

LiDAR simulation for Autonomous Vehicle Dvpt

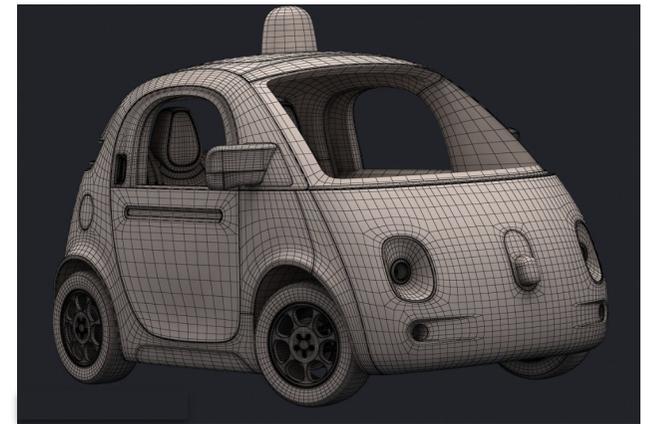
November 20th, 2018 - DVN Frankfurt
Julien Muller - Product Manager

Simulation is the Only Practical Solution: Waymo Case Study

Simulation is the only practical way to validate autonomous vehicles over millions of driving scenarios

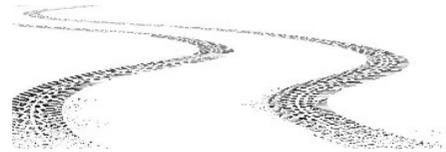


vs.



**4 Million
Road Miles**

Driven in **NINE** Years



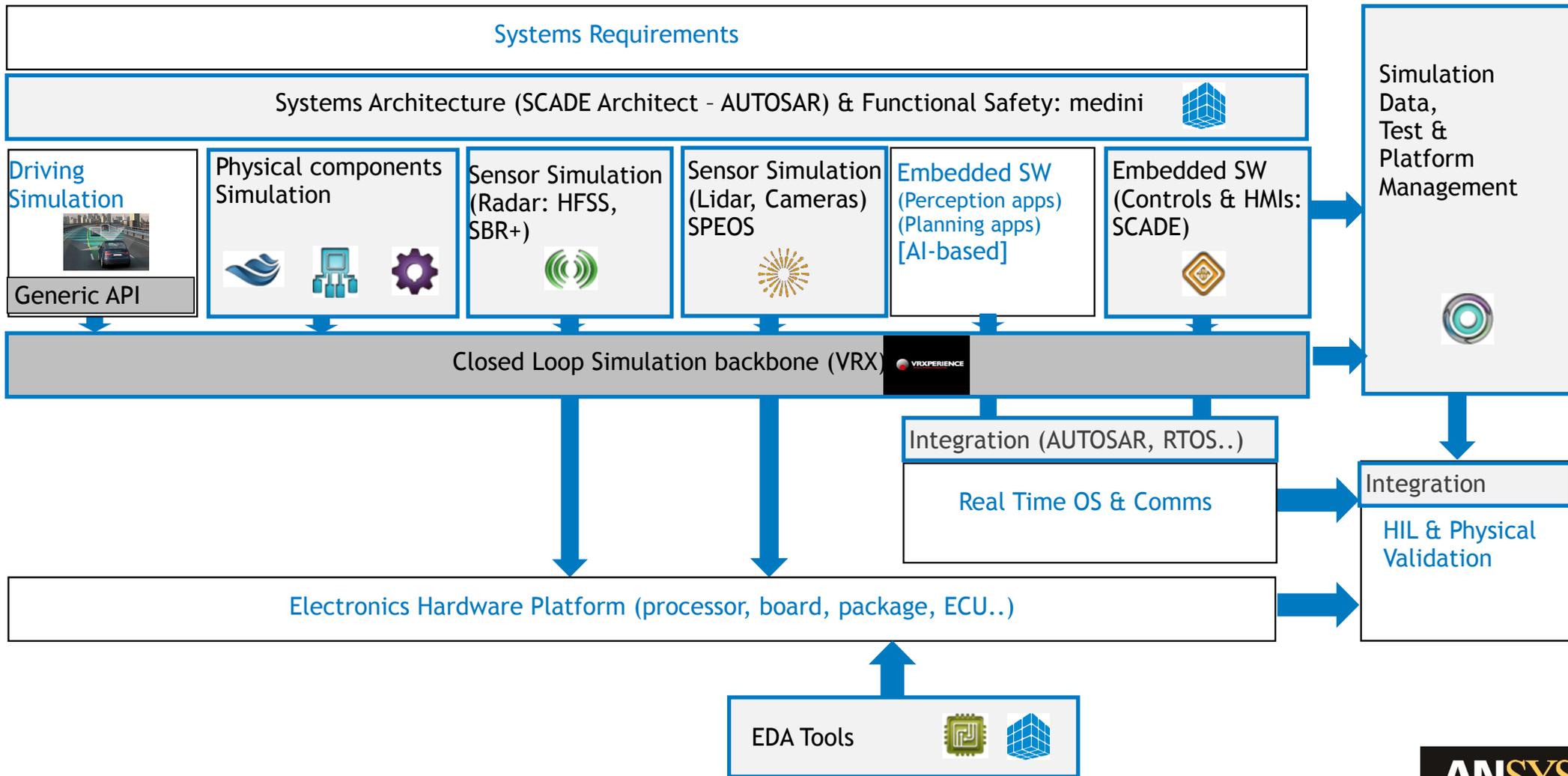
**2.5 Billion
Simulated Miles**

Driven in **ONE** Year

Reference: Waymo Safety Report: On the Road to Fully Self-Driving (2017)

ANSYS

AV Simulation Environment: ANSYS Offering with OPTIS & Partners



Data Workflow

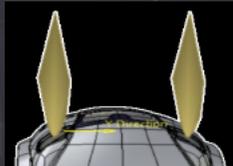
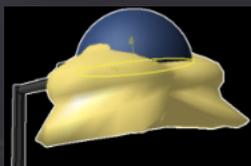
PHYSICAL INPUTS

Luminaires

Natural light

Headlamp

LIGHTING

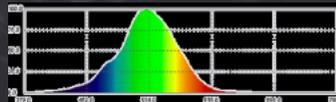
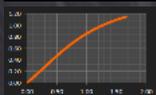
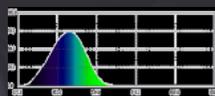


Lens

Imager

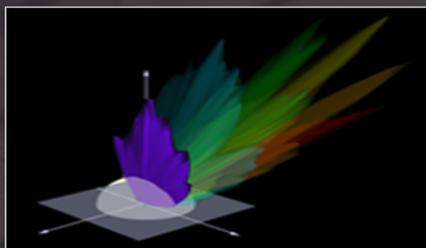
CAMERAS

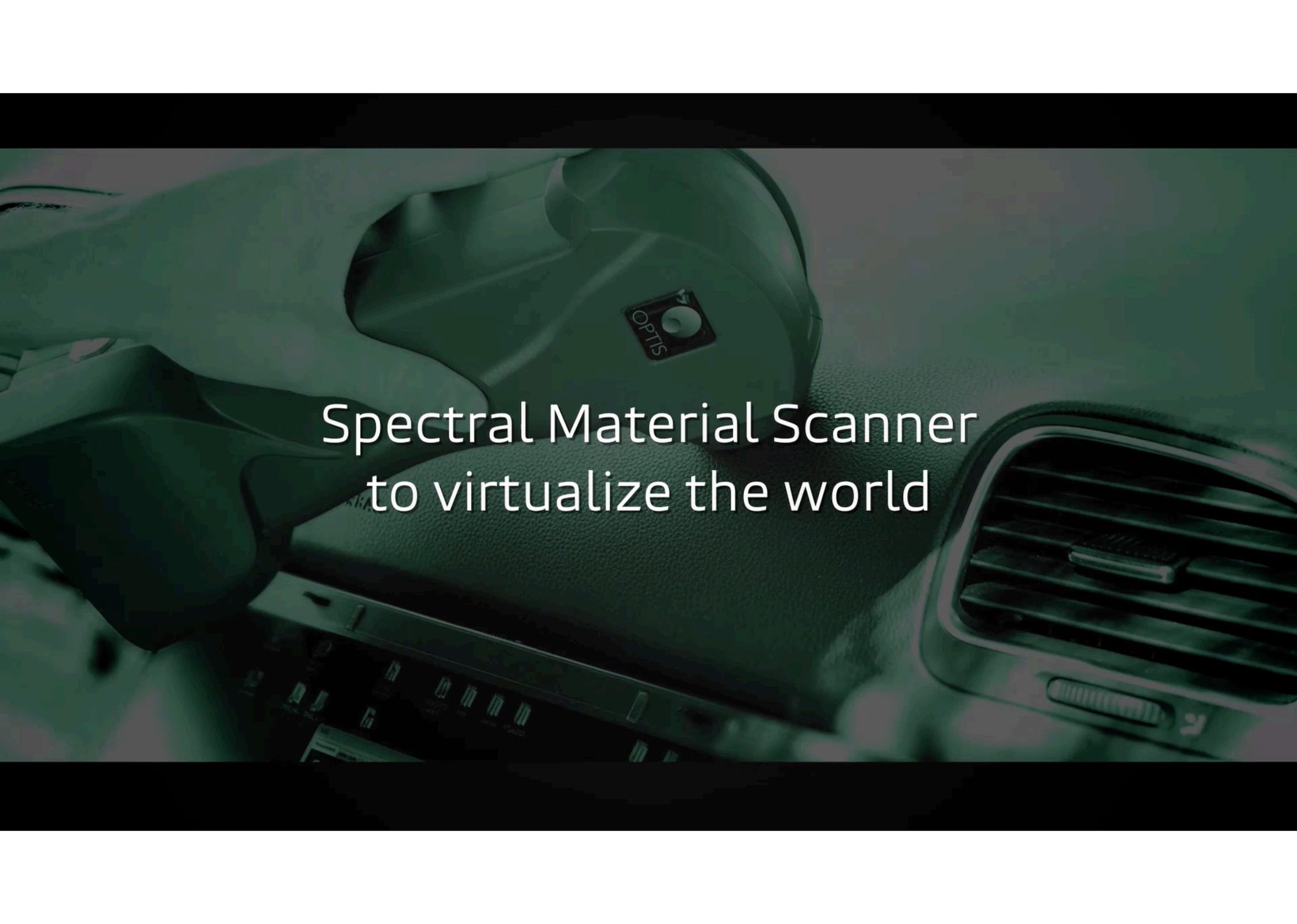
LIDARS



BRDF

MATERIALS



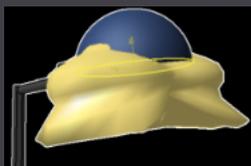
A hand is holding a handheld Spectral Material Scanner (OPTIS) over a car's interior. The scanner is a dark, handheld device with a lens and a small display. The car's interior, including a leather seat and an air vent, is visible in the background. A keyboard is also partially visible in the lower left. The entire scene is overlaid with a semi-transparent dark green filter.

Spectral Material Scanner
to virtualize the world

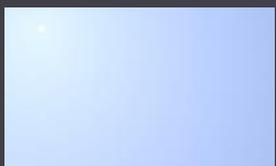
Data Workflow

PHYSICAL INPUTS

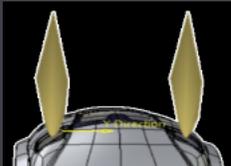
Luminaires



Natural light



Headlamp

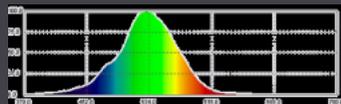
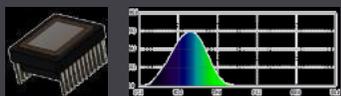


LIGHTING

Lens



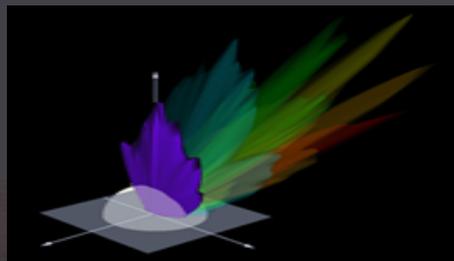
Imager



CAMERAS

LIDARS

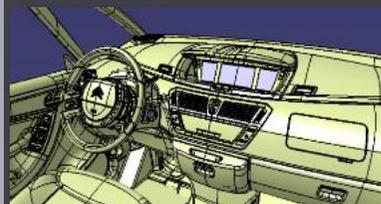
BRDF



MATERIALS

3D MODEL

In CAD



In environment



Simulations Can Utilize Real As Well As Virtual Data

Real Data

Sensor inputs recorded by real AVs driving on real roads

Virtual Data

Virtual vehicles driving in virtual worlds

Example: Simulation Replaying Real Sensor Data

Example: Fully Virtual Simulation



Real Camera Image

Virtual Camera Image



Data Workflow

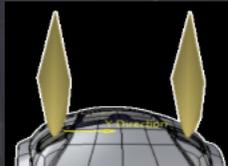
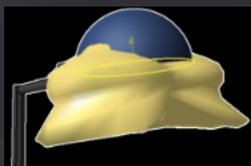
PHYSICAL INPUTS

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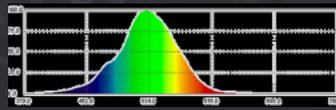
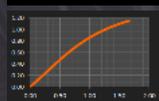
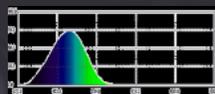


Lens

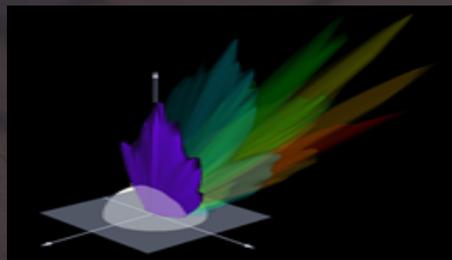
Imager

CAMERAS

LIDARS

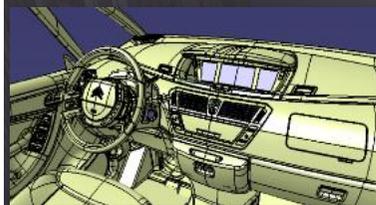


BRDF



3D MODEL

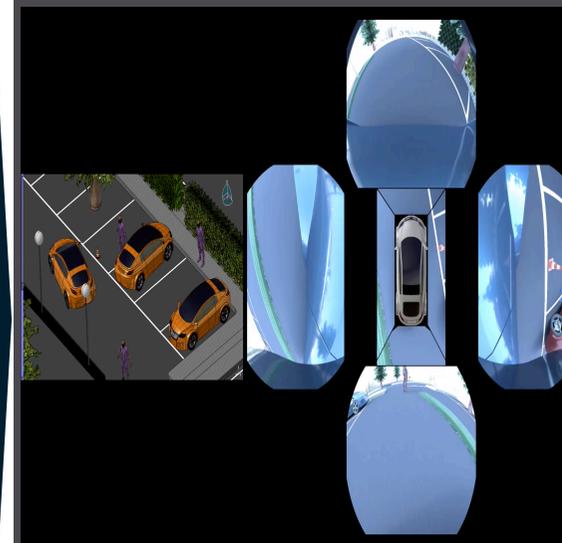
In CAD



In environment



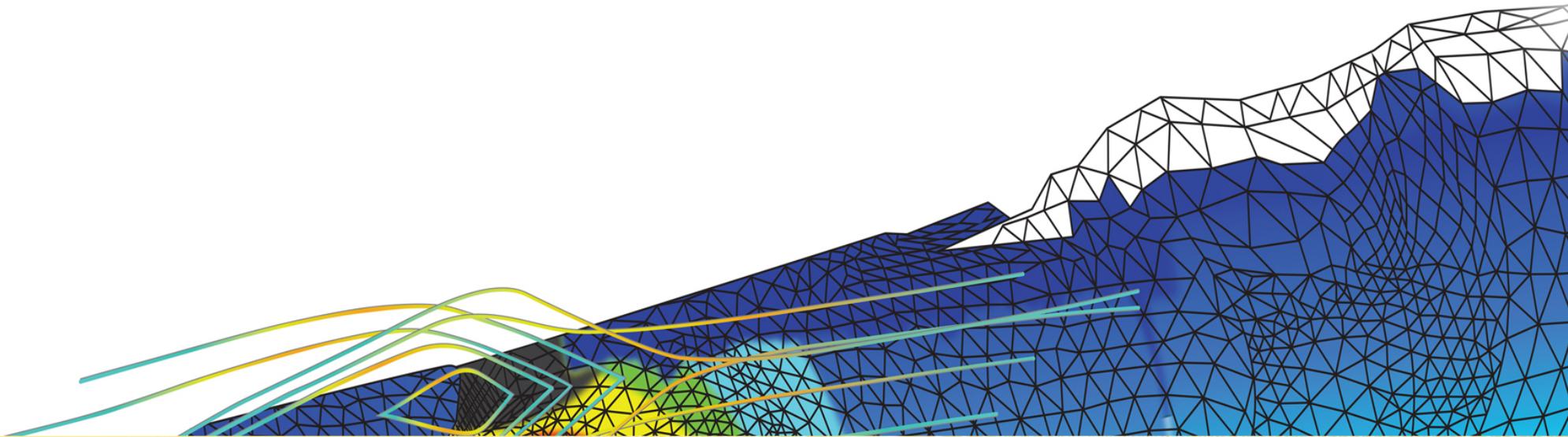
SIMULATION RESULTS



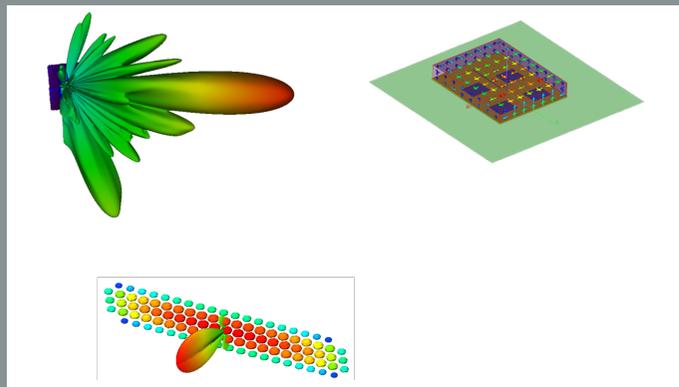
ANSYS®



Sensor simulation

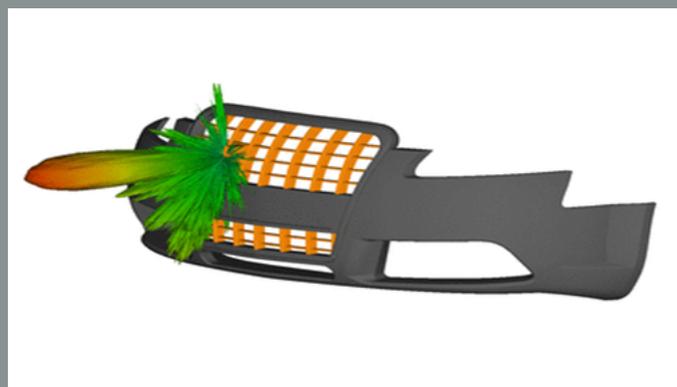


Solutions for Radar System



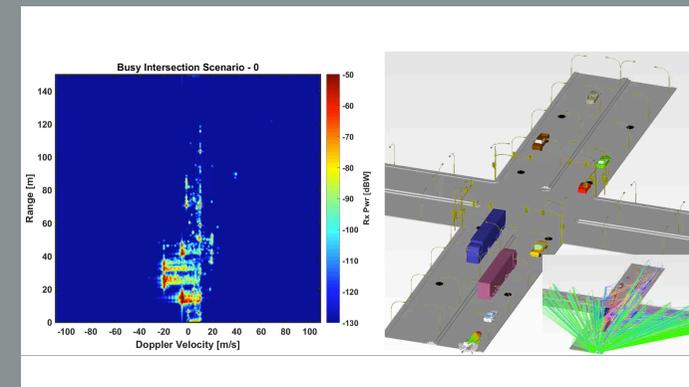
1- Component / Detailed simulation

Radar detailed design
Performance analysis



2- In-car installation

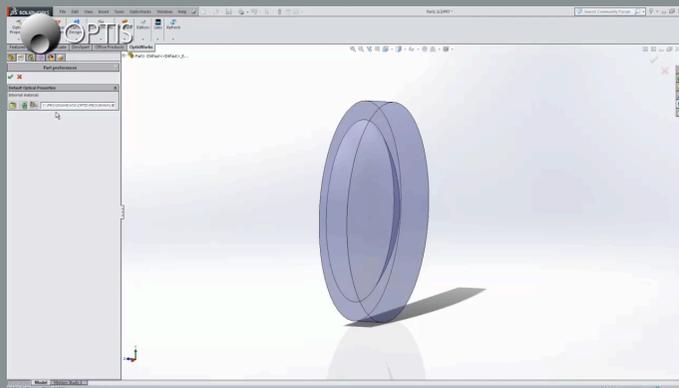
Facia implementation



3- In-driving scenario – MIL/SIL/HIL

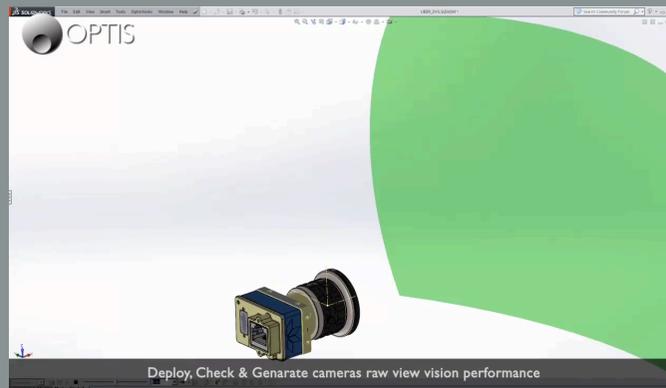
Early evaluation on driving situation
Test & Validation

Solution for Camera Simulation



1- Component / Detailed simulation

Optical Camera
Design & Analysis



2- In-car installation

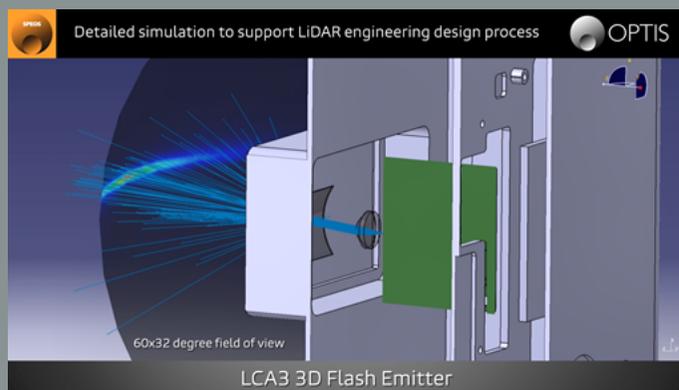
Vision Performance
Analysis



3- In-driving scenario – MIL/SIL/HIL

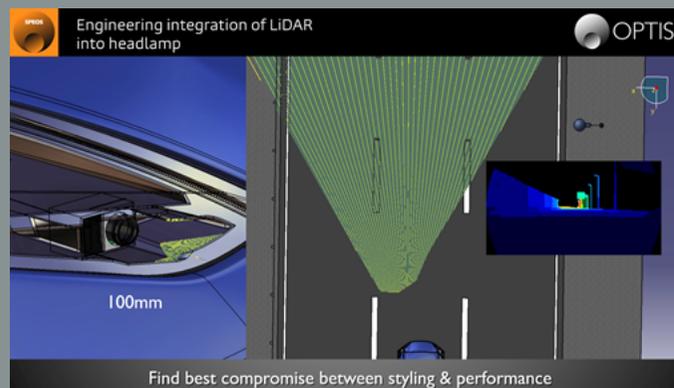
Vision System
Test & Validation

Solutions for LiDAR System



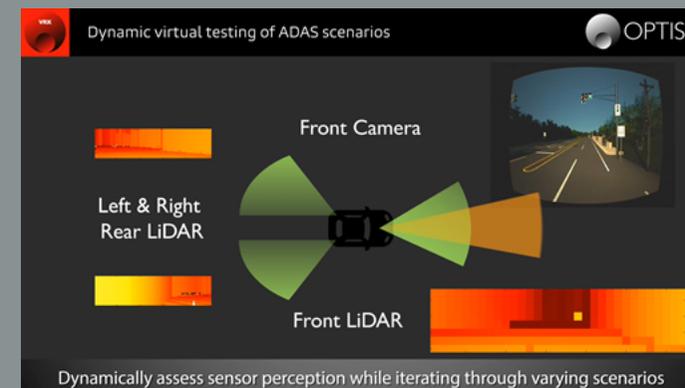
1- Component / Detailed simulation

LiDAR detailed design
Performance analysis



2- In-car installation

Lamps implementation

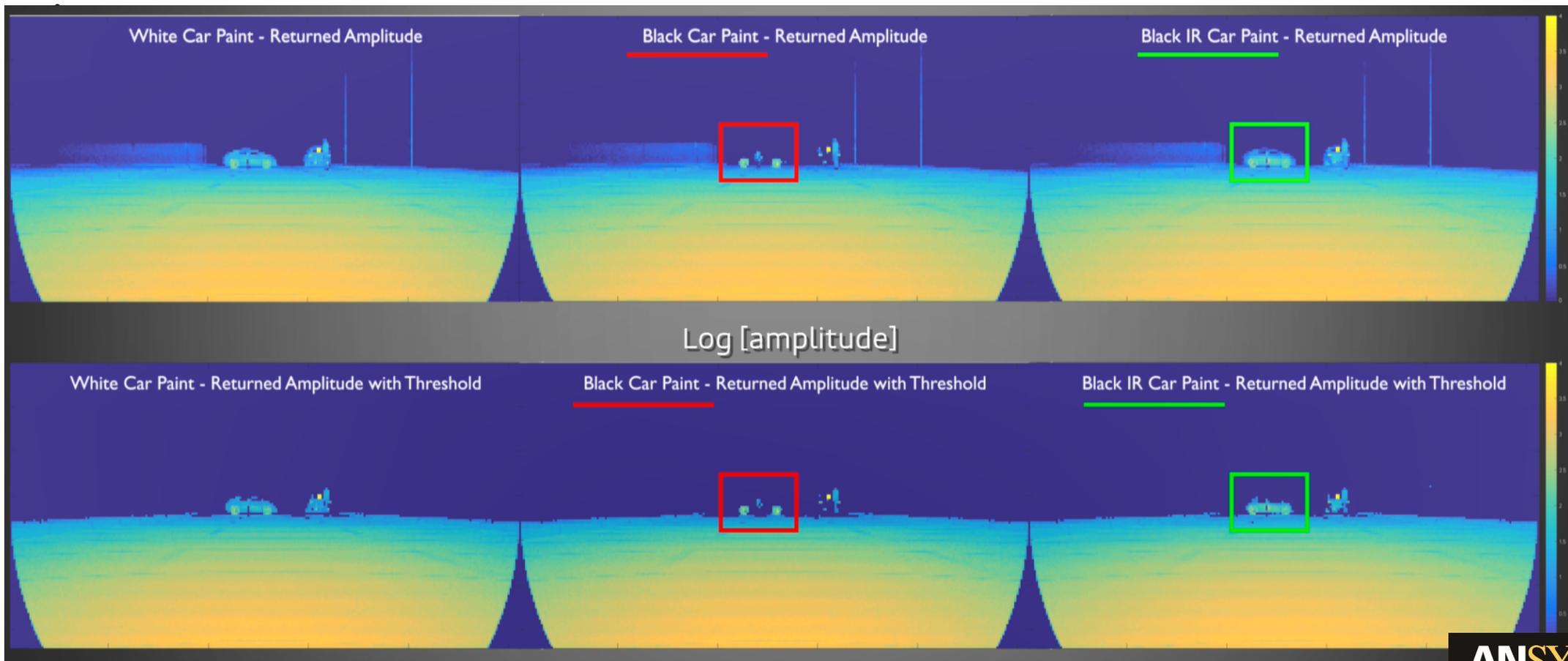


3- In-driving scenario – MIL/SIL/HIL

Early evaluation on driving situation
Test & Validation

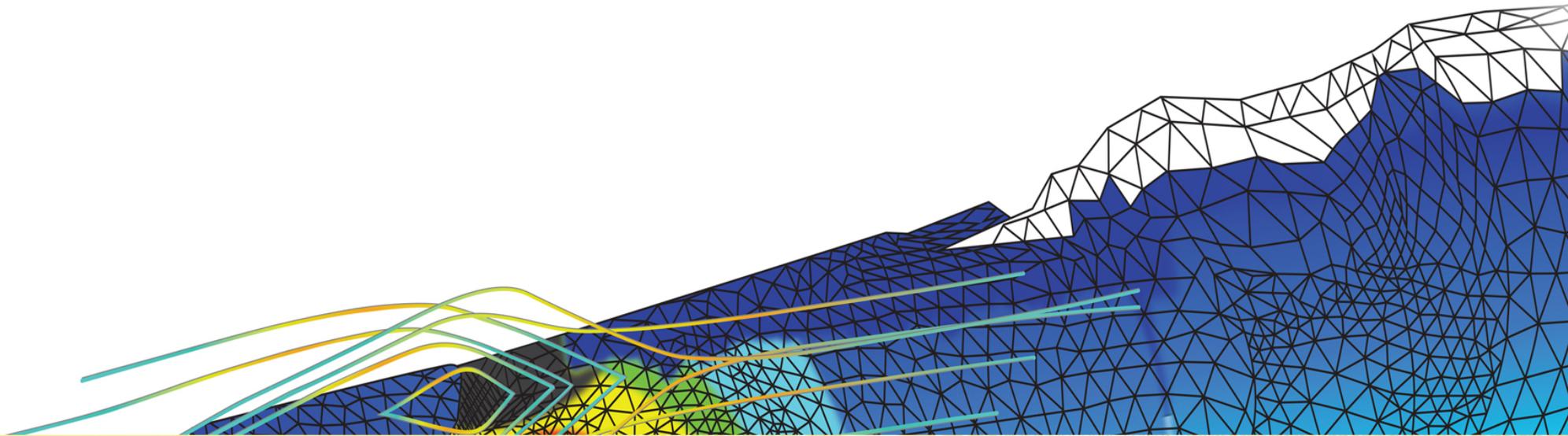
Case Study - Measured materials

Simulate LiDAR performance taking into account the IR reflectivity of car





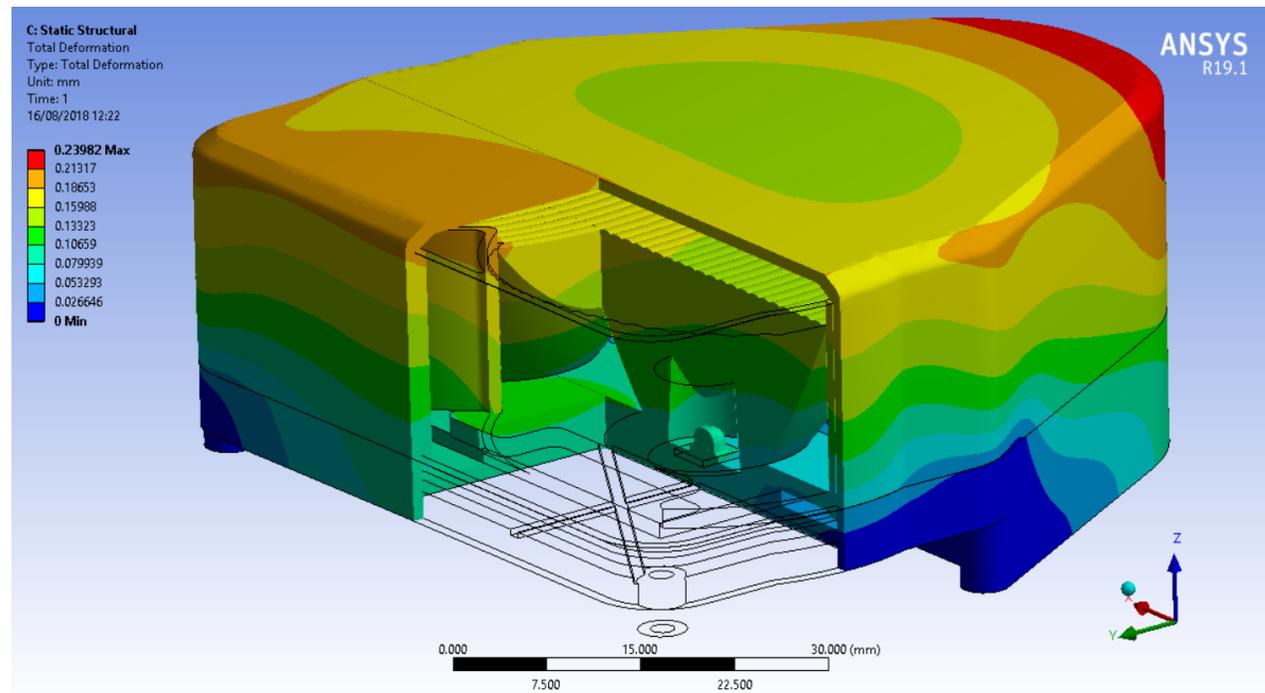
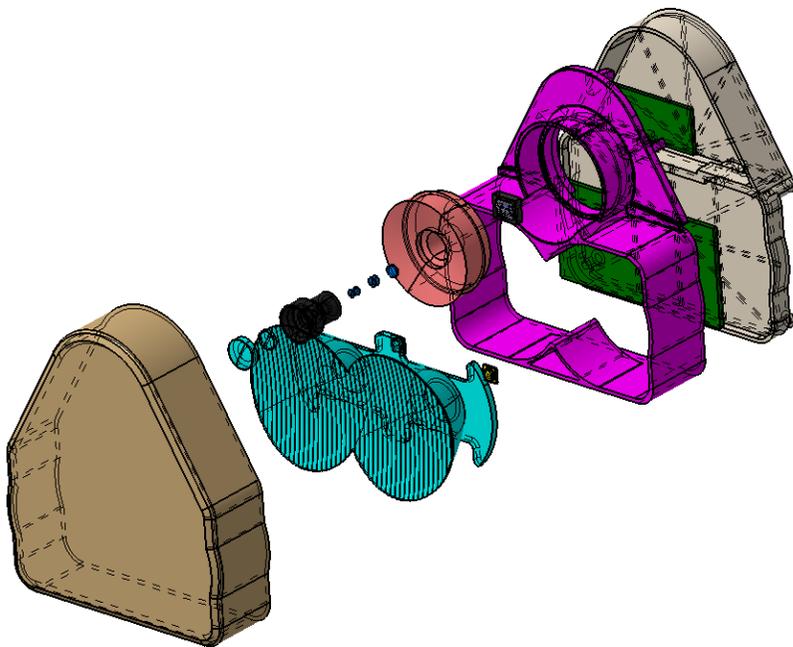
Thermal effect on LiDAR



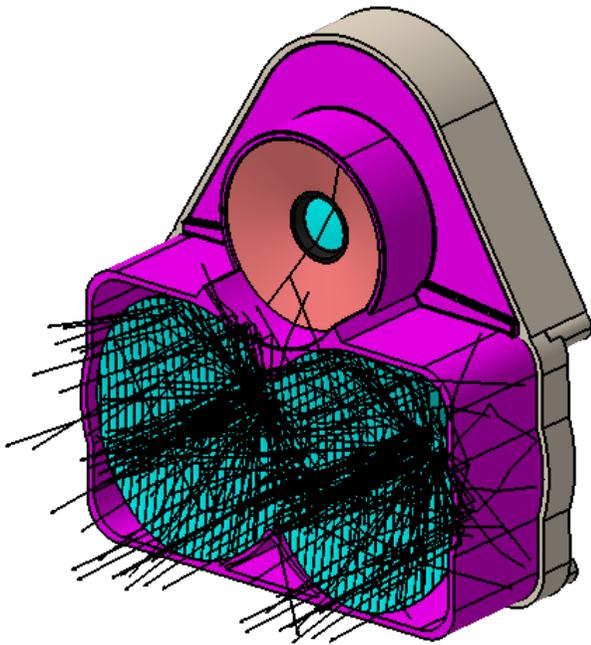
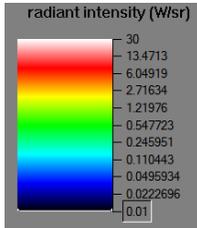
Flash LiDAR - Thermal study

Structural Deformation

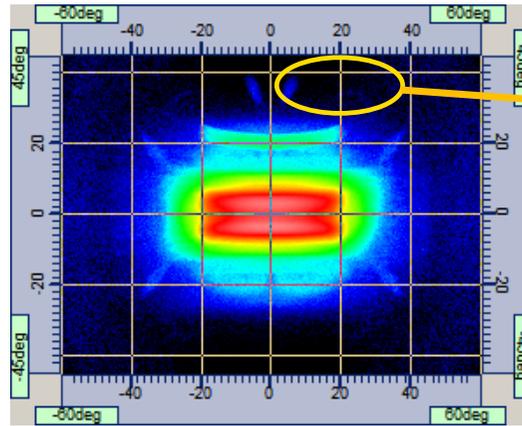
$T_{\text{ambient}} = 20^{\circ} \rightarrow 60^{\circ}$



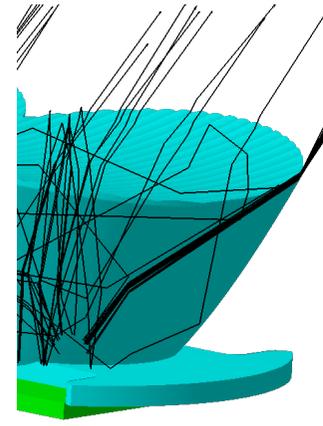
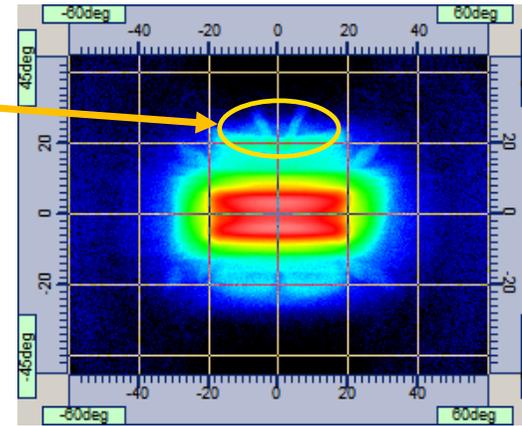
Transceiver beam pattern



$T_{\text{ambient}} = 20^\circ$



$T_{\text{ambient}} = 60^\circ$

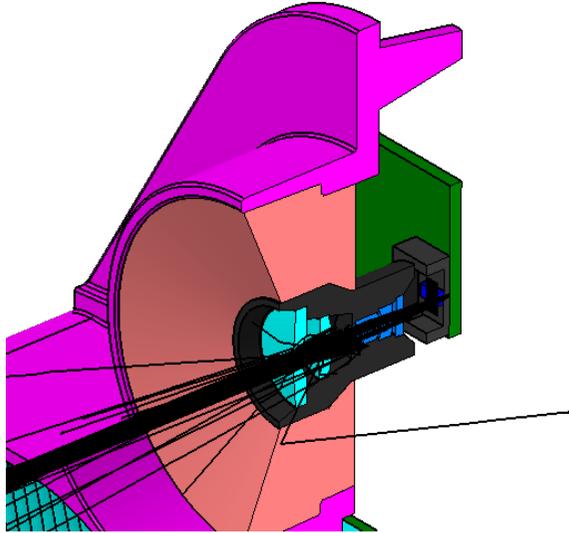


Spot of light leakage migrates toward the center

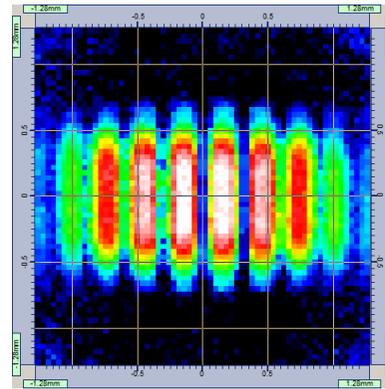
Light leak on TIR lens



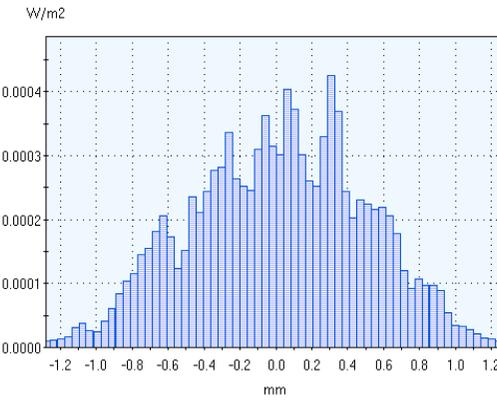
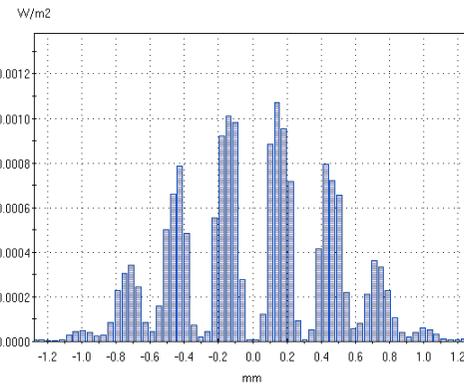
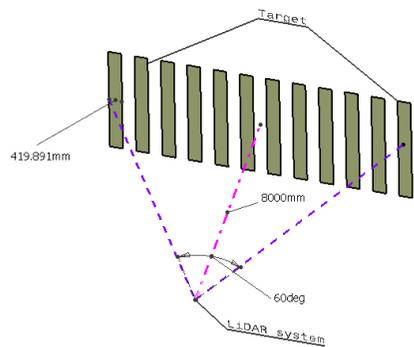
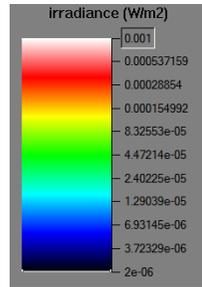
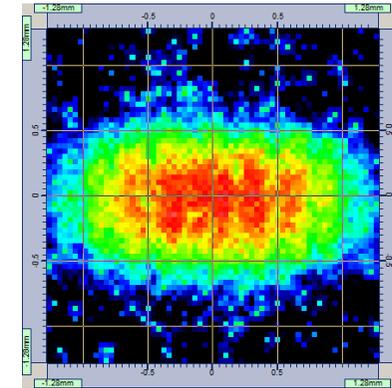
Receiver qualification



$T_{\text{ambient}} = 20^\circ$



$T_{\text{ambient}} = 60^\circ$

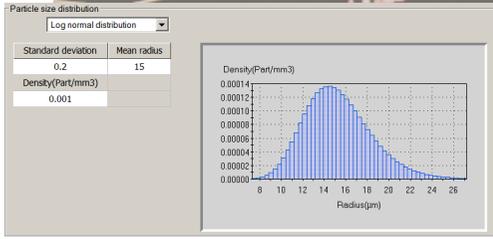


Signal Degradation from lens deformation

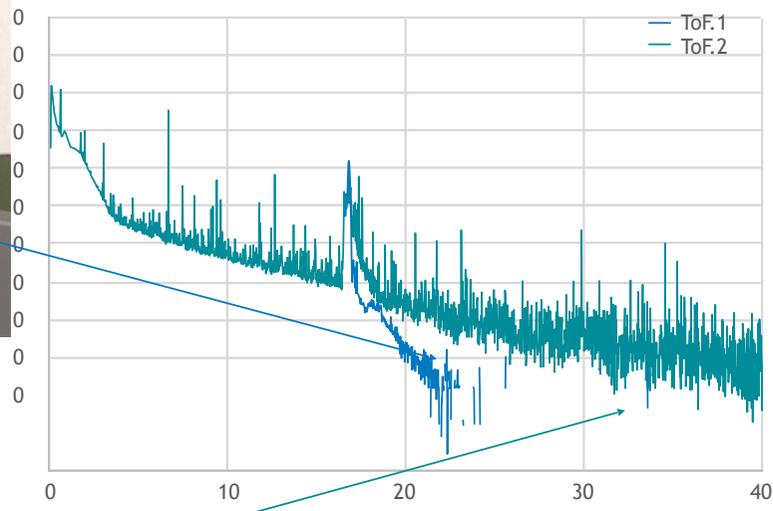


Fog Simulation Camera & Lidar signal degradation

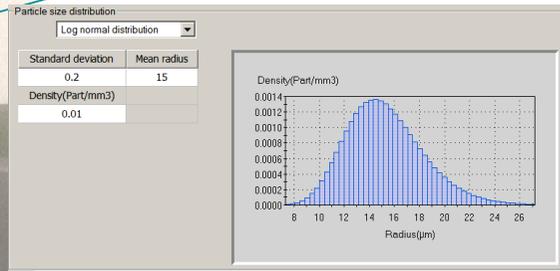
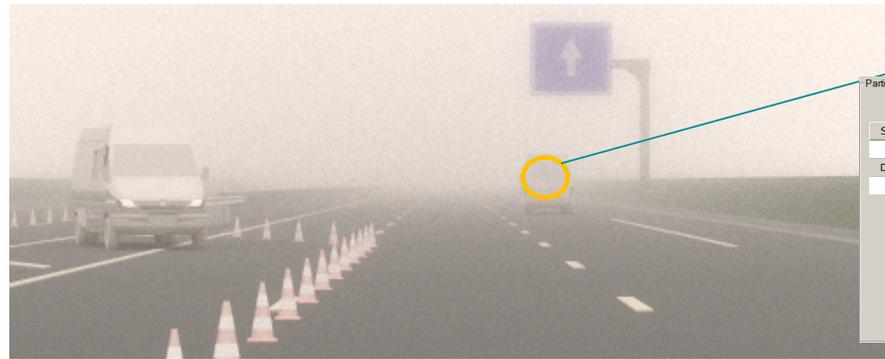
Particle Density = *10 times



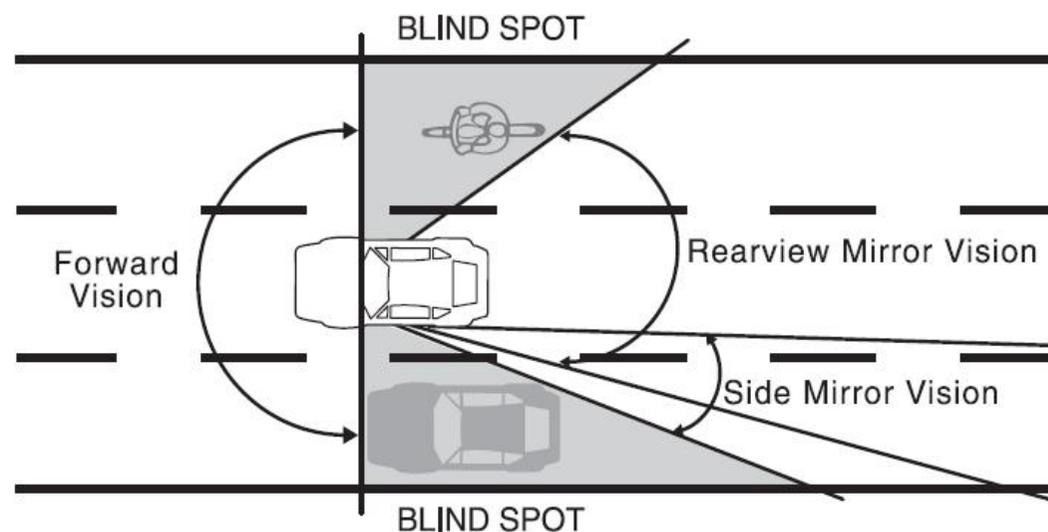
Time Of Flight Signal



water droplet influence



ADAS feature specification



Specify ADAS functions based on sensors
Define sensor and software requirements

The screenshot shows the VRX software interface for dynamic virtual testing of ADAS scenarios. The interface includes:

- VRX Logo:** Top left corner.
- Dynamic virtual testing of ADAS scenarios:** Title text at the top.
- OPTIS Logo:** Top right corner.
- Central Vehicle Model:** A black car with sensor fields of view: **Front Camera** (yellow cone), **Left & Right Rear LiDAR** (green cones), and **Front LiDAR** (yellow cone).
- Surrounding Views:** A top-down view of the car, a side view of the car, and a perspective view of the road ahead.
- Dynamic sensor perception:** A text box at the bottom stating "Dynamically assess sensor perception while iterating through varying scenarios".

Model based simulation with VRX using raytracing and physical based sensor

VRXPERIENCE Sensors



Scenarios with light conditions variations



VRXPERIENCE Sensors



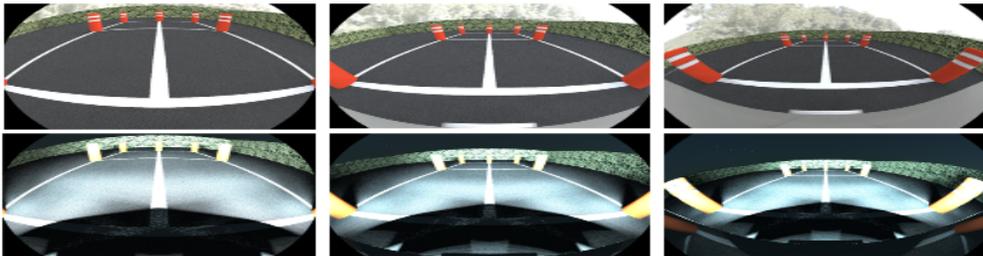
ANSYS

Sensor Simulation solution for AD & ADAS



SPEOS Optical Sensor Test

- Light & Optical sensors Camera & LiDAR
- Vision performance validation
- Open Loop simulation



VRX - AD

- AD testing with light & sensors
- Real-time physics based engine
- MIL/SIL/HIL Closed Loop simulation



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Thank you for your attention

