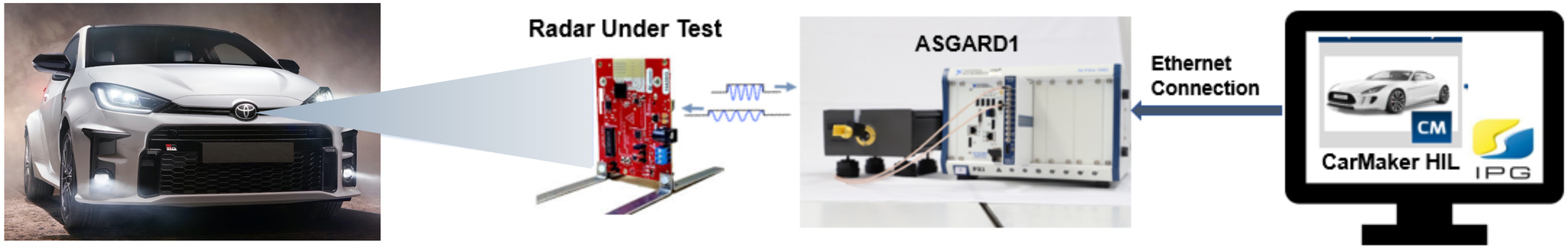
Over-the-Air Real-Time Automotive Radar HiL

with CarMaker for ADAS and AD Validations



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Content

- Radar verification and road safety
- Toyota Safety Sense HiL setup
- ASGARD1 radar testing system
- CarMaker HiFi radar model with ASGARD1
- CarMaker radar RSI with ASGARD1
- Conclusion

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Need for radar validation

- The EU regulations for road safety 2022 obligate new safety features for cars such as intelligence speed assistance, vulnerable road user detection and automatic emergency braking
- Radars are **safety-critical** sensors in driver assistance systems and autonomous driving
- Real-life deployment of radar functions requires high reliability and a lot of testing
- Radars need be tested under **dangerous** traffic scenarios
- **Radar target simulators** enable in-lab testing of radars in a repeatable and accurate manner
- **Hardware-in-loop** test benches are important for testing radars against a ground-truth

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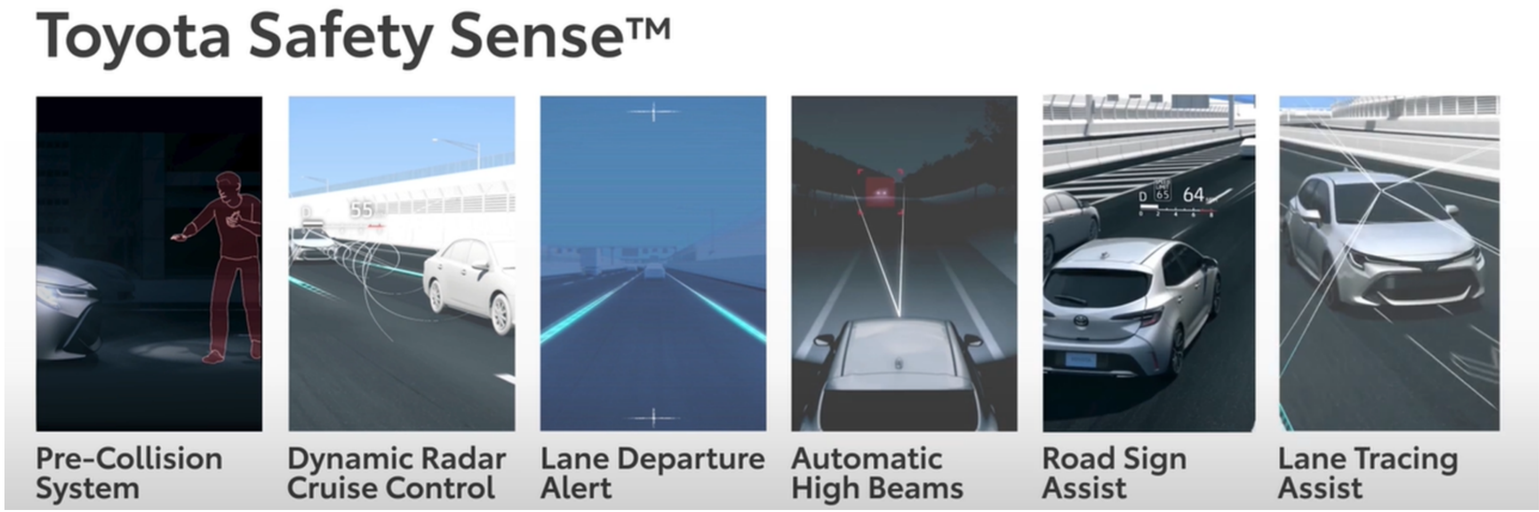
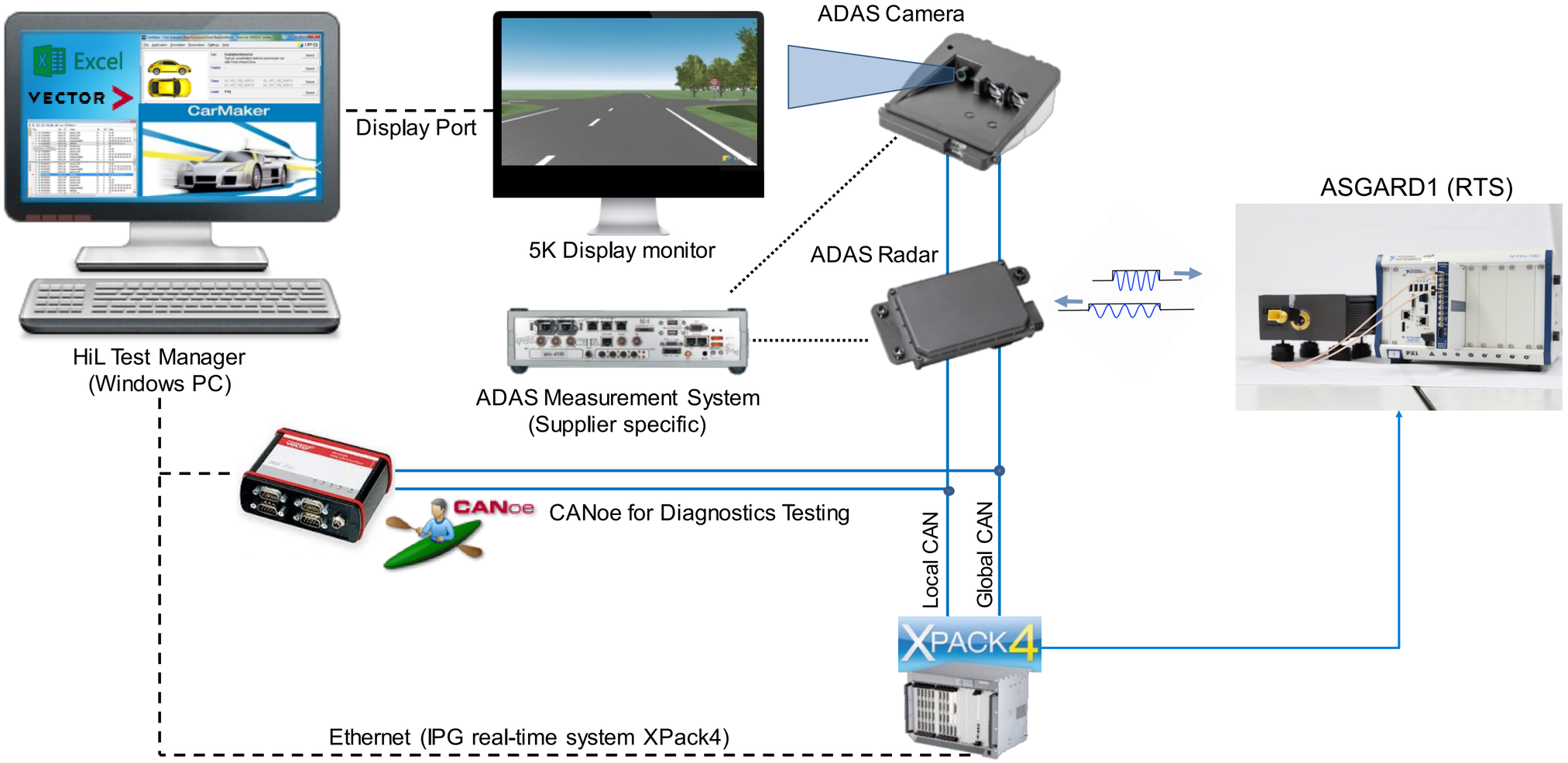
Toyota Safety Sense

- Toyota Safety Sense™ (TSS) is a bundle of active safety features
- TSS is designed to help protect drivers, passengers, people in other vehicles on the road, and pedestrians from harm
- TSS consists of camera- and radar-based driver assistance systems (ADAS)



Toyota Safety Sense HiL setup



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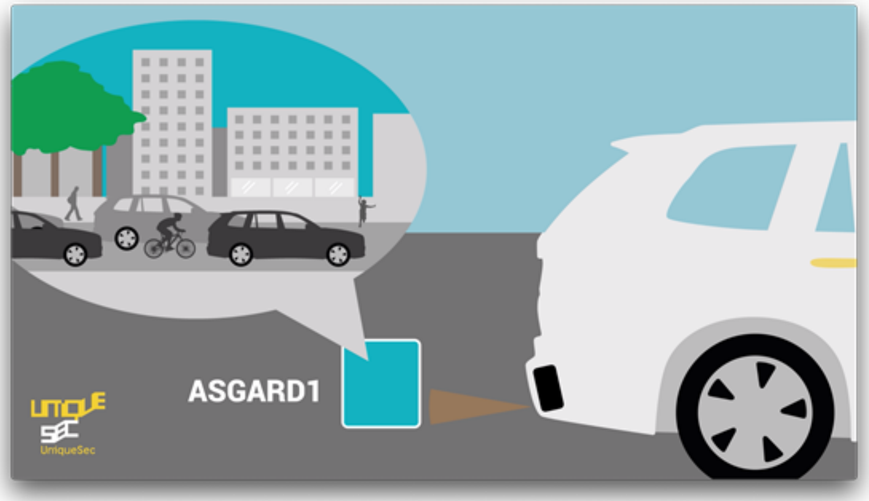
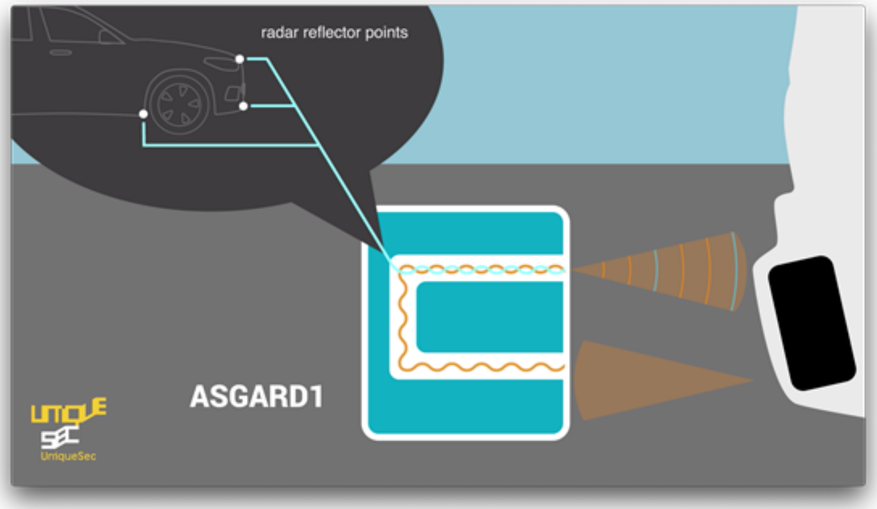
ASGARD1 Automated Signature Generation for Automotive RaDar Verification

- ASGARD1 is a **patented** technology: **Frequency-based** over-the-air radar target simulator
- Translates 3D environment to **radar reflector points**
- Emulates targets by adding distance, speed and angle of reflector points to the radar spectrum rather than creating targets in delay domain



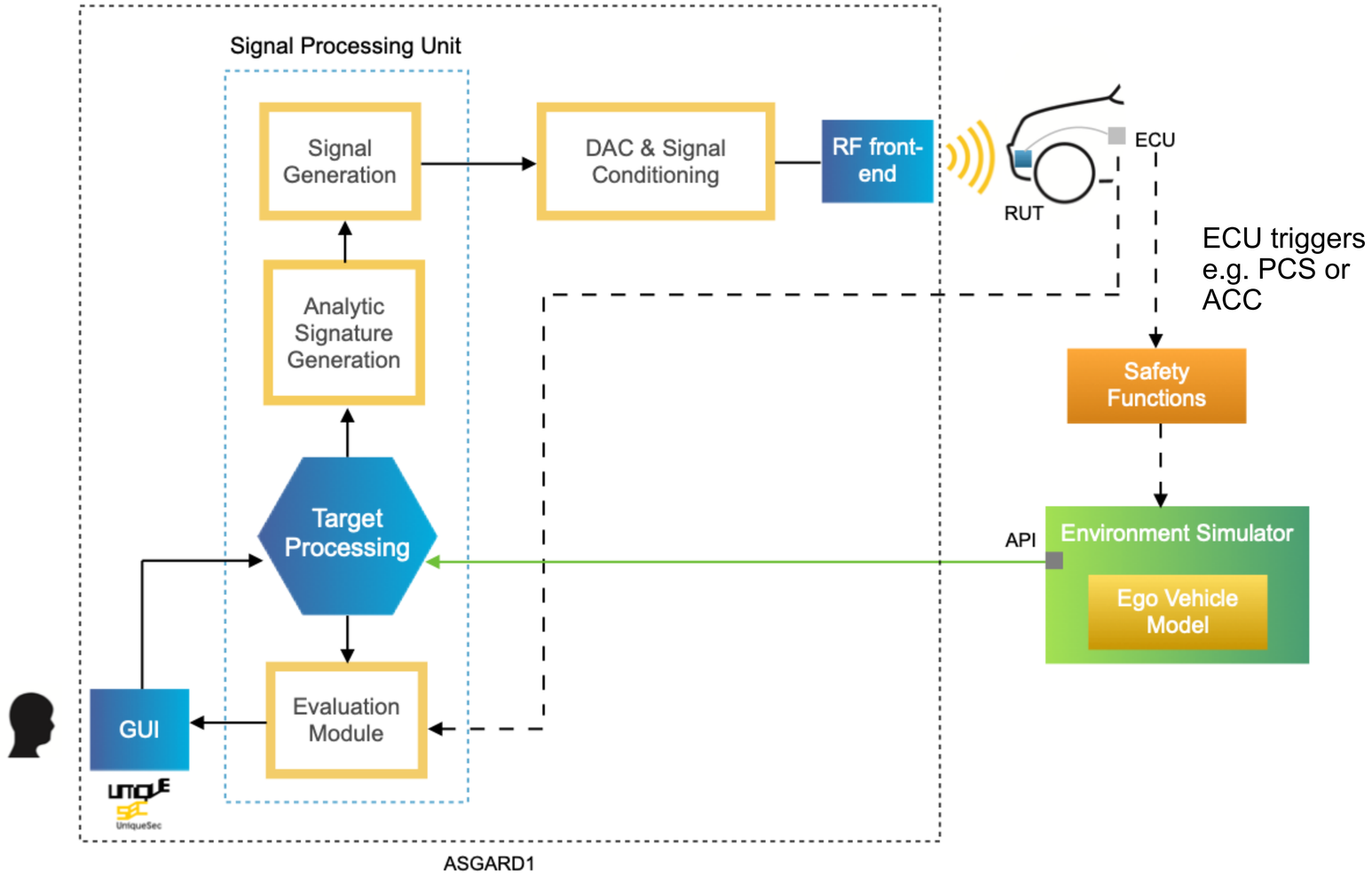


Radar testing technologies

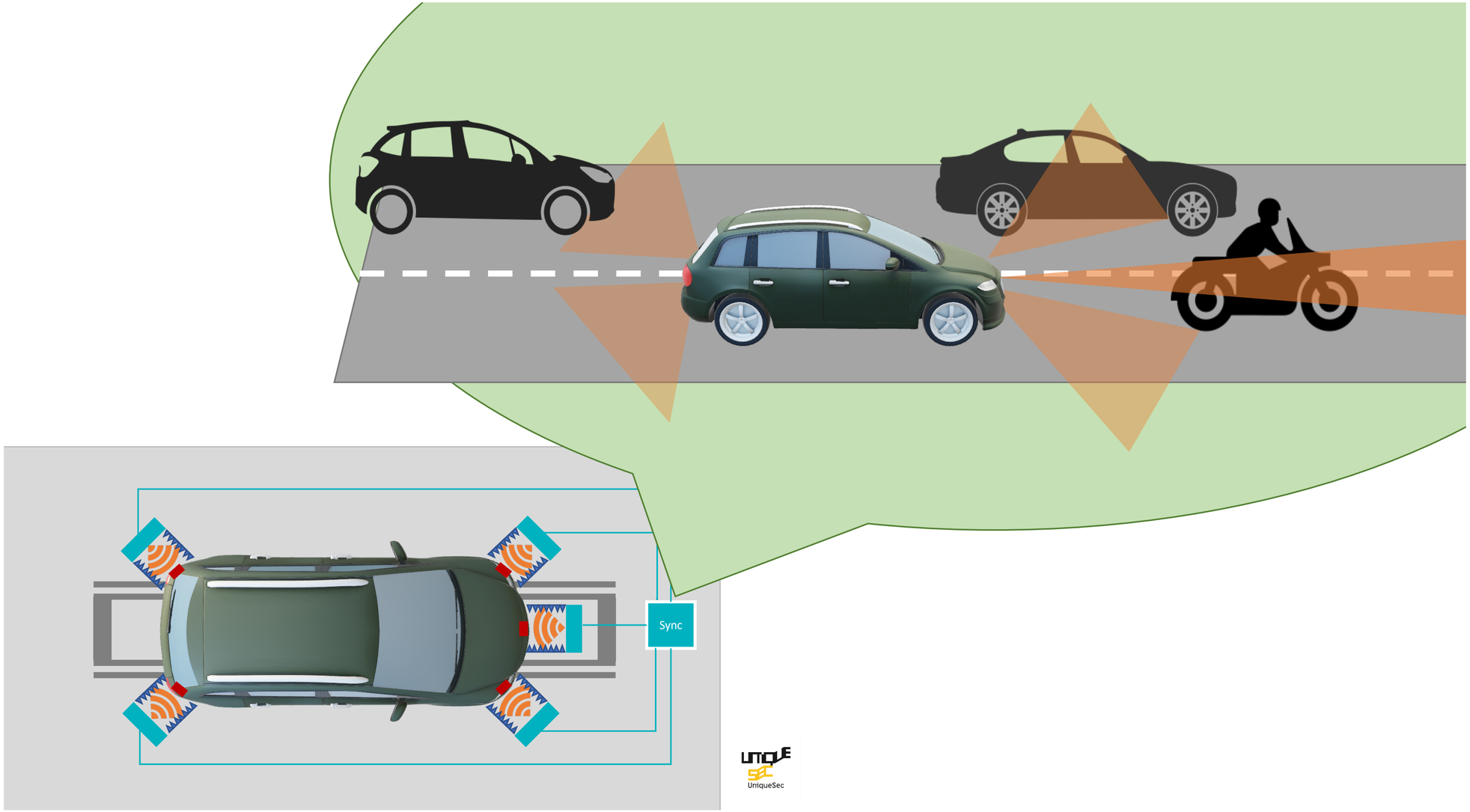
- **Delay-based (Time-domain)**
  - Each target generated by a **delay-line**
  - Addition of targets requires adding to the number of delay-lines i.e. **few targets**
  - Not possible to create small minimum range due to **processing delay**
  - Angles of targets generated by **mechanical rotation** of antennas of target simulator

- **ASGARD1: Spectrum-domain**
  - Targets with **arbitrary trajectory** are simulated in frequency domain
  - New targets are easily added to the spectrum of radar signal i.e. supporting **hundreds of targets**
  - **Minimum distance** of 20 cm is possible
  - Large **dynamic range** for RCS
  - **Real-time** signal generation and adaptation
  - Angles perception can be generated completely **electronically**

ASGARD1 - Radar target simulator for HiL



Scalable solution for full vehicle (multi-radar) HiL testing



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CarMaker HiFi radar model with ASGARD1

Integration of ASGARD1 and

IPG CarMaker in a HiL setup

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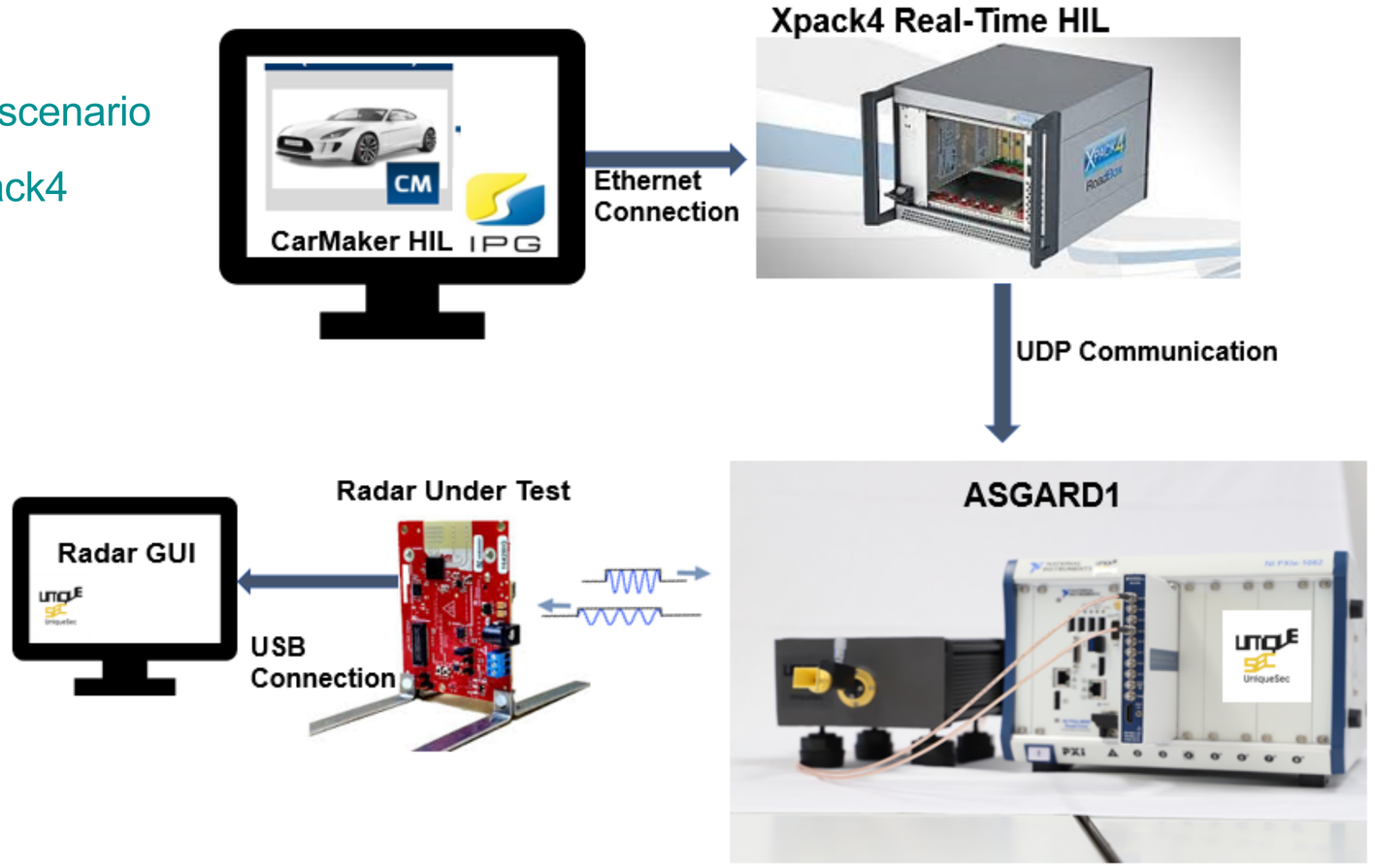
ASGARD1-CarMaker HiL setup

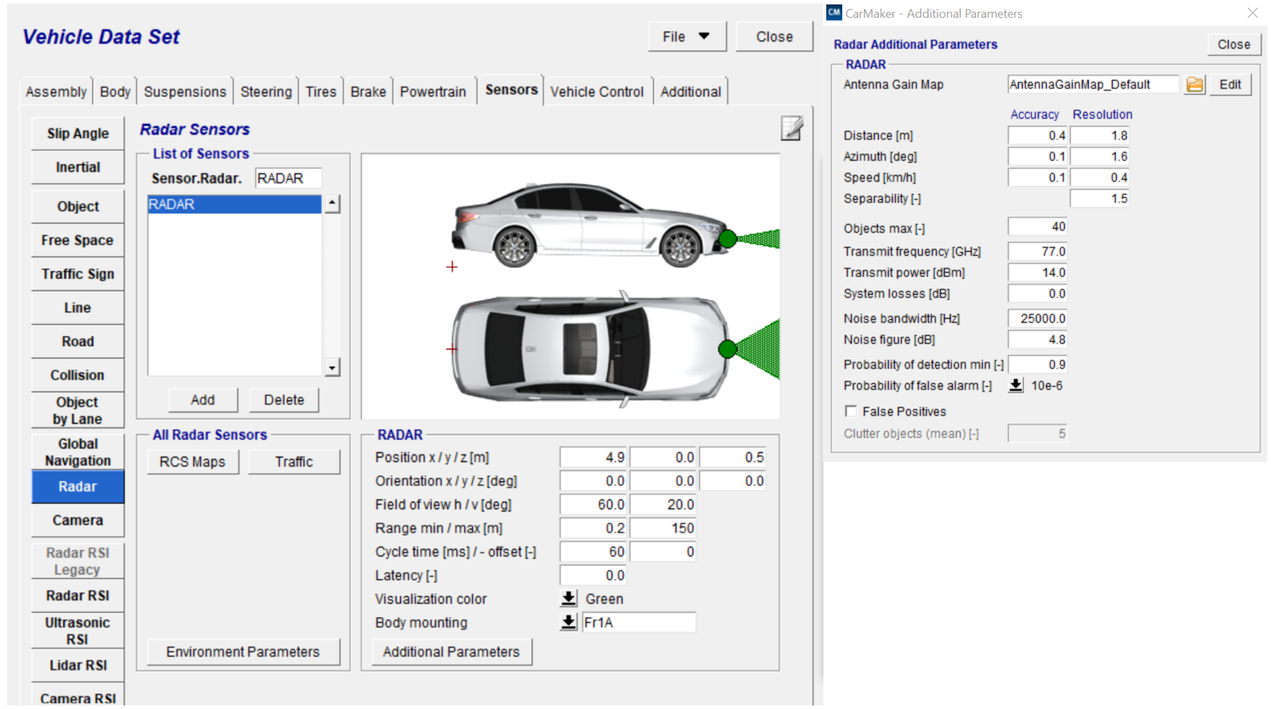
CarMaker for real-time scenario generation through Xpack4



ASGARD1 for emulation of targets in the scenario

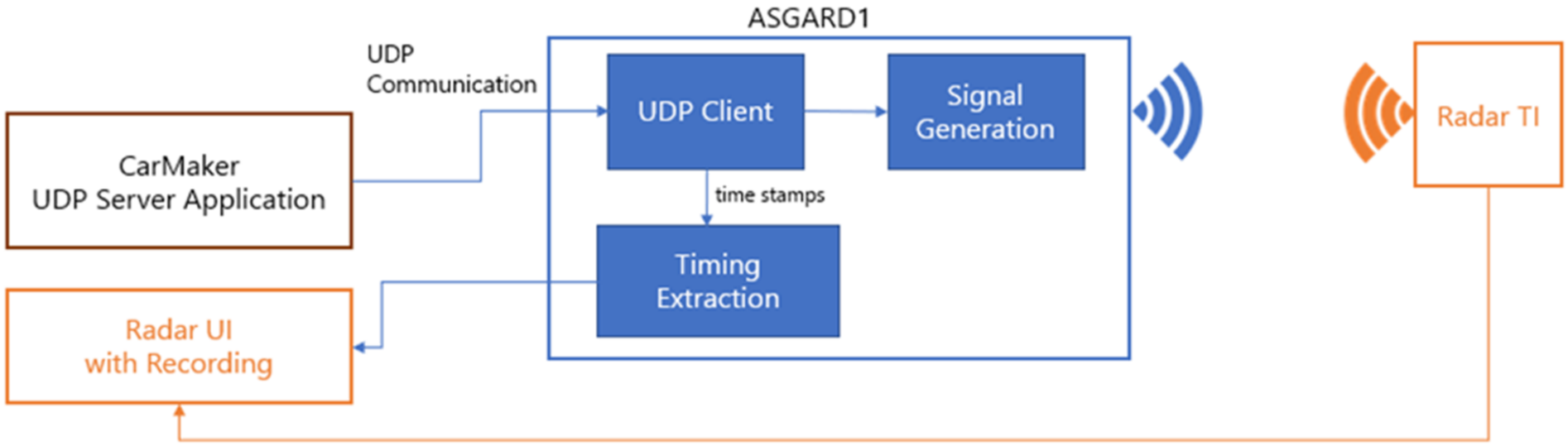
Point target information

- Radar targets are based on CarMaker HiFi Radar Sensor model
- IPG user C-interface extracts and sends targets information
- ASGARD1 receives information of point targets from CarMaker via UDP communication
  - *Range*
  - *Radial velocity*
  - *Azimuth angle*
  - *Elevation angle*
  - *RCS*



Our tool for comparing radar outputs with ground-truth

Time-referenced radar detections can be recorded for comparison against simulated scenario in CarMaker



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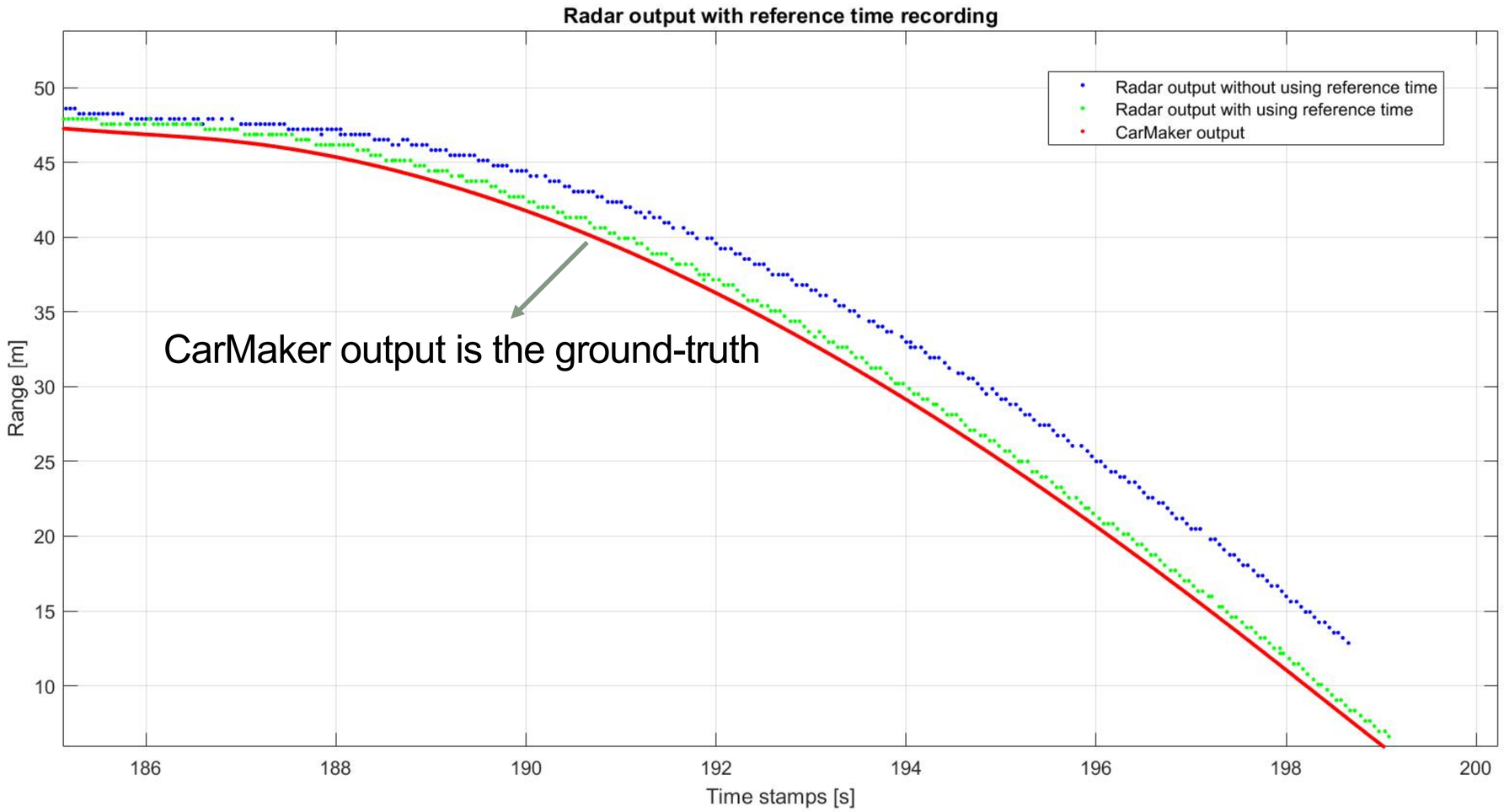
Comparing radar range measurements with ground-truth



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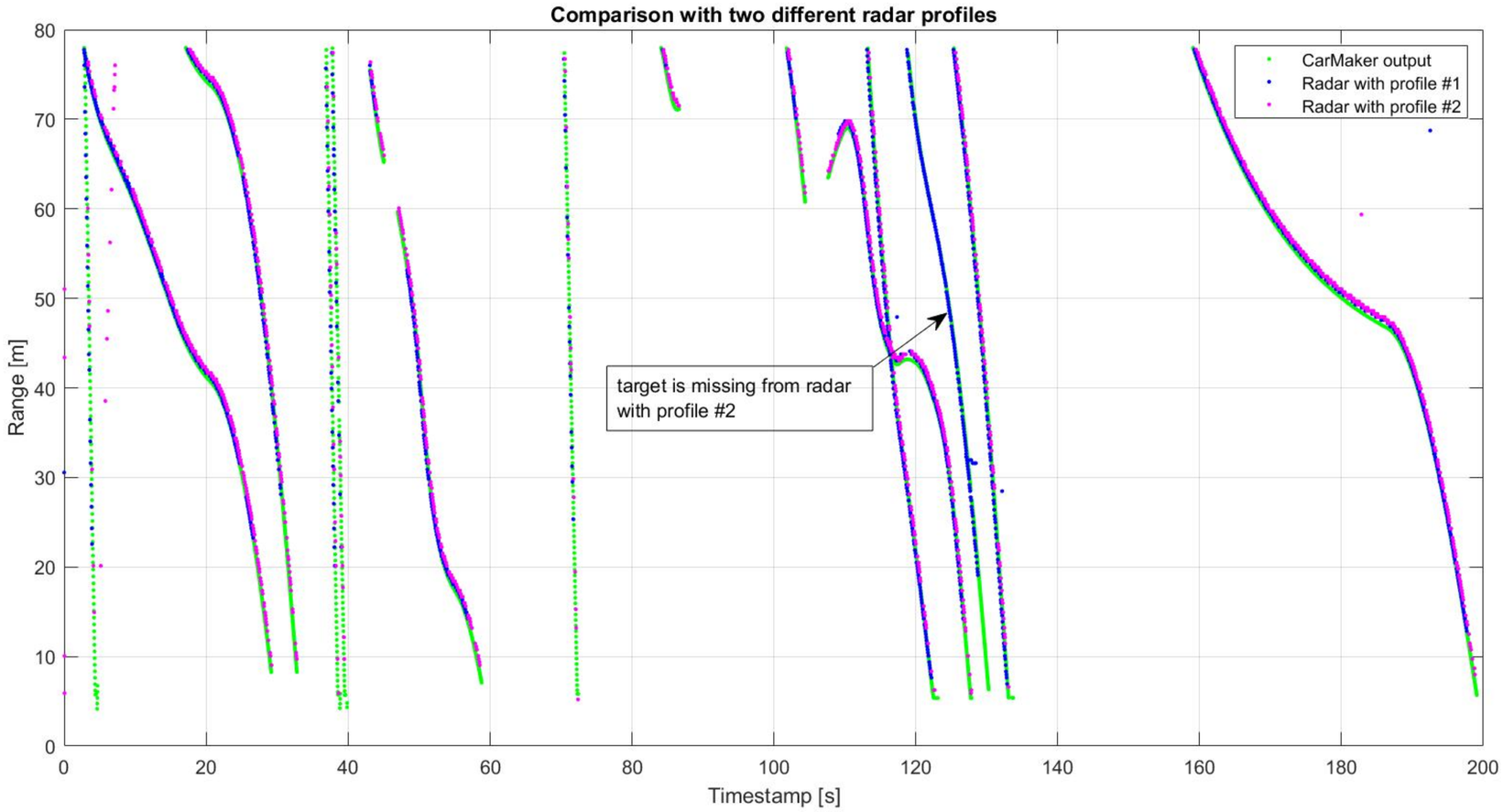
Analysis of target detections with different radars

- ACC scenario
- HiFi Radar Sensor
- UDP Communication
- Radar Target Emulator ASGARD1
- Radar Under Test TI AWR1642



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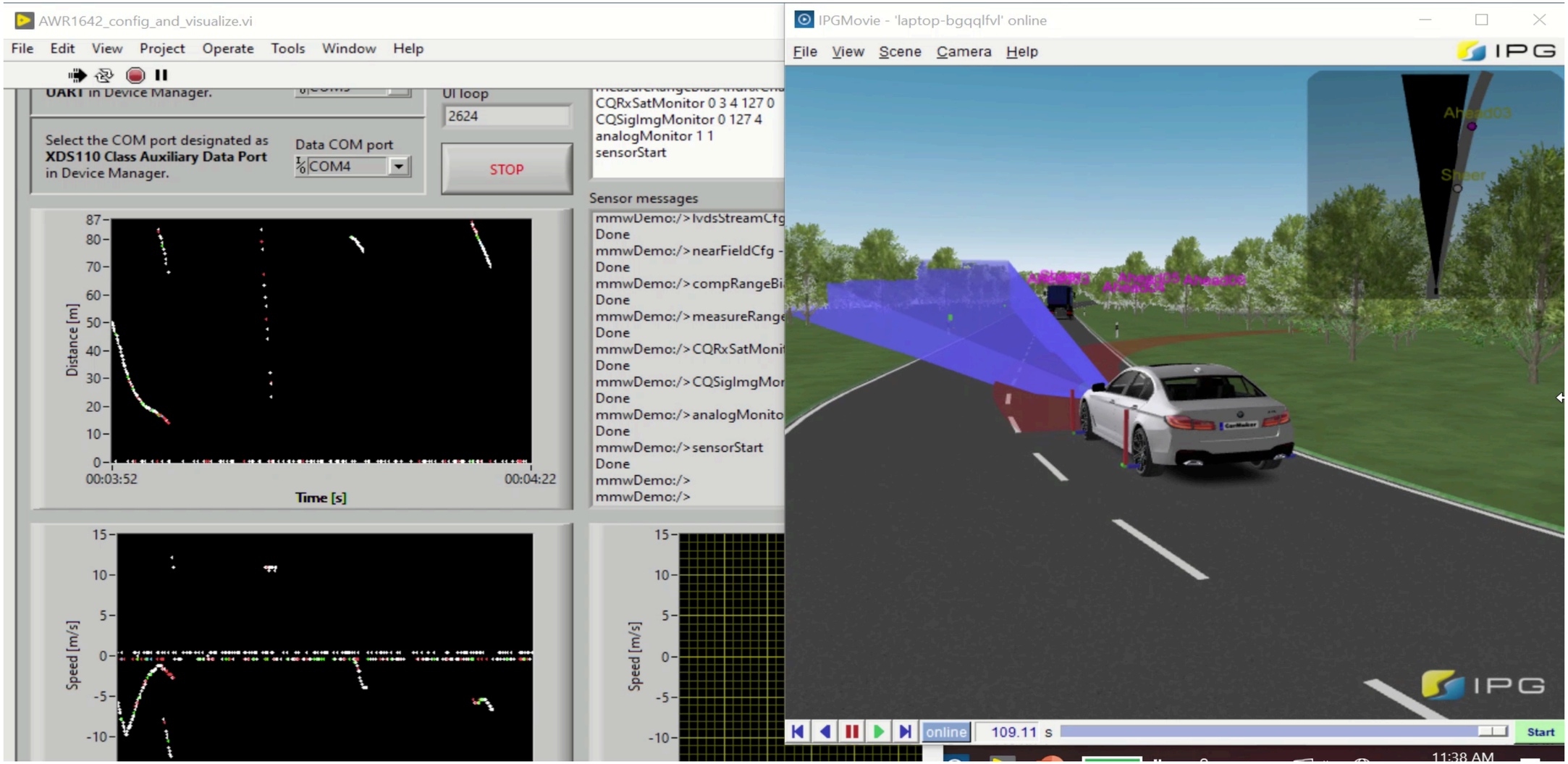
Analysis of radar detections using two radars



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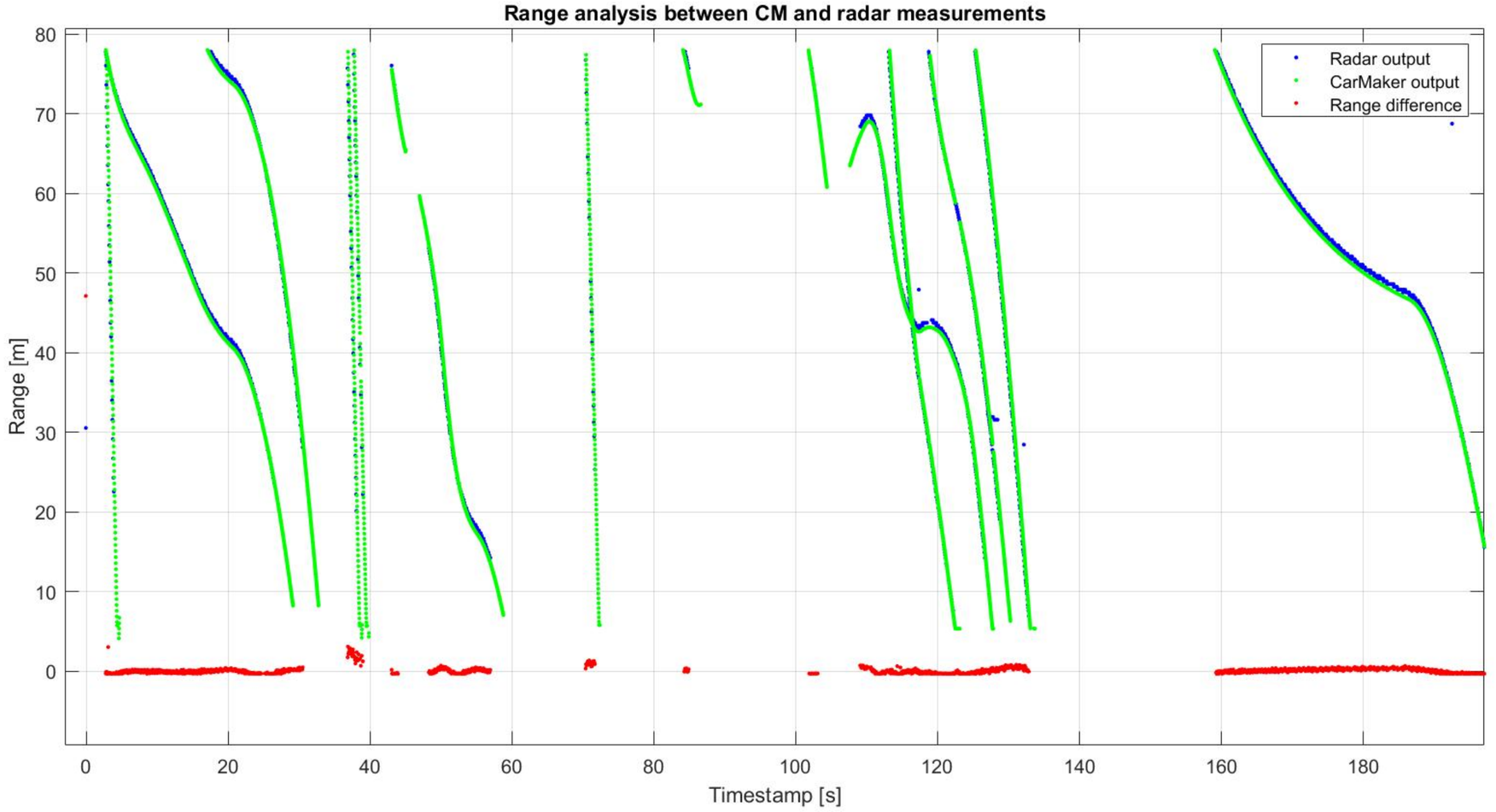
Difference between ranges from CarMaker and radar output



Range difference mean = 0.43 m

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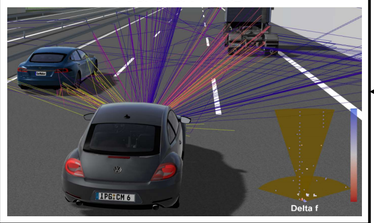
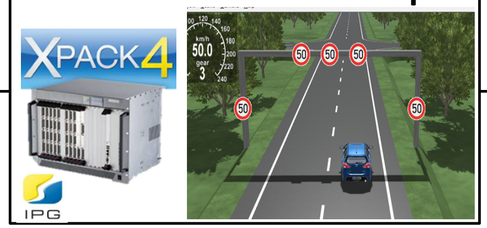
ASGARD1 in Radar RSI HiL

Radar RSI



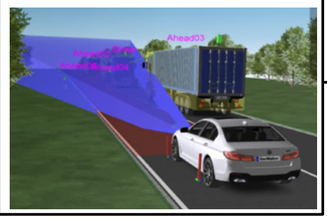
1

TSS CarMaker HiL setup



2

Point Targets



C-Code
(CAN)

Radar ECU
(Mass Production)

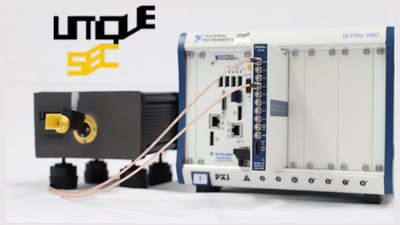
Signal Comparison
(Vector CANoe)
- Target Position
- Target Speed
- …

Point Cloud Processing
(CarMaker 9.0 RSI)

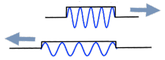
Reflection List
- **Range**: Distance in longitudinal direction (x)
- **Azimuth**: Estimation of the distance in lateral direction (y)
- **Velocity**: Relative radial velocity to the detected object
- **Elevation**: Angle
- **RCS**: Gain

API
(Ethernet UDP)

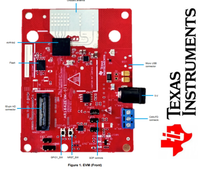
Radar Over-the-Air Testing
(ASGARD1)



OTA



Reference System
(TI Radar ECU)



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Radar RSI with ASGARD1

- Evaluation of RSI point cloud output in different scenarios
- Filtering of RSI detections
- Adapting RSI point cloud for ASGARD1 API
- Simulating Range, Radial velocity, Azimuth angle, Elevation angle, RCS

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Conclusion

- A full real-time over-the-air HiL for validating automotive radars is implemented
- ASGARD1 is interfaced to IPG CarMaker over UDP communication
- Time-referencing helps to accurately perform analysis of radars
- ASGARD1 capability in simulation of multiple point targets enables using high fidelity models for scenarios, such as Radar RSI model.
- OEMs could expect thanks to this technology to reduce ADAS systems vehicle validation on the road and its environmental impact.
- This approach will make ADAS quality easily reachable.