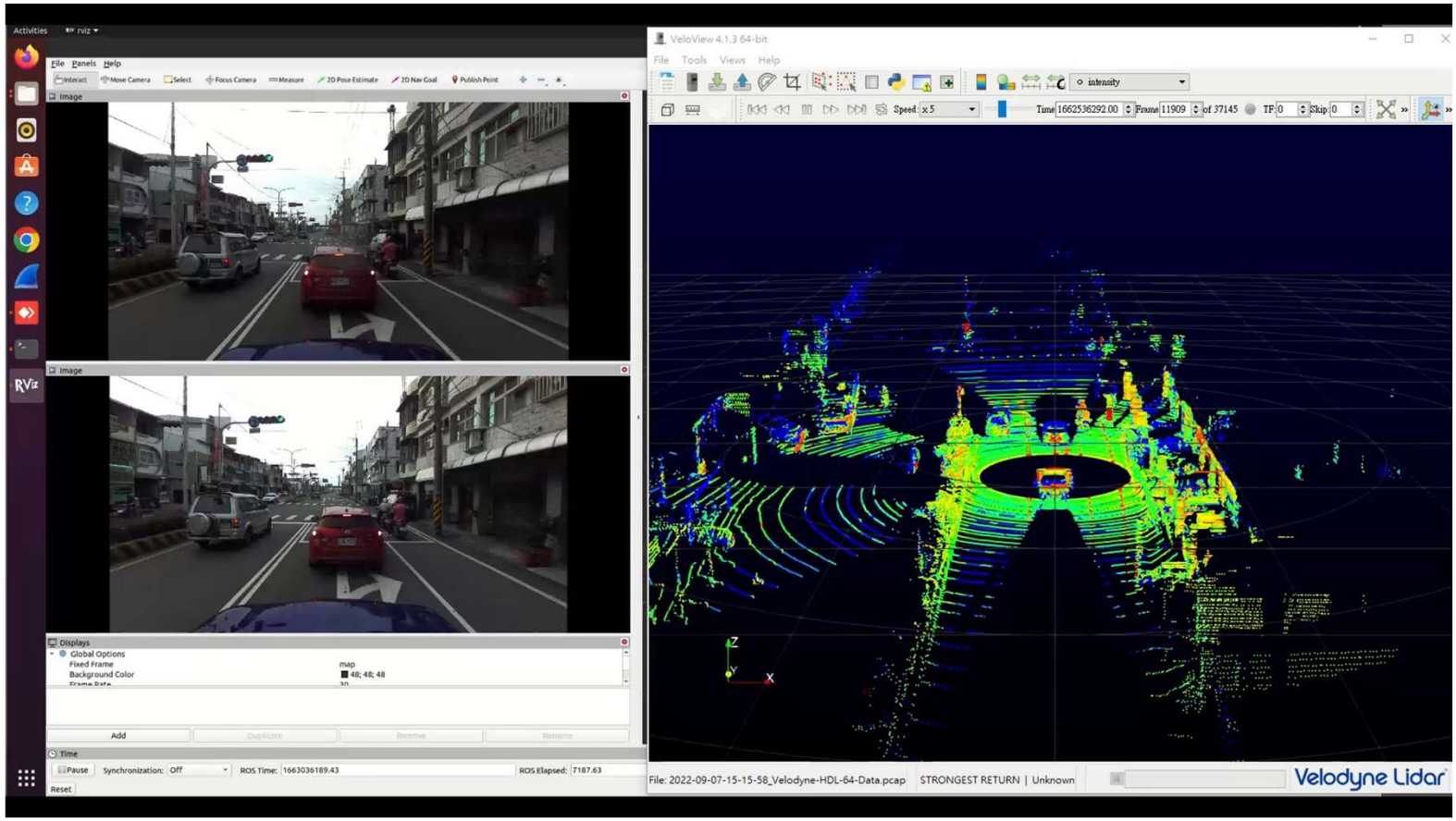
MOI’s solutions

- **Increasing the scale of HD maps production**

- **The total mileage up to 2022 reaches 200 km**
- **There are several level 4 AD services operating on those routes**

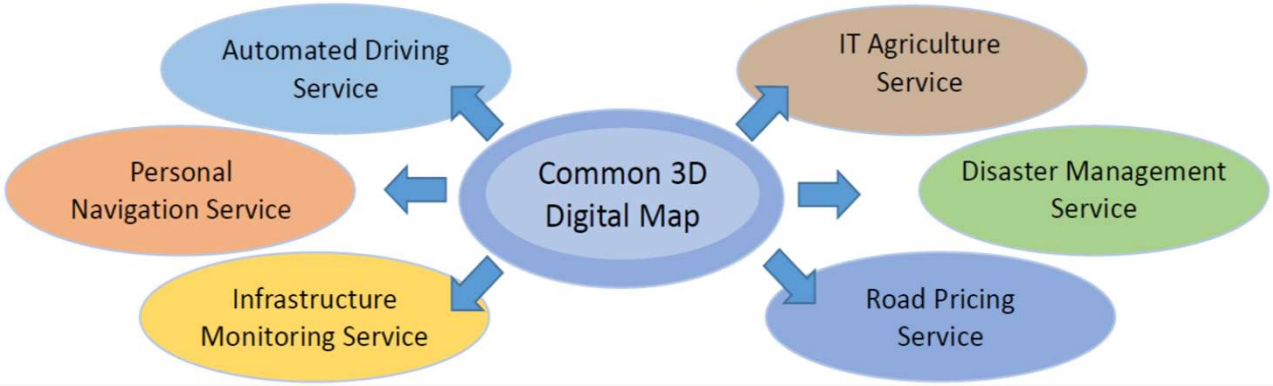
MOI’s solutions

- **Pilot study to build “controlled” HD point cloud map with UAV assisted GCPS**



Concluding remarks

- **The concept of 3D common digital map**



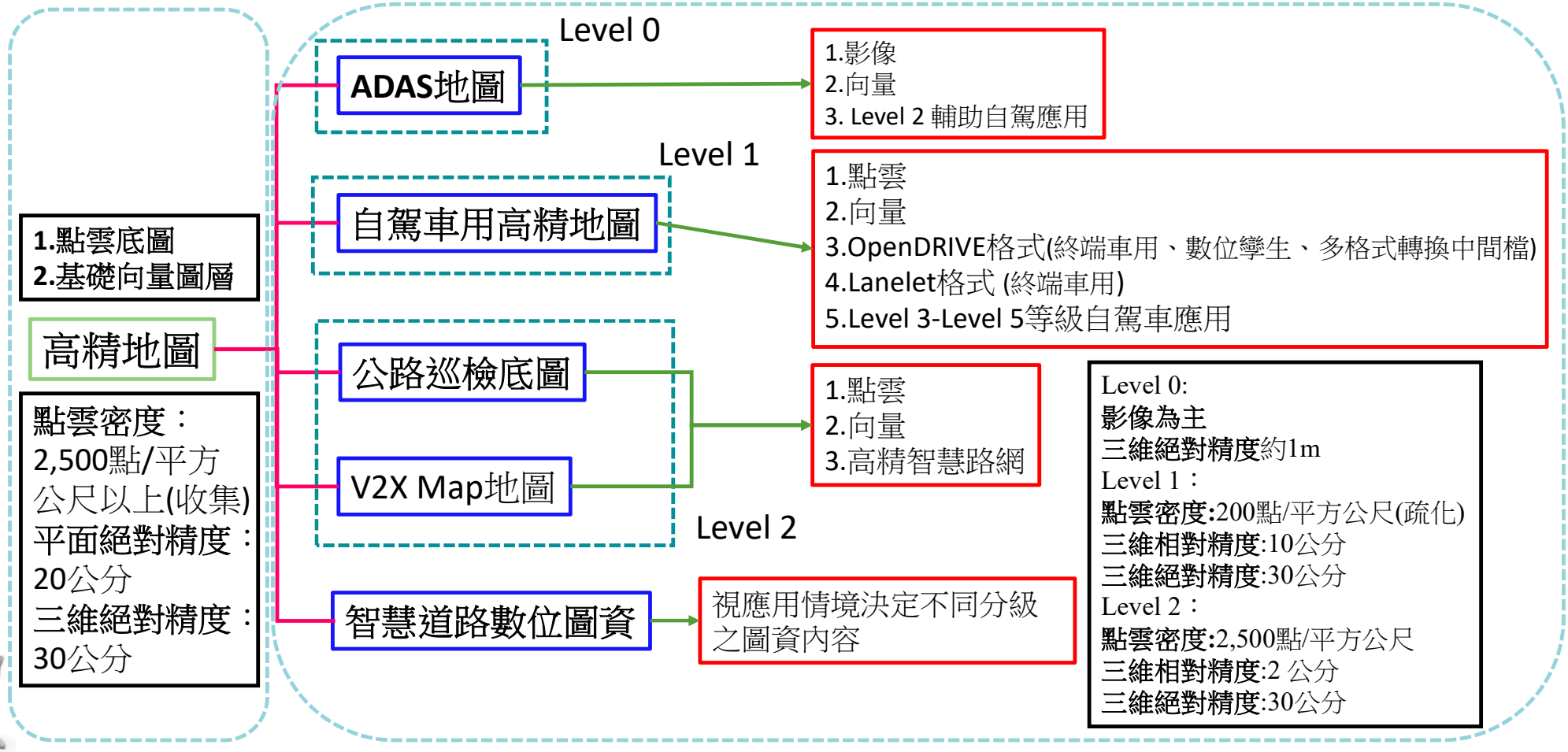
Accuracy Requirements for Common 3D Digital Map(from COCN report, 2014)

	Automatic Driving	Road Pricing	Maintenance of Infrastructure	Disaster Management	IT agriculture	Personal Navigation
Required 3D Map Data	Road	Road	Road (incl. Surface) Tunnel Bridge	Road	Road	Road
Accuracy 1m						
10cm-30cm						
1cm- mm-						

(Koyoma, 2017)

Concluding remarks

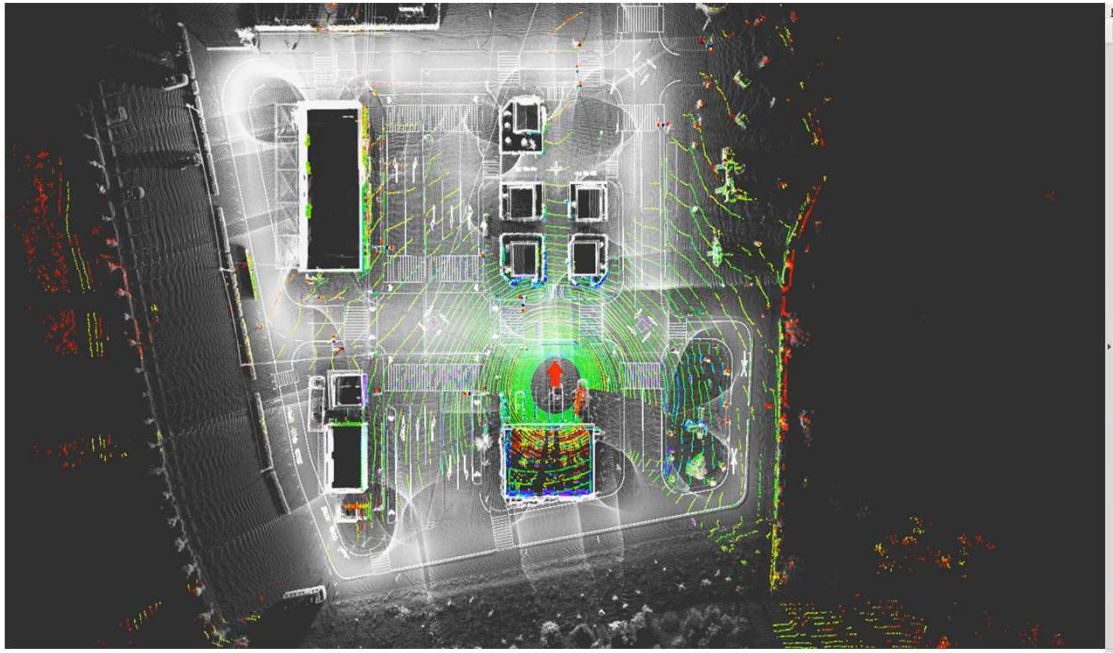
- **The unified intelligent map content for future smart mobility**



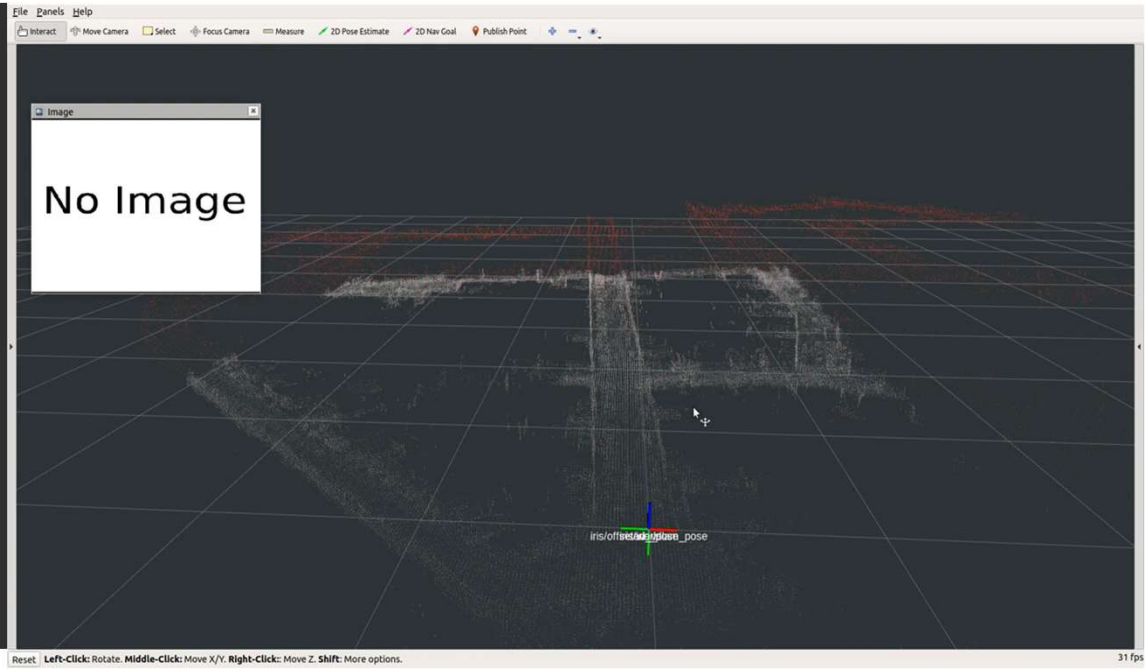
Concluding remarks

- **Unified localization engine supported by HD Maps**

INS+GNSS+Lidar+HD maps



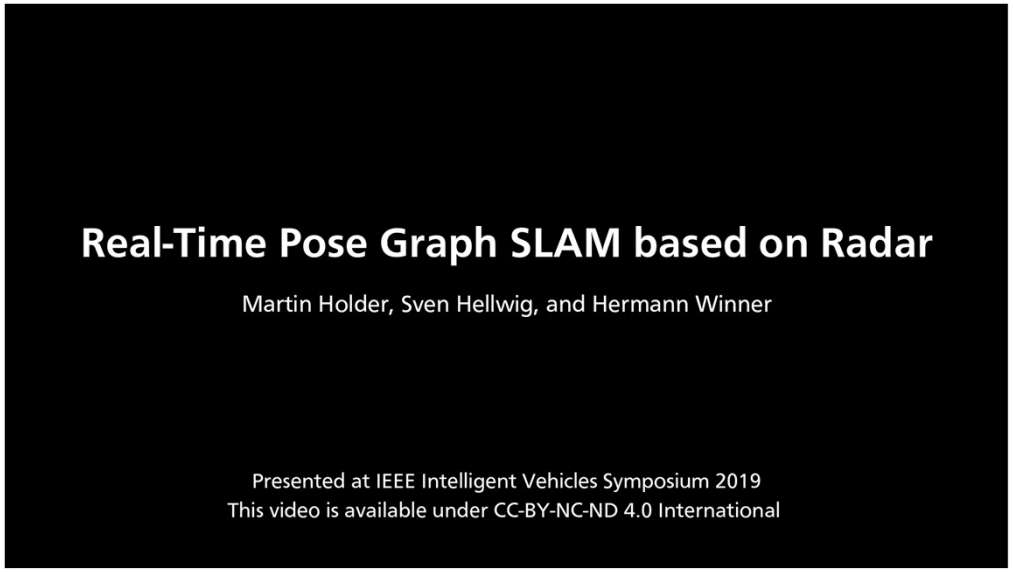
INS+GNSS+Stereo camera+HD maps



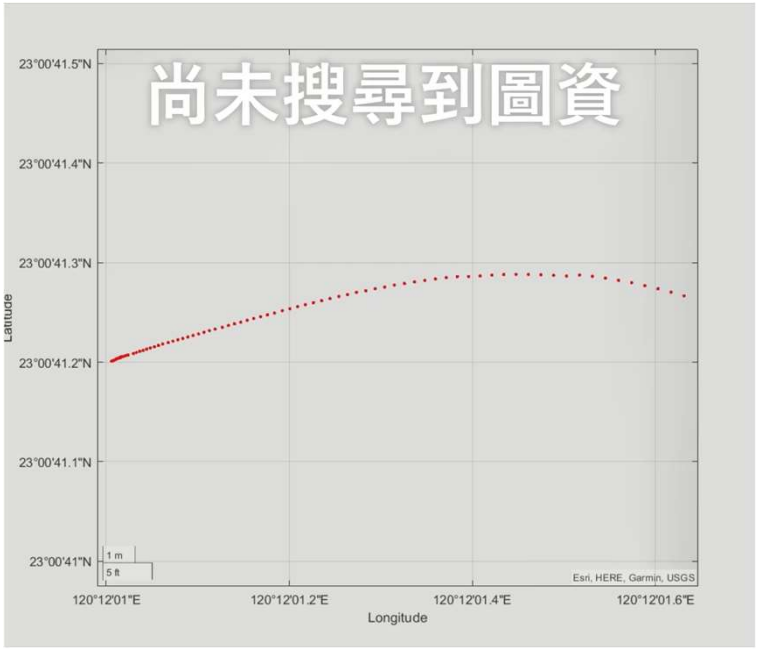
Concluding remarks

- **Unified localization engine supported by HD Maps**

INS+GNSS+Radar+HD maps



INS+GNSS+Odometer+HD vector map



Q & A