NAC2022
17th NSTDA Annual Conference
การประชุมวิชาการประจำปี สวทช. ครั้งที่ ๑๗

HD MAPC | HIGH DEFINITION MAPS CENTER

# Safe Positioning, Localization, and Navigation for Autonomous Vehicle Applications Piloted by HD Maps


**Dr. Kai-Wei Chiang**
**Professor and Director , POINT lab @Department of Geomatics, NCKU**
**Director and Principal Investigator, High Definition Maps Research Center**
**kwchiang@mail.ncku.edu.tw**



OpenDrive

NATIONAL CHENG KUNG UNIVERSITY 1931 窮理致知

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

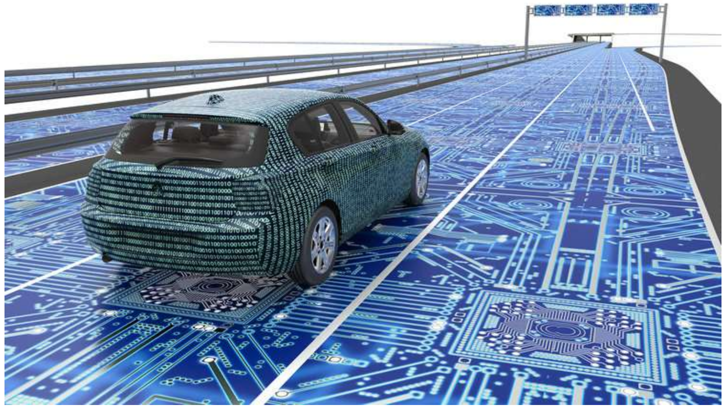
MOST 科技部 Ministry of Science and Technology

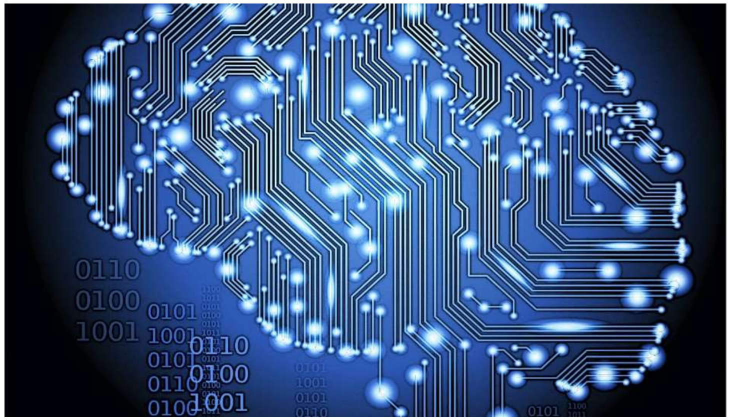
NARLabs 國家實驗研究院 National Applied Research Laboratories

AUTOWARE.AI

# Outline

- Background
- HD Maps and AV Localization
- Lane Level Localization : Challenges
- Lane Level Localization : Solutions
- Navigation Safety





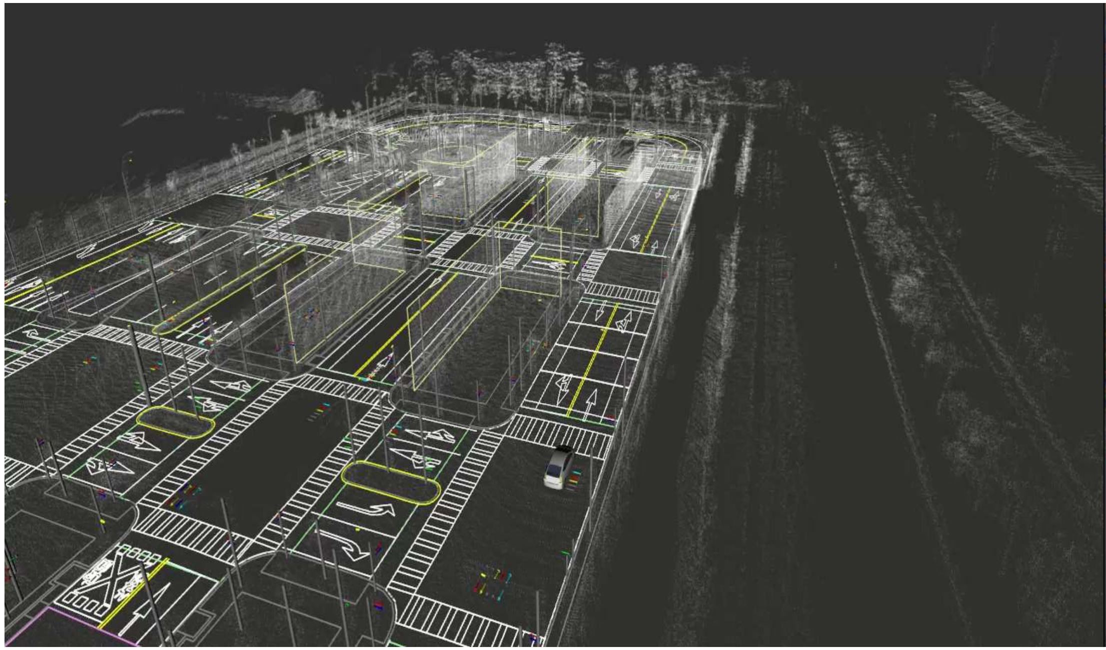
# Background

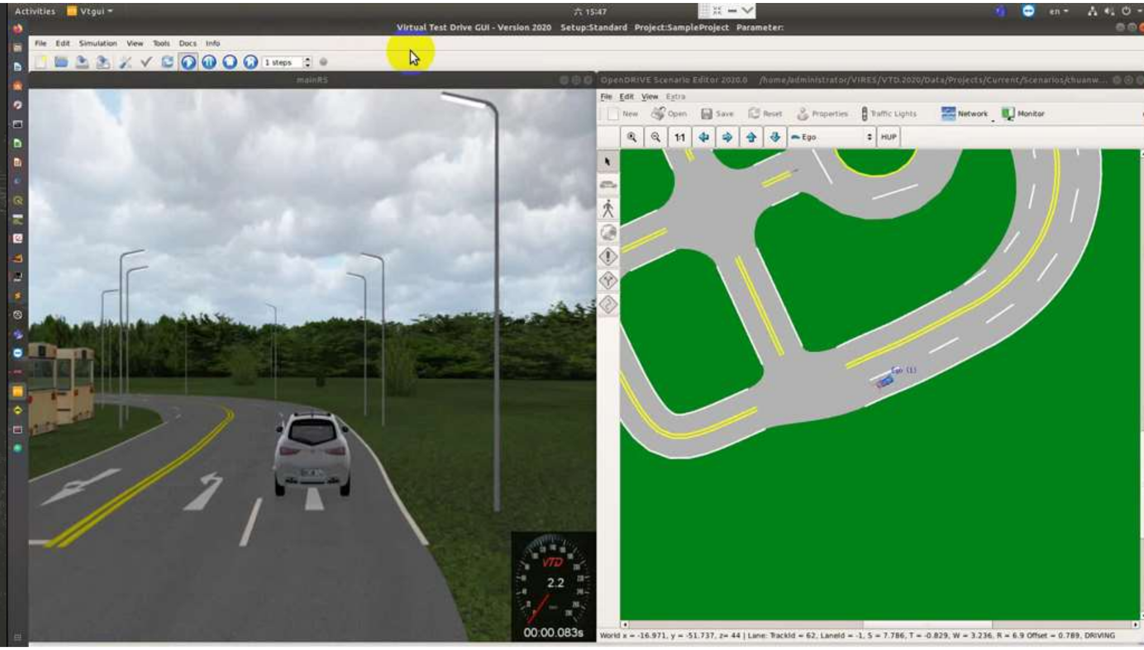
- Autonomous vehicles and HD maps
  - Different levels of self-driving have different content and accuracy requirements for the map

| 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 | | | | |
| 3 (CA) | Conditional Automation | ADAS map<br>+ HD map | Submeter level<br>Centimeter level | Optional |
| 4 (HA) | High Automation | ADAS map<br>+ HD map | Submeter level<br>Centimeter level | Required |
| 5 (FA) | Full Automation | HD map | Centimeter level | Required<br>(update automatically) |

# Background

- What are HD maps





# Background

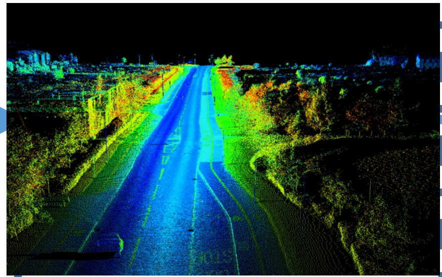
- MOI’ s recommended steps for HD maps production

Map Maker

Published @ TACIS

Taiwan HD map Operation Guideline v2

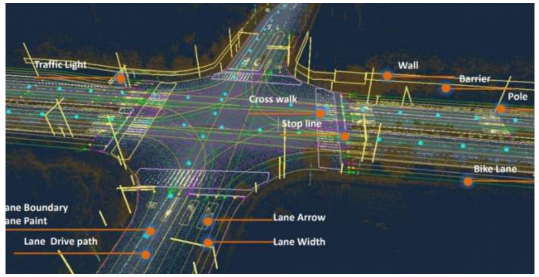
Certified point clouds
(Localization )



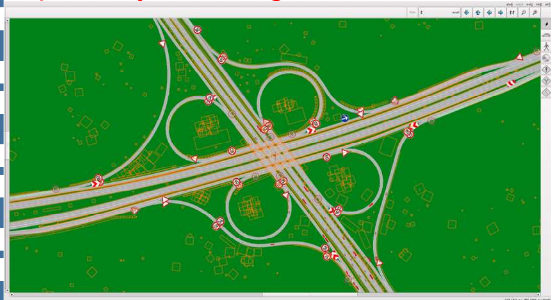
Published @ TACIS

Taiwan HD map standard

Certified vector map layers
(Path planning /Localization/ LBS )




Taiwan HD map
(Path planning/Localization)



Published @ TACIS

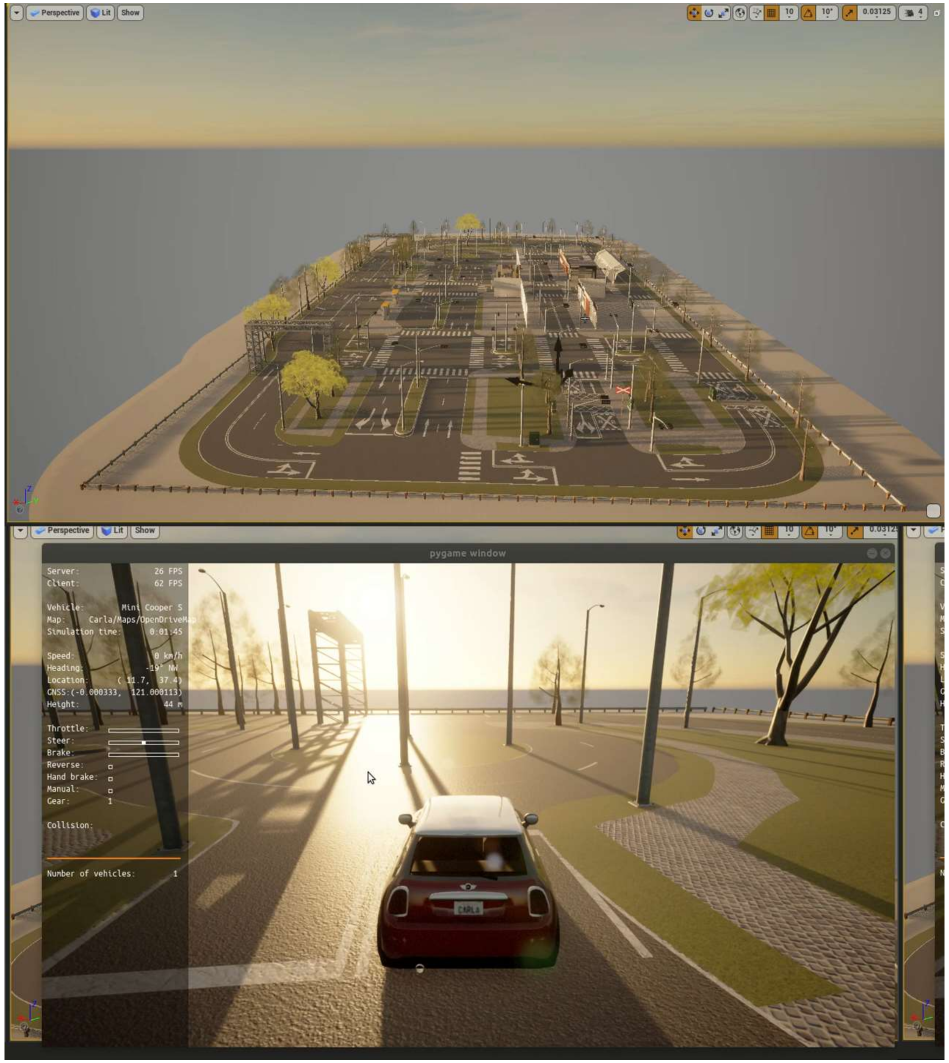
Taiwan HD map validation verification Guideline

Simulator Autonomous vehicle Verification

Publish

# Background

- Taiwan HD maps production

**The total mileage is about 180 km in 2022**

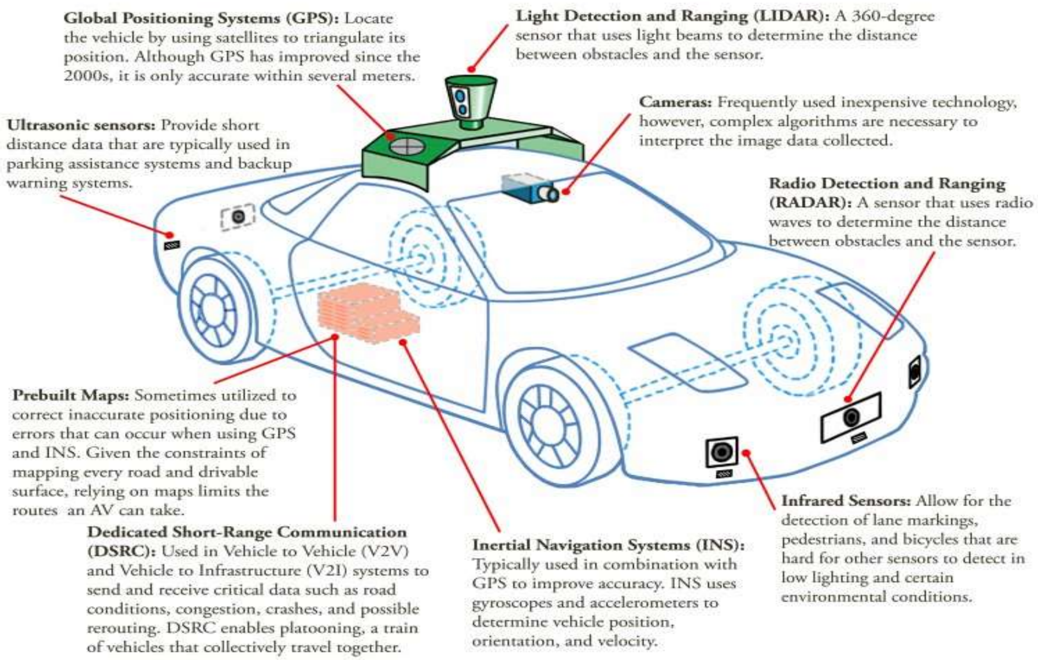
# HD map and AV localization

- Comparison matrix for localization and perception sensors

| Technology | Underground Parking | Tunnels | Downtown Multipath areas | Foggy conditions | Rain Conditions | Snow and slippery roads |
|---|---|---|---|---|---|---|
| GNSS | X | X | O | V | V | V |
| Imaging Systems | V | O | V | X | X | X |
| Lidar | V | V | V | V | O | O |
| Odometer | V | V | V | V | O | O |
| Radar | V | V | V | V | V | O |
| Inertial Sensors | V | V | V | V | V | V |

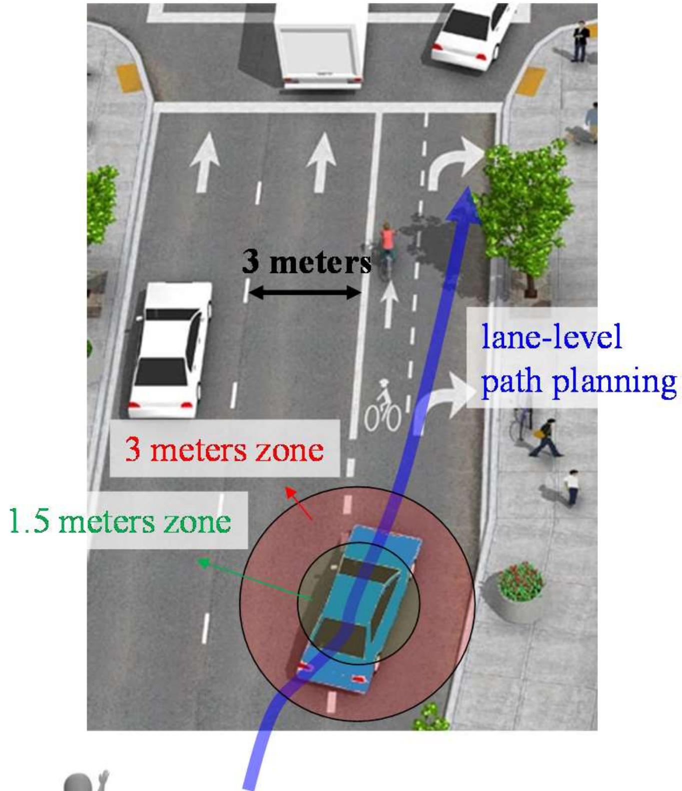
Work V Does not Work X Limited Operation O

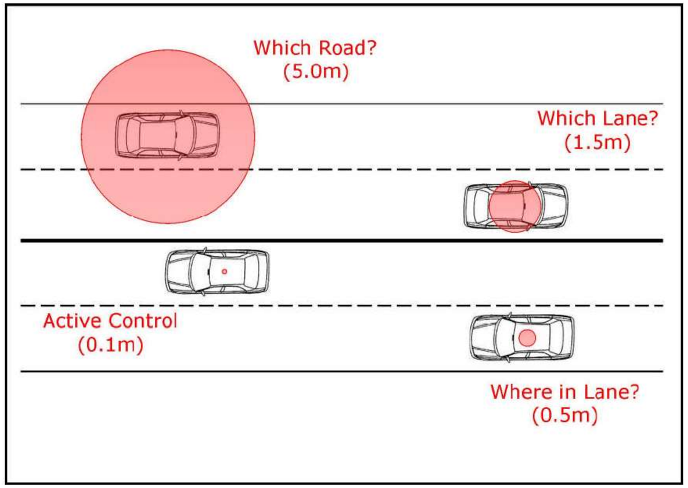
**Inertial and Radar Sensors are the only navigation technologies that can work everywhere and under any weather and operational conditions**



# HD map and AV localization

- Accuracy requirements




- *HD maps absolute accuracy requirements*

*Taiwan: Horizontal: 20 cm 3D: 30 cm*
*Japan: Horizontal: 25 cm 3D: 35cm*
*Korea: Horizontal: 25cm 3D: 35cm*

- *HD maps absolute accuracy requirements*

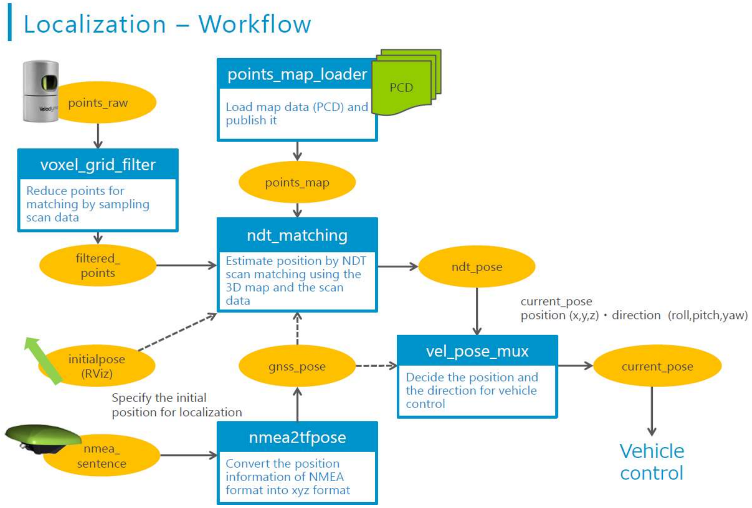
*Taiwan 1~2 cm (1st class PCD)*
*Japan : 1~5 cm*
*Others: 1~10 cm*

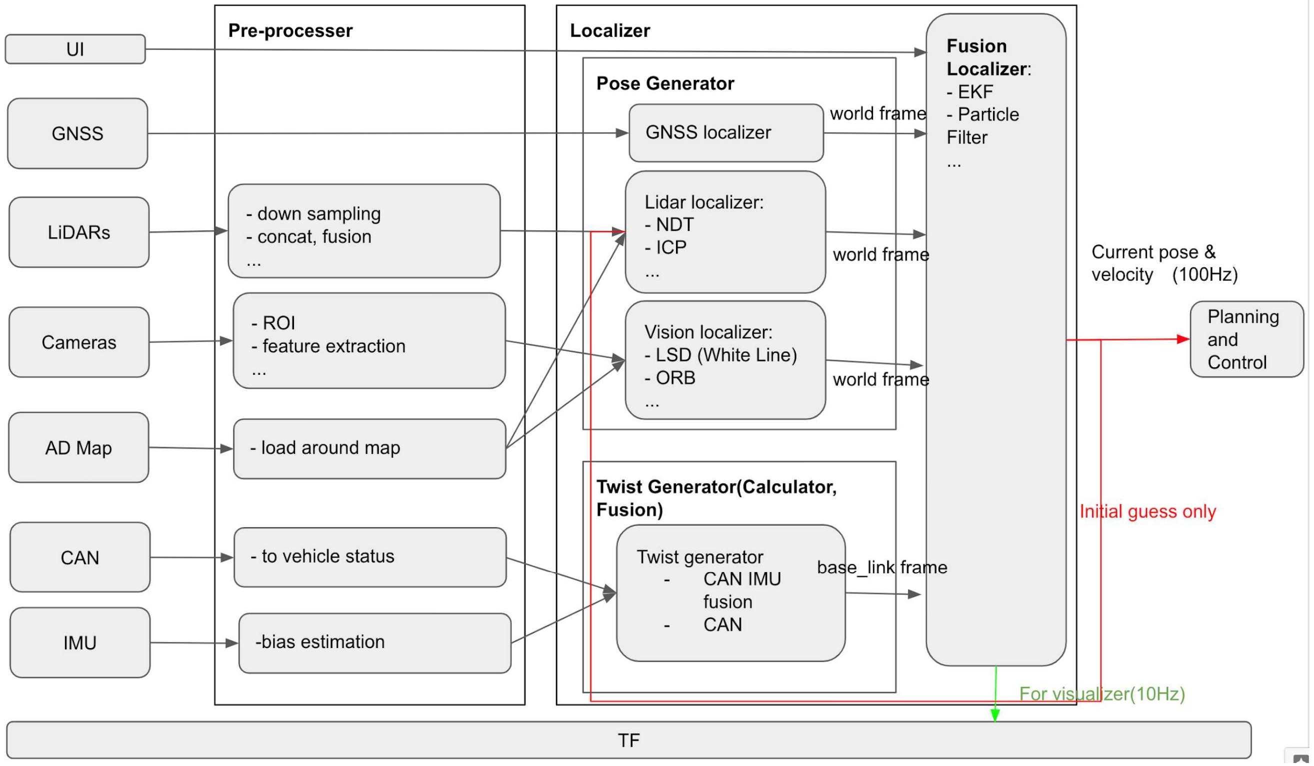
| | Total Error Budget (map + vehicle) [meters 2sigma] | Map Error [meters 2sigma] | Vehicle Positioning Error [meters 2sigma] |
|---|---|---|---|
| WHICHLANE | 1.5 | 0.5 | 1.0 |
| WHEREINLANE | 0.5 | 0.2 | 0.3 |

(CAMP, 2004)

# HD map and AV localization

- Do AVs need HD Maps??
  - ➢Localization Architecture perspectives (Autoware/Apollo/Nvidia)

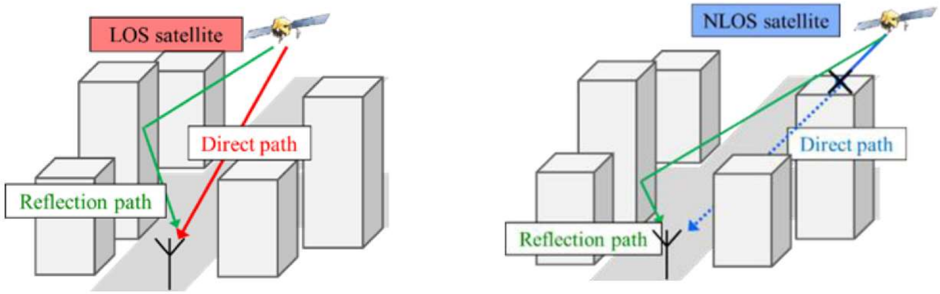



***The current Autoware (v1.11) depends only on LiDAR (ndt_matching). Other inputs such as GNSS, CAN, and IMU are used to guess initial search position in ndt_matching algorithm. It is difficult to scale up scenarios which Autoware can drive.***

# Lane level localization : Challenges

- Real world is tough



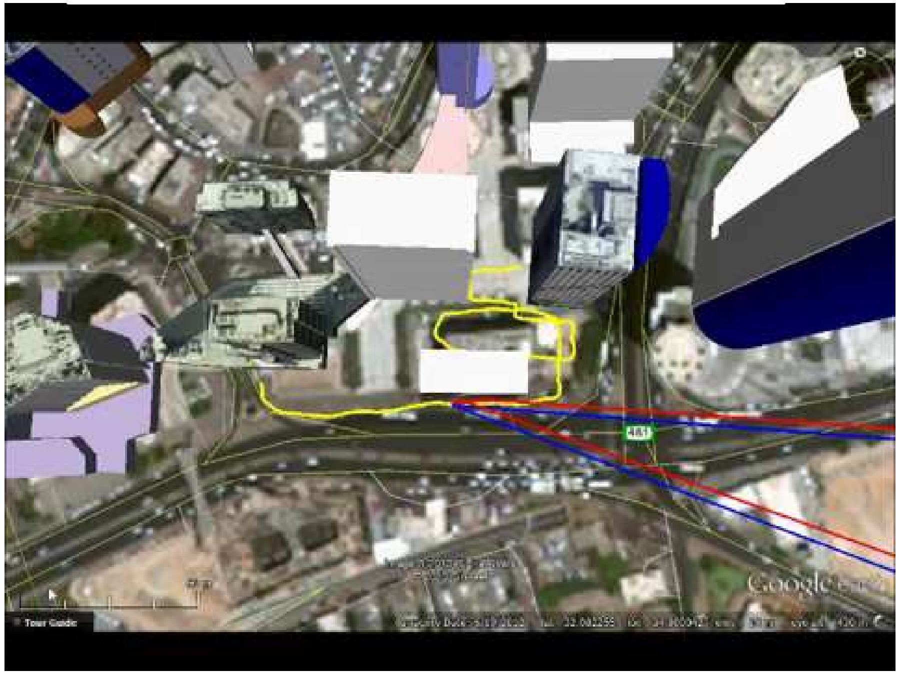

(a) Multipath effect (b) NLOS effect

Figure 7 Sparse GPS coverage

Figure 6 Precise tracking

ERROR CORRECTION APPROACHES FOR GNSS.

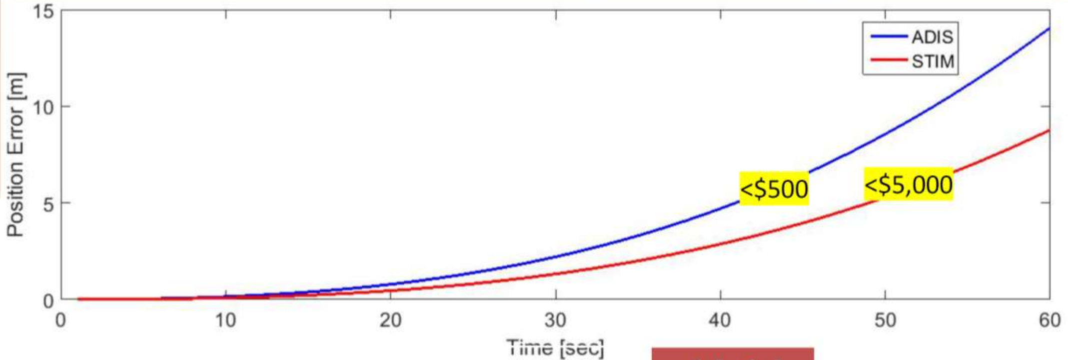
| | PPP | RTK | PPP-RTK |
|---|---|---|---|
| Accuracy | 0.30 m | 0.02 m | 0.10 m |
| Convergence Time | >10 minutes | 20 seconds | 20 seconds |
| Coverage | Global | Regional | Continental |
| Seamless | Yes | No | Yes |



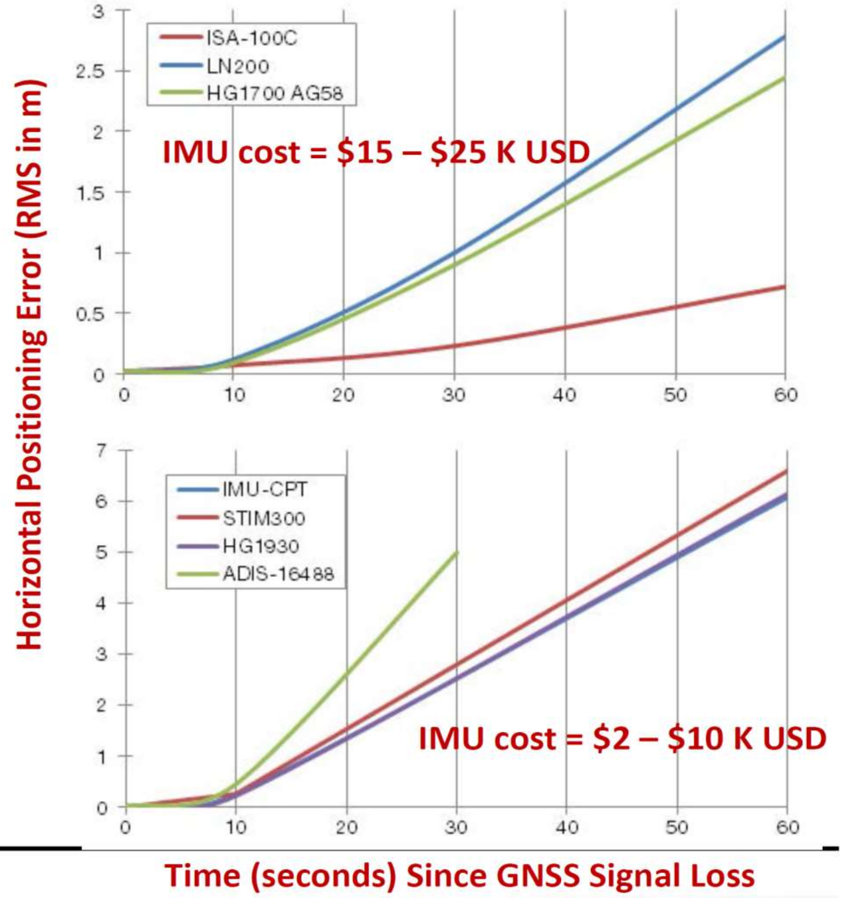
# Lane level localization : Challenges

- INS error accumulation

$$\delta p(t) \approx \delta p(t_0) + \delta v(t_0).\Delta t + \delta b_a(t_0).\frac{\Delta t^2}{2} + \delta b_g(t_0).g.\frac{\Delta t^3}{6} + \delta\theta(t_0).g.\frac{\Delta t^2}{2}$$



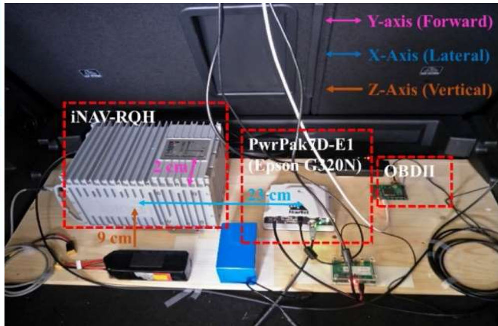

| | | 1 [min] |
|---|---|---|
| Position Error [m] | ADIS | 14.0 |
| | STIM | 9.0 |



# Lane level localization : Challenges

- Performance evaluation methodologies
  - NCKU kinematic test facilities

| Name | Northrop Grumman LN200 | NovAtel SPAN-LCI | SAGEM 33BM61 | iMAR iNAV-RQH | NCKU POS |
|---|---|---|---|---|---|
| |  |  |  |  |  |
| IMU | Tactical grade | Tactical grade | Tactical grade | Navigation grade | Navigation grade |
| Gyro Bias stability | <0.3 deg/hr | <0.3deg/hr | 0.3 deg/hr | <0.005 deg/hr | <0.005 deg/hr |
| Accel. Bias stability | <0.3 mg | <0.3 mg | <1.0 mg | <0.01 mg | <0.05 mg |
| GNSS | NovAtel OEM5 | NovAtel SPAN SE | NovAtel OEM5 | NovAtel OEM6 | NovAtel 7720 |

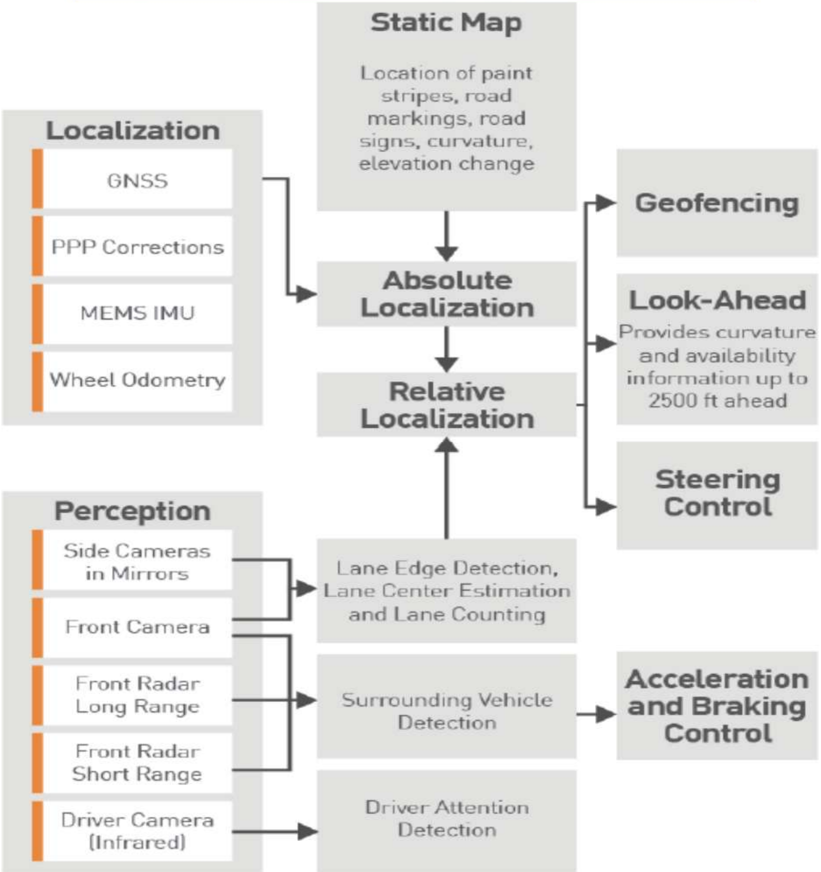




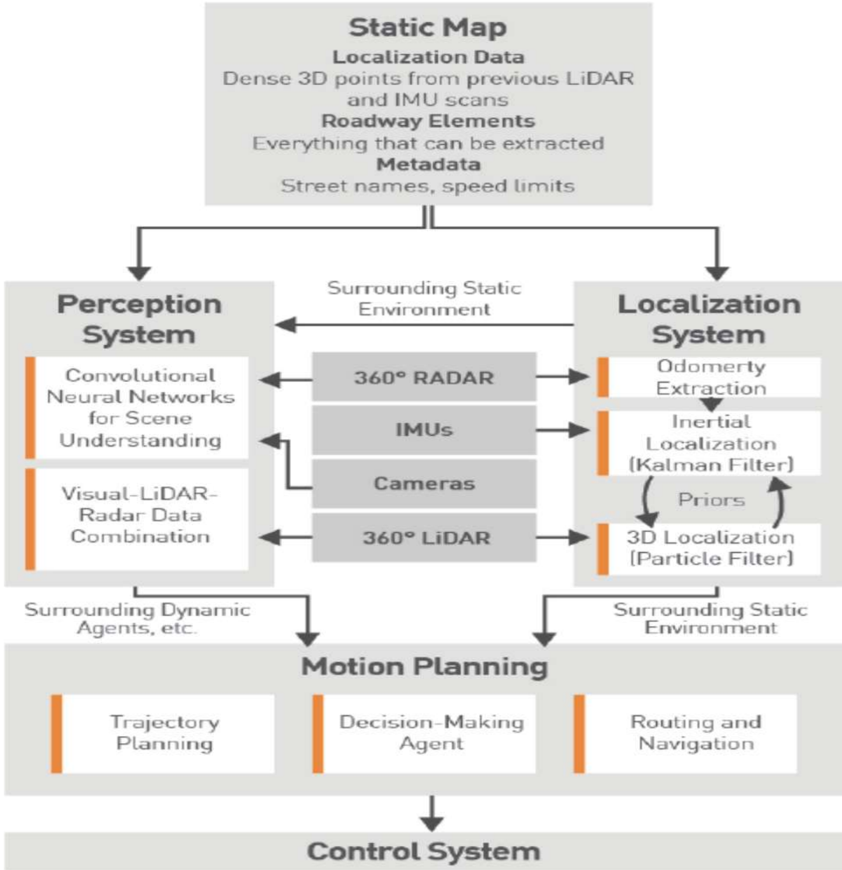

# Lane level localization : Solutions

- Multi-Sensor Fusion is the only way for safe PLAN (Joubert et al., 2020)

SAE Level 2 Vision-based Systems




SAE Level 4 LiDAR-based systems



# Lane level localization : Solutions

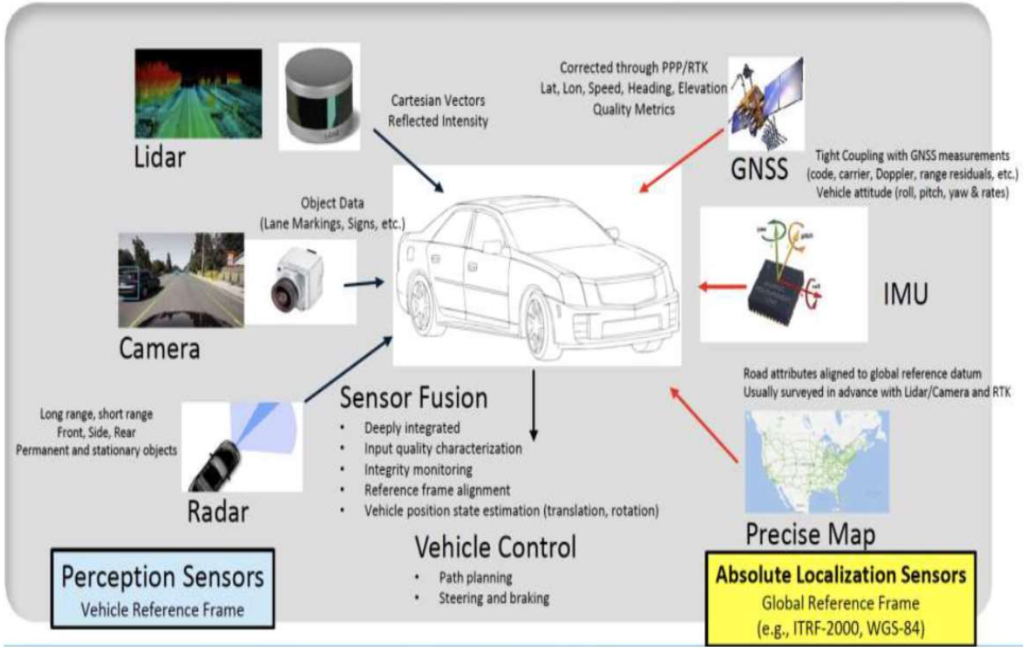
- An unified localization engine for AV piloted by HD Maps

**Truly Autonomous Navigation Sensor:**

**INS**

**Odometry Type Aiding:**
**(Relative Navigation states)- Odometer, Camera, Lidar, Radar, Barometer, magnetometer and smart constrains**

**Position Fix Aiding**
**(Absolute Navigation states)- GNSS, HD maps (PCD/Vector),ADAS map, Land mark, Various ground RF aiding (UWB, BLE, RFID)**

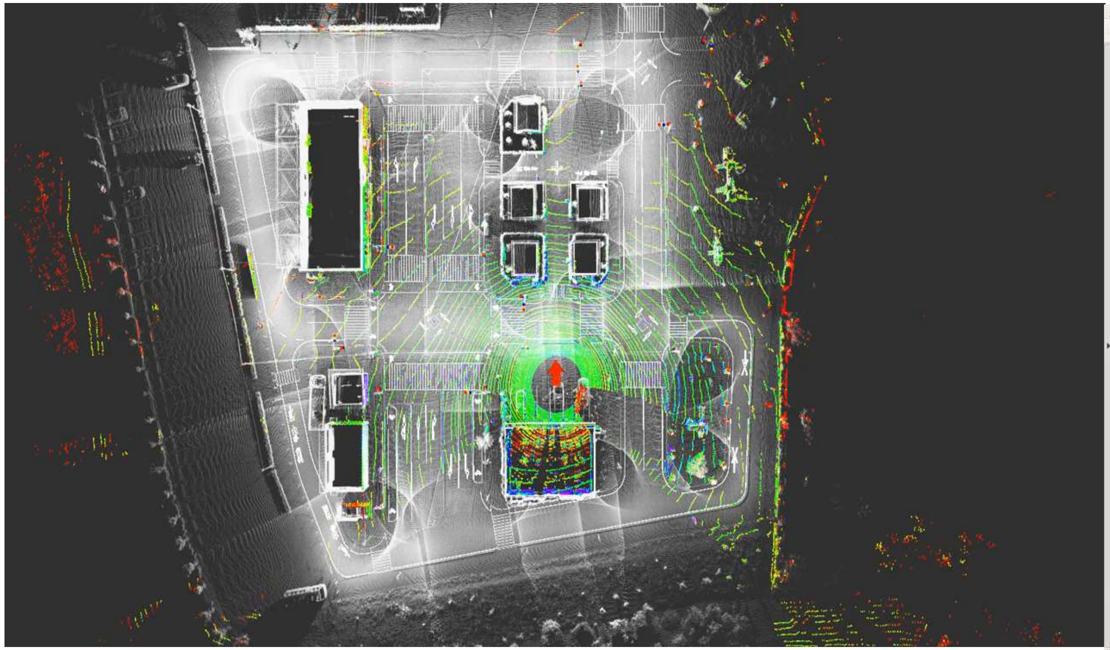


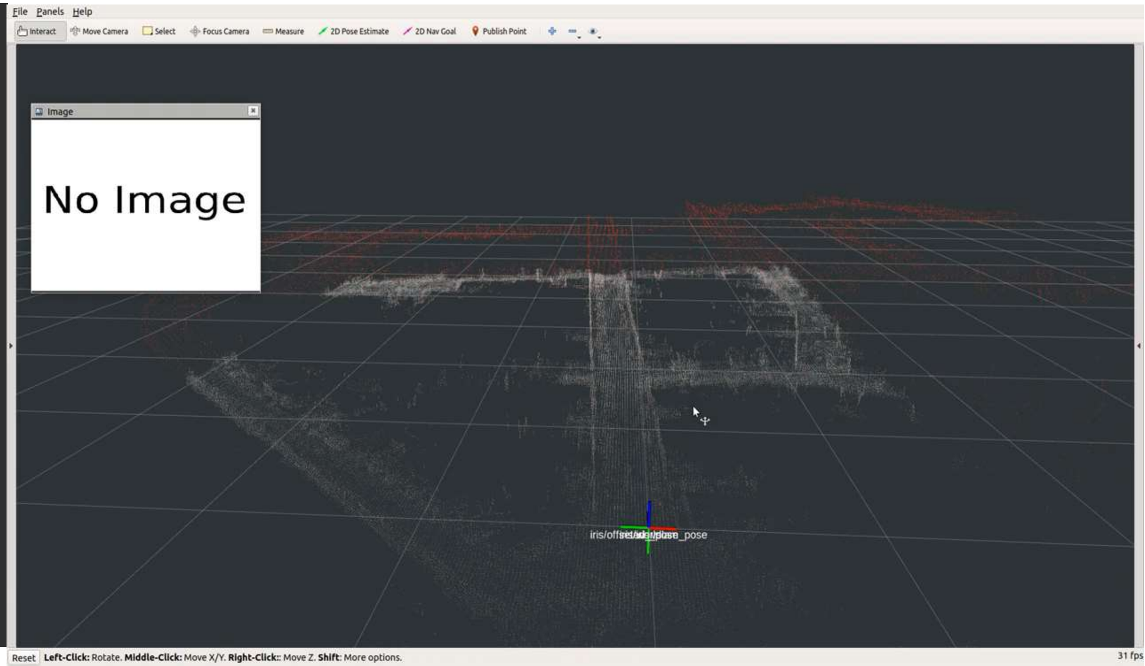
# Lane level localization : Solutions

- An unified localization engine for AV piloted by HD Maps

Lidar localization in HD maps

Camera localization in HD maps (Stereo)






https://www.youtube.com/watch?v=NIZQLEdYi8I

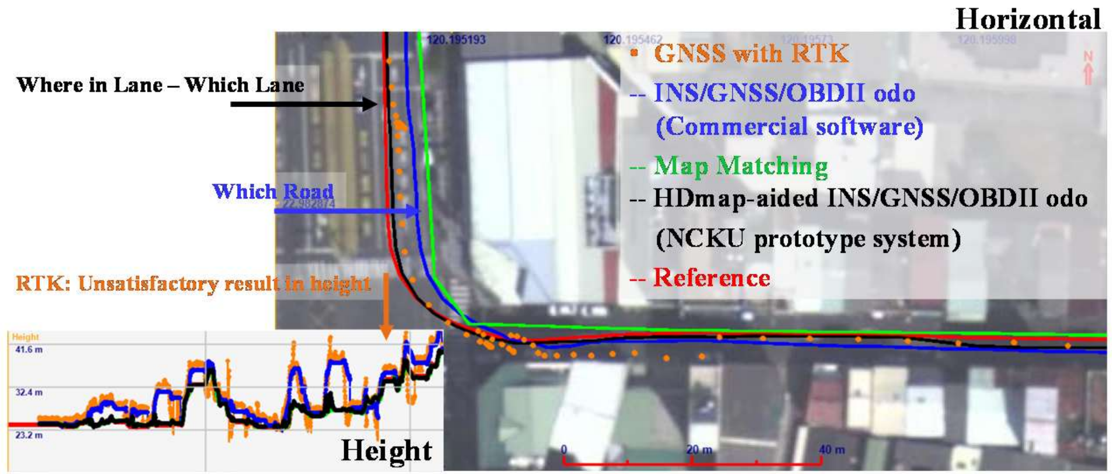
https://www.youtube.com/watch?v=a_BnifwBZC8

# Lane level localization : Solutions

- An unified localization engine for AV piloted by HD Maps

Radar localization in HD maps

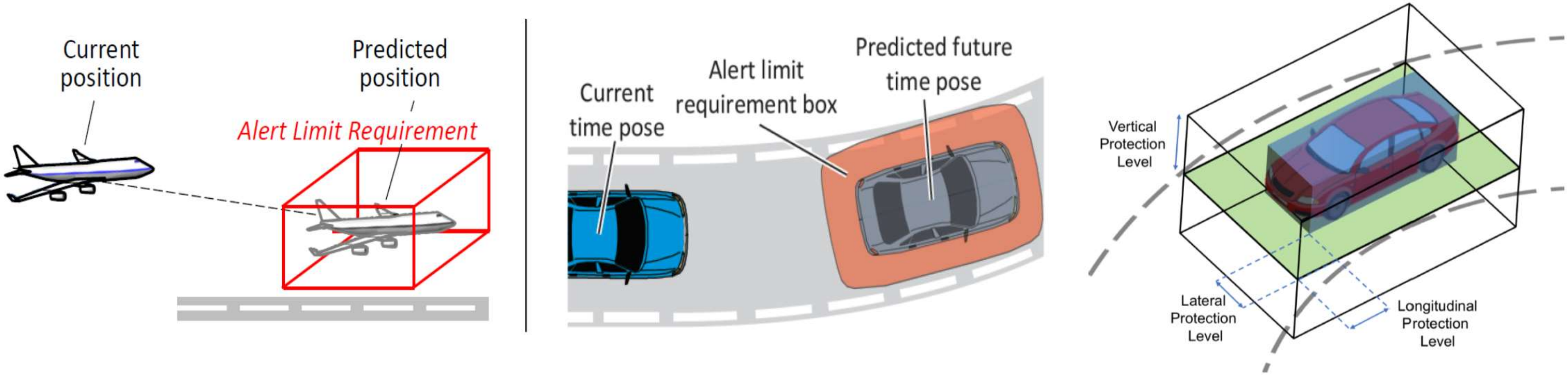
IMU/HD Vector maps/Odometer/GNSS


https://tuprints.ulb.tu-darmstadt.de/8756/

# Navigation safety

- Navigation safety for autonomous vehicle




(Joerger and Spenko, 2017)

**Challenges in bringing aviation safety standards to AVs**

**–GPS-alone is insufficient multi-sensor system needed**

**–not only peak in safety risk at landing continuous risk monitoring**

**–unpredictable meas. availability prediction in dynamic AV environment**

# Navigation safety

- **The operational environment of Avs is far more unpredictable than the aircraft**
  - A changing environment
  - Environmental diversity
  - Road users that may interfere with AV motion
  - Comparatively large number of car manufacturers, equipment suppliers, and vehicle models
  - Non-uniform vehicle and road regulations