# Suggestion for standardization: DIVP® Material Property for ASAM OpenX standards

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DIVP


ASAM Association for Standardization of Automation and Measuring Systems

# Agenda

DIVP® Material property for ASAM OpenX Standards

| | |
|---|---|
| 1 | **Introduction of DIVP® physical sensor modelling** |
| 2 | **Material property initiatives through VIVID collaboration** |
| 3 | **DIVP Proposal for ASAM OpenMaterial** |

# Agenda

DIVP® Material property for ASAM OpenX Standards

# DIVP® Project

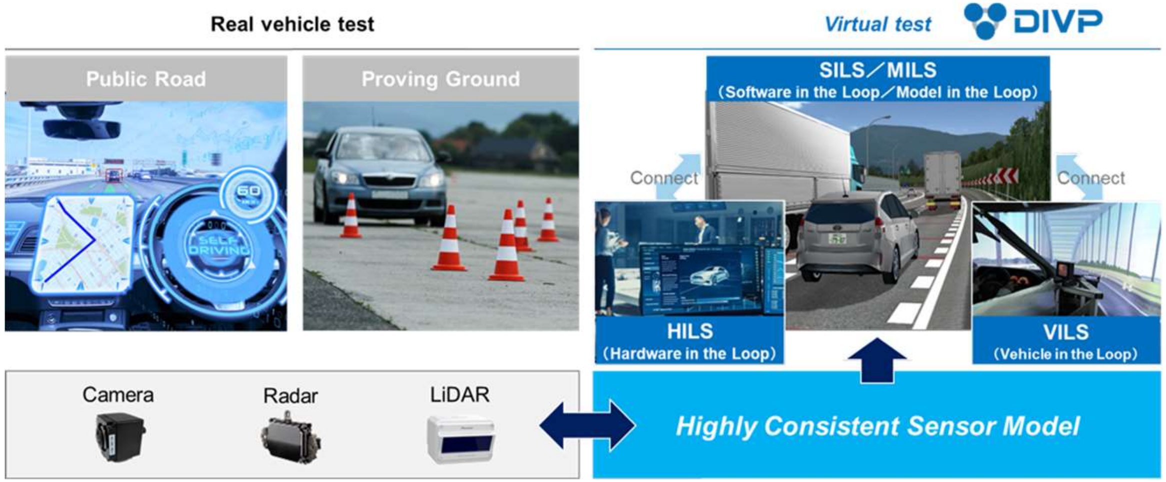
- **Driving Intelligence Validation Platform**

"Driving Intelligence Validation Platform (DIVP®)" project had been funded by Strategic Innovation Program (SIP) Phase 2: Automated Driving (System and Service Expansion).
In this DIVP® project, we are constructing a validation platform in a virtual space characterized by a series of "driving environment objects – electromagnetic wave propagations – sensors" models that are highly consistent with real phenomena. This is intended to enable precise and efficient safety assurance for automated driving under a wide range of environmental scenarios.

Cabinet Office

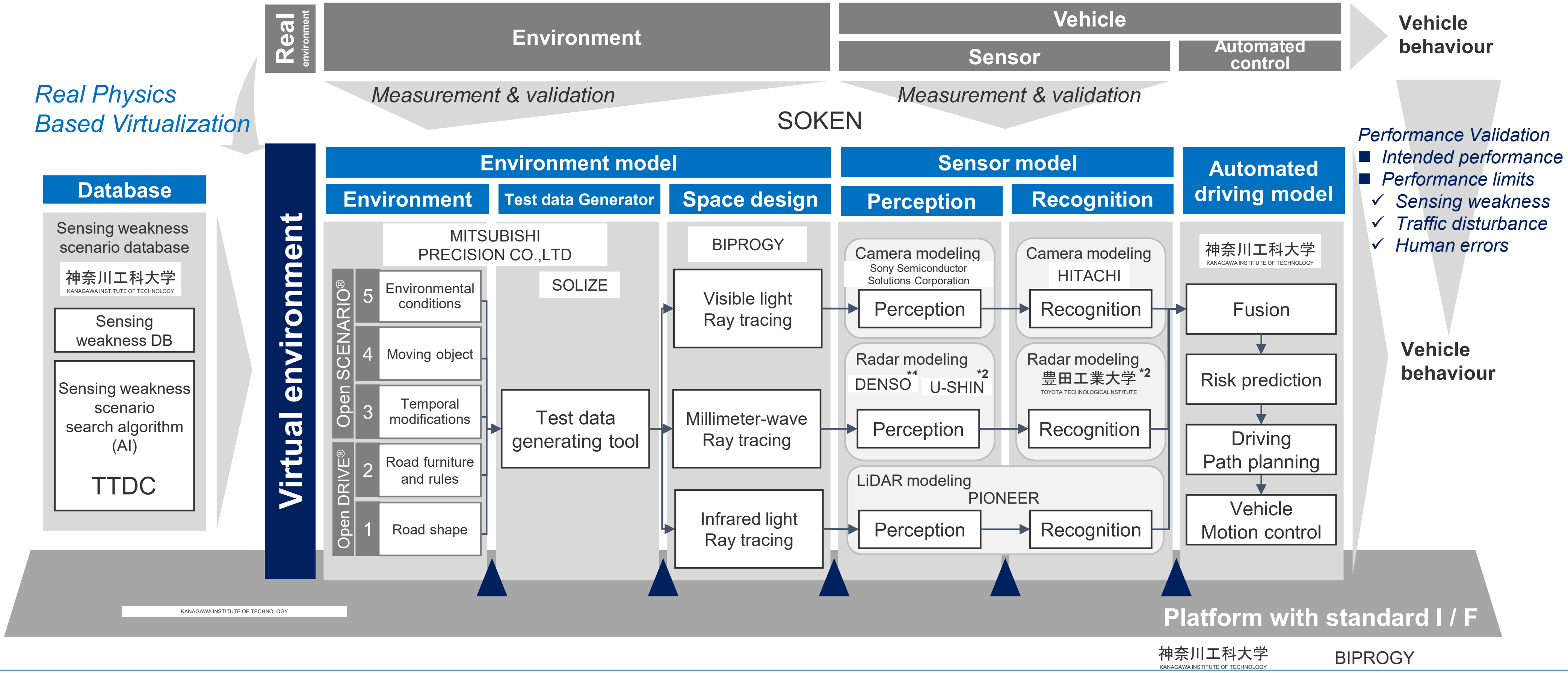
SIP
Cross-ministerial Strategic Innovation Promotion Program

METI
Ministry of Economy, Trade and Industry



## 【2018～2022】Designed research theme, Duplicate from Real to Virtual, and Verification of correlation level by 12-exparts as DIVPTM Consortium

- **DIVP® project design**




*1 Ritsumeikan finished Feb-2021, DENSO finished June-2021, Hitachi finished Sept-2021
*2 TTDC, U-shin, Toyoda-univ joined Mar-2021

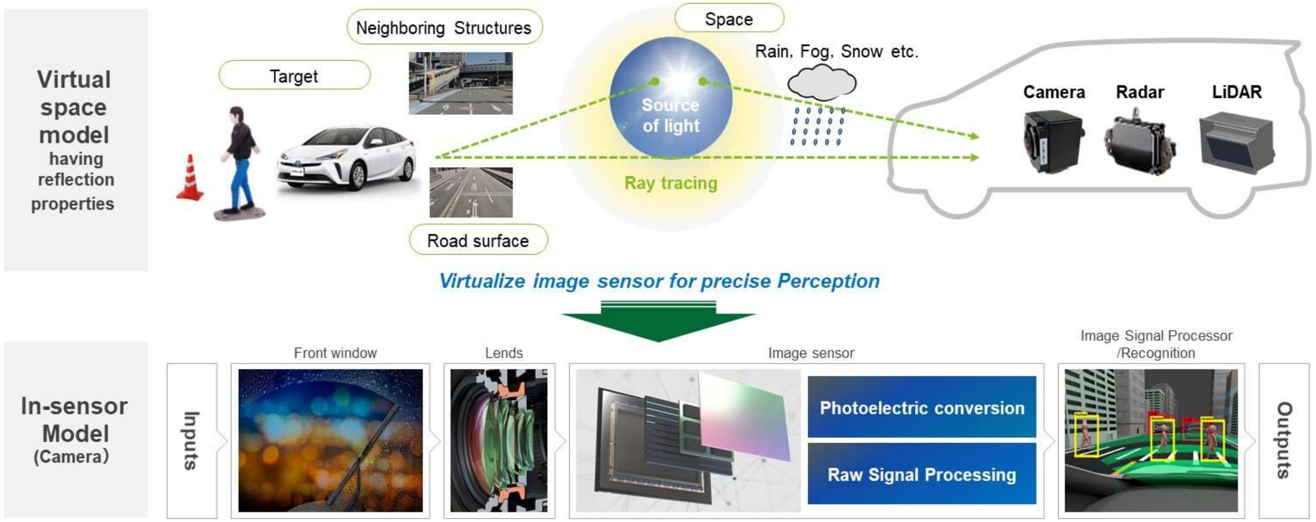
DIVP ASAM

## Building a virtual space simulation platform having highly consistent sensor models to contribute to the safety assessment of automated driving.

### DIVP® motivation

- Sensor modeling that is highly consistent with physical phenomena.
- Platform that enables AD-evaluations throughout “scenario creation” , “verification of recognition” ,  “validation of vehicle control”.
- Enhanced connectivity with existing simulation software.

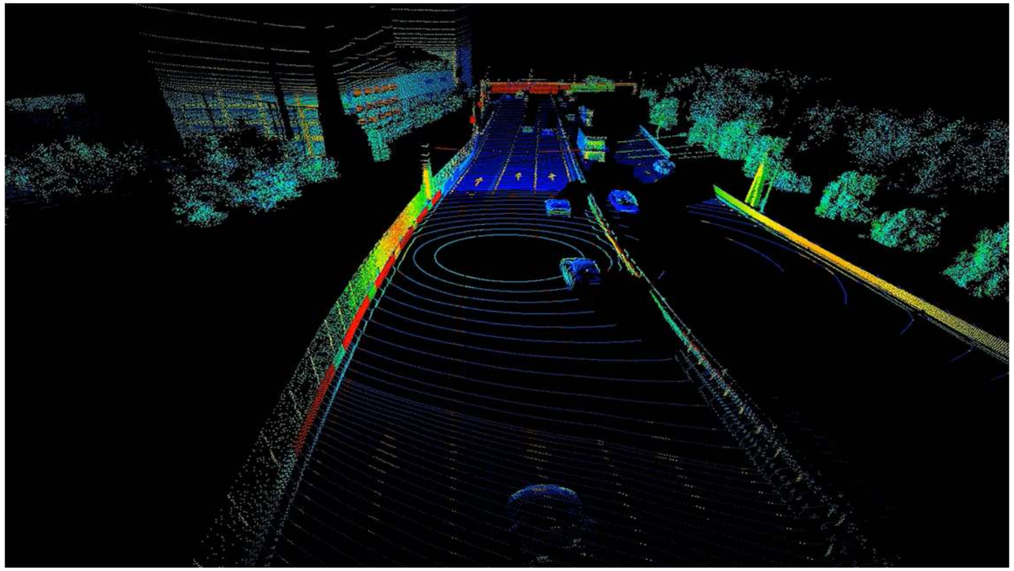
Real world




Virtual space and Sensor model

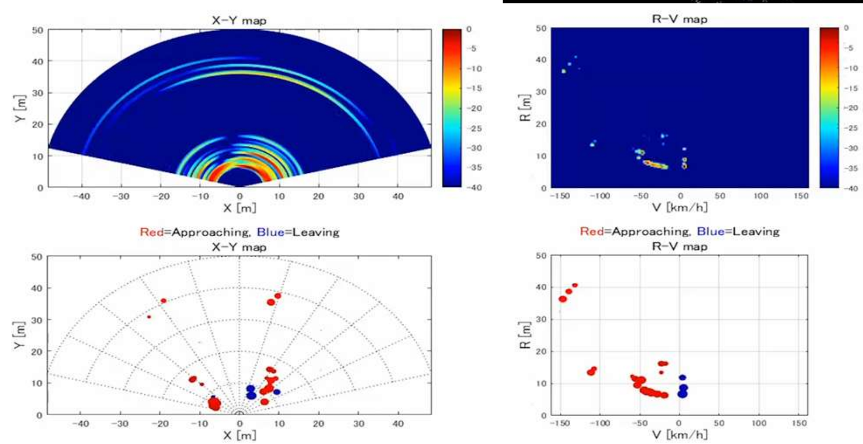
## Using DIVP® Material, simulation results of Camera, LiDAR and Radar appear realistic.


Camera



LiDAR

Time＝0[sec]




Radar

## The reflection characteristics of the light source and target surface are reproduced on an actual measurement basis. We adopt spectral path tracing using measured values.

- **Space designed model for Camera**

**Usual simulator**

RGB based modeling

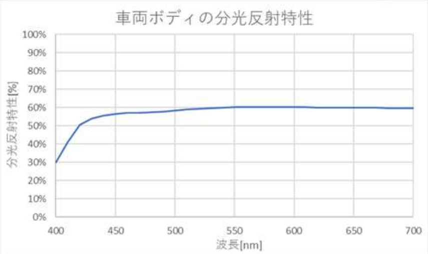
R: 1.0

G: 1.0

B: 1.0

**DIVP®'s**

Measurement based modeling




Source

**【Usual simulator】**

RGB based radiance

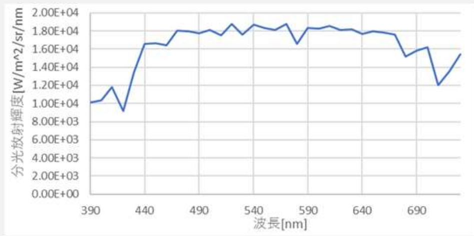
R: 2.3e+6

G: 1.9e+6

B: 1.5e+6

**【DIVP®】**

Measurement based radiance




Target

Camera

**Point**

- RGB is an expression based on the characteristics of the human eye and is not appropriate as an input to an image sensor. ***We adopt spectral path tracing using measurement-based data*** to generate an input that matches the characteristics of the sensor.
- The reflection characteristics of the light source and Target surface are also reproduced ***on an actual measurement basis.***

## Spectral path tracing accurately reproduces the reflectance of visible light and the brightness of sunlight, and reproduces the perception output of the camera close to the real environment.

- **DIVP® Space design**

| DIVP® | General simulator (CARLA) |
| --- | --- |
| **Spectrum modeling** | **RGB modeling** |
|  |  |

## Traffic signal recognition in rainy weather; verification of recognition limit performance is possible with virtual space simulation.

- **Contribution to safety assessment for AD-system evaluation using virtual space model**

**Difficult to catch signal recognition limit conditions in public road due to lack of control over rainfall condition levels.**

| Public road tests | Normal weather | Rainy weather (a few mm/h) |
|---|---|---|
| Recognition rate | 0.982 | 0.984 |

**DIVP® simulation allows for intense rainfall settings → Signal recognition limit verification is possible.**

**Evaluation by extrapolation is possible**

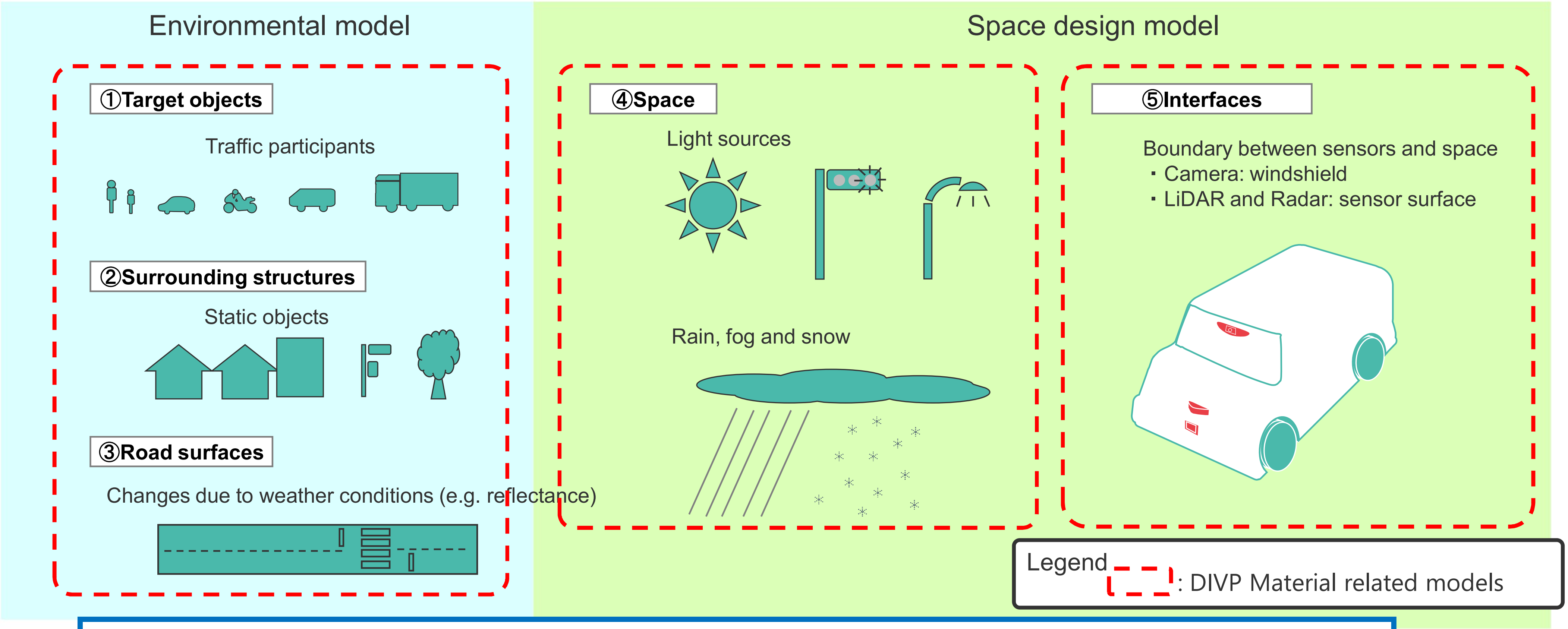
| DIVP® simulation | Normal weather | Intense rainy weather |
|---|---|---|
| Recognition rate | 0.989 | 0.868 |

**The overall recognition rate deteriorated with increasing rainfall in DIVP® simulation.**

- Undetected due to shielding by raindrops
- Misrecognition due to color change, etc.

# Virtual world model segmentation from perception and material property

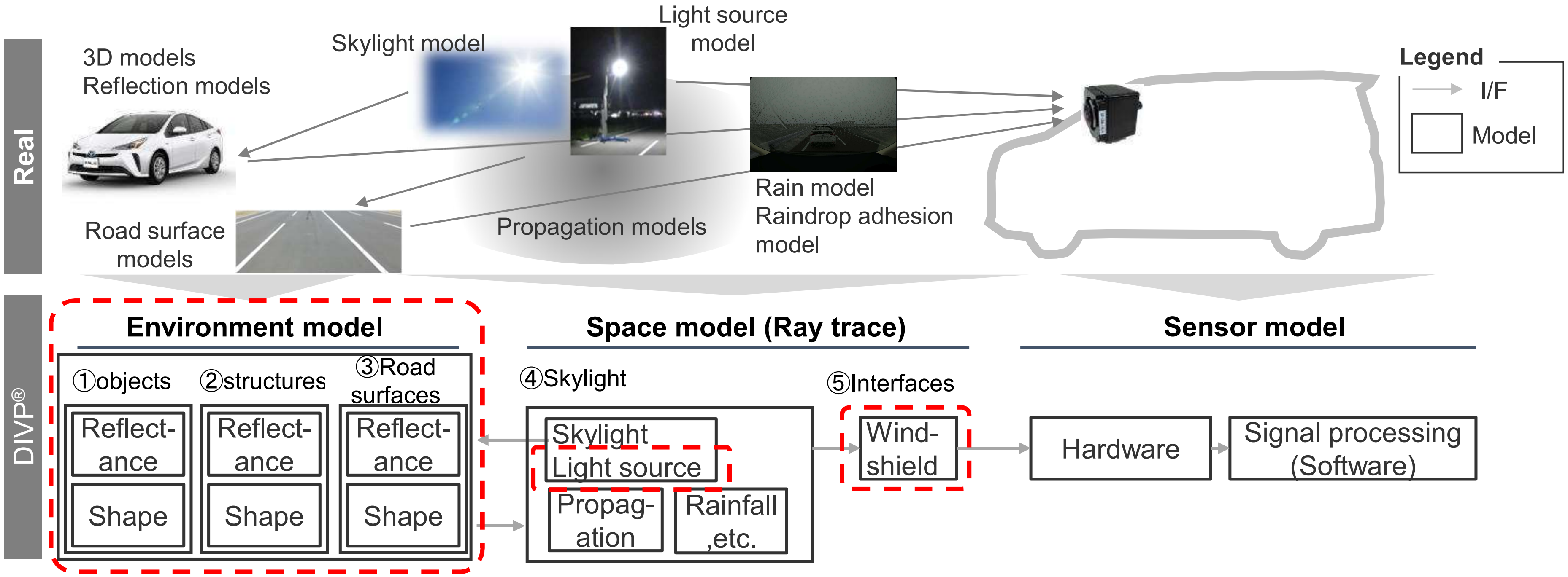
- **5 Segmentations related to DIVP material**




DIVP® define five segmentations for virtual world model.

# Assumed Camera physical model architecture

- **Architecture of camera sensor model**



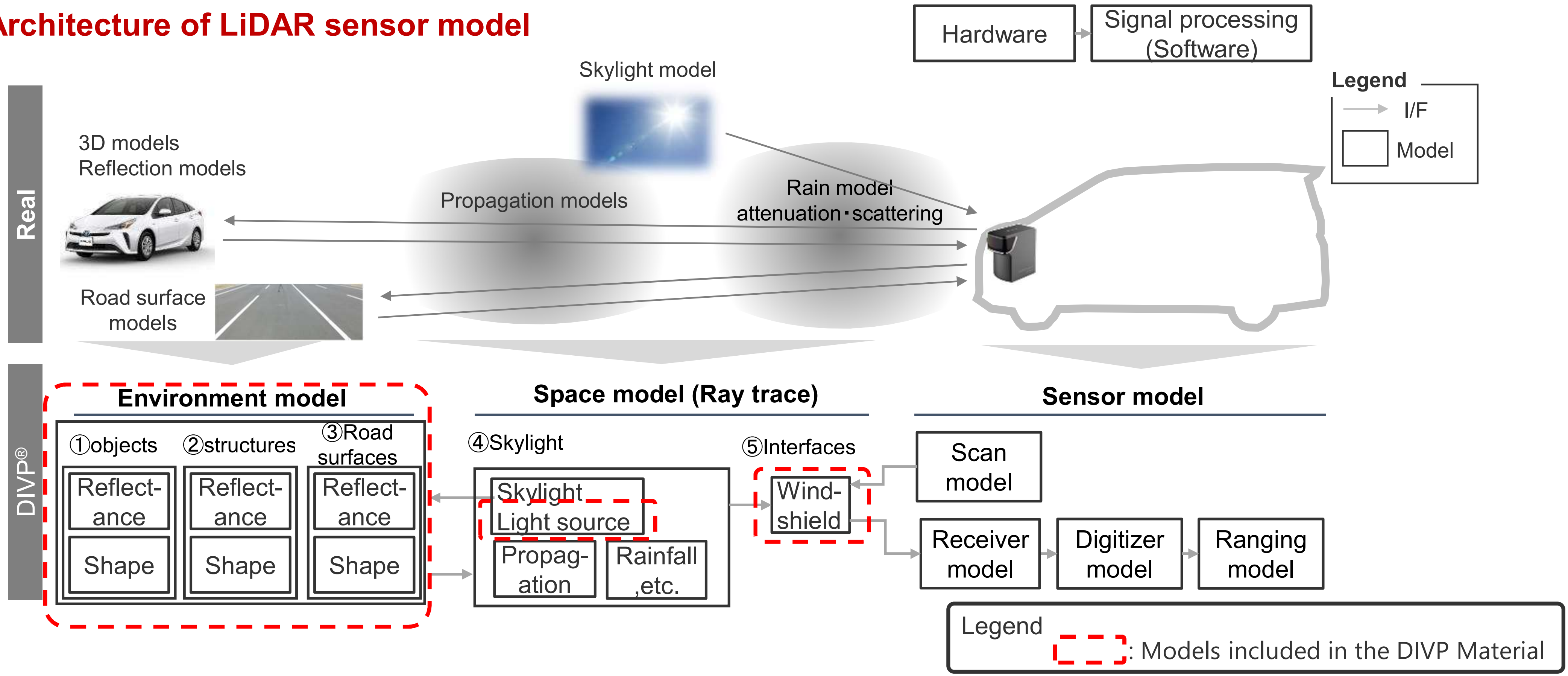

- Environment model: Target objects, surrounding structures and road surfaces
- Space design model: Space and interface
- Sensor model: Sensor itself

Legend : Models included in the DIVP Material

DIVP®'s simulator consists of environment, space design and sensor model.

# Assumed LiDAR physical model architecture

- **Architecture of LiDAR sensor model**




DIVP®'s simulator consists of environment, space design and sensor model.

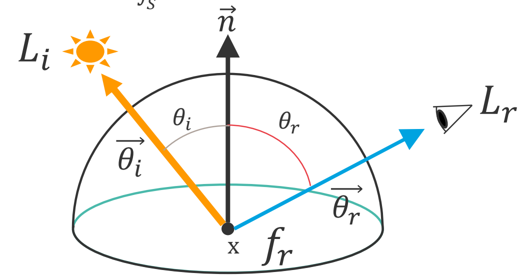
# Physical model architectures for Camera and LiDAR

- **Architecture of Camera and LiDAR model**

## Measurement model

The model based on spectroscopic data that measures reflection characteristics.

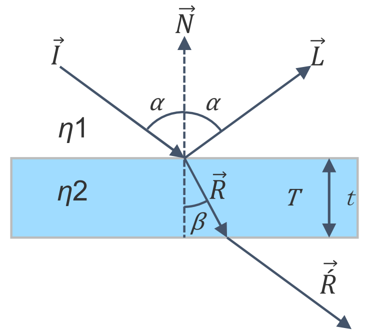
$$L_r(x,\theta_r,\lambda) = \int_S f_r(x,\theta_i,\theta_r,\lambda) L_i(x,\theta_i,\lambda)(\vec{\theta_i}\cdot\vec{n})d\theta_i$$




Measurement Model

## Glass model

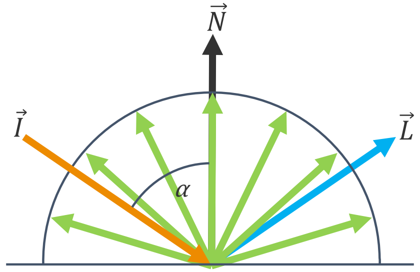
Material expression of highly permeable objects such as glass.




Glass Model

## Lambert model

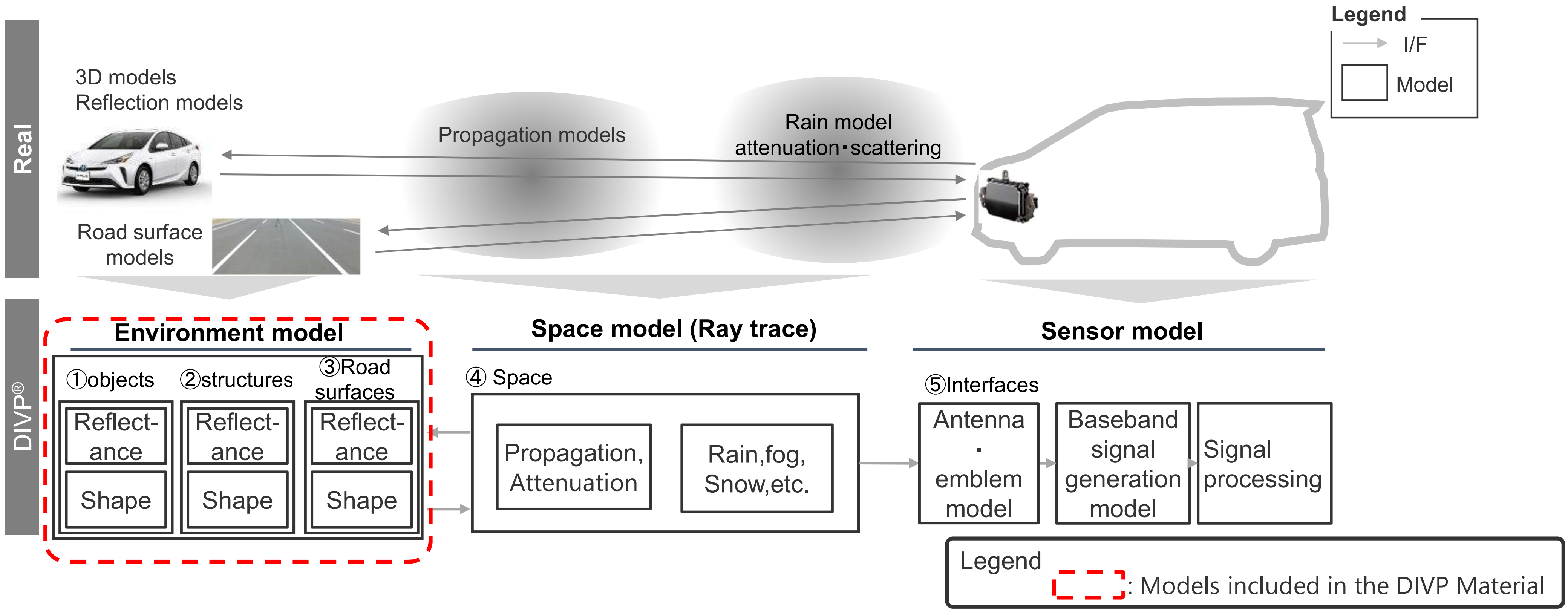
For objects that do not retain the above two attributes.




Lambert Model

# Assumed Radar physical model architecture

- **Architecture of Radar sensor model**



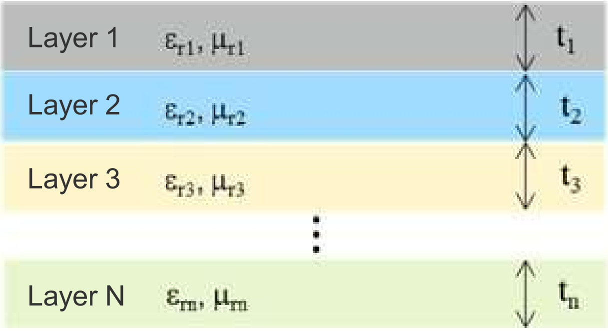

DIVP®'s simulator consists of environment, space design and sensor model.

# Physical model architectures for Radar

- **Architecture of Radar sensor model**

### Scattering model

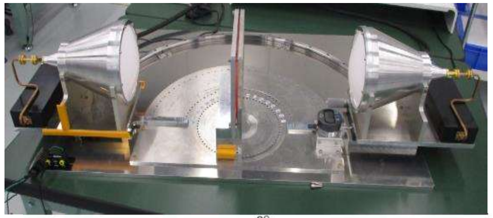
For small object(cars, people, etc.)
Radar equation
(Range quadrature law)
Physical optics approximation

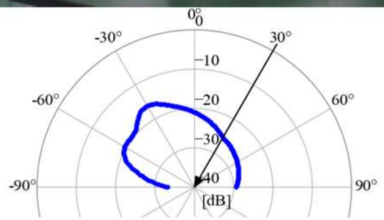



Multi-tier models
(Transfer Matrix Method)

### Reflectance model

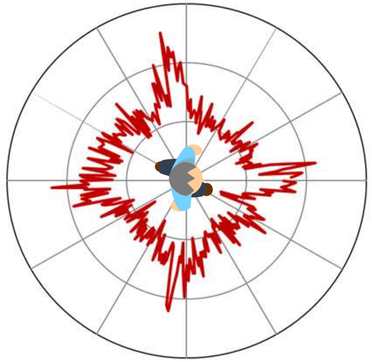
For large object markers
(buildings, road surfaces, etc.)
Friis Transmission Equation
(Distance squared law)
Geometrical Optics approximation






### RCS model

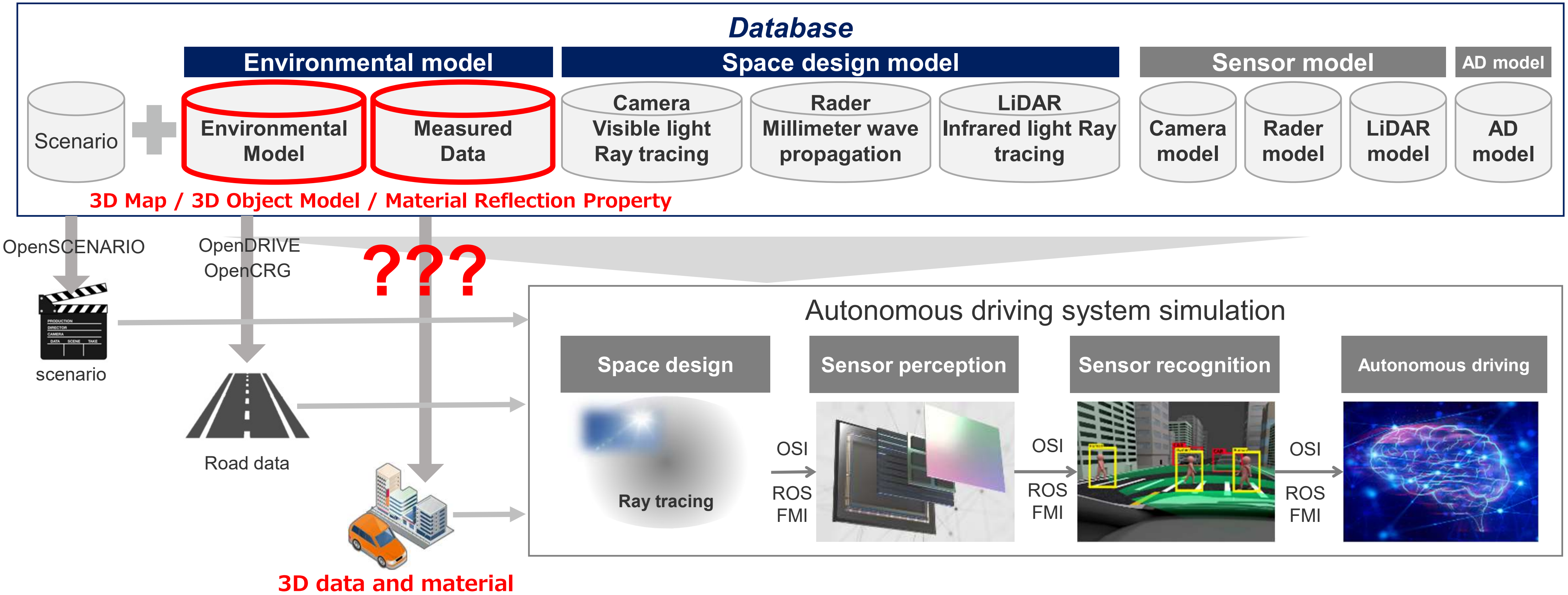
To reduce analysis time
Radar equation (quadrature law)



Three types of reflection models to match the characteristics of the object and surrounding structures.

## A sophisticated simulation environment supported by a group of models in circulation is the ecosystem that DIVP® is aiming for.

- **DIVP® Ecosystem**




**There is an urgent need to standardize the structure of 3D data and their attributes for MAP and ASSET.**

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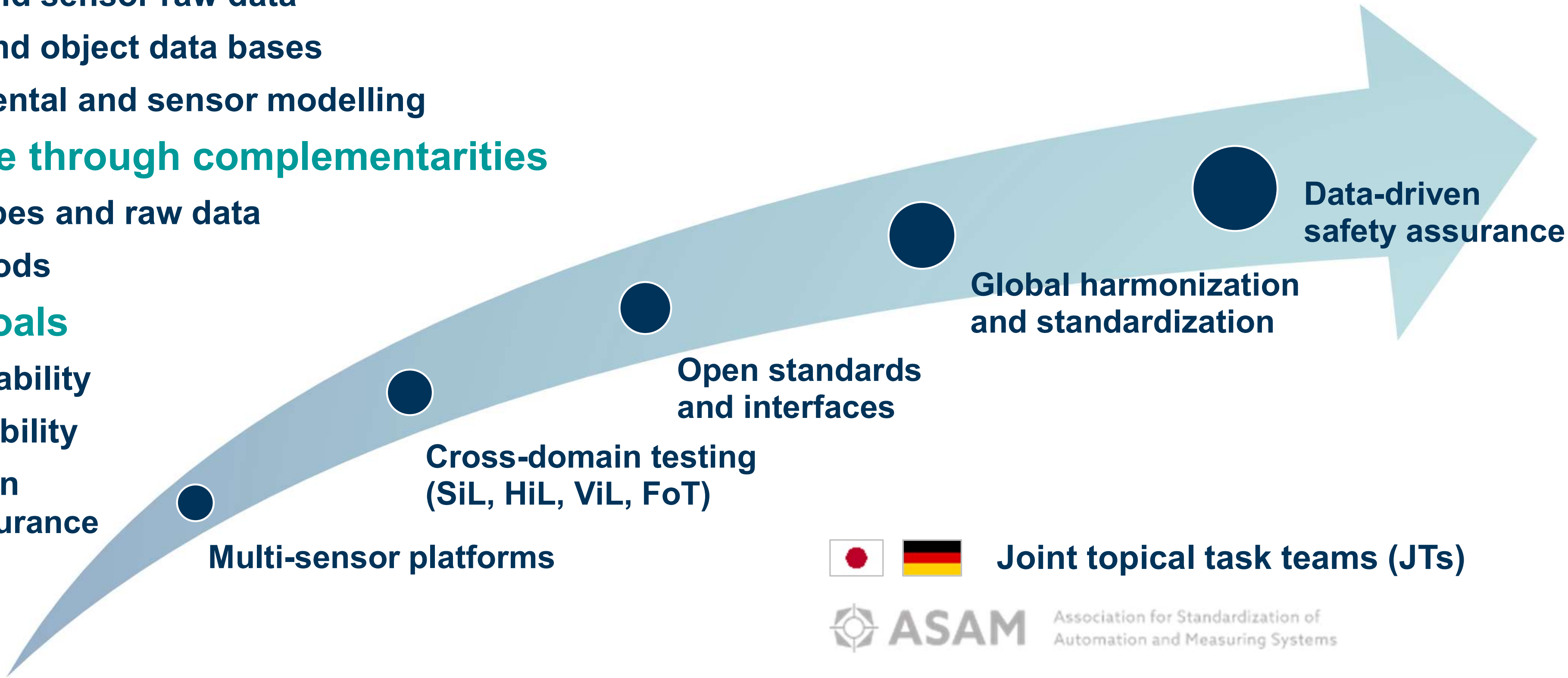
## VIVID has been co-created to establish virtual test environments for CAD-safety assurance by confirming the commonalities and complementarities of VIVALDI and DIVP through each JTs.

**On the Way to Reliable and Realistic Validation for CAD safety assurance**

- **Base value through commonalities**
  - HD map and sensor raw data
  - Material and object data bases
  - Environmental and sensor modelling
- **Added value through complementarities**
  - Sensor types and raw data
  - Test methods
- **Common goals**
  - Exchangeability
  - Interoperability
  - Data-driven
    Safety assurance




Joint topical task teams (JTs)

ASAM Association for Standardization of Automation and Measuring Systems

# For AD safety assurance, geometrical input for system layer & physical materials input for sensor layer are needed as total validation framework

- **Validation framework for AD safety assurance and VIVID JTs' position**

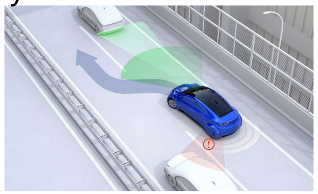
● JT activity

**2** Scenario

**4** Metrics

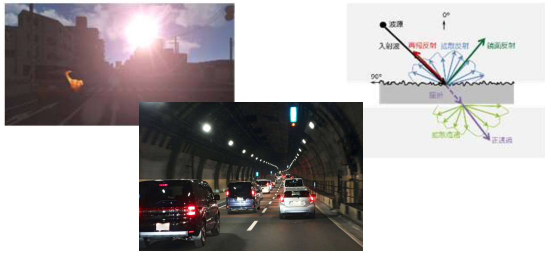
**System layer**

- <u>Geometric movement scenario</u> based on road accident data analysis



**Sensor layer**

- <u>Sensing weakness</u> scenario based on expert knowledge



Sensor model with <u>real/sim consistency</u>

**3.1** Camera

**3.3** Radar

**3.2** Lidar

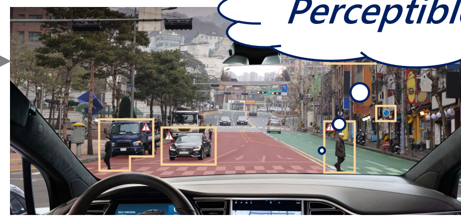
SUT*
AD-control

- <u>Safety risk margin</u> based on geometric positioning simulation

*Foreseeable and preventable ?*

- <u>Perception performance</u> based on highly consistent & measurable outputs

*Perceptible ?*



**1** Tool chain

**4** Measurement, framework

- * SUT : System under test

# DIVP® would like to propose the formulation of "VIVID material" as a joint material format for sensor validation contributes to AD-Safety assurance.

- **VIVID material**

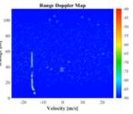
JT activity

## Sensor model defining parameters and interface

2

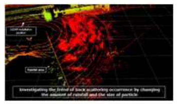
3

Radar



Camera

LiDAR



*Highly related to Geo-Sensing weakness scenario & OpenX*

VIVID Material

## Sensing weakness scenario

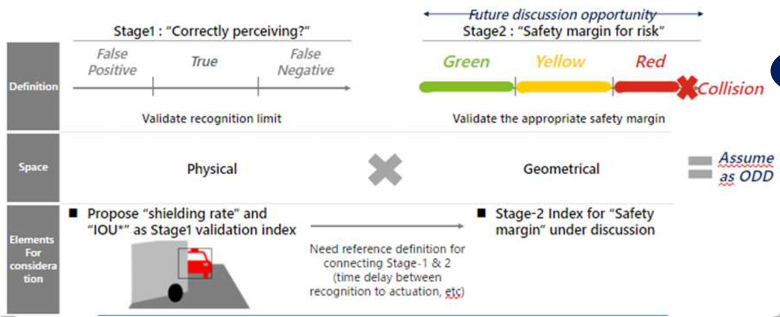
2


## Measurement & validation

4

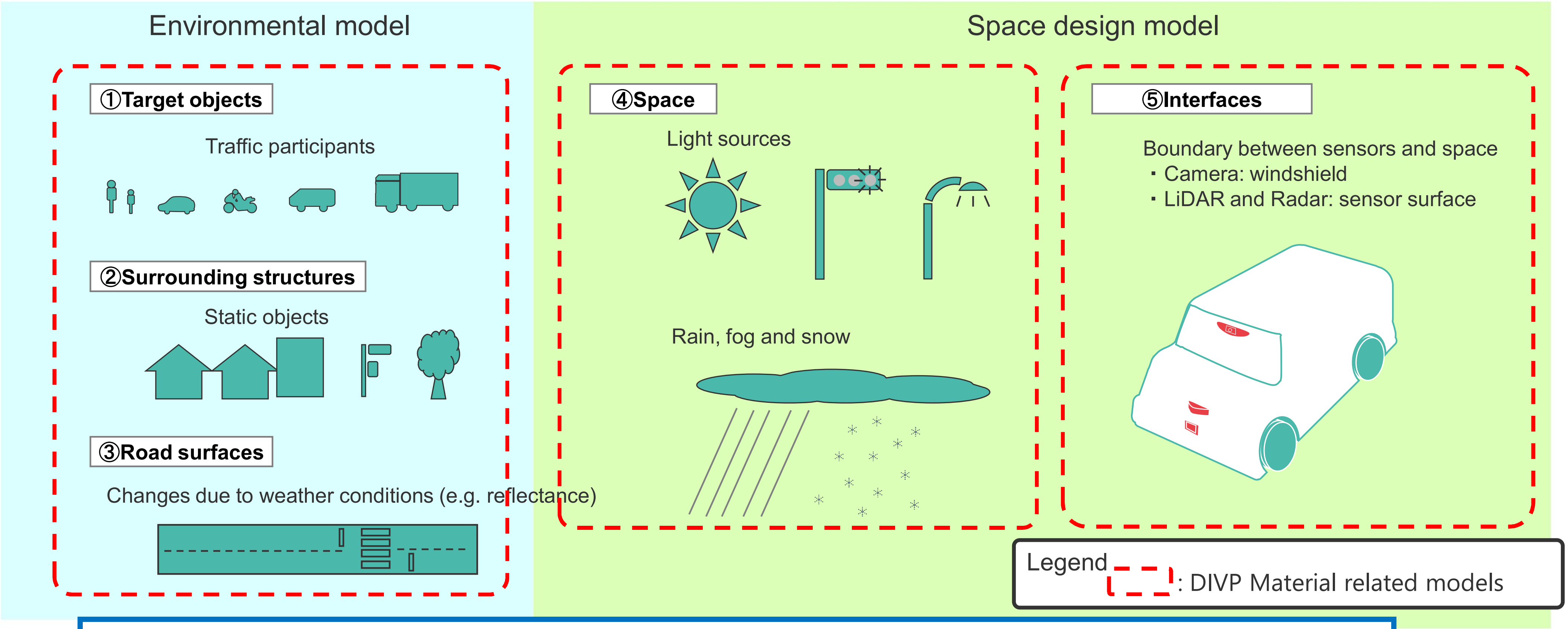
## Metrics

4



# Virtual world model segmentation from perception and material property through VIVID collaboration

- **5 Segmentations related to DIVP material**




**Through VIVID activities, we were able to confirm the idea of DIVP environment models, space design models, and DIVP materials.**

# DIVP® Environment model property through VIVID collaboration

- **For Camera／LiDAR sensor**
  - Measurement model
    Complex refractive index、Reflection data(In-out going angle、Amplitude per wavelength)
  - Glass model
    Complex refractive index per wavelength、Plate thickness、Transparency
  - Lambert model
    Color、Diffuse reflectance、Specular reflectance

- **For Radar sensor**
  - Scattering model
    Resistivity、Relative permittivity、Relative permeability 、Plate thickness
  - Reflectance model
    Measurement Reflection data（In-out going angle、Amplitude and phase of Θ and Φ component per wavelength）
  - RCS model
    In-out going angle、Amplitude and phase of Θ and Φ component per wavelength

## DIVP® Space design model property through VIVID collaboration

- **Raindrop adhesion model**
  - Raindrop property
    - Maximum radius of stationary raindrops、Maximum adherent raindrop radius、Raindrop collision coefficient …

- **Light model**
  - Luminescence property
    - Dimension of Luminescence body、Spectroscopic data、Radiance or Radiance distribution data(IES file)
  - Light source property
    - Position of light source、Vertical vector of light source、Horizontal vector of light source、Spectroscopic data or Color temperature 、Radiance distribution data(IES file)

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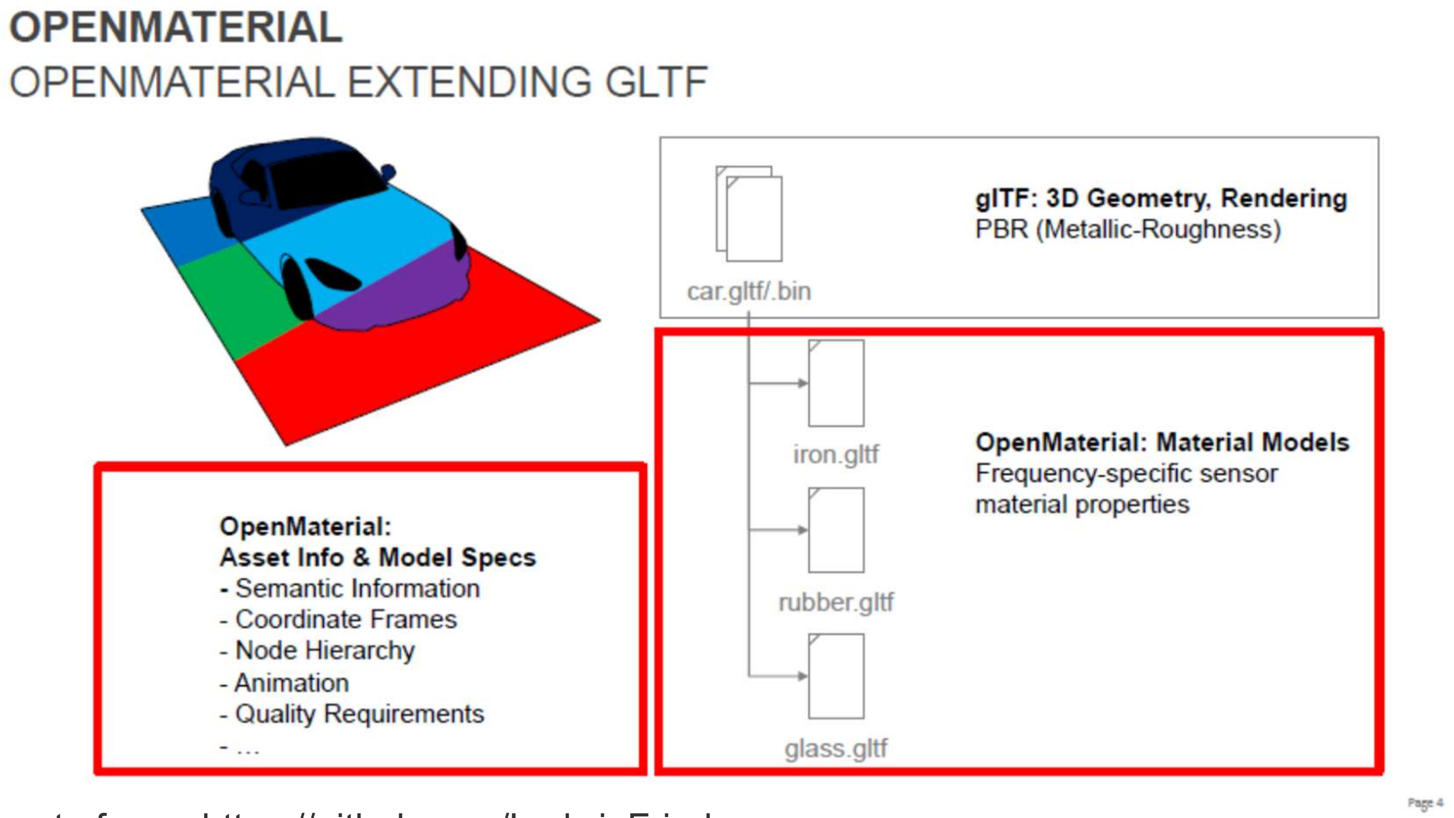
## BMW's OpenMATERIAL proposal has two pillars, Asset Info & Model Specs and Sensor material properties, which are very similar to ours. In particular, the latter is exactly the same.

- **BMW's OpenMATERIAL**

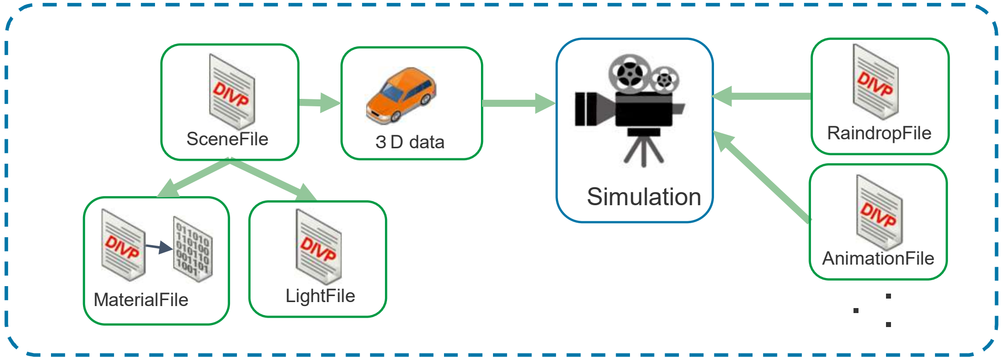



quote from : https://github.com/LudwigFriedmann

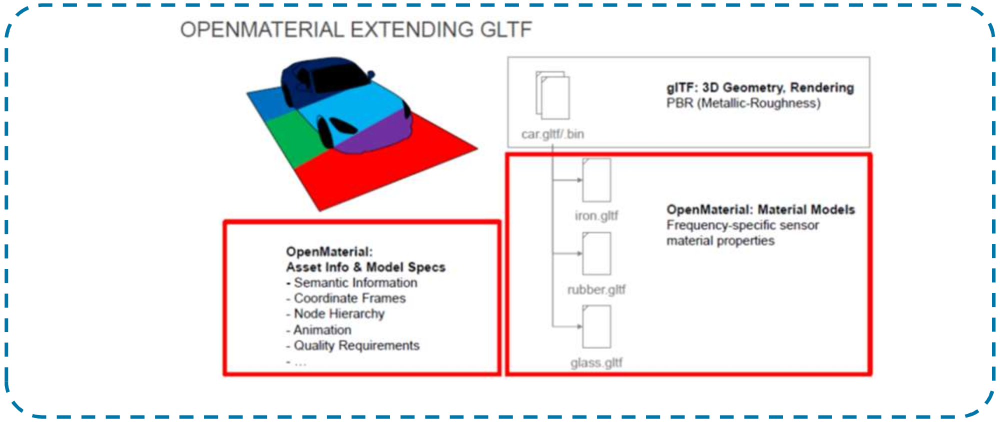
# DIVP® also implements glTF support and collaborates with BMW for standardization.

- **Our proposal by BMW's OpenMaterial discussion**

DIVP®（status quo）

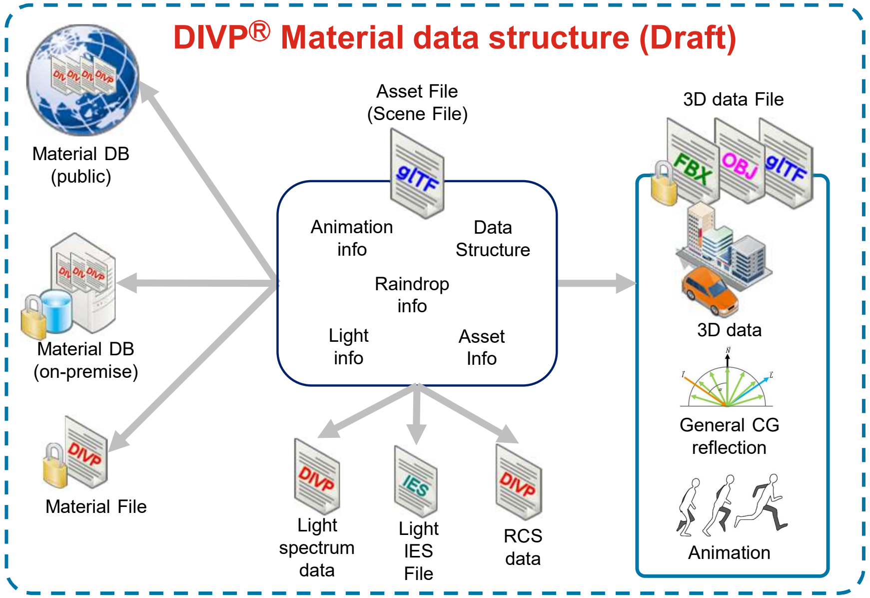



BMW OpenMaterial




**Example of data structure** for exchange that will lead optimization of development and validation process.

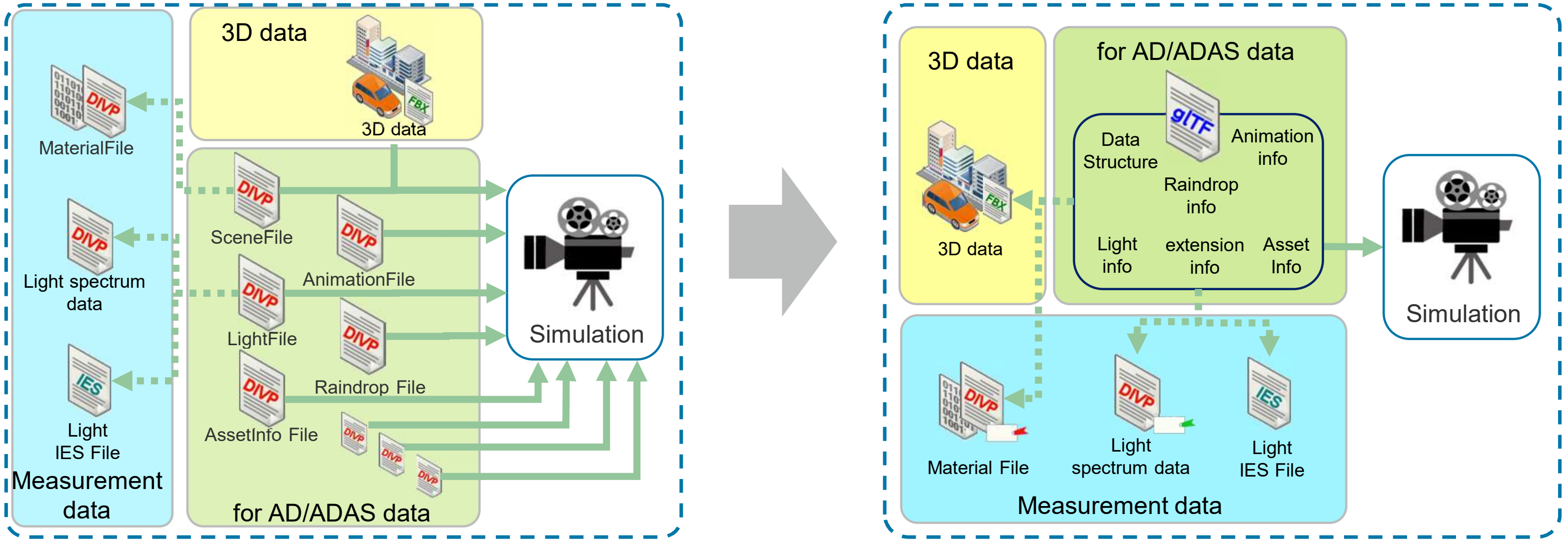
DIVP®（After correspondence）




Using URI reference, the DIVP® Material file and various configuration files are referred to from glTF.
The information you want to close can be set as a password and concealed.

## Consolidate data for AD/ADAS simulation into a single file

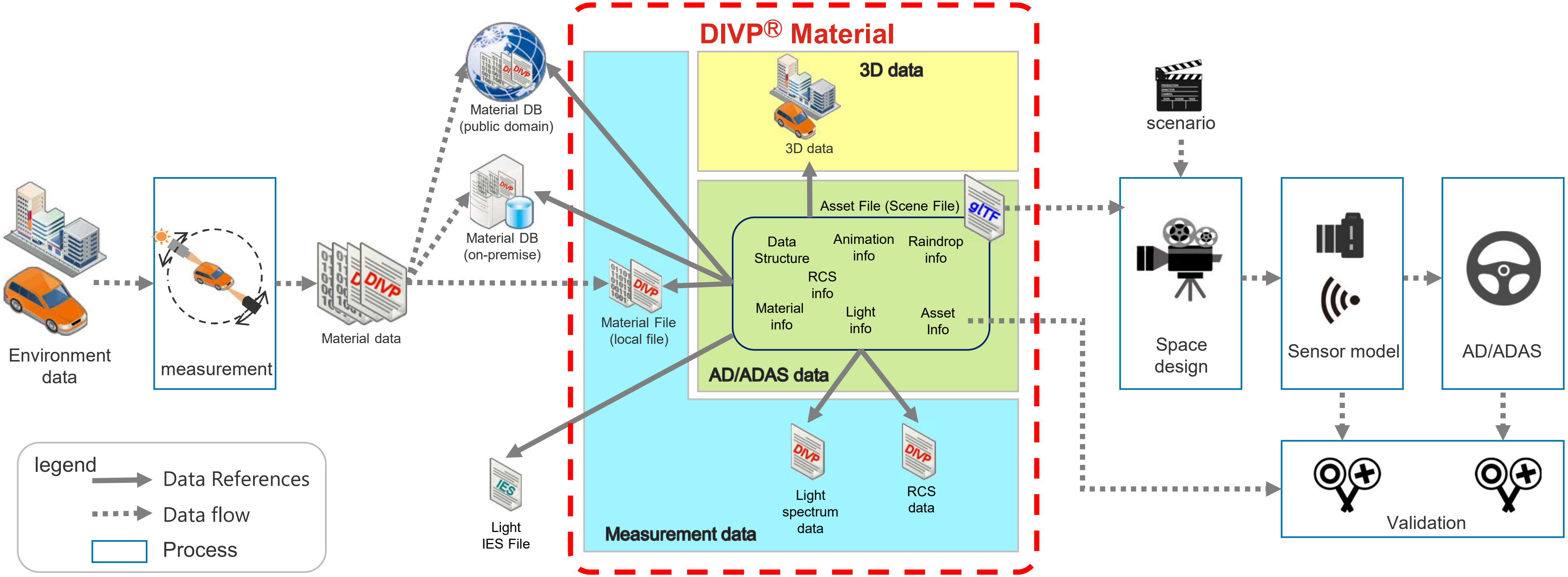
### Consideration for improving data portability and usability




- Consolidate AD/ADAS information that used to span multiple files into a single file. Information about assets has also been added to support search and use of created data.
- The measurement data format is also structured and tagged to improve the availability of measured data.

**By building a foundation for data exchange and asset distribution, It is expected to improve the efficiency and speed of development and evaluation of autonomous driving developers.**

# An overhead view of the DIVP® Material




Information that can be shared with other data is used as an external reference, reducing data preparation costs and promoting data distribution.

## Our proposal under the VIVID framework and BMW discussion concerning material distribution.

- **Our proposal for ASAM OpenMaterial initiatives**

- **Measurement data of physical properties** is critical for **the fidelity of simulation**.
- **3D data** and **material measurement data** are two pillars of OpenMATERIAL.
- **Data exchangeability** will lead the standardization of OpenMATERIAL.

- OpenMATERIAL has been developed under the initiative of BMW.
- DIVP® has collaborative motivation to build up OpenMATERIAL.
- Through the activity of ASAM, we would like to have wide discussion with ASAM members to contribute to the industry.

DIVP ASAM Association for Standardization of Automation and Measuring Systems

# *Thank you for your kind attention!*

*Tokyo Odaiba → Virtual Community Ground*

**END**