Driving Intelligence Validation Platform

FY2021 Year-end report

Weather Forecast

AD safety Assurance*

For Validation & Verification Methodology

* AD : Automated Driving

Index

About the Cross-ministerial Strategic Innovation Promotion Program (SIP)
This is a program for achieving science, technology and innovation as a result of the Council for Science, Technology and Innovation exercising its headquarters function to accomplish its role in leading science, technology and innovation beyond the framework of government ministries and traditional disciplines.
The program strives to promote research and development in a seamless manner from the basic research stage to the final outcome by endeavoring to strengthen cooperation among industry, academia and government under the strong leadership of the Program Director (PD)

* PG : Proving ground, CG : Community ground

Motivation & objective

Highly Consistent Sensor Modeling is a key enabler of virtual validation for AD/ADAS safety assurance. HCSM indicates environmental, ray tracing, and sensor models.

Motivation ： Highly Consistent Sensor Modeling (HCSM)

Real vehicle test

Public Road

Proving Ground

Virtual test

SILS／MILS
（Software in the Loop／Model in the Loop）

Connect

HILS
（Hardware in the Loop）

Connect

VILS
（Vehicle in the Loop）

Camera

Radar

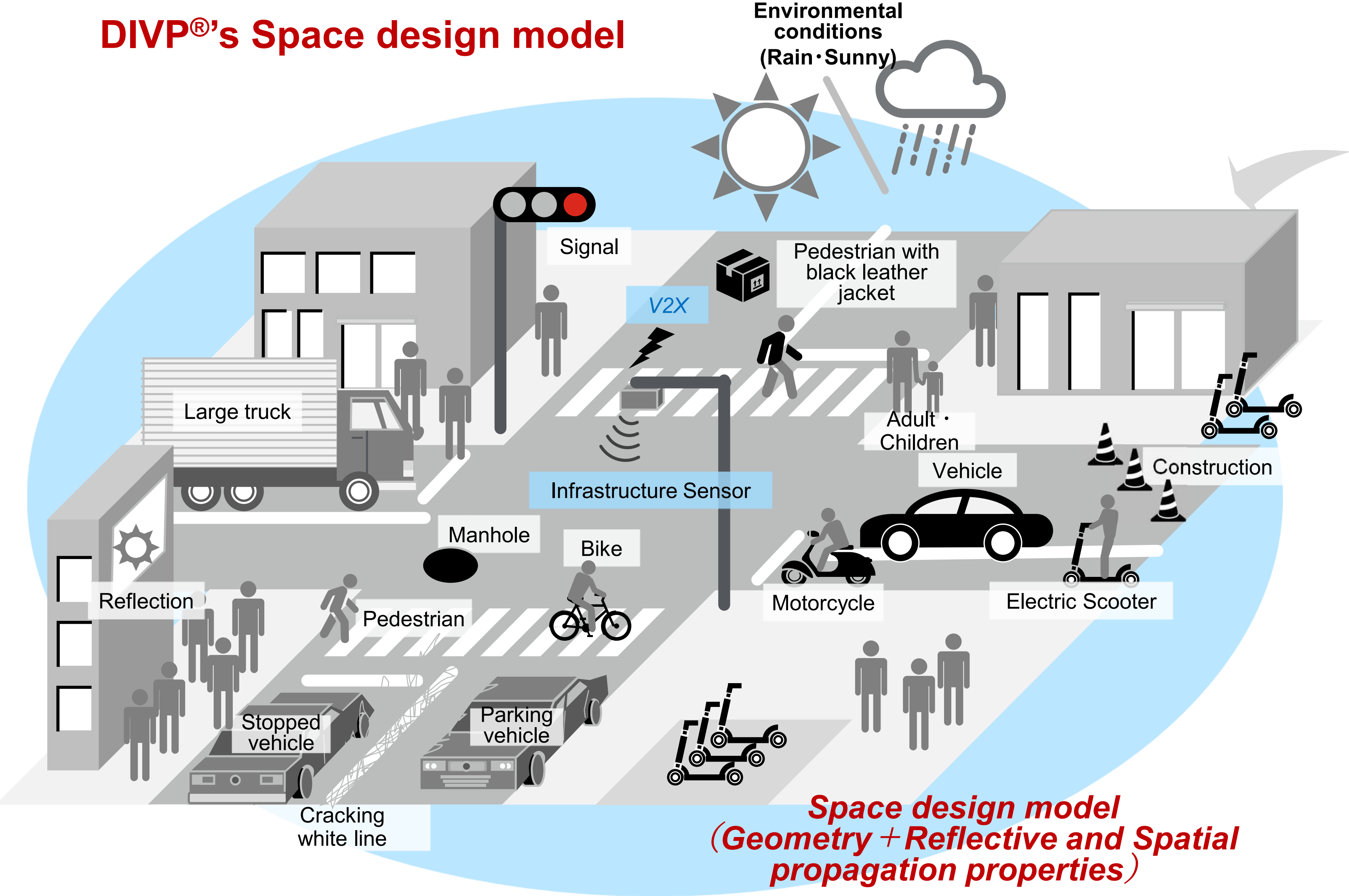
LiDAR

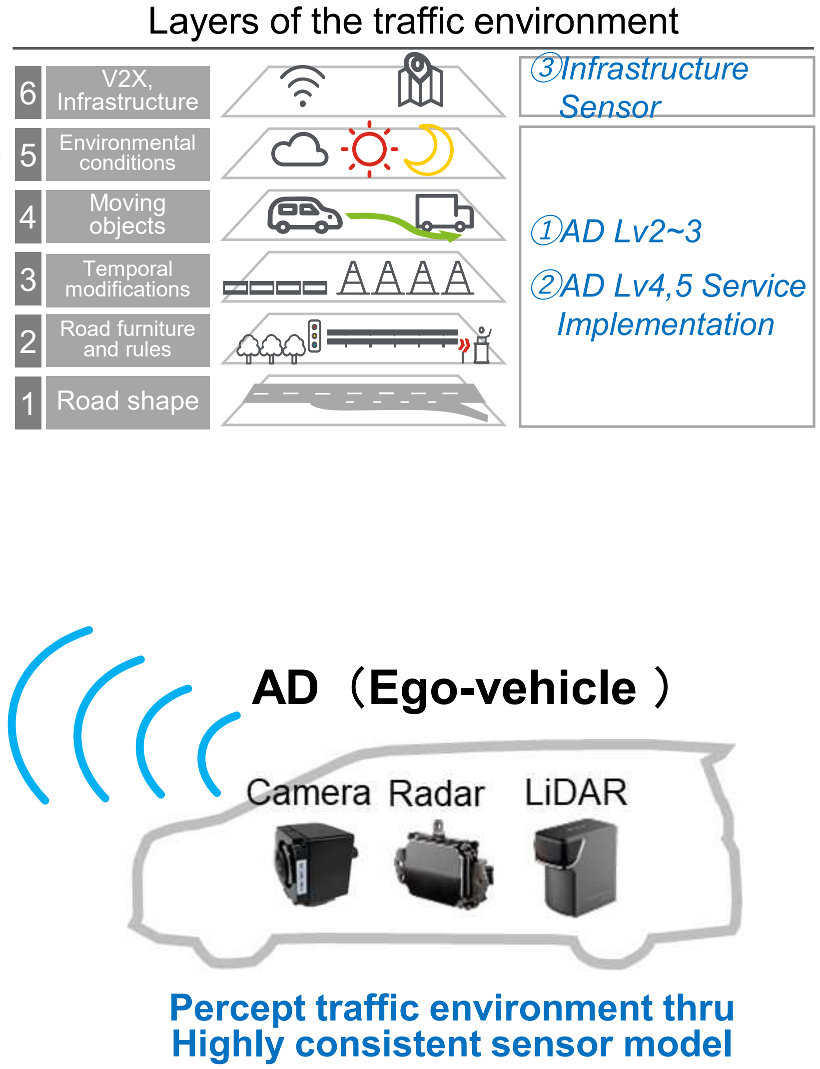
Highly Consistent Sensor Model

Source : Kanagawa Institute of technology, MITSUBISHI PRECISION CO.,LTD., DENSO Corporation, Pioneer Smart Sensing Innovations Corporation, Hitachi Automotive Systems, Ltd.

DIVP® Space design model owns "Geometry-data" & "Reflective and Spatial propagation properties" enable AD-safety validation with Highly consistent sensor models

DIVP®'s Space design model

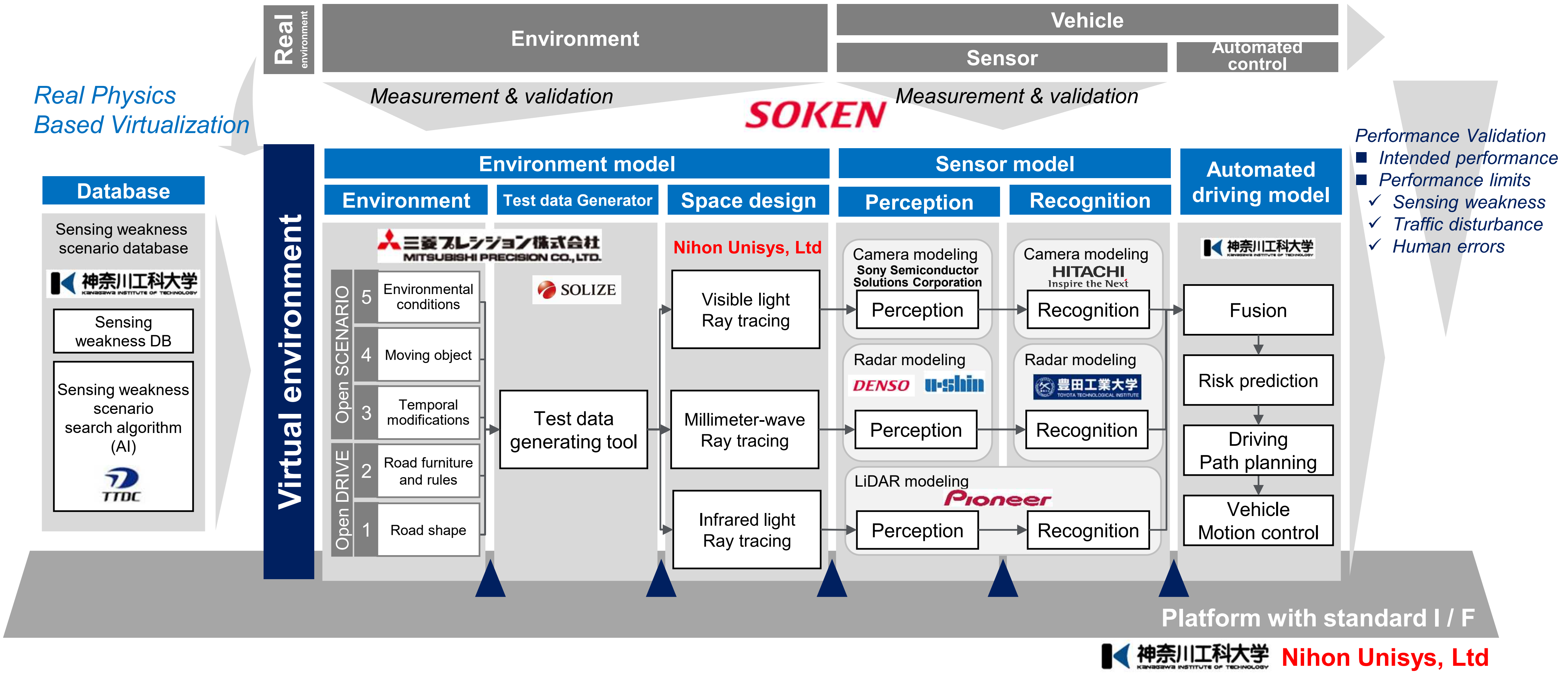




Source : Hitachi Astemo, Ltd. , DENSO INC, Pioneer smart sensing innovation corporation

The project architecture designed by DIVP® precisely duplicates Virtual from Real, and verifies consistency with real testing by 12 experts as DIVP® Consortium

DIVP® project design



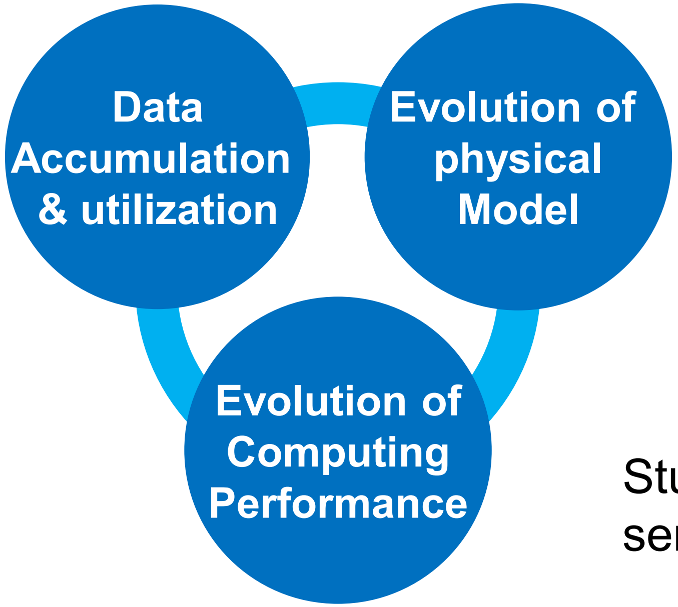
*1 Ritsumeikan finished Feb-2021, DENSO finished June-2021, Hitachi finished Sept-2021
*2 TTDC, U-shin, Toyoda-univ joined Mar-2021

DIVP® scope covers "Physical Model" & "Computing Performance" in Trinitarian approach

DIVP® scope & Objectives

DIVP® Scope

Trinitarian approach



Platform implementation

&

Study reasonable semiconductor spec

DIVP® Objectives

- ***Open Standard Interface***
- ***Reference platform with reasonable verification***
- ***E & S pair model based approach***
  (E : Environmental model, S : Sensor model)

With project outcome DIVP® is to Improve Simulation based AD Safety validation for Consumer acceptable Safety assurance

Source :FY2020 Year-end report

Project overview

- Review of safety assurance basis
- Objective Competitive Assessment of DIVP®
- Future plans
- Provision of business based on research results

Agreed for the project demarcation in JAMA・METI(SAKURA) and SIP(DIVP®) to build a safety assurance basis for automated driving. (unchanged since the beginning of 2018)

The demarcation for building a safety assurance basis for automated driving

	Concept	Data				Structure・I/F
	Scenario structure	Driving data measurement	Scenario generation	Target data generation	Test data generation	Sim PF
Traffic flow	JAMA	METI(highway) *Intersections and ordinary road will be supported	METI(highway) *Intersections and ordinary road will be supported	SIP	SIP	SIP ②Vehicle performance evaluation
Perception performance/ Perception disturbance	JAMA	SIP	SIP	SIP	SIP	SIP ①Sensor perception evaluation ②Vehicle performance evaluation

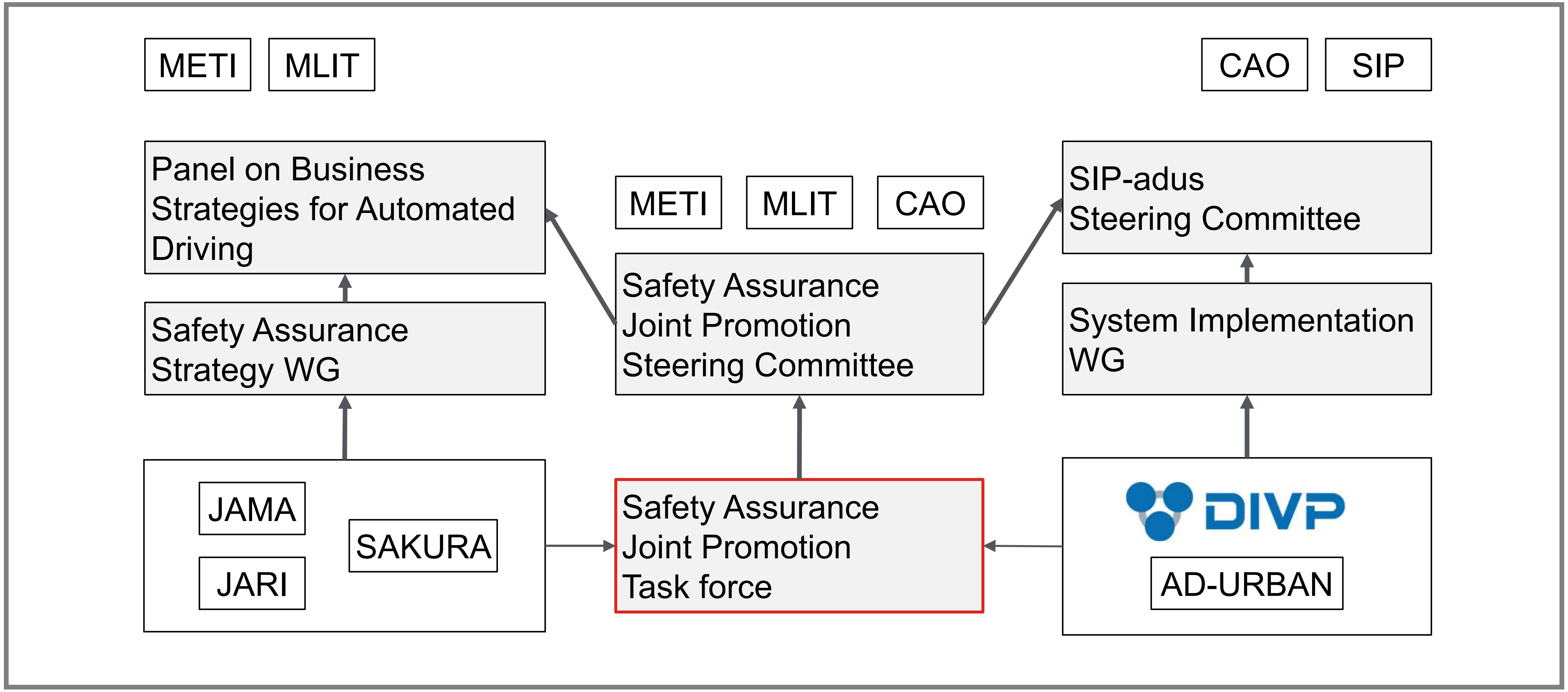
DIVP

Source : Illustration of the project demarcation (DIVP® Implementation Plan: unchanged since the beginning of 2018)

DIVP

In order to build a safety assurance basis for automated driving, made a joint promotion task force with JAMA, JARI, SAKURA, DIVP®, and AD-URBAN.

Promotion structure of safety assurance basis for automated driving in Japan



Source : Overview of the Joint Promotion TF for Safety Assurance of Automated Driving (Materials from the FY2021 Workshop for the Establishment of Safety Assurance Infrastructure)

Human behavior shows that "Can you see it?" and "Don't you run into me?" form the basis of safety.

Basis of the safety assurance

DIVP

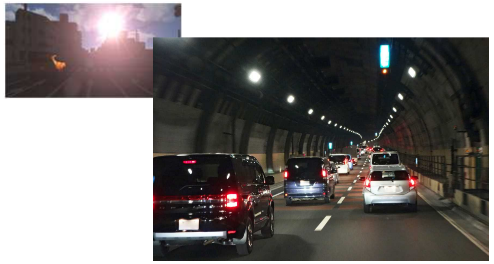
Physical-sim & system-sim combination structuring are needed for AD-safety assuarance, and DIVP® focusing on Physical-sim for Sesnor Physics validation

Features; Construction of sensing model with high consistency with actual phenomena
→ DIVP® simulation contributing to AD safety assurance

tool structure | Scenario | Validation | Judgement

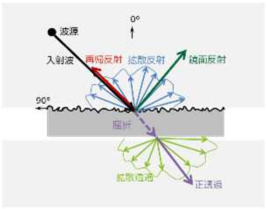
DIVP Physical Sim

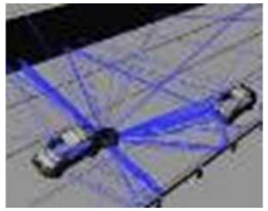
- **Sensor Weakness Scenario** based on expert knowledge



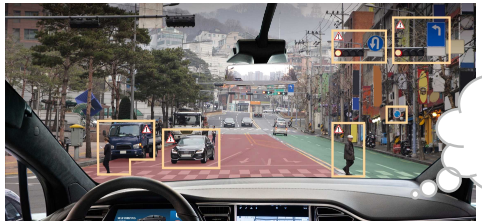
SDM -Generator*

- **Virtual space** based simulation **verified for consistency**





- **Virtual Validation of Cognitive Performance** Based on a Concordance Model of Measurable Perceptual Output

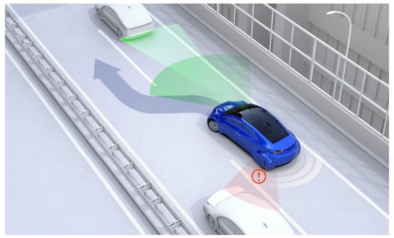


Can you see it?

Combination and application of each method

System Sim

- **Geometric scenario** based on analysis of accident data, etc.



- HILS

- Actual vehicle validation

- Accurate prediction of vehicle position to determine **margin for accident** and.

Don't you run into me?

essence

Weighting scenarios based on risk x frequency x detectability

Alternative and efficient validation of actual vehicles using simulation verified for consistency

Vehicle behavior and sensor perception output and judgment as a rule of AD system

＊SDM – Generator ; Space Design Model - Generator
Source : Hitachi Astemo, Ltd. , DENSO INC, Pioneer smart sensing innovation corporation

DIVP

Based on the JAMA safety evaluation scenario structure, the joint promotion TF of SAKURA, DIVP®, and AD-URBAN implemented scenarios and verified simulation environment validity.

AD-Safety assurance Task force structure

FY2021 Team structure

Scenario definition and implementation

JAMA

Safety Evaluation Framework

- Traffic disturbance
- Perception disturbance
- Vehicle control disturbance

Verification guidelines for sim environment validity

SAKURA

Running/Measurement data

Functional Scenario → Logical Scenario → Concrete Scenario

Simulation environment construction

DIVP

External environment model → Space design model → Sensor model

Simulation PF

- 3D Data (Vehicle/Target)
- Reflection characteristic data

Automated driving system validation

AD-URBAN

- Recognition of the surrounding environment
- Path planning
- Vehicle control
- Localization
- Path tracking

- High-precision map data

Actual AD system vehicle

1 **Scenario I/F Study**

2 **Sim. I/F Study**

3 **Sim. Validity Study**

FY2021 Activities

<Team1> SAKURA DIVP

- Scenario interface definition
- CI Environment implementation

<Team3> JAMA DIVP

- Revision of the safety evaluation framework
- Verification of the simulation environment validity

<Team2> DIVP AD-URBAN

- Integration of AD function and simulation environment
- Verification of the perception limits

Source : FY2021 Year End Report of Safety Assurance Joint Promotion Steering Committee

Project overview

- Review of safety assurance basis
  - In SIP, AD-URBAN linkage
  - JAMA/Sakura Collaboration
- Objective Competitive Assessment of DIVP®
- Future plans
- Provision of business based on research results

The needs/issues of actual AD system are reflected in the virtual environment, and efficient performance/safety validation process of AD system has been built in ties with AD-Urban

Overview of AD-URBAN and DIVP® Project

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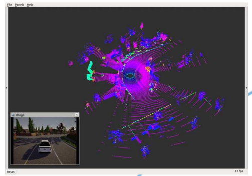
Virtual Space; Construct and deliver virtual environments

Real world; Real environment / System



- Lidar Model

- Camera Model

DIVP

Kanazawa University

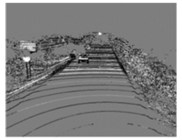
AD-URBAN

②Factor **Analysis**, Reflective property **Measurement** (**Sharing**)

- Sensing Weakness Scenario, Reflecting Data to Model Creation

①System, **Recognition failure**, Scene extraction

③**Environment - Propagation - Sensor Model** Construction



④Environmental Model **Consistency Verification**

⓪Driving validation, **Scenario**, Construction (**Sharing**)

⑧**Improving performance and robustness of** autonomous vehicles

⑤Model validation by Recognition Algorithm (**Sharing**)

- Environmental Model Readiness Assessment for Semantic Segmentation

⑥**Creation and provision of virtual environments, propagation, and sensor models in each scenario**

⑦**Recognition: Validation and improvement of decision module**

- Orthographic mapping validation
- Self position estimation validation (edge case of thermal shielding painting, etc.)
- Signal recognition algorithm validation, etc.
- System – environment model connectivity Improved IF specifications (e.g. time synchronization)

Source : Kanagawa Institute of technology, AD-URBAN

AD-URBAN DIVP

Constructed a combined environment of virtual environment and autonomous driving system, and performed functional validation of the AD-URBAN system

DIVP® Connecting Virtual Environments to AD-URBAN Autonomous Driving Systems

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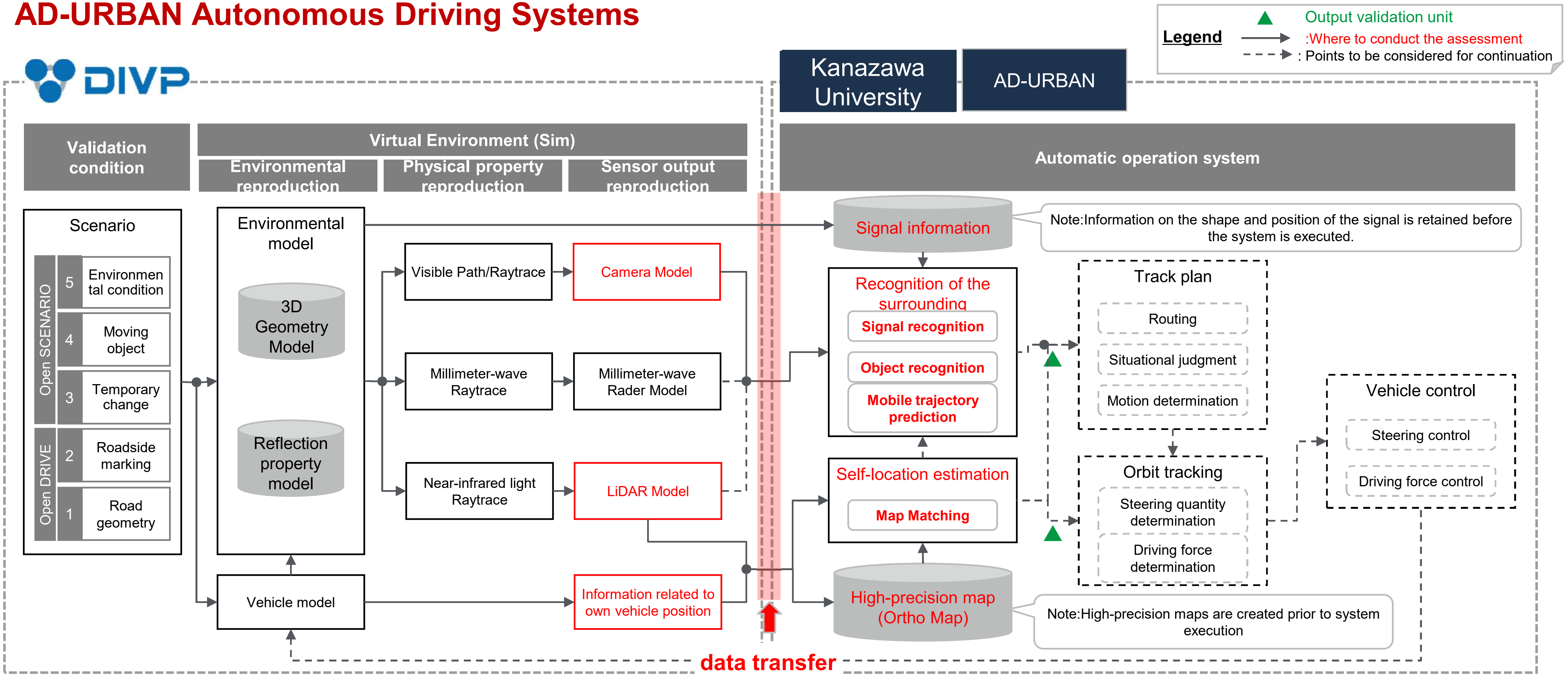


Source : Kanagawa Institute of technology, AD-URBAN

AD-URBAN DIVP

The effectiveness of the simulation is shown below

Implementation Schedule and Assessment Scenario

Legend
Red letter: Action item
🟩 : Model consistency and improvement
🟦 : System performance validation

FY2021

April | August | September | October | November | December | January | February | March

Model consistency validation

- NCAP dummy model
- Vehicle model
- Solar model backlit
- HILS

Model improvement

- Reflection model of the asset
- Solar model (shadows)

Self-location estimation validation (LiDAR)

High	・Heat-shielding coating
Medium	・Weather (rain) ・Puddle
Low	・Hiding by surrounding vehicles ・Splash ・Blurring of white lines

Signal recognition validation (Camera)

High	・Arrow signal ・Flashing signal ・Backlight
Medium	・Weather (rain) ・Night
Low	・Reflected light of the building ・Ramp signal

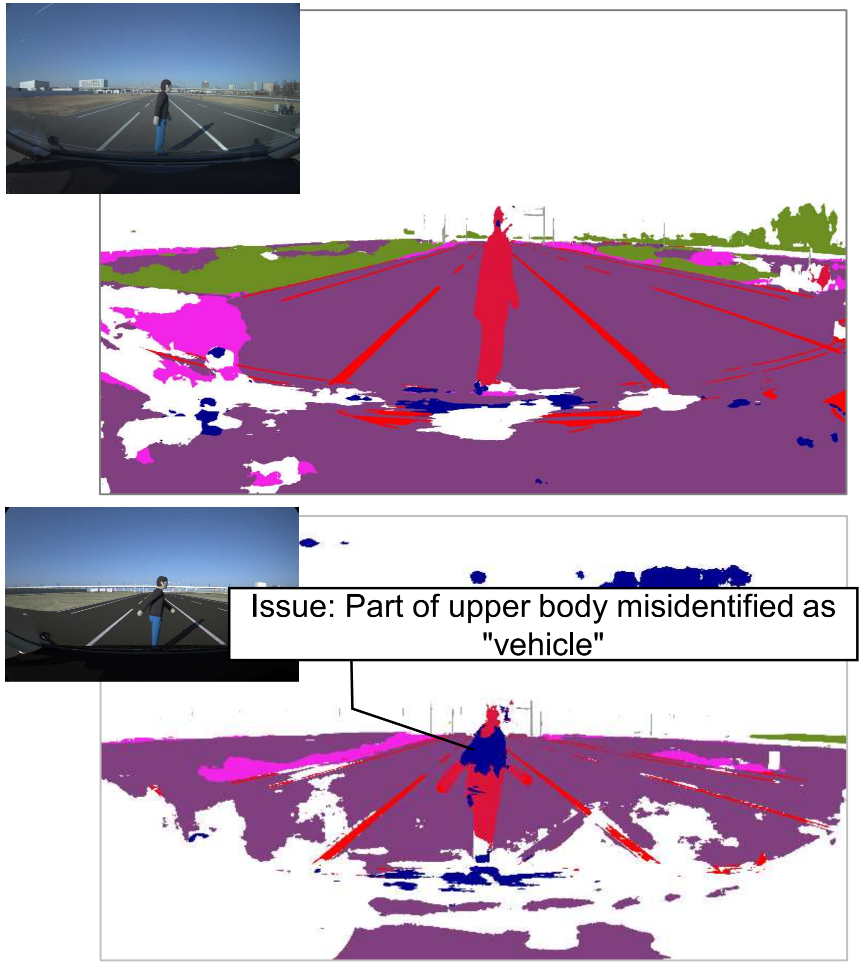
Object recognition validation (Camera/LiDAR Fusion)

High	・Pattern of different objects ・Hidden by surrounding structures
Medium	・Weather (rain) ・Night ・Emergency vehicle ・Water hoisting ・Imitation point due to rain
Low	・Flashing of the alarm lights of emergency vehicles ・Different planting, street trees ・Splash

Source : Kanagawa Institute of technology

[Model Consistency Validation] We verified the consistency using the camera image recognition function of AD-URBAN proj.We verified the model improvement of NCAP dummy.

Basic NCAP dummy cross section scenario in test course (JARI J-town)



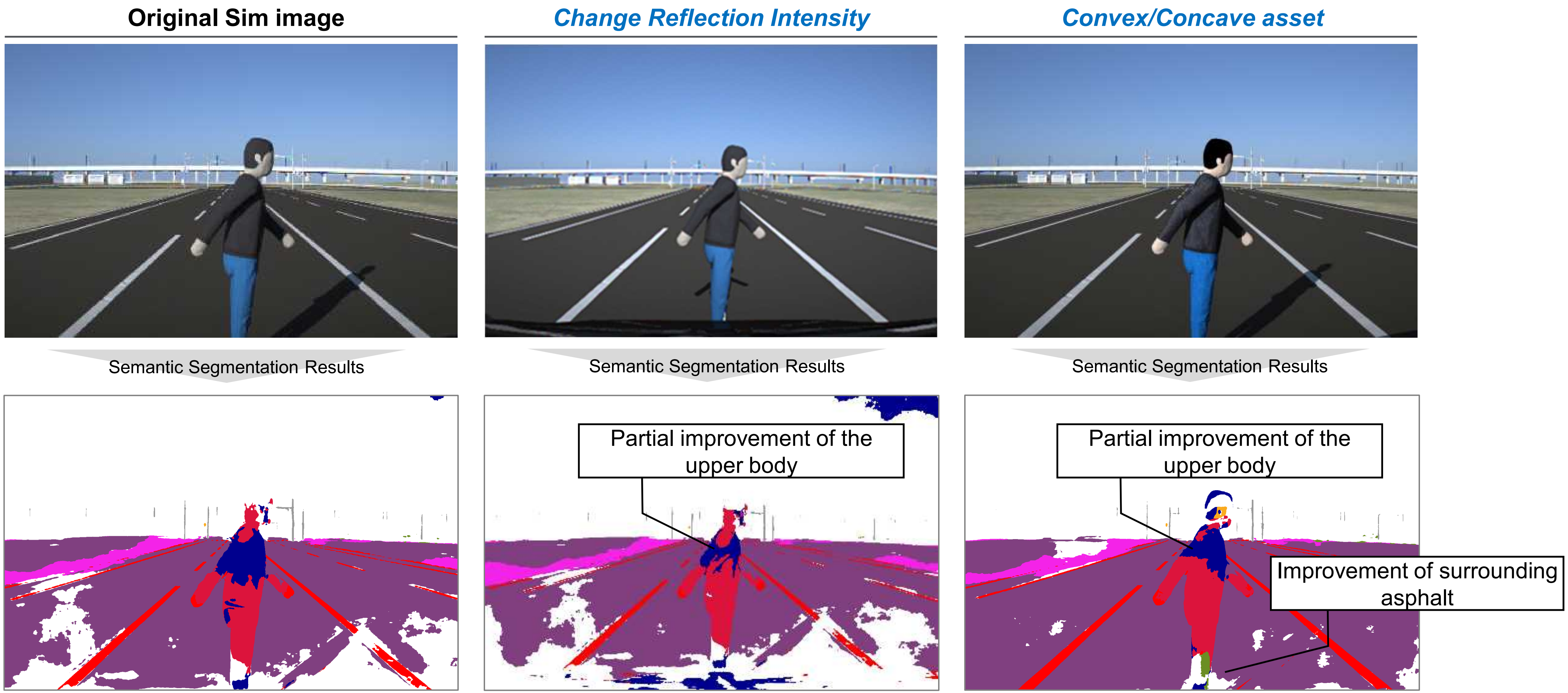
Factor verification for each element

Model element	Putative factor	Verification technique	Verification Results	Relationship to a factor
Light source	■ The way in which light shines	■ changing sun position	No change in perception	×
Reflective object (NCAP Pedestrians)	■ Specular component	■ Change Reflection Intensity	*Improved consistency*	○
	■ Asset Resolution	■ Change resolution	Decreased concordance	×
	■ Unevenness of the asset	■ Change Texture	*Improved consistency*	○
Sensor	■ The degree to which something is out of focus	■ Perform blur processing	Decreased concordance	×

Source : Kanagawa Institute of technology, AD-URBAN

We confirmed that adding reflection intensity of NCAP dummy and unevenness of the surface using the camera image recognition function of AD-URBAN improves consistency

Improving consistency by adding reflection strength and unevenness to assets



Source : Kanagawa Institute of technology, AD-URBAN

[Model Consistency Validation] The specular reflection strength of asphalt was reexamined through consistency verification using the camera image recognition function of AD-URBAN

Basic vehicle separation scenario on the test course (JARI J-town)

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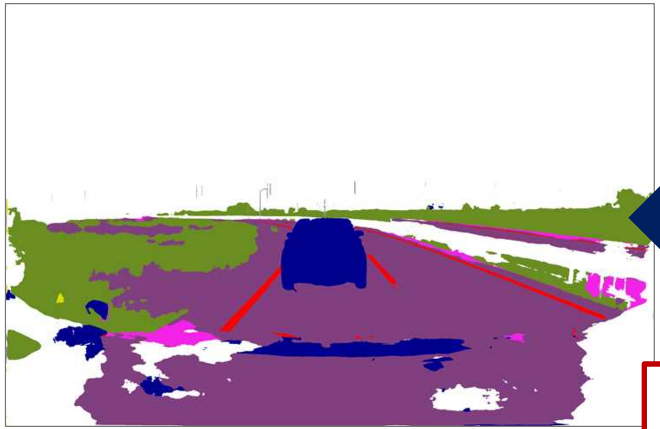
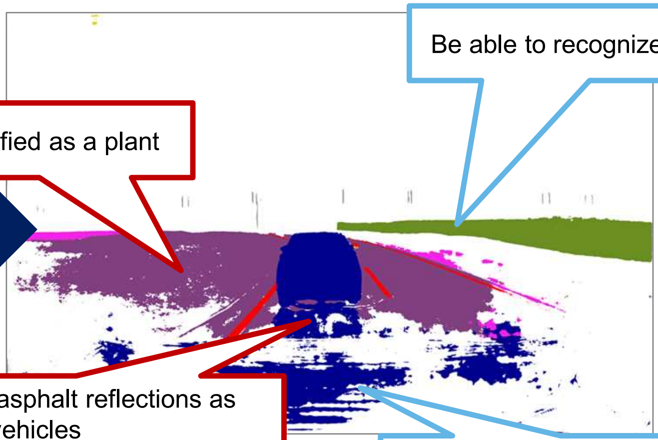
Real image (AD-URBAN)

Semantic Segmentation Results



Sim Image (DIVP®)

Semantic Segmentation Results



Comparison

Be not identified as a plant

Be able to recognize distant plants

Misidentifying asphalt reflections as vehicles

Be mistaken about the interior of one's car

Match

Inconsistency

Road surface
White line
Sidewalk
Sign
Trees

Source : Kanagawa Institute of technology, AD-URBAN

AD-URBAN DIVP

[Model Consistency Validation] Consistency verification using the camera image recognition function of AD-URBAN. The vehicle and white lines were confirmed

Basic vehicle separation scenario on the test course (JARI J-town)

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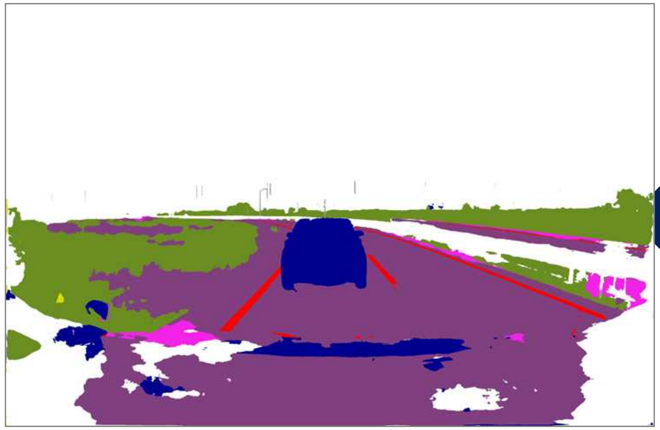
KANAGAWA INSTITUTE OF TECHNOLOGY

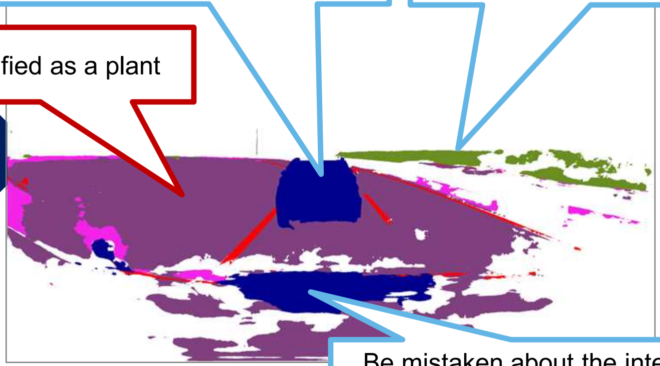
Real image (AD-URBAN)

Semantic Segmentation Results



Sim Image (DIVP®)

Semantic Segmentation Results



The vehicle can recognize the white line.

Be able to recognize distant plants

Be not identified as a plant

Comparison

Be mistaken about the interior of one's car

Match

Inconsistency

Road surface
White line
Sidewalk
Sign
Trees

It was confirmed that the recognition and misrecognition of typical recognition objects were correctly reproduced.

Source : Kanagawa Institute of technology, AD-URBAN

AD-URBAN DIVP

[Model Consistency Validation] Bad scene observed in AD-URBAN, where image was saturated due to backlight and sign went undetected, was reproduced by DIVP® Sim result.

Recreating a Bad Scene Due to "Returning the Sun"

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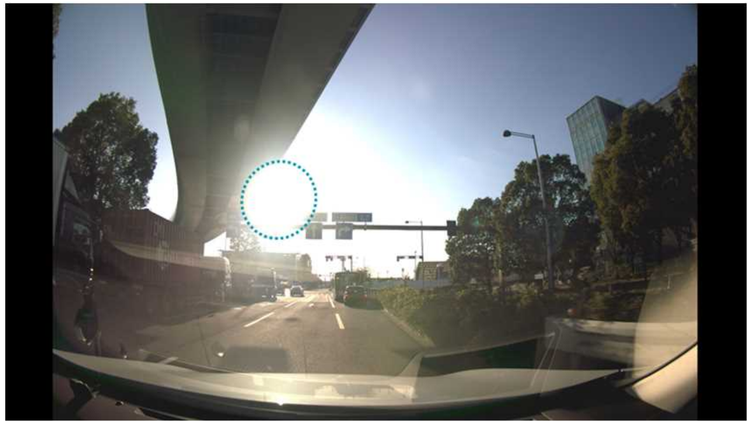
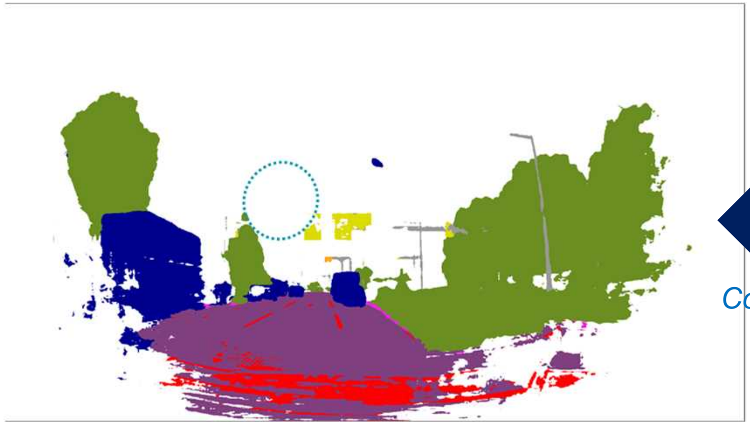
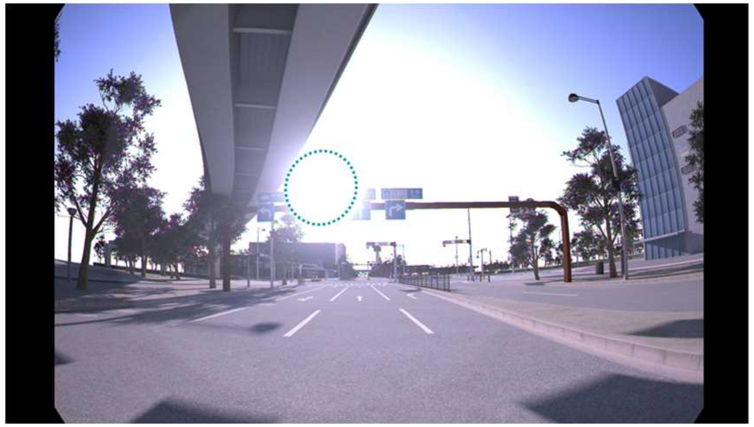
Real image (AD-URBAN)



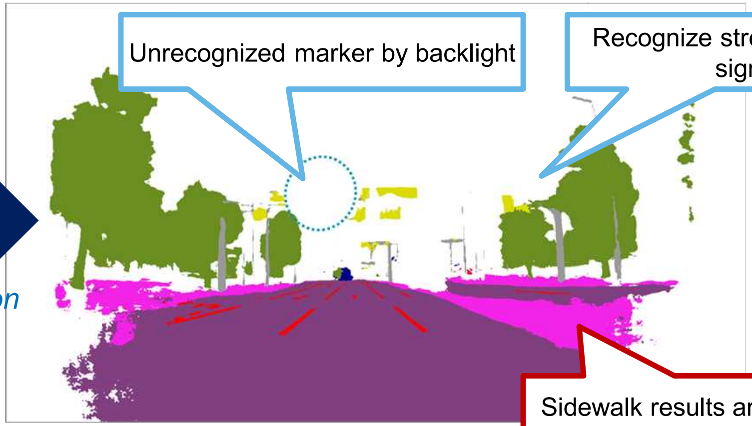
Semantic Segmentation Results



Sim Image (DIVP®)



Semantic Segmentation Results



Comparison

Match

Inconsistency

Road surface

White line

Sidewalk

Sign

Trees

It was confirmed that signs, street trees, and unrecognized backlight were correctly reproduced.

Source : Kanagawa Institute of technology, AD-URBAN

AD-URBAN DIVP

[Model Consistency Validation] The solar light setting was reviewed through consistency verification using the camera image recognition function of AD-URBAN.

Reproducing a bad scene due to the "border with shadows"

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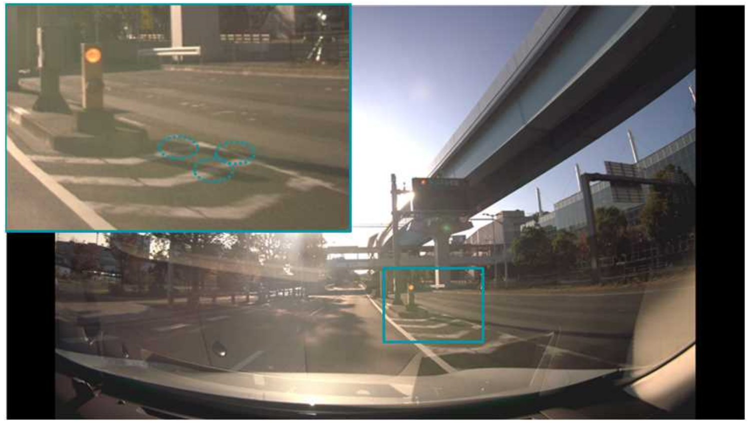
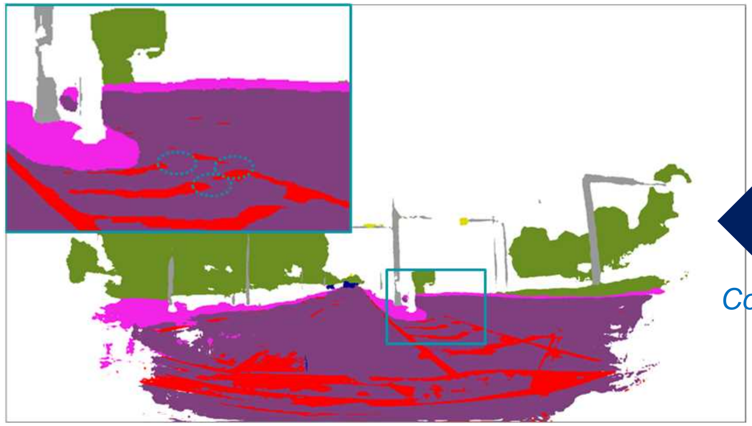
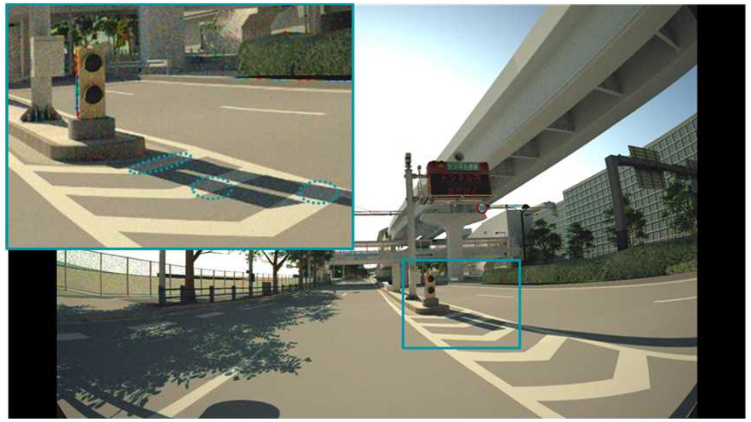
Real image (AD-URBAN)



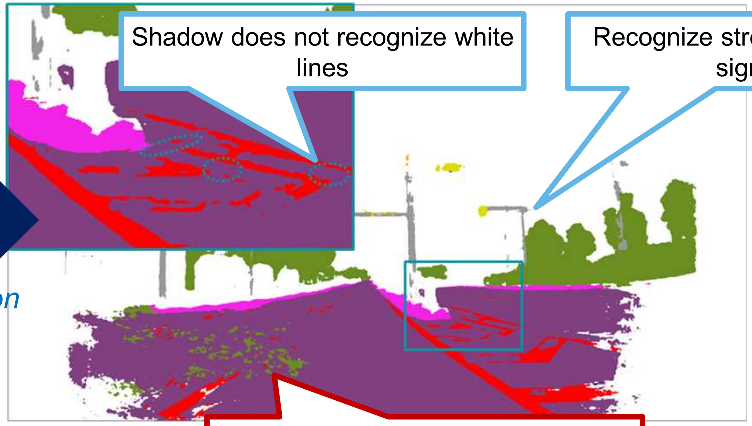
Semantic Segmentation Results



Sim Image (DIVP®)



Semantic Segmentation Results



Comparison

Shadow does not recognize white lines

Recognize street trees and signs

result in different shades

Match

Inconsistency

Road surface
White line
Sidewalk
Sign
Trees

In the real image, the shade of the tree is blurred, but the edge of the Sim is standing and false color occurs.

Source : Kanagawa Institute of technology, AD-URBAN

AD-URBAN DIVP

[Model Consistency Validation] DIVP® Sim result reproduced the bad scene observed by AD-URBAN where the white line goes undetected when overshadowed.

Reproducing a bad scene due to the "border with shadows"

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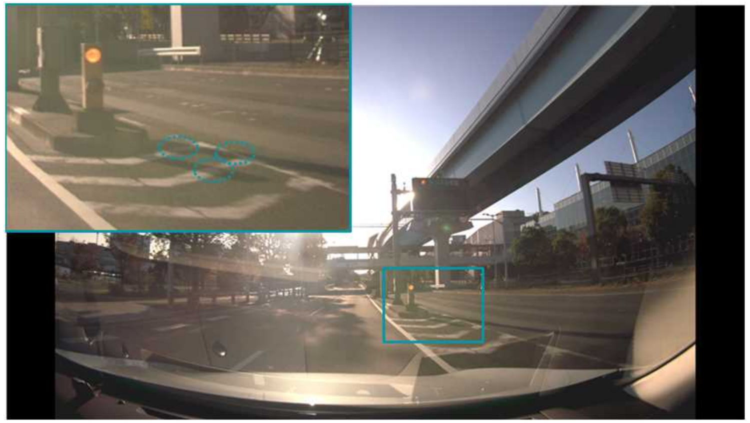
Real image (AD-URBAN)

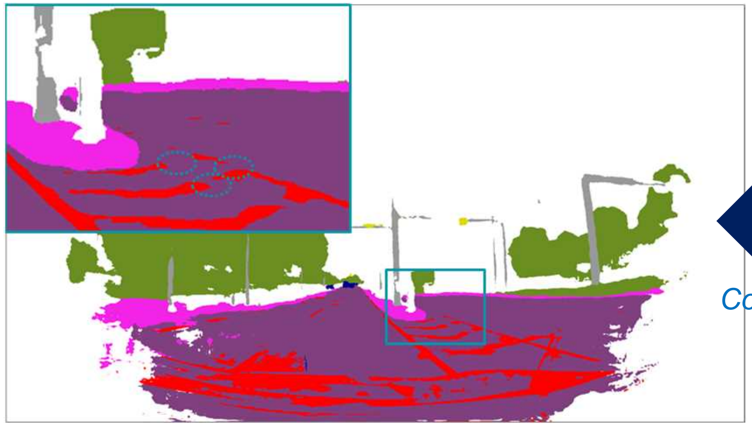


Sim Image (DIVP®)

Match

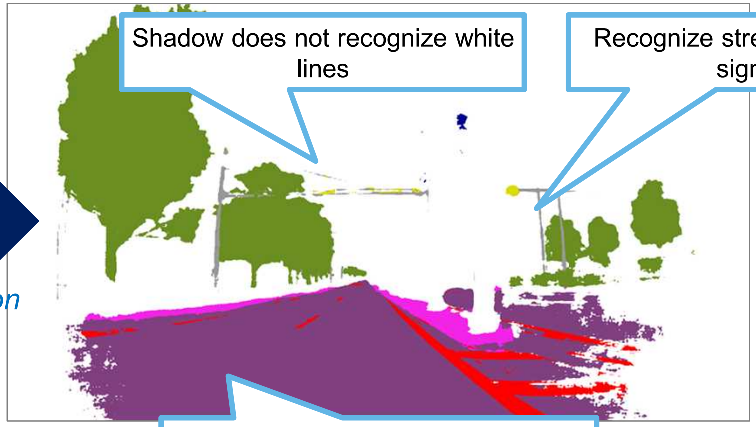
Inconsistency

Semantic Segmentation Results



Comparison

Semantic Segmentation Results



Shadow does not recognize white lines

Recognize street trees and signs

Tree shade result matching

Road surface
White line
Sidewalk
Sign
Trees

It was confirmed that unrecognized signs, street trees, and shadows were correctly reproduced.

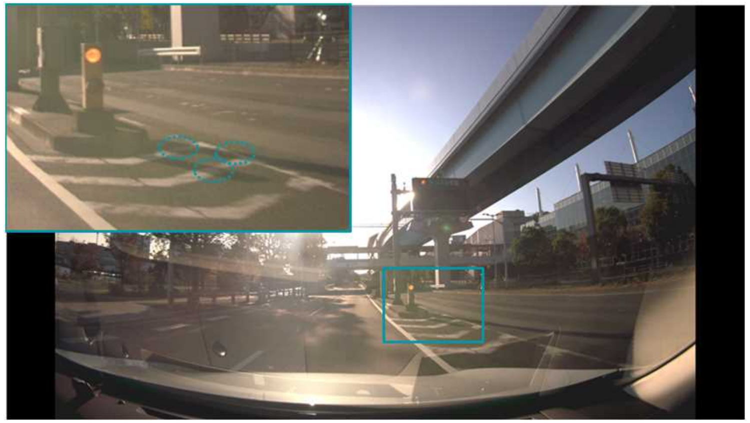
Source : Kanagawa Institute of technology, AD-URBAN

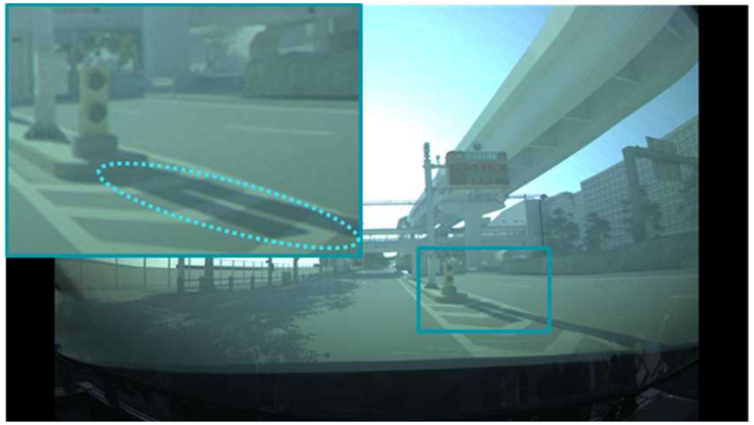
[Model Consistency Validation] The bad scene observed by AD-URBAN where the white line goes undetected when overshadowed, was reproduced by HiLS.

Reproducing Bad Scenes Due to Shadow Breaks (HiLS)

Real image (AD-URBAN)

HiLS Image (DIVP®)



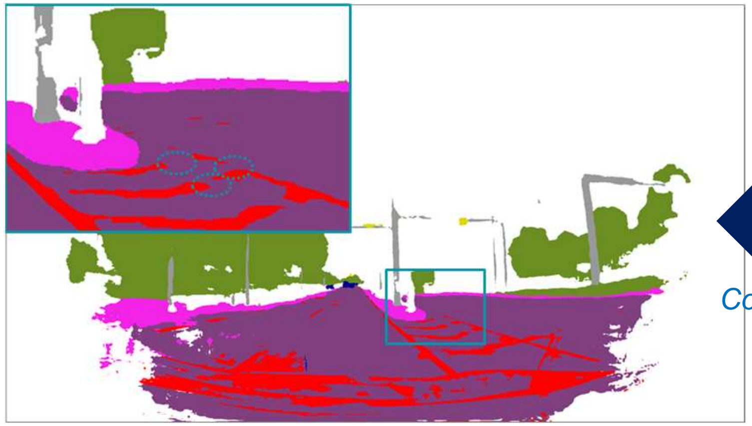


Match

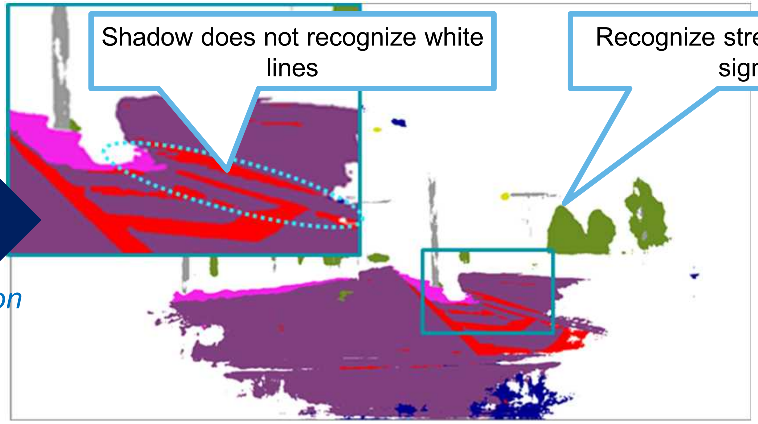
Inconsistency

Semantic Segmentation Results

Semantic Segmentation Results



Comparison



Road surface
White line
Sidewalk
Sign
Trees

It was confirmed that HiLS can also validate bad scenes.

Source : Kanagawa Institute of technology, AD-URBAN

AD-URBAN

[Sharing of driving validation scenarios]In tandem with AD-URBAN, issues for actual vehicle validation are provided from the system and shared as priority weakness scenario.

Self-location estimation validation (LiDAR) | Signal recognition validation (Camera) | Object recognition validation (Camera/LiDAR Fusion)

Rinkai Fukutoshin Area

Validation point

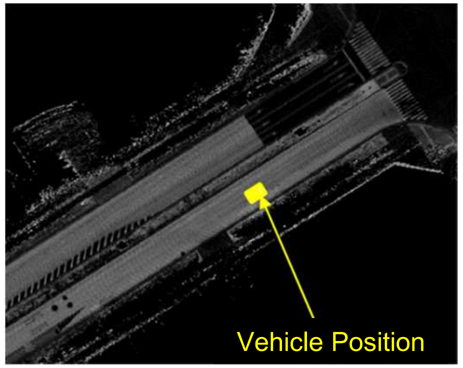
self-positioning (LiDAR)

① Difficult to detect the white line because the reflectance of the asphalt is the same as that of the white line.

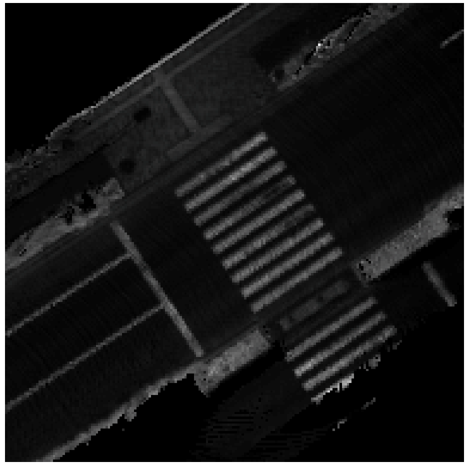
heat-shielding coating

LiDAR Point Cloud

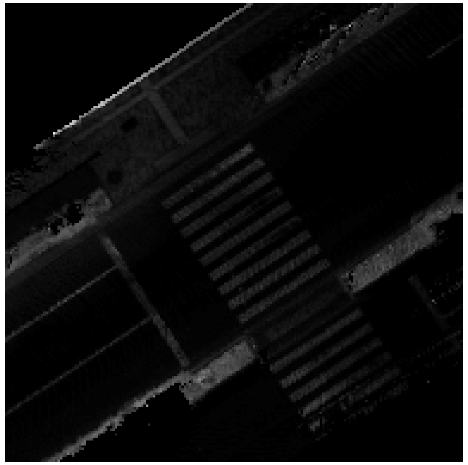
LiDAR Ortho Map



② The reflectance of the white line decreases due to road surface wetness, and it is difficult to estimate the self-position.



Effect of rainfall



Source : AD-URBAN

AD-URBAN DIVP

[Modeling of waterfront subcenter (Virtual-CG development)]Reflection characteristics were modeled based on experimental measurements, and detailed Virtual-CG was reproduced.

Modeling based on experimental measurements

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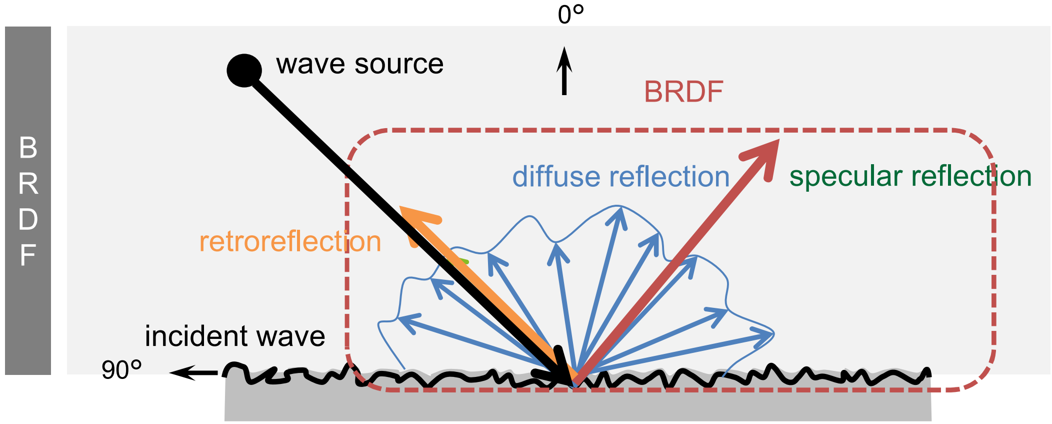
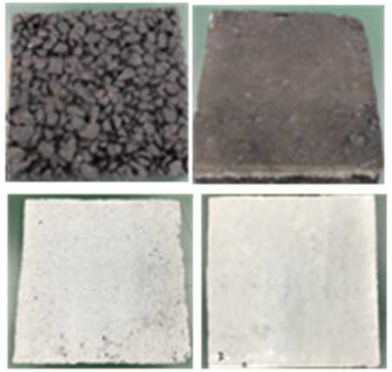
Modeling Reflection Characteristics

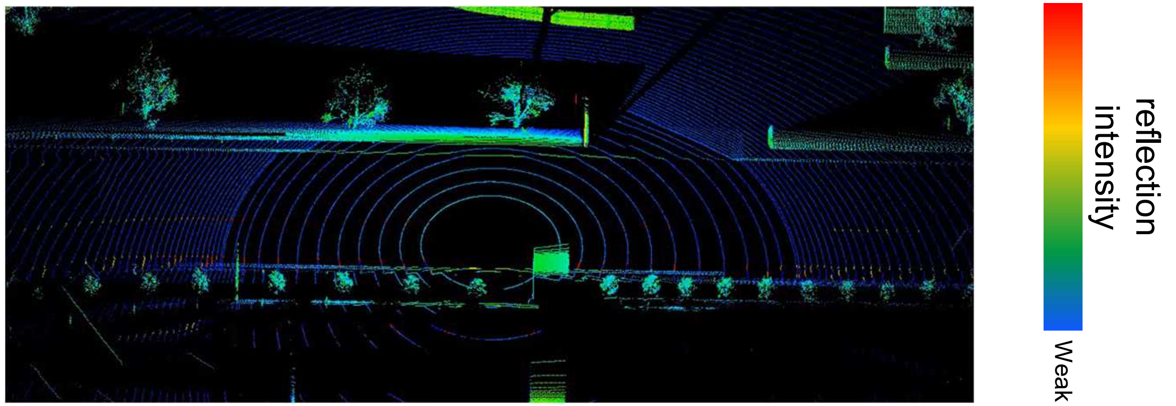
- Measurement characteristic



- Measuring asphalt used locally

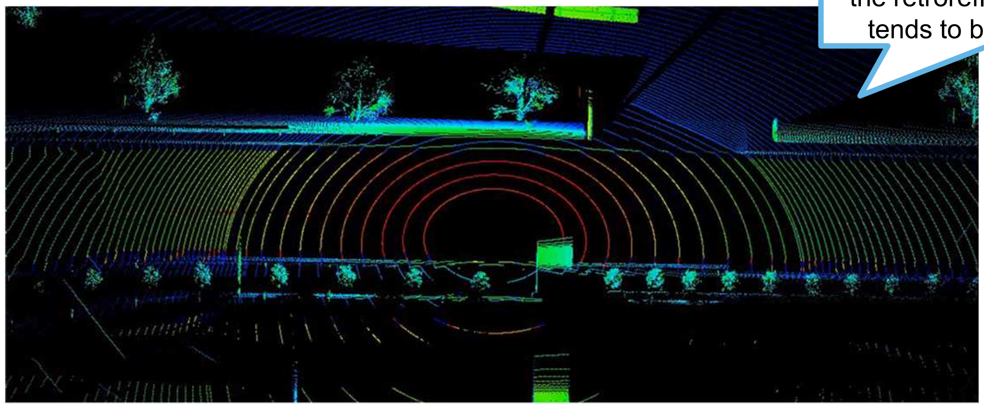


DIVP® Sim (usually asphalt)



DIVP® Sim (Thermal shielding painting)

In the thermal shielding painting, the retroreflective component tends to become stronger.

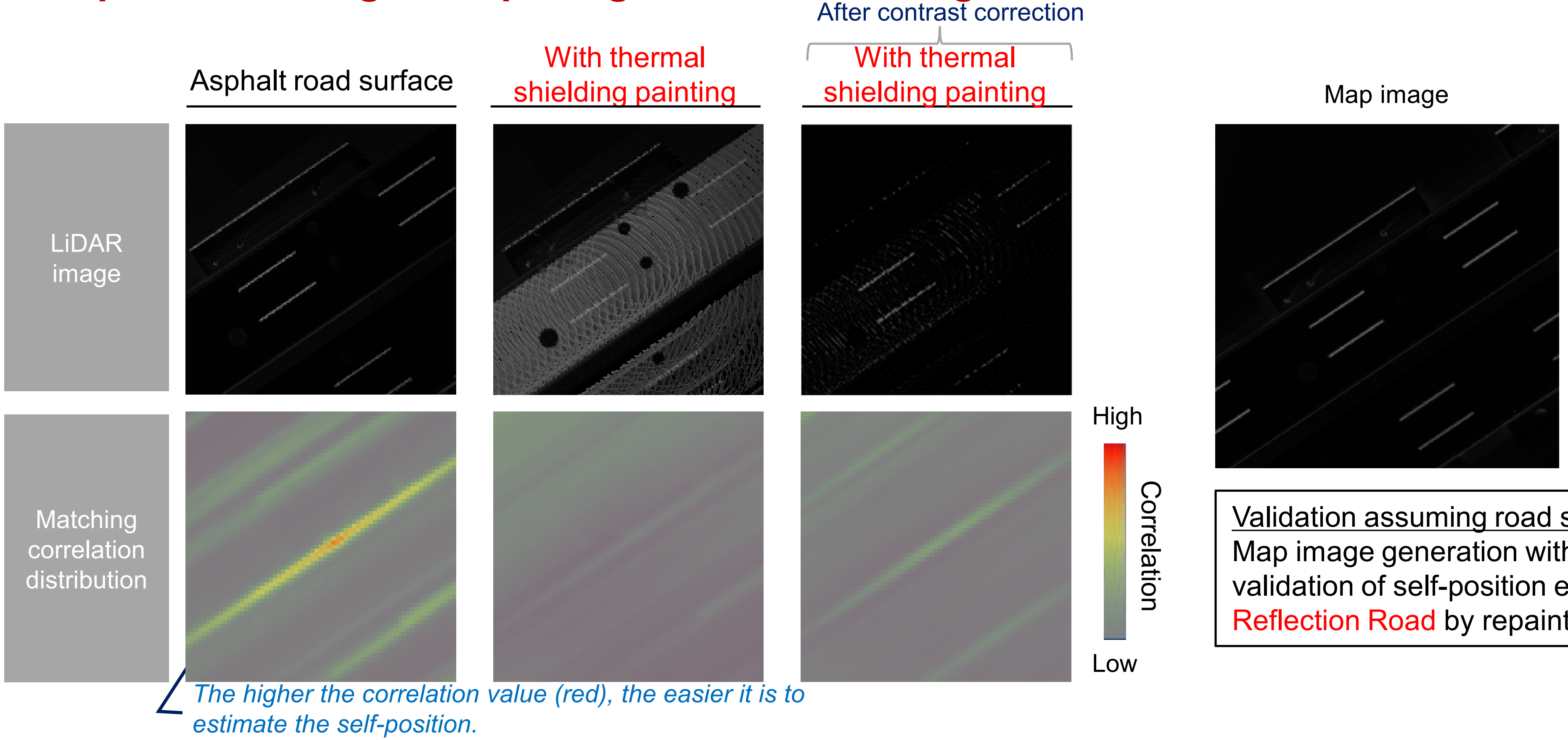


Source : Kanagawa Institute of technology, SOKEN, INC

AD-URBAN DIVP

Self-Position Estimation Validation (Thermal shielding painting)Self position estimation validation is possible at the time of ortho map generation and road surface alteration

Template matching of map image and LiDAR image of each road surface condition



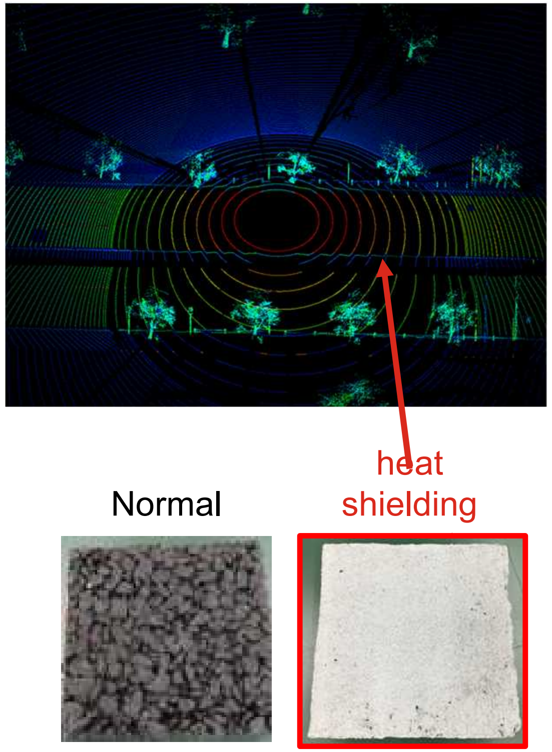
Validation assuming road surface repainting:
Map image generation with asphalt road surface data validation of self-position estimation at Change to High Reflection Road by repainting of road surface

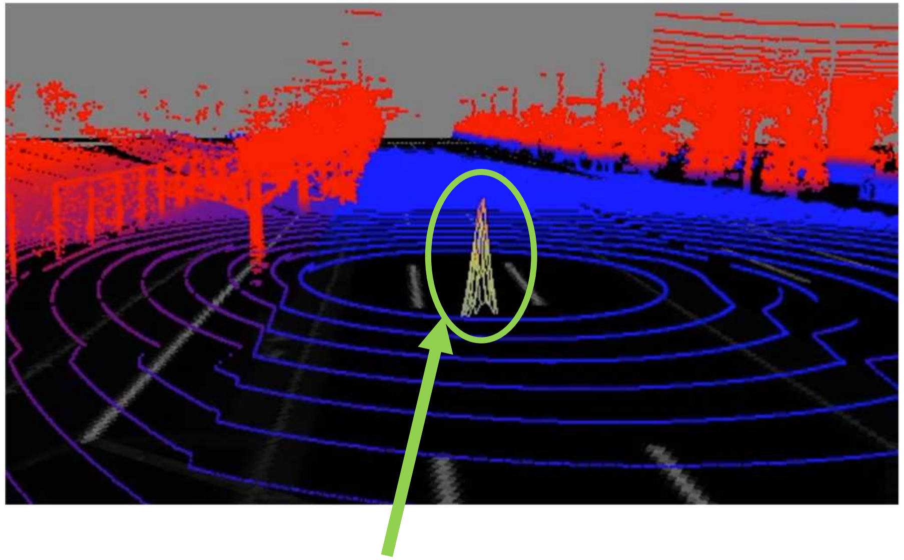
Performance limits limited to specific conditions can be searched by using simulations.
Improving the efficiency of sensor and algorithm development as a reproducible validation scenario standard

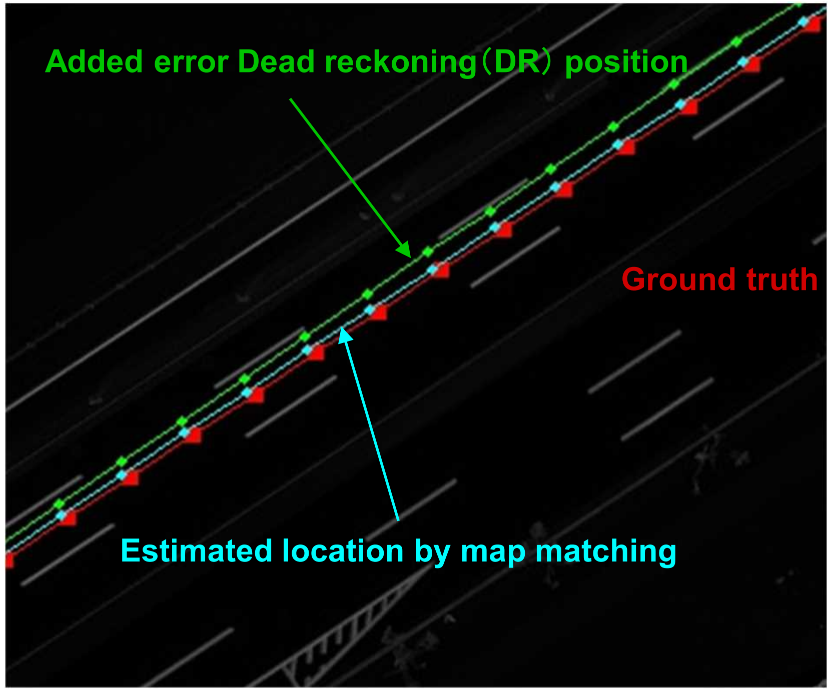
Examples of system control robustness/performance limits for edge case conditions. Searched limits using Sim highly consistent sensor + Sensing weakness scenario

Example of AD-URBAN system linkage; DIVP® Validation of Self-Positioning Algorithm Using sim

DIVP® LiDAR & Camera Sim. → LiDAR & Algorithm output → Effect on localizing accuracy







DIVP® Simulation provided high robustness of the AD-URBAN (Kanazawa University Proj.) self-location estimation algorithm, which we would like to validate in the system but Difficult to set in the real world.

Source : Kanagawa Institute of technology, AD-URBAN

Reproduced recognition performance limit level by modeling reflection characteristics based on white line wet condition, and confirmed influence of retroreflection characteristics

Recognition performance limit level by stepwise “Road surface wetting model"

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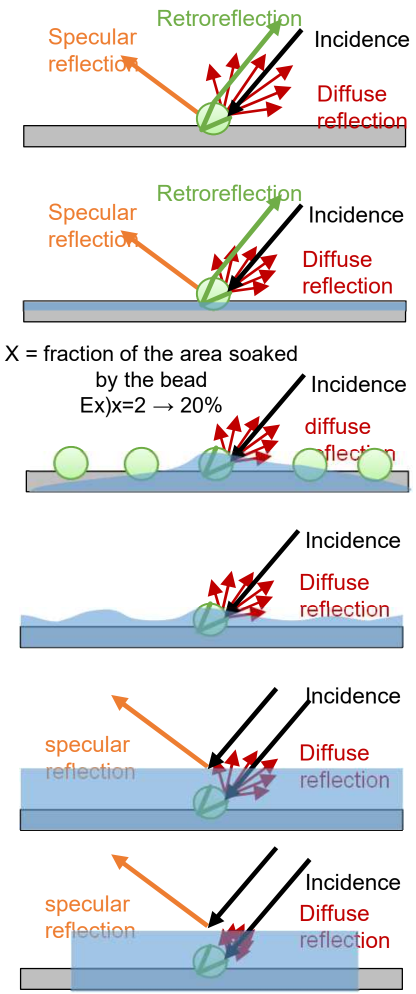
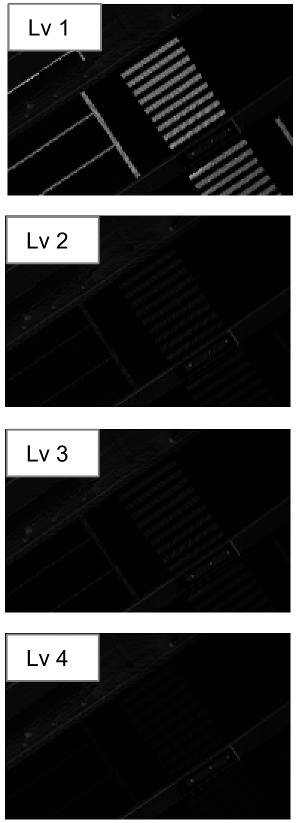
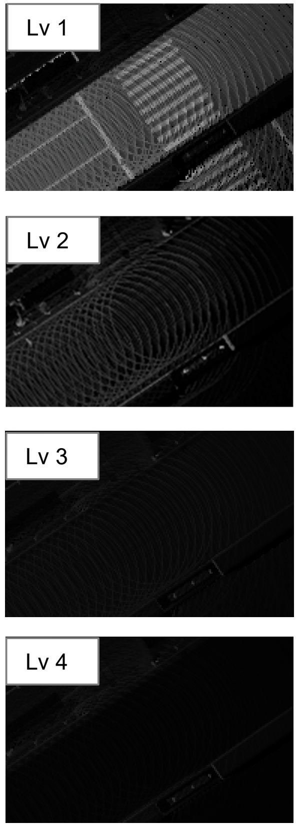
Level	Diffuse reflection	Specular reflection	*Retroreflection*
Level 0 drying	Diffusion characteristics of the material	Specular properties of the material	Recursive property of the material
Level 1 indentation A condition in which a wet place becomes dark	Decreased level	↑	↑
Level 1.x partial saturation state Of water, to seep out of the surface A portion of retroreflective beads in the laser spot area is immersed in water	↑	Specular attenuation proportional to area fraction	Retroreflection diminishes in proportion to area fraction
Level 2 saturated state Of water, to seep out of the surface Retroreflective beads soak in water	↑	Disappearance of specular reflection (= diffuse)	Loss of retroreflexes (= diffuse)
Level 3 thin water film Have a 1 ~ 2 mm water film	↑	Water specular	↑
Level 4 thick water film Have a few millimeters or more of water (I used 10 mm)	Lower levels in the infrared light region (Water extinction coefficient becomes non-negligible)	↑	↑



Normal road surface + Road surface wet



Thermal shielding painted road surface + Road surface wet

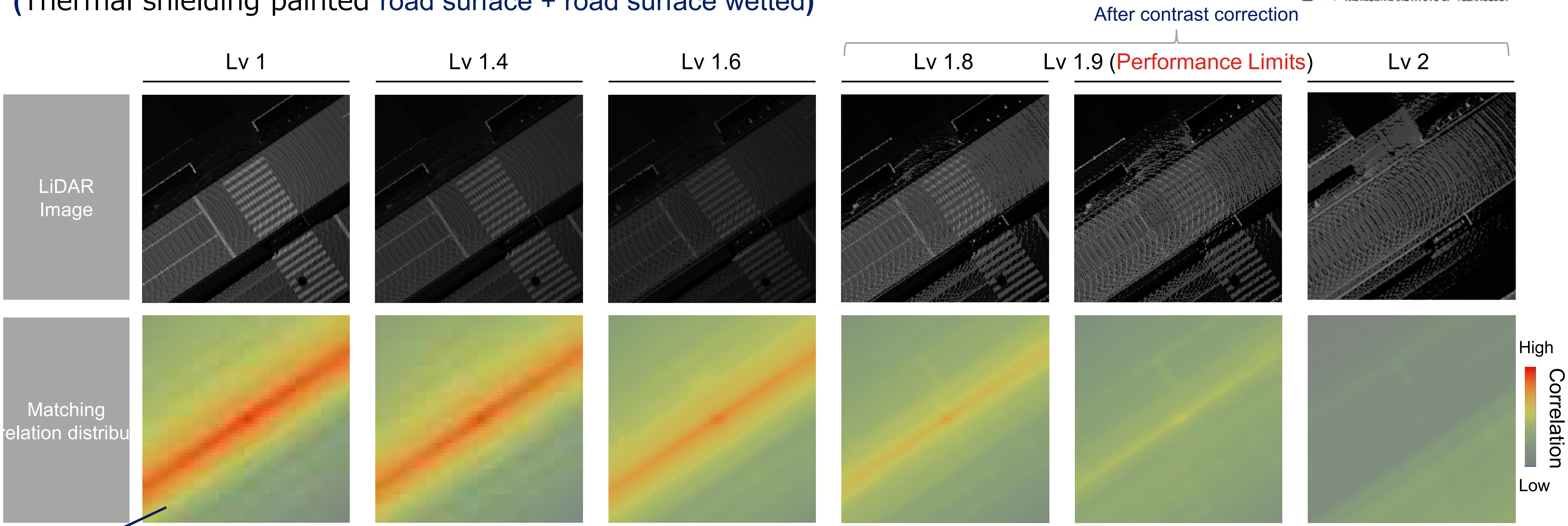


Source : SOKEN, INC, AD-URBAN

AD-URBAN DIVP

Self-Position Estimation Validation (Wetting Model) Validated performance limits of self-position estimation without changing vehicle conditions or other traffic participants

Template matching between map image and LiDAR image of each level:
(Thermal shielding painted road surface + road surface wetted)



The higher the correlation value (red), the easier it is to estimate the self-position.

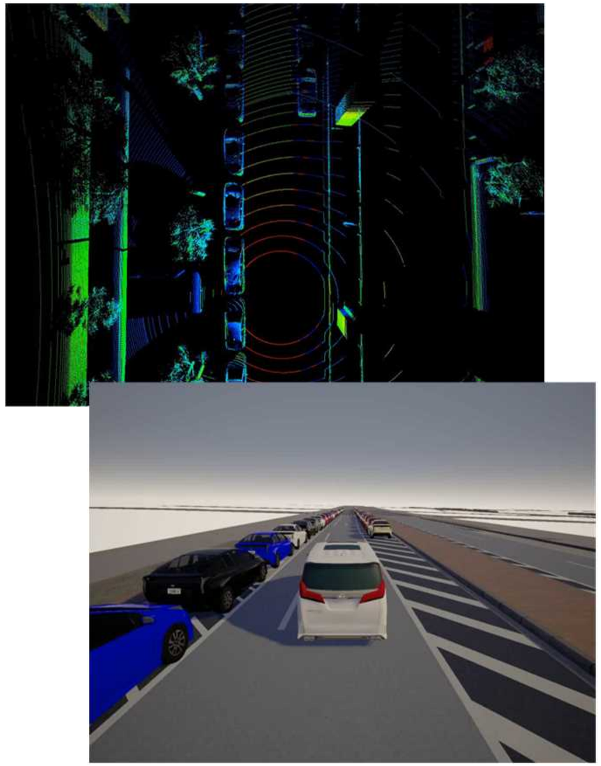
Performance limits limited to specific conditions can be searched by using simulations.
Improving the efficiency of sensor and algorithm development as a reproducible validation scenario standard

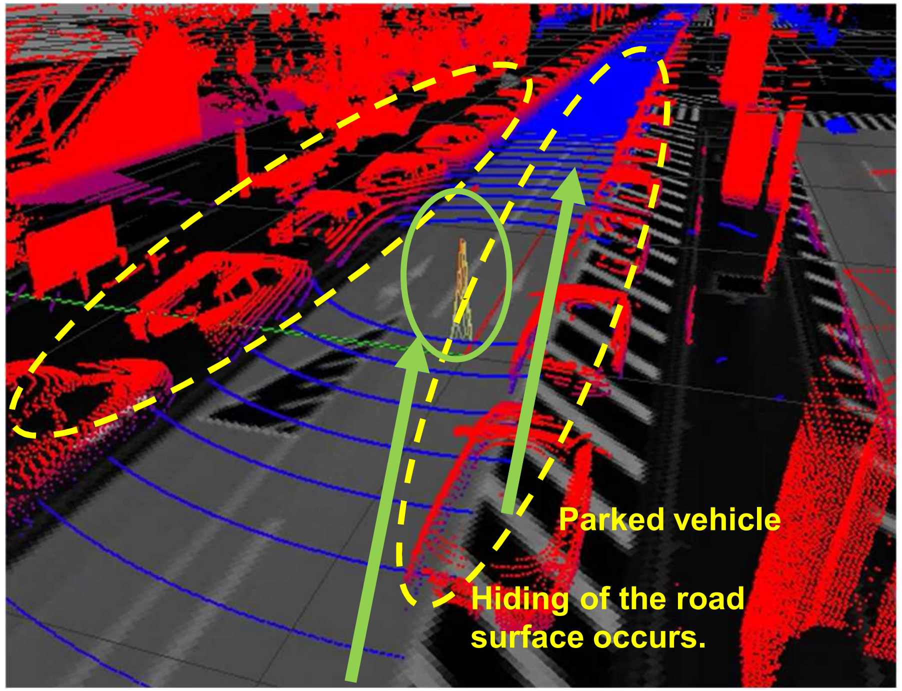
System control robustness for edge case conditions and validation example of performance limit Search sensor using Sim + Sensing weakness scenario with high consistency

Localizing Algorithm Robustness Verification using DIVP®

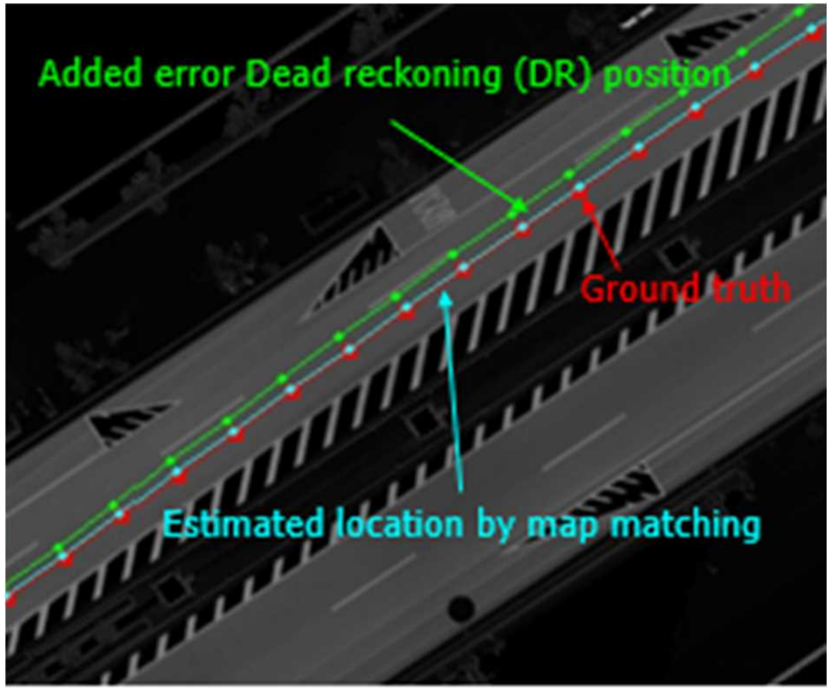
神奈川工科大学
KANAGAWA INSTITUTE OF TECHNOLOGY

DIVP® LiDAR & Camera Sim. → LiDAR & Algorithm output → Effect on localizing accuracy





Estimated location
(posterior probability density distribution)



DIVP® simulation provides adverse conditions that the system wants to validate but is difficult to set in reality. We were able to verify the high robustness of the self-position estimation algorithm of AD-URBAN (Kanazawa University Proj.).

Source : Kanagawa Institute of technology, AD-URBAN

AD-URBAN DIVP

[Sharing of driving validation scenarios] In tandem with AD-URBAN, issues for actual vehicle validation are provided from the system and shared as a priority weakness scenario.

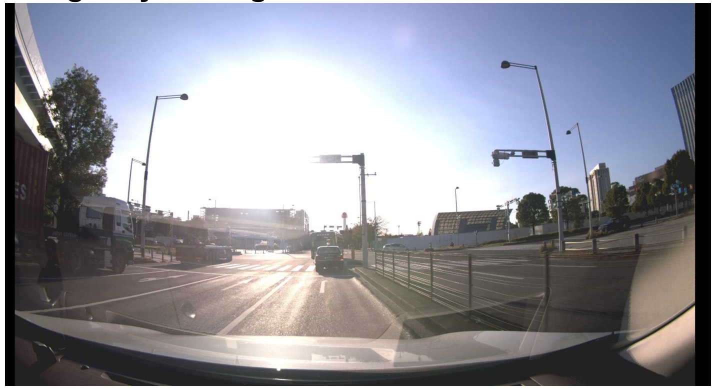
self-location estimation validation (LiDAR) → **signal recognition validation (Camera)** → object recognition validation (Camera/LiDAR Fusion)

Rinkai Fukutoshin Area

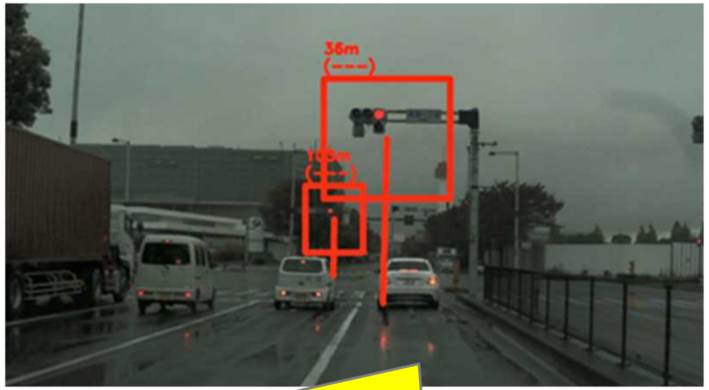
Validation point

Signal Recognition (Camera)

① Signal detection is difficult due to saturation of light by backlight.



② Difficulty in signal detection in rainy weather



Since there was no heavy rain during the demonstration experiment, verified by using simulation
- Demonstration experiment data：few mm/h
- Simulation capability：up to 300mm/h

③ Indirect signal detection is difficult due to building reflection.

Source：AD-URBAN

AD-URBAN DIVP

[Traffic Signal Modeling]Implemented signal model based on light distribution (IES) data and spectroscopic property data for signal recognition (camera) validation

modeled image

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Information collection for signal modeling

② Investigation of the relevant organizations

Coastal demonstration experiment TF

① Request modeling information

③ DIVP® Introduction

⑤ Provision of information

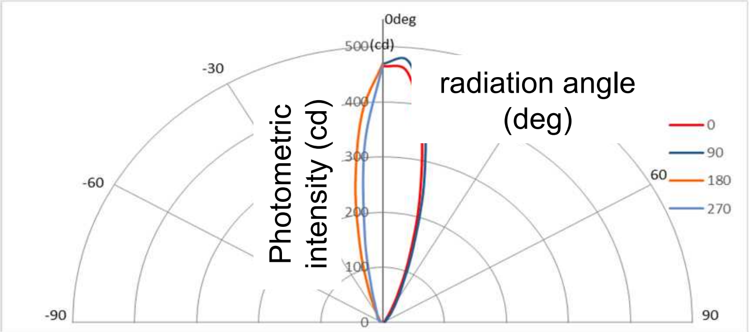
National Police Agency

Signal manufacturer

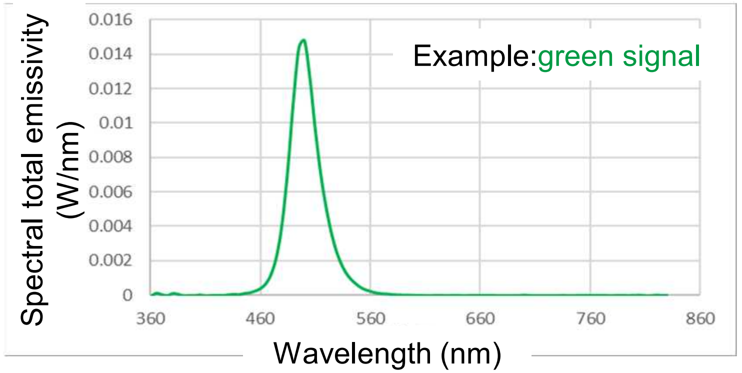
⑥ Signal modeling

④ Specification disclosure and experimental measurement

Generation of precise properties based on real machine measurement



light distribution characteristic; Luminosity per angle of emission
→ Spread of light defined



spectroscopic property; Radiant energy per wavelength
→ light color defined

Green signal data

Yellow signal data

Red light data

Arrow signal data

modeling

[Traffic Signal Modeling]Implemented traffic signal model at the Aomi 1-chome intersection for signal recognition (camera) validation

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KANAGAWA INSTITUTE OF TECHNOLOGY

Source : Kanagawa Institute of technology

AD-URBAN

DIVP

[Signal Recognition Validation]Models backlight, rain, and building reflections, which often cause poor signal recognition

Modeling of failure factors

神奈川工科大学
KANAGAWA INSTITUTE OF TECHNOLOGY

① Signal detection is difficult due to saturation of light by backlight.

Backlight modeling

② Difficulty in signal detection in rainy weather

Rainfall modeling

③ Indirect signal detection is difficult due to building reflection.

Modeling Building Reflections

Reproduction of recognition failures that occur only under certain conditions

- ■ Occurrence condition: Time (about 10 minutes between sunrise and early morning)
  - ➢ Weather (clear)
  - ➢ Building (Physical Properties)
  - ➢ Vehicle position (relative to the building reflection point and the traffic signal)

Source : Kanagawa Institute of technology

[Signal Recognition Validation (Normal weather condition)]
Confirmed that automatic operation system generally recognizes signal without problems

AD-URBAN connection check (Normal weather condition)

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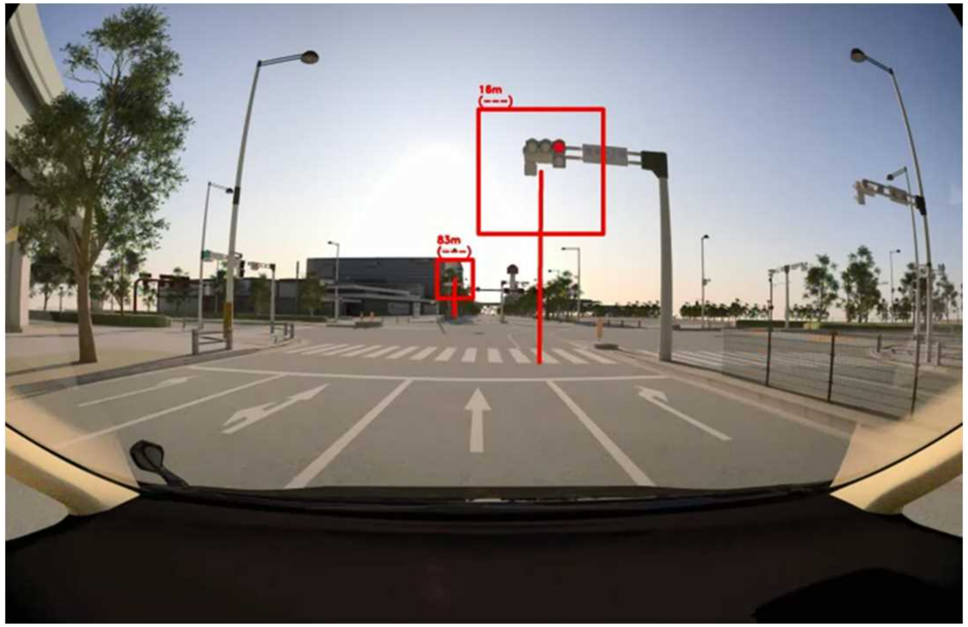
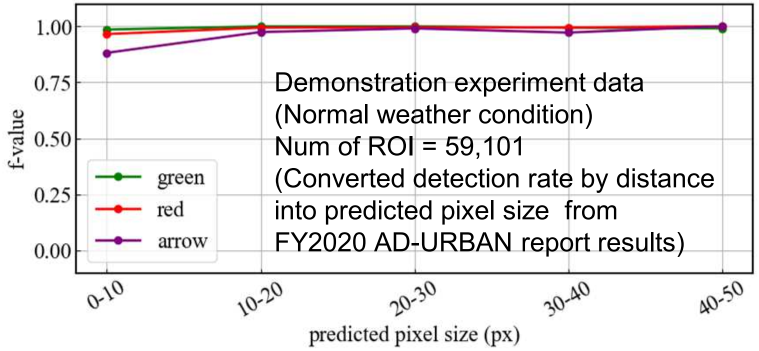
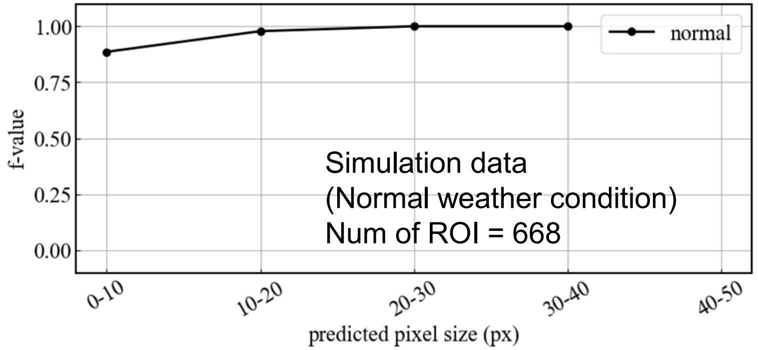
KANAGAWA INSTITUTE OF TECHNOLOGY

Intersection approach scenario



Traffic signal detection rate (Demonstration experiment data/Simulation data)





Average detection rate of demonstration experiment : 0.982

About the same

Average detection rate of simulation : 0.989

Confirmed that the average traffic light detection rate of demonstration experiment and simulation are about the same in normal weather condition

Source : AD-URBAN

AD-URBAN DIVP

[Signal Recognition Validation (Backlight condition)]
Confirmed the reproduction of recognition failures in backlight condition

Confirmation of backlight reproduction

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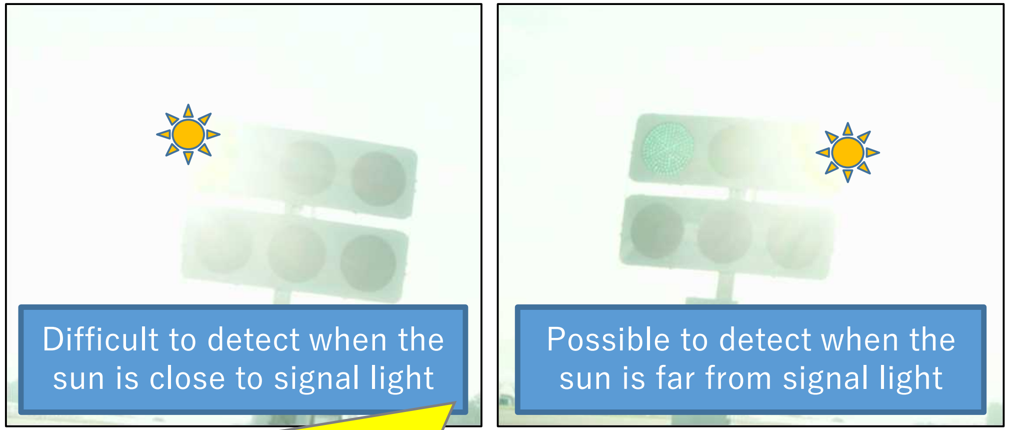
AD-URBAN demonstration experiment results

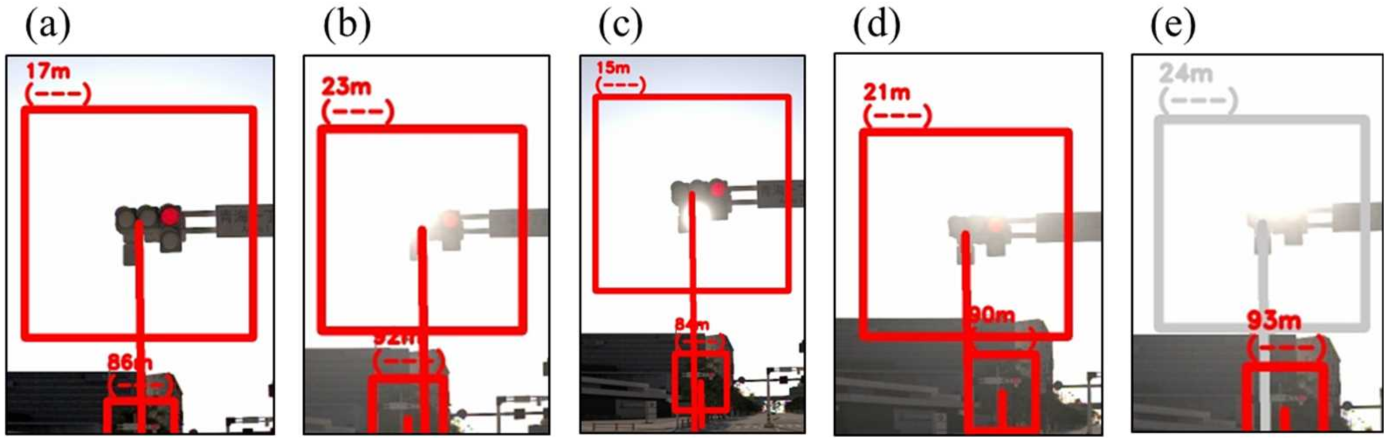


Difficult to detect when the sun is close to signal light

Possible to detect when the sun is far from signal light

Both conditions seem similar, although it is difficult to detect when the sun is close to signal light
→The distance between signal light and sun is key point

DIVP® Simulation results



No impact of backlight when the traffic light and sun overlaps

No impact of backlight when the sun is far from signal light

Difficult to detect when the sun is close to signal light

Confirmed the reproduction of recognition failures when the sun is close to signal light

Source : AD-URBAN

[Signal Recognition Validation (Rainy weather condition)]
Confirmed the reproduction of recognition failures in backlight condition

Confirmation of rainy weather reproduction

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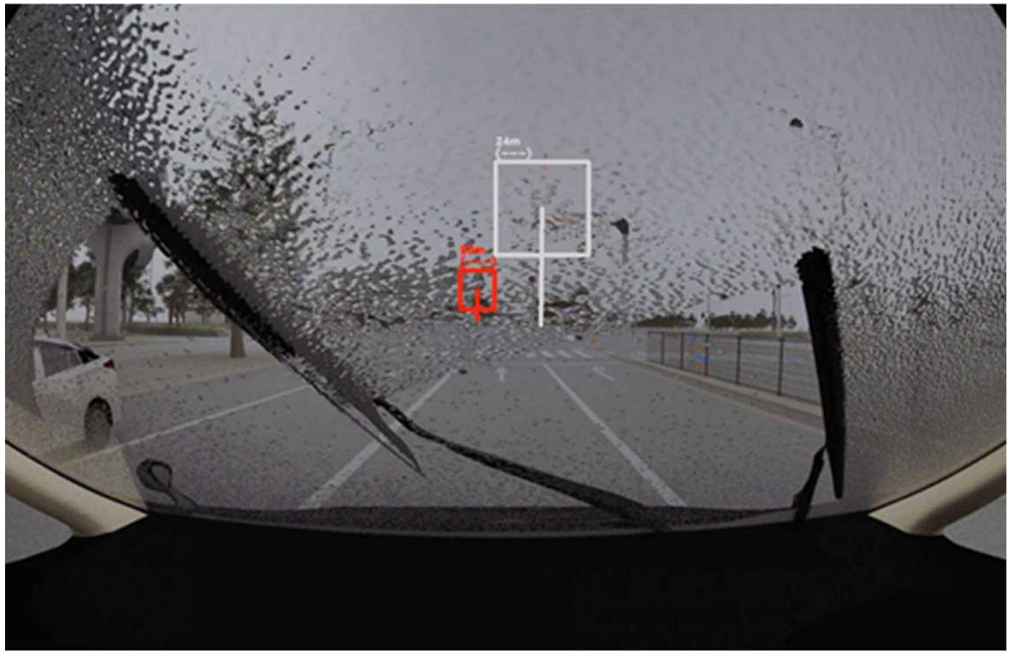
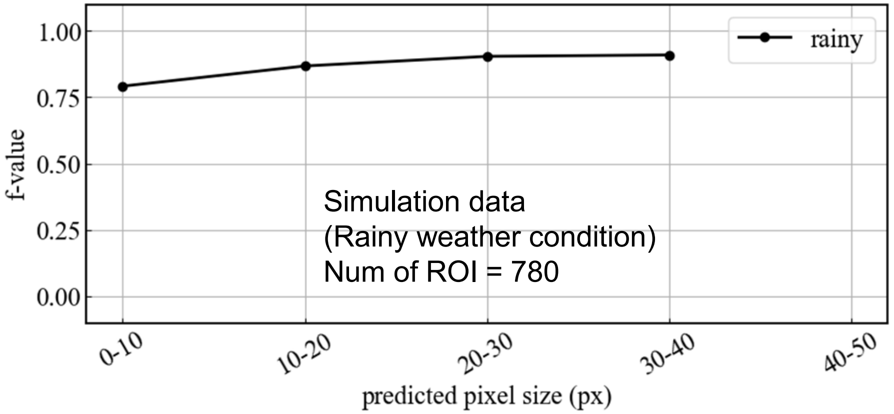
DIVP® Simulation results



Traffic signal detection rate



Average detection rate of simulation : 0.868

The average detection rate was down about 12 percentage points from normal weather condition

[Lowering factor of traffic signal detection]
・Increase of undetected error due to raindrops shielding
・Increase of misrecognition due to coloration changeling

As the rainfall increases, the traffic signal detection rate decreases regardless of distance to traffic light

[Signal Recognition Validation] Difficult to reproduce due to short time phenomenon where specific conditions are overlapped in reality DIVP® Sim can perform reproduction validation

Reproduction of recognition failures that occur only under certain conditions

- Occurrence condition: Time (about 10 minutes between sunrise and early morning)
  - Weather (clear)
  - Building (Physical Properties)
  - Vehicle position (relative to the building reflection point and the traffic signal)

Real image (AD-URBAN)

DIVP® Sim image

Source : Kanagawa Institute of technology, AD-URBAN

[Sharing of driving validation scenarios] In tandem with AD-URBAN, issues for actual vehicle validation are provided from the system and shared as a priority weakness scenario.

self-location estimation validation (LiDAR) → signal recognition validation (Camera) → **object recognition validation (Camera/LiDAR Fusion)**

Rinkai Fukutoshin Area

Validation point

Object recognition (Camera/LiDAR Fusion)

Source : AD-URBAN

[Object Recognition Validation] In tandem with AD-URBAN, planning the evaluation based on “Geometry” and “Physical Properties”

Evaluation viewpoint

Step	Viewpoint	Overview
Step1	Geometry	■ Evaluation based on positional relationship Example : Hidden scenes caused by other traffic participants or surrounding structures ➢ Hidden by large vehicles or special vehicles
Step2	Physical Properties	■ Evaluation based on sensor physical principle Example : Scenes of pedestrian in a black leather jacket crossing at night ➢ Night is a weak point for camera and black leather jacket is a weak point for LiDAR

Assets such as large vehicles and special vehicles

Bus

Truck

Tanker

Scenario of pedestrian cross at night

Source : Kanagawa Institute of technology, AD-URBAN, MITSUBISHI PRECISION CO.,LTD.

AD-URBAN

Collaboration with AD-URBAN enables AD system validation using DIVP® Sim. Recognition performance limit was reproduced, and weakness scenario validation standard could be set

Summary

Using simulations, we confirmed that conditions that are difficult to reproduce in actual vehicles can be validated efficiently.
*On an actual vehicle, *change to any conditions*, *fix specific conditions*, impossible

Validation system	Sensing Weakness Condition	Modification condition	Fixed condition
Self-location estimation	Discrepancy from orthographic map due to road surface repainting	Road surface reflectance by repainting the road surface	Location information accuracy
	Decrease in white line contrast due to rainfall	Road surface reflectivity due to rainfall	
	Deterioration of white line detection by motorcade	Location of nearby traffic participants	
Signal recognition	Signal image saturation due to backlight	Relative position of the light source and the signal	Weather conditions (Weather, sun position)
	Adhesion to windshield due to rainfall	Weather conditions (Weather, sun position)	Lcation information accuracy
	Signal image saturation due to building reflection	Relative position of the light source and the signal	Weather conditions (Weather, sun position)
Object recognition	Pattern of different objects	Types and locations of nearby traffic participants	Weather conditions (Weather, sun position)
	Hidden by surrounding structures	Relative position of the vehicle and the object to be recognized	
	Road surface wetting due to rainfall and windshield adhesion	Weather conditions (Weather, sun position)	Location information accuracy

Source : Kanagawa Institute of technology, AD-URBAN

AD-URBAN

[Future Initiatives] Due to varying degrees of reflectance reduction on the actual road, generation of reproduction model that factors in such variations proves to be a future issue

Comparison between actual driving data and Sim data.
→A dispersion consideration model is required in lieu of a uniform wetting model

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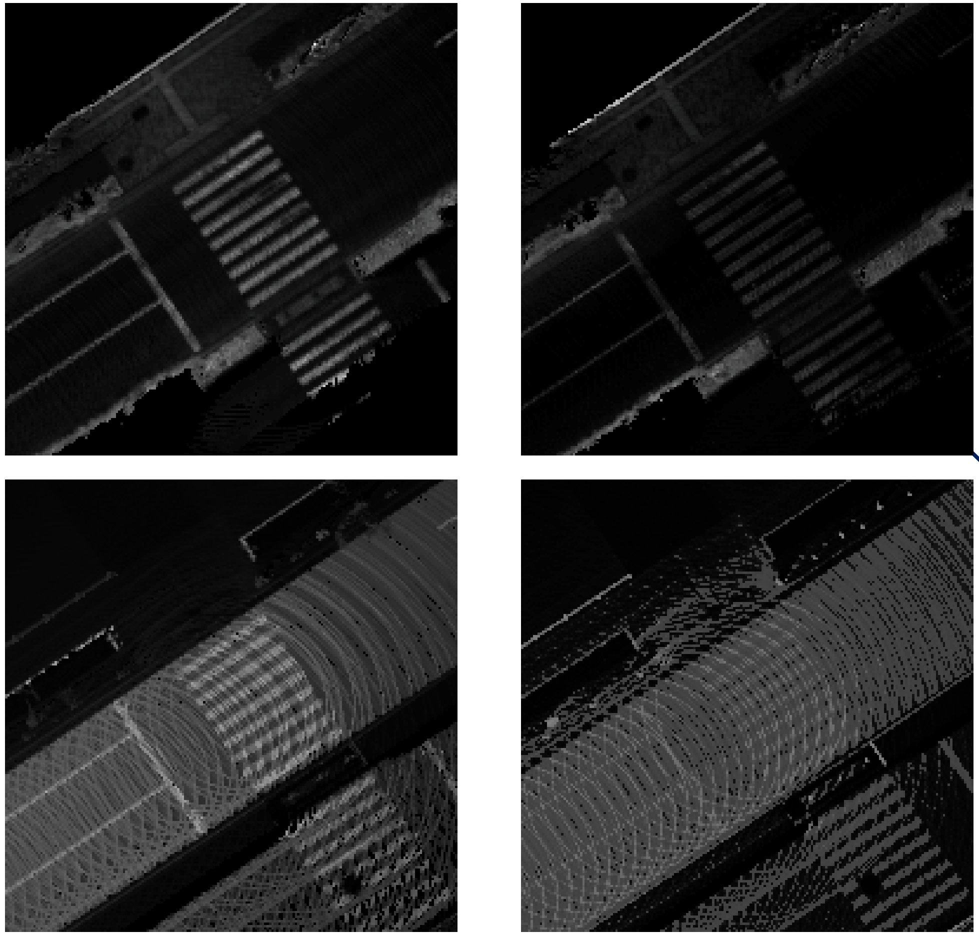
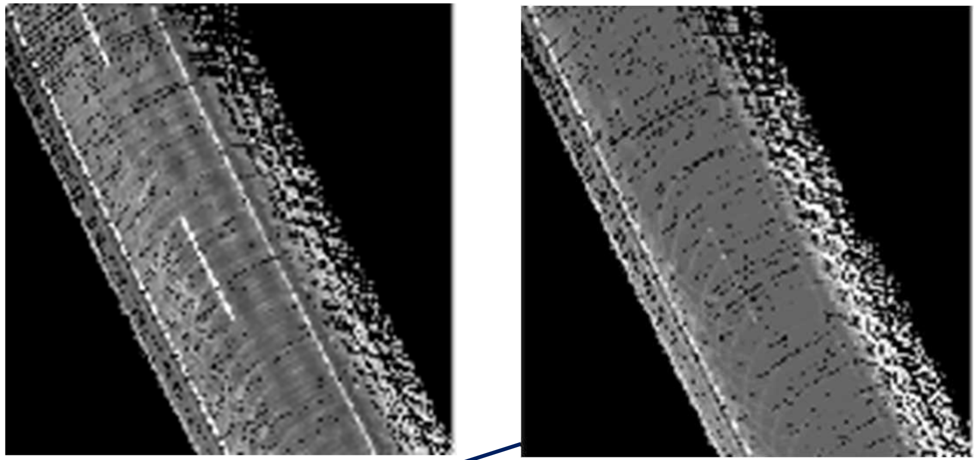
	Dry road surface	Wet road surface
Actual running data		
Sim Data		



Dry road surface | Wet road surface



There is a variation in the degree of decrease in shooting rate.
(Inuniform reflectivity loss)

Source : AD-URBAN

AD-URBAN DIVP

Project overview

- Review of safety assurance basis
  - In SIP, AD-URBAN linkage
  - JAMA/Sakura Collaboration
- Objective Competitive Assessment of DIVP®
- Future plans
- Provision of business based on research results

JAMA has defined principle model/validation scenario of perception failure, and issued guidelines for the Sim environment, on which DIVP® models and validates are based

JAMA Perception failure definition and Validation Items

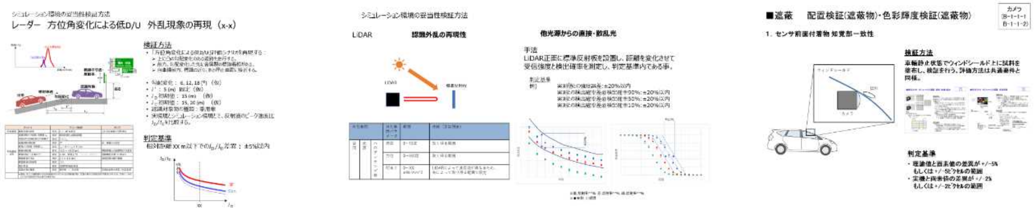
Factors x Principles			Principles					
			Signal S from the recognition target			signal that interferes with recognition	
			Phase	Strength		& Noise	…
			…	…	S intensity difference large	…	…
Factors	Vehicle and sensor		**Definition of perception failure (Factors × Principles)**				
	Surrounding environment						
	Object of recognition						
Principles x Validation items							
Sim environment validation	Basic verification	**Sensor characteristic**	**A: Common Basic Verification Items** Basic sensor characteristics, basic target reflection characteristics, basic traffic flow scenarios, etc.				
		Radio propagation characteristics					
		Reflection characteristics of the object					
		Traffic flow scenario					
	Reproducibility verification	Validation by principle Define as Scenario	**B: Reproducibility verification item of perception failure** Sensor deposits, backlight, specially shaped targets, etc.				

■Common basic verification items (107 items)

Sim environmental validation items			Content of verification	Acceptance criterion
sensor characteristic	Detection accuracy	& Distance	The location of the C/R (corner reflector) shall be detectable in the same manner as in the actual environment.	5% or Less
		Azimuth (θ)		5% or Less
		...	...	...
	Resolution	& Distance	The minimum resolution when two C/Rs are installed close to each other is equivalent to that in the actual environment.	15% or Less
		Azimuth (θ)		15% or Less
		...	...	...
Reflection characteristics of the object	Vehicle	RCS	RCS of passenger cars shall be equivalent to the actual environment in all surroundings.	3 dB or less in all directions
		...	...	...
...	...	...	...	...

■Reproducibility verification items (Priority 9 principles)

Defined as Validation scenarios for each principle



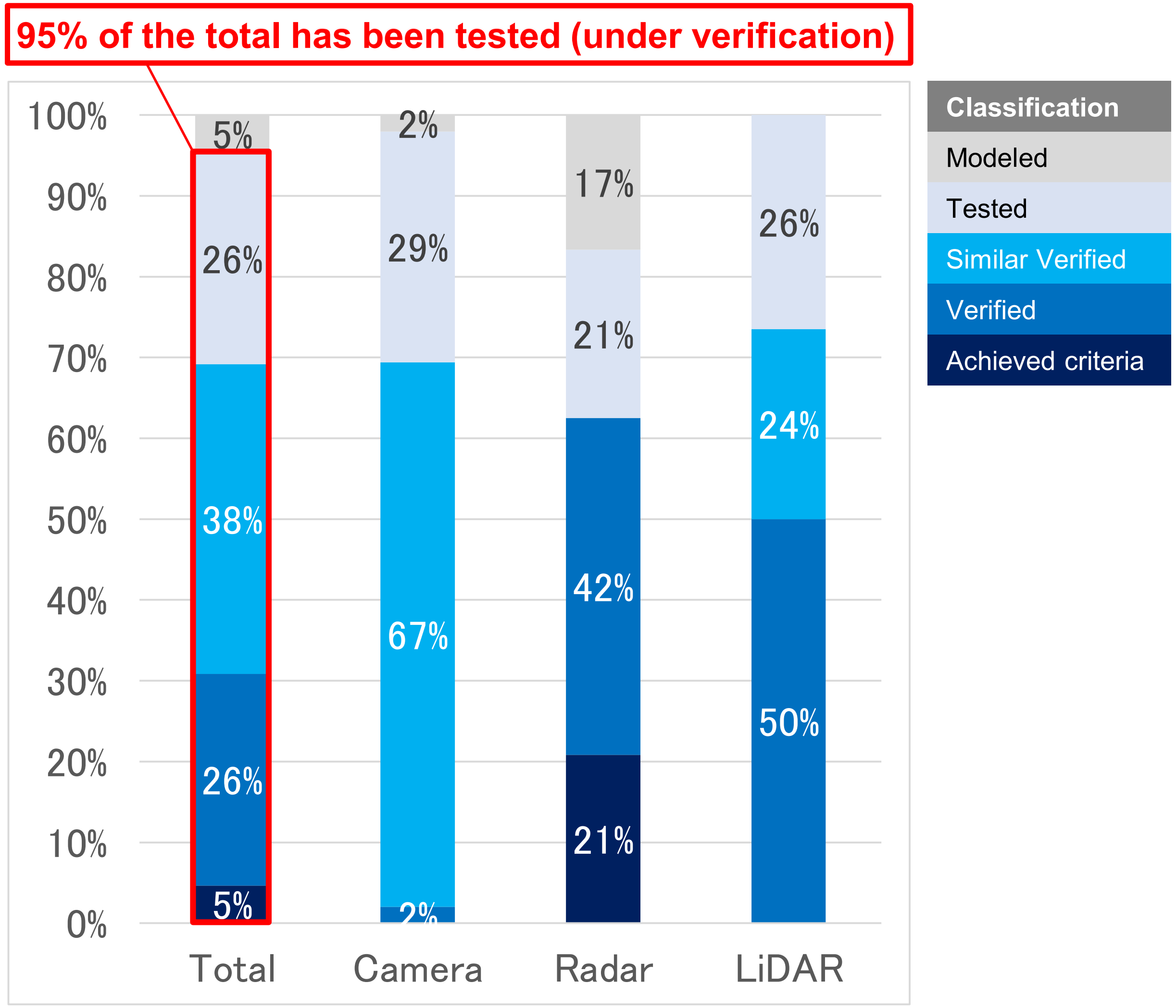
Source : FY2021 Year End Report of Safety Assurance Joint Promotion Steering Committee

DIVP

95% of Sim Environment Validation Status completed the experiment, Verification also progresses to about 70%(Including similar verification).Discussions on verification methods and standards, and arrangement of verification results will be continued next year.

Sim Environment Validation Status (DIVP®)

Verification status	Number of verification items			
	Camera	RaDAR	LiDAR	Total
Modeled, but not similar verification	1	4	0	5
Tested, but verification is incomplete	14	5	9	28
Similar verified	33	0	8	41
Similar verified & not Achieved criteria	1	10	17	28
Similar verified & Achieved criteria	0	5	0	5
Total	49	24	34	107

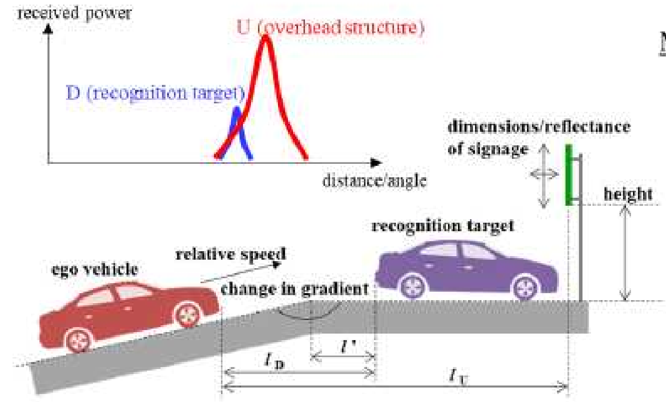


Started scrutinizing the contents of methods and criteria considering measurement in the real environment, regarding the reproducibility verification of recognition malfunction and scheduled to continue next year

Cognitive dysfunction reproducibility verification method / judgment criteria content investigation

mmWave Radar (5-1)

■ Simulating Low D/U Due to Change of the Angle: Simulating the Disturbance Phenomenon – Buried Signals



Parameters		Parameter Range		Explanation
Causal factor	Change in the road gradient	Variable	0 to 10 % equivalent	Use a road which is concave down as a representative
Other than the causal factor	Initial distance to recognition target l_D	Fixed	Distance required to avoid collision	
	Distance to recognition target from the inflection point l'	Variable	0 to l_D	
	Lateral position of recognition target	Fixed	0°	Fixed on the same lane
	Initial distance to signage board l_U	Variable	$l_D - 5$ to $l_D + 5$ (m)	
	Lateral position of signage board	Variable	-3.5 to +3.5 (m)	assume the object within the neighboring lanes
	Height of signage board (to bottom edge)	Fixed	4.5m (above road) / 1.2m (roadside)	According the Traffic Sign Installation Standard
	Dimensions of the signage board	Fixed	2.7 × 3.5 (m)	Guidance signage on highways
	Reflectance of the signage board	Fixed	Measured value of the real board	
	Relative speed	Fixed	Max. speed within ODD	
	Type of the recognition target	Fixed	Passenger vehicle/Pedestrian	Representative traffic participant/low reflectance

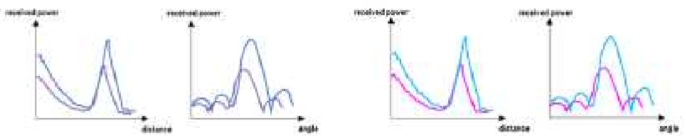
Method of Validation

- Simulate the scenario "Low D/U due to change of the angle":
  - ➤ Traveling a road with a change in gradient (concave down)
  - ➤ A metallic signage board ahead after the inflection point
  - ➤ The ego vehicle is to approach the stationary vehicle stopped nearby the signage board ahead.
- Change in gradient： 2 points between 3 and 10 (°)
- l' ： 5 (m) fixed
- l_D initial value： 15 (m)
- l_U initial value： 20 (m)
- Type of the recognition target：a passenger vehicle

Judgment Criteria

The phenomenon, whereby the signal from the recognition target becomes buried in the signal from the signage board, occurs in the same way in both the actual and the simulated environments.

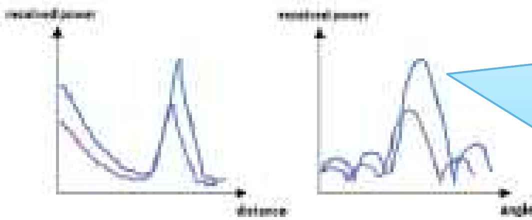
Actual Environment | Simulated Environment



■ Concerns/questions on DIVP®

Cannot obtain output by dispersion the reflection intensity for each target

Actual Environment



Occurring Sensor malfunction＝Spatial resolution is insufficient and cannot be separated

- Measure 1: Use high-resolution measuring instruments instead of automotive sensors

→ Issue：Continuous analysis is not possible such as moving

- Measure 2: Compare 3 pattern data, Vehicle only, sign only and both

→ Issue ：Expansion of test/analysis workload

Test site

→ Issue：no test site can provide a known and stable gradient

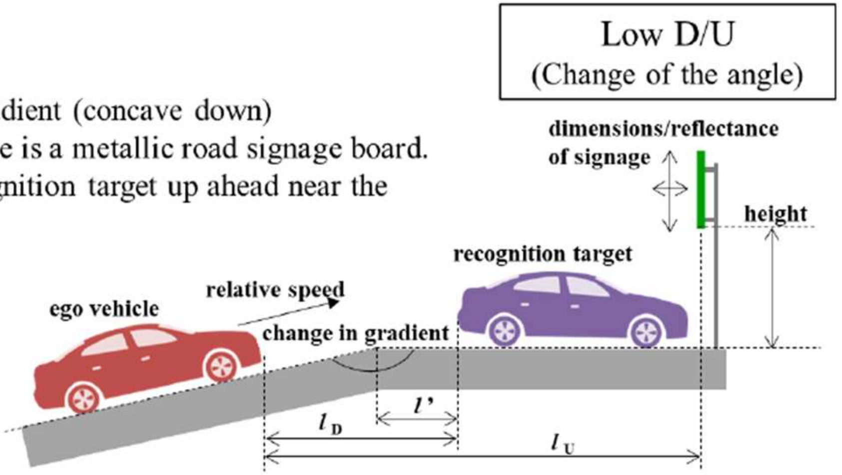
For JAMA's recognition failure scenario, build some scenarios and Sim environment in cooperation with SAKURA and DIVP®

Recognition failure scenario by SAKURA cooperation・Sim environment construction

E.2.3.2.3. Evaluation Scenario

- Traveling a road with a change in gradient (concave down)
- Ahead of the change in gradient, there is a metallic road signage board.
- The ego vehicle approaches the recognition target up ahead near the signage board in its path.

※The situation with a gradient change (concave down) is selected as the representative scenario because of the higher probability of large reflective intensity from a metallic overhead structure than the road surface.



Parameters		Parameter Range		Explanation
Causal factor	Change in the road gradient	Variable	0 to 18 % equivalent	Use a road which is concave down as a representative
Other than the causal factor	Initial distance to recognition target l_D	Fixed	Distance required to avoid collision	
	Distance to recognition target from the inflection point l'	Variable	0 to l_D	
	Lateral position of recognition target	Fixed	0°	Fixed on the same lane
	Initial distance to signage board l_U	Variable	$l_D - 5$ to $l_D + 5$ (m)	
	Lateral position of signage board	Variable	-3.5 to +3.5 (m)	assume the object within the neighboring lanes
	Height of signage board (to bottom edge)	Fixed	4.5m (above road) /1.5m (roadside)	According the Traffic Sign Installation Standard
	Dimensions of the signage board	Fixed	2.7 × 3.5 (m)	Guidance signage on highways
	Reflectance of the signage board	Fixed	Measured value of the real board	
	Relative speed	Fixed	Max. speed within ODD	
	Type of the recognition target	Fixed	Passenger vehicle/Pedestrian	Representative traffic participant/low reflectance

For the scenario specifications of the JAMA priority principle (mmWave Radar - Low D/U due to azimuth change), SAKURA defines two patterns of scenarios, creates assets with DIVP®, and combines them as a Sim environment.

RADAR-AZIMUTH-LOW-DU-0000001.xosc RADAR-AZIMUTH-LOW-DU-0000001.xodr	RADAR-AZIMUTH-LOW-DU-0000002.xosc RADAR-AZIMUTH-LOW-DU-0000002.xodr
18% Longitudinal curve at design velocity 60km/h	←
100m	←
1m	←
Fixed in the same lane	←
100m(vehicle-distance l_D (100m) + 0m)	105m(vehicle-distance l_D (100m) + 5m)
0m	←
4.5m	←
Fixed(width:2.7, height:3.5, length:0.5)	←
divp_Tgt_Guide_110A_Yokohama IC4_EXIT1km	←
60km/h(ego-vehicle: 60km/h, object: 0km/h)	←
divp_Veh_ToyotaAlphard	←

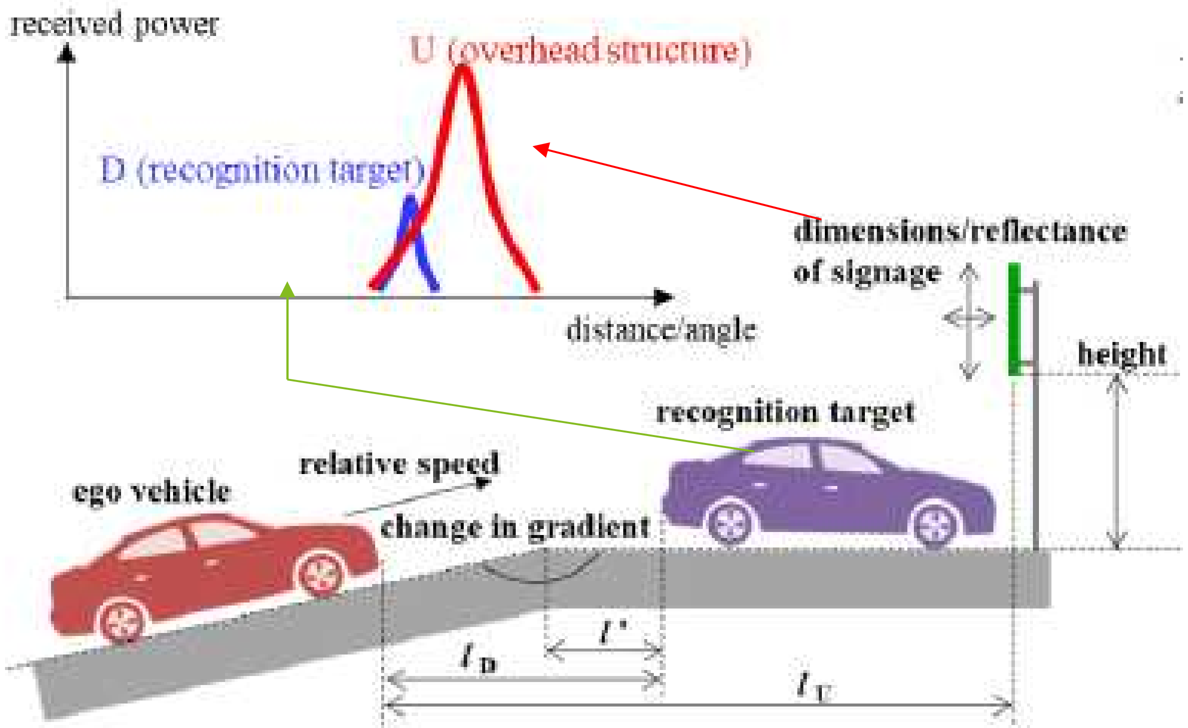
Source : FY2021 Year End Report of Safety Assurance Joint Promotion Steering Committee

Even though the recognition failure scenario is evaluated in the Sim environment, "No recognition failure occurs”. In order to carry out an efficient recognition evaluation, Consider sensor FOV, etc. and angular resolution, etc and Required the ability to design parameters that are boundary conditions.

Issues for reproducing cognitive dysfunction in Sim environment

■Cognitive malfunction verification content

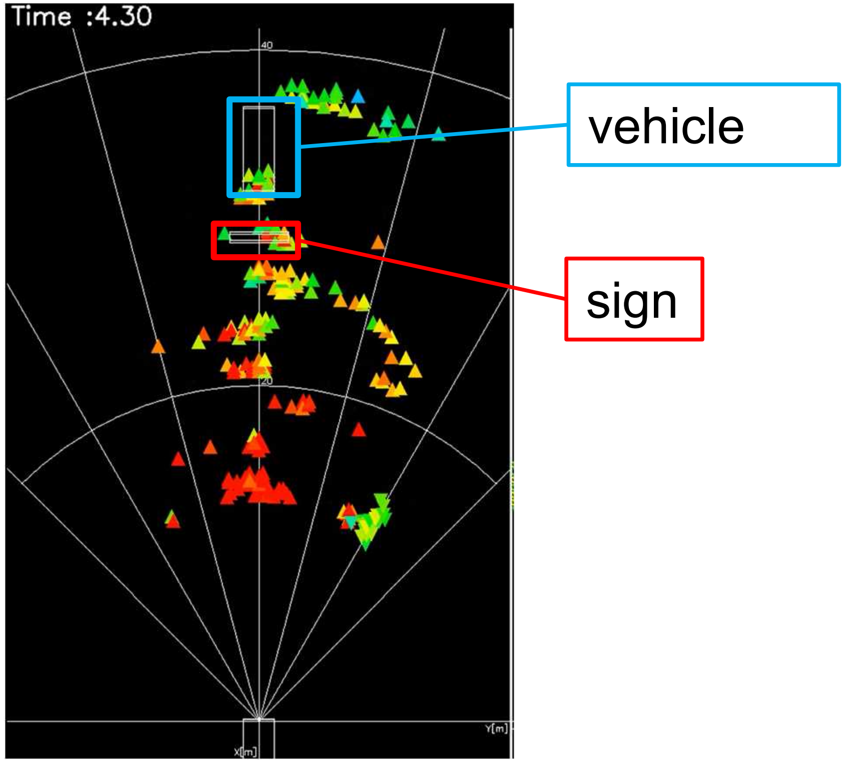
Due to the High reflection of the sign, the recognition target is buried in the signal and falls into an unrecognized state.



■Sim verification result

Both signs and cars can be recognized (can separated)

➡ Parameter design is required to reproduce the phenomenon



Source : FY2021 Year End Report of Safety Assurance Joint Promotion Steering Committee

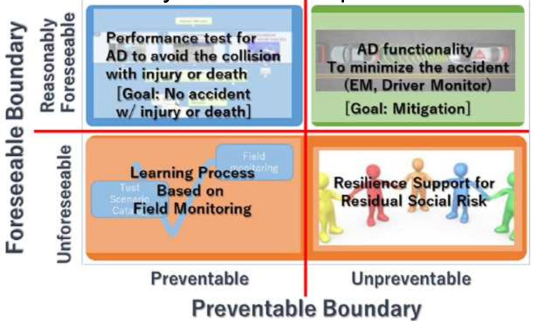
Awareness evaluation scenario/Sim environment is not sufficiently standardized internationally, it is difficult to carry out activities with the same scheme as traffic disturbances, and considering the type of Sim, conducted discussions with JAMA / JARI (SAKURA) to redefine the activity policy for FY2012

Joint TF for Safety Assurance

Background / purpose

Automated driving safety principles （WP29）

No reasonably foreseeable preventable accidents.



Safety Evaluation F/W（JAMA）

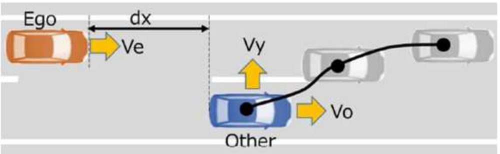
Structured factors that affect each processing process of autonomous driving as a scenario system (makes it possible to specify a finite and range).

Task	Processing results	Disturbance
Perception	Own position, surrounding traffic environment positional information and other traffic information	Perception disturbance
Judgement	Path, speed plan instructions	Traffic disturbance
Operation	Movement instruction allocation for each ACT for achieving path and speed plan instructions	Vehicle control disturbance

Scenario structures

Traffic disturbance scenarios

NCAP, ALKS, etc. （also carry out parameter generation based on actual traffic data by SAKURA ）.

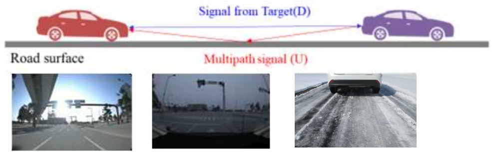


Perception failure scenarios

Evaluate the impact on safety in which factors are added to the traffic disturbance scenario.

・***Geometry factor***

・***Physical characteristics factors (eg spatial propagation / weather***



*Vehicle motion disturbance scenario is omitted.

Sim environment

True value Sim

Simulate speed, position, distance, etc. **Verification of collision avoidance performance.**

[1] Simulate ego vehicle・target position and velocity etc. from "Scenario information".

Considered as an extension of traffic disturbance.

[2] Simulation based on the recognition result considering "Sensor FoV".

Physics Sim

Reproduce the input / output of sensor perception from the external environment, reflection characteristics, etc. **Verify recognition performance.**

[3] Simulate Physical characteristics (reflection characteristics, spatial propagation) and reproduces the input and output of sensor perception.

Issues / discussion content

Scenario

・Necessary to consider from the scenario definition method.

・Considering the type of Sim environment, we will discuss separately including the purpose of evaluation.

➡ Started discussions with JAMA about scenario classification.

Sim environment

・ [1] can be handled to some extent with DIVP®

・ Regarding [2], there are some functions that DIVP® cannot handle (even if the shielding rate is passed as a scenario, there is no function to reflect it as the position of each object).

➡ Started discussions including scenario definition and Sim environment function sharing on SAKURA.

Consistency verification

・The verification method / judgment criteria for perception failure reproducibility evaluation are difficult to measure in an actual vehicle.

➡ Agreed with JAMA to incorporate the opinions of DIVP® and proceed with scrutiny.

Others (Verification purpose / judgment criteria)

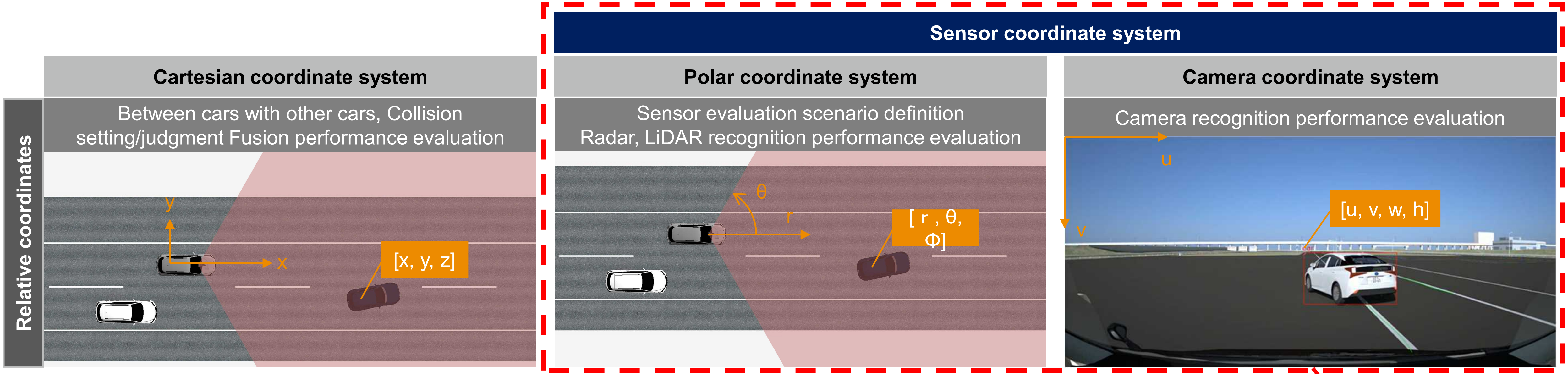
・Require to quantitatively define safety margin without Collision avoidance performance(start discussion with SAKURA).

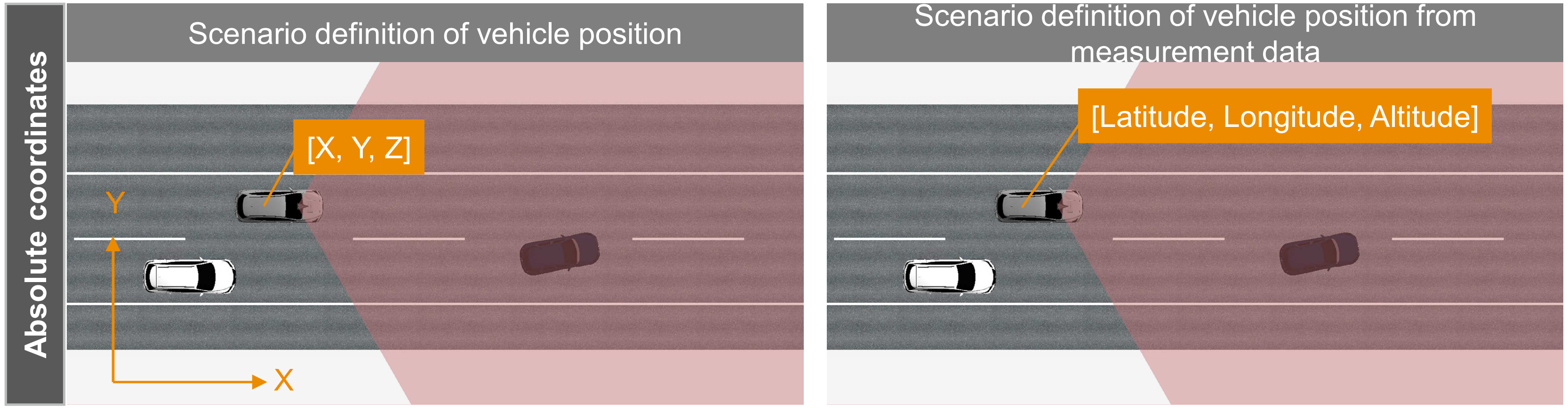
・Activities to quantitatively define recognition performance are required (continued with DIVP®).

Source : FY2021 Year End Report of Safety Assurance Joint Promotion Steering Committee

Necessary to discuss the treatment of "coordinate system of sensor viewpoint" in order to proceed with the scenario definition of recognition evaluation in scenario tool and the Sim environment.

Coordinate system classification and expected use

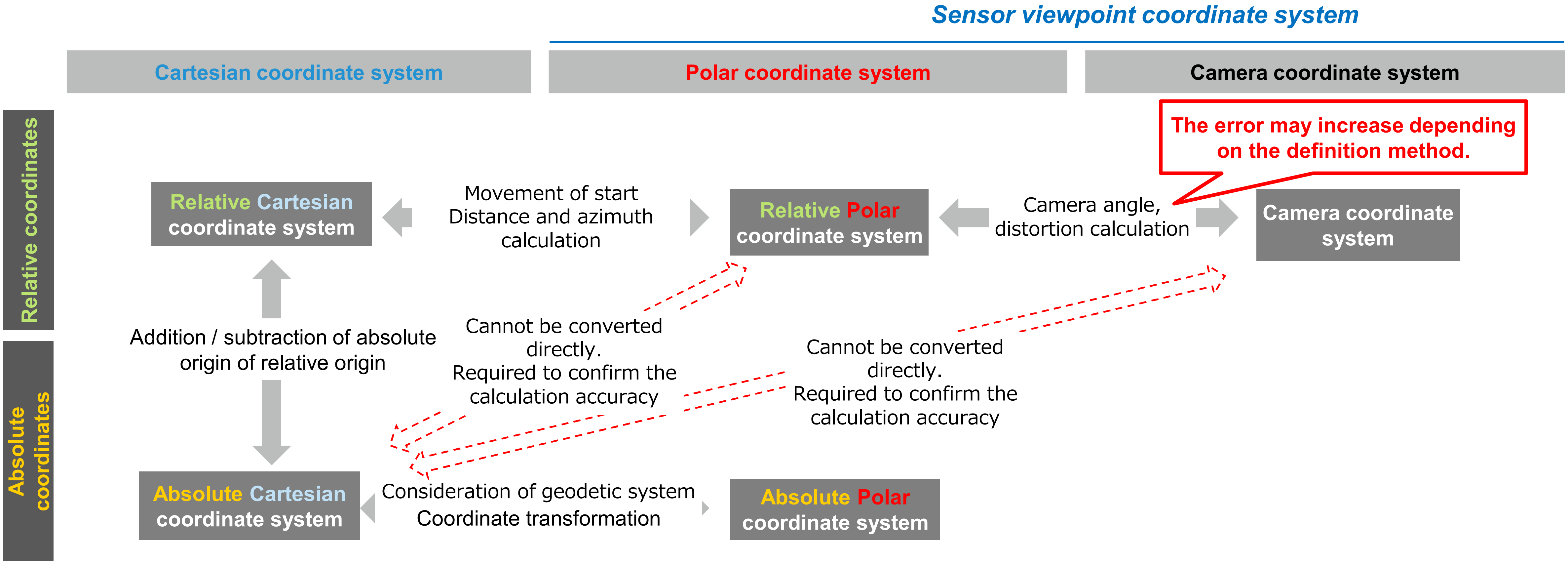




- In order to perform recognition evaluation, it is necessary to be able to do input / output in the coordinate system of the above sensor viewpoint in both scenario definition / Sim.
- On the other hand, the DIVP® scenario tool (SDMG) has not yet been able to support scenario definition based on the coordinate system.
- **JAMA perception failure scenario issues example**
  Even if the target shielding rate in the camera output is input as a scenario, it cannot be reflected in the position on the target object in Sim.

Necessary to discuss the treatment of "coordinate system of sensor viewpoint" in order to proceed with the scenario definition of recognition evaluation in scenario tool and the Sim environment. The measurement/ calculation error may increase in the case of a lens model equivalent to the actual machine.

Coordinate transformation



Position coordinate conversion is relatively easy, carefully when converting the coordinates of posture (rotation) （error prone. eg, Relative-absolute coordinate system, Euler angles - Quaternion - Direction vector + Amount of rotation, Rotation order, ad-degree）

Build a more efficient and highly applicable Sim environment and promote expansion of provided value in AD safety evaluation(reflected in the FY22 study plan) by supporting the scenario definition and Sim output including the "coordinate system of the sensor viewpoint"

Things to consider for AD safety assessment

Scenario system

AD safety evaluation metrics

AD Safety evaluation
・ Collision avoidance performance, etc.

Jointly promote risk assessment research on accidents, safety margins, etc. together with JAMA / JARI (SAKURA) / AD-URBAN

Scenario definition
・OpenSCENARIO
Dynamic content: vehicles, pedestrians, weather, etc.
・OpenDRIVE
Static content: roads, signs traffic lights, etc.

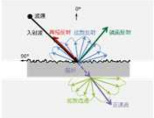
True value Sim (geometry calculation: new study)

For traffic scenarios and recognition scenarios (geometry factors), it can be expected to contribute to efficient AD safety evaluation by supporting scenario definition and Sim output including the coordinate system of the sensor viewpoint.

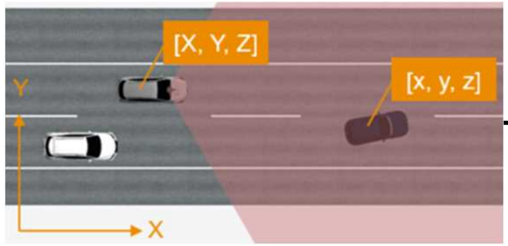
SDM-G
・Scenario editing
・3D data (map)

・3D data (vehicles/object)

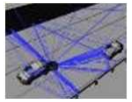
・Reflection data



Physical Sim (conventional DIVP®)
Input ego vehicle・target position, velocity, and acceleration, and physical calculation is performed using 3D data and the reflection characteristic data.

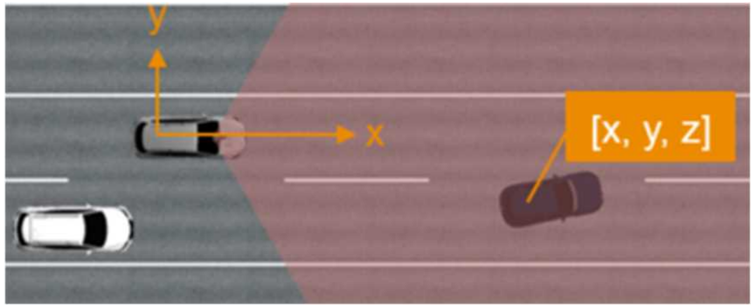


Spatial drawing



Sensor (perception)

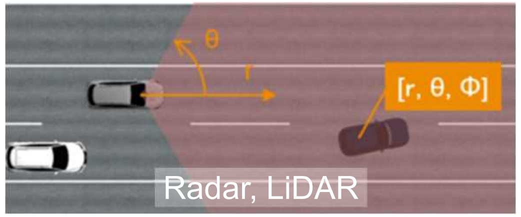
Fusion



Vehicle control

AD control

Sensor (recognition)



DIVP®-Sim-P/F

Source : FY2021 Year End Report of Safety Assurance Joint Promotion Steering Committee

Reflected in the FY2022 activities from considering about the FY2021 issues, build a new team for international cooperation promotion.

FY2021 Team structure

Scenario definition and implementation

JAMA Safety Evaluation Framework
- Traffic disturbance
- Perception disturbance
- Vehicle control disturbance

Verification guidelines for sim environment validity

SAKURA Running/Measurement data

Functional Scenario → Logical Scenario → Concrete Scenario

Simulation environment construction

DIVP

External environment model → Space design model → Sensor model

Simulation PF

・3D Data (Vehicle/Target)
・Reflection characteristic data

Automated driving system validation

AD-URBAN

- Recognition of the surrounding environment
- Path planning
- Localization
- Path tracking
- Vehicle control

・High-precision map data

Actual AD system vehicle

1 Scenario I/F Study

2 Sim. I/F Study

3 Sim. Validity Study

FY2022 Activities

＜Team1＞ SAKURA DIVP
- Expantion of the scenario structure
- Definition of the geometory scenario parameter

＜Team3＞ JAMA DIVP
- Improvement of the simulator and scenario tools
- Definition of the perception scenario priority

＜Team2＞ DIVP AD-URBAN
- Investigation of the requirement for simulation environment
- Investigation of the metrics for perception limits

＜Team0＞ ※NEW
- International cooperation promotion
- Investigation of the metrics for safety assurance

JAMA SAKURA DIVP AD-URBAN

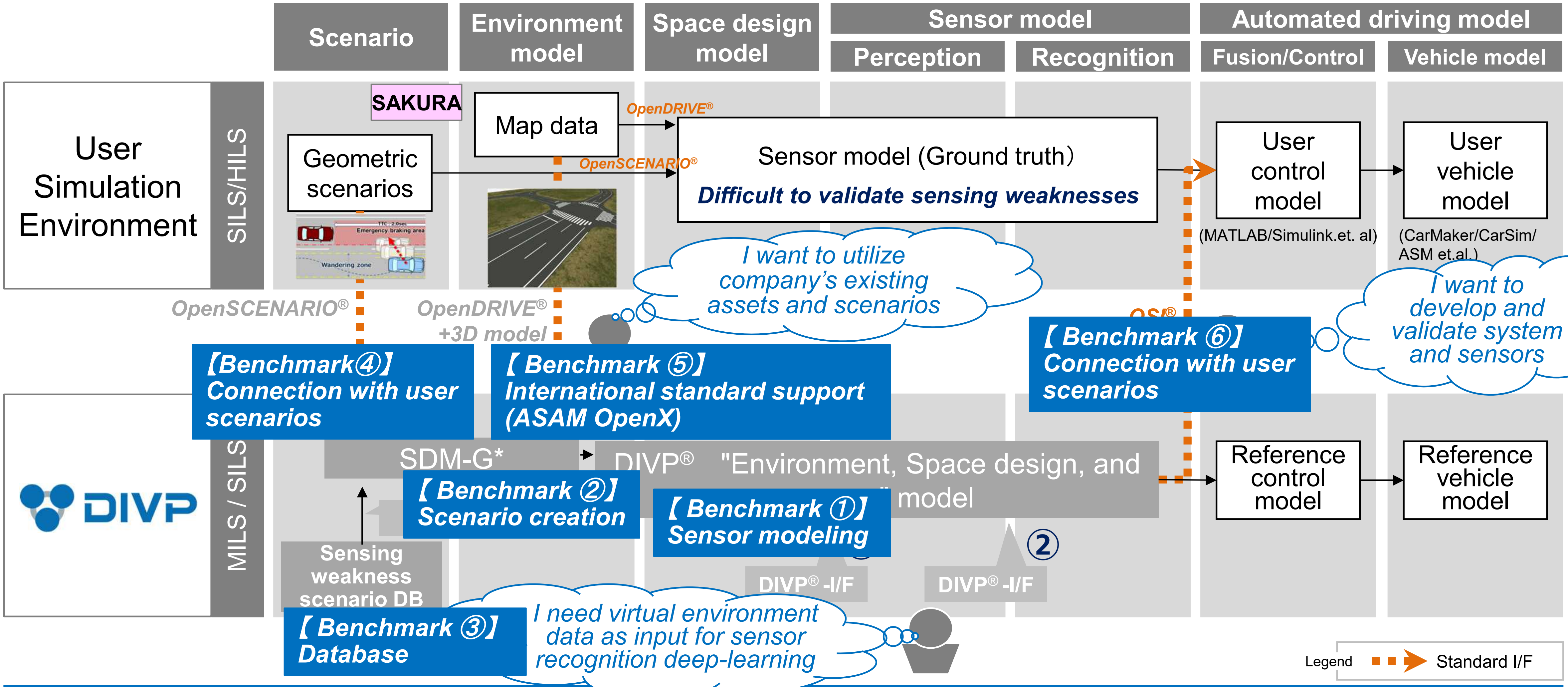
Source : FY2021 Year End Report of Safety Assurance Joint Promotion Steering Committee

Project overview

- Review of safety assurance basis
- Objective Competitive Assessment of DIVP®
- Future plans
- Provision of business based on research results

Further to defining "reflective physical characteristics-sensor model", representing DIVP® strength, benchmarks are set for *"Connectivity"/"Database" /"international standardization"*

Contents of benchmark validation



* SDM-G : Space Design Model Generator

【 Benchmark result ①：Sensor mode】
Benchmark result of Camera simulation

Classification	Phenomena	CarMaker 10.1	VRX 2021R2	PreScan 2021.2	DIVP®	
Source	General light source (vehicle lamp, etc.)	〇	〇	〇	◎	
Source	Radiance of solar	〇	〇	〇	◎	①
Source	Radiance of sky	×	×	△	◎	
Source	Indirect light	〇	〇	〇	◎	
Optics	*Reflection, diffusion, transmission on the object surface*	△	〇	△	◎	②
Optics	Aging of the object surface	×	×	〇	◎(asphalt)	
Optics	Fouling（Target）	×	×	△	×	
Propagation	*Scattering(Participating medium)*	〇	×	〇	〇(fog)	
Sensor	*Effect of vehicle dynamics*	〇	△	△	〇	
Sensor	Effect of temperature characteristic	×	〇	×	×	
Sensor	Aging of the sensor	×	×	×	×	
Sensor	Lens distortion	〇	〇	〇	〇	
Sensor	Lens flare	〇	×	〇	〇	
Sensor	Ghost	×	×	×	×	
Sensor	Fouling (Fr Glass)	△	×	△	〇（raindrop)	③

◎: supported（with actual verification）
〇: supported（with no verification）
△: partially supported
×: unsupported
※:investigating

Items that shows the superiority of DIVP®

① Only DIVP® is to verify the actual machine.
② CarMaker: only supports reflection and transmission, Prescan: only supports reflection
VRX: only supports radiance of sky.
③ Only DIVP® responds to the effects of sensor deposits

【 Benchmark result ① : Sensor modeling】
Benchmark result of Radar simulation

Classification	Phenomena	CarMaker 10.1	VRX 2021R2	PreScan 2021.2	DIVP®
Source	*Other vehicle radar (interference)*	×	×	×	×
Optics	Reflection, diffusion transmission on the object surface	△	△	△	◎
Optics	Aging of the object surface	×	×	×	○(asphalt)
Optics	Fouling	△	×	×	○(raindrop)
Optics	Phase/polarization change during reflection	○	○	○	◎
Optics	Diffraction	×	×	×	×
Propagation	Multi reflection/transmission	△	△	△	◎
Propagation	Scattering(attenuation), interference in space	○	×	○	◎
Propagation	Doppler	○	○	○	◎
Propagation	Micro-Doppler	○	○	○	◎
Sensor	Radio source (reproduction of modulation method)	△	○	○	◎
Sensor	*Effect of vehicle dynamics*	○	△	△	○
Sensor	Effect of temperature characteristic	○	×	○	×
Sensor	Aging of the sensor	×	×	×	×
Sensor	Fouling	×	×	×	×
Sensor	Internal reflection	×	×	×	×

② ③ ④ ①

◎: supported（with actual verification）
○: supported（with no verification）
△: partially supported
×: unsupported
※:investigating

Items that shows the superiority of DIVP®

① Only DIVP® is to verify the actual machine.
② Only DIVP® supports reflection, scattering and transmission
③ Only DIVP® responds to the effects of extraneous matter and phase / polarization changes during reflection
④ Only DIVP® supports transmission

【 Benchmark result ① : Sensor modeling】
Benchmark result of LiDAR simulation

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Classification	Phenomena	CarMaker 10.1	VRX 2021R2	PreScan 2021.2	DIVP®
Source	Other vehicle light source(interferences)	×	×	×	×
Source	Other source(halogen lamp)	×	×	×	◎
Source	*Radiance of solar*	×	×	×	◎
Source	*Radiance of sky*	×	×	×	◎
Optics	*Reflection, diffusion, transmission on the object surface*	△	△	○	◎
Optics	*Aging of the object surface*	×	×	×	◎(asphalt)
Optics	*Fouling*	△	×	×	◎(raindrop)
Propagation	*Multi reflection/transmission*	○	○	○	◎
Propagation	*The cross sectional area of a laser beam*	○	○	○	◎
Propagation	Scattering in space(attenuation)	○	○	○	◎
Sensor	*Own light source*	×	○	○	◎
Sensor	*Scanning*	×	○	○	◎
Sensor	*Effect of vehicle dynamics*	○	△	△	○
Sensor	Effect of temperature characteristic	×	×	×	×
Sensor	Aging of the sensor	×	×	×	×
Sensor	*Fouling*	×	×	×	◎(raindrop)

①
②
③

◎: supported（with actual verification）
○: supported（with no verification）
△: partially supported
×: unsupported
※:investigating

Items that shows the superiority of DIVP®

① Only DIVP® is to verify the actual machine.

② Only DIVP® supports the radiance of sunlight, radiance of sky light, reflection / scattering / transmission on the object surface, influence of deterioration, attached matter, multiple reflection / transmission

③ Only DIVP® responds to the effects of sensor deposits

DIVP

[Benchmark results①: Summary of sensor models]
DIVP® Modeling for Consistency Validation based on experimental measurements only

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1. Sensor Model (Evaluability of sensing weaknesses, Sim performance per sensor)

	IPG CarMaker (10.1)	ANSYS VRX (2021R2)	Siemens PreScan (2021.2)	DIVP®	DIVP® Features
Camera	○	○	○	◎	① Consistency verification based on experimental measurements ② Reproduce the reflection characteristics based on the sensor principle (CarMaker: reflective, transmissive; Prescan: reflective only) ③ Responding to the effects of sensor deposits
Radar	○	△	○	◎	① Consistency verification based on experimental measurements ② Reflect, scatter, and transmit ③ Corresponds to the effects of deposits and changes in phase and polarization during reflection ④ Support Transparency
LiDAR	△	△	○	◎	① Consistency verification based on experimental measurements ② Corresponds to the radiance of sunlight, radiance of sky light, reflection, scattering, transmission on the surface of objects, effects of degradation, and deposits ③ Responding to the effects of sensor deposits
Total	○	△	○	◎	-

DIVP

[Benchmark results②: Summary of scenario generator]
Confirmed that the UI is easy to use, and scenario creation is as efficient as the competition.

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2. Scenario Generator (Ease of handling UI, scenario generator function)

	IPG CarMaker (10.1)	ANSYS VRX (2021R2)	Siemens PreScan (2021.2)	DIVP®
■ screen configuration (Easy-to-understand settings and ease of use)	△ Setting of running track and running speed is different window.	〇 Collapse settings into one window	〇 Collapse Settings into One window	〇 Collapse settings into one window
■ Ease of creating scenarios (Validation based on the time required to create a new NCAP pedestrian jumping scenario)	〇 30 minutes to 1 hour	× 1 ~ 2 hours Map creation is heavy DS and AP have different axes	〇 30 minutes to 1 hour	〇 30 minutes to 1 hour
■ scenario reusability (Partitioning of settings/parameters, etc.: external file storage, etc.)	〇 Map Vehicle setting Sensor Individual Parameters	〇 Map Sensor Individual Parameters	〇 Map Sensor Individual Parameters	〇 Map Running track Vehicle setting
Total	△	△	〇	〇

DIVP

[Benchmark results③: Summary of database]
Underperformed by competitors in terms of asset count

3. Database (Enrichment of driving environment database and assets)

Layer	Asset item	IPG CarMaker (10.1)	ANSYS VRX (2021R2)	Siemens PreScan (2021.2)	DIVP®
1	■ Map	31	12	0	12
2	■ Road sign	Eight countries	Six countries	Four countries	One country
	(Signal)	16	1	36	1
3	■ Stationary target (Buildings, etc.)	583(*1)	76	117	13
4	■ Moving target (Cars, pedestrians, etc.)	536(*2)	63	83	17
5	■ Weather	3 (Clear, cloudy, rainy)	1 (Clear)	2 (Clear, rain.)	3 (Clear, cloudy, rainy)

Total	IPG CarMaker	ANSYS VRX	Siemens PreScan	DIVP®
Total	◎	○	○	△

*1: Buildings (Large, Medium, Small), different colors, poles/bus stops/garbage bags/cardboard boxes and other small items
*2: Multiple vehicle manufacturers (including different colors): approximately 400, pedestrians (Adults, Children, Clothes)

[Benchmark results④: Connectivity summary] Confirmed superiority of connecting to general scenario/sensing weakness scenario DB, also looking to promote differentiation.

4. Connection (Connection with general scenarios (Geometry, traffic flow, etc.), and connection with reflectance property definition data/sensor models)

	IPG CarMaker (10.1)	ANASYS VRX (2021R2)	Siemens Prescan (2021.2)	DIVP® FY20	DIVP® FY21	DIVP® FY22
■ Connecting to General Scenarios (Geometry, traffic flow, etc.)	○	—	△	×	△	○
■ Connection to physical property data file	×	△	×	○	○	○
■ Connection to the sensing weakness scenario DB	×	×	×	—	△ Start of DB construction	○
Total	△	△	△	×	△	○

[Benchmark Results⑤: Summary of International Standardization] Gradually promoting OpenX compliance, including competition. DIVP® to accelerate response by working withSAKURA

5. Standardization of association (response to international standards, etc.)

	IPG CarMaker (10.1)	ANASYS VRX (2021R2)	Siemens Prescan (2021.2)	DIVP®		
				FY20	FY21	FY22
■ Open SCENARIO (Logical Scenario)	○	—	○	×	△	○
■ Open DRIVE (Road Networks)	○	○	○	○	○	○
■ Open CRG (Road Slope)	○	○	×	×	×	○
■ 3D models	OBJ DAE KNZ	FBX OBJ DAE 3DS DXF	DAE IVE OSG OSGB OSGT	FBX	FBX	FBX
Total	○	○	△	×	△	○

[Benchmark results⑥: Summary of commercialization] Enhanced connection with user models by supporting MATLAB/Simulink, FMI/FMU, etc. The true value to be strengthened

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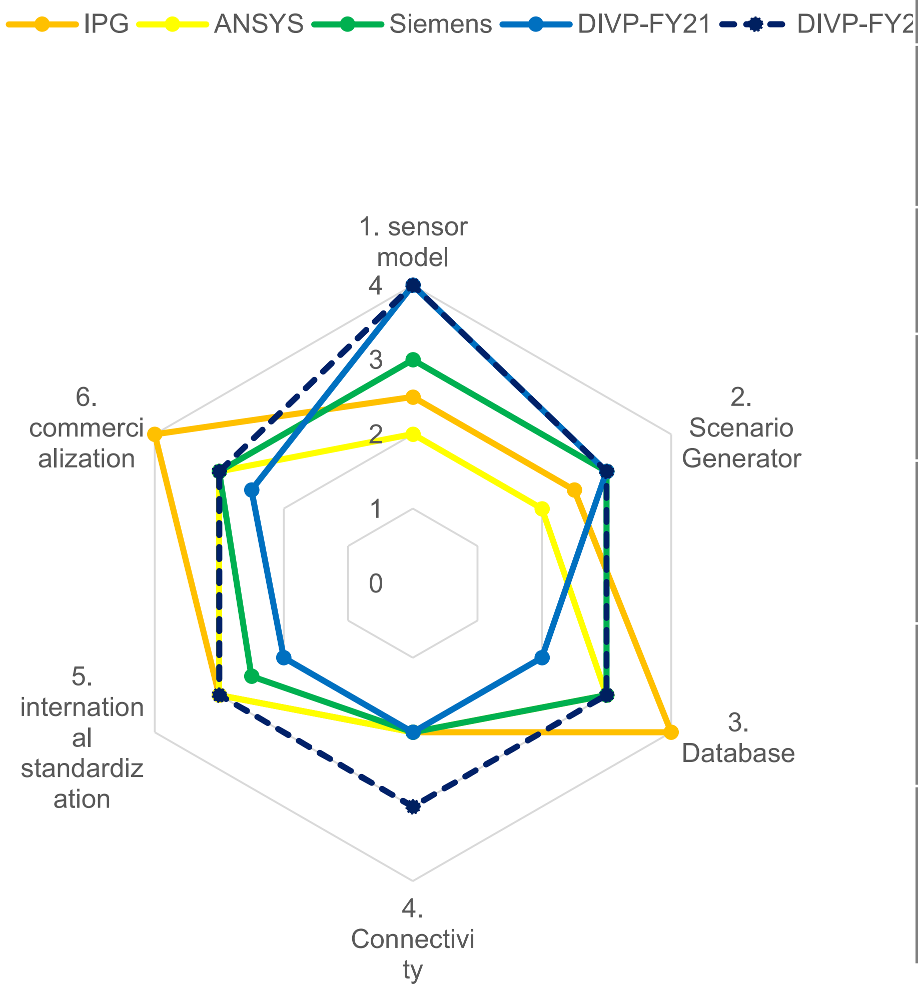
6. Commercialization (responding to various user use cases)

	IPG CarMaker (10.1)	ANASYS VRX (2021R2)	Siemens Prescan (2021.2)	DIVP®		
				FY20	FY21	FY22
■ true value output (Geometry)	○	―	△	×	△	○
■ FMI/FMU (User Model Connection)	○	○	○	×	○	○
■ MATLAB/Simulink (User Development Environment)	○ From 2018a 2020b	○	○ From 2015b 2019b	×	○	○
■ HILS	○	△	○	△	△	△
Total	◎	○	○	×	△	○

DIVP

While superior in terms of precision sensor models, database, connectivity, international standardization, DIVP® commercialization was inferior to long-established European tools.

Summary of Benchmark Results



	Current status	Next step
1. sensor model	■ Consistency with the actual environment has been verified based on experimental measurements.	■ Aiming to systematize safety assurance based on sensor validation performance
2. Scenario Gen	■ Ease of handling UI and efficiency of scenario creation are the same as the competition	■ Improve usability based on customer needs
3. Database	■ Assume that the number of assets and the general scenario database are inferior to the competition	■ True value Sim. enhanced utilization of user scenario DB, enhanced asset continuation in connection
4. Connectivity	■ Connectivity issues with general scenarios (Geometry, traffic flow, etc.) have been addressed in compliance with the standard IF	■ Establish connectivity with the Sensing Weakness Scenario DB and promote further differentiation
5. international standardization	■ The progress of Japan and Germany VIVID, and the results of DIVP® are being reflected in ASAM OpenX (scenario)/OSI (sensor).	■ DIVP® will accelerate its response through collaboration with the SAKURA project.
6. commercialization	■ Lack of user experience due to lateness	■ Enhancements to the true value Sim. that the user currently needs (and enhancements to toolchain connectivity enhancements)

Project overview

- Review of safety assurance basis
- Objective Competitive Assessment of DIVP®
- **Future plans**
- Provision of business based on research results

The modeling elements necessary for general road Validation using virtual space are arranged and development isin progress

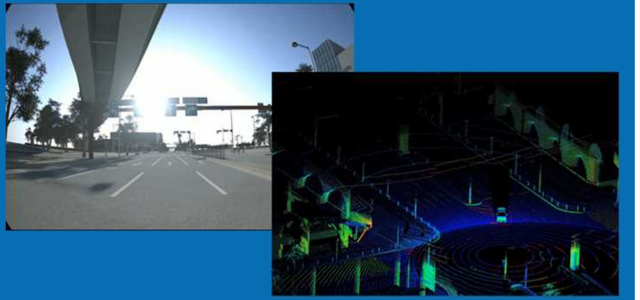
Extension to general road validation scenarios

三菱プレシジョン株式会社
MITSUBISHI PRECISION CO.,LTD.

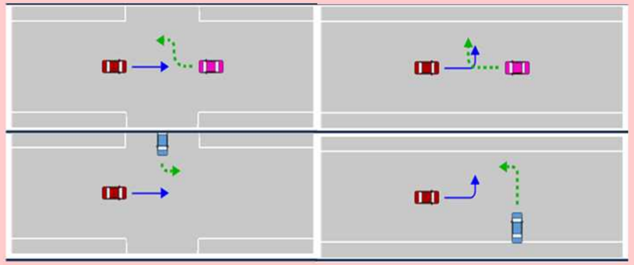
Scenario

- Sensor Validation
- Intersection
- Motorcycle sneak
- :

Odaiba Scenario Package



Behavioral model



Environmental model

Asset

- 3D geometry
- Reflection characteristic
- Light source characteristic

Pedestrian's belongings

Motorcycles and Special vehicles

Traffic lights and signs

Urban map

DIVP

24/32 of FY 2021 end assessment packages and 13/25 of Odaiba community packages were modeled. Update needed based on user needs and international cooperation

Scenario Package Construction

	FY2021				FY2022		
	April - June	July - September	October - December	January - March	April - June	July - September	October - December
Milestones	OEM/Sensor Maker Monitor Assessment			November: Coastal area demonstration experiment (Step 1/Step 2) November: SIP-adus work shop	April: Start of business		
Assessment package Safety verification scenario (NCAP/ALKS, etc.)	**Euro NCAP** **・Pedestrian (When going straight, there is a pedestrian crossing, a car shadow, day/night)** CPFA/CPNA /CPNC /CPLA **・Against a car (when going straight, there are other cars)** CCR	**ALKS** ・Cut-In ・Cut-Out	**Euro NCAP** **・Pedestrian (There was a pedestrian crossing when going backward)** CPRA **・Car (there is another car when switching lanes)** LSS - Road Edge test/Solid test/Oncoming vehicle Others	**Euro NCAP** **・Pedestrian (There is a pedestrian crossing when turning left and right)** CPTA **・Car (Oncoming car when turning left/right)** CCFtap **・Bicycle (When going straight, there is a pedestrian crossing, and the car shadow is seen.)** CBNA/CBFA	**Euro NCAP** **・Against a bicycle (There is a person who is proceeding in the same direction when going straight)** CBLA **・Bikes (Straight, turning right and left, switching lanes)** CMR/CMF/LSS – Oncoming vehicle and others	Continue to study the development of further scenario packages after FY 2023	
Odaiba community package Reflect sensing weakness scenario	**Camera** White Line Misrecognition by Street Tree Shadow/Reproduction of Light Distribution of Signal/Non-recognition of Blurred White Line **LiDAR** Recognition rate of black leather pedestrians/road surface with thermal barrier coating/mistaken recognition of sunlight and highly reflective objects **Millimeter-wave** Signal strength due to road surface fading/Misrecognition of road surface clutter/Separation of objects with the same distance		**Camera** ・Adtrak's mistaken identity ・Unawareness of low floor vehicles ・Tunnel (for general light sources) **Millimeter-wave** ・Tunnel Multipath ・upper structure	**Camera** ・Pedestrian overlooked by raindrops and wipers ・specular reflection **Millimeter-wave** ・Improvement of microDoppler recognition performance	**Camera** ・Misunderstanding due to water hoisting ・Motion Blur ・Signal (flicker) **LiDAR** ・Misunderstanding due to rainfall probability ・puddle ghost ・mistaken recognition due to water winding **Millimeter-wave** ・Decrease in recognition rate due to heavy rain	**Camera** ・Snow (details TBD) **LiDAR** ・Misunderstanding due to suspected snow hoisting ・Undetected frozen surface **Millimeter-wave** ・Undetected due to ice on emblem	

Scenario packages for reflection characteristics, light sources, and white lines are complete.Expanding to include rain, multi-path ghost testing, snowfall, and motion blur

Developed and planned environmental conditions

MITSUBISHI PRECISION CO., LTD.

Developed | **Experiment, modeling**

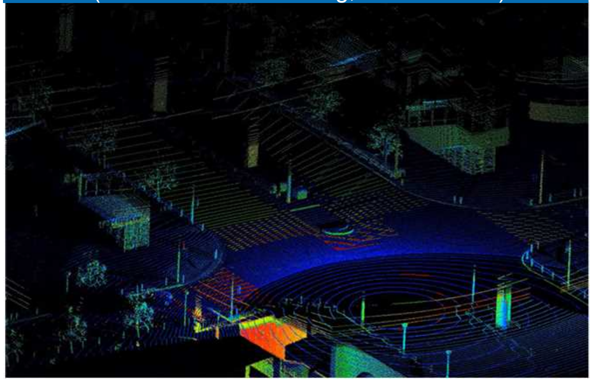
Backlight

A white line in the shade of a tree

Rainfall
(Raindrops, Spatial Damping/Scattering, Doubt)

Snowfall (+ snow)

Change in reflective properties
(Thermal barrier coating, black leather)



Night headlight

Multipath ghosts (tunnels, etc.)

Motion blur, flicke

Source : Kanagawa Institute of Technology

Model and verification of cars, pedestrians and traffic signs as basic models are complete. Expanding to special behaviors and shapes, ie. motorcycles, special vehicles and animals

Developed and planned assets

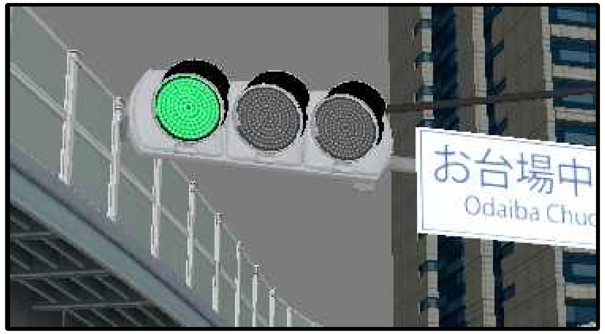
三菱プレシジョン株式会社
MITSUBISHI PRECISION CO.,LTD.

Developed

Experiment, modeling

Passenger vehicles (11 models)

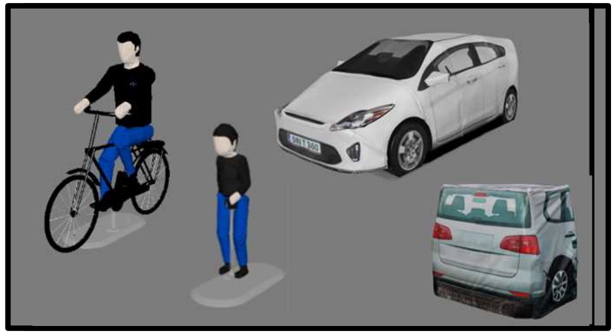
Traffic signal



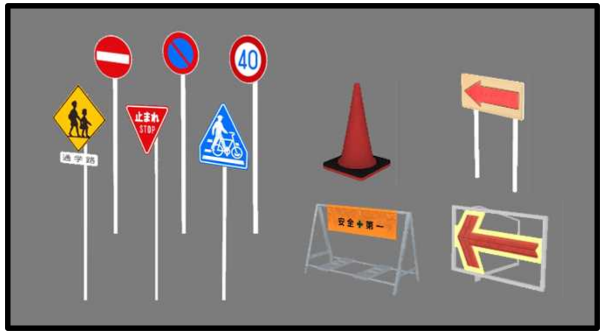
Pedestrians and their belongings

Motorcycles and special vehicles

NCAP dummies



Traffic signs and construction equipment



Large vehicles (including towing)

Animal

Source : MITSUBISHI PRECISION CO.,LTD.

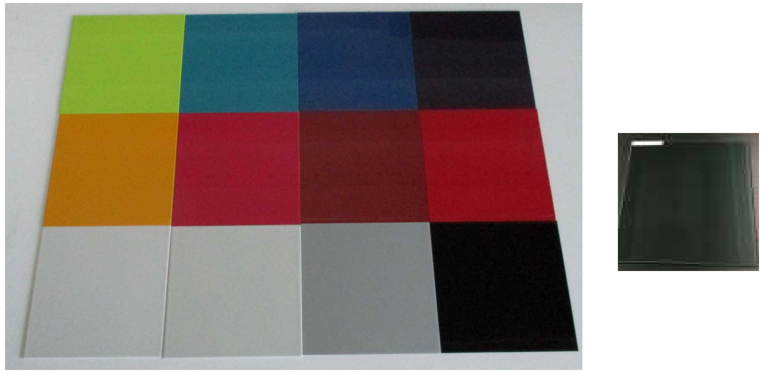
DIVP

Completed modeling of camera, LiDAR, and millimeter-wave reflectivity for basic materials. Modeling changes in reflectance characteristics associated with environmental conditions

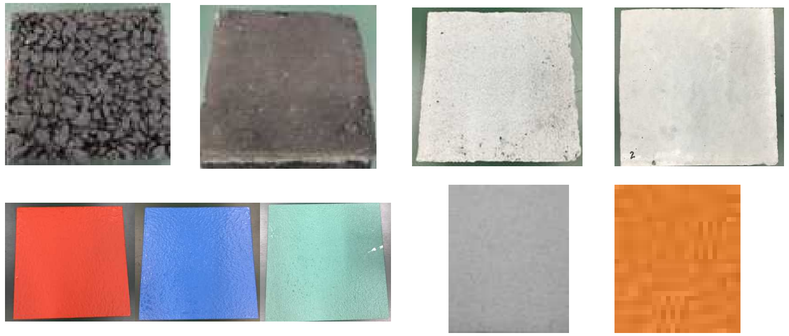
Developed/Planned Materials

Developed

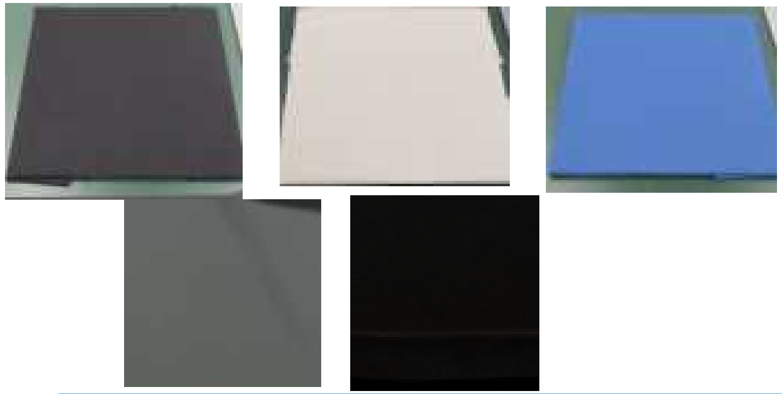
Vehicle paint, glass



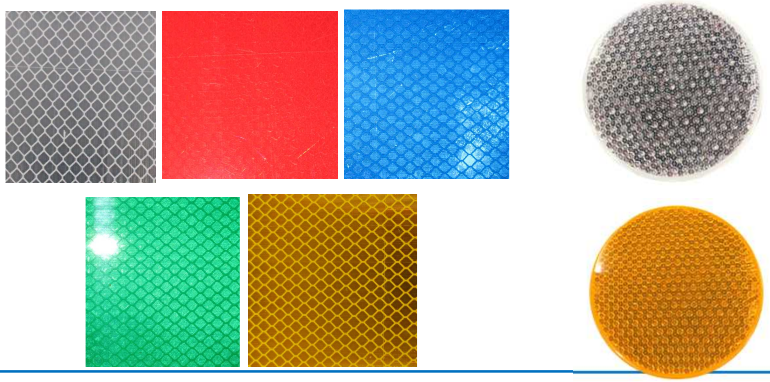
Road surface material (Asphalt, concrete, etc.)



NCAP dummies



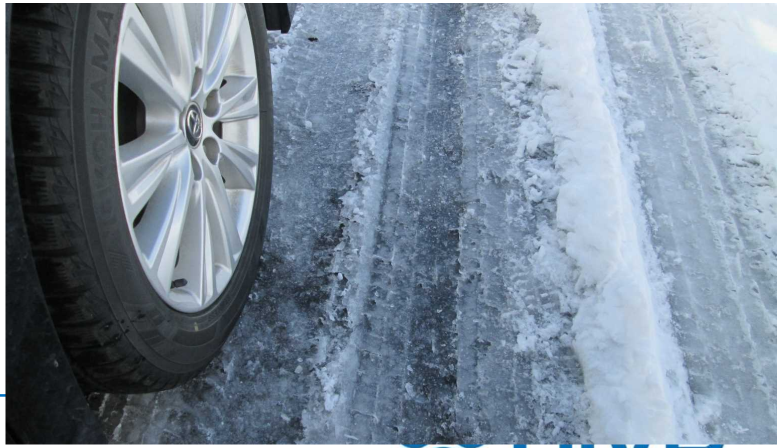
Road signs and eye markers



Modeling In Progress

Wet road surface

Snow, ice



Source: SOKEN, INC. Kanagawa Institute of Technology

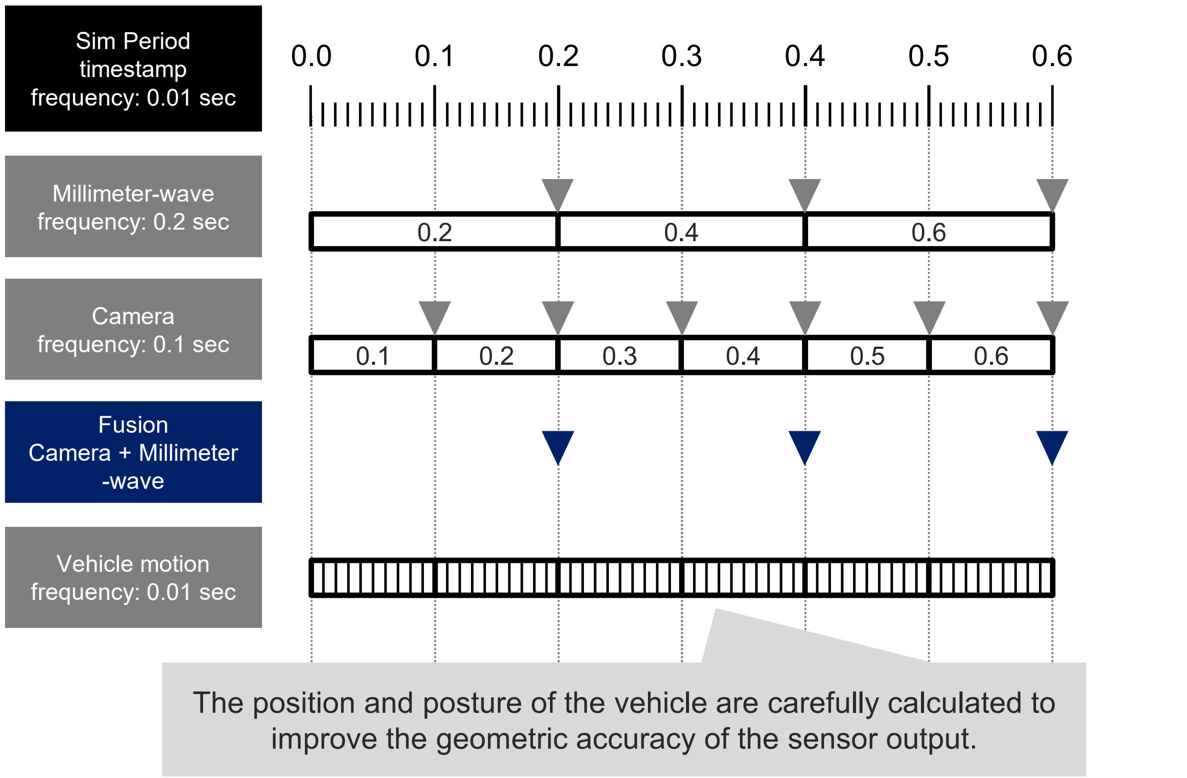
Issue identified in the calculation speed of the camera due to detailed physics simulation. Each sensor output bears time stamp corresponding to simulation time

Efforts to Improve Calculation Speed

Current status

Sensor	Key Specifications	Calculation speed Real time ratio
LiDAR 	・Method : 128 pivoting lanes ・Number of measuring points : 2.3 million points/second ・Frame rate: 10 Hz	x1 (real-time)
Millimeter - wave 	・Detection range : Horizontal ± 30 deg. ・Frame rate: 20 Hz	x2
Camera 	・Resolution :2896x1786 ・bit depth :24bit RGGB ・Frame rate: 10 Hz	x30~

Timestamp Synchronization (working image)



Each output is time synchronized with a timestamp, allowing ClosedLoop vertification, including Fusion and later.

DIVP

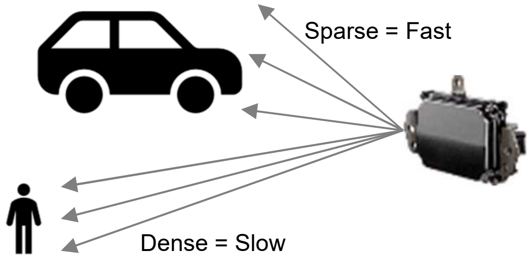
Model improvement and parallel distributed processing are planned to improve calculation speed. By the end of FY22, company aims to double speed of Millimeter-wave Cameras.

Efforts to Improve Calculation Speed (Millimeter-wave cameras)

Model improvement

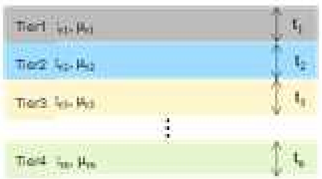
Space design

- Ray Density for FOV

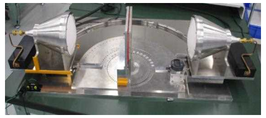


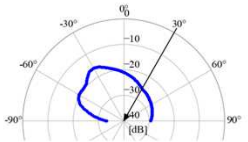
- Target Leveraging Composite Models by Characteristics

Scatterer model



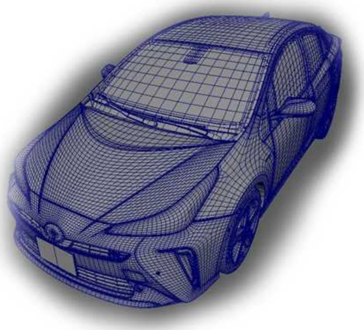
Reflector model





Asset

- Request Meshing for Accuracy



Parallel distributed processing

- Parallel distributed processing on a sensor basis

- Parallel distributed processing on a per-process basis

Project overview

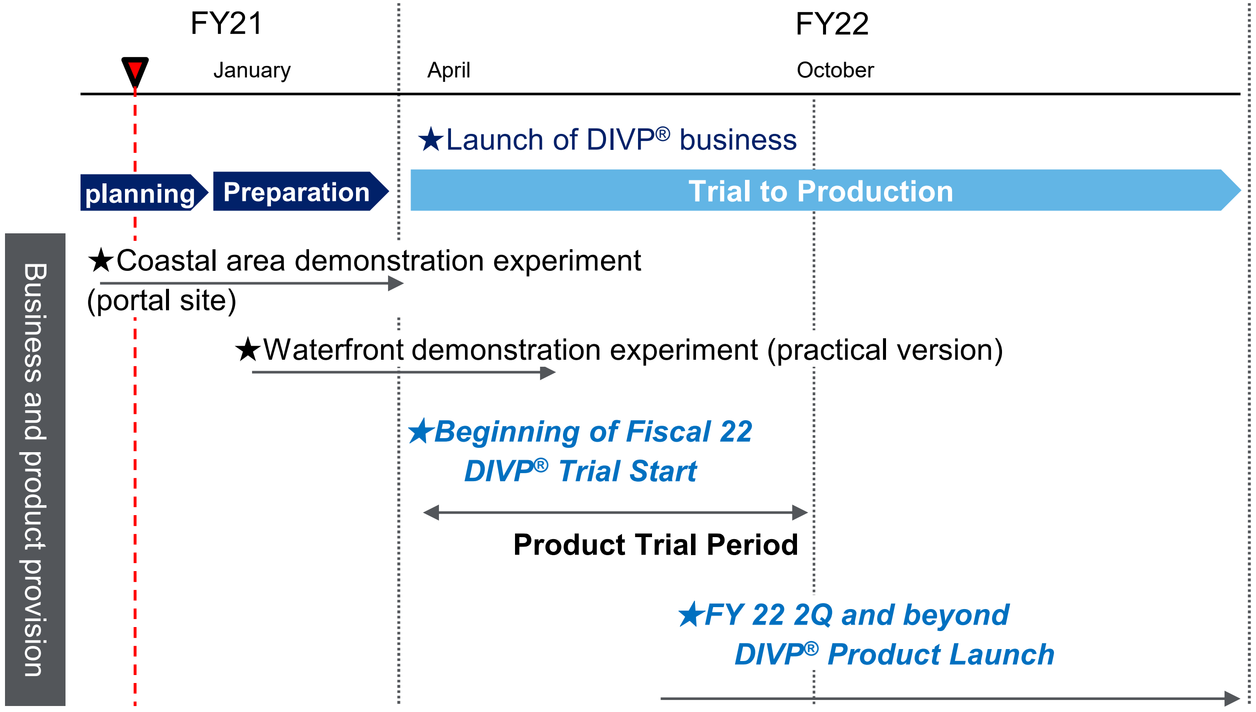
- Review of safety assurance basis
- Objective Competitive Assessment of DIVP®
- Future plans
- **Provision of business based on research results**

We are planning to launch a trial version in early FY 22 and a production version in the second quarter of FY 22.

[Under consideration] Provision schedule of DIVP®

Nihon Unisys, Ltd

Delivery schedule



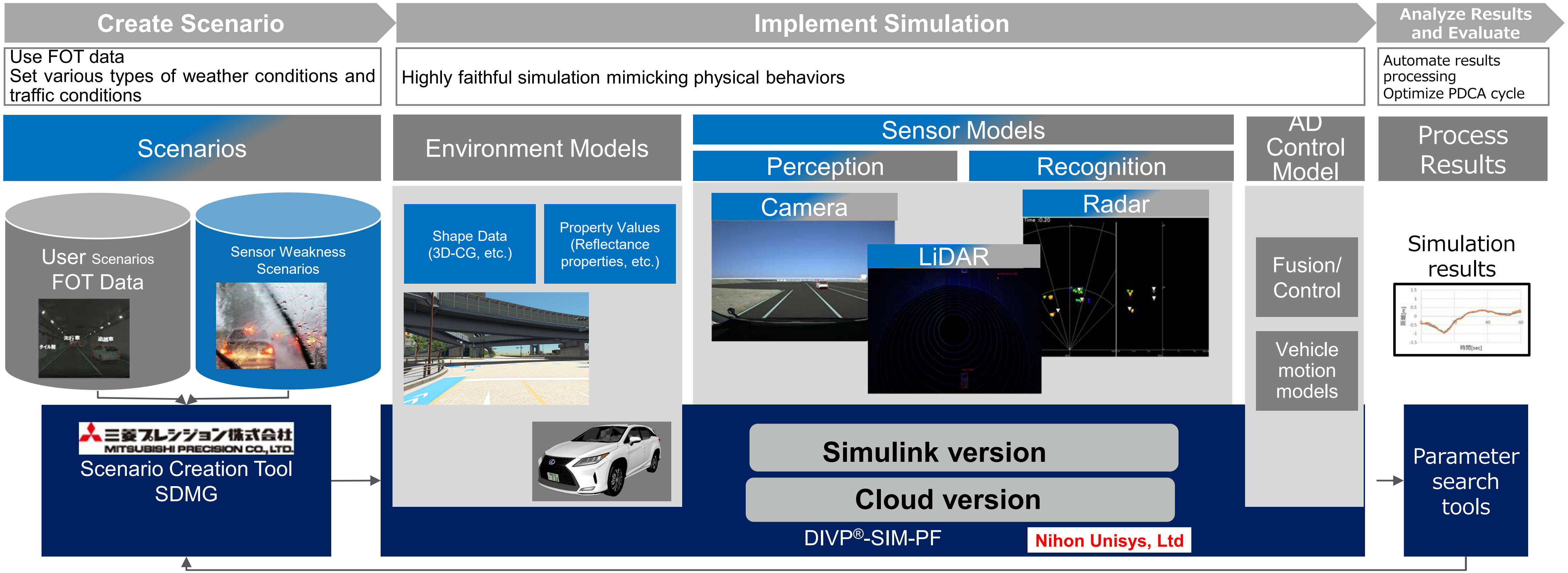
Proposed product package

Product package	Contents
■ Basic set	■ Scenario Tools (SDM Generator) ■ Simulator body ■ For cameras, LiDAR, and millimeter - waves ➢ Space design model ➢ Reference sensor model
■ Sensor Opt	■ Product sensor model
■ Asset Opt (Scenario pkg)	■ Additional Targets (Additional vehicles, obstacles, etc.) ■ Additional Maps (Examples: C1, Odaiba, Ariake)

Use the DIVP® Toolchain for streamlining the AD/ADAS System Evaluation Process of Reproducing Sensor Weaknesses, Creating Scenarios, Analyzing Results and Evaluating

DIVP® Total Toolchain (Plan)

Legends: DIVP® standard model | User model | Provide reference



Implementation Effects	
	■ Evaluate AD/ADAS control robustness, optimize AI (recognition learning) development and evaluation cycles, use FOT Scenarios ■ Accelerate the process of creating scenarios and analyzing results for evaluation, automate the process

DIVP

SDM-Generator, product to create scenarios and environment models for space design, can be used for predicting external evaluations conducted in compliance with NCAP and other vehicle development & design certification programs.

Product Details（plan） : SDM-Generator

MITSUBISHI PRECISION CO.,LTD.

Product Summary

Name

■ SDM-Generator

Functions

- ■ Create scenarios/environment models for simulation
- ■ Convert scenario data owned by customers

I/O

- ■ Support ASAM standardization
- • Support **ASAM OpenDRIVE,** road driving environment
- • Support **ASAM OpenSCENARIO**, scenario environment
- ■ Support **FBX**, general asset data format
- ■ Support importing measurement data

Product Features

Strength

■ Enable format conversions and deal with customers' asset and scenario data in formats supported by DIVP® Simulation
(*) Data types supported for importing and processing are limited. This limitation is subject to future improvement.

Competitors

- ■ dSPACE
- ■ MathWorks
- ■ ARC, etc.

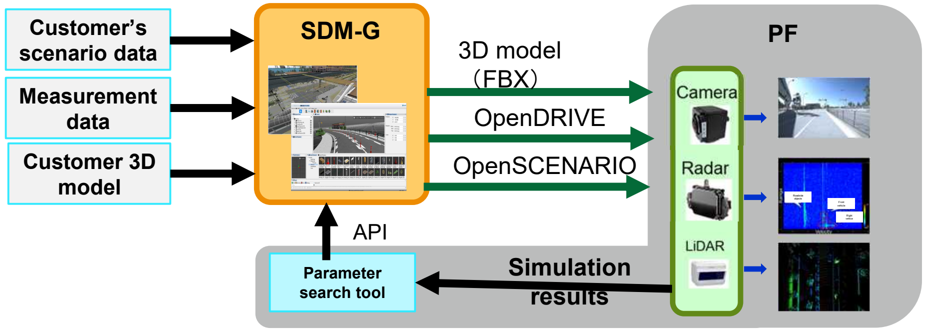
Use Examples (implementation effects)

■ Implementation Effects

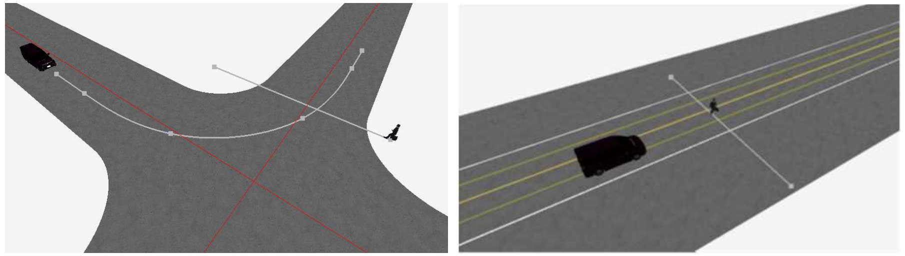
Prediction of external evaluations by certifiers based upon NCAP, etc. :
SDM-G that efficiently uses scenarios of NCAP, etc. can **reduce workloads by approx. 23%**

■ Implementation Example

See below the implementation example chart



■ NCAP Scenario Example



DIVP

DIVP® PF (Cloud version), product that enables and evaluates space designs based upon scenarios defined by SDM-G

Nihon Unisys, Ltd

Product Details (draft)：DIVP® PF（cloud version）

Product Summary

Name

■ DIVP® PF

Functions

■ Enable space designs based upon user-defined scenarios through the use of SDM-G and implement evaluations

I/O

■ Input
- Login（authenticate, authorize）
- Scenarios（obtain, register, update）
- 3D models（obtain, register, update）
- Sensor models（obtain, register, update）

■ Output
- Output results of each sensor of specified scenario

Product Features

Strength

■ Highly faithful space design
■ Support **concurrent simulation** executions of gigantic amount of data
■ Enable cloud tool merits
➢ Optimize costs of creating and operating (using, maintaining) environments
➢ Easily share data intra-company and inter-company

Competitors

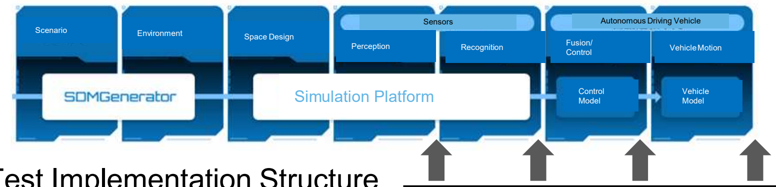
■ CarMaker

■ ANSYS, etc.

Use Examples (implementation effects)

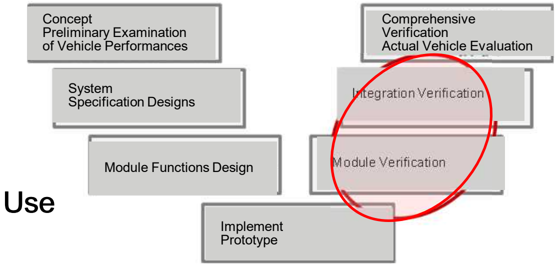
■ Implementation Effects
- Enable tests equivalent to tests based upon actual sensors mounted on vehicles, attributable to highly faithful space design
  ⇒ Reduce tests that are based upon actual sensors mounted on vehicles, reduce an entire workload by early detecting problems
  ⇒ Strengthen robustness by confirming patterns that are dangerous and hardly reproduced
- Reduce test durations by concurrently executing massive simulations
  ⇒ Reduce robustness test durations, detect early problems identified in massive tests
- Enable sharing issues easily as a result of intra-company and inter-company data sharing

■ Implementation Example
① massive test implementation phase for developing sensors (perception, recognition)
② massive test implementation phase for control models and vehicle models



Test Implementation Structure (Image Diagram)

① ② Examine/Evaluate (*) Upload to the Cloud own models of perception, recognition, control and vehicle.



Development Phase Use (Image Diagram)

DIVP® PF (Simulink version), product that enables and evaluates space designs based upon scenarios defined by SDM-G

Nihon Unisys, Ltd

Product Details (draft) : DIVP® PF（Simulink version）

Product Summary

Name

■ DIVP® PF

Functions

■ **Read in** DIVP® scenarios

■ Execute **space designs** for scenarios and **evaluation**

I/O

■ Input
- Scenario (via SDMG, Automated Driving Toolbox)
- Light distribution properties, Reflectance properties

■ Output
- Space design results of specified scenarios

Product Features

Strength

■ **Highly faithful** space design
■ High adaptability to a development environment of each company through the use of Simulink
（Usable only by adding into the MBD environment of own company) (*)
The premise is that a Simulink environment is obtained and an environment with MBD engineers is obtained.

Competitors

■ CarMaker

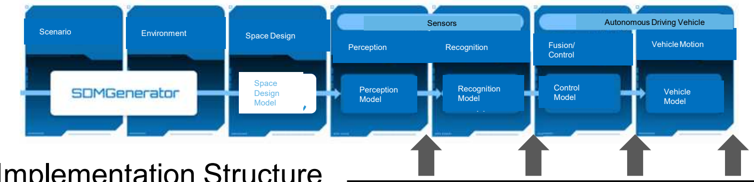
■ CarSim, etc.

Use Examples (implementation effects)

■ Implementation Effects
- Enable tests equivalent to those that are based upon actual sensors mounted on vehicles, attributable to highly faithful space design
⇒ Reduce tests that are based upon actual sensors mounted on vehicles, reduce an entire workload by early detecting problems
⇒ Strengthen robustness by confirming patterns that are dangerous and hardly reproduced
- Enable **efficient use of the existing assets** by using own development environments
⇒Intensify the efficiency by also using cloud version if many tests are implemented

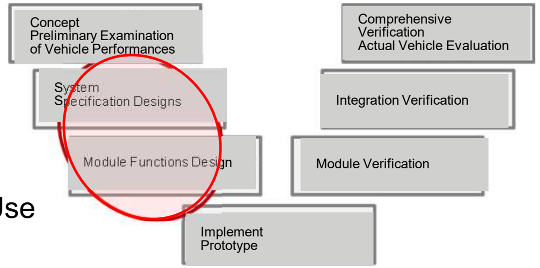
■ Implementation Example
① Examine and evaluate in a case of developing sensor (for perception, recognition) MBDs
② Examine and evaluate in a case of developing control model/vehicle model MBDs

(*) Own Development Environment
（MATLAB/Simulink）



Test Implementation Structure
(Image Diagram)

① ② Examine/Evaluate (*) Upload to the Cloud own models of perception, recognition, control and vehicle.



Development Phase Use
(Image Diagram)

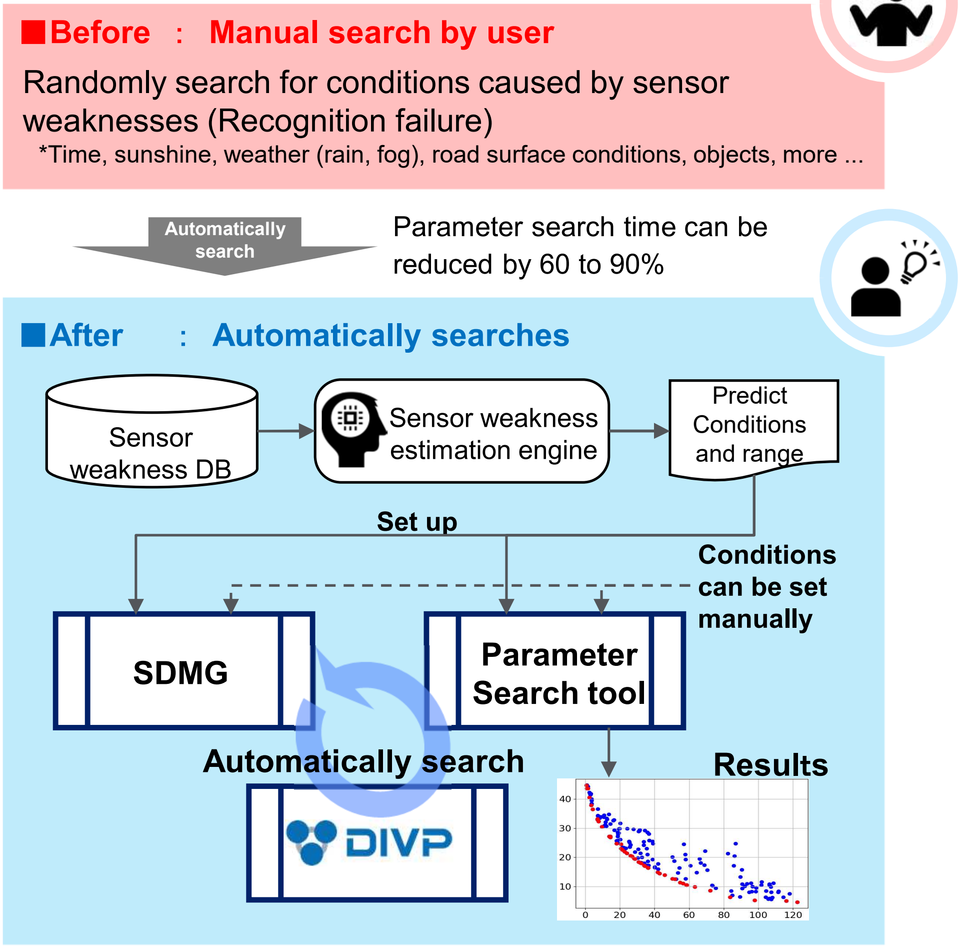
Parameter Search Tool can automatically search the environmental parameters that occur sensor weaknesses and can utilize ODD caused by sensor system.

Product Details (draft) ：Parameter search tool

Product Summary	Name	■ Parameter search tool
	Functions	■ **Search for environmental parameters that cause sensor weaknesses** using evaluation equation and optimized algorithms ■ **Automatically performs** from scenario creation to simulation according to evaluation conditions
	I/O	■ Input (User sets) ・ Search parameters ・ Evaluation function *Condition setting is easy with the sensor weakness estimation engine ■ Output ・ Sensor weakness parameter search results
Product Features	Strength	■ Automatic parameter search in DIVP® simulation environment *Expansion of algorithm types will be improved in the future
	Competitors	■ modeFRONTIER ■ HEEDS ■ Matlab/Simulink etc.

活用例
(導入効果)

e.g) In case of Scenes of sensor system examination and evaluation



DIVP

DIVP® Data Analysis Tool is a simulation analysis tool that can read simulation result files and analyze various time series data linked with sensor images.

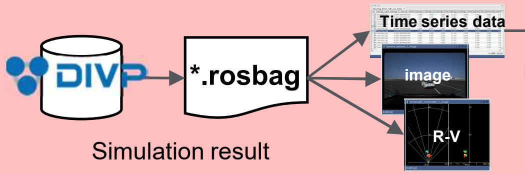
Product Details (draft)： Data analysis tool

Product Summary	Name	■ **Data analysis tool**
	Functions	■ Load DIVP® simulation results (rosbag) ■ Linked display of simulation time series data and image data ■ Calculations, filters, feature extraction of time series data, etc.
	I/O	■ Input (User sets) ・ DIVP® simulation result file (* .rosbag) ■ Output ・ Analysis results
Product Features	Strength	■ DIVP® simulation analysis results file contains bulk loading and processing of vehicle, environment, sensors and other data. ■ Only the data and images required for analysis can be selected and load. (Reduction of analysis data capacity)
	Competitors	■ Excel, DIAdem, UNIPLOT etc. ■ Matlab, Python etc.

活用例
(導入効果)

e.g) In case of Scenes of sensor system examination and evaluation

■Before ： User prepared confirmation tool for each data and read and analyzed the data.



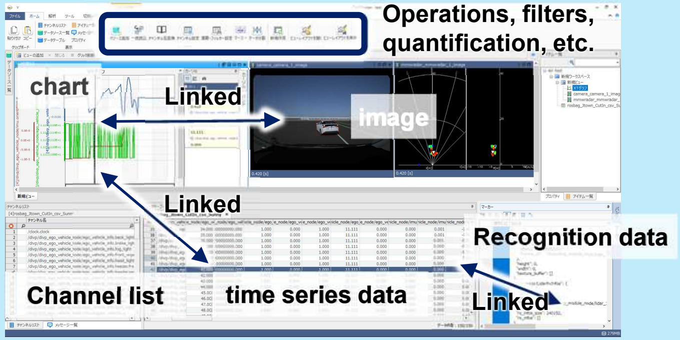
User preparation & production
・Refer to using RosOS
・Graph with Python / Matlab
・Manually adjust the time series for each sensor

Bulk loading

20 to 30% reduction in overall analysis man-hours
(Reading is reduced by 80 to 90%)

■After ： Load one-shot analysis data and display linked to analysis data to fit DIVP® (* .rosbag)

Data analysis tool

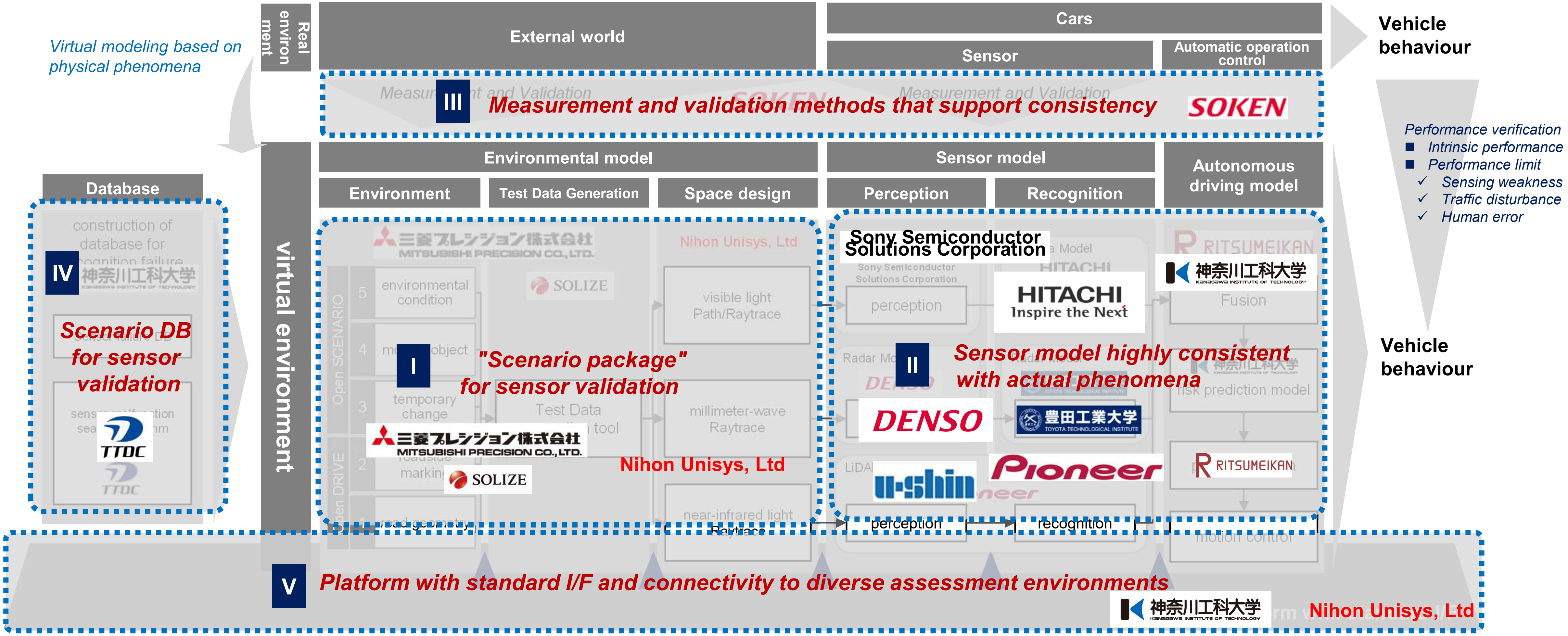


Save analysis conditions such as operations, filters, feature extraction and quantification, and share conditions among users.
Repeated analysis is possible under the same conditions

DIVP

Outcome

DIVP® Design



DIVP

Outcome

I	■ "Scenario package" for sensor validation
II	■ Space and sensor model highly consistent with actual phenomena
III	■ Measurement and validation methods that support consistency
IV	■ Scenario DB for sensor validation
V	■ Platform with standard I/F and connectivity to diverse assessment environments

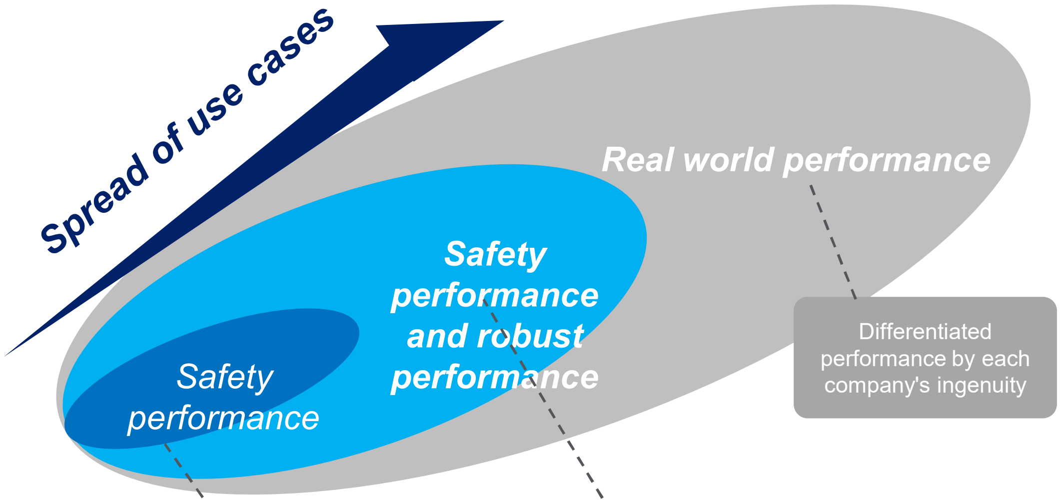
- ■ Scenario package
- ■ SDM-Generator

In FY 2020, in addition to improving simulation accuracy based on consistency verification, Virtual-PG (Proving ground) will be developed to reproduce simulations of NCAP protocols.

Virtual-PG Expansion Policy

Spread Use Case Roadmap

- Spreading awareness of platform effectiveness through "safety" assurance that are shared by all industry players



Fundamental safety performance that all automobiles should have in order to reduce serious and fatal accidents

Basic safety performance that will serve as a benchmark for consumer confidence in autonomous driving

DIVP® scope

Promoting Virtual-PG with two Pillars

Assessment package

1

Safety verification for accident reduction

- The test protocol was reproduced based on accident data. Safety assurance simulation is possible.
  - ➢ Generation based on accident analysis (Especially casualties, general roads)
  - ➢ Generation based on highway (automatic driving) driving state data

Prioritize from investigation of Eur-NCAP protocols generated based on accident data

Odaiba Community Package

2

Verification of safety performance and robustness

- Reproduces the Sensing weakness input conditions. Enables robust simulation in Real World.
  - ➢ Unfavorable environment due to each sensor detection principle and electromagnetic wave band used

Prioritize by DIVP® Consortium suppliers and OEM communications

Reproduced AD/ADAS safety verification protocols such as NCAP as an assessment package.The Odaiba Community Package defines validation scenarios based on actual map.

DIVP® - Scenario Package

April: DIVP® Business launched (start of FY2022)

	FY2021				FY2022		
	April - June	July - September	October - December	January - March	April - June	July - September	October - December
Assessment Package Safety verification scenario (NCAP/ALKS, etc.)	Euro NCAP (from April - June, FY2021 to April - June, FY2022)						
		ALKS (from July - September, FY2021 to October - December, FY2022)					
Odaiba Community Package Robustness assessment scenario	Sensing weakness scenario (from April - June, FY2021 to October - December, FY2022)						

Euro NCAP

ALKS

Sensing weakness scenario

A faded white line | Thermal barrier coated road surface | Backlight | Tunnel | Rain | Snow

Source: MITSUBISHI PRECISION CO., LTD., Kanagawa Institute of Technology

DIVP

24/32 of FY 2021 end assessment packages and 13/25 of Odaiba community packages were modeled. Update needed based on user needs and international cooperation

Scenario Package Construction

	FY2021				FY2022		
	April - June	July - September	October - December	January - March	April - June	July - September	October - December
Milestones	OEM/Sensor Maker Monitor Assessment			November: Coastal area demonstration experiment (Step 1/Step 2) November: SIP-adus work shop	April: Start of business		
Assessment package Safety verification scenario (NCAP/ALKS, etc.)	**Euro NCAP** **・Pedestrian (When going straight, there is a pedestrian crossing, a car shadow, day/night)** CPFA/CPNA /CPNC /CPLA **・Against a car (when going straight, there are other cars)** CCR	**ALKS** ・Cut-In ・Cut-Out	**Euro NCAP** **・Pedestrian (There was a pedestrian crossing when going backward)** CPRA **・Car (there is another car when switching lanes)** LSS - Road Edge test/Solid test/Oncoming vehicle Others	**Euro NCAP** **・Pedestrian (There is a pedestrian crossing when turning left and right)** CPTA **・Car (Oncoming car when turning left/right)** CCFtap **・Bicycle (When going straight, there is a pedestrian crossing, and the car shadow is seen.)** CBNA/CBFA	**Euro NCAP** **・Against a bicycle (There is a person who is proceeding in the same direction when going straight)** CBLA **・Bikes (Straight, turning right and left, switching lanes)** CMR/CMF/LSS – Oncoming vehicle and others	Continue to study the development of further scenario packages after FY 2023	
Odaiba community package Reflect sensing weakness scenario	**Camera** White Line Misrecognition by Street Tree Shadow/Reproduction of Light Distribution of Signal/Non-recognition of Blurred White Line **LiDAR** Recognition rate of black leather pedestrians/road surface with thermal barrier coating/mistaken recognition of sunlight and highly reflective objects **Millimeter-wave** Signal strength due to road surface fading/Misrecognition of road surface clutter/Separation of objects with the same distance		**Camera** ・Adtrak's mistaken identity ・Unawareness of low floor vehicles ・Tunnel (for general light sources) **Millimeter-wave** ・Tunnel Multipath ・upper structure	**Camera** ・Pedestrian overlooked by raindrops and wipers ・specular reflection **Millimeter-wave** ・Improvement of microDoppler recognition performance	**Camera** ・Misunderstanding due to water hoisting ・Motion Blur ・Signal (flicker) **LiDAR** ・Misunderstanding due to rainfall probability ・puddle ghost ・mistaken recognition due to water winding **Millimeter-wave** ・Decrease in recognition rate due to heavy rain	**Camera** ・Snow (details TBD) **LiDAR** ・Misunderstanding due to suspected snow hoisting ・Undetected frozen surface **Millimeter-wave** ・Undetected due to ice on emblem	

Scenario packages for reflection characteristics, light sources, and white lines are complete. Expanding packages to include rain, multi-path ghost testing, snowfall, and motion blur

Developed and planned environmental conditions

Developed | **Experiment, modeling**

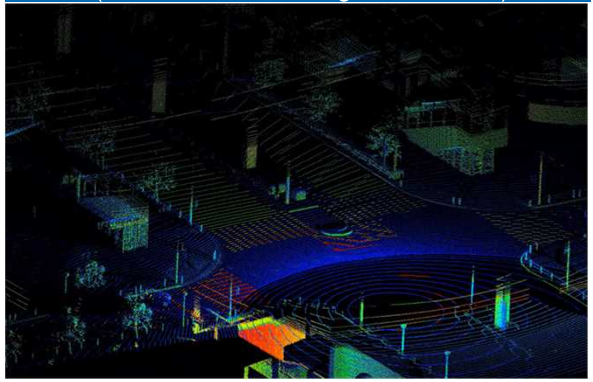
Backlight

A white line in the shade of a tree

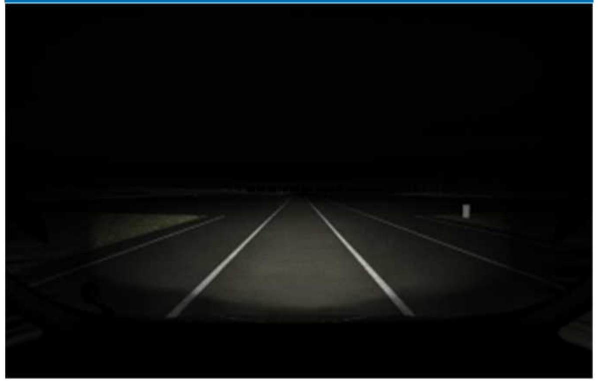
Rainfall
(Raindrops, Spatial Damping/Scattering, Doubt)

Snowfall (+ snow)

Change in reflective properties
(Thermal barrier coating, black leather)



Night headlight



Multipath ghosts (tunnels, etc.)

Motion blur, flicke

Source : Kanagawa Institute of Technology

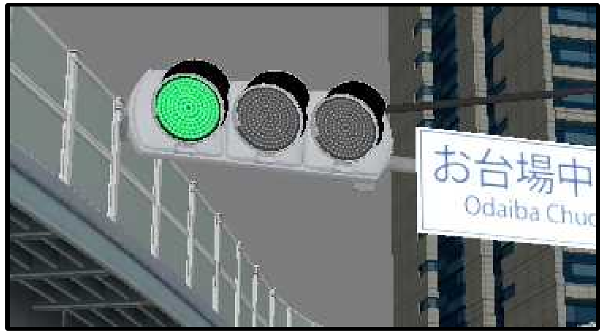
Modeling and verification of cars, pedestrians, and traffic signs completed.Expanding to models with specific behaviors and shapes, i.e. motorcycles, special vehicles, and animals

Developed and planned assets

Developed | **Experiment, modeling**

Passenger vehicles (11 models)

Traffic signal

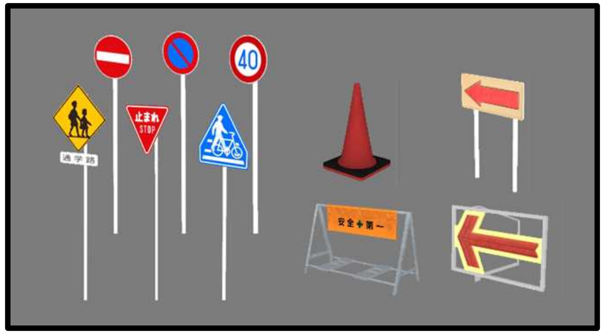


Pedestrians and their belongings

Motorcycles and special vehicles

NCAP dummies

Traffic signs and construction equipment



Large vehicles (including towing)

Animal

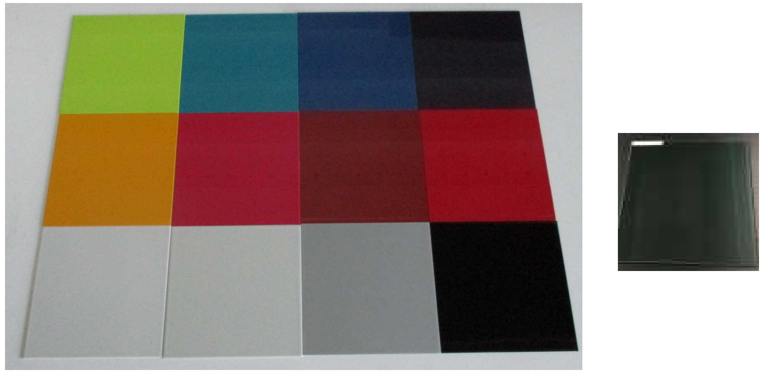
Source : MITSUBISHI PRECISION CO.,LTD.

Completed modeling of sensor reflectivity for basic materials used in vehicles and maps. Modeling changes in reflectance characteristics associated with environmental conditions

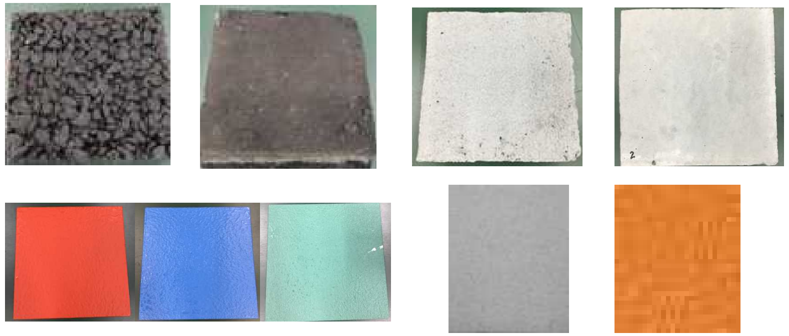
Developed/Planned Materials

Developed

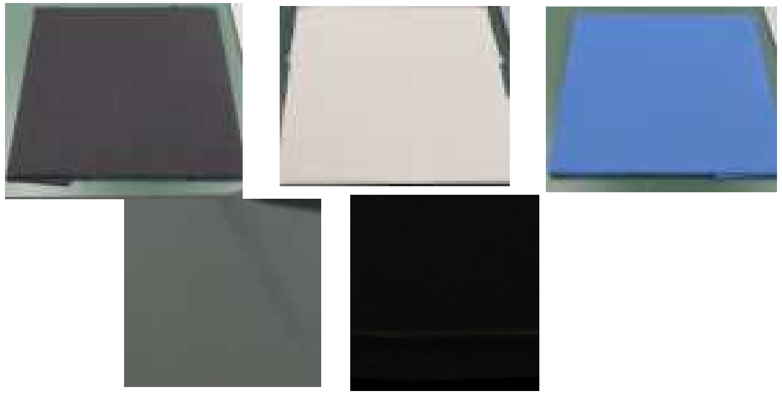
Vehicle paint, glass



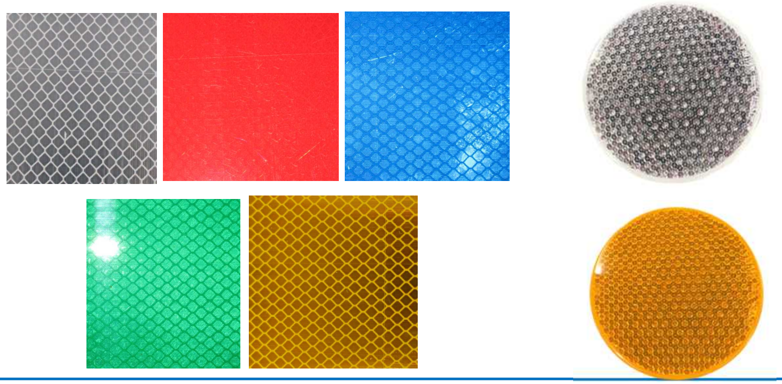
Road surface material (Asphalt, concrete, etc.)



NCAP dummies



Road signs and eye markers



Modeling In Progress

Wet road surface

Snow, ice

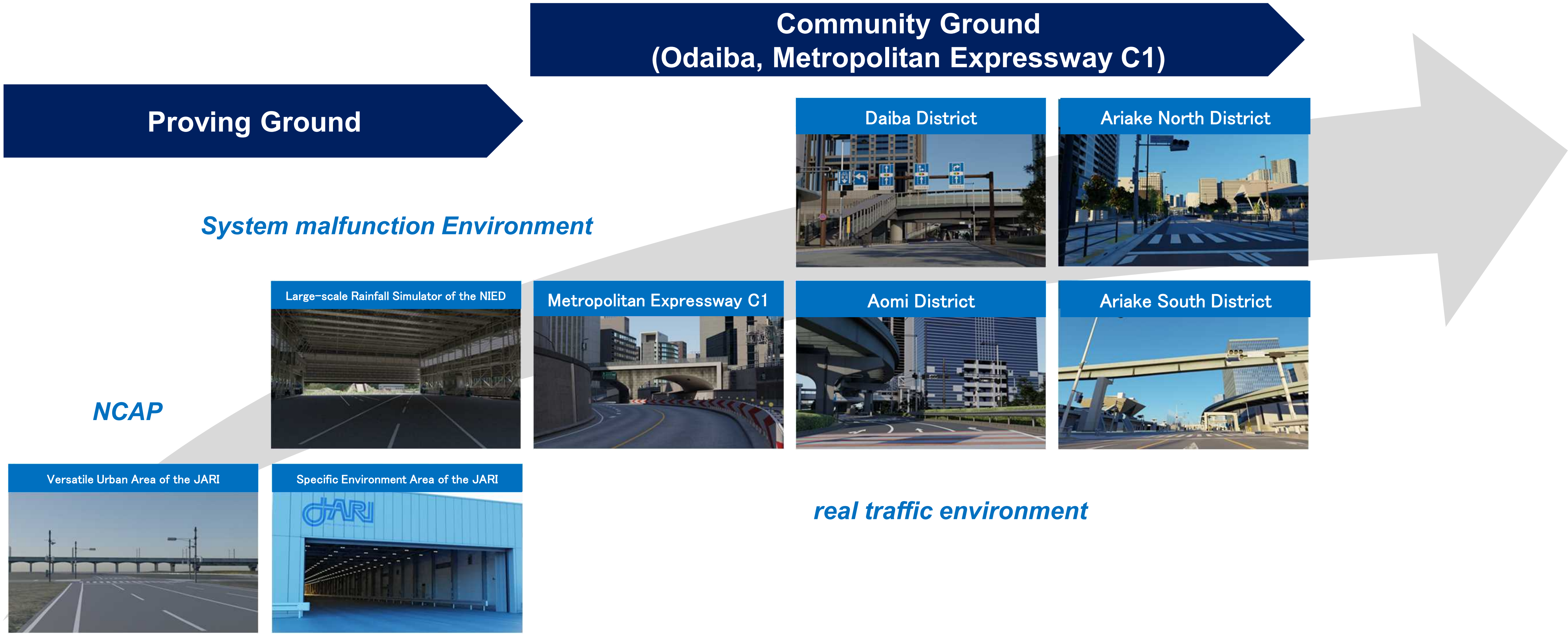
Source : SOKEN, INC, Kanagawa Institute of Technology.

DIVP

Odaiba Virtual Community Ground to be constructed to evaluate sensor malfunctions in a real traffic environment.

Development Virtual PG/CG

MITSUBISHI PRECISION CO.,LTD.



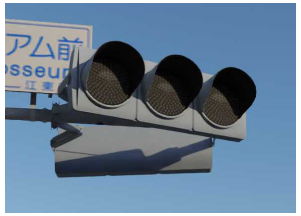
Source : MITSUBISHI PRECISION CO.,LTD.

In FY 2021, the Ariake district was established as a Virtual Community Ground to be utilized for further demonstration experiments.

Virtual Community Ground developed in FY 2021

三菱プレシジョン株式会社
MITSUBISHI PRECISION CO.,LTD.

Community Ground
(Odaiba Metropolitan Expressway C1)


Traffic signal for automobiles


Pedestrian traffic signal


Push button

Ariake North District

Ariake South District


Bus stop


Pedestrian bridge

Source : MITSUBISHI PRECISION CO.,LTD.

DIVP

Building high-precision map assets from actual measurements

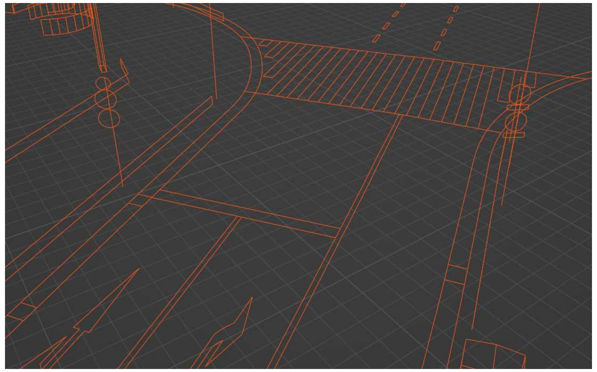
Measure with map accuracy required for simulation

三菱プレシジョン株式会社
MITSUBISHI PRECISION CO.,LTD.

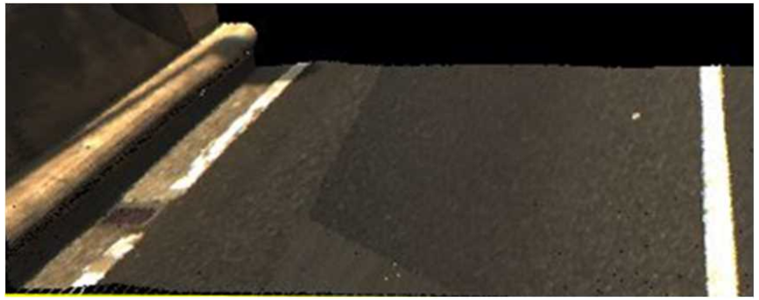
	Items	DIVP® request		Existing SIP instrumentation data
3D point cloud data	Reflection intensity information	○		○
	Color information	○		○
	Resolution	***1 cm horizontal***	>	***Horizontal 6cm***
Camera image	Resolution	2400x2000x3@24bits		2400x2000x3@24bits
	Installed number	3-cameras		3-cameras
	Onboard information	***Include***	>	***None***

Measurement data

Vector data



Data measured by DIVP®



>

Existing SIP instrumentation data

In the general traffic environment, it is difficult to create maps because there are many defects in point cloud data, such as parking vehicles, and poor measurement. By creating vector data from measurement data, the creation efficiency was improved by partially complementing missing point cloud data and poor measurement.

Source : MITSUBISHI PRECISION CO.,LTD

DIVP

Developing Ordinary Vehicle Assets to Reproduce Actual Traffic Environments

Developed Assets

三菱プレシジョン株式会社
MITSUBISHI PRECISION CO.,LTD.

Ordinary car

Created: 13 units FY 22 Completed: 56 units

Source : MITSUBISHI PRECISION CO.,LTD.

DIVP

Provision of large vehicles, motorcycles, and pedestrian assets to contribute to the reproduction of sensor malfunctions and sensing weakness

Developed Assets

MITSUBISHI PRECISION CO.,LTD.

Large vehicle

Created: 4 units, When FY 22 is completed: 11 units

Use of false recognition due to low vehicle height

Utilized to improve millimeter-wave micro-Doppler recognition performance

Used for false recognition by specular materials

Two-wheeled vehicle, pedestrian

Created: 4 units, When FY 22 is completed: 33 units

Supports a variety of motions
- walking
- running
- stop [turn right]
- stop [turn left]
- Walking while looking at a smartphone

Source : MITSUBISHI PRECISION CO.,LTD.

DIVP

Validating sensor recognition for false detection and non-detection using roadside objects and obstacle assets, as well as the construction of actual traffic environments

Developed Assets

三菱プレシジョン株式会社
MITSUBISHI PRECISION CO.,LTD.

Roadside objects and obstacles

Created: 6 units, When FY 22 is completed: 31 units

Use of false recognition in low-reflection targets

Use of false recognition of road clutter

Source : MITSUBISHI PRECISION CO.,LTD.

DIVP

Future plans for asset expansion

An example of an asset being prepared [* Image under development]

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MITSUBISHI PRECISION CO.,LTD.

Vehicle

Large/Medium-sized vehicles

- Bus
- Track
- Semi-trailer
- Car carrier
- Microbus

- Tank truck
- 6t track
- Truck mounted crane
- Low-floor trailer
- Adtrack

Large/small special motor vehicles

- Road roller
- Bulldozer
- Agricultural tractor
- Forklift
- Excavator loaderr
- Dump truck

Special vehicle

- Snow plow
- Military vehicle
- Tram
- Segway
- Ambulance

- Fire truck
- Patrol car
- Garbage truck
- Cart for driving on public road
- Mixer car

Motorcycle

Large/Standard Motorcycles

- Large motorcycle
- Sidecar
- Big Scooter

Motorized bicycle

Type 1 / Type 2 motorized bicycle

- Scooter
- Bike
- Specific motorcycles (tricycles)
- Electric kick board

Bike

Bike

- Children's bike
- Adult bicycle
- Bike with children
- Road bike

Pedestrian

Pedestrian

- Adult
- Children
- Older people
- Wheelchair
- With pets

- Umbrella
- Bag
- Raincoat
- Black school bag
- Stroller

construction equipment

Signboard

- Construction sign
- Tiger fence
- Vehicle entrance and exit sign

Road safety supplies

- Safety cone
- Cushion drum
- Barricade
- Road pole
- Cat's Eye
- Curve Mirror

Illumination

- Security light
- Beacon
- Work light

Traffic guidance

- Guide staff
- Guidance robot
- Guided display
- Arrow plate
- Triangular display plate

Road obstacle

Parked vehicle

- Small vehicle
- Large vehicle
- Track
- Accident vehicle/broken down vehicle

Falling object

- Cardboard
- Board
- Stepladder
- Utility pole
- Fallen tree
- Tire
- Pail can
- H-Steel

Other

- Lying down
- Animal carcass
- Manhole
- Flare light

Other

Large animal

- Boar
- Deer
- Large dog

Small animal

- cat
- Raccoon dog
- Small dog

Flying object

- Bird
- Soccer ball
- Drone
- Plastic bag
- Aluminum bag

Source : MITSUBISHI PRECISION CO.,LTD.

DIVP

High definition polygons reproduce the internal structure for the millimeter-wave radar, where reproduction of internal structure reflection transmitted through object surface is key.

Laser measurement to produce a model that can guarantee accuracy

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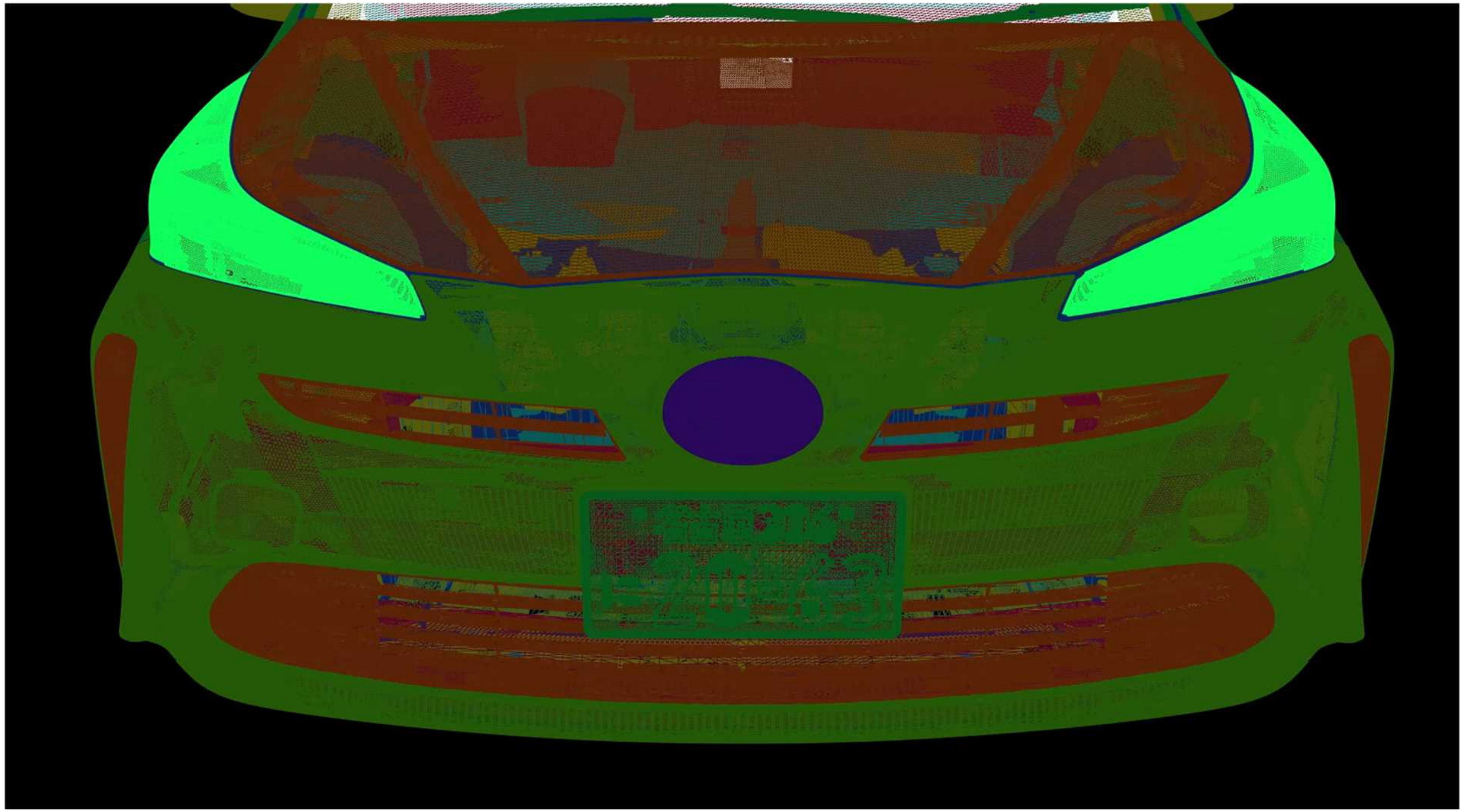
Laser measurement		Polygon modeling
 	Detailed modeling based on actual measurements	

Source : MITSUBISHI PRECISION CO.,LTD.

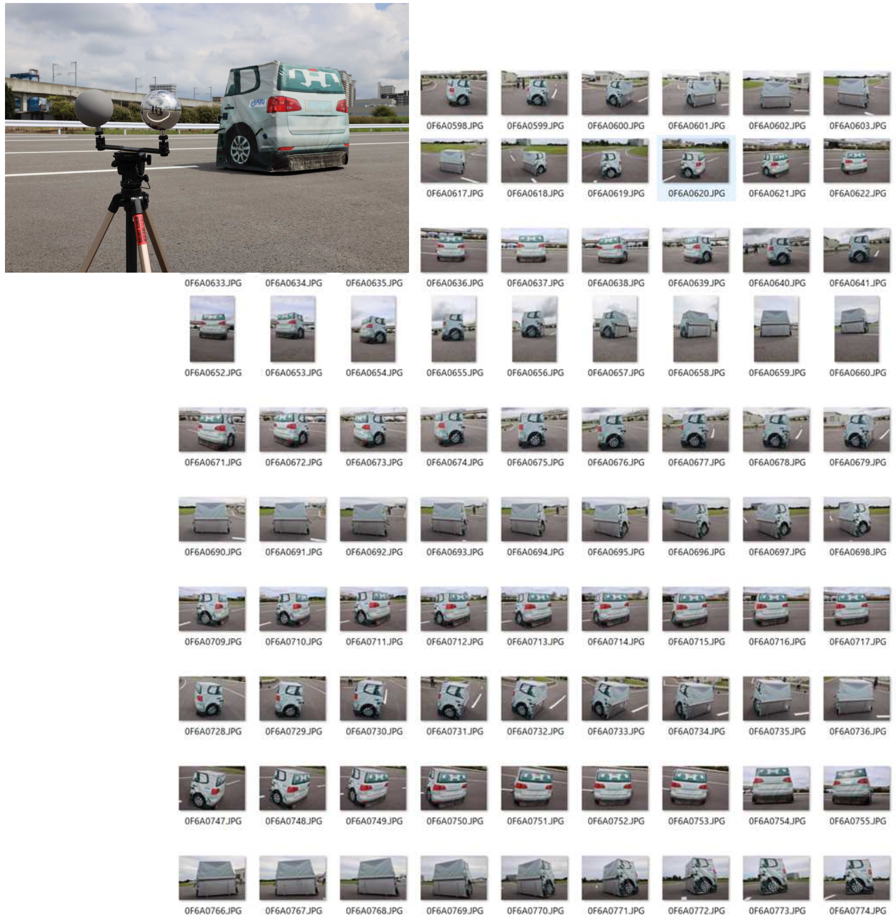
DIVP

Photographing targets from various angles using optical imaging equipment, and analyzing, integrating, and modeling data

Use of photogrammetry technology to create models of targets with indefinite shapes and large targets difficult to measure with laser

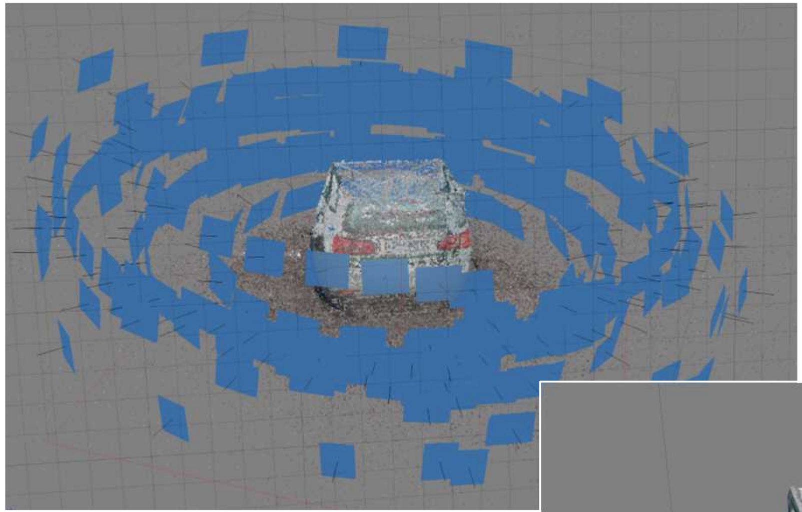
MITSUBISHI PRECISION CO.,LTD.

Shooting from multiple points



Modeling based on optical imaging equipment measurement

Modelling by photogrammetry



Useful for modeling balloon cars and NCAP dolls that change shape every time they are assembled.

Large vehicles and other objects that are difficult to measure with laser can also be used

Source : MITSUBISHI PRECISION CO.,LTD.

DIVP

Outcome

I	■ "Scenario package" for sensor validation
II	■ Space and sensor model highly consistent with actual phenomena
III	■ Measurement and validation methods that support consistency
IV	■ Scenario DB for sensor validation
V	■ Platform with standard I/F and connectivity to diverse assessment environments

- ■ Scenario package
- ■ SDM-Generator

Space Design Model Generator (SDM Generator) Development generates test environment for performing safety assurance in virtual space by using database of driving environment.

Development Objectives and Comparison with Other Companies

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MITSUBISHI PRECISION CO.,LTD.

■ Development objective

Construction of scenarios incorporating physical property information to evaluate perception and recognition of sensors, etc.
Also supports true value information output to evaluate vehicle position

■ Comparison with other companies

Comparison with other competitors - We confirmed that the UI is easy to use and the scenario creation efficiency is similar to the competition.

	IPG CarMaker (10.1)	ANSYS VRX (2021R2)	Siemens PreScan (2021.2)	DIVP®
■ Screen configuration (Easy-to-understand settings and ease of use)	△ Setting of running track and running speed is different window.	○ Collapse Settings into One Window	○ Collapse Settings into One Window	○ Collapse Settings into One Window
■ Ease of creating scenarios (validation based on the time required to create a new NCAP pedestrian jumping scenario)	○ 30 minutes to 1 hour	× 1 ~ 2 hours Map creation is heavy DS and AP have different axes	○ 30 minutes to 1 hour	○ 30 minutes to 1 hour
■ Scenario reusability (Partitioning of settings/parameters, etc.: external file storage, etc.)	○ Map vehicle setting Sensor Individual Parameters	○ Map Sensor Individual Parameters	○ Map Sensor Individual Parameters	○ Map Running track vehicle setting
Total	△	△	○	○

Source : MITSUBISHI PRECISION CO.,LTD.

Advantage of DIVP® sensor validation lies in physical properties added to the environmental model and the input/output. Development of true value output function is underway.

Input/Output and True Value Output in SDM-G

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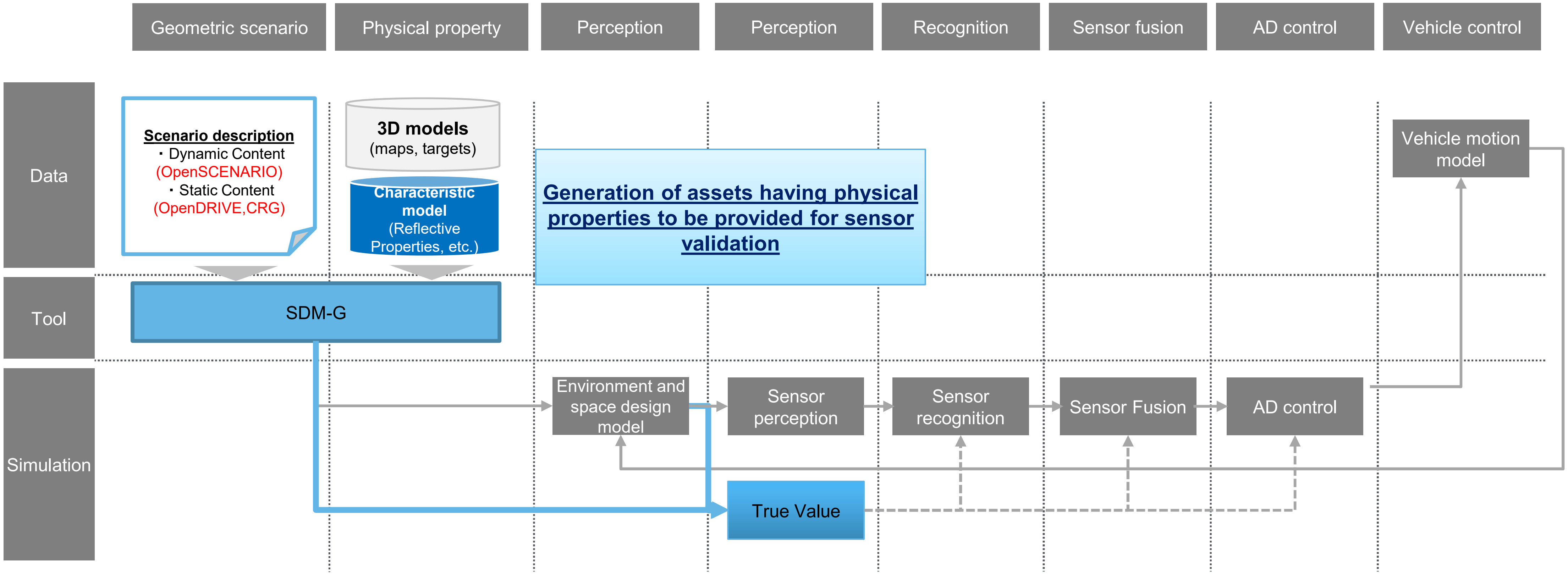

Source: Materials provided by Nexty Masui

DIVP

Space Design Model Generator (SDM Generator) creates and manages scenarios for DIVP® simulators by placing vehicles and targets in virtual space environments.

Key Features of SDM Generator

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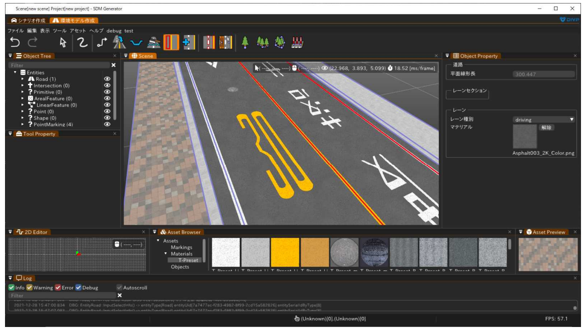
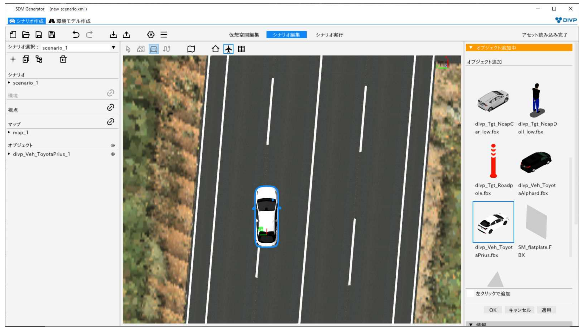
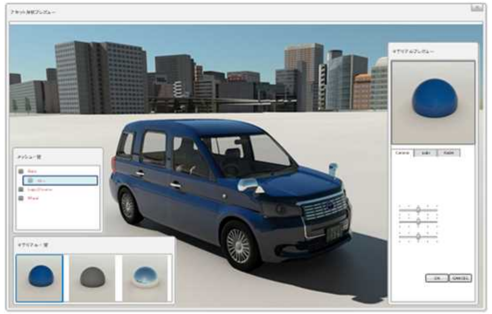
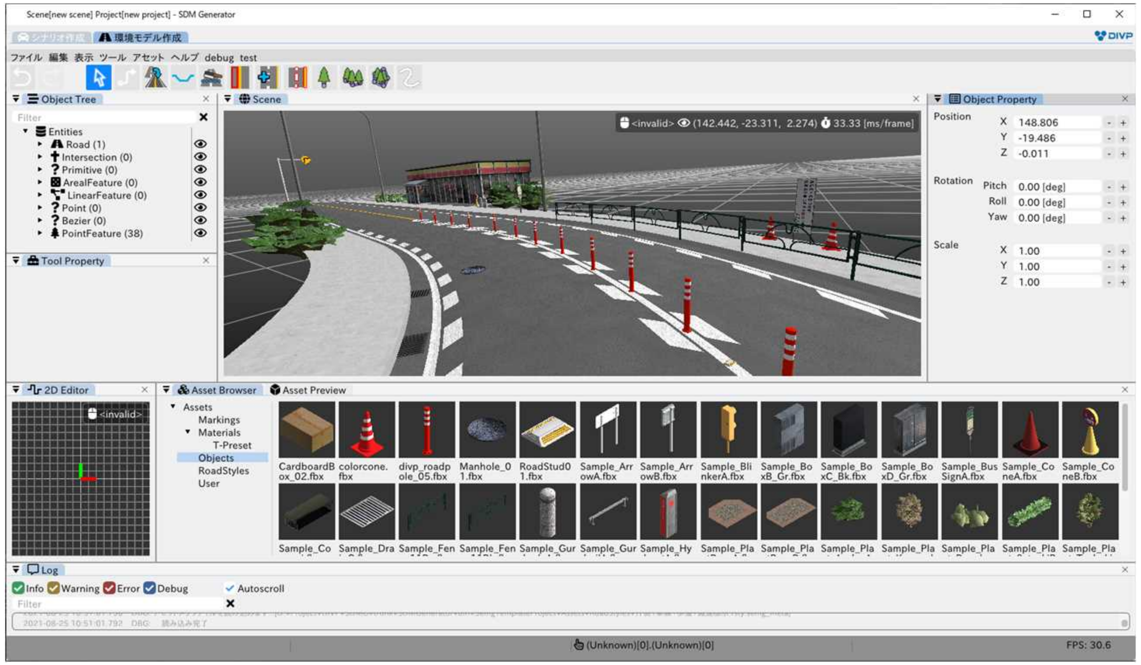
	SDM Generator		
	Environment model creation function	Scenario creation function	Asset editing features
screen example			
Key Features	■Optional Road Model Creation ■Road model creation from OpenDRIVE data ■Arrangement of road markings, road signs, buildings, etc.	■OpenSCENARIO import/export ■Import of driving data by GPS or IMU ■Arrangement of own vehicle, other vehicles, persons, etc. ■Control settings related to event/condition judgment	■Assign a DIVP® material to an asset. ■Reviewing Asset Control Information ■Asset confidentiality

Source : MITSUBISHI PRECISION CO.,LTD.

Developed function that can flexibly create necessary traffic environment models, enabling reproduction of various scenes

SDM Generator Environment Model Creation

MITSUBISHI PRECISION CO., LTD.



Development of driving environment model functions

Supports ASAM standardization

■Road running environment

・OpenDRIVE Data Import/Export

・FBX Import/export format assets

Virtual Environment Create

■Creating a Driving Environment Model Using the Mouse

・Plotting Control Points, By Entering Parameters, Creating Road Alignment Data, Creating

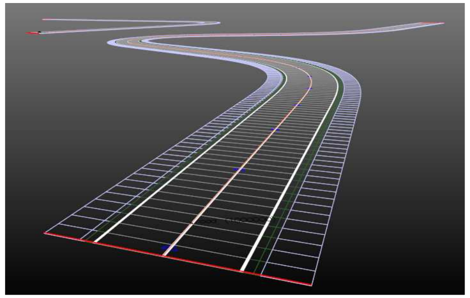
・Road specifications from the library, Textures, etc. Set by selecting.

・Select and place road markings, road signs, roadside features, buildings, etc. from the library

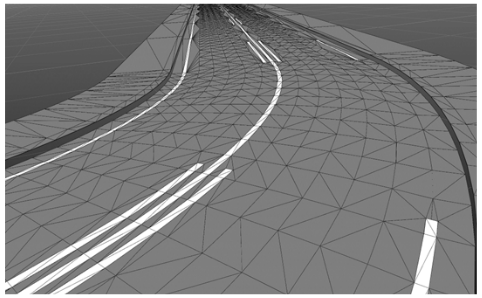
・Set white blurred lines (automatically generated by specifying 0 ~ 100% peel rate)

■Output of the driving environment model

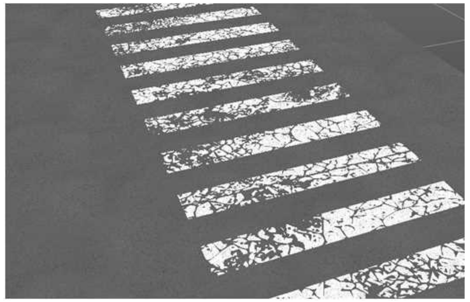
・Assets (FBX format), and OpenDRIVE, Output data in pairs

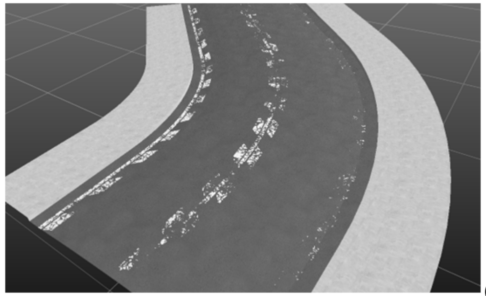


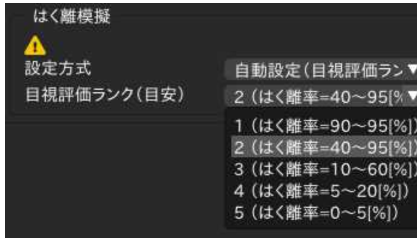
*Generating OpenDRIVE Data



*Integration of white lines and realization of water gradient







(Automatically generated with 0 ~ 100% peel rate)

*Realization of blurred white lines

Source : MITSUBISHI PRECISION CO.,LTD.

DIVP

Currently placing vehicles and targets, creating scenarios for DIVP® simulator, developing editing functions, and using them to create assessment scenarios such as NCAP

SDM Generator Scenario Editor

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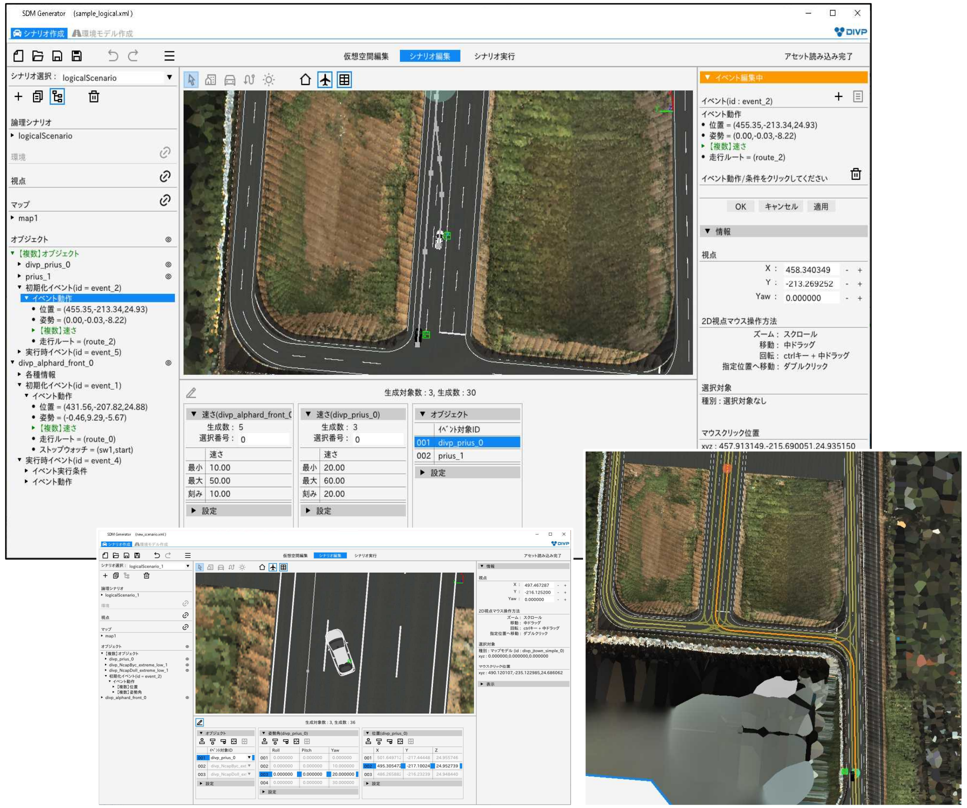
MITSUBISHI PRECISION CO.,LTD.



*Logical scenario/concrete scenario editing function

*Scenario editing using OpenDRIVE data

Developing a scenario creation/review environment

Standardization support

■Scenario environment

・OpenSCENARIO Import/Export

・I/O of the proprietary (including complementary) scenario file (XML)

Various scenarios incorporation of

■Incorporation of experimental data

・CSV data Importing

■Incorporation of various scenarios

・SAKURA, Customer-Name Creation Scenario, OpenSCENARIO, Import

Setting Up Your Own Scenario

■Configuring Routes and Events

・Way Point, OpenDRIVE, Setting a driving route along a route

・Select and place your own vehicle, other vehicles, people, etc. from the library

・Setting of controls related to various events/conditions such as speed/acceleration

■Setting Environmental conditions

・Weather (rain, snow), time (sun position), etc. depending, sensor failure scenario, setting

Review various scenarios

■Use the Play button on the GUI to check the scenario

・On the driving environment model, in real time, in preview

■Combined scenario linkage with traffic environment model (future response)

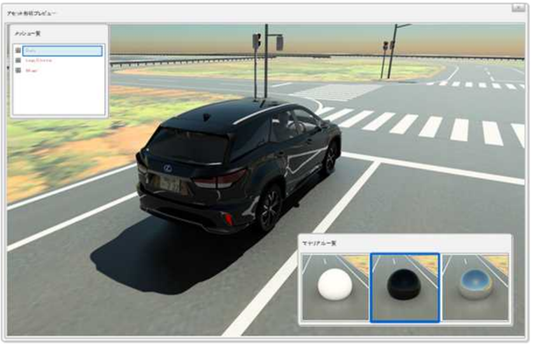
・Traffic lights, switching, other vehicles, running and people supporting independent control such as walking

Source : MITSUBISHI PRECISION CO.,LTD.

DIVP

SDM Generator can easily check materials and assign different materials to assets, which can be used for various verifications

SDM Generator asset Editing Capabilities



*Change Material Assignment

*Edit Material

Development of material editing functions

Change Material

■Material Assignments
- ・Assign materials from GUI and use DIVP® PF
- ・Quick preview of assignment result on screen is available.

Material Quick Edit

■Support for quick material editing
- ・Quick preview While viewing Editable

Confirm Asset Control

■Review controls set on asset
- ・naming conventions and tree structure switching, part-by-part rotation,

Ability to check animation controls

Custom Convert to Format

■For concealment and Conversion to original form
- ・Support for custom format conversion

Source : MITSUBISHI PRECISION CO.,LTD.

By supporting international standards as Input/output, it can be connected to various simulators.

Support of international standards

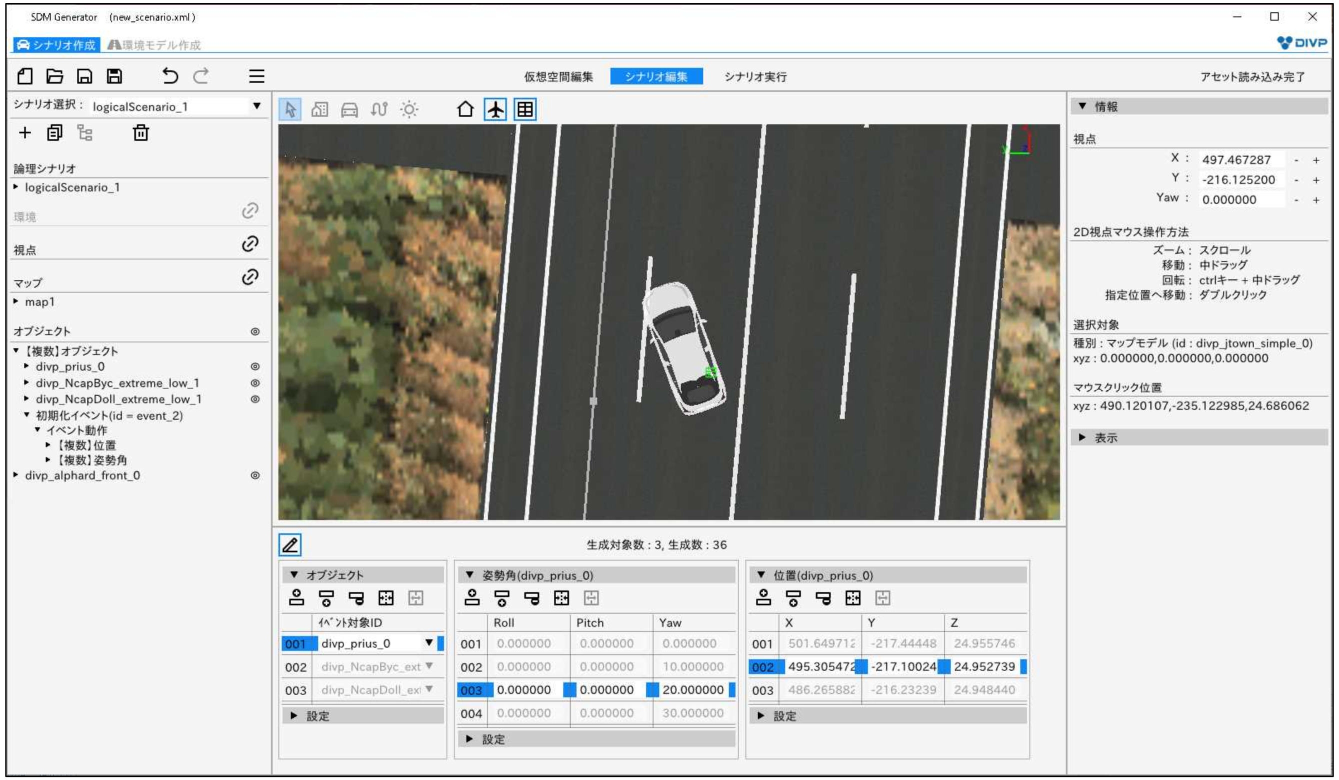
MITSUBISHI PRECISION CO.,LTD.

Import

Environment Model
- OpenDRIVE
- FBX

Scenario
- OpenSCENARIO
- running data

SDM Generator



Export
- OpenDRIVE
- FBX
- DIVP® Material
- DIVP® Assets
- OpenSCENARIO
- DIVP® Scenario

Sim
- DIVP® Simulator
- Other simulators

Source : MITSUBISHI PRECISION CO.,LTD.

DIVP

Outcome

I	■ "Scenario package" for sensor validation
II	■ Space and sensor model highly consistent with actual phenomena
III	■ Measurement and validation methods that support consistency
IV	■ Scenario DB for sensor validation
V	■ Platform with standard I/F and connectivity to diverse assessment environments

Simulation modeling predicated on mathematical model based on principles. Consistency verification was carried out by comparing experiment and simulation in sensor output.

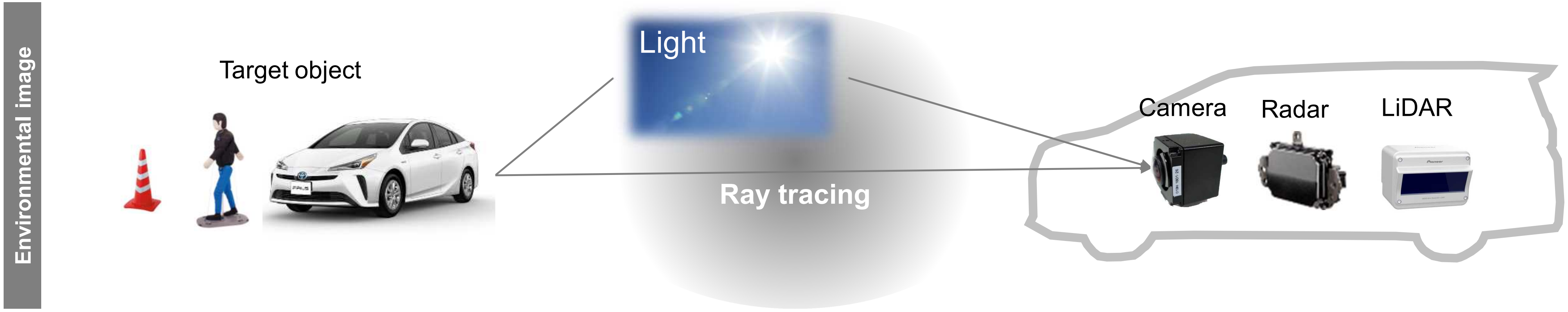
Modeling approach

Steps	Details of implementation	Implementation step
Step1	■ Real physics modeling ✓ Mathematical modeling of physical phenomena in the real world ✓ interface design	Understanding the principles of each sensor Function assignment for each part interface design
Step2	■ Real physics based simulation model ✓ Simulation modeling of mathematical model ✓ Design Competitive Advantage	Design the simulation model DIVP® Design for Advantage
Step3	■ Verification & Validation ✓ Verifying Virtual vs Real Consistency ✓ Verification of extrapolability based on Verified modeling	Basic operation verification Extended operation verification

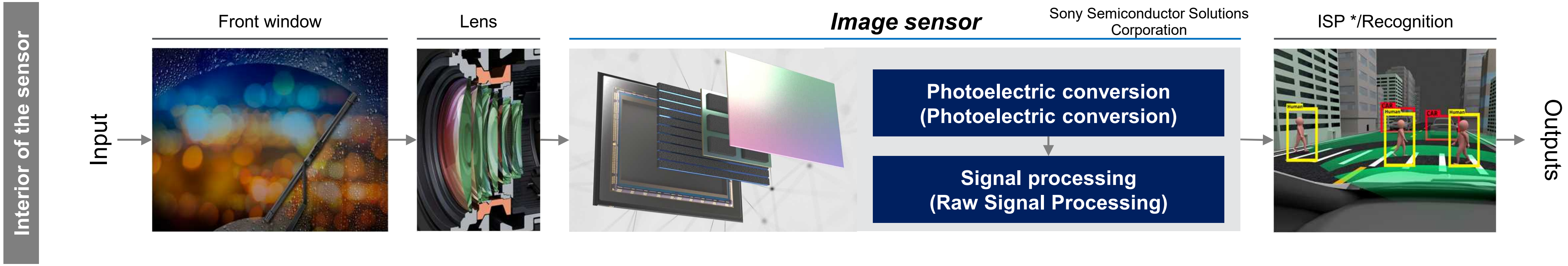
Virtual modeling of physical phenomena is based on sensor detection principle and modeling of image. Sensor interior is virtualized for precise perceptual output.

Example of Camera Detection Principle

HITACHI Inspire the Next　Sony Semiconductor Solutions Corporation　DENSO　SOKEN　Pioneer



In addition, the sensor interior is precisely virtualized for precise perceptual output.



* Image Signal Processor

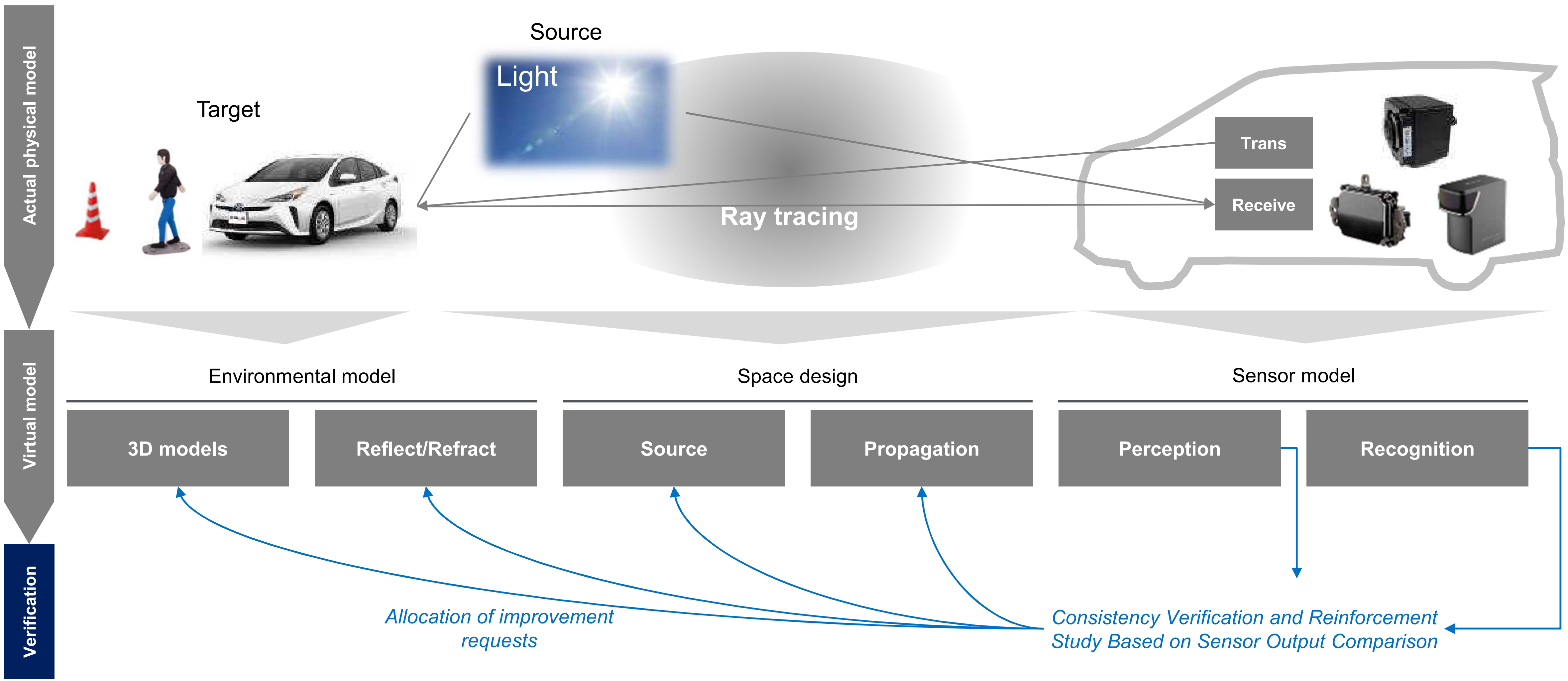
Source : , MITSUBISHI PRECISION CO.,LTD., SOKEN, INC, Sony Semiconductor Solutions Corporation

DIVP

Model modeling was conducted based on principle of sensor detection and physical phenomena, and consistency was verified by matching with the actual vehicle test results.

Verification Efforts

Sony Semiconductor Solutions Corporation



Source : DENSO, INC, HitachiAutomotiveSystems, INC, PIONEER SMART SENSING INNOVATIONS CORPORATION

Outcome

I	"Scenario package" for sensor validation
II	Space and sensor model highly consistent with actual phenomena
III	Measurement and validation methods that support consistency
IV	Scenario DB for sensor validation
V	Platform with standard I/F and connectivity to diverse assessment environments

II → Camera / Radar / LiDAR

- Camera
- Radar
- LiDAR

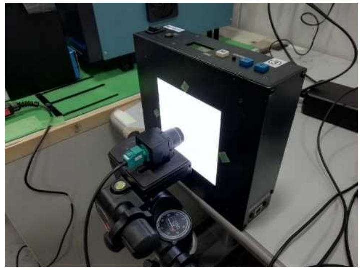
[Camera Consistency Verification] By shifting indoor validation environment, proving ground, and general road environment, error factors are clarified and accuracy improved

Consistency Verification Flow of Camera Perceptual Output

Sony Semiconductor Solutions Corporation

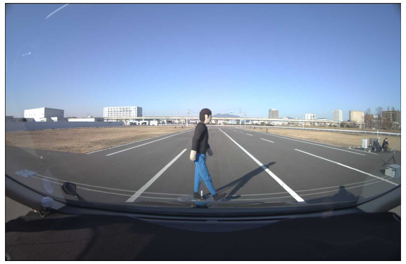
① Camera perception model simplex verification - Indoor Assessment Environment

- Verification of a single camera physical model using a light source capable of measuring spectroscopy and luminance, and a subject



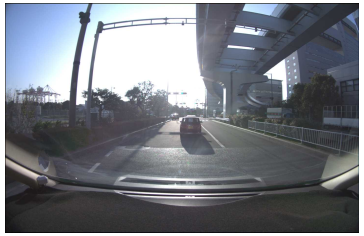
② Camera perception model + Environment model verification - Proving Ground Environment

- Validity verification of various assets and spatial drawing settings in a proving ground environment where environmental conditions can be easily set
- Feedback to the environmental model part by factor separation with the camera perception model



③ Camera Perception Model + Environment model verification - General road environment

- Various asset settings based on the general road environment, validation of malfunctions (Backlight, bad weather, etc.),
- Feedback to the environmental model part by factor separation with the camera perception model

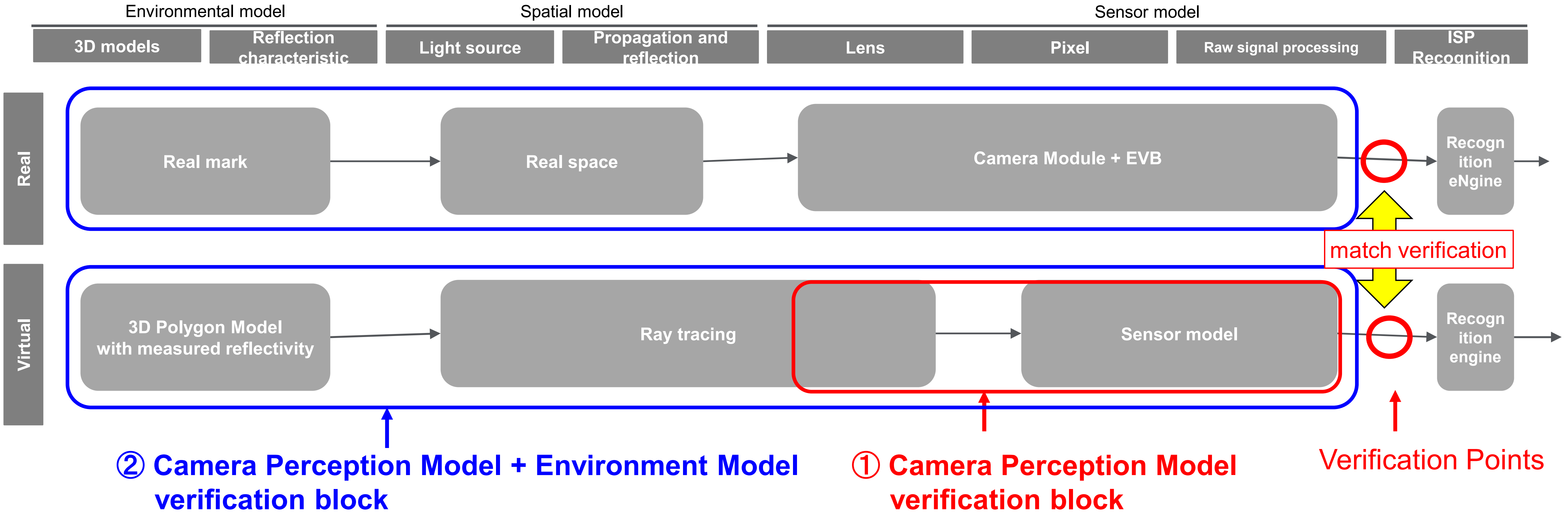


[Camera Consistency Verification] By comparing camera's perceptual output, scenes and places causing differences are identified, and factors are fed back for improvement.

Sony Semiconductor Solutions Corporation

Process Flow of Real Machine Photographing and Simulation in Consistency Verification

- Comparing sensor model output results with actual camera shooting results using RAW data
- Compare the data to identify the scene where the difference occurs, where it occurs, and what causes it.

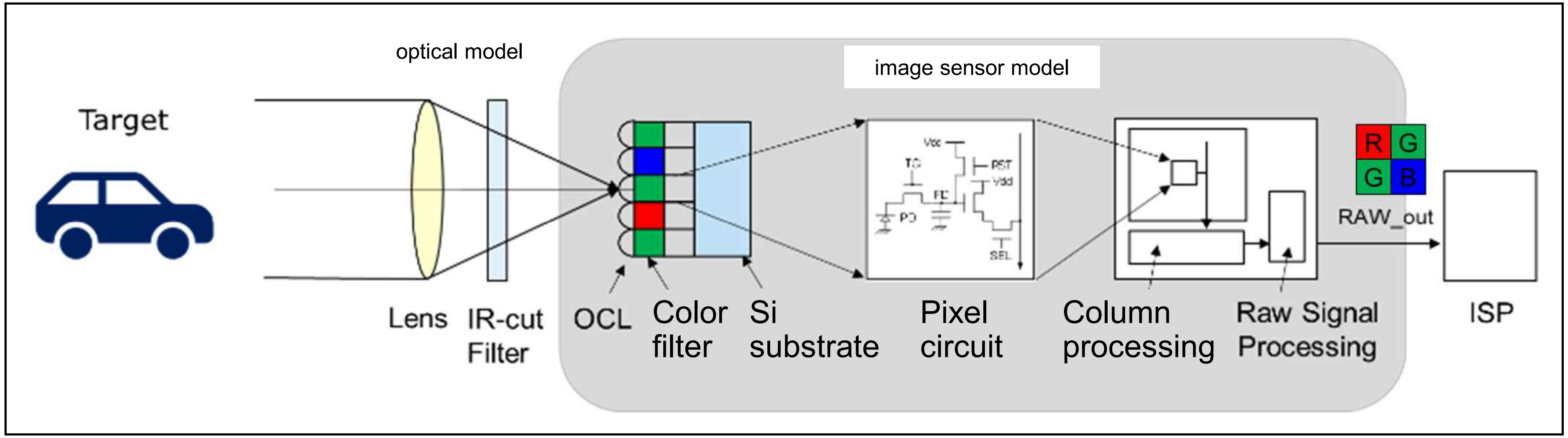


DIVP

[Camera Consistency Verification]During consistency verification, factors that cause errors are extracted and consistency verification is conducted based on these factors.

Configuration of Camera Perception Model and Error Factors

Sony Semiconductor Solutions Corporation



	Input	OCL (On Chip Lens)	Color Filter	Si substrate	Pixel circuit	Column processing	RAW Signal Processing
Error factor	■ Spectroscopy ■ Projection data ■ Shading	■ Light collection factor	■ Spectroscopic property	■ Quantum efficiency ■ Noise	■ In-pixel circuit	■ Analog gain	■ HDR Synthesis
Error affected area	■ Color reproduction ■ Pixel misalignment ■ Brightness distribution	■ Brightness	■ Color reproduction	■ Brightness ■ Noise Level	■ Signal level	■ Signal level	■ Halftone expression
Error impact	Large	Small	Large	Large	Small	Small	Large

Source : Sony Semiconductor Solutions Corporation

[Camera Consistency Verification] Perception model is independently verified in indoor environment by comparing measured data with simulation results.

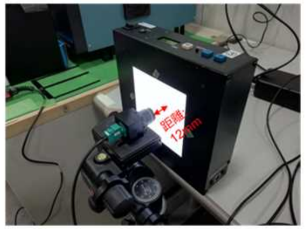
Consistency Verification of Camera Perception Model (Optical Model + Sensor Model)

Sony Semiconductor Solutions Corporation

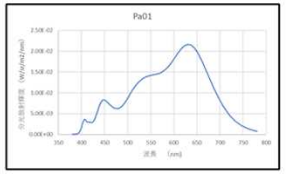
Validation procedure

- Shooting a subject with an actual camera and acquiring RAW data
- Measuring the spectral radiance value of the subject and creating simulation input data based on the measured value
- Execute the simulation (SIM) using the input data and obtain the output results in RAW data format.
- Comparing pixel values for each color R, G, and B of RAW data between the real machine data and SIM results

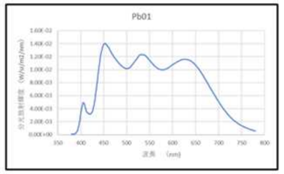
Evaluation with pattern box



3200K

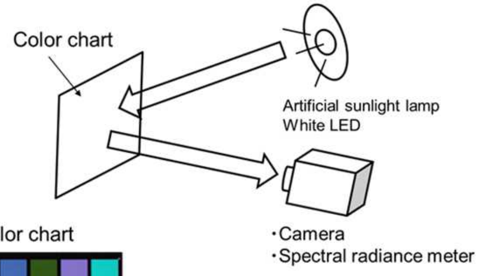


5500K



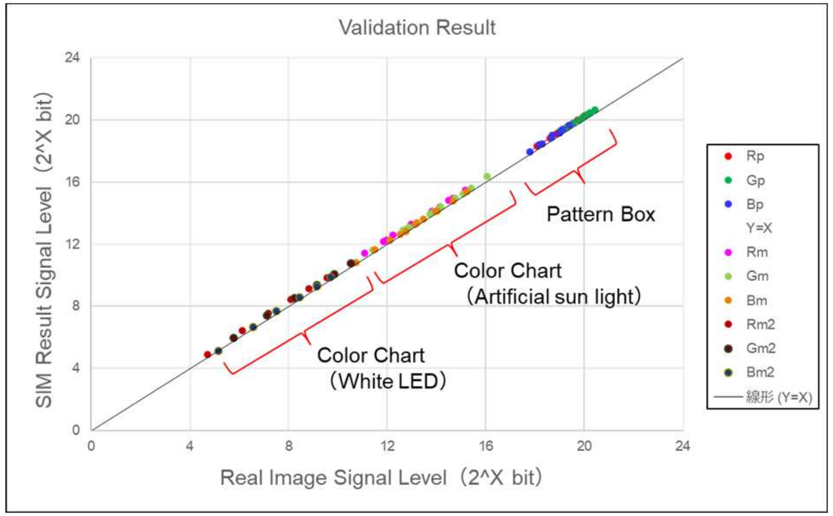
•Evaluation with two different color temperature

Evaluation with color chart



Validation result

- The signal level of each color pixel in RAW data (Bayer array) is compared.
- Check that the difference between low brightness and high brightness region is within about 20%.



[Camera Consistency Verification] Verification is performed in a system that combines camera perception model and environment model in an outdoor environment

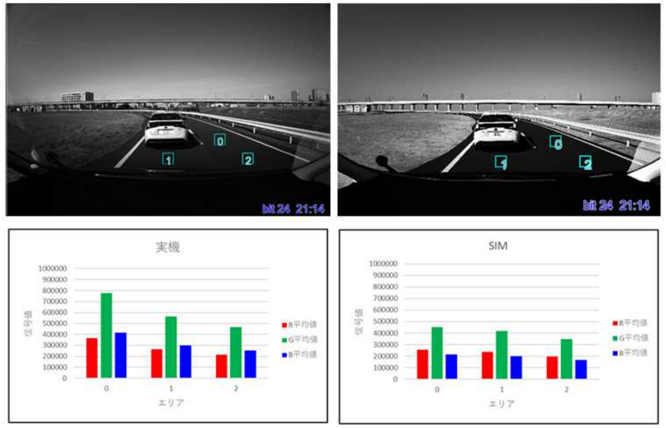
Comparison with Real Equipment - SIM

Sony Semiconductor Solutions Corporation

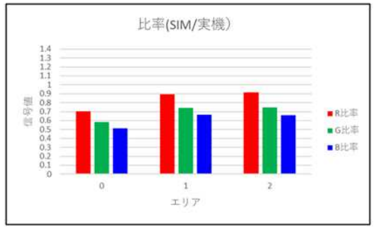
Actual Camera Results (after development)

SIM result (after development)

Image acquired on real camera　　Simulation (SIM) results

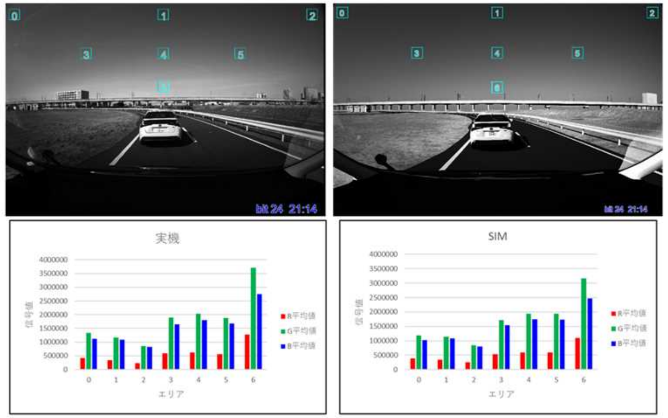


Consistency of asphalt areas (Sim/Real)

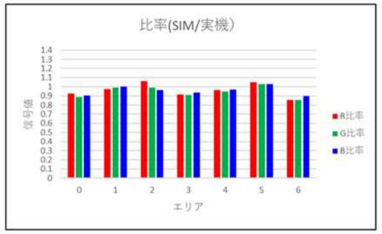


Pixel	Ratio average (SIM / Real)
R	0.84
G	0.69
B	0.61

Image acquired on real camera　　Simulation (SIM) results

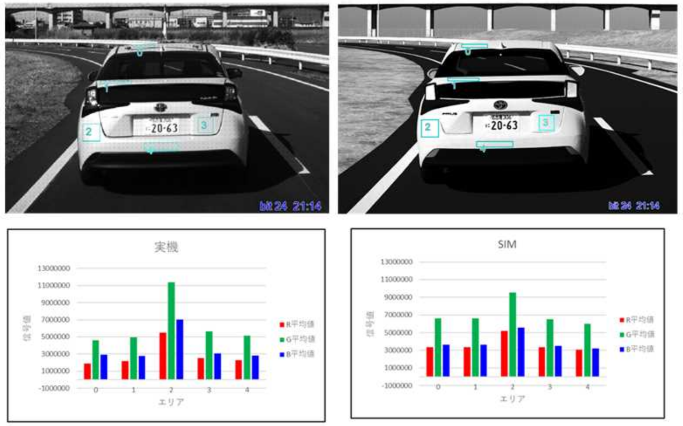


Consistency of sky areas (Sim/Real)

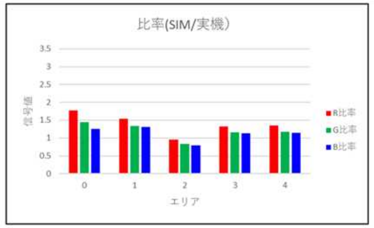


Pixel	Ratio average (SIM / Real)
R	0.96
G	0.94
B	0.96

Image acquired on real camera　　Simulation (SIM) results



Consistency of vehicle areas (Sim/Real)



Pixel	Ratio average (SIM / Real)
R	1.39
G	1.19
B	1.13

Source : Sony Semiconductor Solutions Corporation

validation results: The average value for each asset must be consistent with a difference of approximately 40% or less.

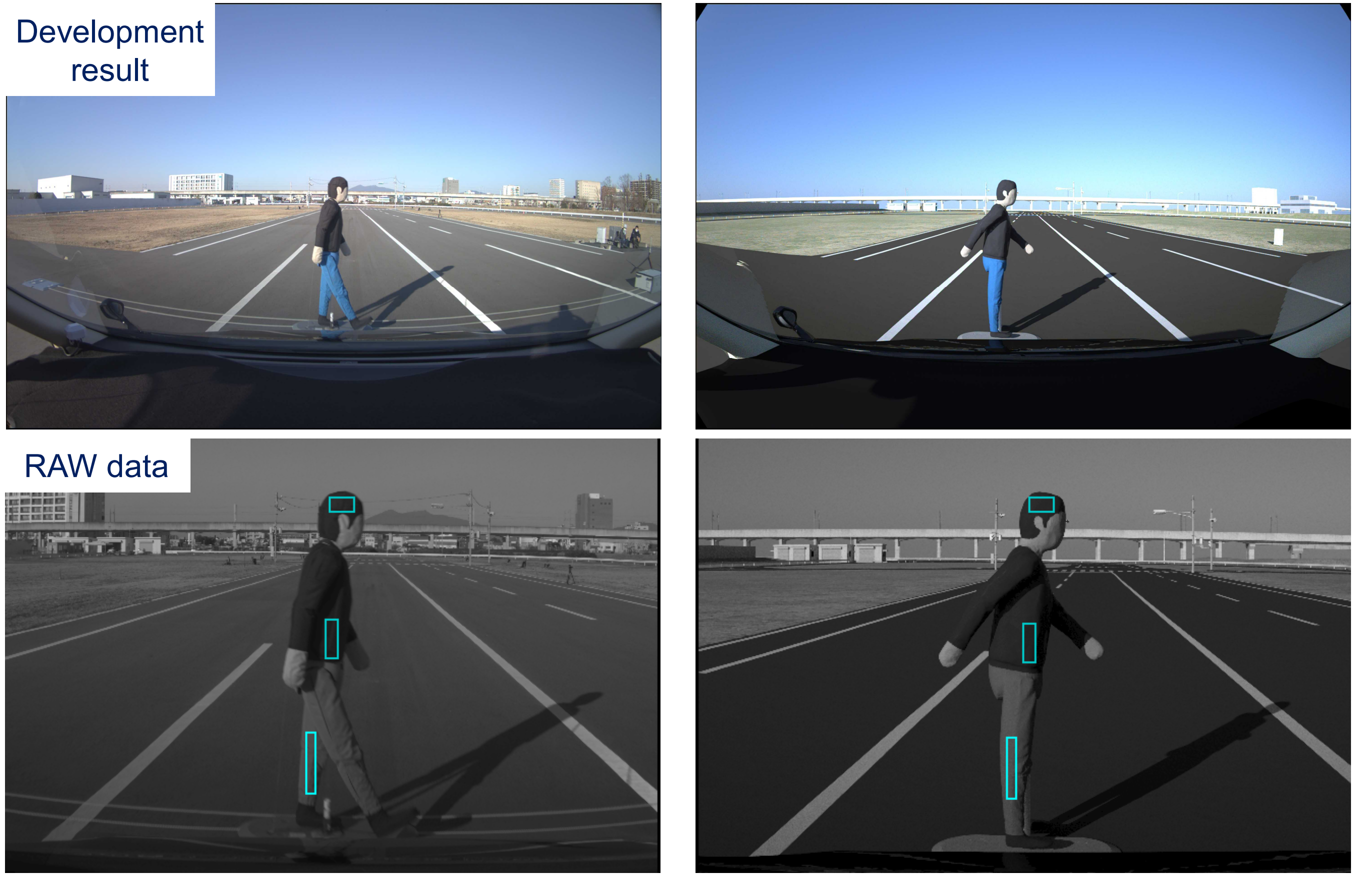
Source : Sony Semiconductor Solutions Corporation

[Camera Consistency Verification]Each part of NCAP pedestrian dummy was verified to ensure consistency of the assessment package.

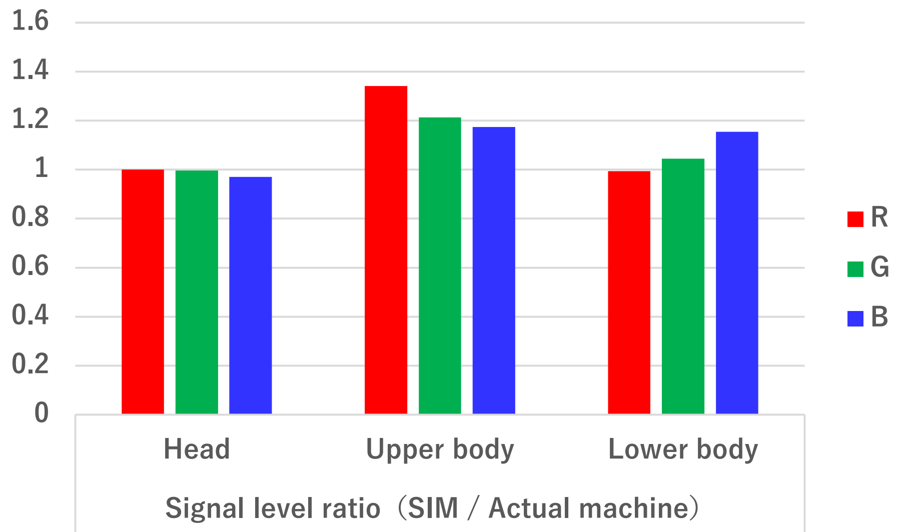
Consistency Verification Result of NCAP Pedestrian Dummy

Sony Semiconductor Solutions Corporation

Results of real machine shooting | SIM Results



Consistency verification result of NCAP pedestrian dummy



validation result

Check that the head, upper body and lower body match within approximately 40%.

[Camera Consistency Verification]　Nighttime NCAP pedestrian dummies and headlight characteristics were verified for each part.

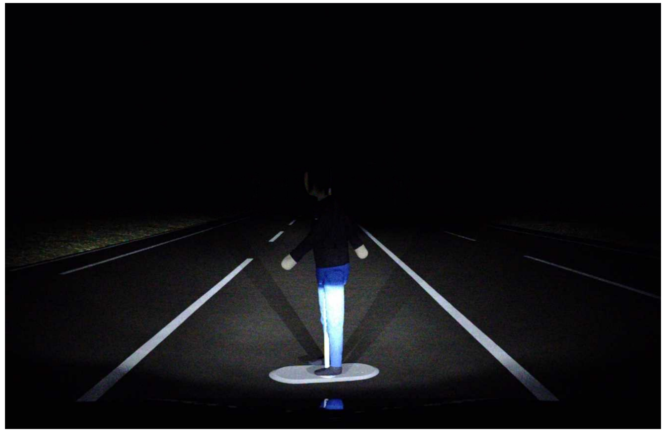
Sony Semiconductor Solutions Corporation

Consistency between NCAP Pedestrian Dummy and Headlight Characteristics Verification Results

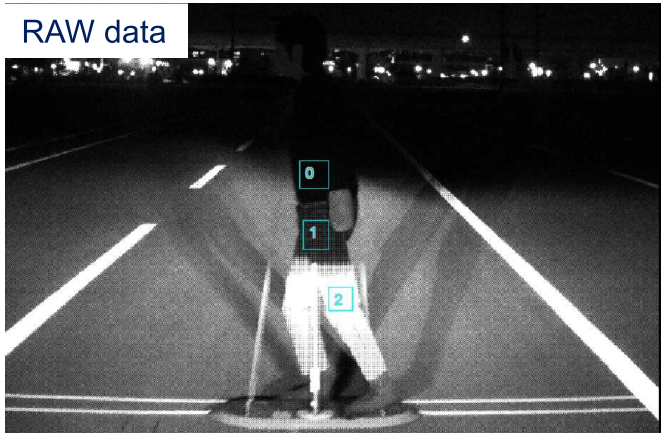
Results of real machine shooting

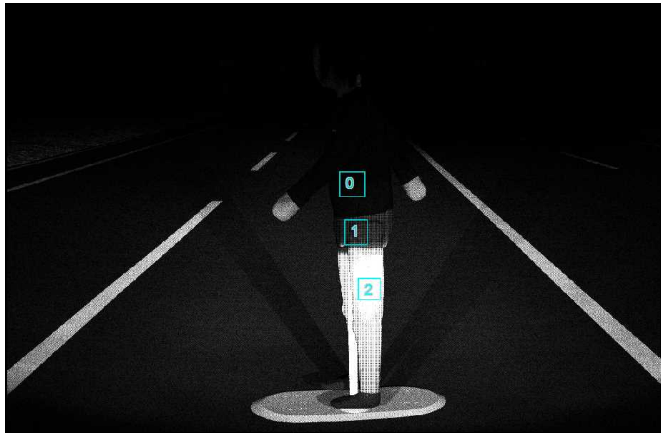
SIM Results

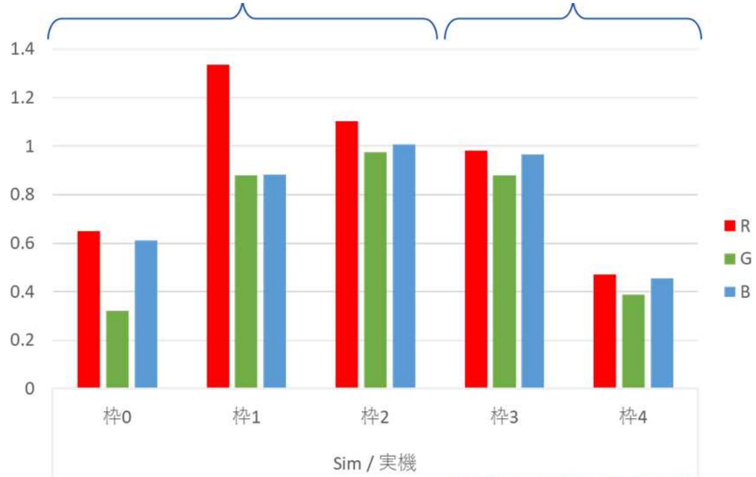
Development result



RAW data







平均値	0.527	1.03	1.03	0.942	0.439

Validation result

The difference between headlight irradiation and non-irradiation areas was about 40%.

Challenge:

The cause of the difference in road surface brightness is being investigated, whether it is due to road surface reflectance data or headlight characteristics.

Source : Sony Semiconductor Solutions Corporation

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[Camera Consistency Verification]Verified road surface model as consistency verification of Odaiba driving scene

Asset Model Verification Example: Odaiba Road Surface Consistency Verification Result

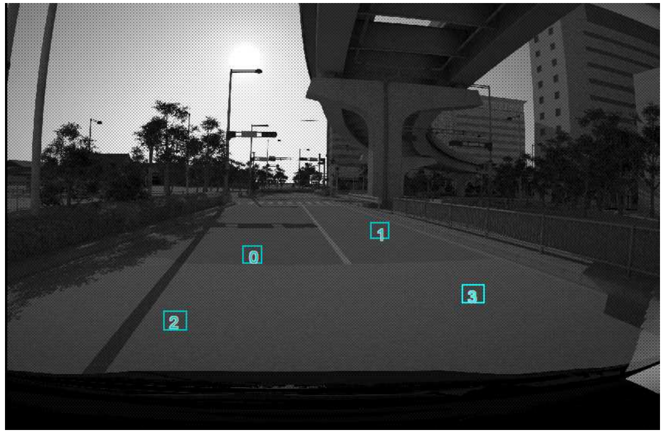
Sony Semiconductor Solutions Corporation

Results of real machine shooting

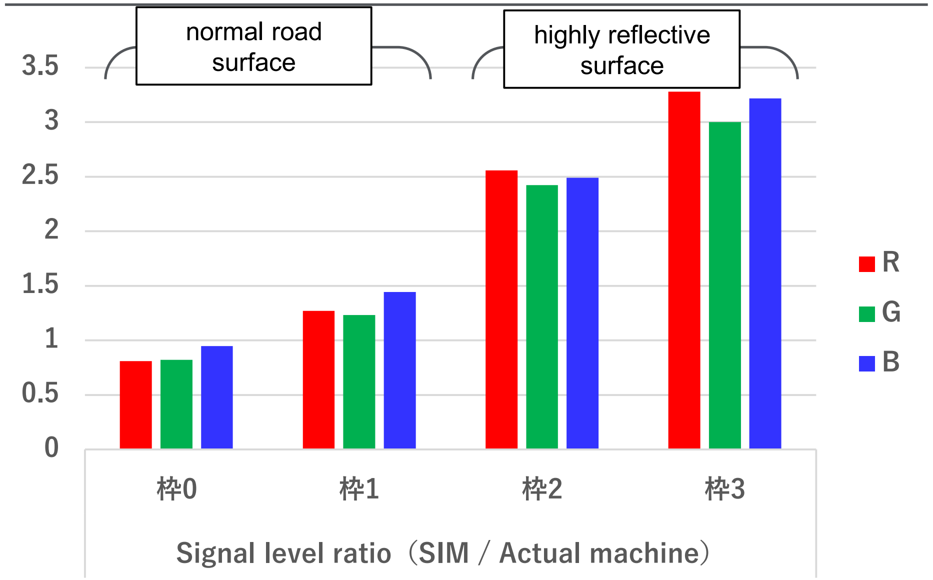
SIM Results

Development result

RAW data



Results of consistency verification of Odaiba driving scene



Validation result

Normal surface:
- Make sure the differences match within about 40%

High reflecting surface (reference):
- Application of reflectance measurement data is not being considered.

Source : Sony Semiconductor Solutions Corporation

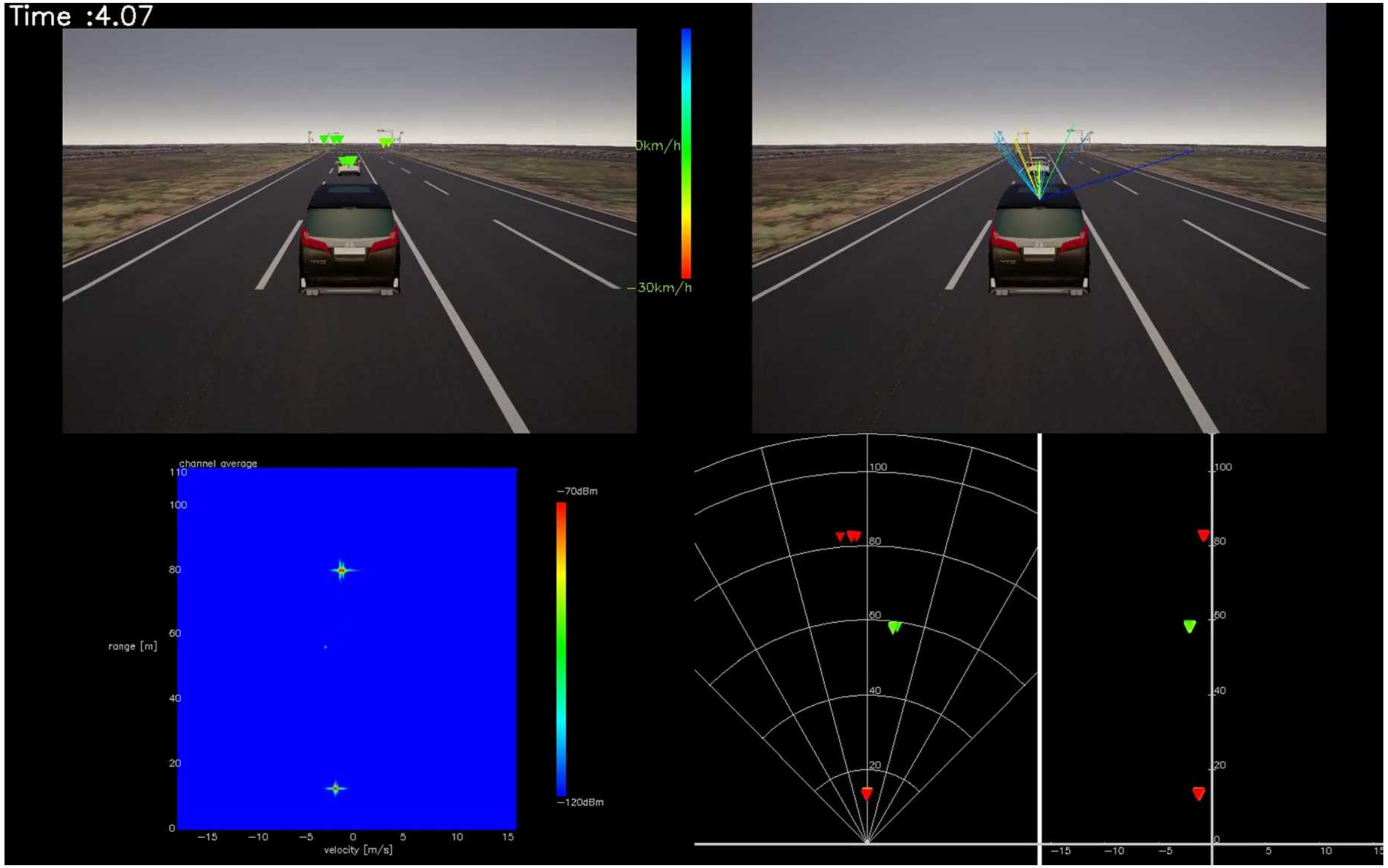
Outcome

- I ■ "Scenario package" for sensor validation
- II ■ Space and sensor model highly consistent with actual phenomena
  - ■ Camera
  - ■ Radar (Perception)
  - ■ LiDAR
- III ■ Measurement and validation methods that support consistency
- IV ■ Scenario DB for sensor validation
- V ■ Platform with standard I/F and connectivity to diverse assessment environments

The implementation of the millimeter-wave Radar model was completed and simulation was sublimated to enable validation of physical phenomena.

Radar Simulation Results

DENSO SOKEN Nihon Unisys, Ltd



Source : SOKEN, INC

DIVP

[Radar modeling] By evaluating the functions of the simulator step by step, each hierarchy (sensor model, asset, Propagation Model) Issues

Consistency Verification

SOKEN Nihon Unisys, Ltd U-shin MinebeaMitsumi Group

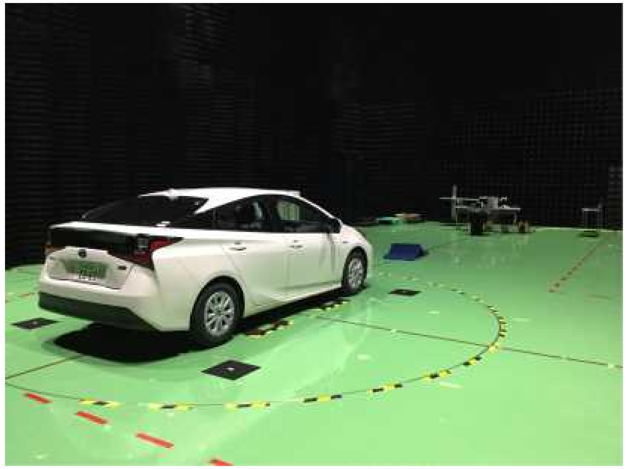
Step	Purpose of the verification	Confirmation characteristic	Validation index
Join Behavior Check	■ Validation of Defined I/Fs and Verification of Perceived Output for Point Wave Sources (Corner Reflectors)	■ Distance, speed, bearing and signal strength	■ Distance, speed, direction and signal strength in anechoic chamber
		■ antenna directivity and circuit noise	■ Direction dependence of signal intensity and signal intensity distribution of noise
		■ Emblem Error	■ azimuth measurement error
Pre-verification (Stationary Objects)	FY 21 Scope ■ Verification of basic single targets (Prius, NCAP dummy persons, bicycles)	■ Reflection intensity and reflection point distribution	■ Orientation Dependence of Reflection Intensity and Reflection Point Distribution
		■ Multipath due to road surface	■ Distance dependence of corner reflector signal intensity
Basic verification (Movable Objects)		■ Micro doppler	■ Signal Strength Distribution in the Speed Direction by Pedestrian Swing and Tire Rotation
		■ azimuthal separation capability	■ Increase in the number of antennas and azimuth separation capability by MIMO
Failure reproduction Verification	■ Verification of spatial attenuation due to rainfall and clutter generation due to raindrop scattering ■ Examination of snow effect, snow road surface clutter	■ rain attenuation	■ Spatial attenuation relative to precipitation
		■ rain scattering	■ Raindrop shape distribution and clutter distribution
		■ Snow attenuation, road clutter	■ Spatial attenuation, clutter intensity and distribution for snowfall
Scalability verification	■ Verification in actual traffic environment ■ Verification of targets (manholes and corrugated cardboard) that are prone to false detection and non-detection by millimeter-wave radar	■ Reflection intensity and reflection point distribution of peripheral structure	■ Signal intensity distribution for distance, speed and direction of tunnels and overpasses
		■ Multipath with Tunnel Walls	■ Occurrence of ghosts on overtaking vehicles

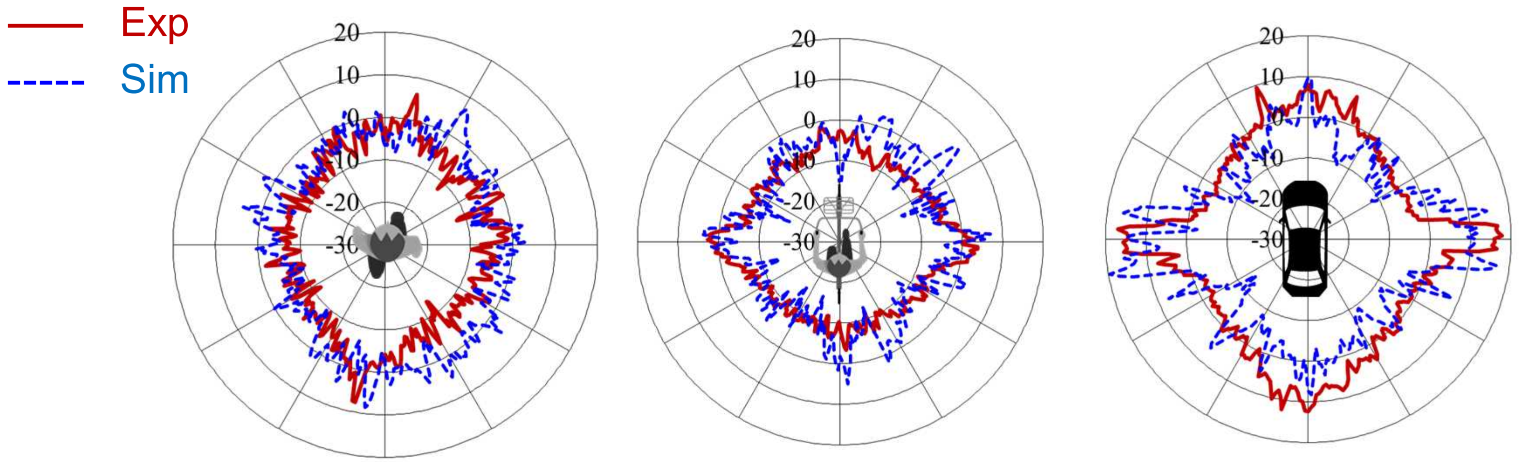
Average RCS in horizontal plane confirmed to match of approximately 3 dB or less.
Consistency of detailed angular characteristics remains an issue.

Angular Characteristics of Radar Cross Section

SOKEN

Test environment	Test Results





in-plane average [dBsm]	NCAP Doll		NCAP Bicycle		Prius	
	-5.3	-2.3	-6.2	-5.3	1.59	-1.0

Source : SOKEN, INC

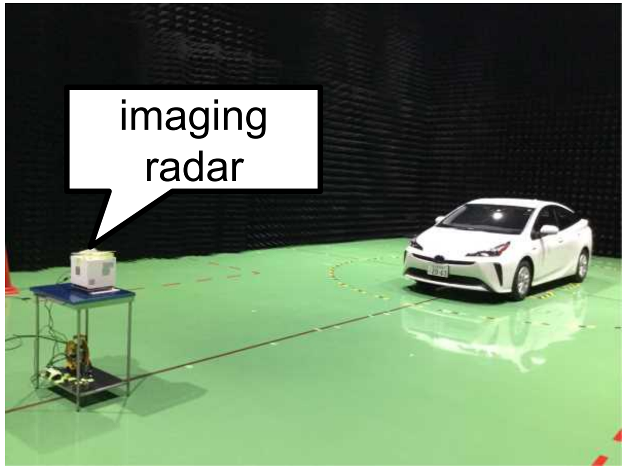
DIVP

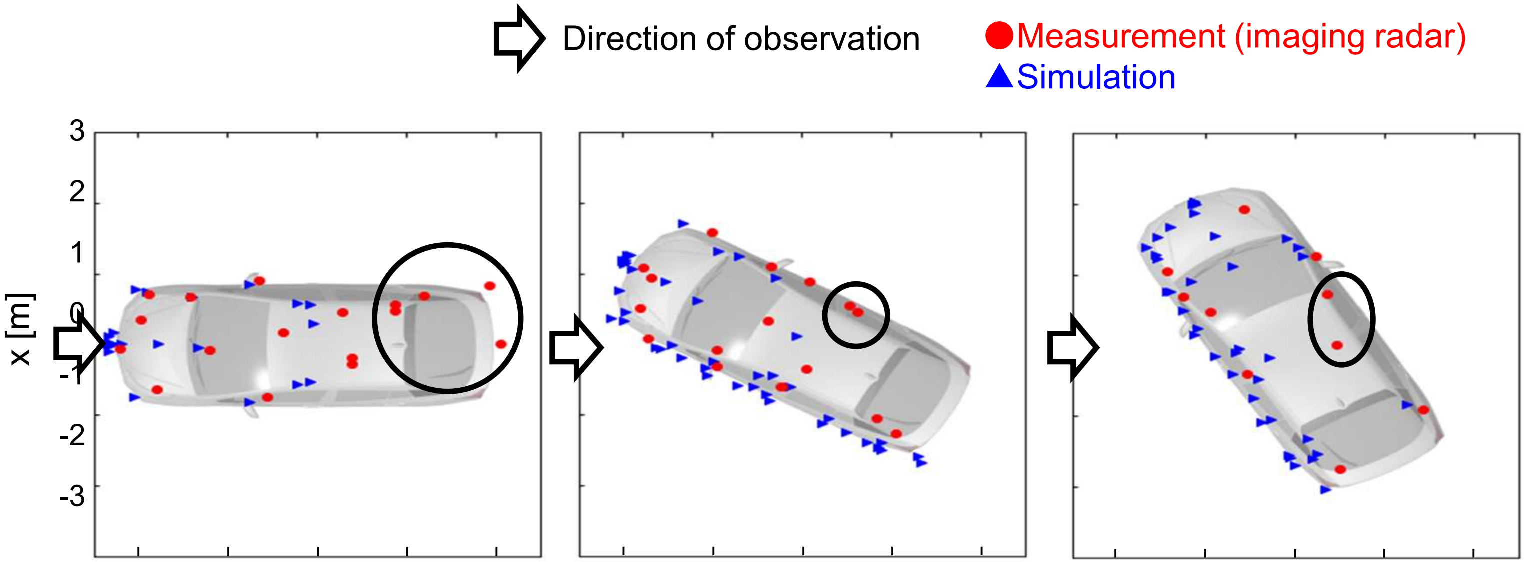
confirmed to match of approximately 0.2m or less.
Discrepancy of reflection points on the far side with respect to the direction of observation is an issue.

Angular Characteristics of Reflection Point Distribution

SOKEN

Test environment	Test Results



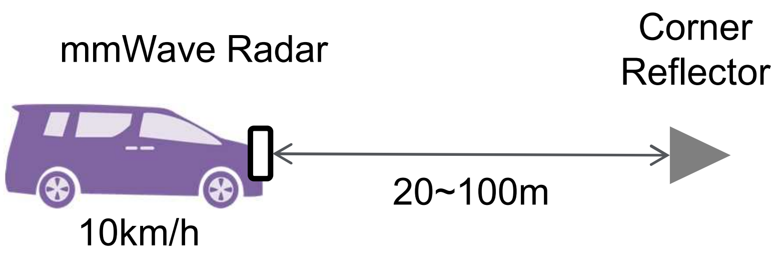


The Received signal strength varied with distance and the maximum peak level error was confirmed less than 5 dB.
Differences in depth of depression of received strength is an issue.

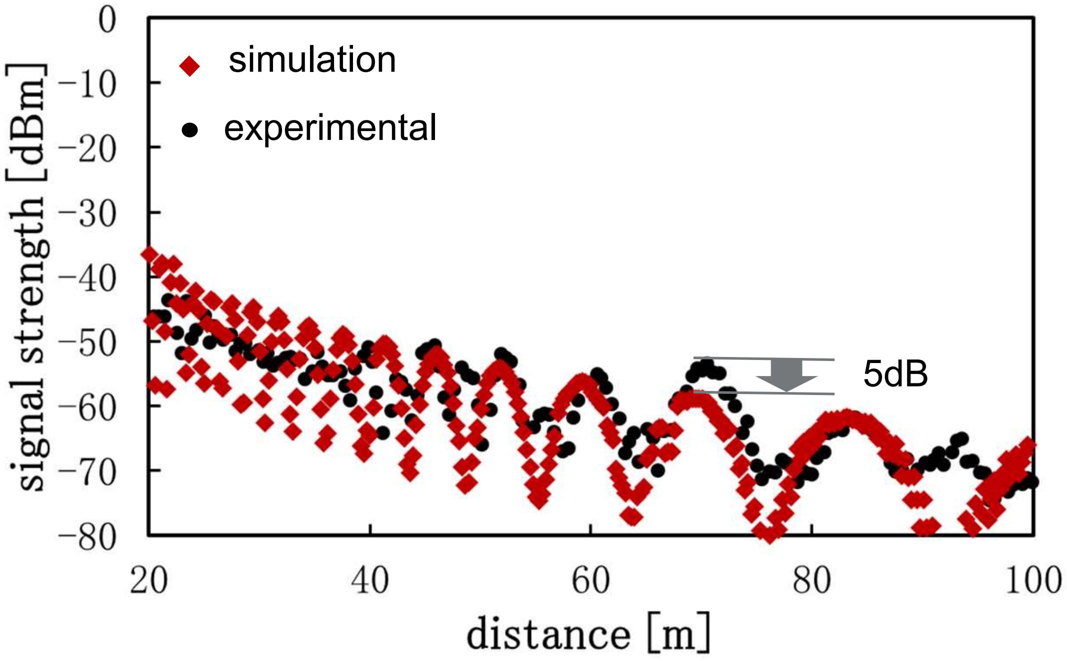
SOKEN

Multipath fading due to road surface

Test environment



Test Results

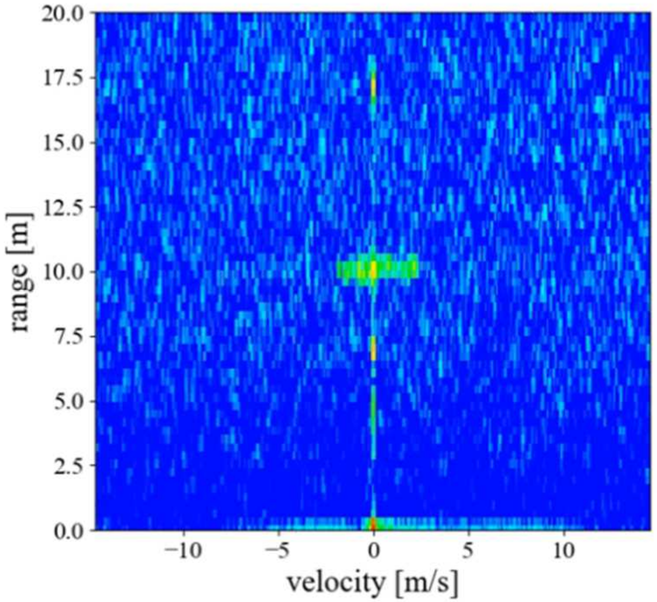


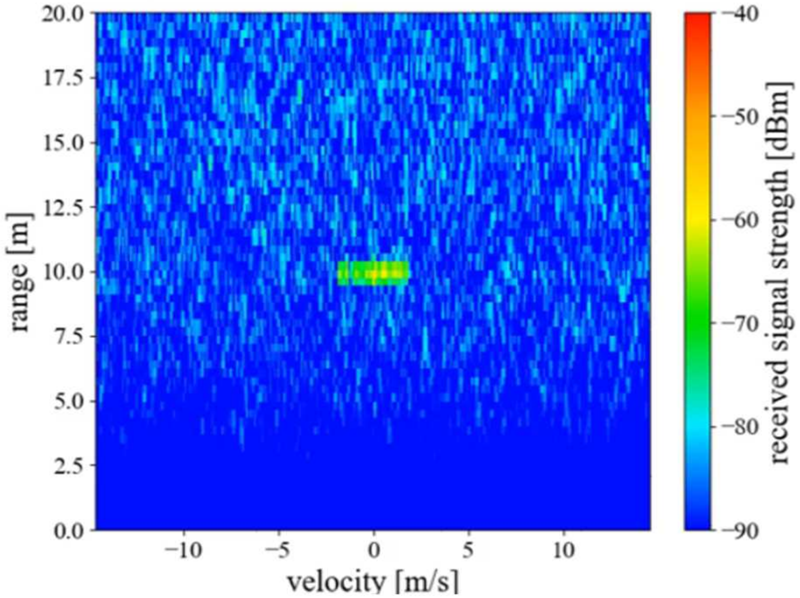
A pedestrian motion model was constructed.
The consistency of micro doppler pattern in Range-Velocity Map was confirmed.

SOKEN

Micro doppler (Pedestrian Walk Cycle)

Test environment	Experimental Result	Simulation Result





Source : SOKEN, INC

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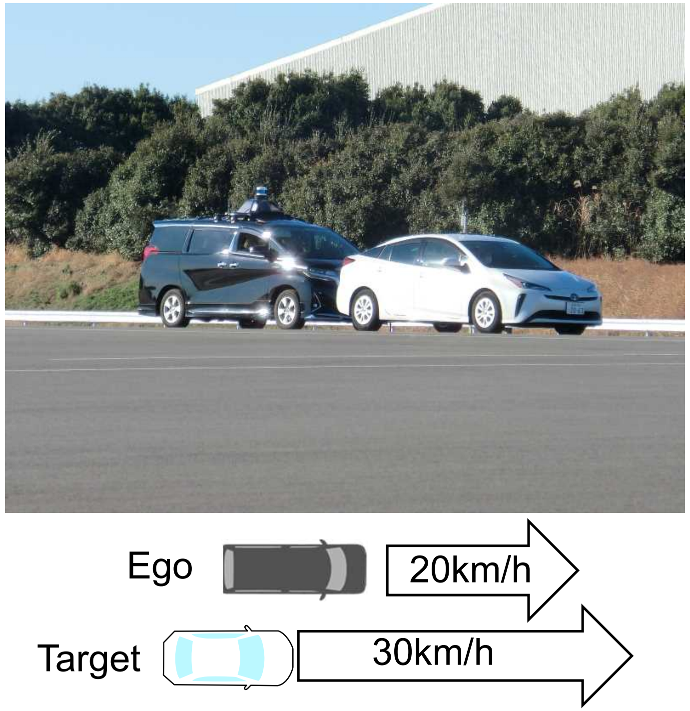
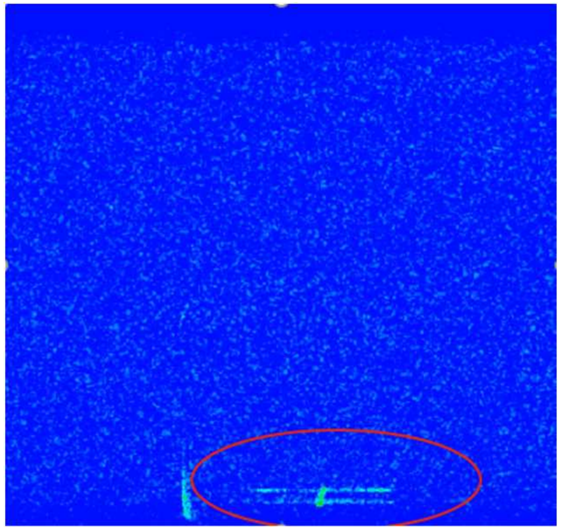
A rotational motion model of wheels was designed.
The consistency of micro doppler pattern in Range-Velocity Map was confirmed.

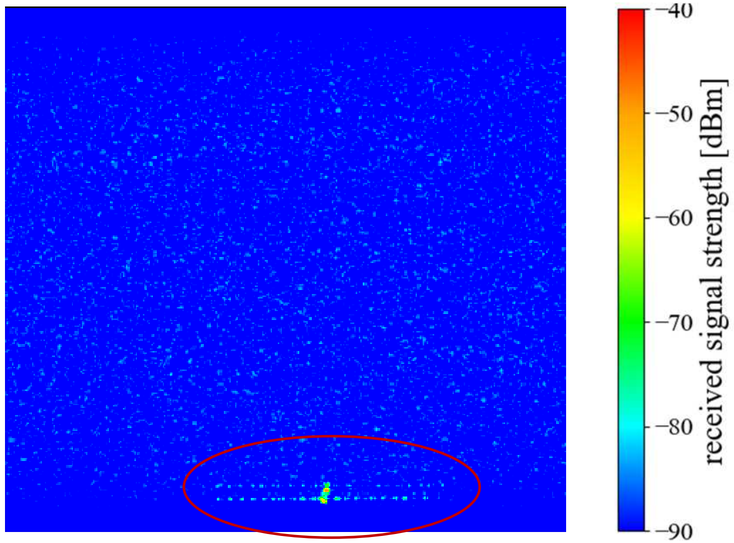
SOKEN

Micro doppler (Wheel Rotation)

Test environment	Experimental Result	Simulation Result



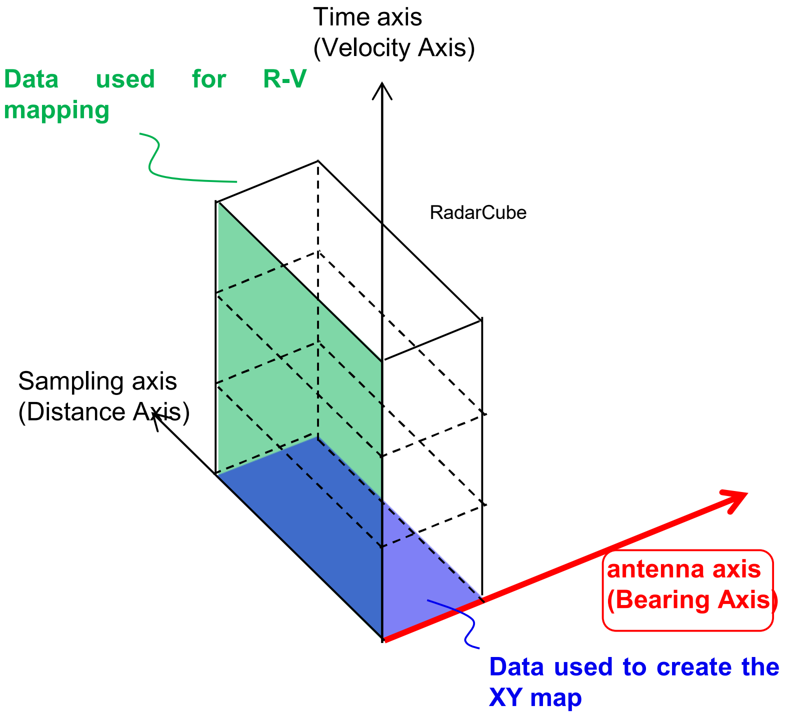




In order to improve the azimuth separation performance, radar technology was updated to recent trend technology.

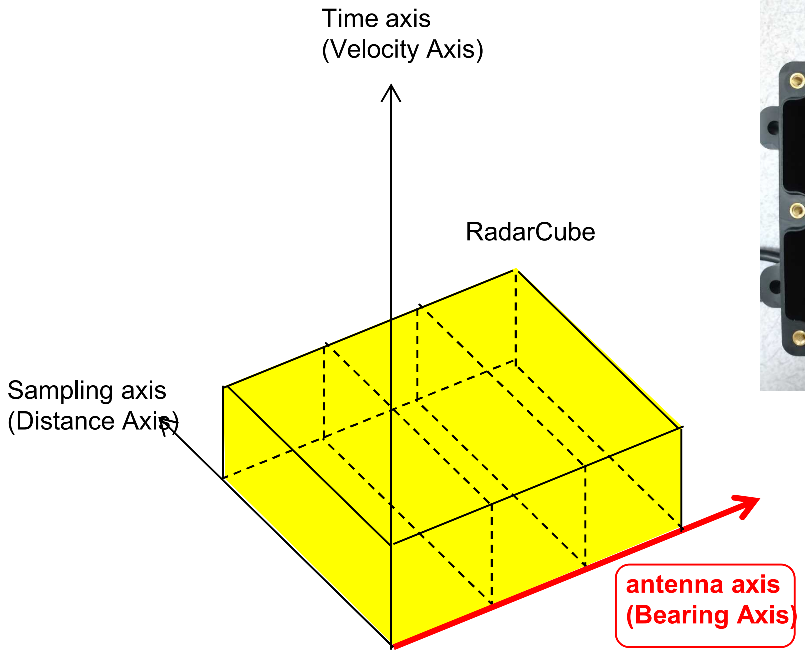
A new Radar Sample (NXP) with MIMO Function was Launched and Signal Processing was also Modified.

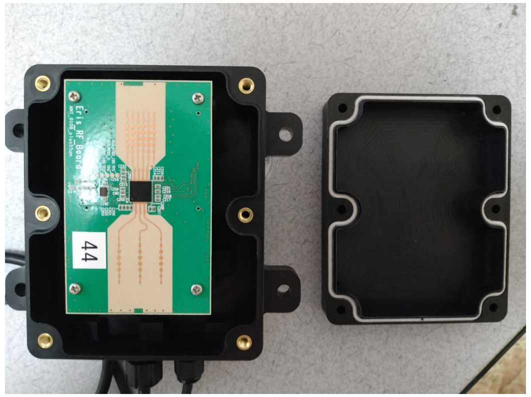
DIVP® Radar Technology until last year



- The volume of the measured data (RadarCube) is slightly small.
  ADC Sampling Frequency = 12.5 or 6.25 Msps
- Virtual Antennas = 1 x 4 = 4 (non-MIMO)
- 3D RadarCube to 2D signal processing

Updates made this year



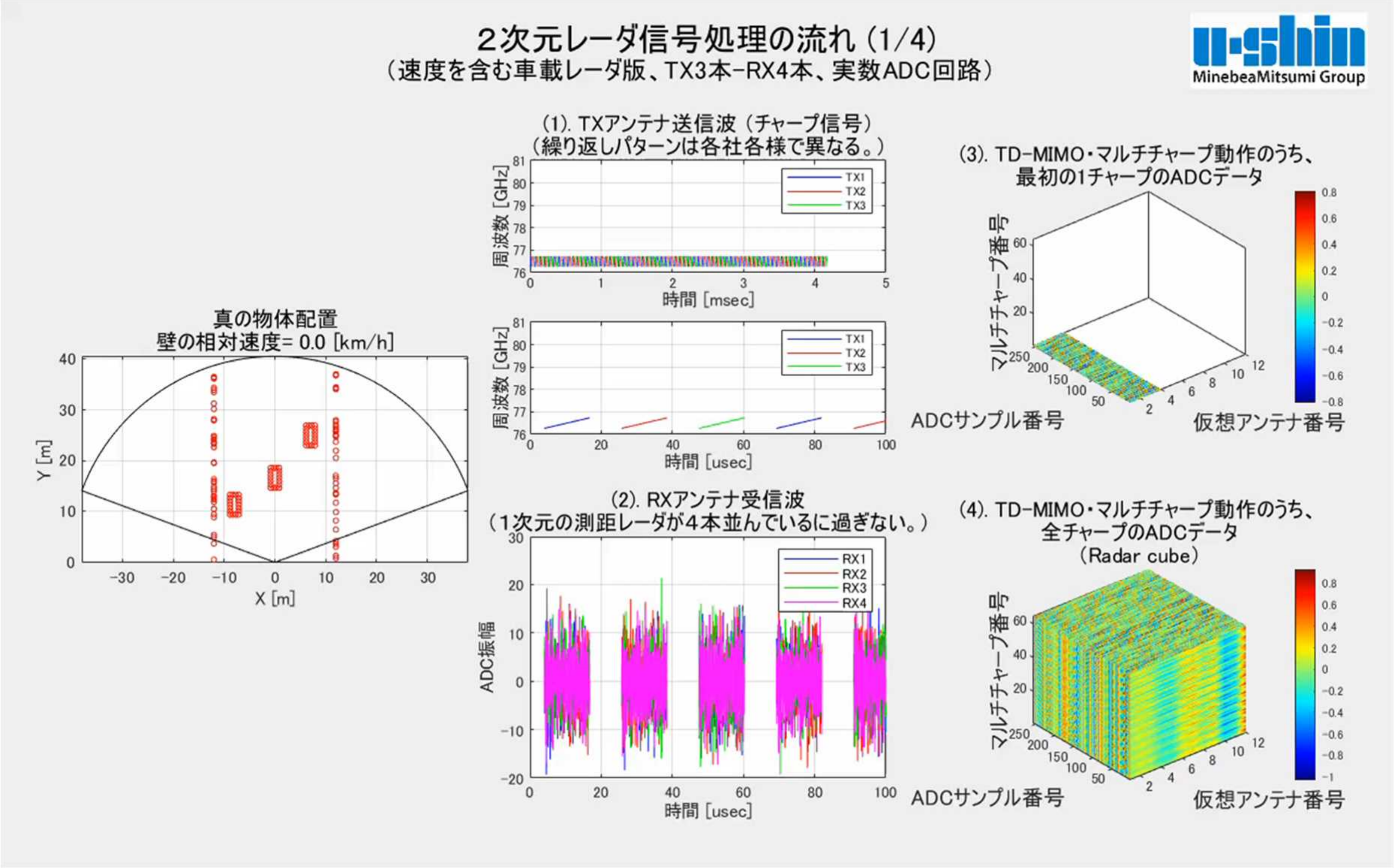


- The volume of the measured data (RadarCube) was enlarged.
  ADC Sampling Frequency = 20 Msps
- Virtual Antennas = 3 x 4 = 12 (MIMO)
- 3D RadarCube can be converted to 3D signal processing (peak search)

Source : U-Shin Ltd.

In order to improve the azimuth separation performance, the radar technology was updated to recent trend technology.

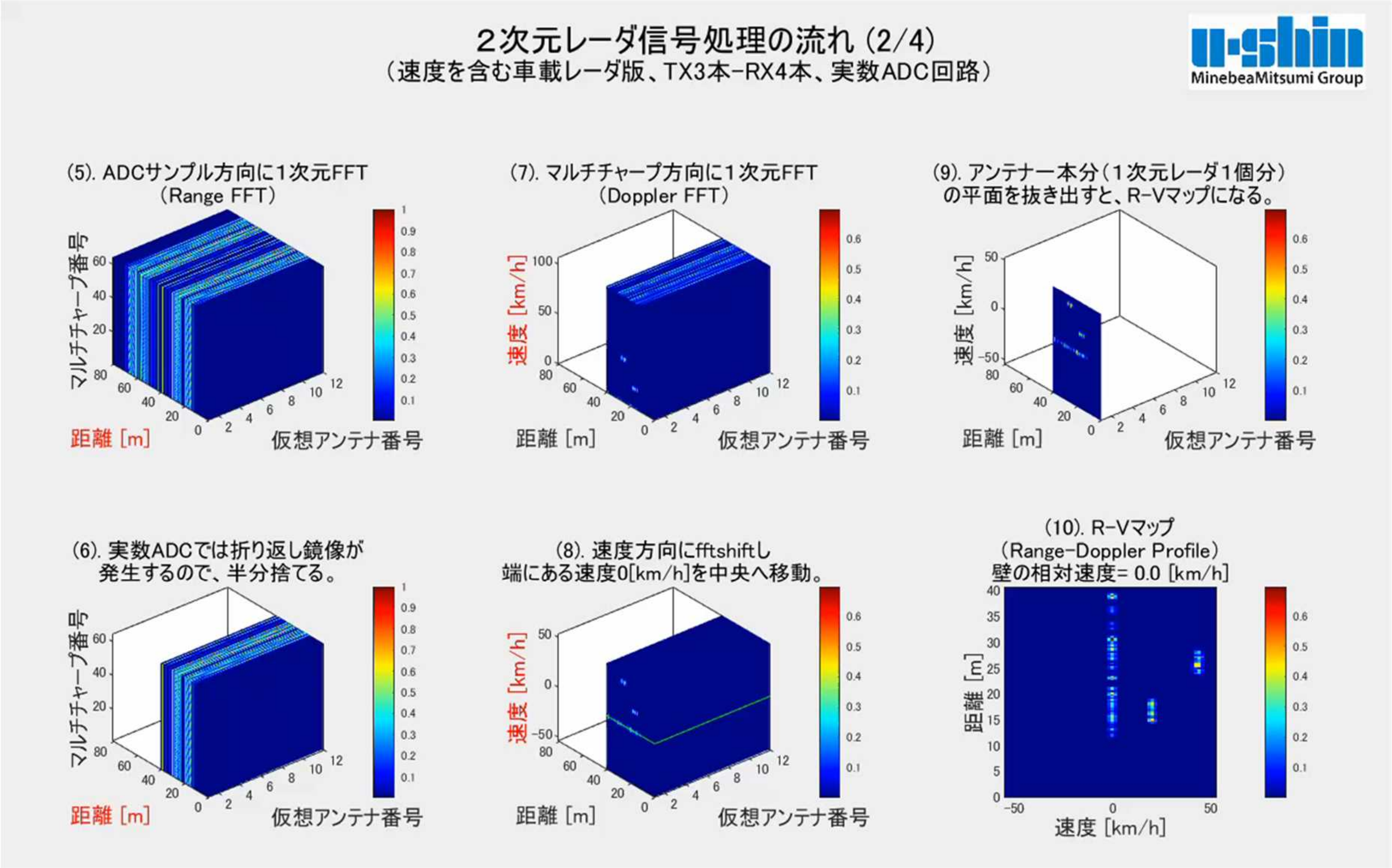
Flow of 2D radar signal processing(1/4)



Source : U-shin ltd.

In order to improve the azimuth separation performance, the radar technology was updated to recent trend technology.

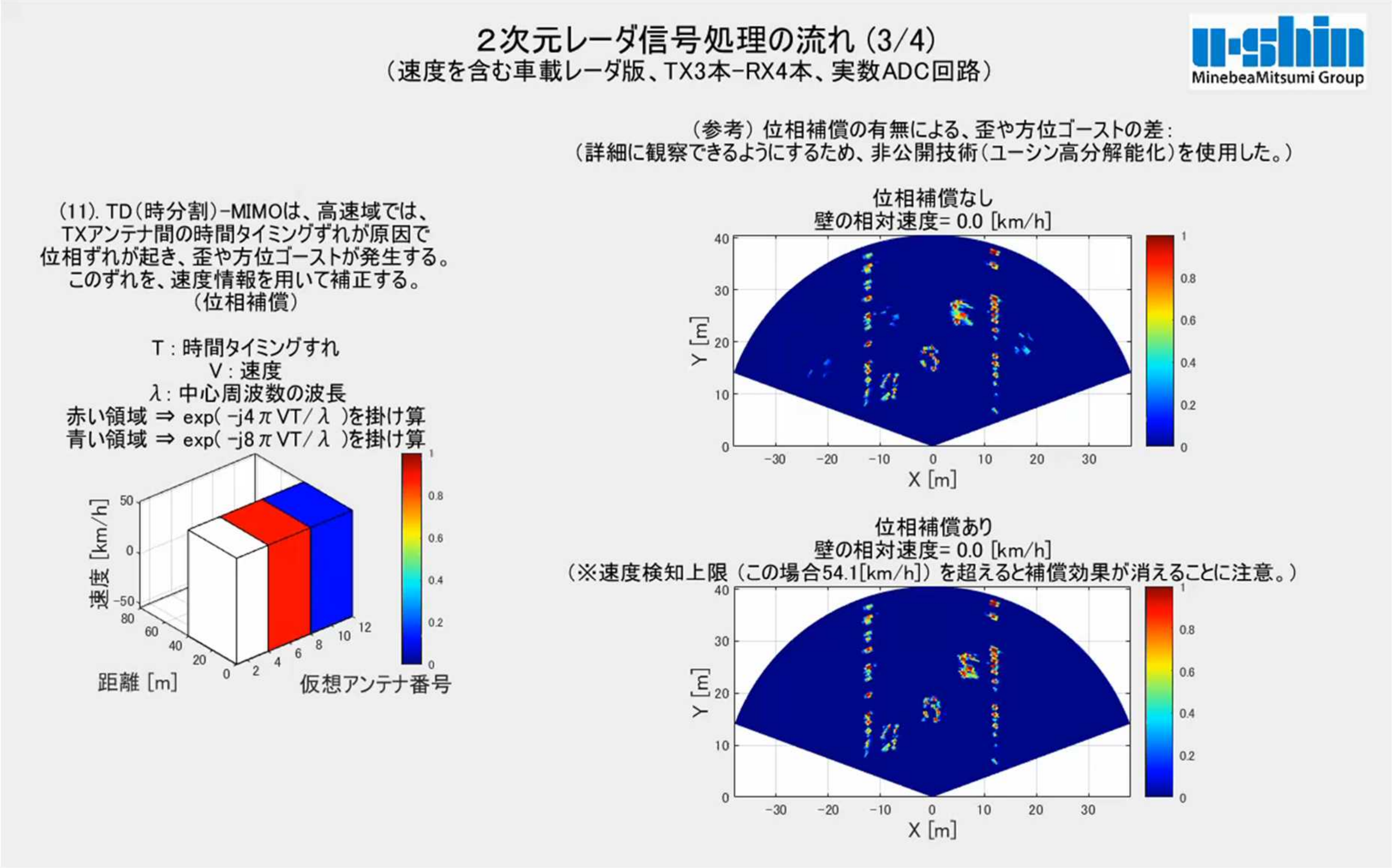
Flow of 2D radar signal processing(2/4)



Source : U-shin ltd.

In order to improve the azimuth separation performance, the radar technology was updated to the trend technology.

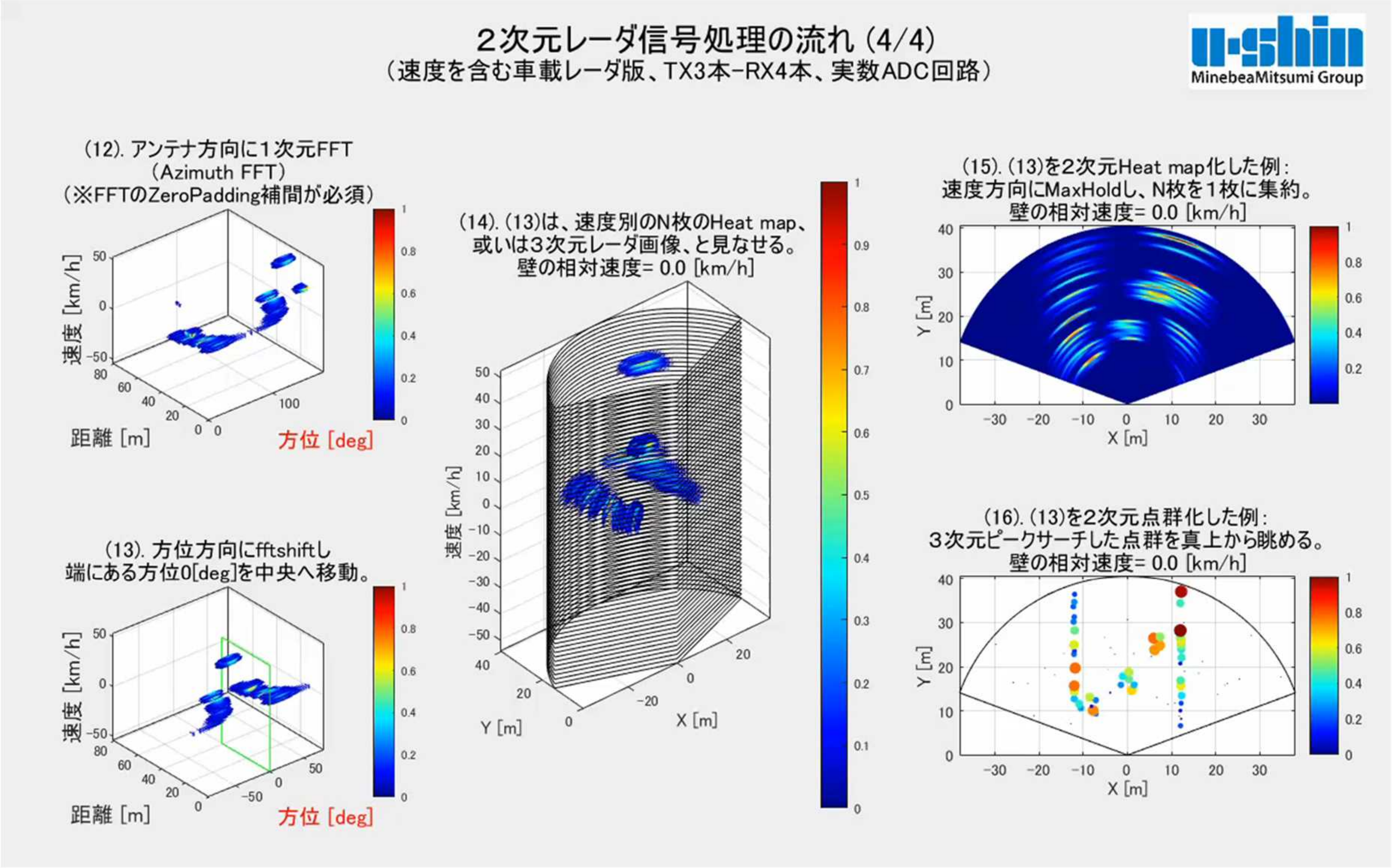
Flow of 2D radar signal processing(3/4)



Source : U-shin ltd.

In order to improve the azimuth separation performance, the radar technology was updated to recent trend technology.

Flow of 2D radar signal processing(4/4)

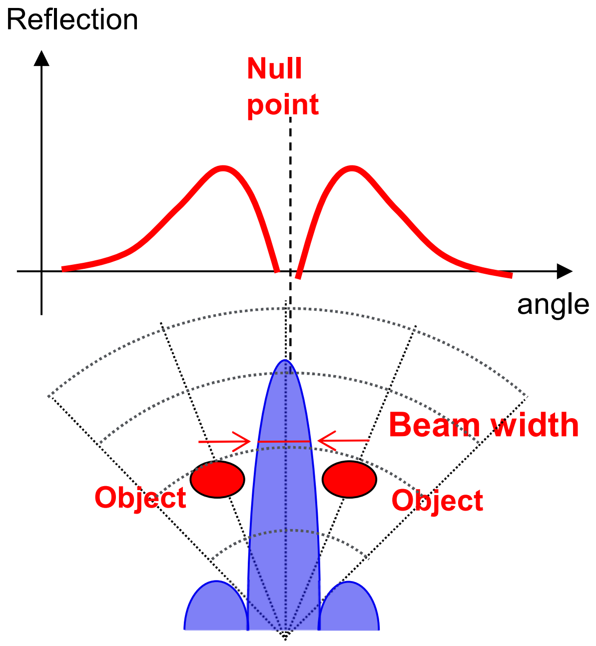


Source : U-shin ltd.

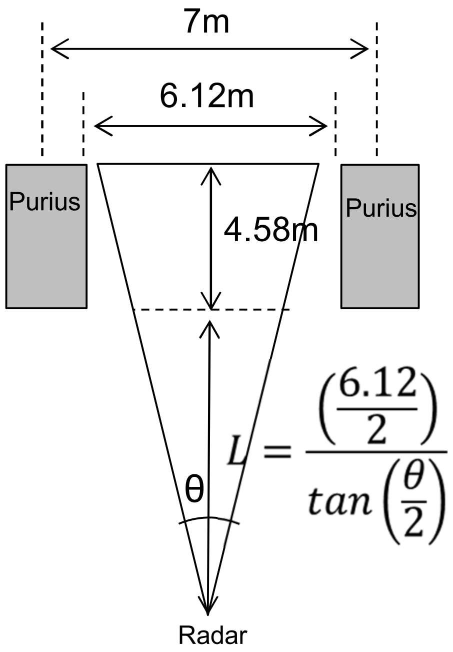
DIVP

As a result of the basic experiment at jTown, it was confirmed that the azimuth separation performance was improved by MIMO.

Definition of direction separation function, estimated distance limit, test result



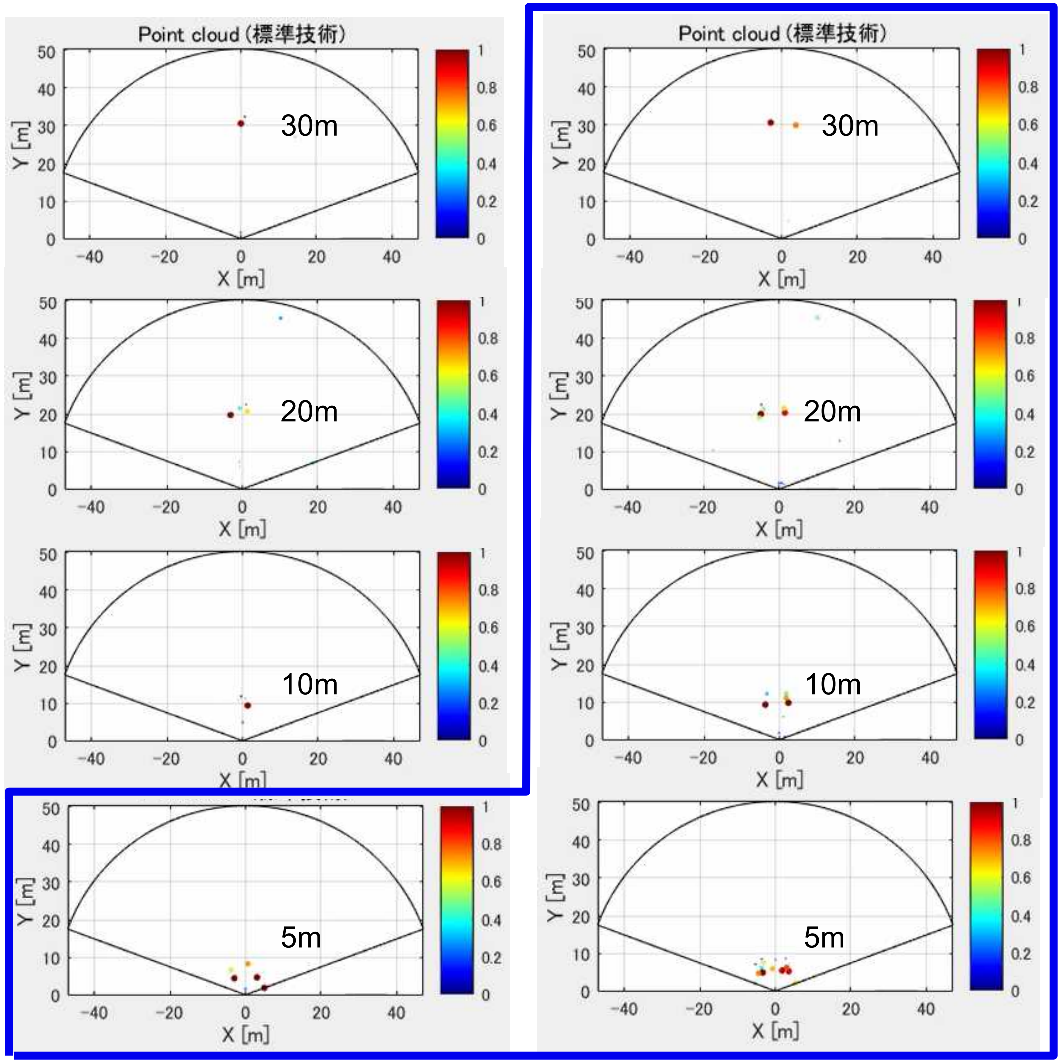
Theoretically, the beam width when a null point is generated when a single beam is completely inserted between objects is called "azimuth separation performance".



$$L = \frac{\left(\frac{6.12}{2}\right)}{\tan\left(\frac{\theta}{2}\right)} - 4.58$$

	4 antennas (non-MIMO)	12 antennas (MIMO)
Beam width θ	34 deg	9.2 deg
Min L	5.4 m	33.5 m

Distance L expected from theory

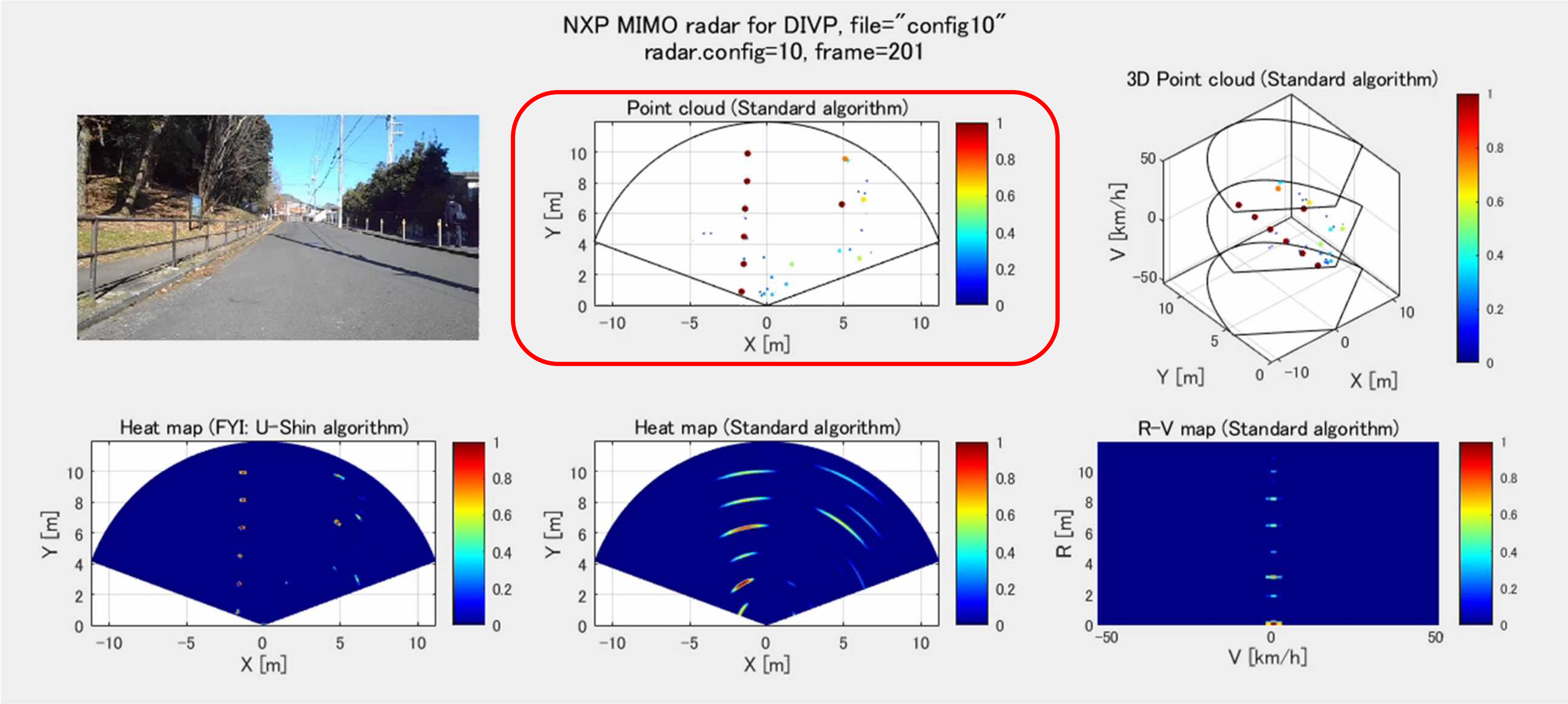


Non-MIMO mode (4 antennas)　　MIMO mode (12 antennas)

Source : SOKEN, INC , U-Shin Ltd.

The resolution improvement of radar image was confirmed even in the real environment of complicated urban area.

Test result in residential area simultaneously capturing numerous obstacles



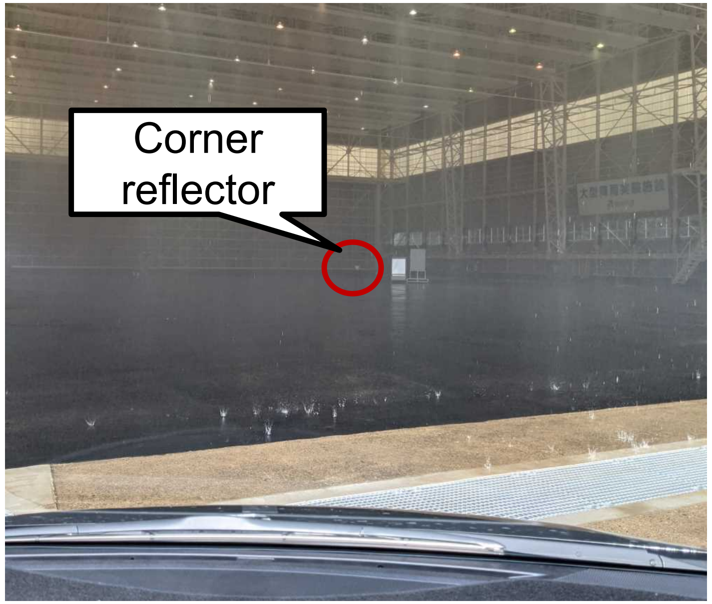
Source : SOKEN, INC , U-Shin Ltd.

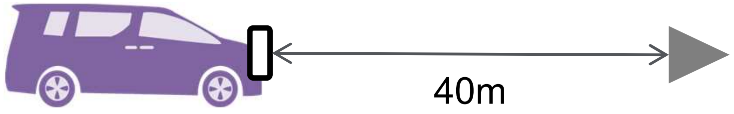
Spatial attenuation due to rain was estimated from raindrop shape distribution using attenuation model based on Mie scattering equation.The estimated spatial attenuation values was confirmed to have an error of less than 20%.

Rain attenuation

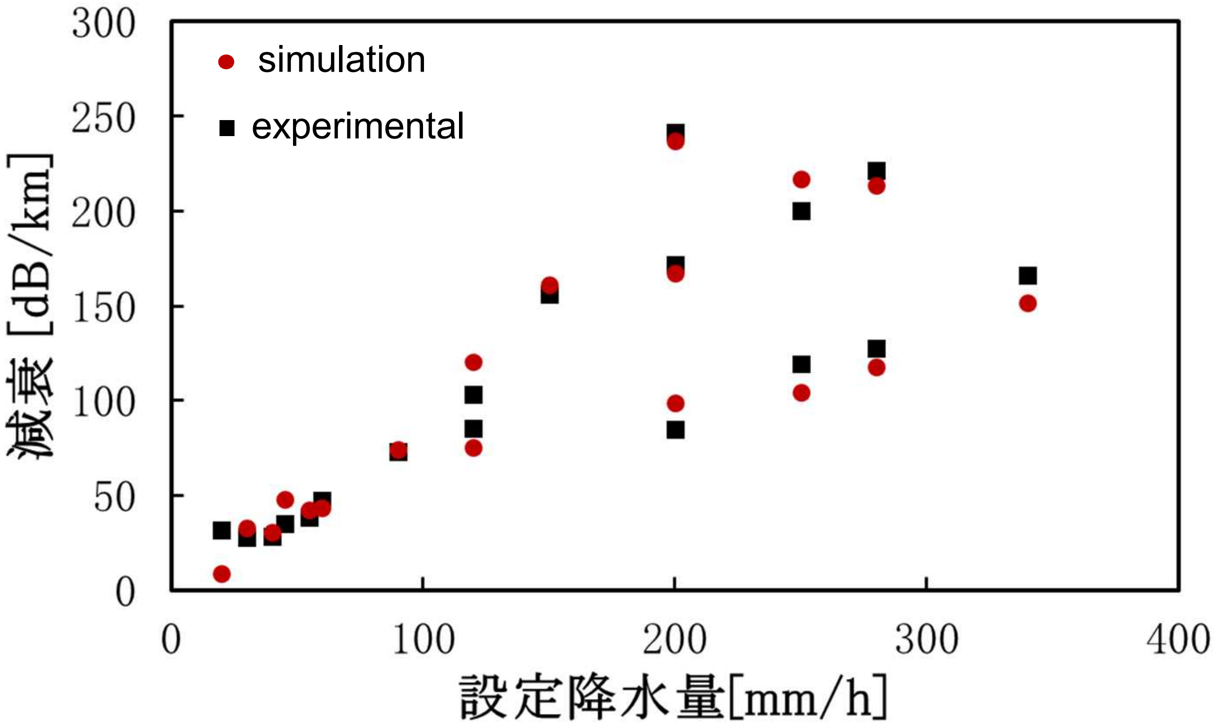
SOKEN

Test environment	Test Results





Validation of the relative reflection intensity under rainless conditions

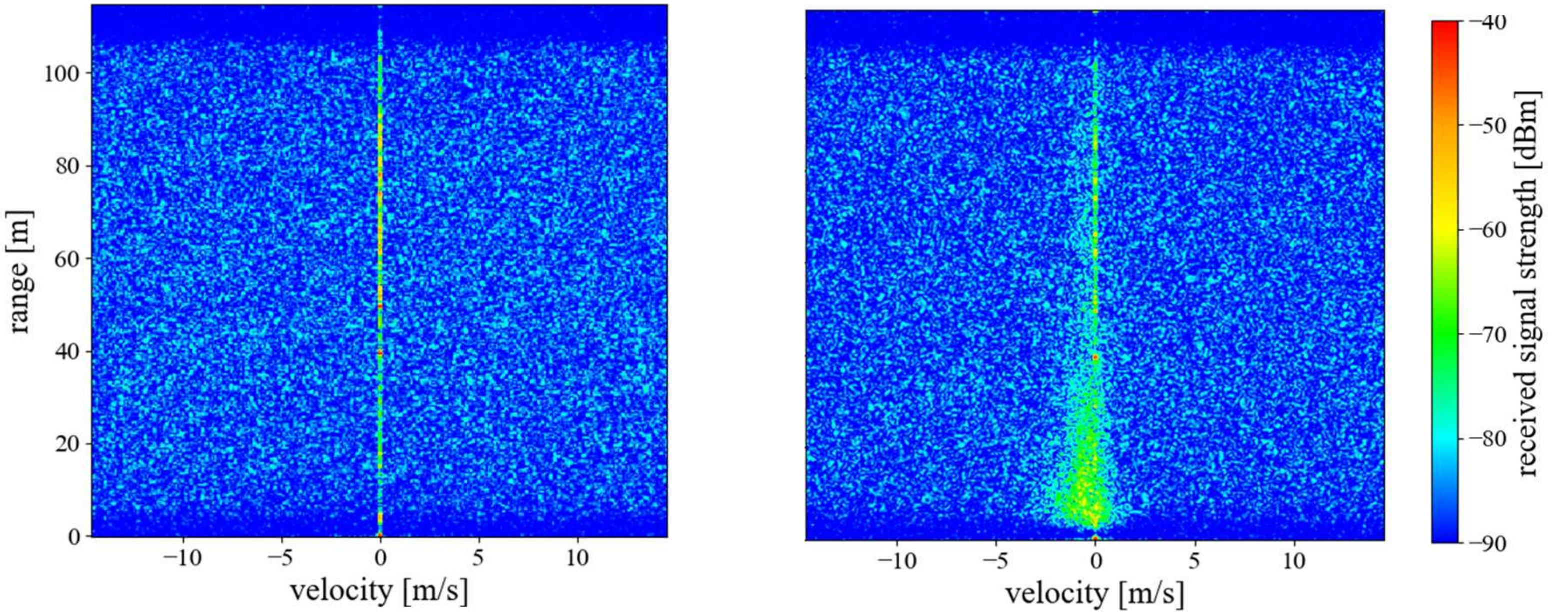


Millimeter wave radar measurements confirm that rainfall causes clutter in RV maps.

Rain scattering

SOKEN

Test environment	Experimental Result



no rainfall

set precipitation 30mm/h

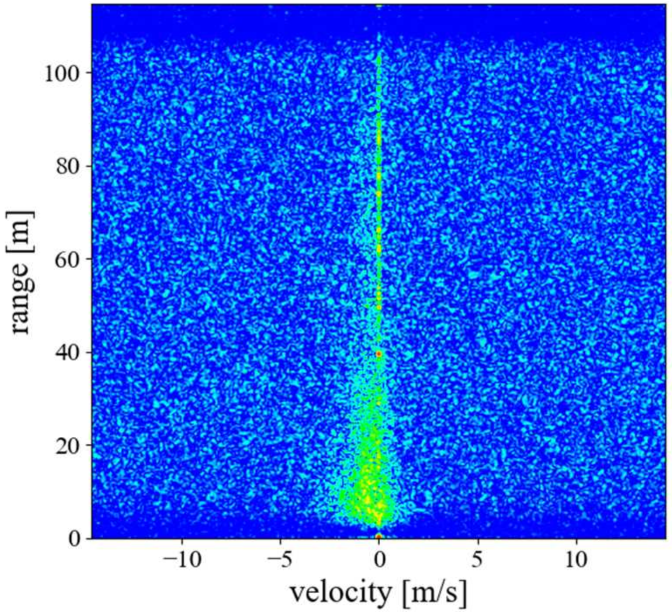
DIVP

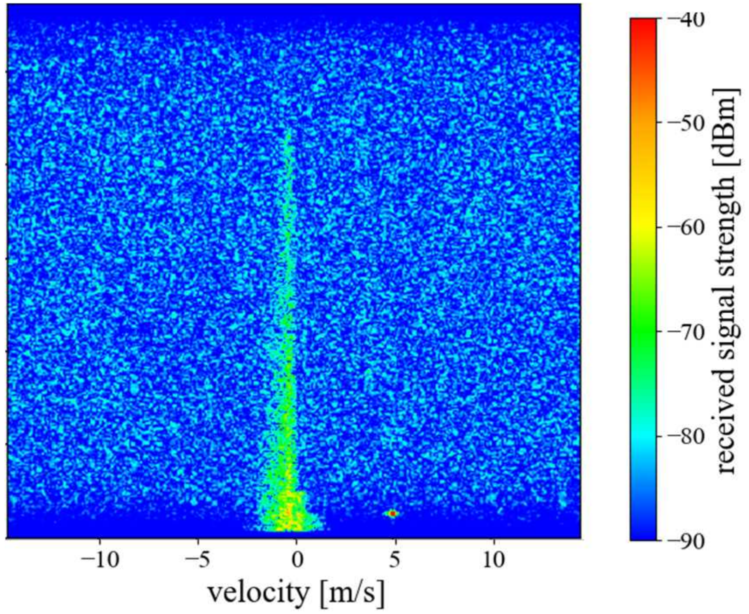
Clutter distribution was estimated from raindrop shape distribution using a scattering model based on the Mie scattering equation. Measured and simulated clutter distributions were verified.

Rain scattering

SOKEN

Test environment	Experimental Result	Simulation Result





Set precipitation: 30 mm/h

Source : SOKEN, INC

The consistency of the millimeter-wave radar model was confirmed, and residual problems were extracted.

Concordance confirmation result of millimeter-wave radar model

SOKEN Nihon Unisys, Ltd U-shin MinebeaMitsumi Group

Confirmation characteristic	Check item	Consistency can be verified	Current issues → Proposed measures
Reflection intensity spot distribution	Angular Properties of Reflection Intensity (RCS) Angular characteristics of reflection point distribution	■ Error of in-plane mean RCS less than or equal to 3 dB ■ Reflection point distribution with a distance error of 0.2 m or less	■ Consistency of detailed angular properties ■ Coherence of the distant reflection points of the target ->Considerations such as multi-pass, glass transmission, etc.
Multipath	Distance dependence of received signal strength	■ Coincidence of peak generation positions ■ Peak signal level error: 5 dB or less	■ Consistency in the depth of the dip in the signal level ->Review of low elevation reflectance of road surface
MicroDoppler	Signal strength distribution in the velocity direction	■ Micro-Doppler pattern due to pedestrian walk cycle and wheel rotation is almost identical.	-
Azimuthal separation capability	Confirmation of improvement of azimuth separation performance by the number of antennas	■ With the increase in the number of antennas due to MIMO, the azimuth resolution is improved almost as theoretically.	■ **Due to the performance limit of the experimental radar (NXP), phase compensation is not possible up to ± 50 km/h. ->Consistency verification is performed within this range.**
Rain attenuation	Relationship between precipitation and attenuation	■ Orientation estimation errors are generally consistent.	■ Coherence verification in natural rain
Rain scattering	Clutter generation distribution	■ The clutter generation distribution is almost the same.	■ Consistency verification in XY distribution

Source : SOKEN, INC , Nihon Unisys, Ltd, U-Shin Ltd.

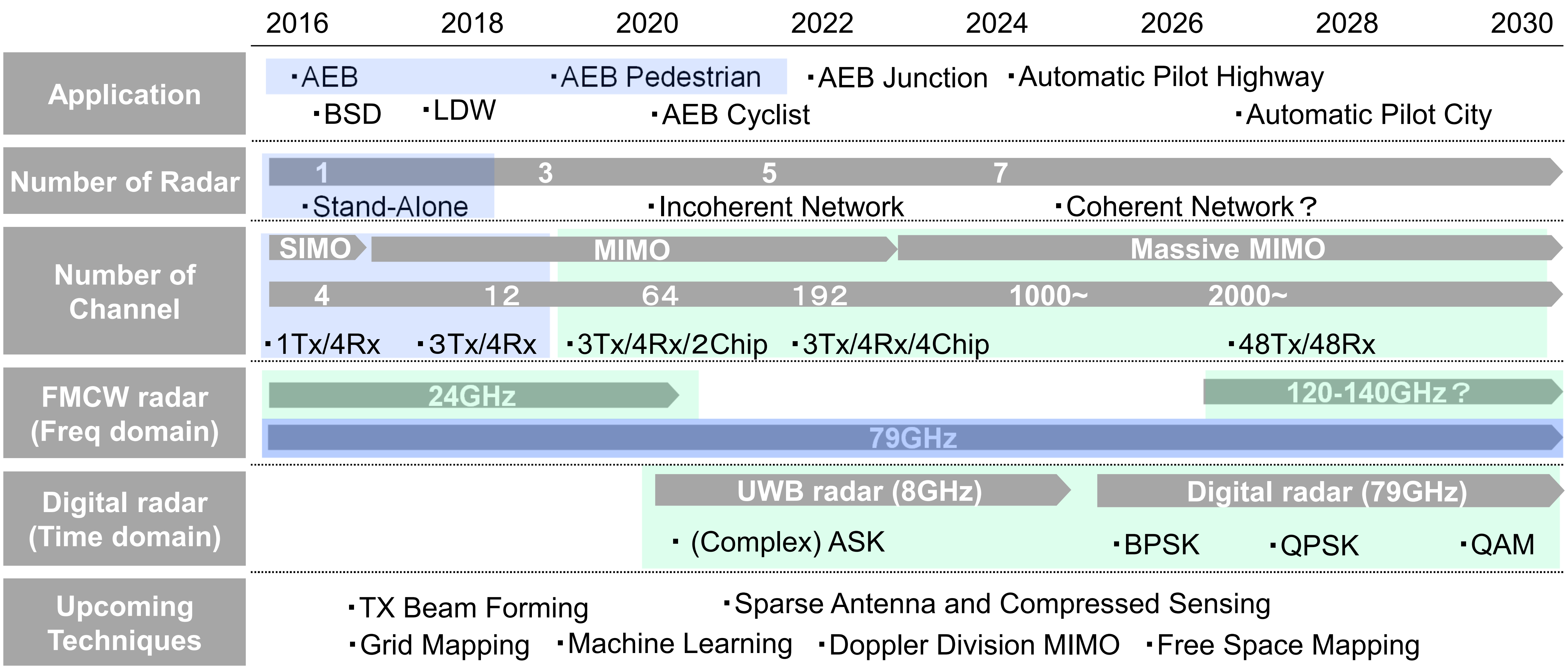
DIVP

Single radar function (number of channels, frequency, modulation method) supported. Plan to support interference/synchronization between multiple radars, expand range of ADAS applications supported.

Technology Trend Forecast and DIVP® Coverage

Verified
Not verified (Supportable in principle)

SOKEN
U-shin MinebeaMitsumi Group



Source : SOKEN, INC, U-shin Ltd.

DIVP

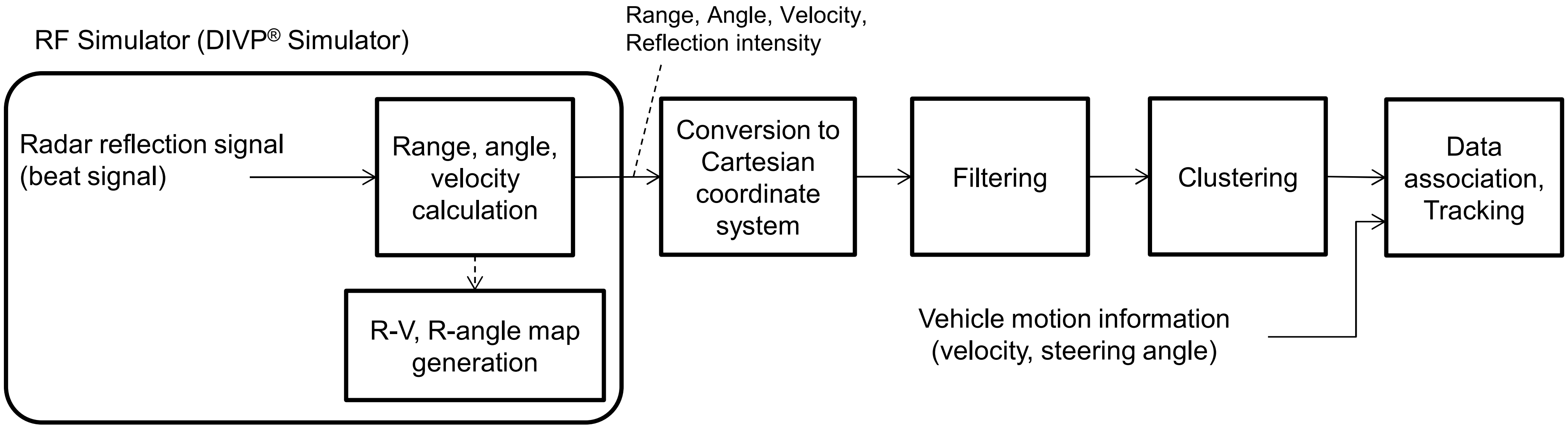
Outcome

I	■ "Scenario package" for sensor validation
II	■ Space and sensor model highly consistent with actual phenomena
III	■ Measurement and validation methods that support consistency
IV	■ Scenario DB for sensor validation
V	■ Platform with standard I/F and connectivity to diverse assessment environments

II:
- ■ Camera
- ■ Radar (Recognition)
- ■ LiDAR

Millimeter-wave Radar Recognition Logic for Object Detection and Tracking Using Simulator Output

Overall configuration of recognition logic using millimeter-wave radar



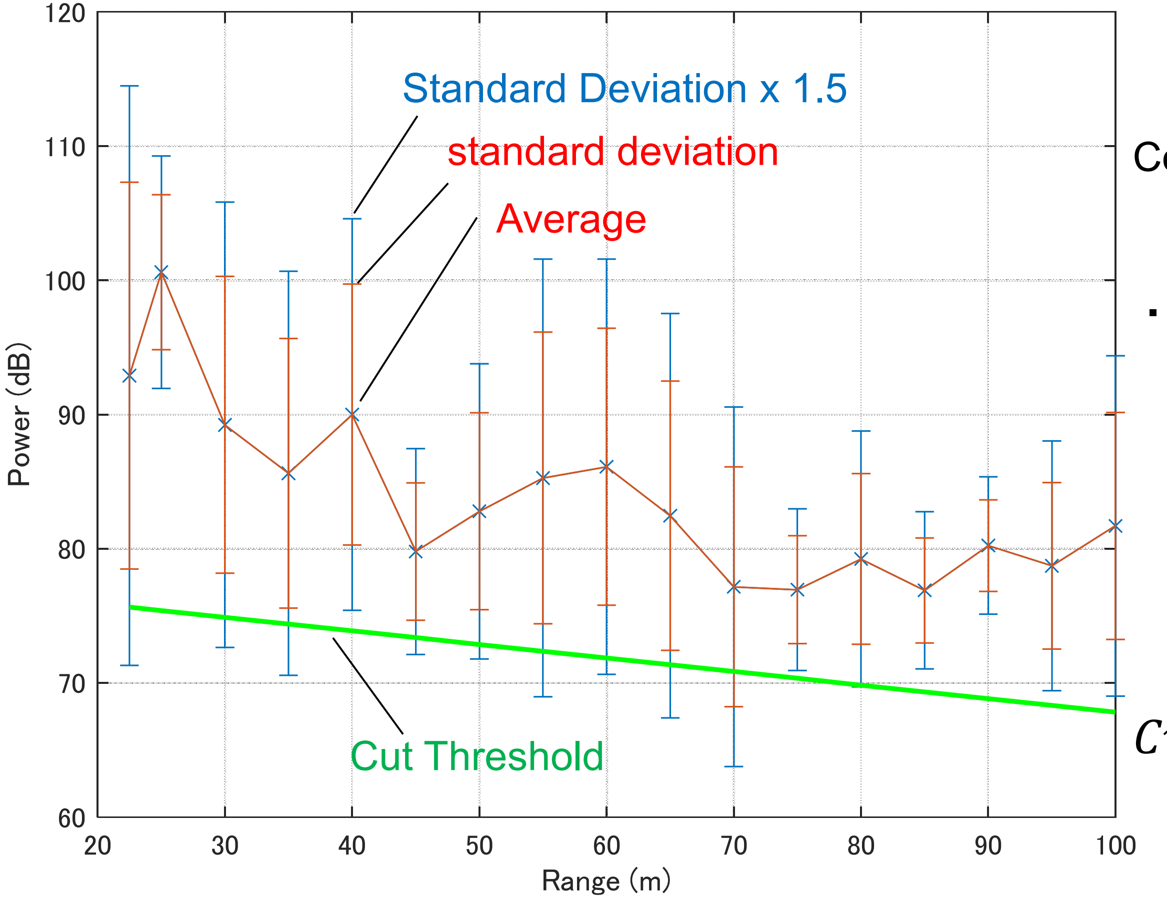
Overall configuration of millimeter-wave radar recognition logic

DIVP® Logic for object detection and tracking was constructed using the output of the simulator.
In this summary report, clustering and data association tracking are extracted and reported.

Source : Toyota Technological Institute

Statistical design of noise filter by reflection intensity

Analysis of Reflection Point Intensity Distribution for Distance between Preceding Vehicle and Noise



Distance of preceding vehicle
point cloud reflection intensity (mean, standard deviation)

Conditions: cut out scenario

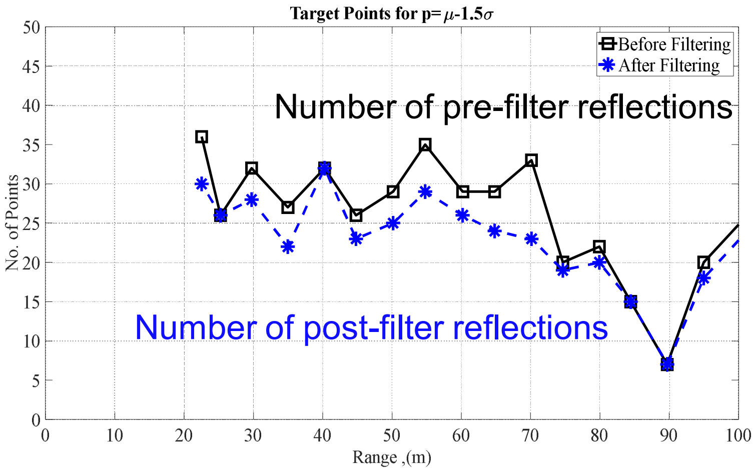
- Low reflection intensity point removing filter
  - Remove low reflection intensity points
  - Because thresholds vary with distance
    Set from average and standard deviation of preceding vehicle reflection point group intensity for each distance
    =>Sets the threshold for a regression line with a mean of -1.5 x standard deviation.

$$Cut\ Threshold:\ \mu_p - 1.5\,\sigma_p = -0.101 * range + 77.92$$

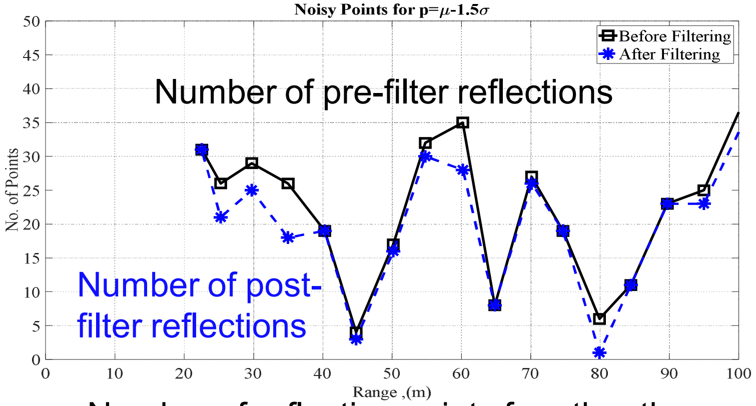
Source : Toyota Technological Institute

Statistical design of noise filter by reflection intensity

Noise reduction effect by reflection intensity filter

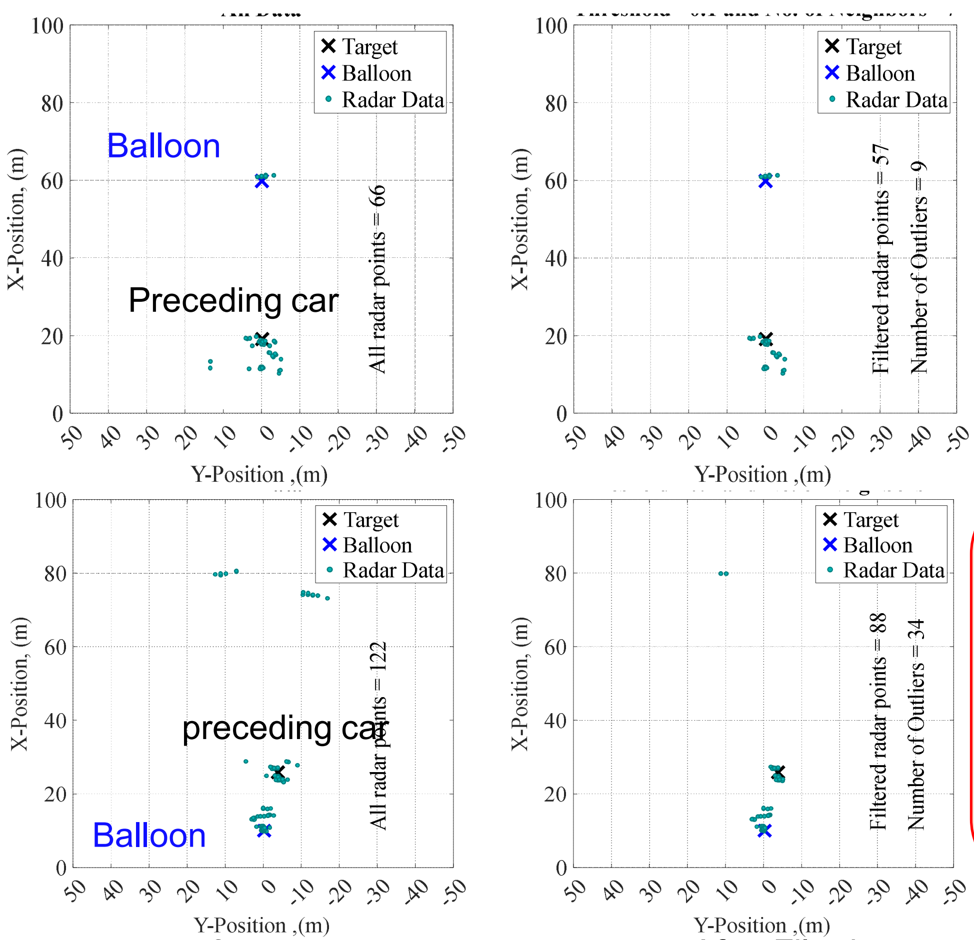


Reflection point for preceding vehicle



Number of reflection points for other than preceding vehicle (noise)

Number reduction effect of filters



Before Filter

After Filtering

Example of noise reduction effect

Since the reflection intensity of the object to be detected is close to that of the noise, a large effect is not observed, but a statistical design method is constructed.

Source : Toyota Technological Institute

Optimize clustering logic with distance based parameterization

Construction of distance adaptive clustering logic

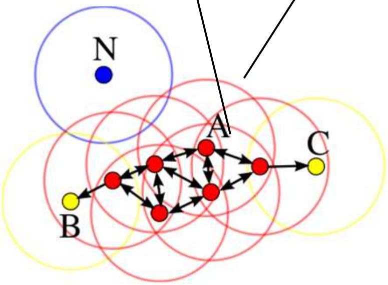
Variable Distance Parameter DBSCAN Creation

For certain parameters, clustering performance decreases with the distance to the detection target.

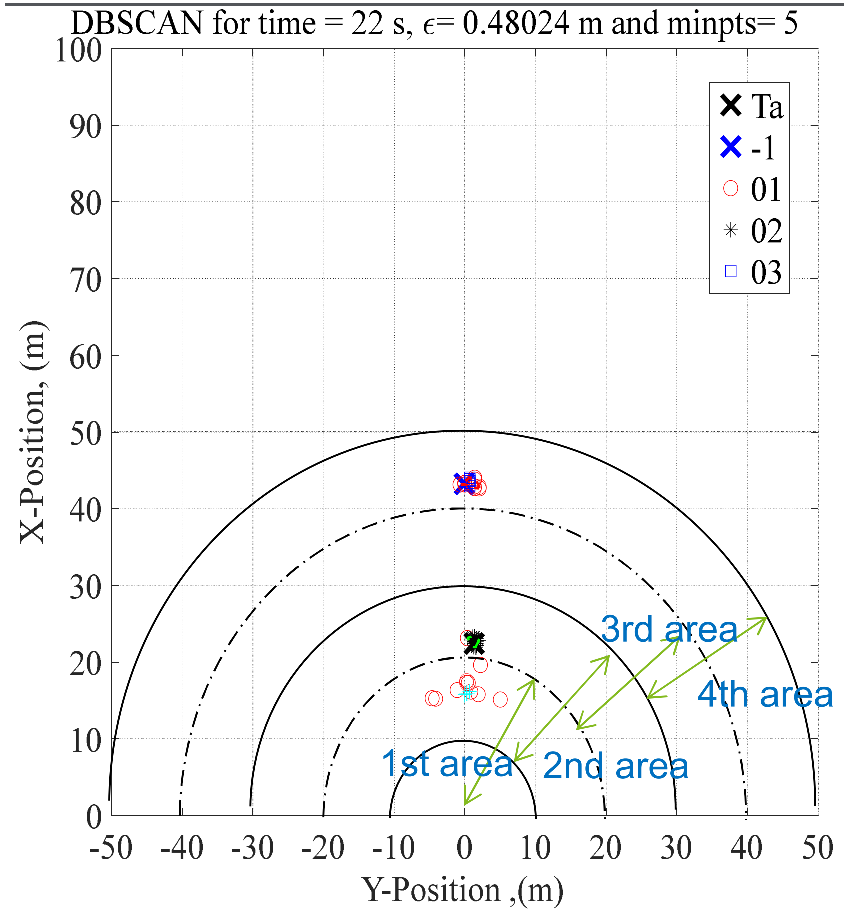
Variable parameter depending on distance

・Logic
- Divide the distance area and set the DBSCAN parameters according to the point cloud average distance in the area
  (Overlapping areas are consolidated after calculation)

DBSCAN parameters: epsilon, Minpts

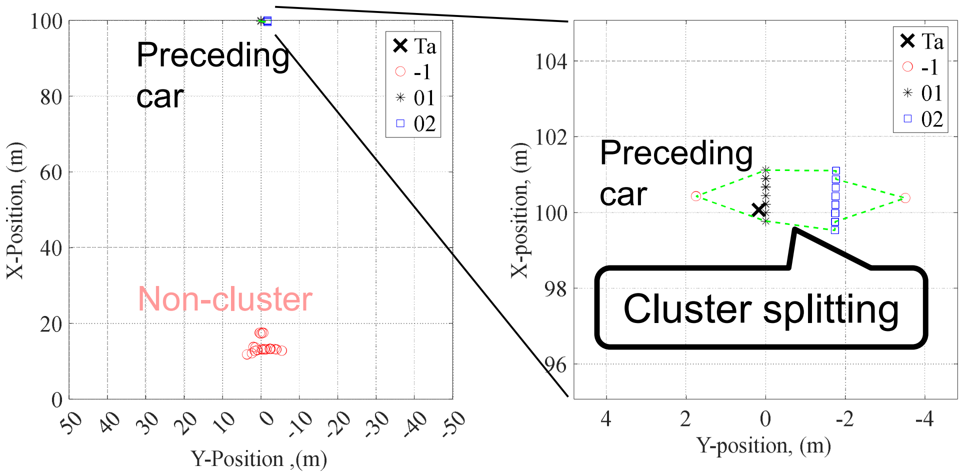


Space Separation for Variable Distance DBSCAN Parameters

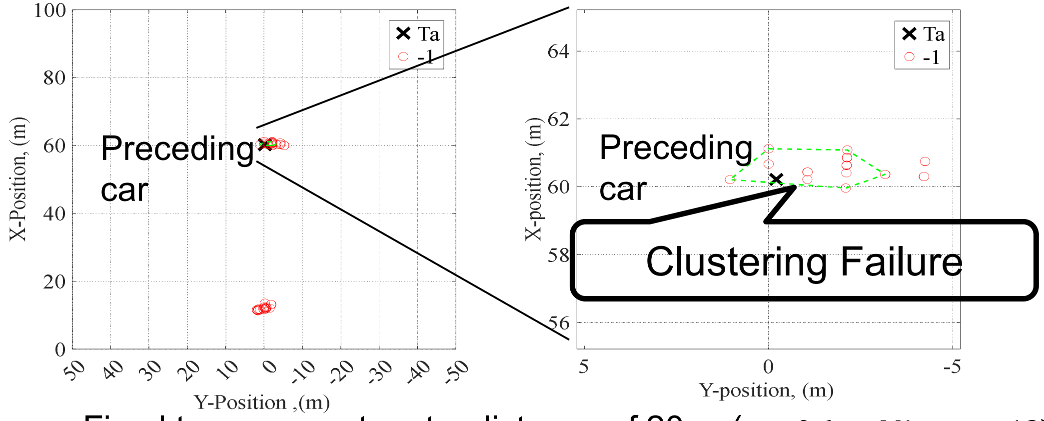


Optimize clustering logic with distance based parameterization

Variable Distance Parameter DBSCAN validation/Comparison with Fixed Parameter (Prior Art)

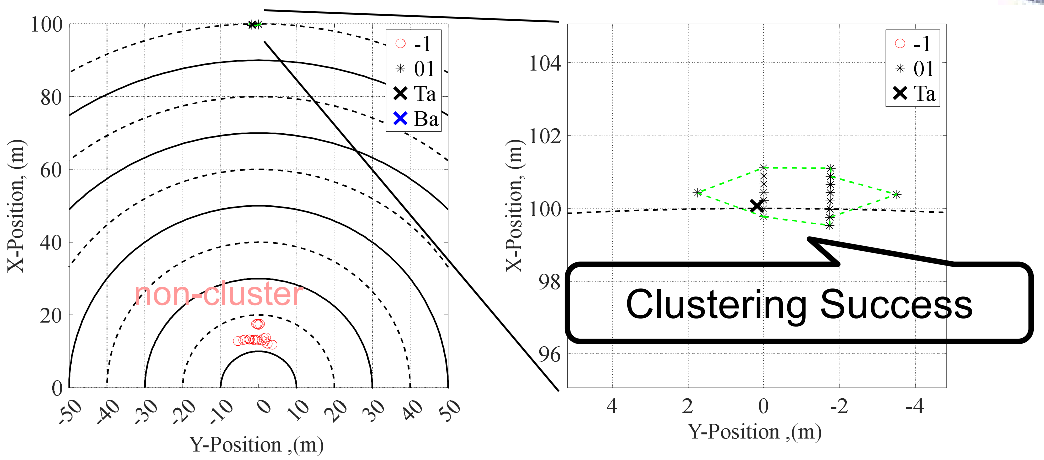


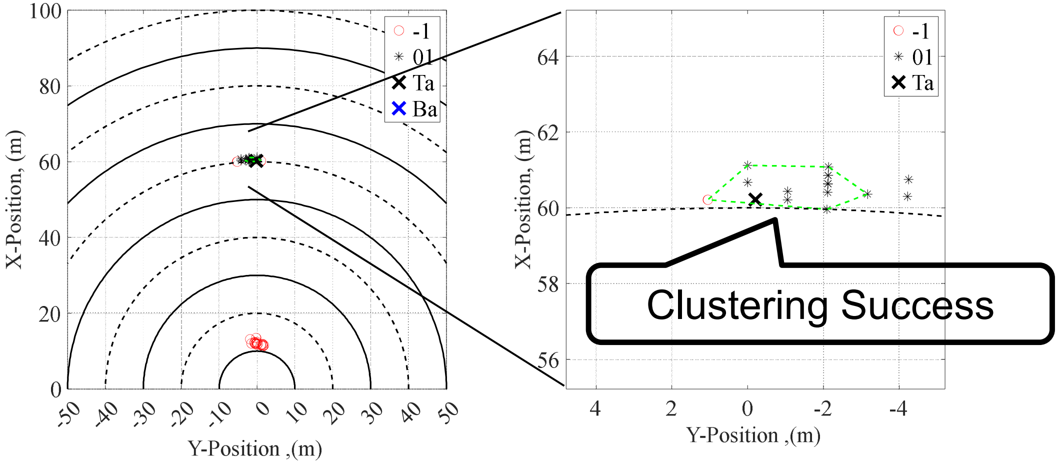
Fixed to a parameter at a distance of 50 m ($\epsilon = 1.4\,m, Minpts = 9$)



Fixed to a parameter at a distance of 20 m ($\epsilon = 0.6\,m, Minpts = 13$)

validation Results Sample for Fixed Parameter DBSCAN





Sample validation Results for Variable Distance Parameter DBSCAN

Cluster success for all areas with variable distance parameter DBSCAN

Various tracking logics were quantitatively compared and evaluated, and it was confirmed that all could be tracked by simulator data.

Building Data Association Tracking Logic

Various technical investigations were carried out and the following algorithm candidates were extracted.
Quantitative comparative validation of various combinations in cutout scenarios

Algorithm	Overview	Advantages	Disadvantages
GNN (Global Nearest Neighbor)	Correspond to the point with the highest probability of existence in the nearest neighborhood	・Be not computationally intensive ・High performance in simple situations	・Optimality is not guaranteed for multiple objects
PDA (Probabilistic Data Association)	Selection by fusing a plurality of associated candidates having a corresponding probability within a threshold	・Be more computationally intensive than GNN	・Performance degradation when there is a lot of noise or when multiple objects are nearby
MHT (Multi Hypothesis Tracking)	Keep track of multiple correspondences	・High performance for multi-object tracking	・Be computationally intensive

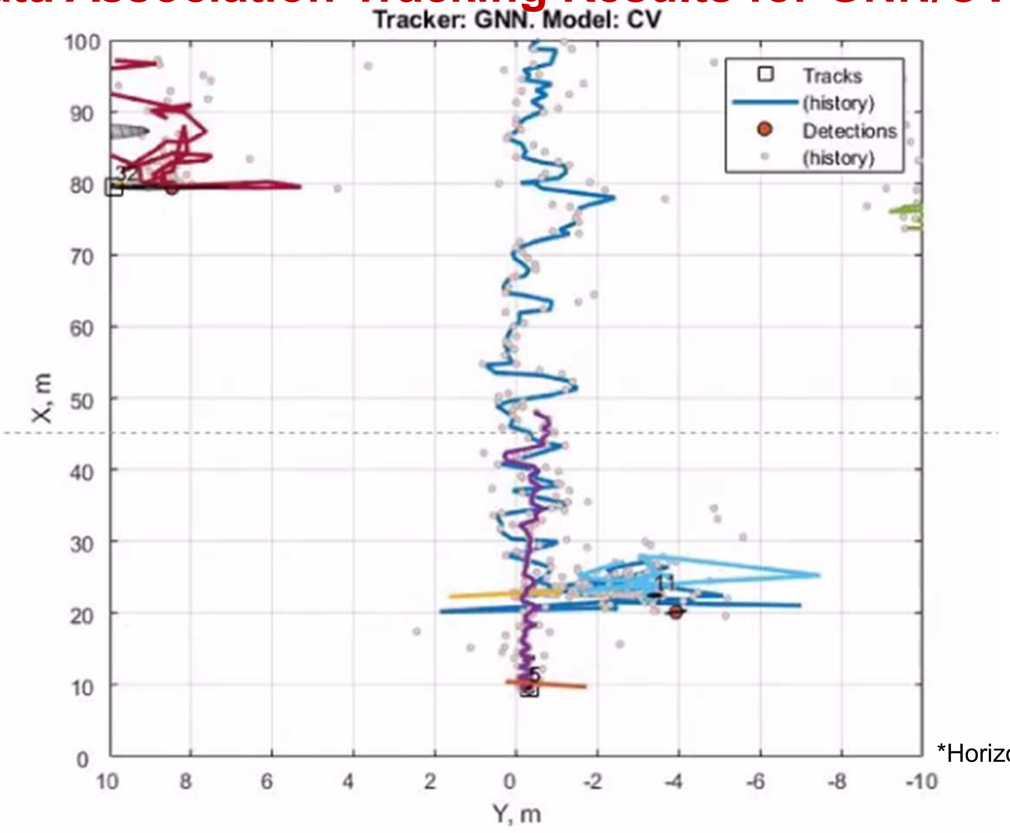
Parameters

・object model	CV (Constant Velocity model) IMM (interacting Multiple Model)
・tracking filter	KF (Kalman Filter) EKF (Extended Kalman Filter) UKF (Unscented Kalman Filter)

Source : Toyota Technological Institute

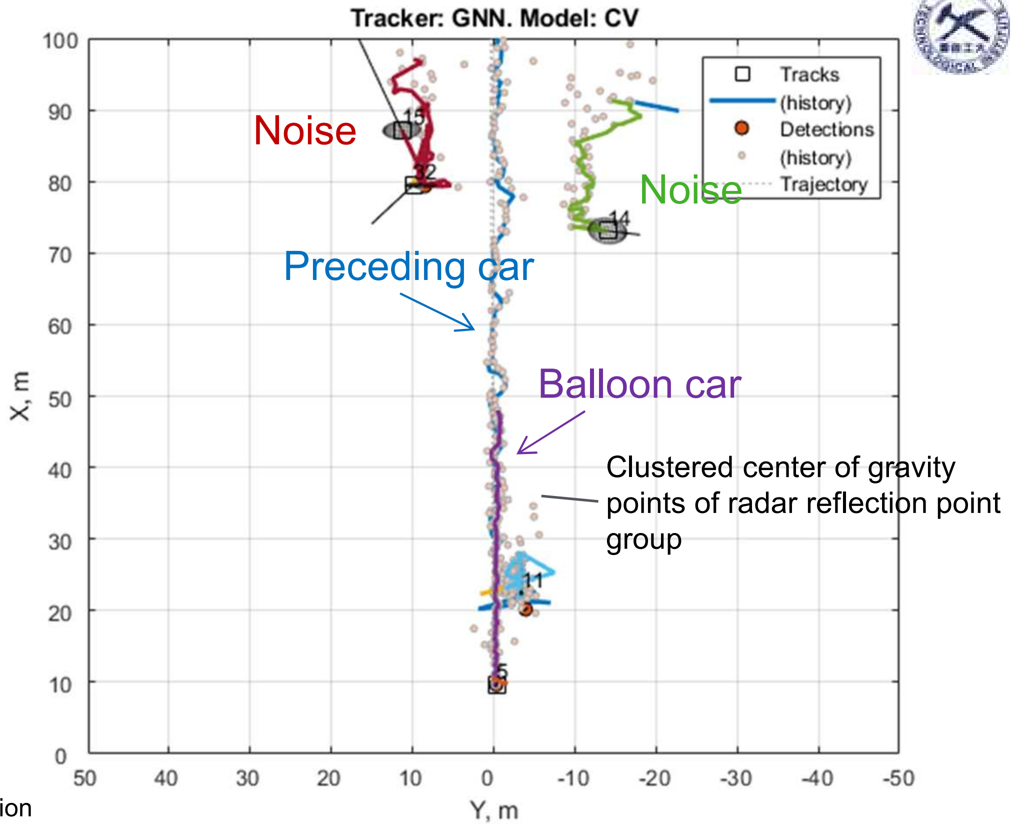
Various tracking logics were quantitatively compared and evaluated, and it was confirmed that all of could be tracked by simulator data.

Data Association Tracking Results for GNN/CV



*Horizontal axis scale expansion

Detected object tracking video in cutout scenario



(0.1sec/frame)

Object Locus to be Detected in Cutout Scenario (Example)

It is confirmed that the object can be tracked with these logics.
However, in this simple scenario, it is difficult to make a clear difference.
=>In the future, comparative validation and improvement will be promoted in the real environment scenario.

Object	Tracking discontinuity number	Tracking length
Preceding car	1	225
Balloon car	0	87

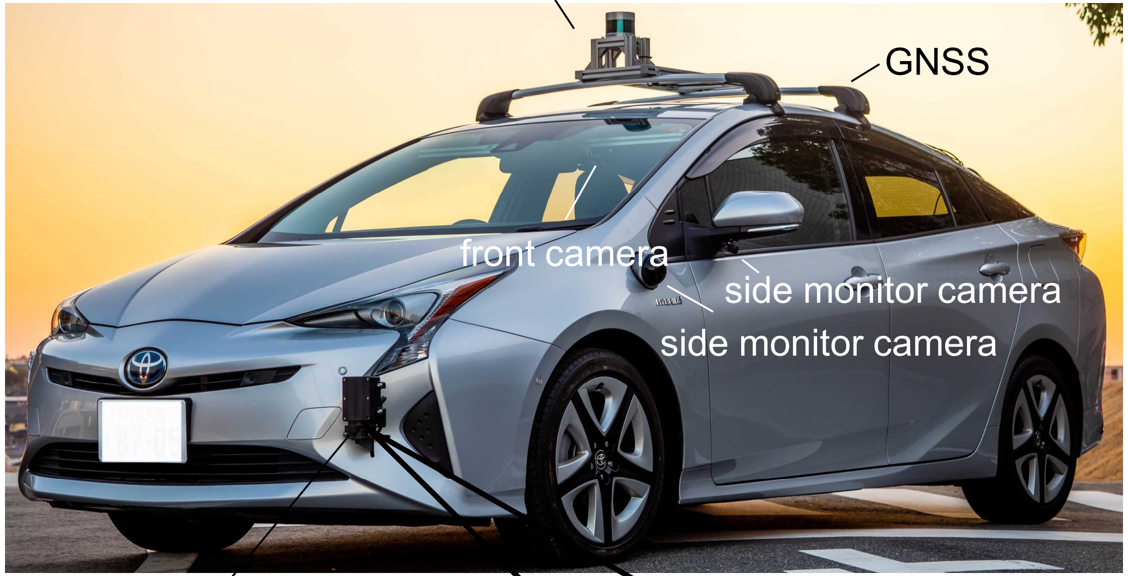
No tracking error except when a large number of interference noise occurs near the balloon car.

Source : Toyota Technological Institute

A real environment measurement experimental vehicle for millimeter-wave radar recognition model construction was constructed.

Millimeter-Wave radar measurement experimental vehicle and its sensor configuration

LiDAR (Velodyne/VLP -32 C, FOV 360 °, 32 layers)



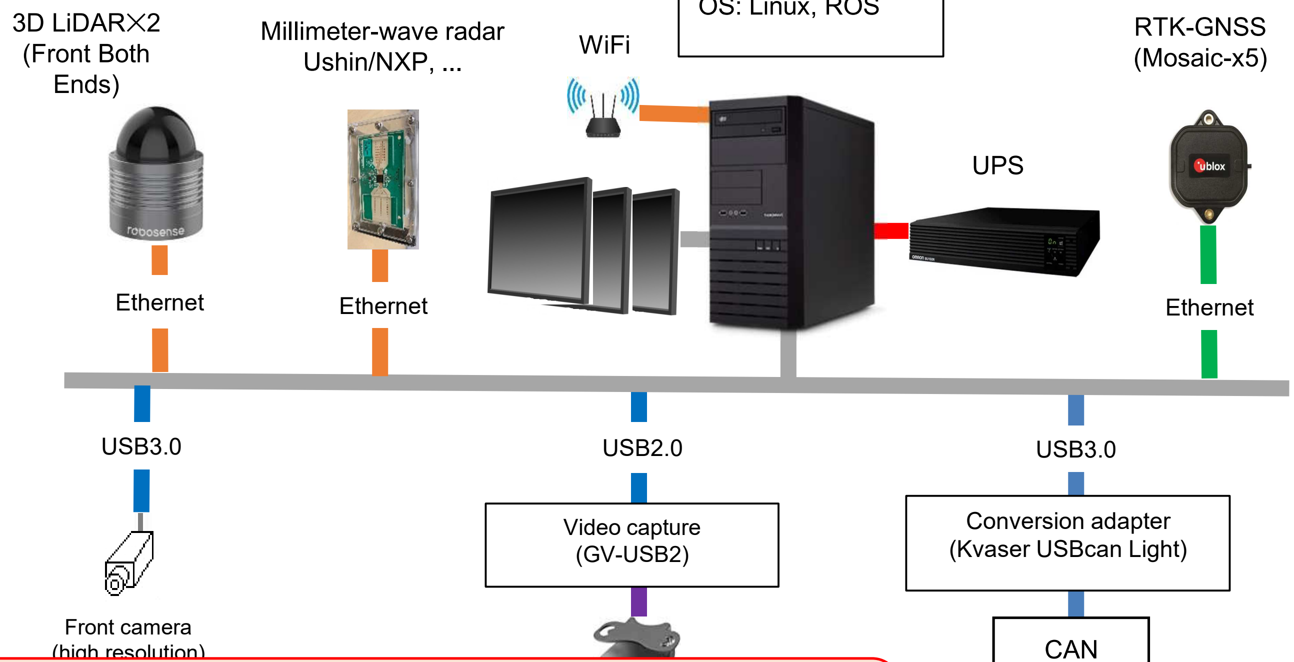
Millimeter-wave radar (Articles Provided by U-shin)

Mounting angle variable (Front 0 ° to Side 90 °)

Experimental vehicle

Measurement system configuration

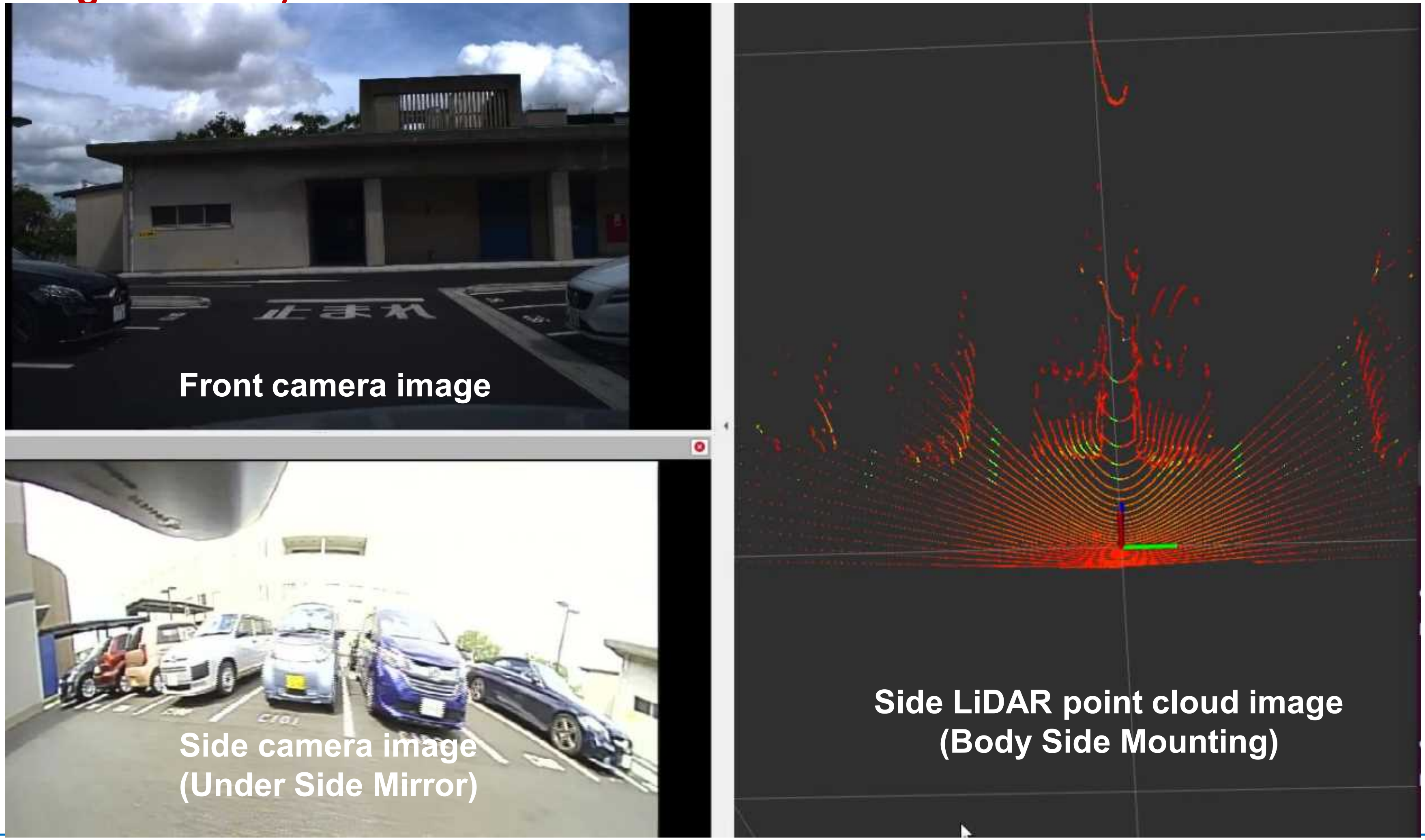
Tower PC
CPU: i7
GPU: GTX3070
OS: Linux, ROS



Construction of Millimeter-Wave Radar and Reference Sensor Data Measurement System for Original Measurement of Urban Scenes

Measuring software using real environment measuring test vehicle for millimeter-wave radar recognition model construction was produced, and preparation was carried out

Example of measurement data display by millimeter-wave radar measurement test vehicle (parking lot scene)



Construct a system capable of measuring 3D point clouds and peripheral images based on ROS, such as urban scenes

*At present (2022/2/18), full perimeter LiDAR and millimeter-wave radar measurement software are being produced and adjusted. (To be completed by the end of 2022/2)

Source : Toyota Technological Institute

Outcome

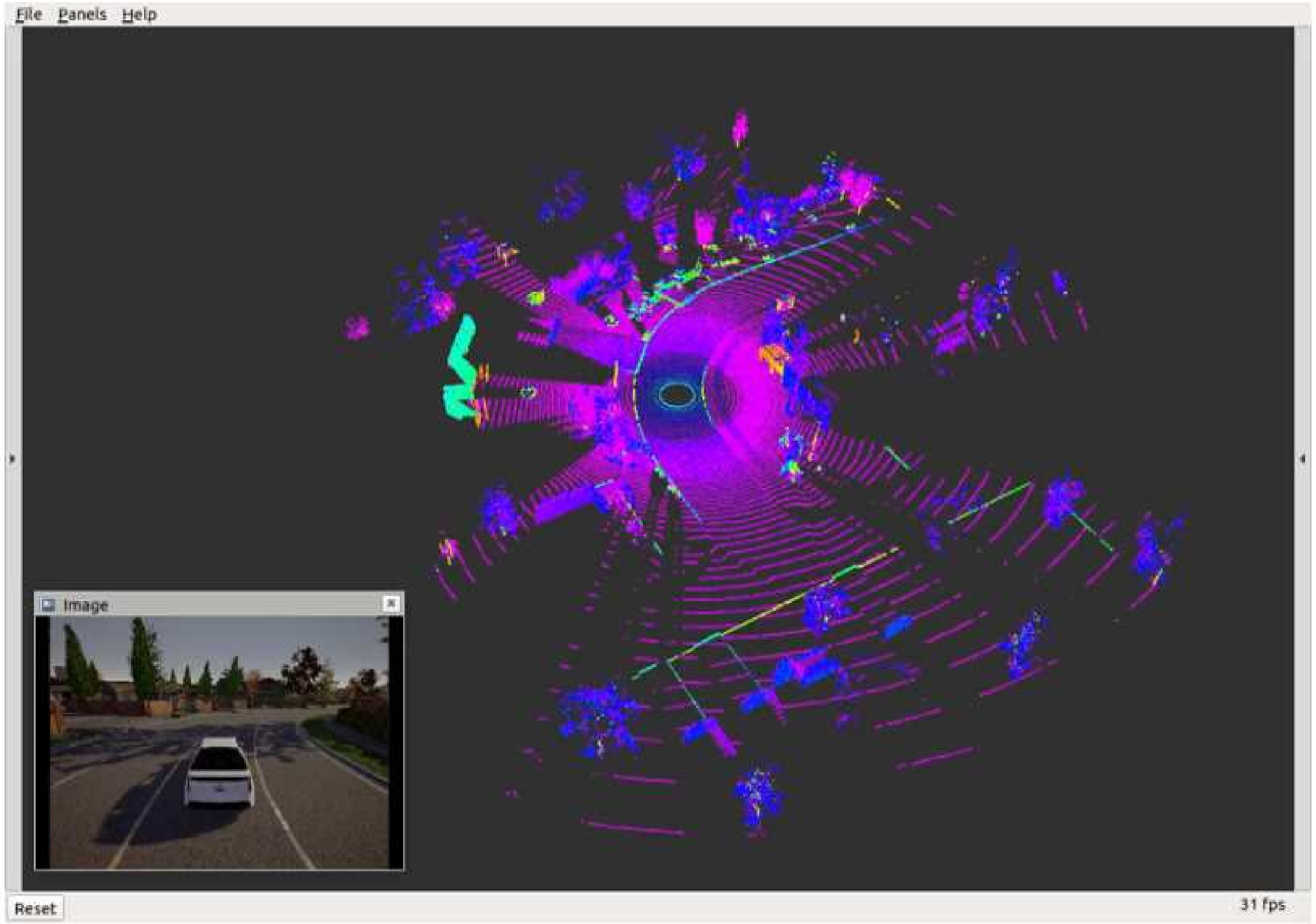
- I — "Scenario package" for sensor validation
- II — Space and sensor model highly consistent with actual phenomena
  - Camera
  - Radar
  - LiDAR
- III — Measurement and validation methods that support consistency
- IV — Scenario DB for sensor validation
- V — Platform with standard I/F and connectivity to diverse assessment environments

LiDAR Sim delivers high accuracy, high speed, and consistent simulation

LiDAR simulation results

Nihon Unisys, Ltd

Pioneer



Source : Nihon Unisys, Ltd

[LiDAR Consistency Verification]

Effectively verify consistency by eliminating error factors other than the object of validation as much as possible at each step

LiDAR Consistency verification Process

Understanding and analysis of physical phenomena are important for modeling and reproduction of malfunctions

Pioneer

Step	Purpose of the verification	Output to be evaluated	validation parameter	validation index
LiDAR Model Consistency verification	■ Evaluate consistency of LiDAR perceptual models (scanning and ranging models) by eliminating errors due to environmental models, spatial propagation models, and scenarios as much as possible	■ RX Model Output * PSSI LiDAR Only	■ Intensity distribution of the received signal	■ Consistency of intensity distribution, average and variance at each distance of a target whose shape and reflection characteristics are known
			■ Intensity distribution of the noise	■ Consistency of intensity distribution, average, and variance of noise at each distance of a target whose shape and reflection characteristics are known
		■ Perceptual model output	■ Angle	■ Vertical resolution (elevation angle between adjacent lines) ■ Consistency of horizontal resolution (azimuth angle between horizontal neighbors)
			■ Distance ■ Intensity	■ Consistency of accuracy and precision at each distance of a target whose shape and reflection characteristics are known
			■ Range limit	■ Consistency of detection probabilities of targets whose shape and reflection characteristics are known
Environment Model + LiDAR Model Consistency verification	■ Evaluate the consistency of environmental models and LiDAR perception models (scanning and ranging models) by eliminating errors caused by spatial propagation models and scenarios as much as possible.	■ Perceptual model output	■ Distance to target	■ Consistency of accuracy and precision of distance
			■ Number of points hit by a target	■ Consistency of the number of points
			■ Target Size	■ Consistency of target size
			■ Intensity of the target point cloud	■ Consistency of intensity distribution
Impact assessment on recognition model output	■ Evaluate the effect of the difference between the perceptual model output point cloud and the actual LiDAR output point cloud on the recognition model output.	■ Recognition model output	■ Distance detection limit	■ Detection probability of the target
malfunction reproduction verification	■ Evaluate rainfall / snowfall effects, failure reproduction, consistency velification	■ Perceptual model output ■ Spatial attenuation model	■ Number of points hit by a target ■ Intensity of the target point cloud	■ Consistency of the number of points ■ Consistency of intensity distribution
Extendability verification	■ Reproduction of malfunctions on highly reflective road surfaces and validation of consistency	■ Perceptual model output	■ Number of points of white line point cloud ■ Intensity ratio of twhite line point cloud	■ Consistency of the number of points ■ Consistency of intensity ratio

Source : PIONEER CORPORATION

DIVP

Investigation for subjects pertaining to the measurement method with background light and the effect of material with directional reflection characteristics were carried out. For reproduction of malfunctions, modeling of rain attenuation was invented. Further verification of malfunctions reproduction to be conducted.

Consistency Verification Summary and Issues

Pioneer

Validation items		PSSI LiDAR
LiDAR Perceptual Model Consistency Verification		
	peak level of received signal	○
	Noise Level	○ ※1
	Angle	○
	Distance	○
	Intensity	○
	distance measurement limit	○
Environmental Model + LiDAR Perceptual Model Consistency Verification		
	Target Size	○ ※2
	Minimum distance to target	Not evaluated
	The number of points hit by a target	○
	Intensity distribution of the target point cloud	○
Impact assessment on recognition model output		
	Target Distance Detection Limit	○ ※3
Malfunction reproduction verification		
	Rain attenuation	○
	Rainfall false point	In progress
	Snow effect	Not evaluated

Updates from last year

*1 Problems with disturbance light and measurement methods have been solved.
*2 AEB NCAP and ALKS scenarios were evaluated. Results of ALKS consistency have an issue to be clarified
*3 The effect of materials with directional reflection characteristics, such as black leather jackets, was evaluated alternatively to confirm the improvement of consistency.

Source : PIONEER CORPORATION

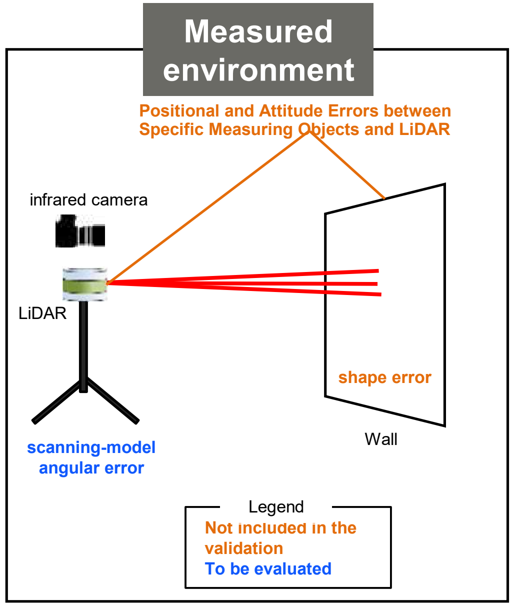
DIVP

[Verification of Consistency of Scanning Angle of PSSI-LiDAR]
Consistency in scanning angle between horizontal resolution and vertical resolution was confirmed.

Verification of Scan Angle Consistency of PSSI-LiDAR

Pioneer

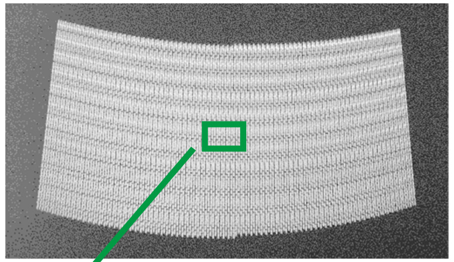
Verification environment



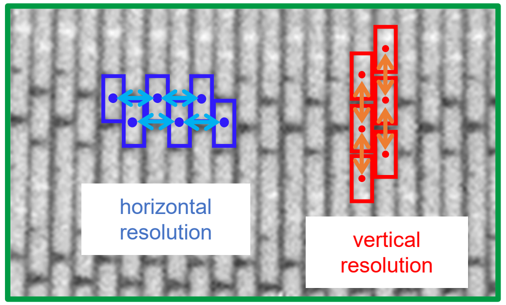
LiDAR beams are projected onto a plane and the resolution is measured with an infrared camera.

Acquired Data/Validation Metrics

PSSI medium LiDAR scan trajectory



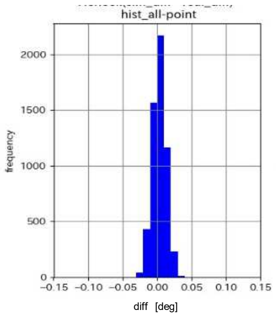
Validation index



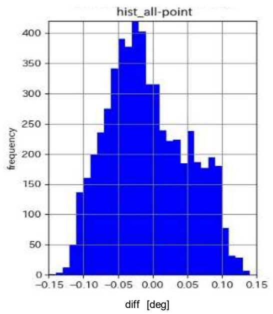
Consistency verification of scanning angle Difference between sim and actual measurement of horizontal resolution and vertical resolution

PSSI short LiDAR

horizontal resolution difference between Sim and actual measurement



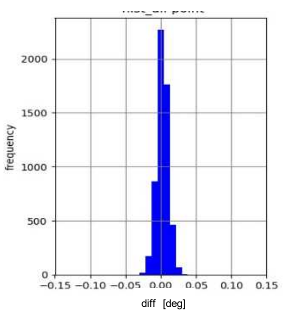
vertical resolution difference between Sim and actual measurement



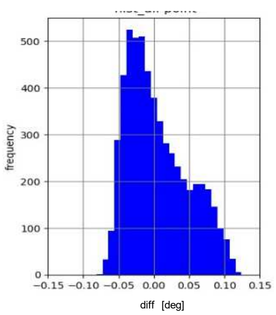
Difference in horizontal resolution	Vertical resolution Difference
± 0.05 deg or Less	± 0.15 deg or Less

PSSI medium LiDAR

horizontal resolution difference between Sim and actual measurement



vertical resolution difference between Sim and actual measurement



Difference in horizontal resolution	Vertical resolution difference
± 0.04 deg or Less	± 0.13 deg or Less

■Driving method of PSSI-LiDAR scanning unit (MEMS mirror)

✓ Horizontal scan ⇒ resonant drive ⇒ Vibrate stably
✓ Vertical scan ⇒ Electrical saw wave ⇒ May be affected by electrical circuit noise

It is determined that there is a difference in the resolution between the horizontal direction and the vertical direction, but there is no problem and we judged there is consistency between Sim and actual measurement.

Source : PIONEER SMART SENSING INNOVATIONS CORPORATION

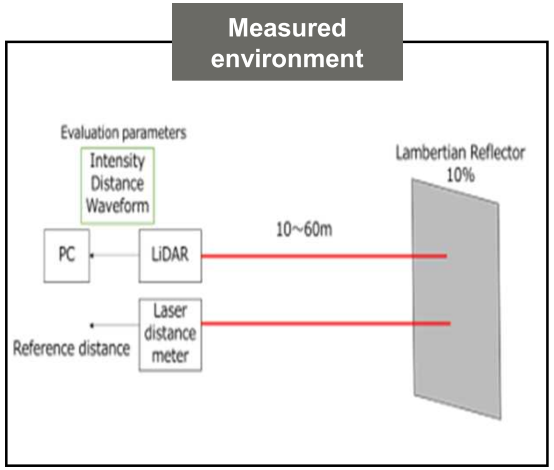
DIVP

[Perceptual Model Consistency Verification of PSSI-medium-LiDAR : No Background Light]
Sufficient consistency of the perceptual model (received waveform and point cloud) was confirmed.

Consistency Verification of PSSI-medium-LiDAR under Conditions without Background Light

Pioneer

Verification environment

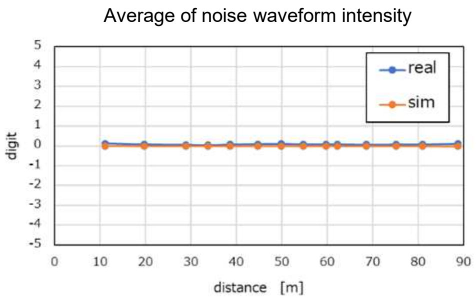


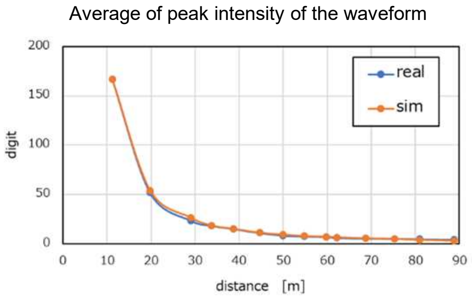
- Measure by varying the distance between the LiDAR and the Lambertian reflector.

Perceptual Model Consistency validation of PSSI-medium-LiDAR : No Background Light

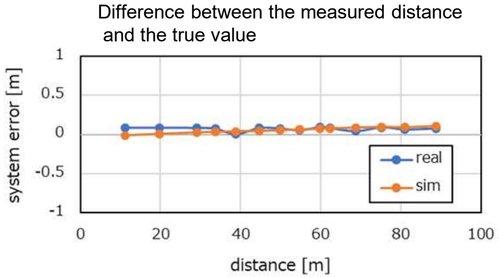
Validation index	Congruence
Average and variance of peak intensity of received signal waveform	Ensures sufficient consistency
Consistency between average and variance of received noise waveform intensity	Ensures sufficient consistency
Consistency between average and variance of ranging distance and intensity of point cloud	Ensures sufficient consistency
Consistency of detection probabilities	Ensures sufficient consistency

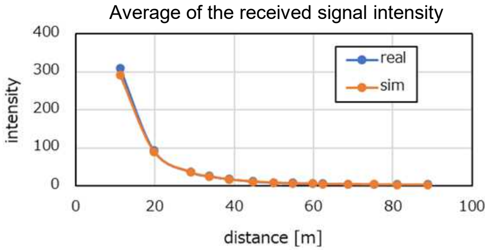
Received waveform consistency (partial)



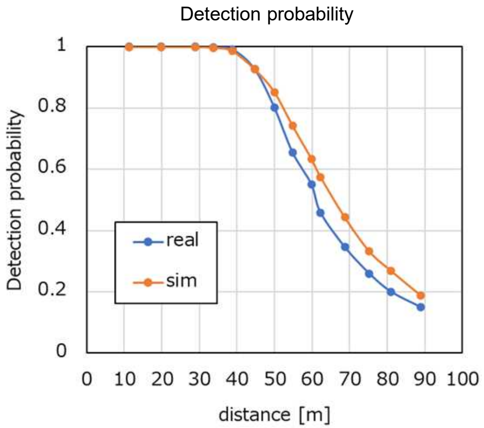


Point Cloud Consistency (partial)





Consistency of detection probabilities



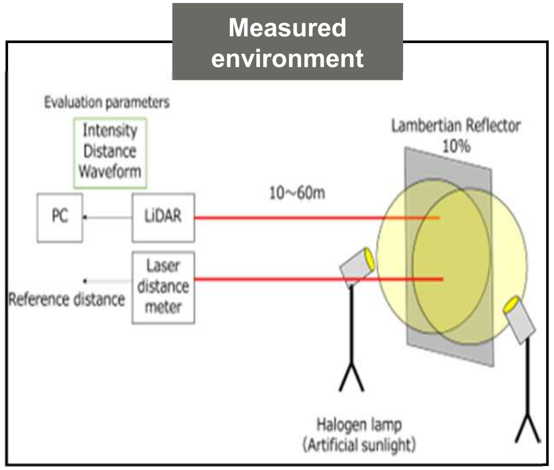
Source : PIONEER SMART SENSING INNOVATIONS CORPORATION

DIVP

[Perceptual Model Consistency Verification of PSSI-medium-LiDAR with Background Light]
Sufficient consistency of the perceptual model (received waveform and point cloud) was confirmed.

Consistency Verification of PSSI-medium-LiDAR under Conditions with Background Light

Verification environment

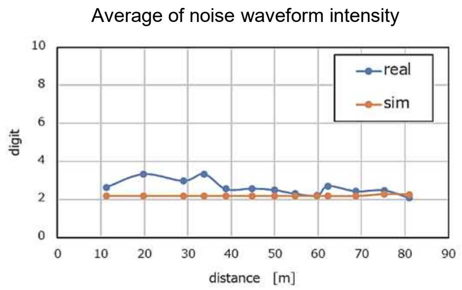


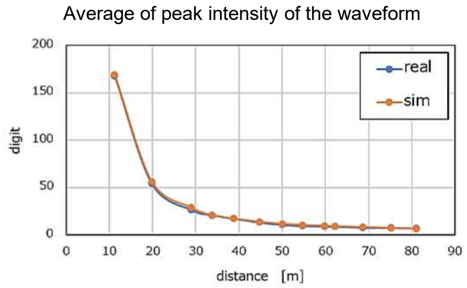
- **Measure by varying the distance between the LiDAR and the Lambertian reflector.**
- **A halogen lamp is used as a simulated sunlight for the background light.**

Perceptual Model Consistency validation of PSSI-medium-LiDAR with Background Light

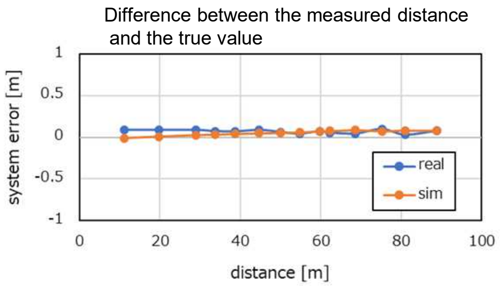
validation index	Congruence
Average and variance of peak intensity of received signal waveform	Ensures sufficient consistency
Consistency between average and variance of received noise waveform intensity	Ensures sufficient consistency
Consistency between average and variance of ranging distance and intensity of point cloud	Ensures sufficient consistency
Consistency of detection probabilities	Ensures sufficient consistency

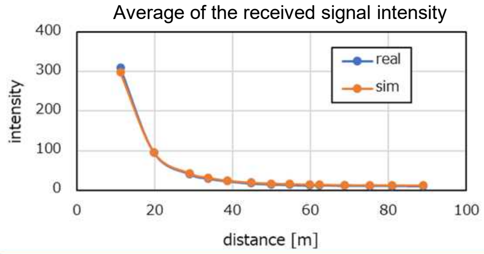
Received waveform consistency (partial)



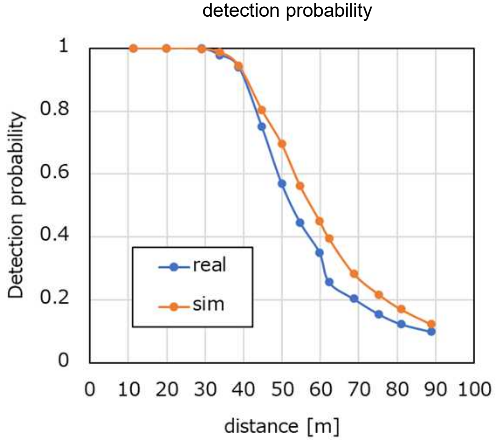


Point Cloud Consistency (partial)





Consistency of detection probabilities



Source : PIONEER SMART SENSING INNOVATIONS CORPORATION

[Improvement of Consistency of Objects with Directivity in Reflection Characteristics]
Modifying interpolation method of reflection model improved consistency in received signal intensity

Modification of Reflection Model of Object with Directivity in Reflection Characteristics

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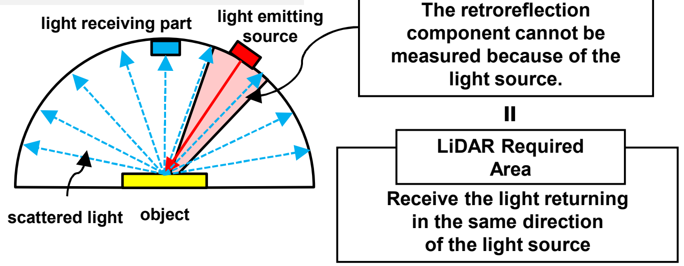
Background

Challenges

Image of reflection characteristic measuring apparatus

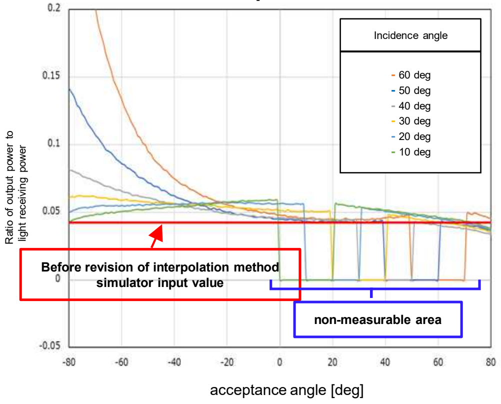


- Since the recursive part cannot be measured in the measurement for the reflection model generation, the interpolated value is used.
- With current interpolation method, actual directivity of the reflection characteristic is not reproduced.

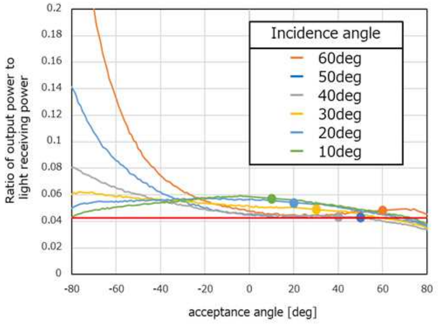
Revision of the reflection model

- A styrene board was used as one of the objects with directivity in reflection characteristics.

Current interpolation method



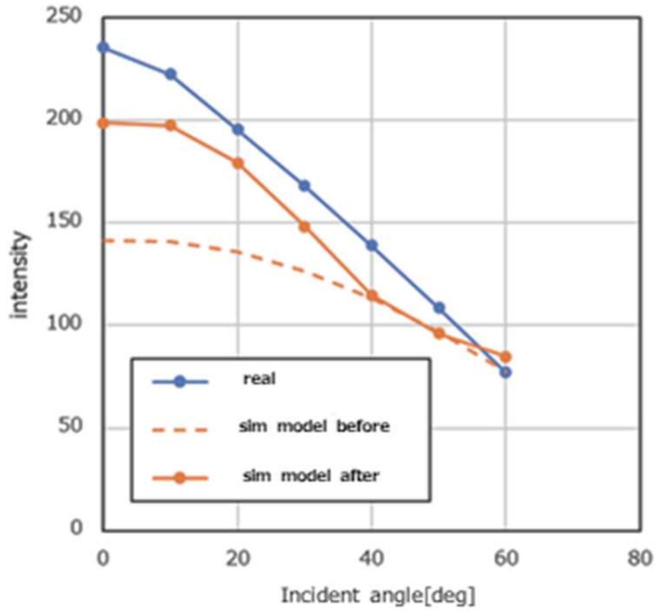
Modified interpolation method



Linearly interpolate unmeasurable areas

Improvement of received signal intensity of object having directivity in reflection characteristic

styrene board with 10% reflectivity
Received signal intensity characteristics due to incident angle



In the modifed reflection model, the reflection characteristics with the measured directivity could be reproduced.
As a result, it was confirmed that the received signal intensity was improved.

Source : PIONEER CORPORATION, SOKEN, INC

DIVP

[Validation of Intensity Consistency of Highly Reflective Object]
Consistency in received light intensity of high reflection object was evaluated

Consistency validation of received signal intensity of highly reflective object

Pioneer SOKEN

Background

- It has been confirmed that there is a consistency difference in received signal intensity by objects with high reflectivity.

Roads with highly reflective coatings

Reflector of the vehicle

Verify whether the consistency improves by changing the calibration material used to measure the reflection model

< Reflection Model >

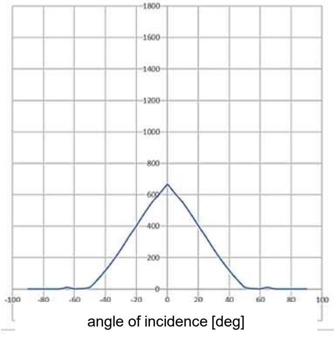
① Reflection model using Lambert with low reflectivity for calibration

② Reflection model using highly reflective retroreflective material for calibration

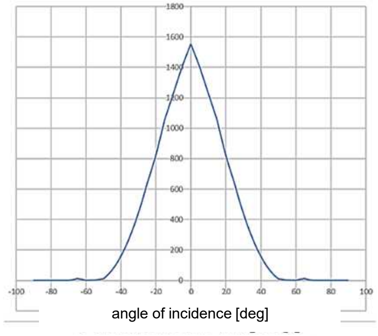
Validation of the consistency of received signal intensity of highly reflective objects (ongoing validation)

Reflection property model

① Lambert was used as a calibration matrial
incidence angle characteristics of the reflection model



② Retroreflective material is used as a calibration material
incidence angle characteristics of the reflection model

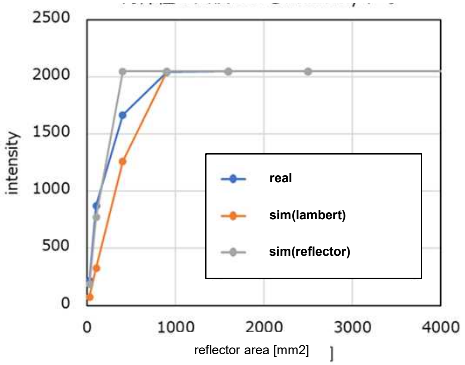


Reflectance in case of facing becomes 2.3 times stronger in (2) than in (1)

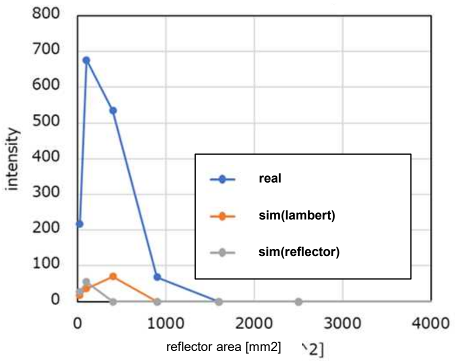
Intensity Consistency Assessment

- The validation index is the average and standard deviation of the received light intensity according to the area of the retroreflective material.

Average received signal intensity by area of retroreflective material



Standard deviation of received signal intensity with area of retroreflective material



[NCAP Consistency Verification - Linear Approach Scenario (Targets: Vehicles (Prius), NCAP Pedestrian, NCAP Bicycle)] Target position and size were checked for consistency.

Comparison of target position and size between actual measurement and simulation.

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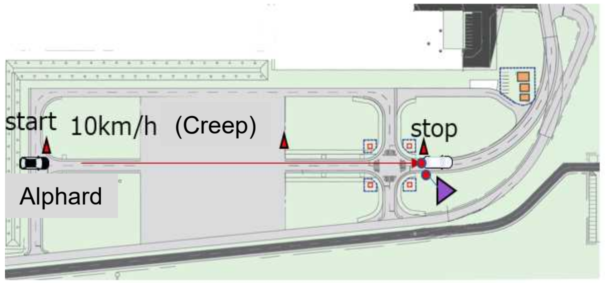


○Velocity condition
・Alphard: 10 km/h (Creep)

○Target
① Prius
② NCAP Pedestrian
③ NCAP Bicycle

○Target Angle
① 0 °

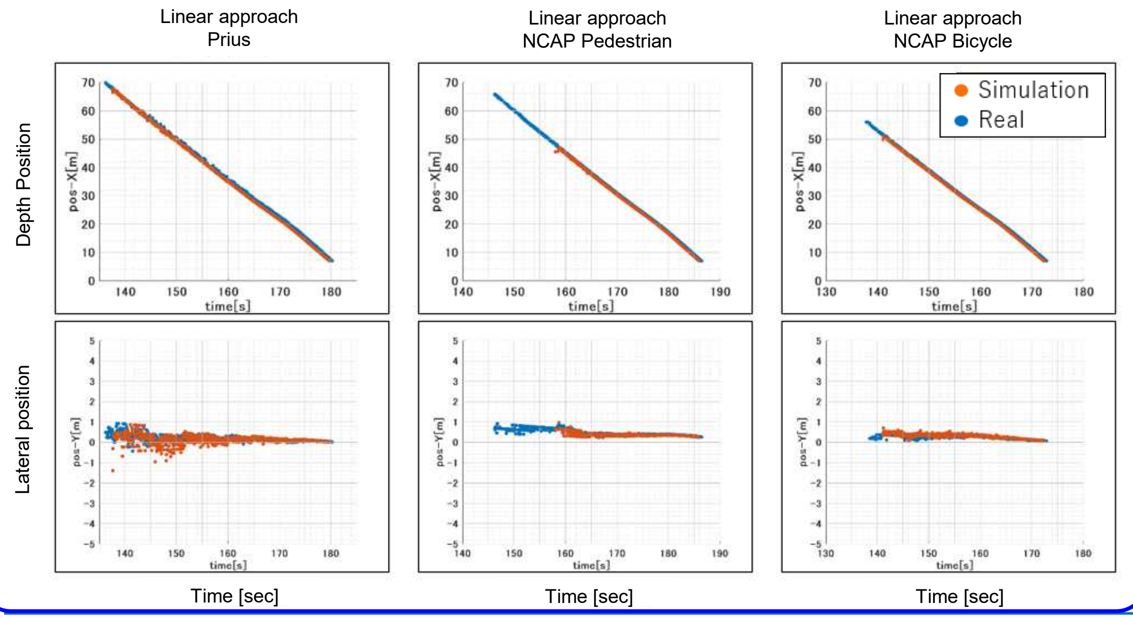
◆Position

- Consistency between actual measurement and simulation was confirmed. Up to 1m difference

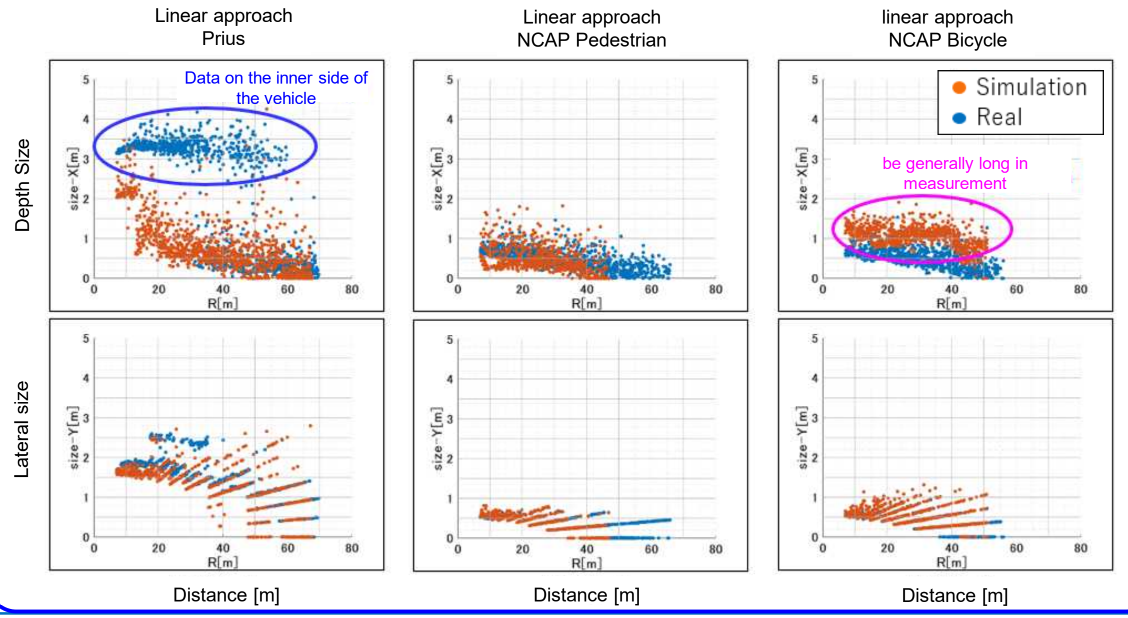
◆Size

- Pedestrian:
  Consistency between actual measurement and Simulation was confirmed.
- Vehicles, bicycles:
  The measured depth size is longer. The reason is described later.

Target Position



Target Size



Source : PIONEER CORPORATION, SOKEN, INC, Kanagawa Institute of Technology

DIVP

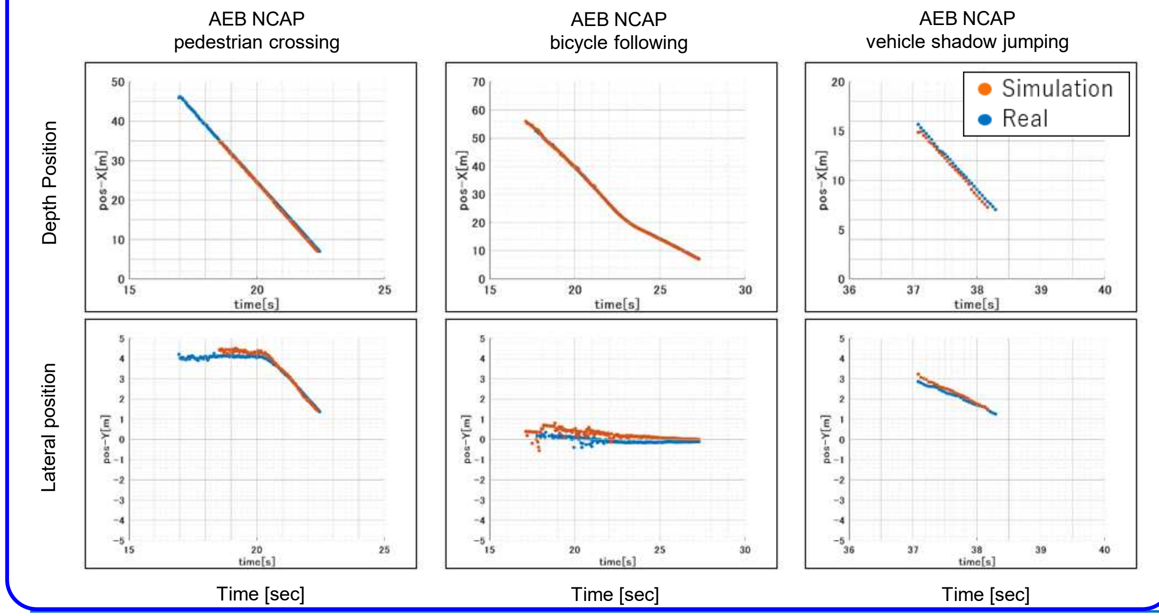
[NCAP Consistency Verification - AEB NCAP Scenario (Pedestrian crossing, Bicycle following, Vehicle shadow jumping)] Target position and size were checked for consistency.

Comparison of target position・size between actual measurement and simulation

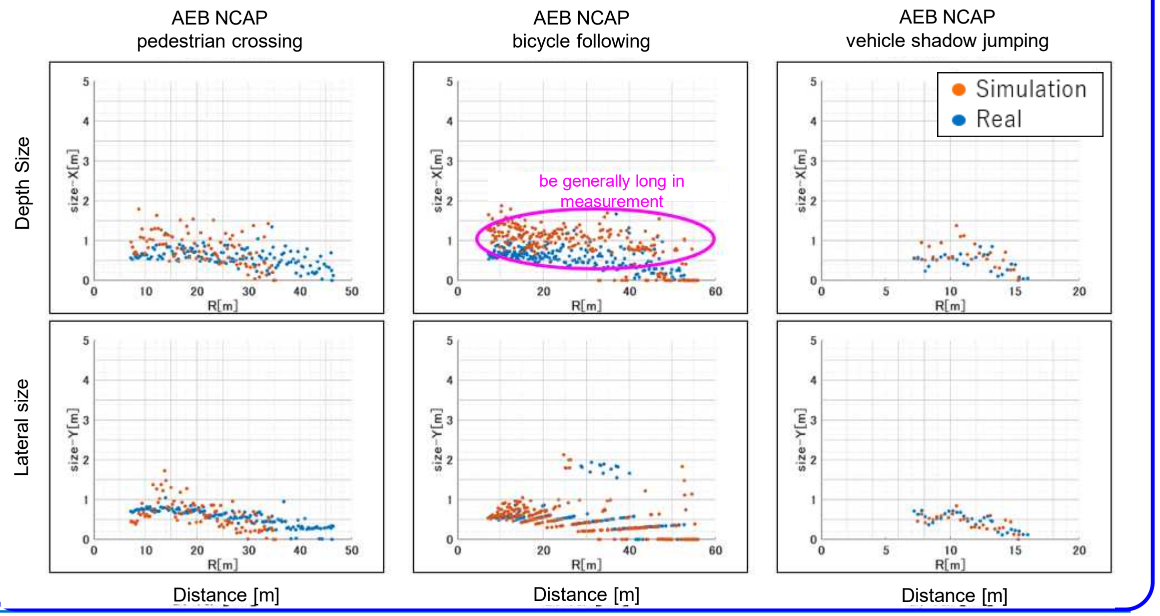
◆**Position**
- Consistency between actual measurement and simulation was confirmed. Up to 1m difference

◆**Size**
- Pedestrian crossing, vehicle shadow jumping:
  Consistency between actual measurement and simulation was confirmed.
- Bicycle:
  Depth size is longer in actual measurement. The reason is explained below.

Target Position



Target Size



Source : PIONEER CORPORATION, SOKEN, INC, Kanagawa Institute of Technology

[NCAP Consistency Verification: Linear Approach Scenario, AEB NCAP Scenario]
Cause of difference between linear approach and AEB NCAP scenario was confirmed.

Check point cloud of the vehicle and bicycle for scenarios which have differences.

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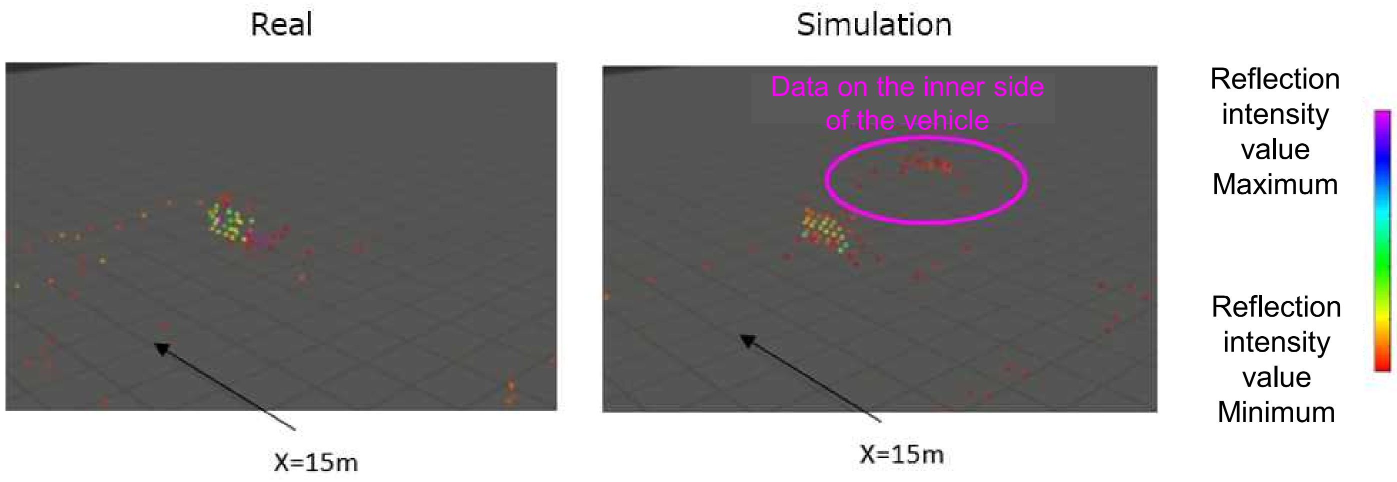
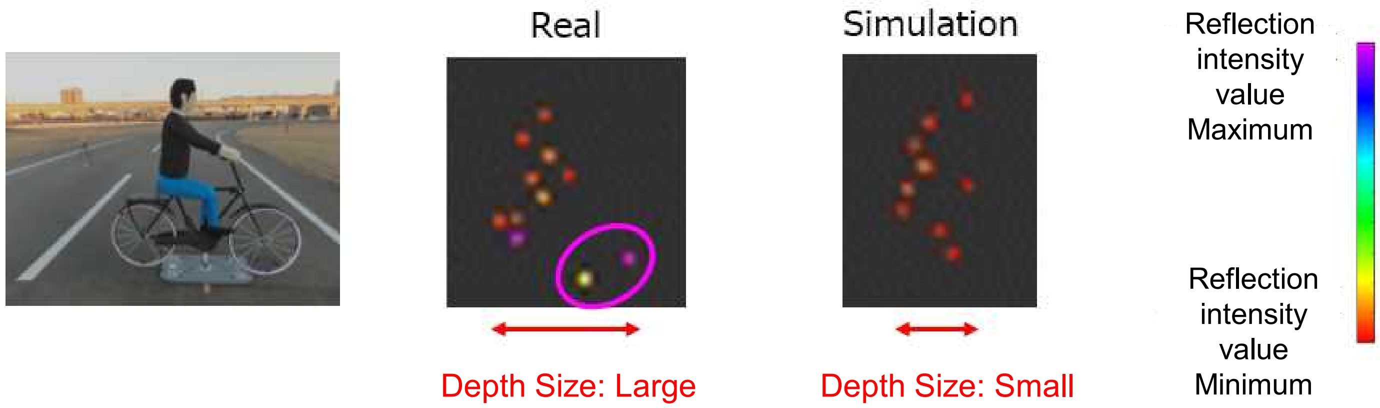
[Vehicle]

- In the simulation, point cloud data on the rear side of the vehicle
  exists. But it does not exist in the actual measurement.
  Therefore, the size in the vehicle depth direction is increased.
- It is assumed that the vehicle model used in the simulation was different from the actual measurement, and that the vehicle
  model with 100% rear glass transmittance was used.



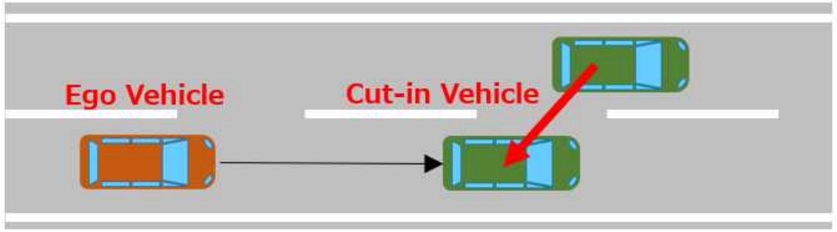
[Bicycle]

- In actual measurement, high reflection intensity data
  is observed in the front part of the bicycle. (Metal, etc.)
- As a result, it is considered that the size in the depth
  direction of the actual measurement is larger than that of the simulation.



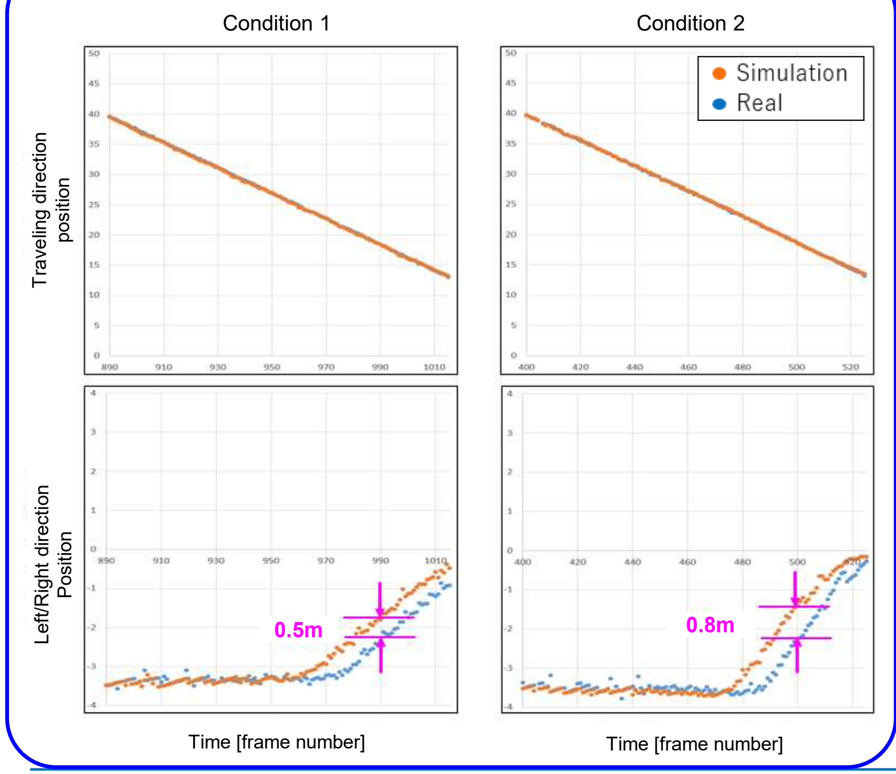
[NCAP Consistency Verification: ALKS Cut-In Scenario]
Consistency was verified with regard to the position of the vehicle cutting in front.

Comparison of Cut-In vehicle position (traveling direction, left and right direction) between actual measurement and simulation

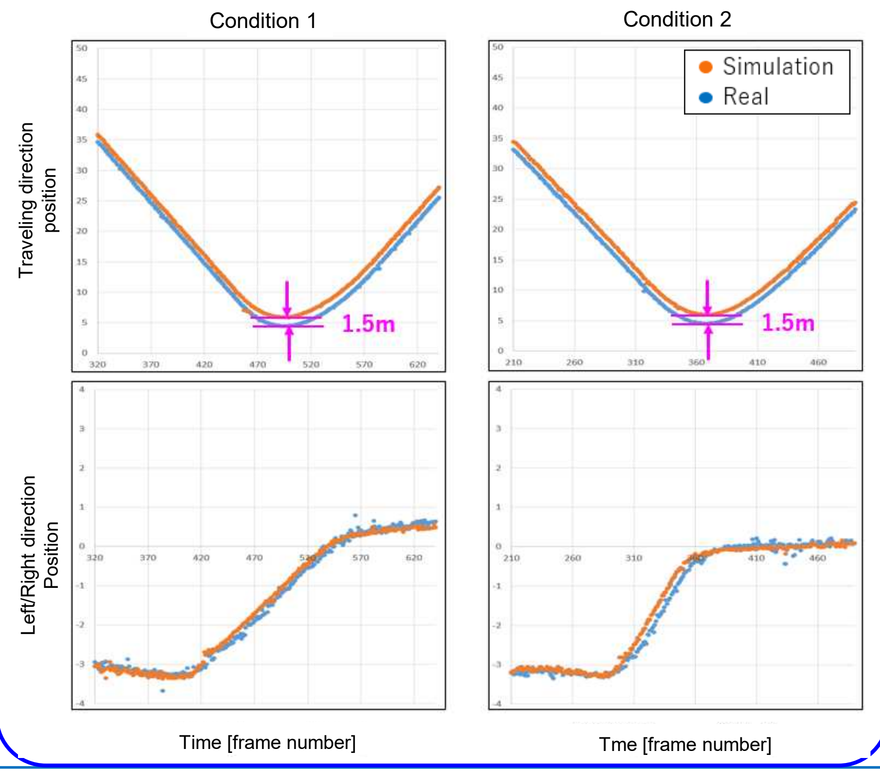



Cut-In vehicle

Experiment 2 -1 -1: Cut-In vehicle position



Exp eriment 2 -1 -2: Cut-In vehicle position



◆**Experiment 2 -1 -1 Cut-In vehicle position**

- Traveling direction:
  Matching
- Left/Right direction:
  Difference of about 0.5 ~ 0.8m

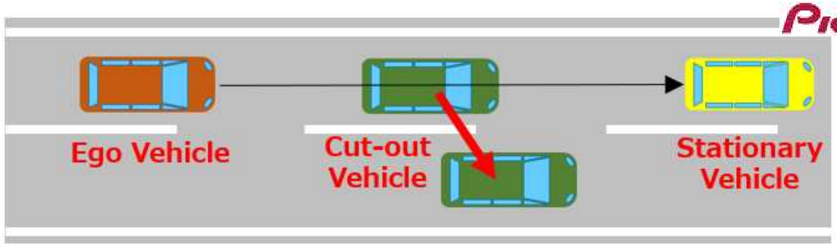
◆**Experiment 2 -1 -2 Cut-In vehicle position**

- **Traveling direction:**
  Difference of about 1.5 m
- Left/Right direction:
  Matching

Source : PIONEER CORPORATION, SOKEN, INC, Kanagawa Institute of Technology

[NCAP Consistency verification: ALKS Cut-Out Scenario]
Consistency was verified regarding location of the cut-out vehicle and the stationary vehicle ahead.

Comparison of the positions of Cut-Out vehicle and stationary vehicles (in the traveling direction and the left and right direction) between actual measurement and simulation



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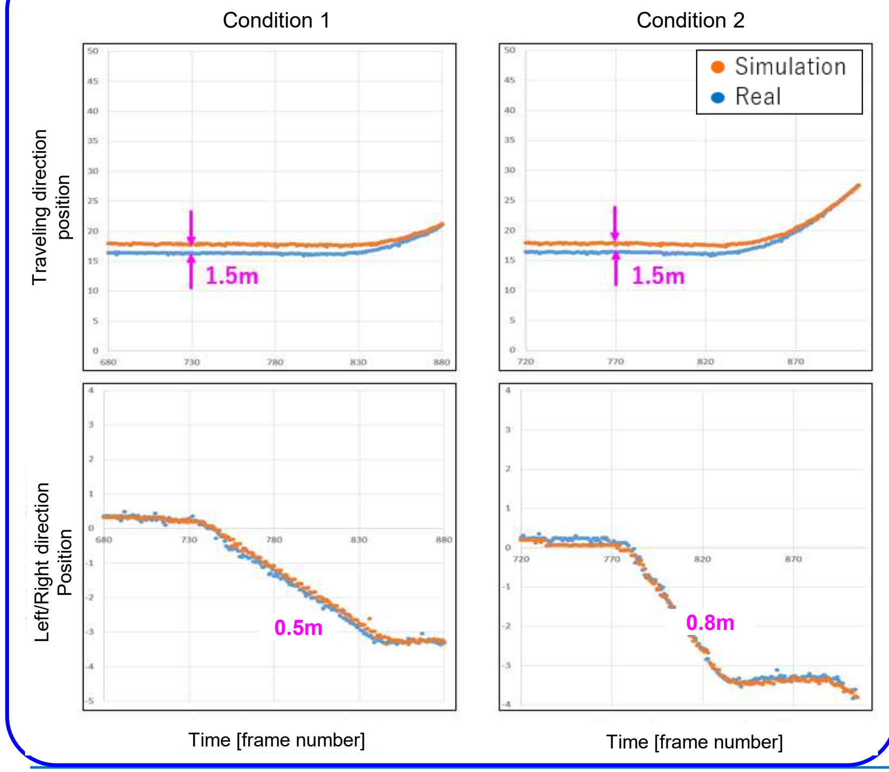
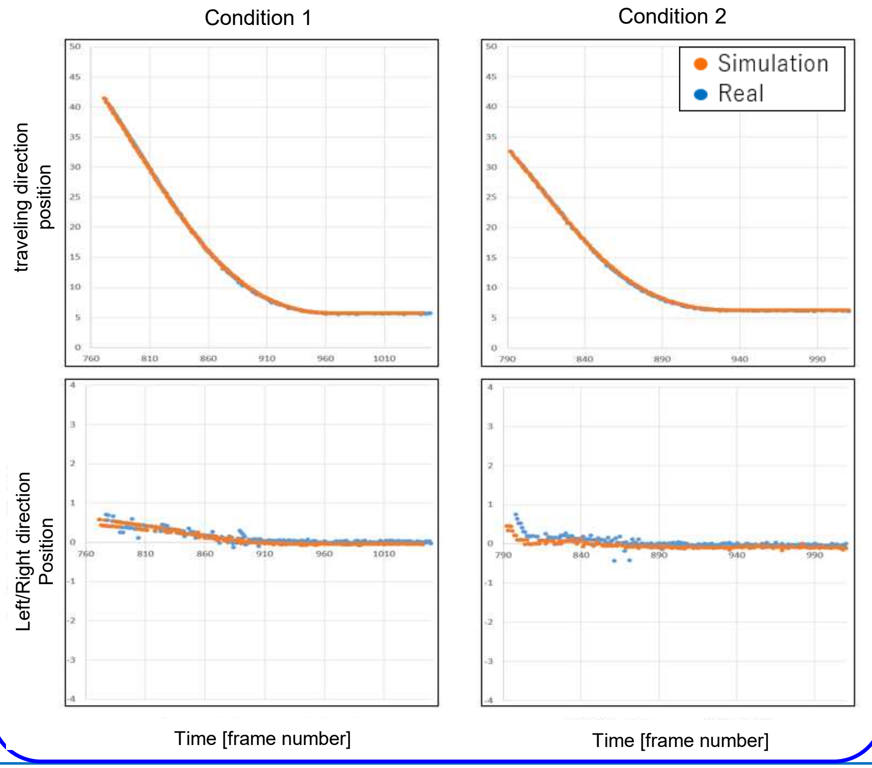
Experiment 2 -2 -1: Cut-Out vehicle position



Experiment 2 -2 -1: Position of stationary vehicle



◆**Cut-Out vehicle position**

- **Travering direction: Difference of about 1.5 m**
- Left/Right direction: Matching

◆**Position of stationary vehicle**

- Traveling direction: Matching
- Left/Right direction: Matching

The cause of the difference of about 1.5 m in the traveling direction observed in both the Cut-In and Cut-Out scenarios will be confirmed in the future.

Source : PIONEER CORPORATION, SOKEN, INC, Kanagawa Institute of Technology

DIVP

[Extendability verification: High reflection road surface] Road surface and white line separation method studied by validating normal and highly reflective road surface.

Confirmation of malfunctions caused by highly reflective road surface, comparison with normal road surface, and study of methods to separate the road surface and white lines

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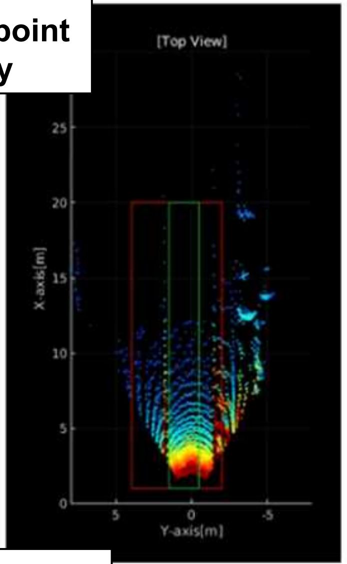
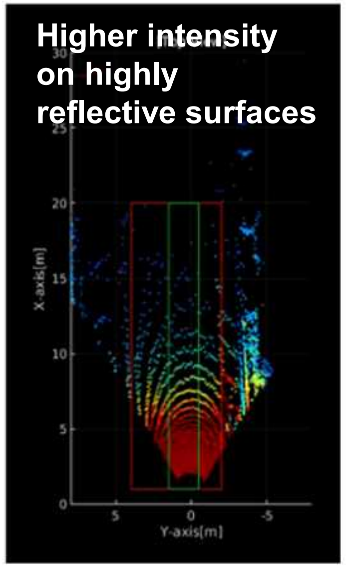
Ortho-viewpoint intensity

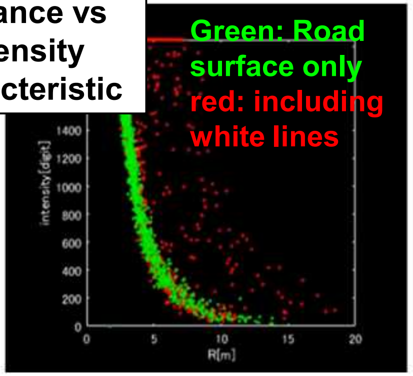
Normal road surface

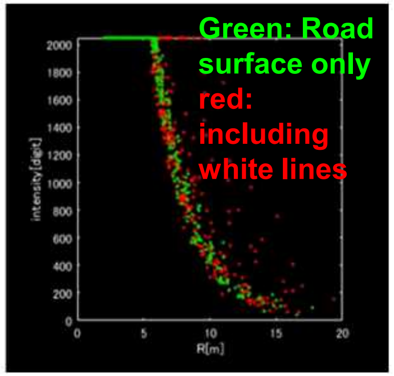


Highly reflective surface



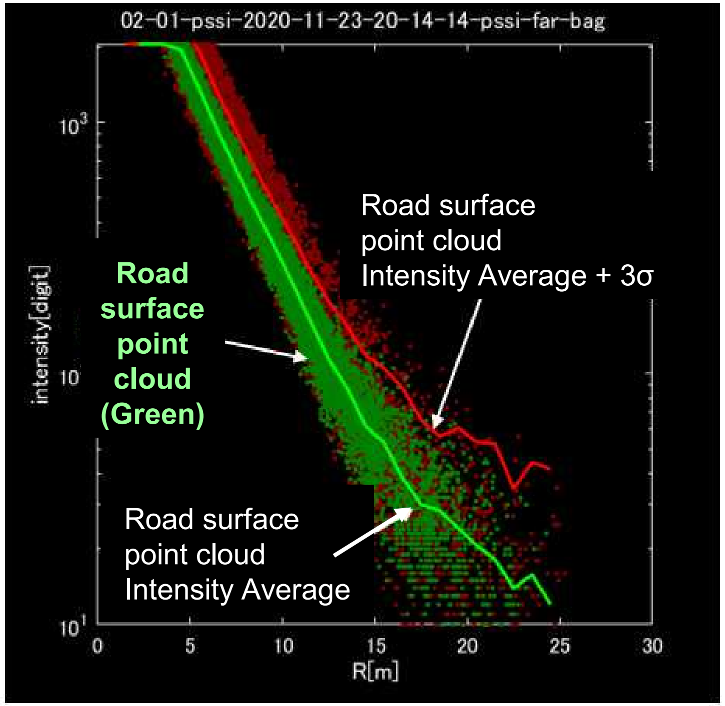
Distance vs intensity characteristic





On highly reflective road surface, intensity values of asphalt are high. So it seems to be difficult to separate the road surface and white lines.

"Distance vs intensity characteristics" of the cumulative road surface point cloud



Separation of road surface point cloud and white line point cloud using
" Intensity separation threshold = average intensity of road surface without white line + 3 σ "

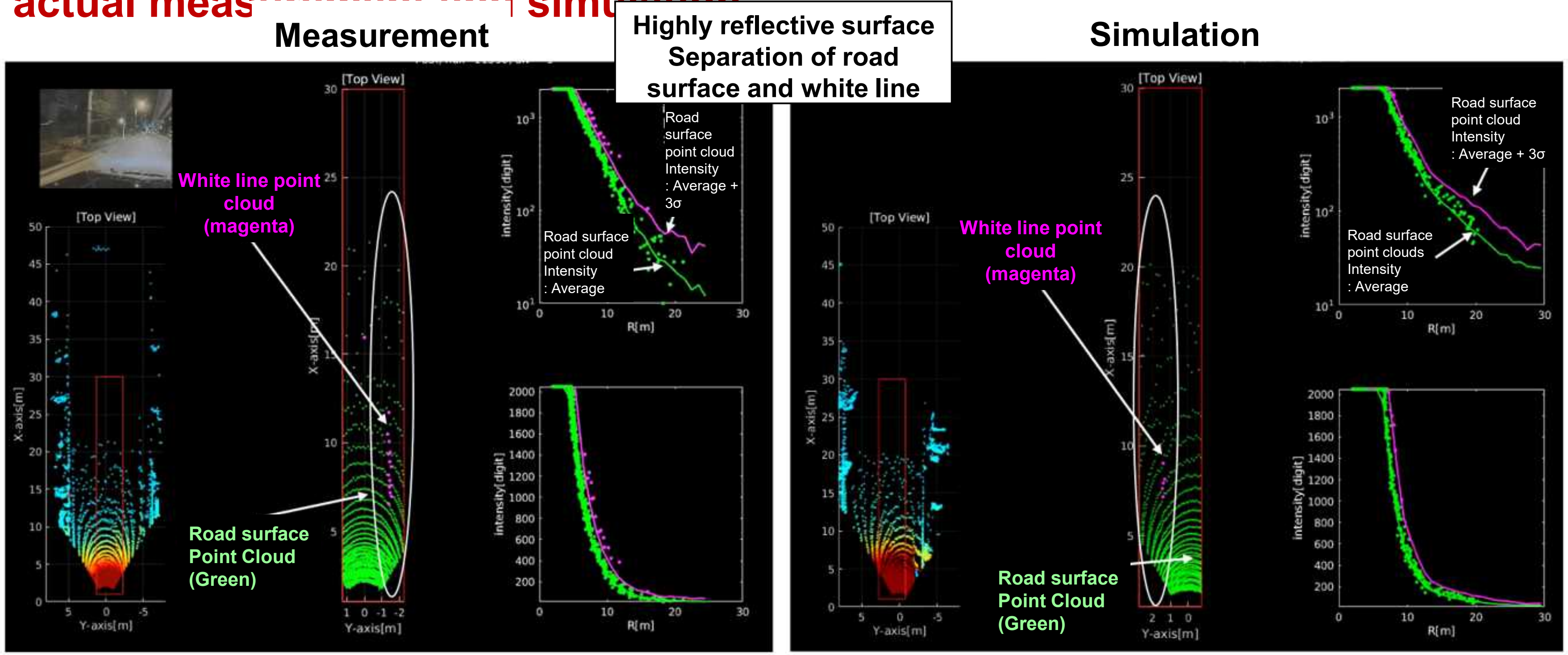
Source : PIONEER SMART SENSING INNOVATIONS CORPORATION, SOKEN, INC

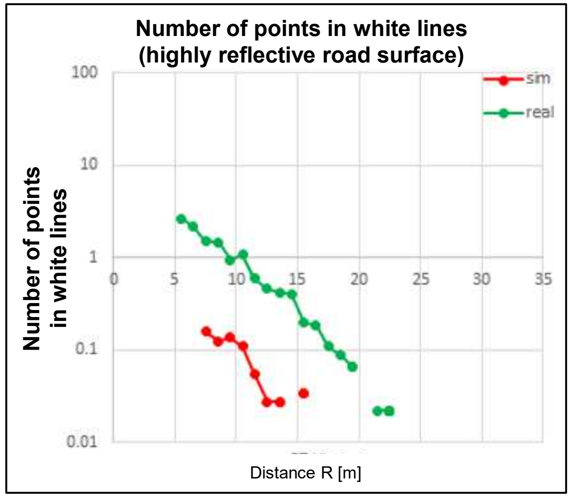
DIVP

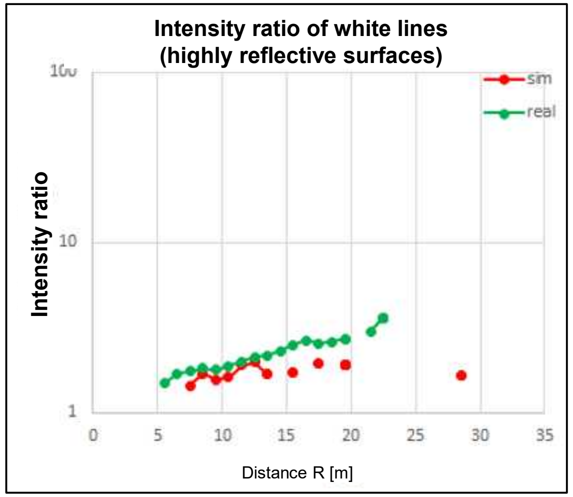
[Extendability verification: High reflection road surface] Road surface and white line separation method applied to highly reflective road surface, and consistency verification carried out.

Application of road surface/white line separation method to highly reflective road surface.
The number of points in extracted white lines and intensity ratio * are compared between actual measurement and simulation

Intensity ratio * = [mean intensity of white line point cloud] / [mean intensity of road point cloud]







- Intensity ratio: Simulation is about 20% smaller than actual measurement
- Number of points in white line: Simulation is 1/10 of actual measurement, which is quite small.

*Reflectance of highly reflective road surface may differ between actual measurement and simulation.
->Confirm alternatively in the consistency verification with the retro-reflecting material

Source : PIONEER SMART SENSING INNOVATIONS CORPORATION, SOKEN, INC

[Reproduction of Malfunction: Consistency verification of spatial attenuation of signal due to rainfall]

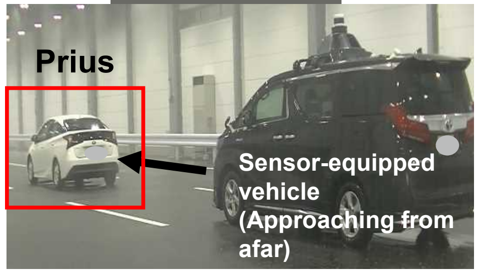
Verified consistency for the combination of LiDAR perceptual model and spatial attenuation model due to rainfall

Consistency Verification of Spatial Attenuation under Rainfall-Malfunction Conditions

Pioneer SOKEN

Verification environment

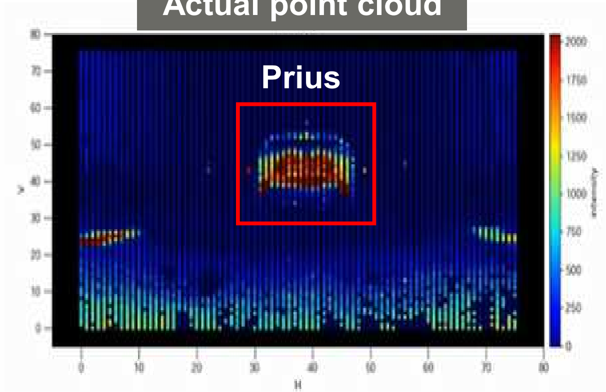
Measured environment



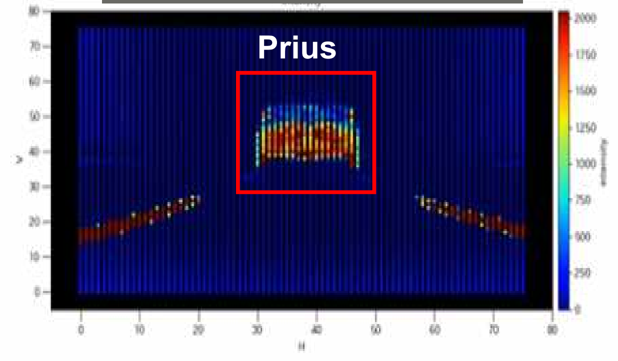
・Rainfall Amount: 80 mm/h

Output point cloud

Actual point cloud

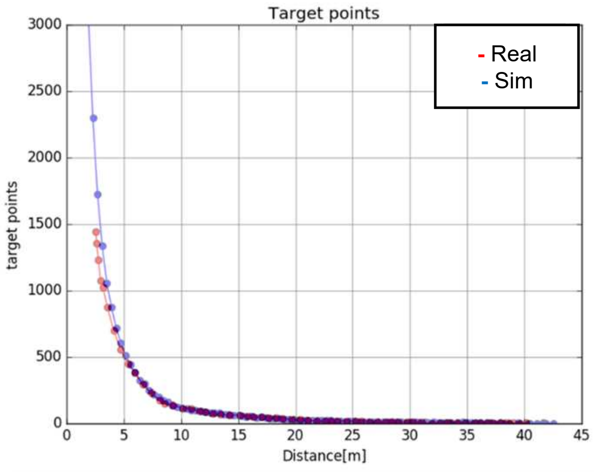


Simulation Point cloud

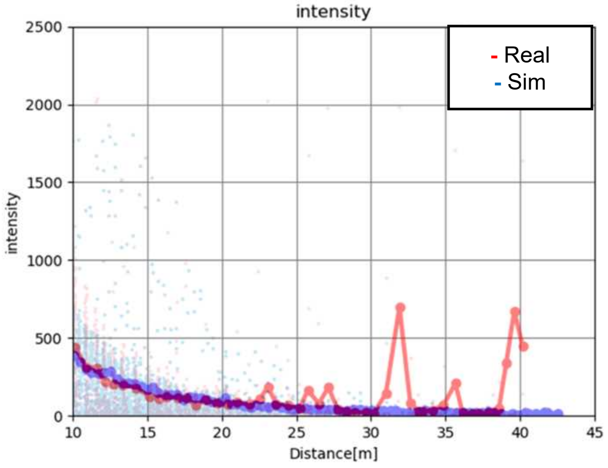


Consistency between the number of ranging points and the received signal intensity according to the distance of the target vehicle (Prius)

Consistency in the number of ranging points



Consistency of received signal intensity



It was confirmed that the effects of spatial attenuation due to rainfall were almost consistent.

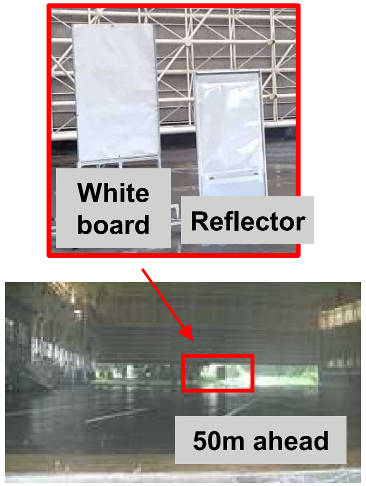
[Reproduction of Malfunction: Investigation of phenomena of rain drop false point due to rainfall]
Confirmed the trend of rain false point on occurrence, position, intensity distribution by actual data.

Phenomenal Confirmation of False Points under Rainfall Malfunction Conditions

Pioneer SOKEN

Verification environment

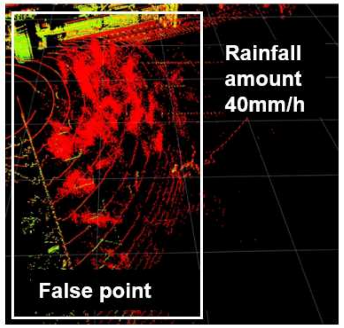
Measured environment



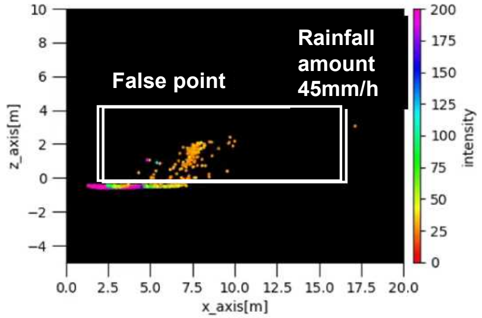
[Rainfall for each particle size]
Small : 20, 30, 40, 45 mm/h
Medium : 55, 60, 90,120 mm/h
Large : 120,150,200 mm/h

Output point cloud (raindrop false point)

Company V model (b)



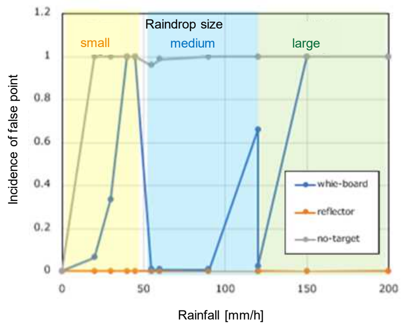
PSSI short LiDAR



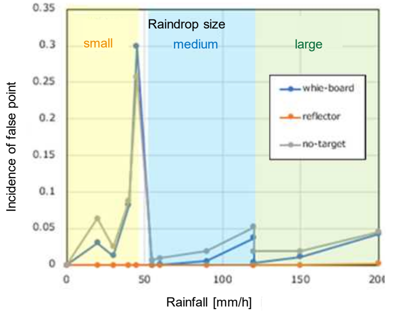
Investigating the trend of occurrence of false points due to rainfall

1) Frequency of occurrence

Company V model (b)



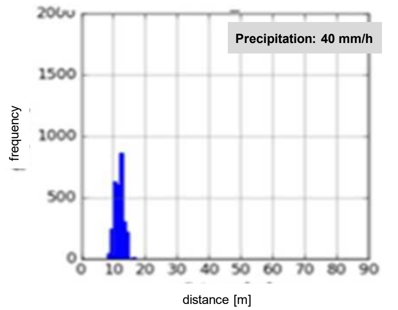
PSSI short LiDAR



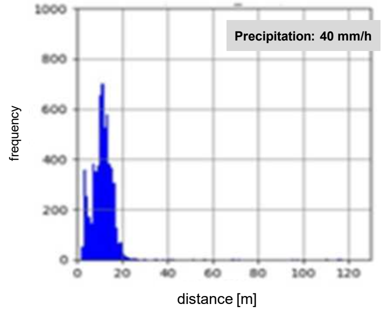
The higher the amount of rainfall and the smaller the particle size, the higher the frequency of occurrence.

2) Generation position

Company V model (b)



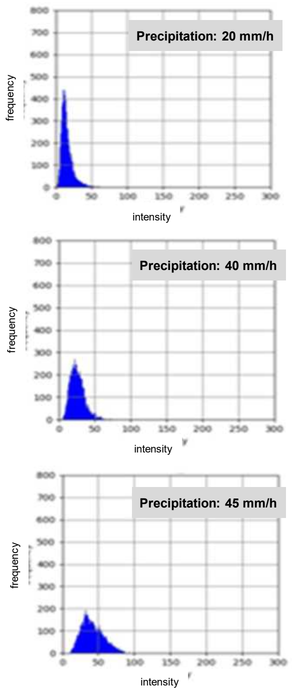
PSSI medium LiDAR



It occurs within a distance of 20 m regardless of LiDAR model and the presence or absence of a target.

3) Intensity distribution

PSSI medium LiDAR



As the amount of rainfall increases, the distribution spreads to the side with higher received signal intensity.

In order to reproduce the rain malfunction, it is essential to understand the phenomenon of false points of raindrops and the effect on LiDAR output

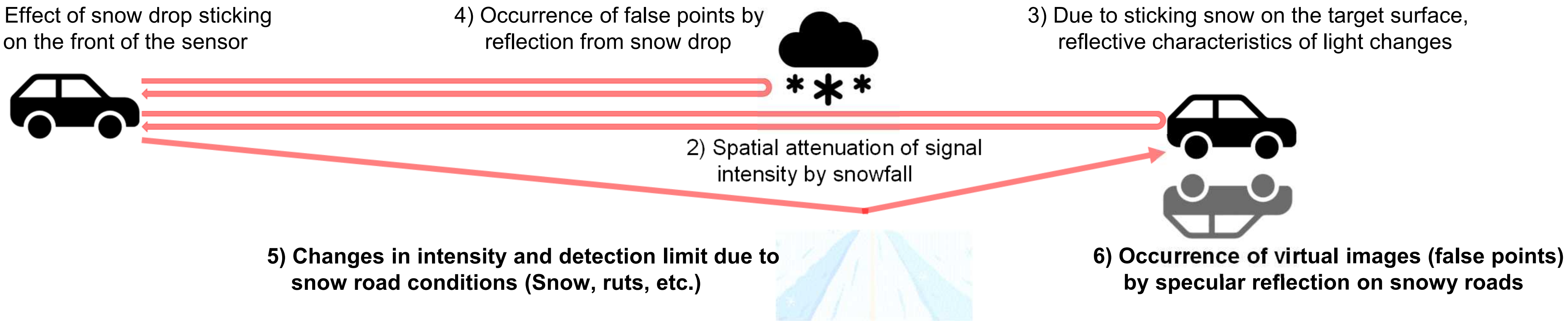
Source : PIONEER SMART SENSING INNOVATIONS CORPORATION, SOKEN, INC

DIVP

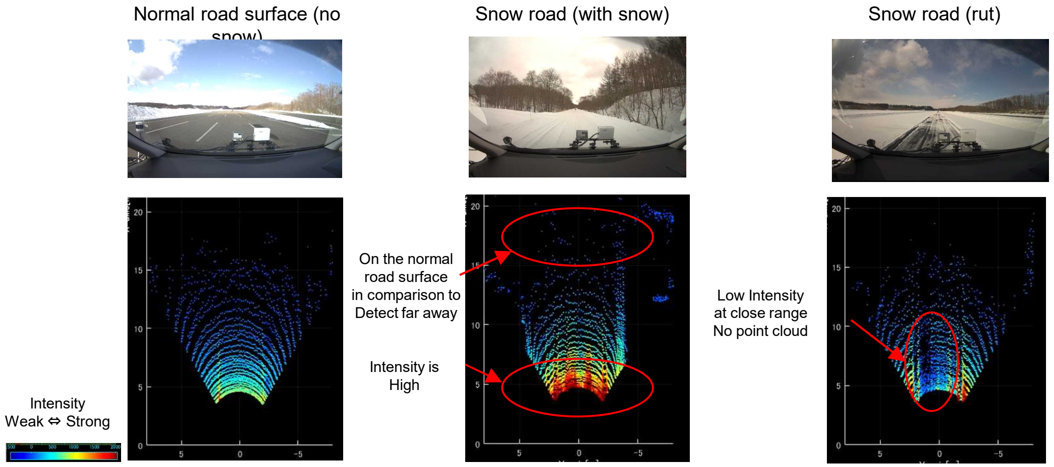
[Reproduction of malfunction: Confirmation of the effect of snowfall]
Effect of snow on LiDAR was summarized and several actual phenomena were confirmed.

Effects of Snow on LiDAR

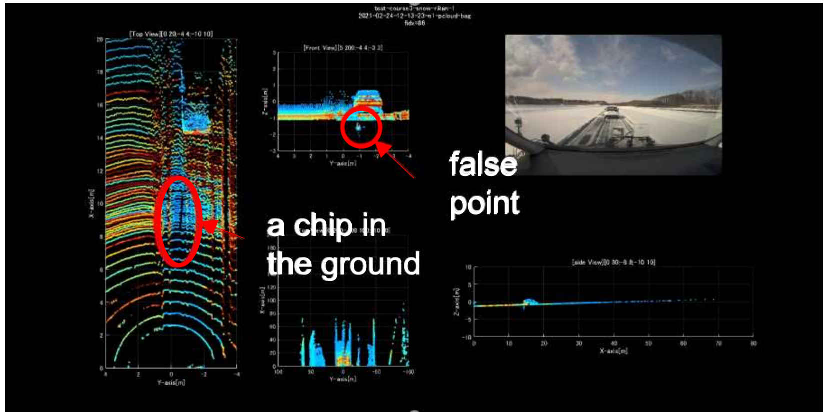
Pioneer SOKEN 神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY



Actual Point Cloud Data regarding snow effect 5)



Actual Point Cloud Data regarding snow effect 6)



@ FT-Techno
Toyokoro Exp. Stn.

Source : PIONEER SMART SENSING INNOVATIONS CORPORATION, SOKEN, INC, Kanagawa Institute of Technology

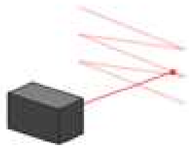
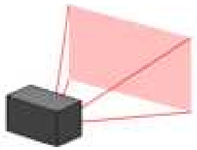
DIVP

[LiDAR Model Interface]
Interface specifications compatible with various type of LiDARs based on industry trends

LiDAR perception input

Types of LiDAR optical system

Categorize LiDAR optical systems in terms of modulation scheme, laser wavelength, and scanning type

modulation type	pulse modulation	CW modulation	
wave length	IR		
scanning metod	 motor scan	 MEMS scan	 flash type

Supported LiDAR types

- ***Pulse modulation method is supported.***
  （CW modulation method is not supported）
- ***Laser wavelength supports near-infrared light including 900nm band and 1500nm band.***
- ***Scanning method supports motor method, MEMS method, flash method.***

In order to reproduce the scanning of various existing devices, the irradiation direction is implemented as a fixed table

Source : PIONEER SMART SENSING INNOVATIONS CORPORATION

Outcome

I	■ "Scenario package" for sensor validation
II	■ Space and sensor model highly consistent with actual phenomena
III	■ Measurement and validation methods that support consistency
IV	■ Scenario DB for sensor validation
V	■ Platform with standard I/F and connectivity to diverse assessment environments

III → ■ Measuring Equipment and Evaluation Methods

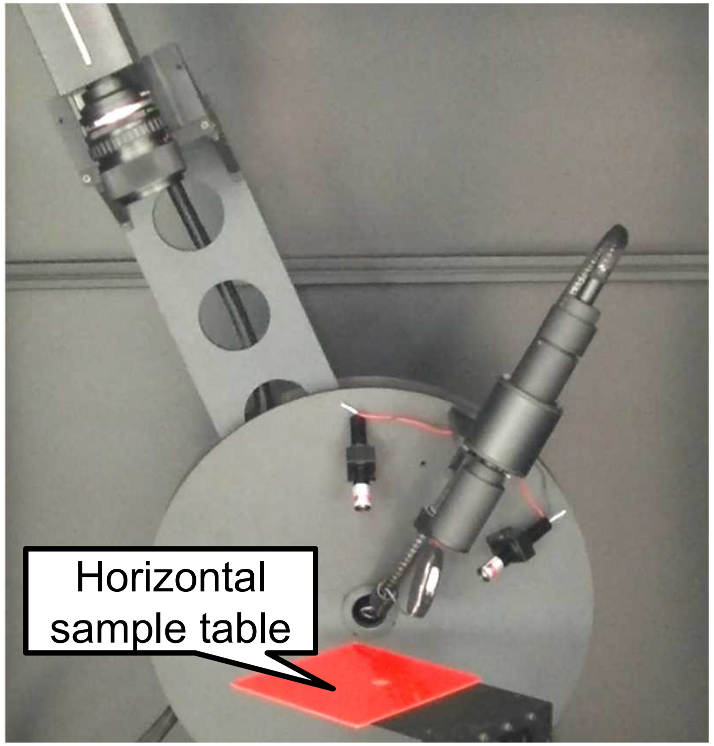
III → ■ Standardization of consistency evaluation methods

DIVP

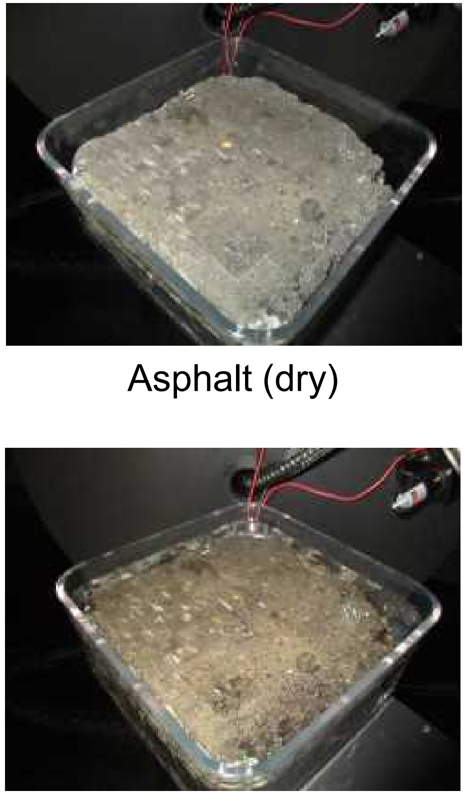
The reflectance measuring device is designed so that samples can be installed horizontally, so it is possible to measure reflectance of submerged samples. Based on the measured results, an equation was derived to predict the reflectance in the wet state from that in the dry state.

Techniques for measuring and predicting reflectance of wet samples

SOKEN



Visible and infrared reflectance measurements goniometer

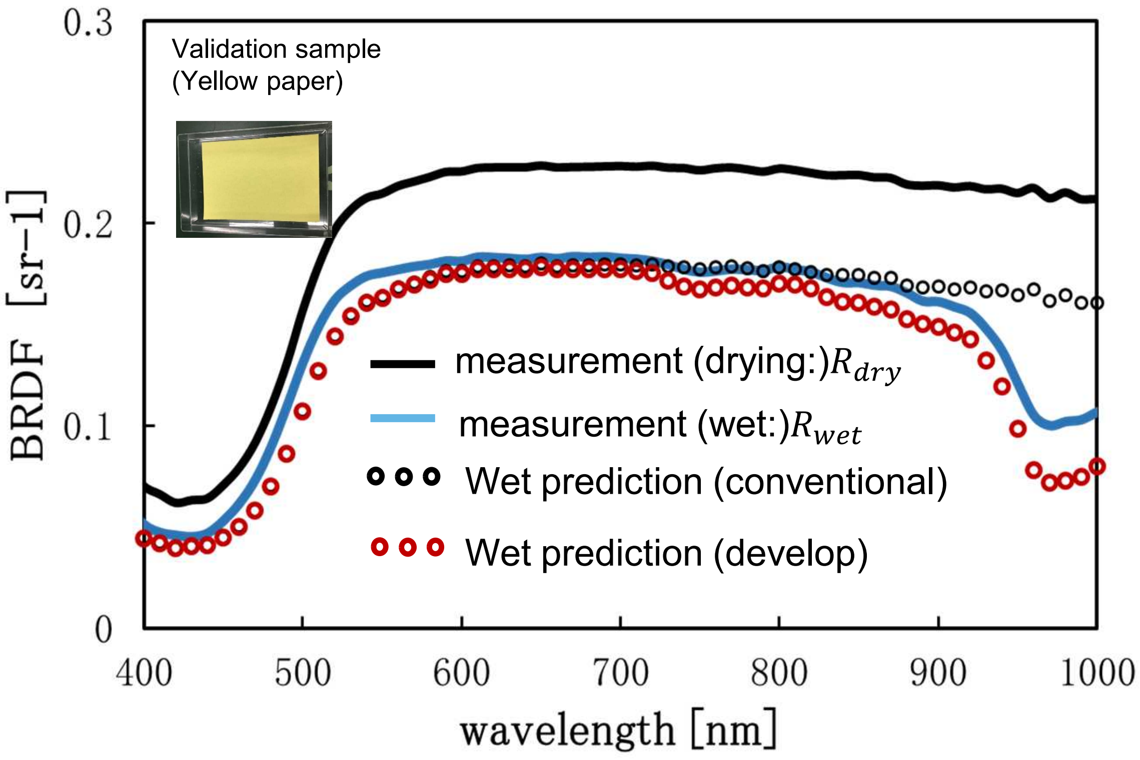


Asphalt (dry)

Asphalt (wet)

$$R_{wet} \approx (1-r)\sum_{k=0}^{\infty} p^k f^k(n, R_{dry})\, \underline{e^{-2k\alpha l}}$$

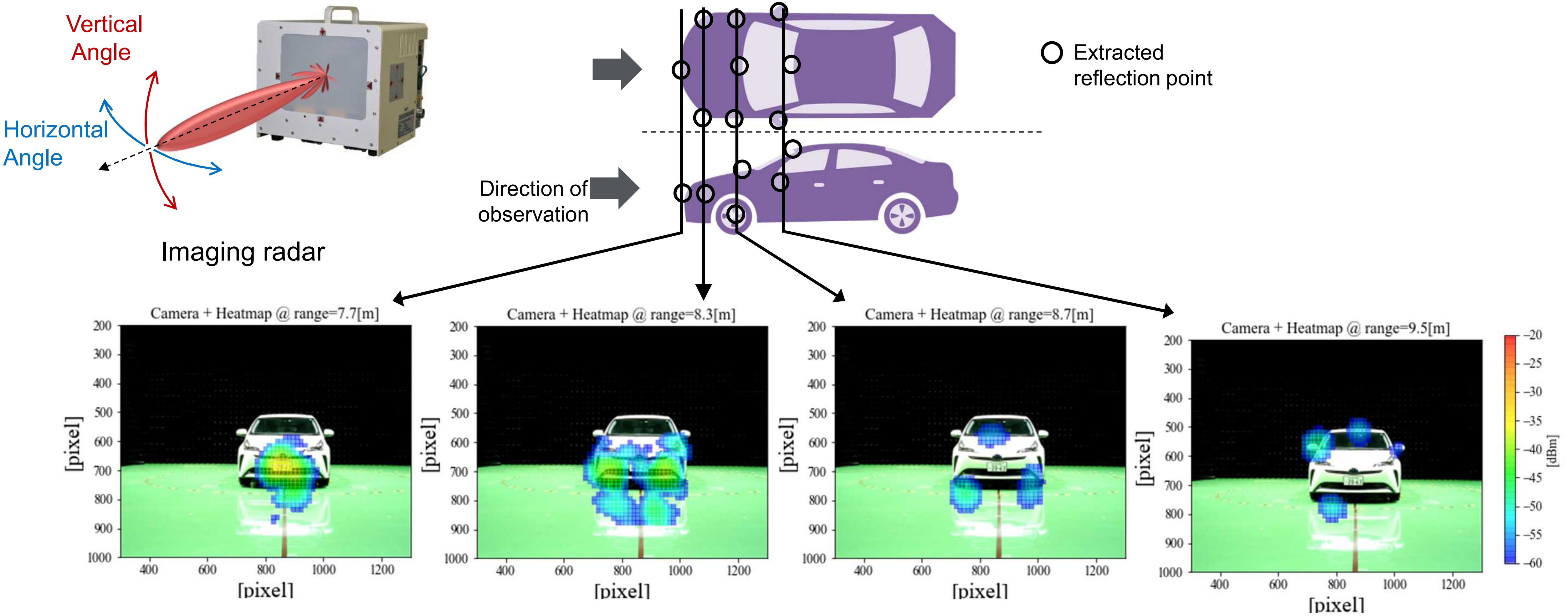
Water absorption coefficient



The reflection point and reflectance at the target of the millimeter-wave radar are visualized by the three-dimensional scanning imaging radar. This method was applied to the development of CG model for radar and improved the accuracy of scattering cross section calculation by PO approximation.

三菱プレシジョン株式会社 MITSUBISHI PRECISION CO., LTD.   Nihon Unisys, Ltd   SOKEN

Visualization of millimeter-wave radar reflection points



Source : SOKEN, INC

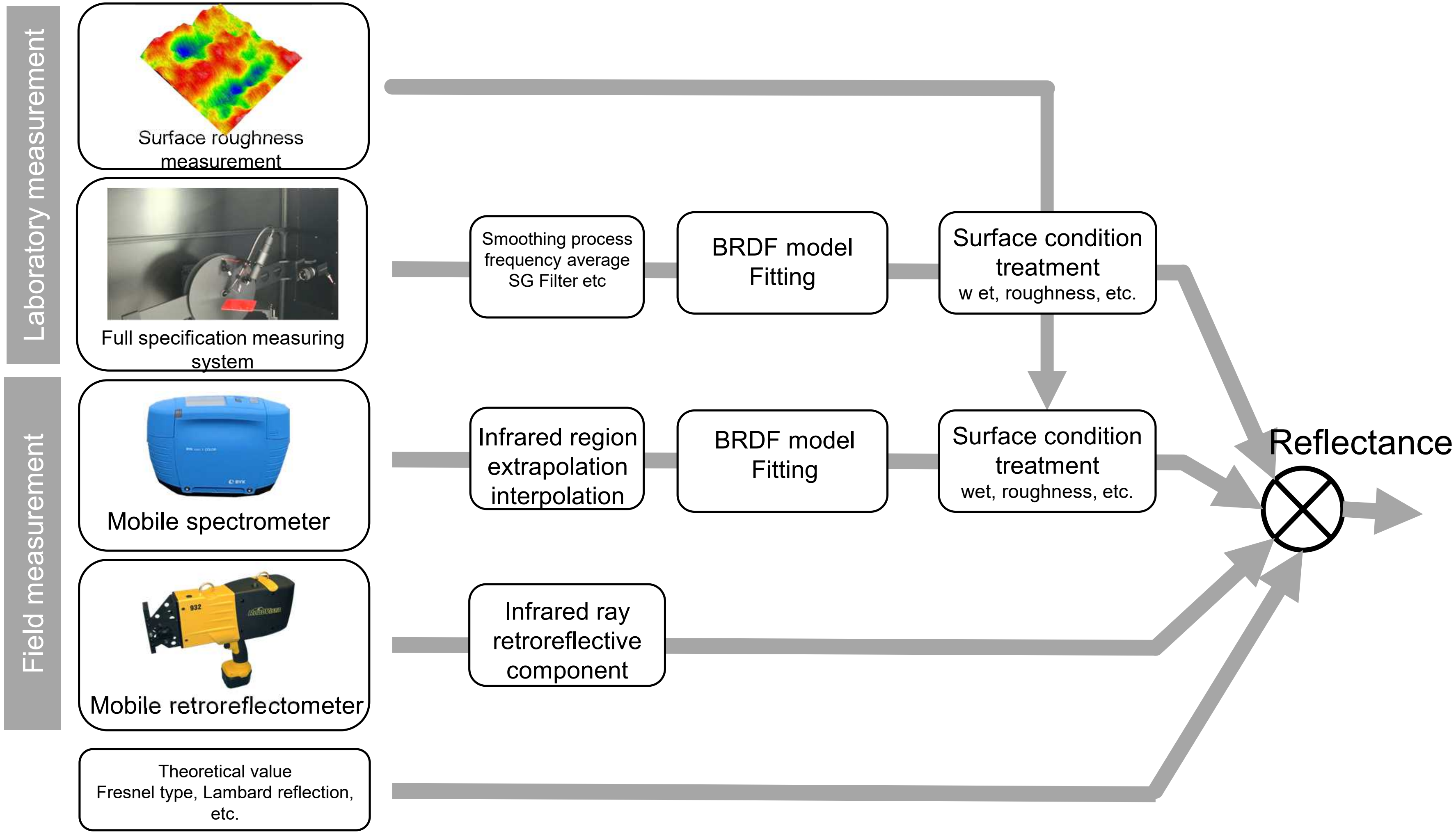
DIVP

A mobile retroreflectometer has been introduced to measure the retroreflectance of deteriorated white lines on site. By combining with the reflectance measurement results of multiple measurement systems, it is possible to create reflectance under various environments.

Combined example of actual measurement data of each equipment

SOKEN

Mobile retroreflectometer
Compatible with 905 nm



Source : SOKEN, INC., Kyokko Trading Co.,Ltd.

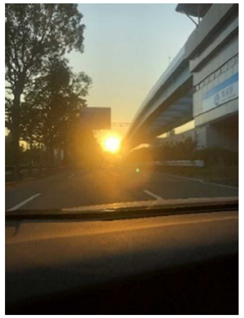
DIVP

We acquired data for conformity verification for scene reproduction, which sensor performance is not good at, such as perception on public roads, recognition malfunction data, rain, and snow effect data.

SOKEN 神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY TTDC

Road failure

(Tokyo Waterfront City:Odaiba, Metropolitan Expressway C1)

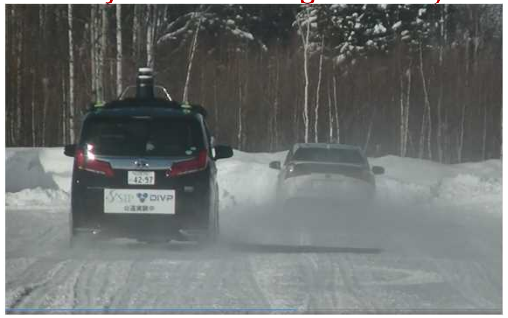


Highly reflective surface **Elevated reflection** **Backlight**

Snow Effects

(Toyota Technical Center Shibetsu, FT TECHNO Toyokoro Proving Ground)

Validation of spatial attenuation characteristics due to snowfall



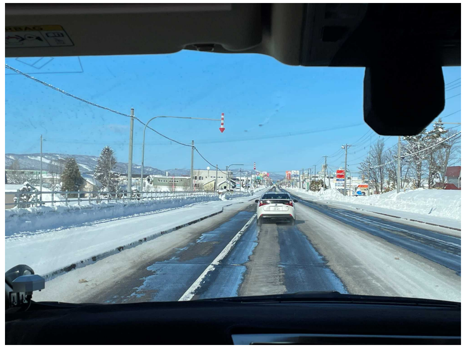
Snow hoisting phenomenon

Rain Effects

(National Research Institute for Earth Science and Disaster Resilience)

Validation of spatial attenuation characteristics due to rainfall

Verification of rain drop adhesion effect



White line recognition failure scene

Small amount

heavy amount

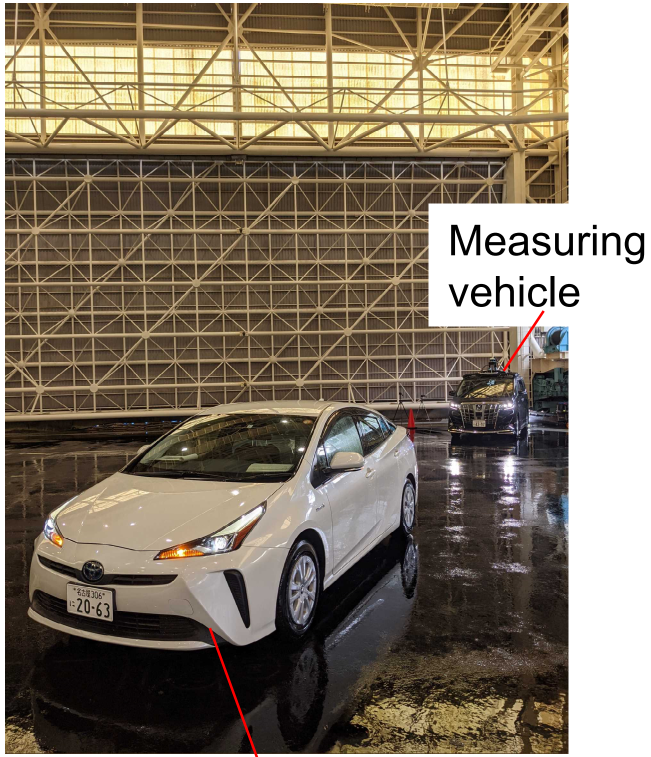
Millimeter-wave snow accretion effect

Source : SOKEN, INC

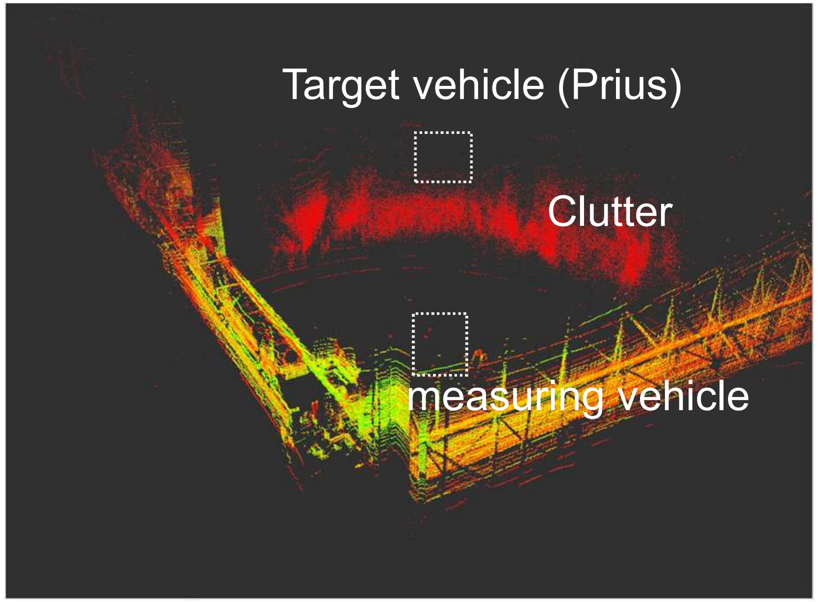
We investigated the effects of rainfall intensity and raindrop particle size on sensor performance, and obtained findings that the smaller the rainfall droplets, the worse the recognition performance in LiDAR.

SOKEN 神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY TTDC

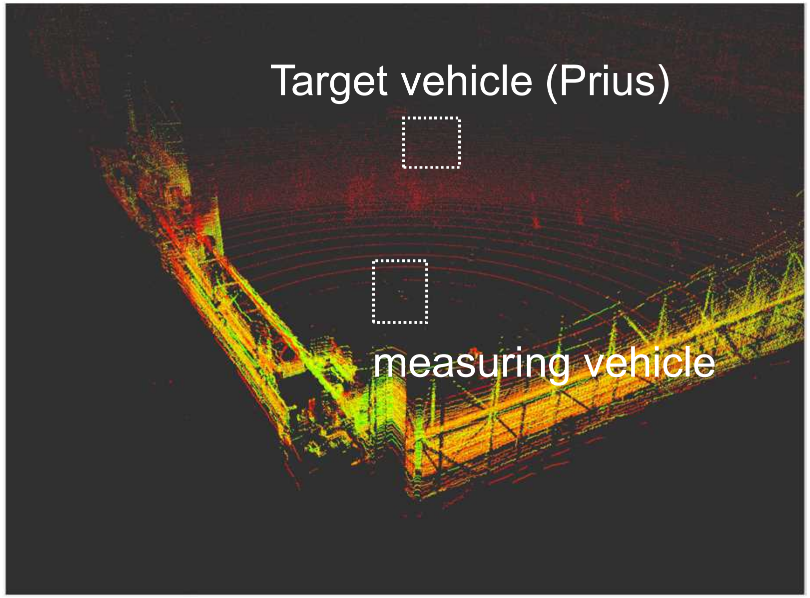
Relationship between Rainfall Conditions and LiDAR Perceptual Performance



Target vehicle (Prius)



Raindrop size small (rainfall 45 mm/h)



Raindrop size Medium (rainfall 55 mm/h)

The smaller the raindrop size, the more likely it is to reflect infrared light.

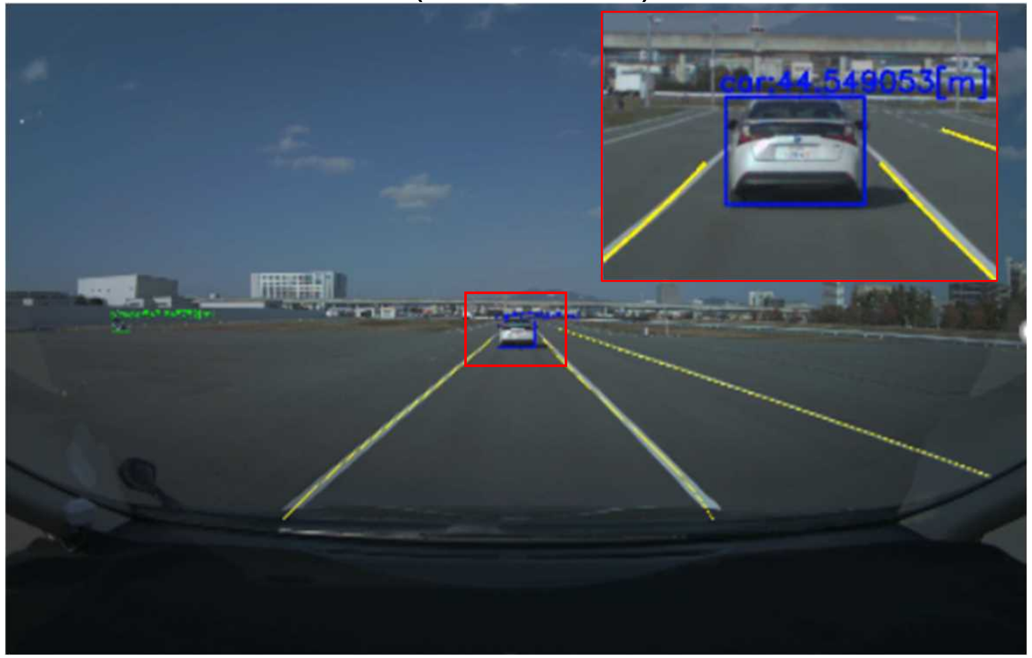
Source : SOKEN, INC

We conducted an experiment to verify the effect of snowfall on the sensor performance, and found problems with the effect of snowfall, such as camera recognition problems caused by a decrease in contrast between the white vehicle and the snow environment in the background.

SOKEN 神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY TTDC

Comparison of Camera recognition performance

Asphalt Road Environment
(JARI Jtown)



Can be recognized as a vehicle from 80m or more in front

Snow environment
(Toyota Technical Center Shibetsu)

Recognition is not stable even at a position of 30 m or less

Source : SOKEN, INC

DIVP

We conducted experiments using large vehicles and children's dummies, which have high user needs.

Heavy vehicle * experiment

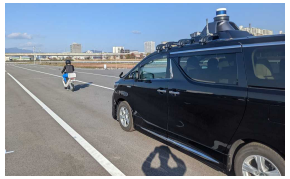
Multipath propagation condition

ALKS Cut-In scenario

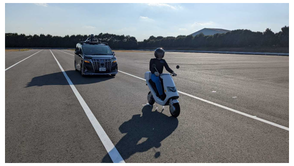
*Hino Profia 12 x 2.5 x 3.8 m

NCAP CCRs(Car to Car Rear stationary)

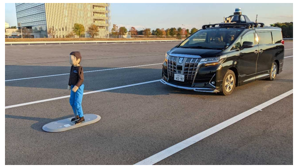
Heavy vehicle



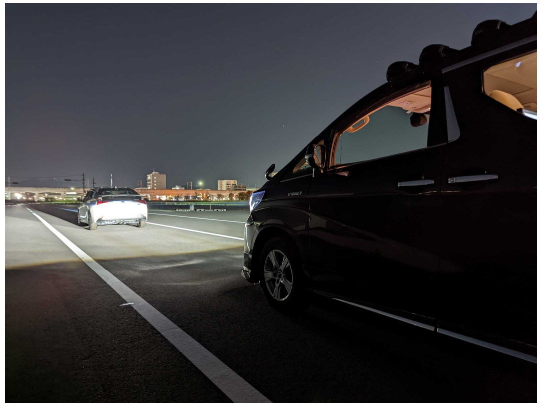
PTW



Escooter

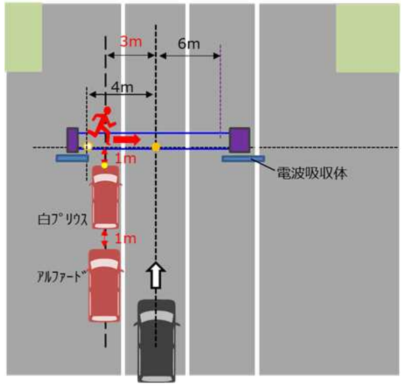


Dummy doll



Night-time CCRs scenario

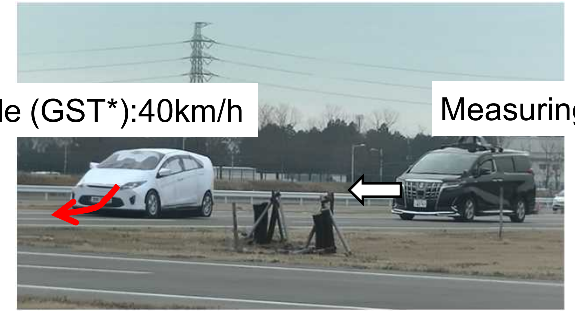
NCAP CPNC (Car-to-Pedestrian Nearside Child)



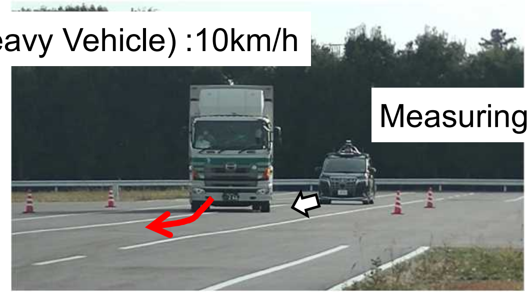
We have started sensor perception and recognition performance verification experiments targeting Heavy vehicles. In the millimeter-wave radar, we found that the reflection point range of large vehicles is widely distributed in the front-rear direction of the vehicle.

SOKEN 神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY TTDC

Comparison of Millimeter-Wave Radar Perceptual Performance under ALKS Cut In Scenario

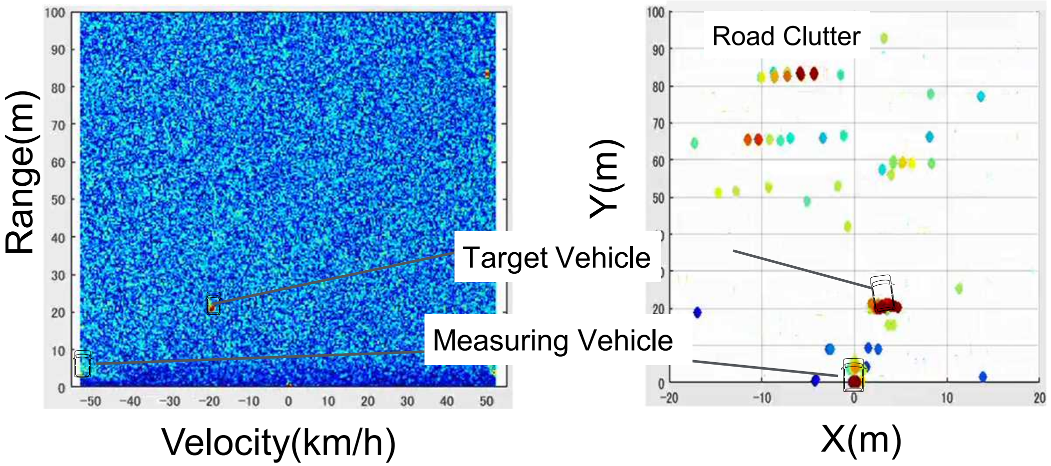


*Guided Soft Target

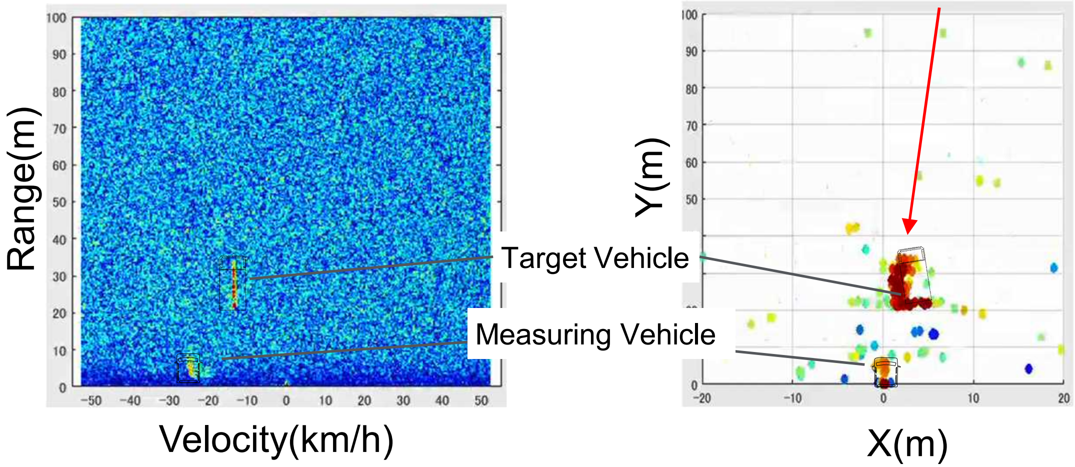


* Due to the experimental risk, the experiment was conducted at a low speed.

Reflection points occur over a wide area along the length of the entire length.



Automobile dummy (Passenger car size)



Heavy vehicle(12 x 2.5 x 3.8 m)

Source : SOKEN, INC, TTDC

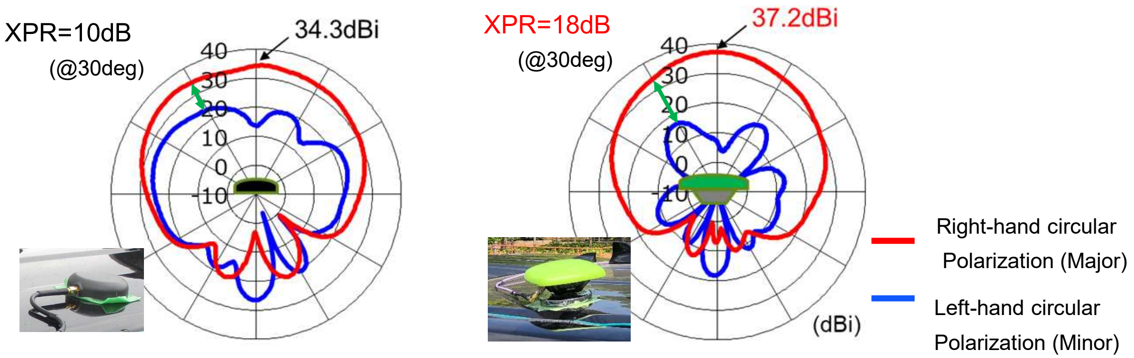
DIVP

Measurement system was improved in terms of improving the accuracy of GNSS and IMU and improving the experimental efficiency for any of the previous year's issues.

SOKEN

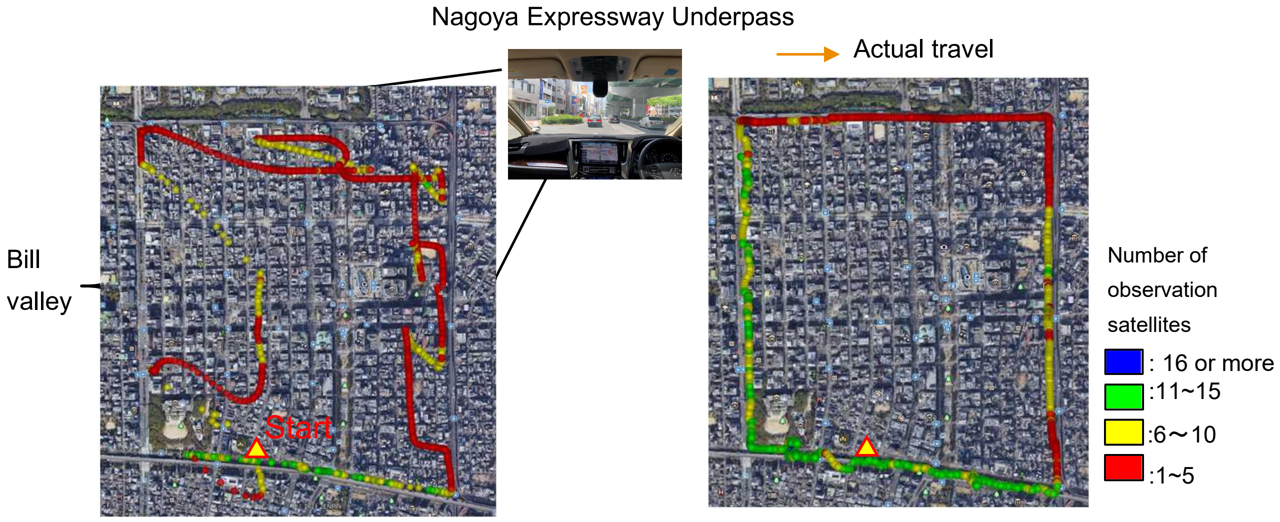
Examples of GNSS measurement system improvement effects

We reduced the effect of reflected waves due to multipath by adopting a surveying antenna with a high cross-polarization ratio (XPR).



standard product antenna

Surveying class antenna



Standard Product

Surveying class

<u>Comparison of Satellite Receiving Performance under Difficult GNSS Satellite Receiving Conditions</u>

(Course around Sakae, Nagoya City, no pre-run calibration (Conditions under which the route correction function is not effective))

Other vehicle measurement system improvements

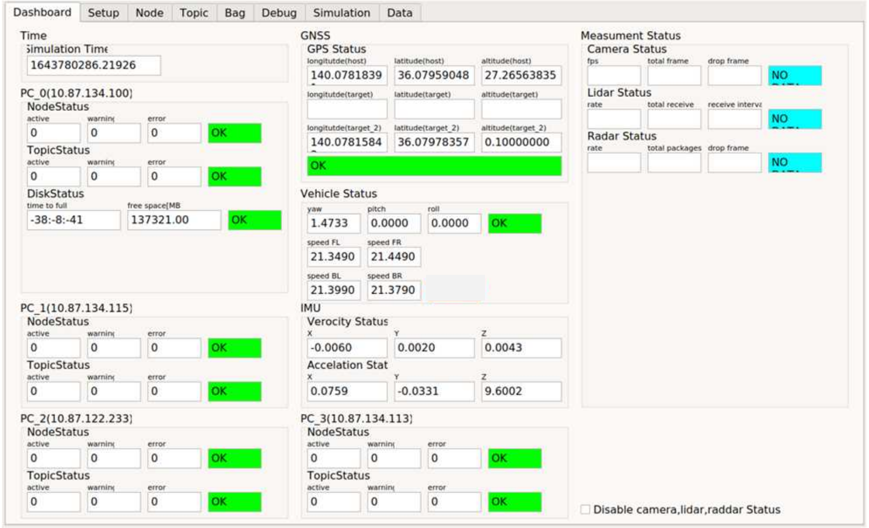
・Suppression of abnormal IMU oscillation by countermeasure against conduction noise in the power supply system (change to an exclusive power supply for the IMU separated from the vehicle power supply)
・Individual HUB system for each sensor prevents data loss due to interference with other sensors
・Improving Experimental Efficiency by Storing Data Directly to SSD (Copy time: approx. 2h/day reduction)
・Data anomaly monitoring software was developed to prevent problems such as latitude/longitude drift and data omissions at the test site.

We have developed software that can monitor the data status during measurement in real time, eliminating the need to redo experiments and improving the efficiency of scenario creation of measurement data.

SOKEN

Data check software

Error monitoring function

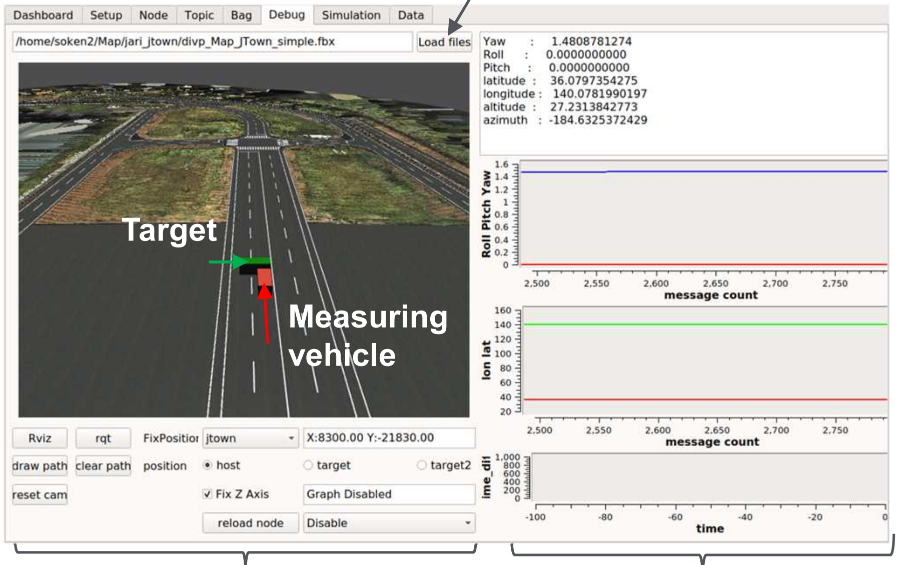


- GNSS failure (Latitude-Longitude Divergence, Missing)
- Body information (velocity, yaw, roll, pitch)
- IMU error (Acceleration, Latitude Longitude)
- Data communication error between PCs

Debug function

Measuring vehicle

Jtown, Odaiba and Metropolitan Expressway C1 map compatible



Traveling locus on MAP

Latitude Longitude, yaw, roll, pitch

Real-time display of the vehicle, target location, and travel route, which have had many troubles, on the scenario MAP, so that the presence or absence of data differences can be seen

Source : SOKEN, INC

DIVP

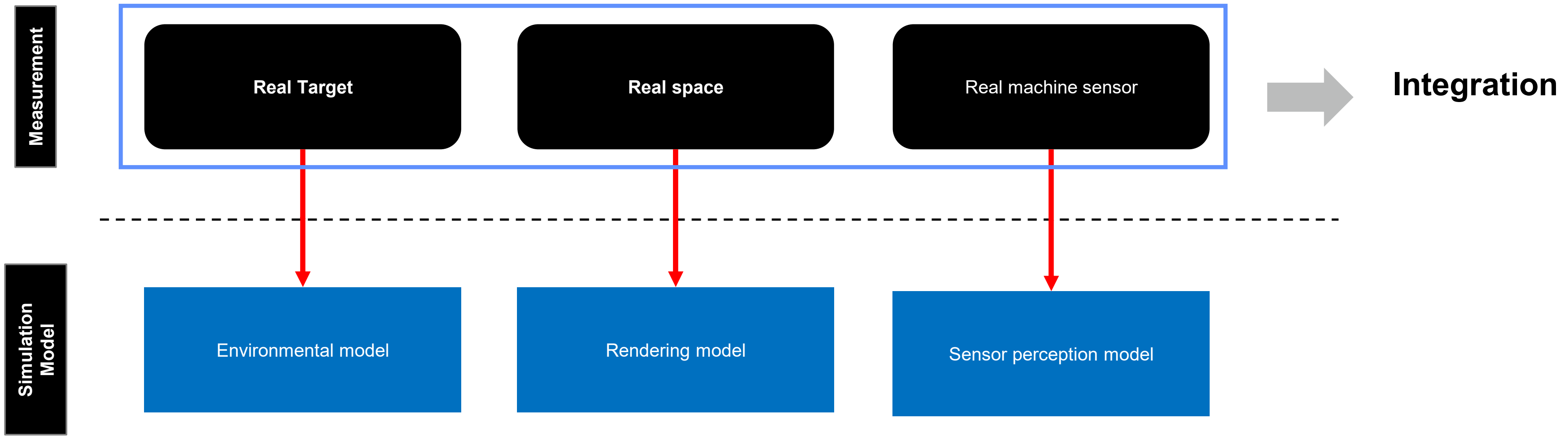
Outcome

I	■ "Scenario package" for sensor validation
II	■ Space and sensor model highly consistent with actual phenomena
III	■ Measurement and validation methods that support consistency
IV	■ Scenario DB for sensor validation
V	■ Platform with standard I/F and connectivity to diverse assessment environments

III →
- ■ Measuring Equipment and Evaluation Methods
- ■ Standardization of consistency evaluation methods

The DIVP® results have visualized by integrating and systematizing the methods of experiments and measurement used to be developed the DIVP® model.

The flow of integrating and systematizing the methods of experiments and measurement



Integrate and systmatize measurement information for modeling the environment, interspatial propagation, and sensors.

Main purpose of integrating and systematizing experimental and measurement methods

- To clarify and record measurement contents and conditions
- To ensure traceability between models and verification results and measurements
- To establish Standards for DIVP®

The DIVP® results have visualized by integrating and systematizing the methods of experiments and measurement used to be developed the DIVP® model.

List of experimental and measurement methods for modeling

List item settings

No.	Item name	Overview
1	Modeling parameters	Parameters to be measured in the model in DIVP®
2	Model Requirements	Required accuracy of measurement
3	Asset to model	Apply modeling parameters asset
4	Experimental name	Experimental nomenclature
5	Experimental purpose	Purpose of the experiment
6	Instrumentation	Measurement method, units
7	Object to be measured	Sample or target to be measured
8	Related sensor	Camera, LiDAR, and Radar target sensors
9	Environmental condition	Environment settings for measurement (location and laboratory)
10	Measurement condition	Setting conditions of the measuring instrument
11	Instrument/Spec	Measuring instruments and performance (Resolution, accuracy, etc.)
12	Equipment, Jigs, and Specifications	Trial equipment, jigs and their specifications
13	Methodology Overview	Outline of measurement method and precautions
14	Implementer	Person in charge of measurement implementation
15	Proof-of-Calibration Allowability	Measurement and modeling challenges
16	Data storage location	Data storage location LINK
17	Challenges	Measurement and modeling challenges

Study and develop necessary information for experiments and measurement methods

Excerpt from the list

Modeling Parameters	Model Requirements (Target Accuracy)	What to model Asset	Experimental name	Experimental purpose	Instrumentation (Units)	Object to be measured	Related sensor
Visible and near infrared light reflection	± 10% Request (PSSI) 1 nm unit measurement (SSS) ± 5% or Less (Equipment Specifications)	Road surface, white lines, vehicle (White, Glass)	Visible and near infrared reflectance precision measurement	Measurements to Obtain Characteristics of Visible Light and Near-Infrared Regions	BRDF	Sample piece	Camera LiDAR
		Vehicle NCAP dummy NCAP Dummy Bicycle	Visible light simple reflectance measurement	Visible light reflection characteristic measurement performed simply for an object that cannot be precisely measured	BRDF	Spot goods	Camera LiDAR
			Specular reflection characteristic measurement	Measurements to obtain specular reflection characteristics for objects that cannot be precisely measured and for objects that are glossy	Gross Value GU	Spot goods	Camera LiDAR
		Retroreflective material white line	Simple retroreflectance measurement	For objects which cannot be precisely measured and which have retroreflective properties, measurement to obtain retroreflectance	Retroreflectance (cd/lx/m2)	Spot goods	LiDAR
Millimeter-wave scattering	None	Vehicle NCAP dummy NCAP Dummy Bicycle	Millimeter-wave scattering measurement	Radar Equation (Distance Quadratic Measurement): Measurement for the PO Approximation to Create a Scatterer Model	Permittivity (F/m) Permeability (H/m)	Sample piece	Radar

Categorize target assets and experiment methods by modeling parameters

Source : Toyota Technical Development Corporation

The DIVP® results have visualized by integrating and systematizing the methods of experiments and measurement used to be developed the DIVP® model.

Brochure of experimental and measurement methods for modeling

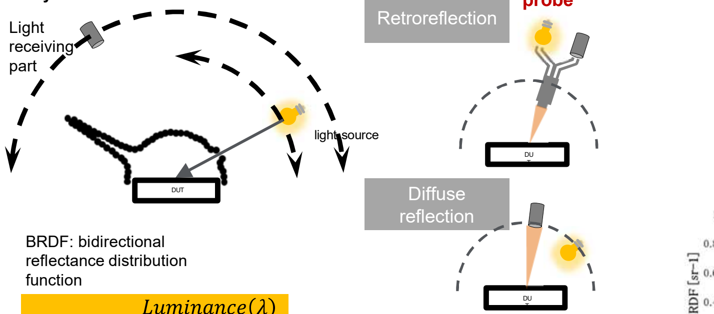
MITSUBISHI PRECISION CO., LTD. / SOKEN / TTDC

[Precision Measurement of Light Reflectance]

Measurement condition
- Measured wavelength: 360 -1100 nm
- Incident angle: 0 to 90 degrees
- Light receiving angle: 0° to ± 180°
- Angle between light source and light receiving
  - Retro-reflections: 0 degrees
  - Reflectivity: > 10 degrees
- TOM SURVEY: BRDF [sr^{-1}]

Measuring instruments and equipment used
- Fiber light source: 390 nm to 1100 nm
- Monochromator spectrometer: 360 nm to 1100 nm, resolution 0.9 nm
- Goniometer: Resolution 0.1°, Positioning Accuracy 0.1°, Reproducibility 0.01°

Outline of measurement system The light source is moved and fixed, and the light receiving section is scanned repeatedly.

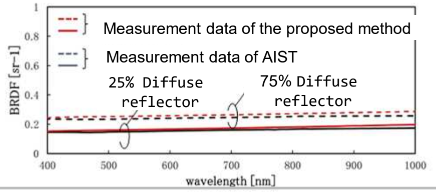


BRDF: bidirectional reflectance distribution function

$$BRDF(\lambda) = \frac{Luminance(\lambda)}{Illuminance(\lambda)}$$

Measurement scene

Measurement result



Displayed instrument information, measurement scene, etc. on one page to be able to get an overview of the measurement at a glance.

List of creating catalogs
- Precision mesurement of light reflectance
- Simple measurement of light reflectance
- Millimeter-wave scattering and reflectometry
- Millimeter-wave RCS measurement
- Map shape measurement
- 3D model geometry
- Rainfall and droplet deposition experiments
- Snowfall and snow accretion experiment

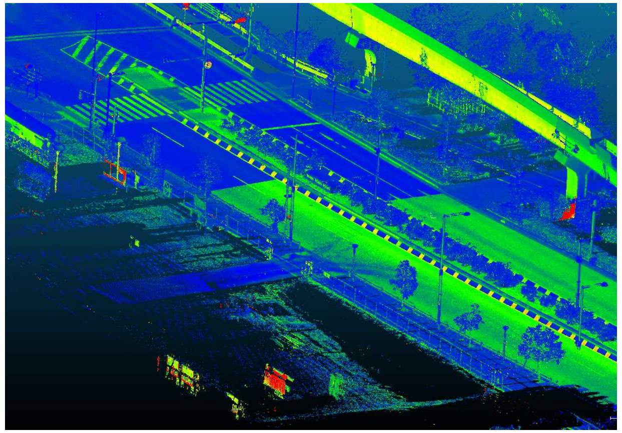
[Map Shape Measurement]

Measurement condition
- Measurements: point clouds
- Coordinate precision: 10 cm

MMS mounted measuring instrument
- GNSS
- Camera
- High Precision IMU
- High precision laser scanner

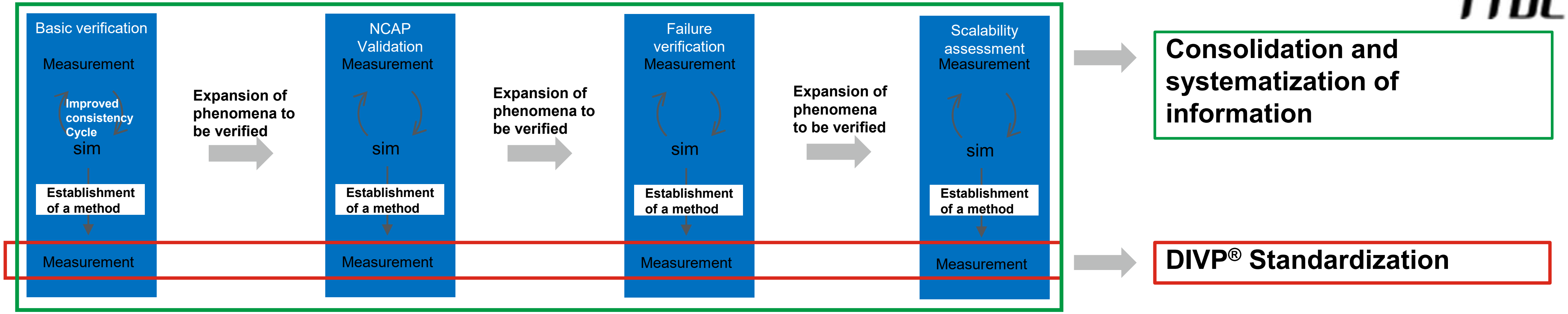
Measurement scene

Measurement point cloud data



The DIVP® results have visualized by integrating and systematizing the methods of experiments and measurement used to be verified consistency of the DIVP® model.

Flow of stabdardization of experimental and measurements methods for consistency verification



Consistency verification is performed within each verification step of basic verification, NCAP validation, failure validation, and scalability validation.In the course of verification, measurements will be brushed up and established as verification methods, which will be made the DIVP® standard.

Main purpose of integrating and systematizing experimental and measurement methods

- To clarify and record measurement contents and conditions
- To clarify relationship between JAMA adverse factors and verification
- To ensure traceability between models and verification results and measurements
- To establish Standards for DIVP®
- To establish foundation for proposing of safety assurance method for autonomous driving in virtual space

Source : Toyota Technical Development Corporation

The DIVP® results have visualized by integrating and systematizing the methods of experiments and measurement used to be verified consistency of the DIVP® model.

List of experimental and measurement methods for verifing consistency

List item settings

No.	Item name	Overview
1	Experimental section	Experimental section in DIVP®
2	Experiment No.	Number within the experimental section
3	Experimental name	Experimental name for consistency verification
4	JAMA failure phenomenon	Tsu superphenomena in the corresponding JAMA malfunctions system
5	Bad classification	Number of the problem
6	JAMA Request	JAMA validation number
7	Sensor model	Target sensor, model
8	Objectives and items to be verified	Purpose of verification, Items
9	Outline of measurement	Outline of measurement procedures, etc.
10	Object	Target during measurement
11	Measurement environment	Location and equipment when measuring
12	Measurement condition	Conditions such as vehicle speed during measurement
13	Consistency verification analysis	Consistency verification Analysis Status
14	Data storage location	Storage location of measurement data and verification result data

Collect and develop the information necessary for experiments and measurement methods

Excerpt from List (Millimeter Wave)

Experimental section	Experiment No.	Experimental name	JAMA failure phenomenon	Bad classification	JAMA Request	Sensor model	Objectives and items to be verified	Outline of measurement
PV	1-1	Target Quiesce _ Distance _ Direction	Reflection intensity decreases due to the shape, size, or posture of the object to be recognized.	M21	Radar0-7 Radar0-8	Camera LiDAR Radar	Static detection distance verification	Position the target in front of the sensor and measure by changing the distance and the direction of the target. Camera ISX019
PV	2	Prius Stationary _ Bearing				Camera LiDAR Radar	Static detected azimuth verification	Measured in front of the sensor at different levels of target distance in the lateral direction
BV	1-1	Linear separation				Camera LiDAR Radar	Dynamic target detection distance verification	Measuring the state in which the vehicle in front of the sensor is moving away from the sensor in a straight line
BV	1-2	Corner separation				Camera LiDAR Radar	Verification of dynamic target detection orientation	Measure the state of the vehicle in front of the sensor as it moves away from the sensor along the corner
BV	1-3	Linear approach	Multi-Path fading due to road surface	M22	Radar2-6 Radar2-7	Camera LiDAR Radar	Verification of Detectability of Dynamic Stationary Targets	Measured in a situation where a vehicle equipped with a sensor is approaching a stop target

Status

- **Total number of experiments: currently 105 experiments**

To Next year

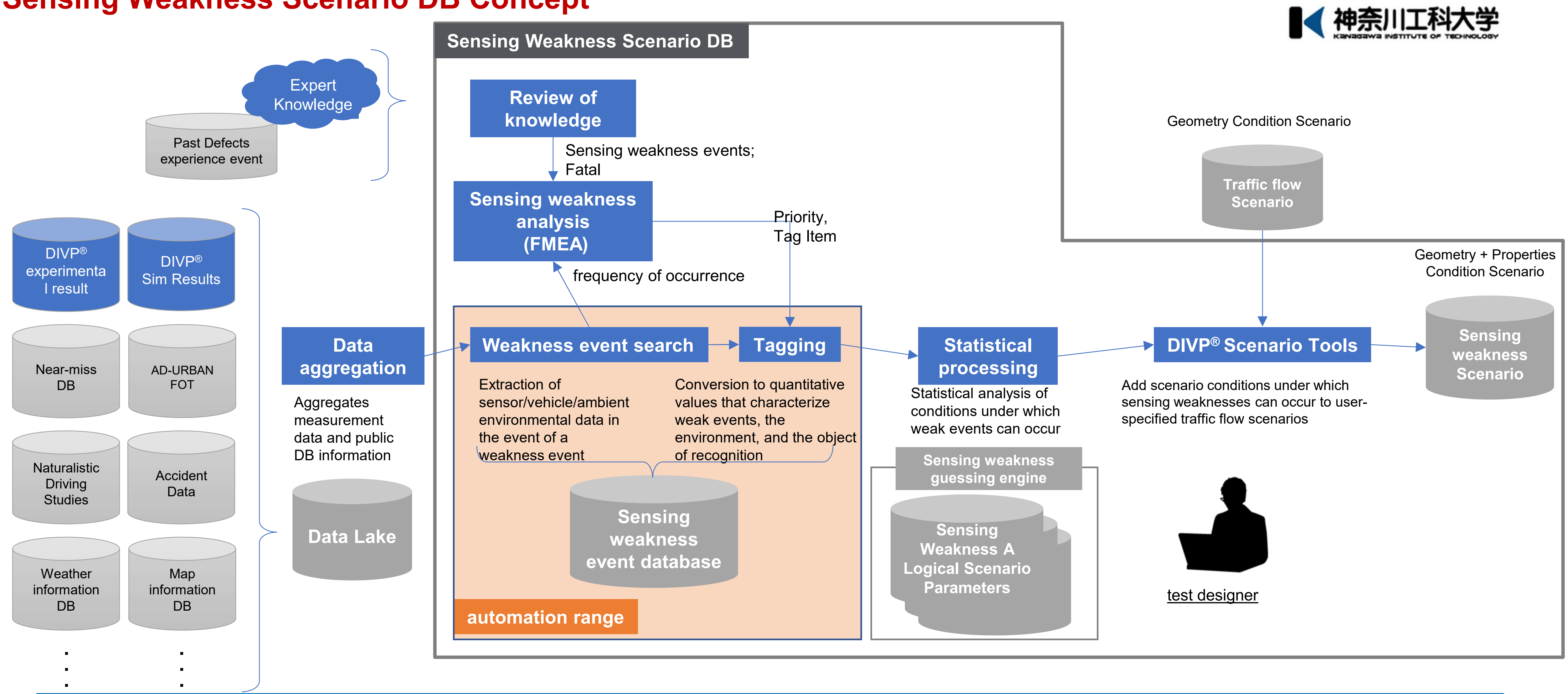
- **Will be added about 30 items in experiment**

Outcome

I	■ "Scenario package" for sensor validation
II	■ Space and sensor model highly consistent with actual phenomena
III	■ Measurement and validation methods that support consistency
IV	■ Scenario DB for sensor validation
V	■ Platform with standard I/F and connectivity to diverse assessment environments

Create database to extract sensing weakness scenarios from database and generate sensor weak point logical scenarios with high validation priority.

Sensing Weakness Scenario DB Concept

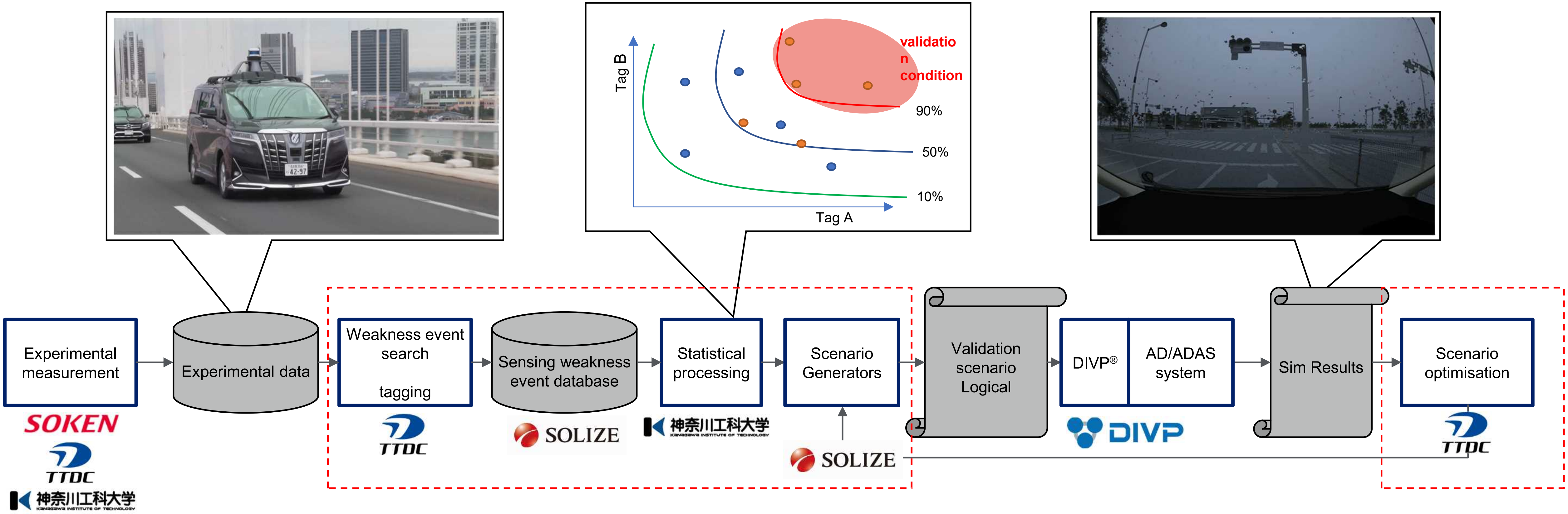


Source : Kanagawa Institute of Technology

Constructed prototype sensing weakness scenario DB that automatically searches sensing weakness occurence from Odaiba travel and statistically obtains the occurrence conditions.

Sensing Weakness Scenario Database

FY 21 R & D Elements



Verification using DIVP® to see if a sensing weakness actually occurs based on scenarios derived from the database

Source : Kanagawa Institute of Technology

Scoring was performed for each phenomenon to determine priority of targeted sensing weakness scenarios.

Scenario Priority Review

SOLIZE

- Weakness phenomena of each sensor are scored on the basis of "lethality/impact" and "necessity of simulation".
- Score for weak point phenomena of each sensor = <u>Severity and impact of weak point phenomena</u> x <u>Need for simulation of weak point phenomena</u>
- <u>Severity and Impact of Weakness Phenomena: Three-level assessment of the impact of weakness phenomena on safety assurance</u>
- <u>Need to simulate weakness phenomena:</u>The superiority of simulation over real machine validation (Cost, repeated validation, etc.) is evaluated by three levels.

不調現象再現の課題まとめ

誤認識（False Positive）：
何もないのに検知、OFF性能低下
未認識（False Negative）：
検知すべきものを正しく検知できず、ON性能低下
位置ずれは未認識

誤認識（FP）
未認識（FN）

大
中
小

大
中
小

Sim必要性 ➡
実車で危険、遭遇頻度低、繰り返し性必要

							優先度				
No.	センサー	ID	不調原理	対応状況	不調現象	結果	スコア	致命度・影響度	致命度・影響度説明	Sim必	Sim必要性
1	ミリ波	M01	周波数	×	信号周波数の異常（センサ本体の不調でのみ発生）	両方	2	小	距離/速度の誤認識、未認識	中	実車での再現が困難
2	ミリ波	M02	反射(間接波)	○	壁等の路側構造物あるいは周辺移動物によるマルチパスゴースト	誤認識（FP）	4	中	ゴーストを誤認識する	中	再現テストが容易になる
3	ミリ波	M03	反射(間接波)	○	壁等あるいは周辺移動物によるマルチパスゴーストと本来の物標が分離できず水平方向の位置検出精度が落ちる	未認識（FN）	4	中	目の前の車両が認識できない	中	再現テストが容易になる
4	ミリ波	M04	屈折	○	バンパ、エンブレム等による電波の屈折	誤認識（FP）	4	中	車両の方位を誤る	中	再現テストが容易になる
5	ミリ波	M05	屈折	○	搭載ばらつき、搭載ズレによる屈折の変化	誤認識（FP）	4	中	車両の方位を誤る	中	再現テストが容易になる
6	ミリ波	M06	屈折	×	センサ前面の付着物による屈折の変化	誤認識（FP）	2	小	車両の方位を誤る	中	再現テストが容易になる
7	ミリ波	M07	屈折	×	バンパ、エンブレム等の破損による屈折の変化	誤認識（FP）	2	小	車両の方位を誤る	中	再現テストが容易になる
8	ミリ波	M08	伝搬遅延変化	○	バンパ、エンブレム等による伝搬遅延	誤認識（FP）	4	中	車両の方位を誤る	中	再現テストが容易になる
9	ミリ波	M09	伝搬遅延変化	○	搭載ばらつき、搭載ズレによる伝搬遅延の変化	誤認識（FP）	4	中	車両の方位を誤る	中	再現テストが容易になる
10	ミリ波	M10	伝搬遅延変化	×	センサ前面の付着物による伝搬遅延の変化	誤認識（FP）	2	小	車両の方位を誤る	中	再現テストが容易になる
11	ミリ波	M11	伝搬遅延変化	×	バンパ、エンブレム等の破損による伝搬遅延の変化	誤認識（FP）	2	小	車両の方位を誤る	中	再現テストが容易になる
12	ミリ波	M12	Sなし(部分的)	△	路側または上方構造物により認識対象の一部が隠れる	未認識（FN）	4	中	認識対象をロストする	中	再現テストが容易になる
13	ミリ波	M13	Sなし(部分的)	△	雨や雪、砂や虫などの空間障害物により認識対象信号の一部が消失する	未認識（FN）	4	中	認識対象をロストする	中	遭遇頻度低
14	ミリ波	M14	折返し	○	観測範囲を超える強信号の折返し(エイリアシング)によるゴースト	誤認識（FP）	4	中	遠方の物標を近傍に誤認識する	中	再現テストが容易になる
15	ミリ波	M15	高調波	×	回路歪によるゴースト	誤認識（FP）	2	小	ゴーストを誤認識する	中	再現テストが容易になる
16	ミリ波	M16	高調波	○	多重エコーによるゴースト	誤認識（FP）	2	小	ゴーストを誤認識する	中	再現テストが容易になる
17	ミリ波	M17	S強度差大	△	隣接する強信号による小信号の埋没、精度劣化	未認識（FN）	6	大	車両横のバイク、歩行者を検出できない	中	再現テストが容易になる
18	ミリ波	M18	低S/N	○	車両姿勢、道路傾き、搭載ばらつきなどによりアンテナ指向性方向から認識対象が外れる	未認識（FN）	4	中	検知距離低下、低反射物が検出できない	中	再現テストが容易になる
19	ミリ波	M19	低S/N	×	センサ前面の付着物、エンブレム、バンパ等の破損により信号が減衰する	未認識（FN）	2	小	検知距離低下、低反射物が検出できない	中	再現テストが容易になる
20	ミリ波	M20	低S/N	△	雨や雪、砂や虫などの空間障害物により信号が減衰する	未認識（FN）	4	中	検知距離低下、低反射物が検出できない	中	遭遇頻度低
21	ミリ波	M21	低S/N	△	認識対象の形状、大きさ、姿勢などにより反射強度が低下する	未認識（FN）	6	大	検知距離低下、低反射物が検出できない	中	再現テストが容易になる
22	ミリ波	M22	低D/U	○	路面等によるマルチパスフェージング	未認識（FN）	6	大	認識対象をロストする	中	再現テストが容易になる
23	ミリ波	M23	低D/U	○	車両姿勢、道路傾き、搭載ばらつきなどによりアンテナ指向性方向が変わりクラッタが増えて信号が埋もれる	未認識（FN）	4	中	認識対象をロストする	中	再現テストが容易になる
24	ミリ波	M24	低D/U	○	路面や周辺および上方構造物によるクラッタで認識対象の信号が埋もれる	未認識（FN）	4	中	検知距離低下、低反射物が検出できない	中	再現テストが容易になる
25	ミリ波	M25	低D/U	△	雨や雪、砂や虫などの空間障害物によるクラッタで認識対象の信号が埋もれる	未認識（FN）	4	中	検知距離低下、低反射物が検出できない	中	再現テストが容易になる
26	ミリ波	M26	低D/U	×	他車レーダの電波が干渉し、認識対象の信号が埋もれる	未認識（FN）	4	中	検知距離低下、低反射物が検出できない	中	再現テストが容易になる
27	ミリ波	M27	U増大	○	車両姿勢、道路傾き、搭載ばらつきなどによりアンテナ指向性方向が変わりクラッタが増える	誤認識（FP）	4	中	前方に物標があると誤認識する	中	再現テストが容易になる
28	ミリ波	M28	U増大	○	路面や周辺および上方構造物によるクラッタを誤認識する	誤認識（FP）	4	中	前方に物標があると誤認識する	中	再現テストが容易になる

Determining priority scenarios based on Odaiba data collection volume->Set interim frequency

Camera
- Misrecognition of reflection by mirror surface
- Misrecognition of reflection by glossy finish
- Decreased recognition due to local strong reflexes
- Cognitive decline due to snow
- Misidentification of lot line due to road repair remains, ruts and shadows

LiDAR
- Loss of recognition due to low reflection due to shape
- Decrease in recognition due to low reflection from materials
- Loss of recognition due to low reflection from dirt
- Decreased recognition due to black or mirror surface
- Decreased recognition due to size and posture

Millimeter-wave
- Decreased recognition due to road surface clutter noise
- Misrecognition of wall multipath ghosts
- Misrecognition of track multipath ghosts
- Loss of awareness due to rain and wind-up
- Recognition lost by slope

Source : SOLIZE Corporation

DIVP

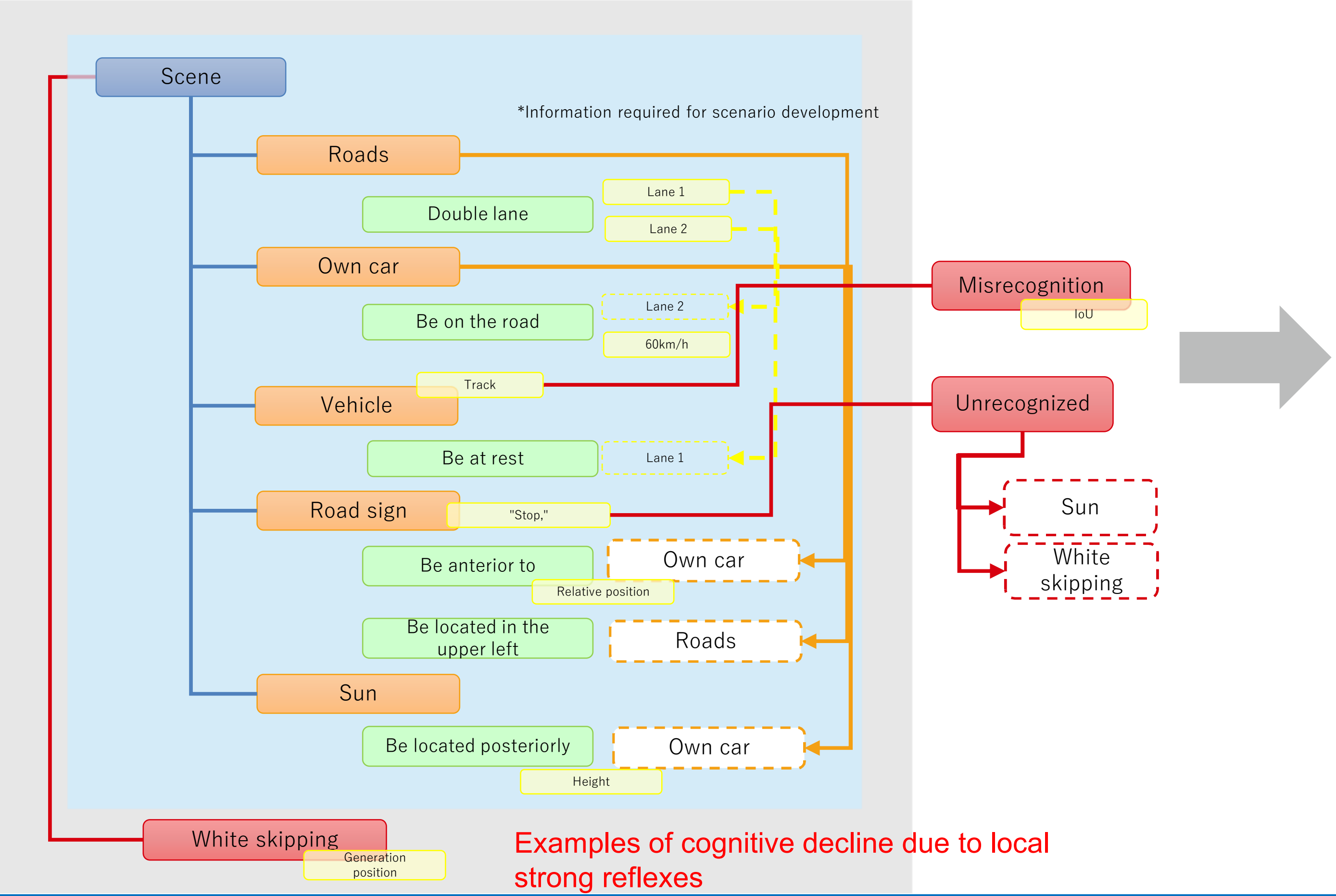
Conditions necessary for expressing sensing weakness scenario were identified, and information (tag information) that need to be derived from the driving data were organized.

SOLIZE

Tag structure study

A tag structure with the following features was constructed to accurately represent the situation (scene) at a specific time.

- **Maintain a certain level of abstraction that can be tagged by humans or AI**
- **Relative position representation centering on the vehicle**
- **The sensing weakness phenomenon is described so that the difference from the reference data can be expressed.12**



Entity and Phenomenon Classification in Sensor Weakness Domi						
	Entity					
		Traffic participants (Controllable Entity)				
			Person			
				NCAP Dummy Person		
				Posture		
					Other	
					squatting	
					fallen	
					standing	
				Age		
					Other	
					Adult	
					Child	
					Elderly	
				Walking a bike		
				In a wheelchair		
			Vehicle			
				Shape		
					Other	
					Trunk open	
					Door open	
				Type		
					Other	
					Is towing	
					Truck	
						Flat Truck

Source : SOLIZE Corporation

DIVP

By reviewing the specifications of Sensing Weakness DB, more than 200 representative data on Sensing Weaknesses were searched and listed.

Search for representative Sensing Weakness data

Image at the time when Sensing Weakness occurred

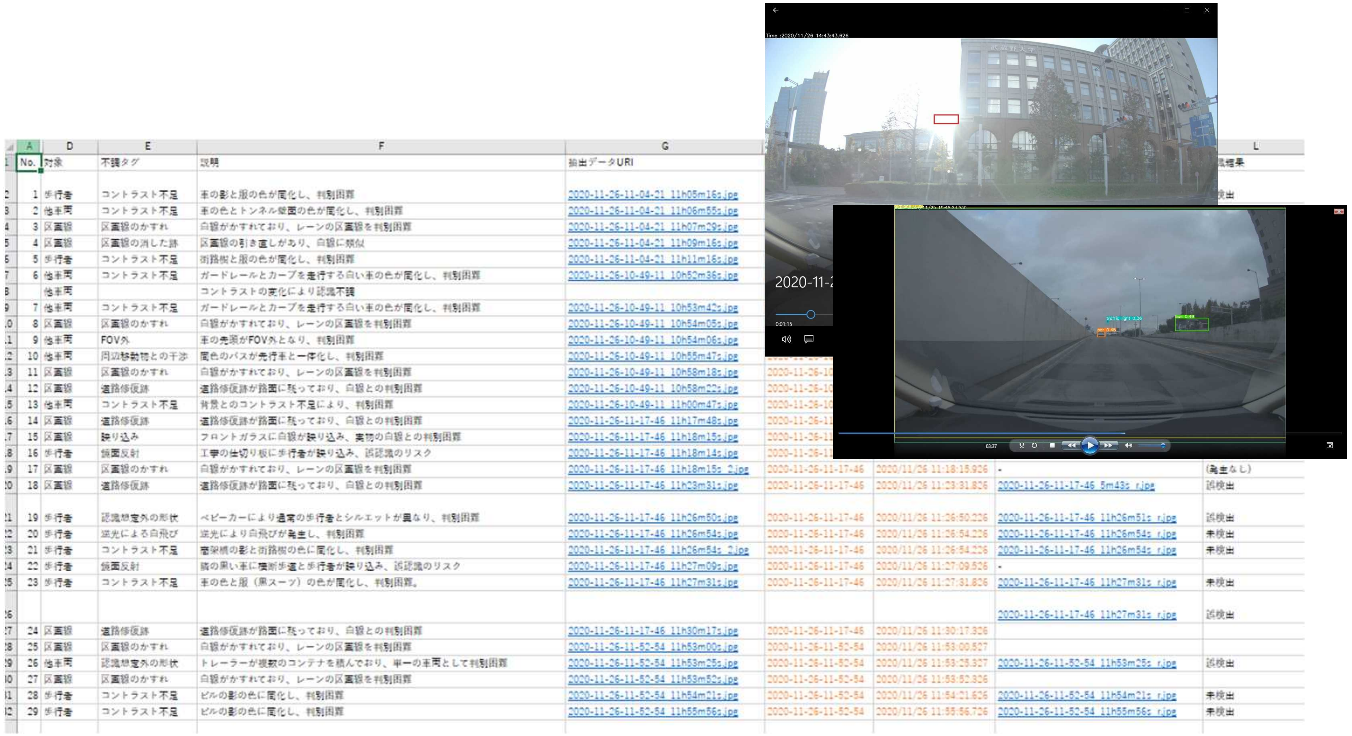


Figure: List of representative data of Sensing Weaknesses

Table. Principal items in the representative data list of Sensing Weaknesses

Items	Description
Target	object detection target
Weakness Tag	Tag information on Sensing Weakness phenomena/factors/principles
Description	Detailed description of weakness tags
Extract Data URI	URI of the image indicating Sensing Weakness phenomenon (perception)
Display time	Time when the Sensing Weakness occurred
Recognized Extract Data URI	URI of the image indicating Sensing Weakness phenomenon (recognition)
recognition result	Recognition Error Classification

Source : Toyota Technical Development Corporation

Planned a public road experiment to be conduct in Odaiba last June, where test patterns and driving routes are determined by being based on both expected number of Sensing Weaknesses and attributes of past tests. Regarding typical data of Sensing Weaknesses, see previous page.

Planning and participation in experiments (Odaiba)

Table. Pick up attributes from previous studies

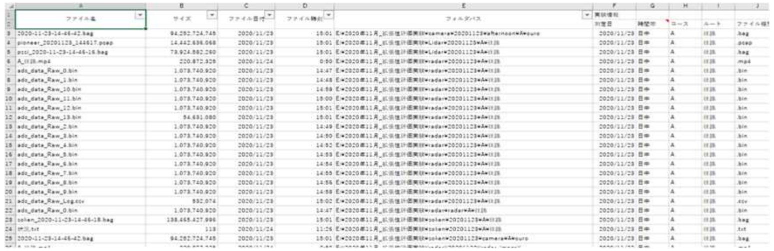


Table. List of representative data of Sensing Weakness

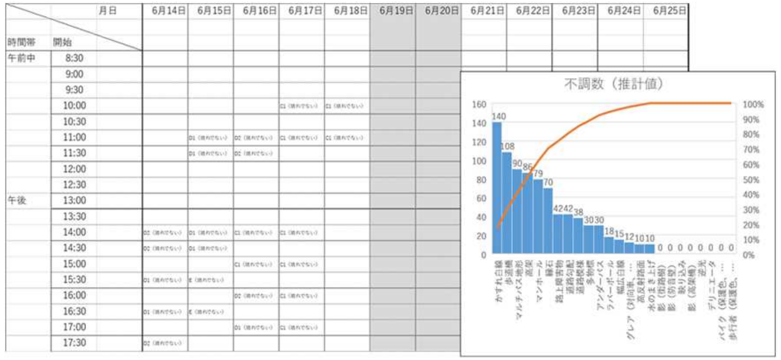
Table. Sensing Weakness frequency/test sheet

				ミリ波			カメラ	
日付	時間帯	コース	ルート	上方構造物誤認識	マルチパス	多物標	防音壁の影	街路樹の影
2020/11/26	日中	A	往復	0	0	0	0	0
2020/11/26	夜	A	往復	0	0	0	0	0
2020/11/23	日中	A	往路	0	0	0	0	0
2020/11/23	夜	A	往路	0	0	0	0	0
2020/11/23	日中	A	復路	0	0	0	0	0
2020/11/23	夜	A	復路	0	0	0	0	0
2020/11/23	日中	B	時計	1	0	0	0	1
2020/11/23	夜	B	時計	1	0	0	0	1
2020/11/23	日中	B	反時計	0	0	0	0	0
2020/11/23	夜	B	反時計	0	0	0	0	0
2020/11/24	日中	C1	外	3	3	1	2	0
2020/11/24	夜	C1	外	3	3	1	2	0
2020/11/24	日中	C1	内	3	3	1	1	0
2020/11/24	夜	C1	内	3	3	1	1	0
				14	12	4	6	2

Table. Sensing Weakness/Test Attribute Matrix

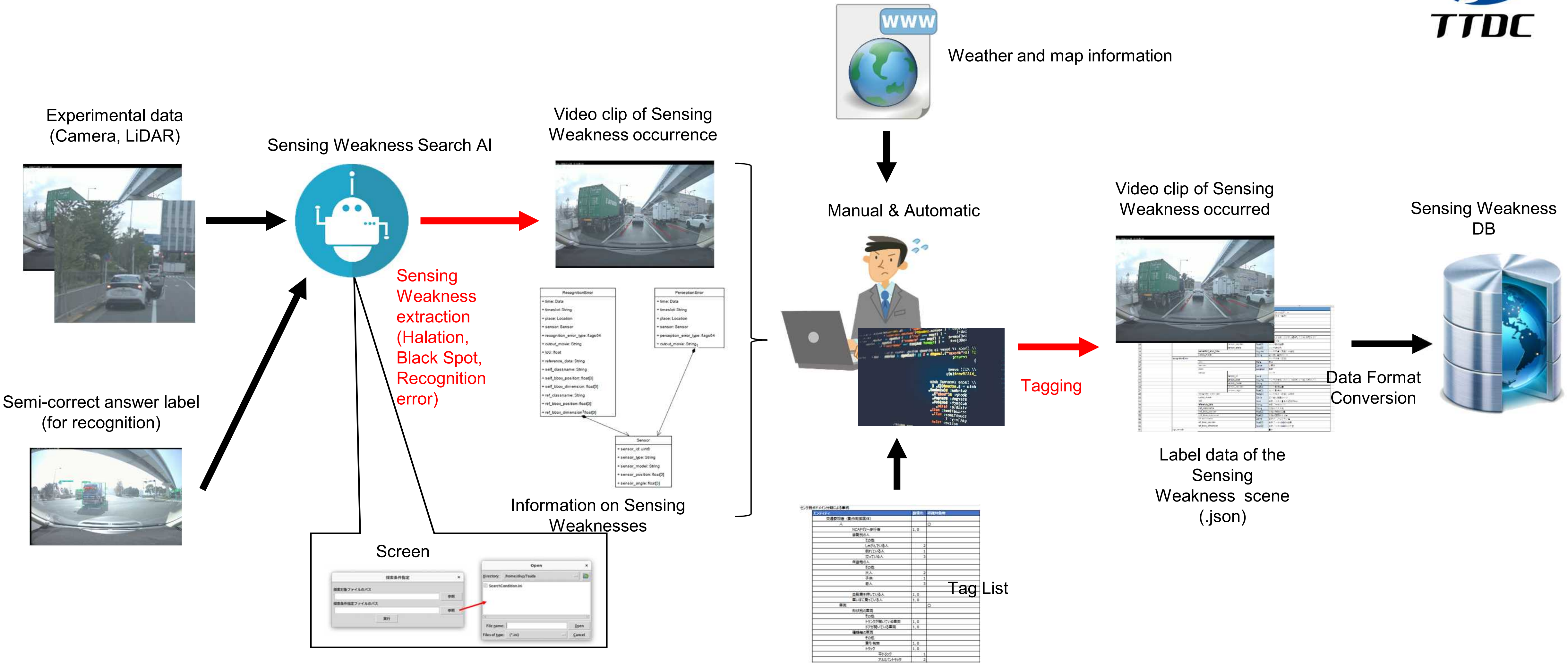
Figure. traveling route

Table. Test pattern and expected number of sensing weaknesses



Prototyped algorithms to automatically search for Sensing Weaknesses in the perceptual or recognized output of each sensor. Tagged information semi-automatically in various ways(e.g. by accessing public informations such as weather data)

Process flow from experiment data to Sensing Weakness DB



Source : Toyota Technical Development Corporation

Focused on sensors' perceptual output besides sensors' recognized output, clarifying Sensing Weakness phenomena, factors, and principles. Studied search methods, limited to six types of Sensing Weakness.

Extract of Sensing Weaknesses definition(red frame: for this year)

State of the sensor	Perceptual output	Sensing Weakness Determination	Sensing Weakness Phenomenon	Sensing weakness Factor (Example)	Sensing Weakness Principle
Abnormal	-	Sensor failure (≠ Sensing Weakness)	-	-	
Normal	Inappropriate intensity of reaction	Perceptual Weakness	White Out	Backlight	Low contrast
			Black Spot	Black object	Low reflectivity
			Clutter	Rain	Low S/N
	The position of the reaction is different from the assumption.		Ghost	Tunnel	Multipath

State of the sensor	Recognized output	Sensing Weakness Determination	Sensing weakness Phenomenon	Sensing Weakness Factor (Example)	Sensing weakness Principle
Abnormal	-	Sensor failure (≠ Sensing Weakness)	-	-	
Normal	Found in semi-correct answer label but not in recognition	Cognitive Weakness	FN	Night	Low contrast
	Found in recognition but not in semi-correct answer label		FP	Shadow	Similar Hue
	BBOX position differs between semi-correct answer labels and recognition		Low IoU	Headlight	Contrast difference
	Class differs between semi-correct answer label and recognition		Class error	Wagon	Similar shape

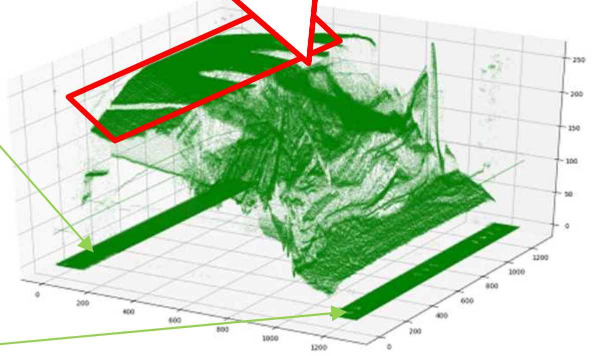
Source : Toyota Technical Development Corporation

Developed an algorithm to automatically search for Sensing Weakness (e.g., white out) in the perceptual output of camera.

Searching for White Out areas(Camera)

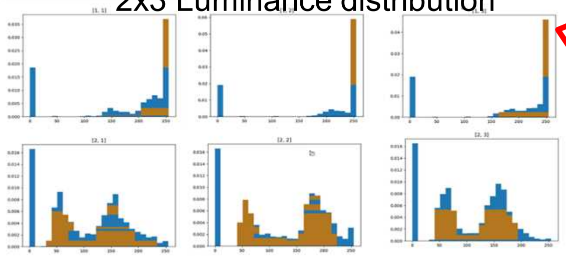
Based on the following analysis of the luminance values, divide into grids by the specified number of divisions, and use the average luminance value of each grid to determine white out phenomena.

- Luminance maps(right) and histograms(left bottom) to check thresholds



Areas of high brightness (> = 240) and low disperity

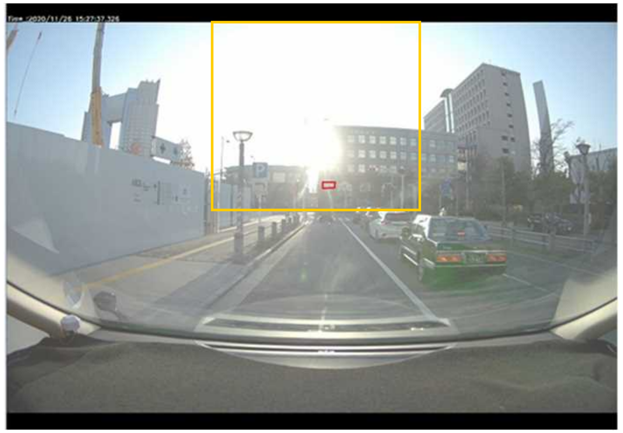
2x3 Luminance distribution

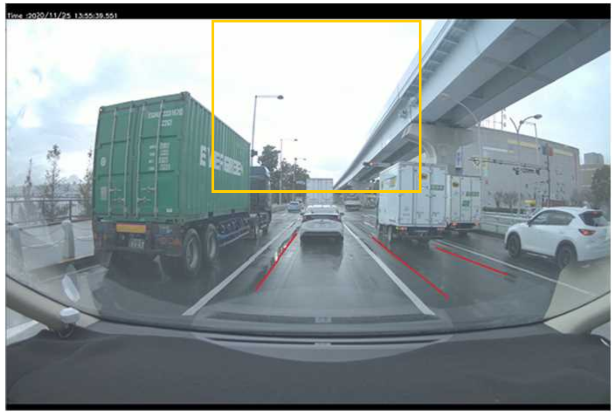


Distinct difference in distribution between the top and bottom of the screen

Confirmation result

Detected the white out(yellow frame) caused by backlight (top) and contrast degradation(bottom).





Source : Toyota Technical Development Corporation

Developed an algorithm to automatically search for Sensing Weakness(e.g., black spots) in the perceptual output of LiDAR

Searching for Black spot areas (LiDAR)

Convert to 2D grayscale image and search for black spot areas from luminance distribution by extracting point cloud position and reflection intensity based on LiDAR recognition data

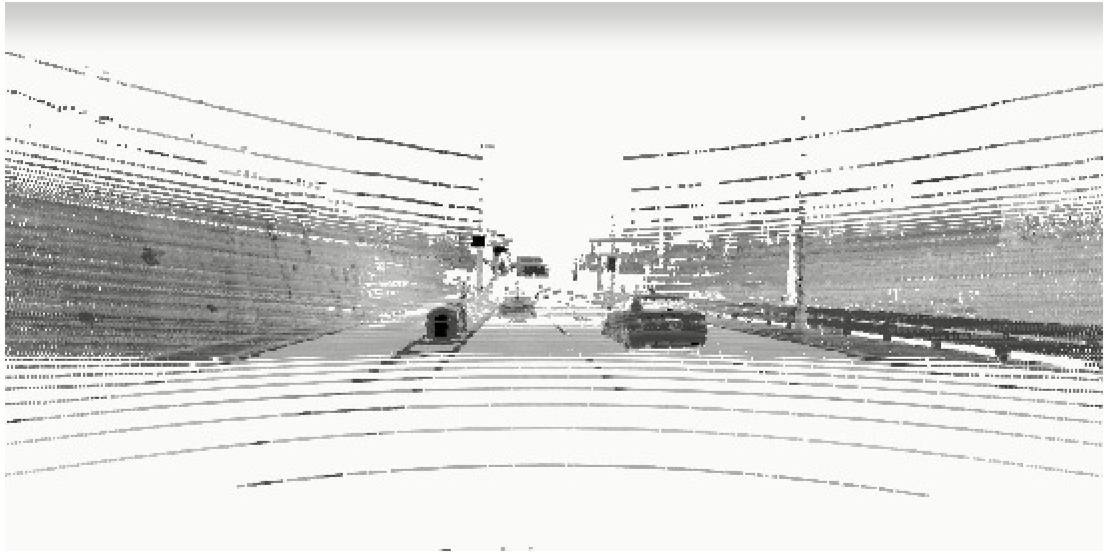


Figure. 2D Grayscale Image (Black: High Reflectivity, White: Low Reflectivity)

Confirmation result

Detection of black spots (blue border) including black cars

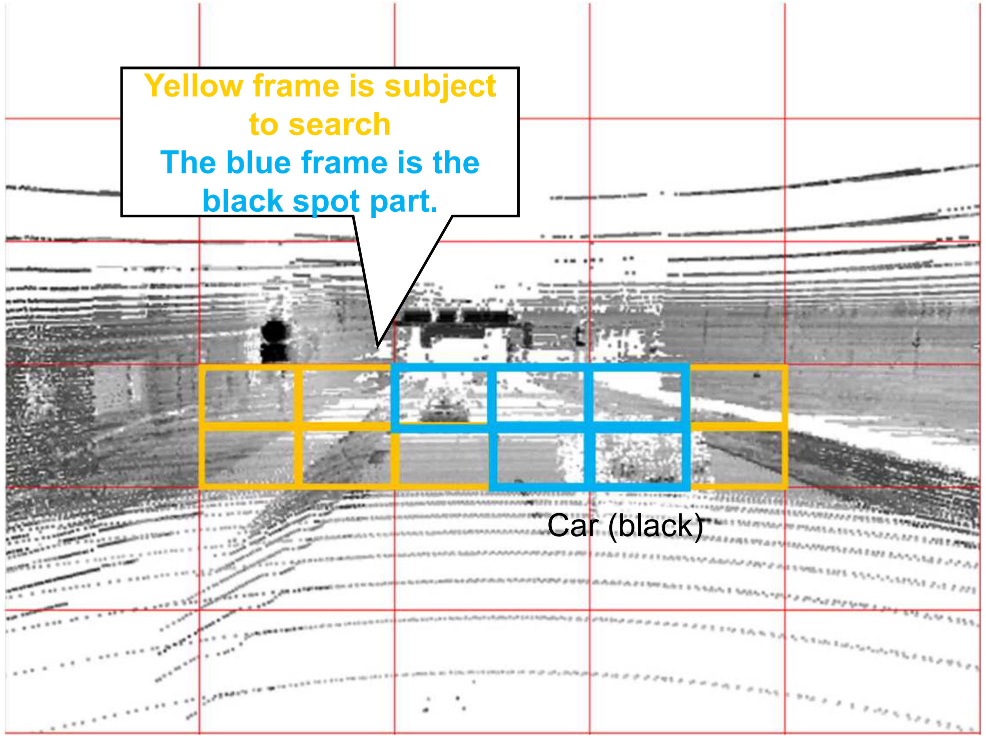


Figure. Black Car and Black Spot

Developed algorithms to automatically search for Sensing Weakness(FN, FP, Low IoU, Class Error) in the recognized output of camera.

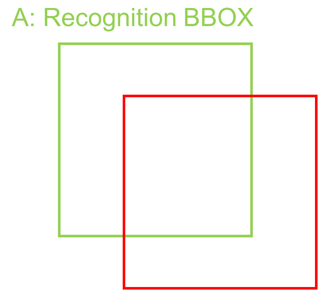
Searching for Cognitive Weaknesses

Recognition results are compared with semi-correct answer labels generated by using another object detection model. Afterwards, the error data are classified into four types of errors in which "low IoU" and "class error" in addition to FP and FN.

Table. Types of Recognition Errors and Decision Methods

Recognition error	Definition	Decision method
FN	Target is undetected	If BBOX of recognized data is not found in the vicinity of BBOX of semi-correct answer label, it is judged as "FN".
FP	Part of the background is recognized as a target	If BBOX of semi-correct answer label is not found in the vicinity of BBOX of recognized data data, it is judged as "FP"
Low IoU	The position or dimension of the BBOX of the target differs greatly from the correct one	The BBOX of semi-correct answer label closest to the BBOX of recognized data data is paired, and "Low IoU" is judged if the IoU is less than 0.7.
Class Error	Target is missclassified	The BBOX of the semi-correct answer label closest to the BBOX of the recognized data data is paired, and if the class does not match, it is judged as a "Class Error".

"IoU", an index for object detection, is used for error determination



IoU(Intersection over Union)
= Area of intersection / area of union

Confirmation result

Checked the following four types of recognition errors can be detected.

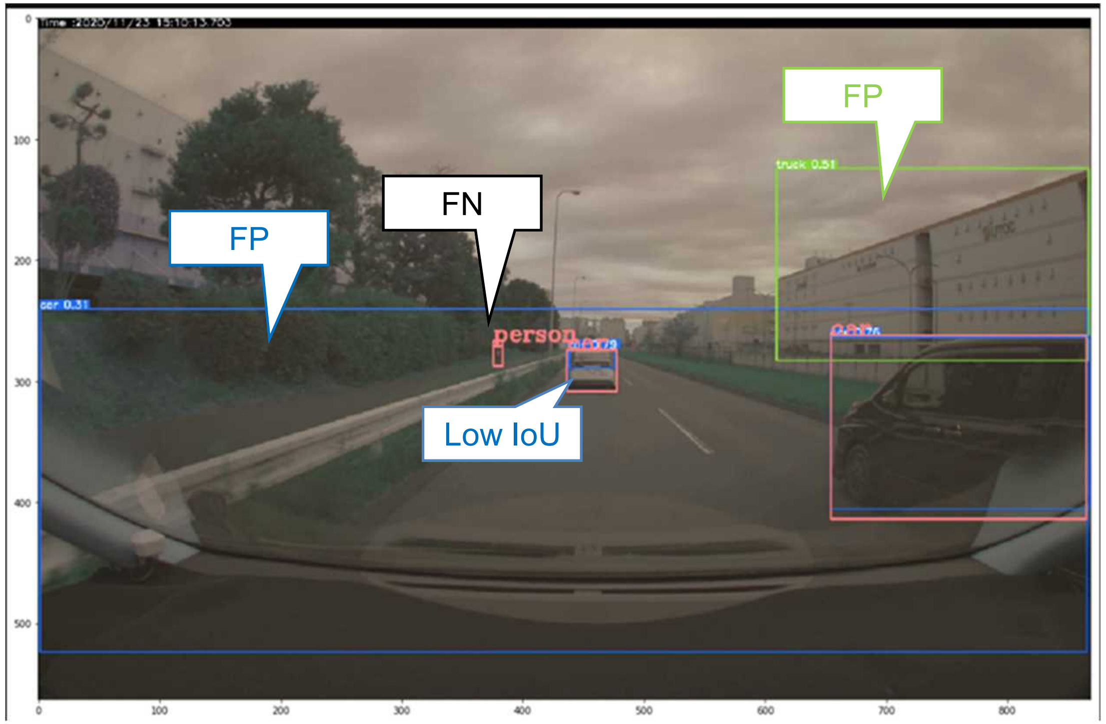
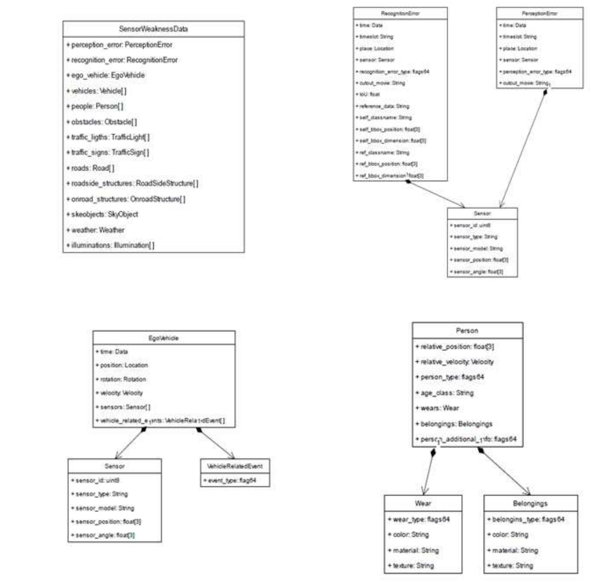


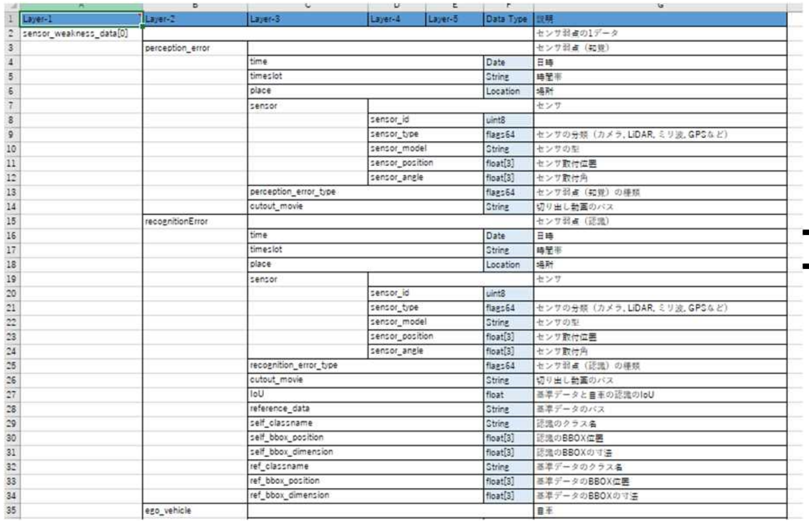
Figure. Example of FN, FP and low IoU. * All of them can be detected.

Constructed database that stores data by adding predefined relationships to automatically calculated tag information

Define and develop tagging data based on scenarios



a) Class modeling of tag information required for scenarios (from the viewpoint of Sensing Weakness search AI)



	Layer-1	Layer-2	Layer-3	Layer-4	Layer-5	Data Type	説明
2	sensor_weakness_data[0]						センサ弱点の1データ
3		perception_error					センサ弱点（知覚）
4			time			Date	日時
5			timeslot			String	時間帯
6			place			Location	場所
7			sensor				センサ
8				sensor_id		uint8	
9				sensor_type		flags64	センサの分類（カメラ, LiDAR, ミリ波, GPSなど）
10				sensor_model		String	センサの型
11				sensor_position		float[3]	センサ取付位置
12				sensor_angle		float[3]	センサ取付角
13			perception_error_type			flags64	センサ弱点（知覚）の種類
14			cutout_movie			String	切り出し動画のパス
15		recognitionError					センサ弱点（認識）
16			time			Date	日時
17			timeslot			String	時間帯
18			place			Location	場所
19			sensor				センサ
20				sensor_id		uint8	
21				sensor_type		flags64	センサの分類（カメラ, LiDAR, ミリ波, GPSなど）
22				sensor_model		String	センサの型
23				sensor_position		float[3]	センサ取付位置
24				sensor_angle		float[3]	センサ取付角
25			recognition_error_type			flags64	センサ弱点（認識）の種類
26			cutout_movie			String	切り出し動画のパス
27			IoU			float	基準データと自車の認識のIoU
28			reference_data			String	基準データのパス
29			self_classname			String	認識のクラス名
30			self_bbox_position			float[3]	認識のBBOX位置
31			self_bbox_dimension			float[3]	認識のBBOXの寸法
32			ref_classname			String	基準データのクラス名
33			ref_bbox_position			float[3]	基準データのBBOX位置
34			ref_bbox_dimension			float[3]	基準データのBBOXの寸法
35		ego_vehicle					自車

b) Tree structure of tag information

c) Development of Sensing Weakness data

Tag information for the scene (.json)

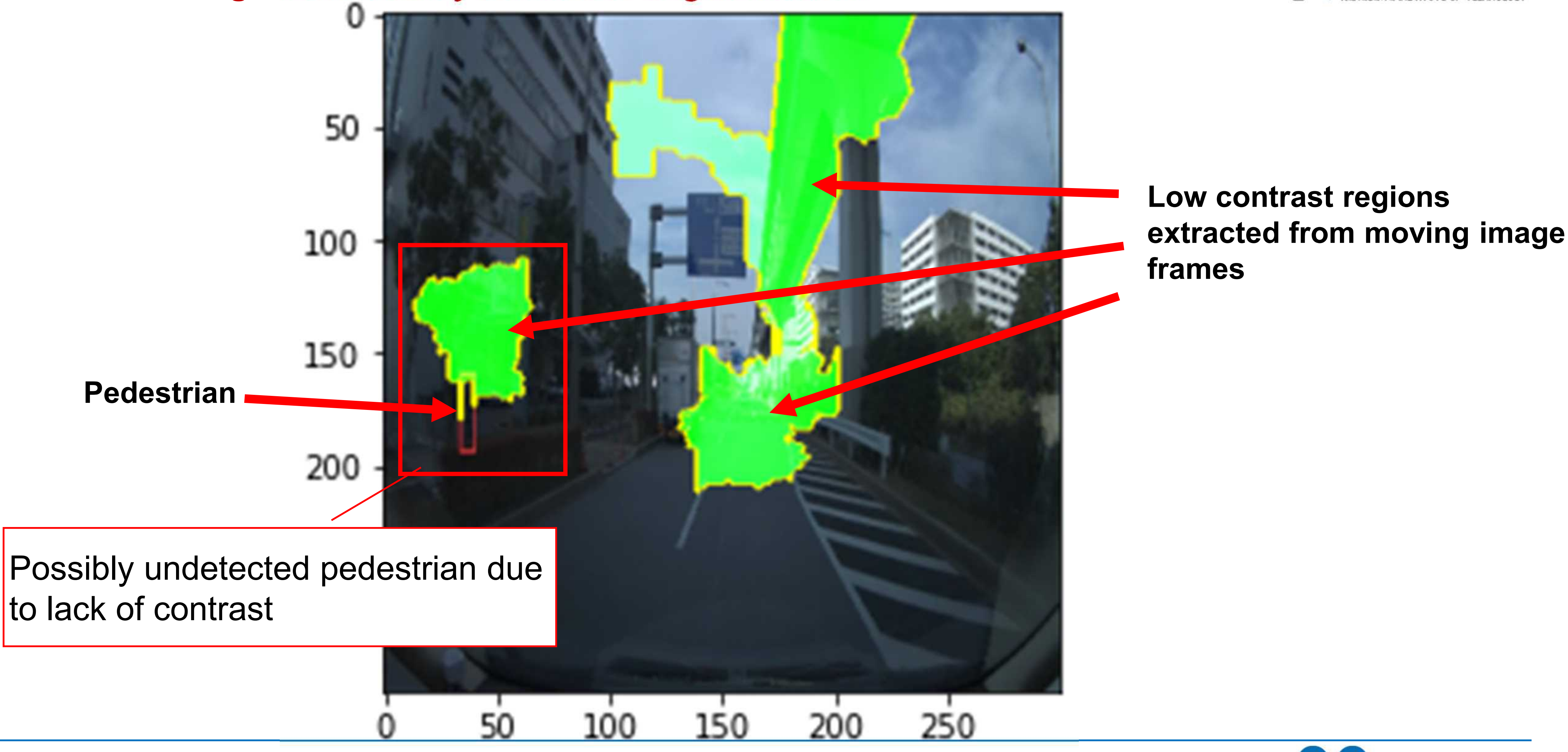
Video clip of occurred scene (.mp4)

< Point >
Some tags, such as Sensing Weakness, are automatically attached, but others are manually done.

Source : Toyota Technical Development Corporation

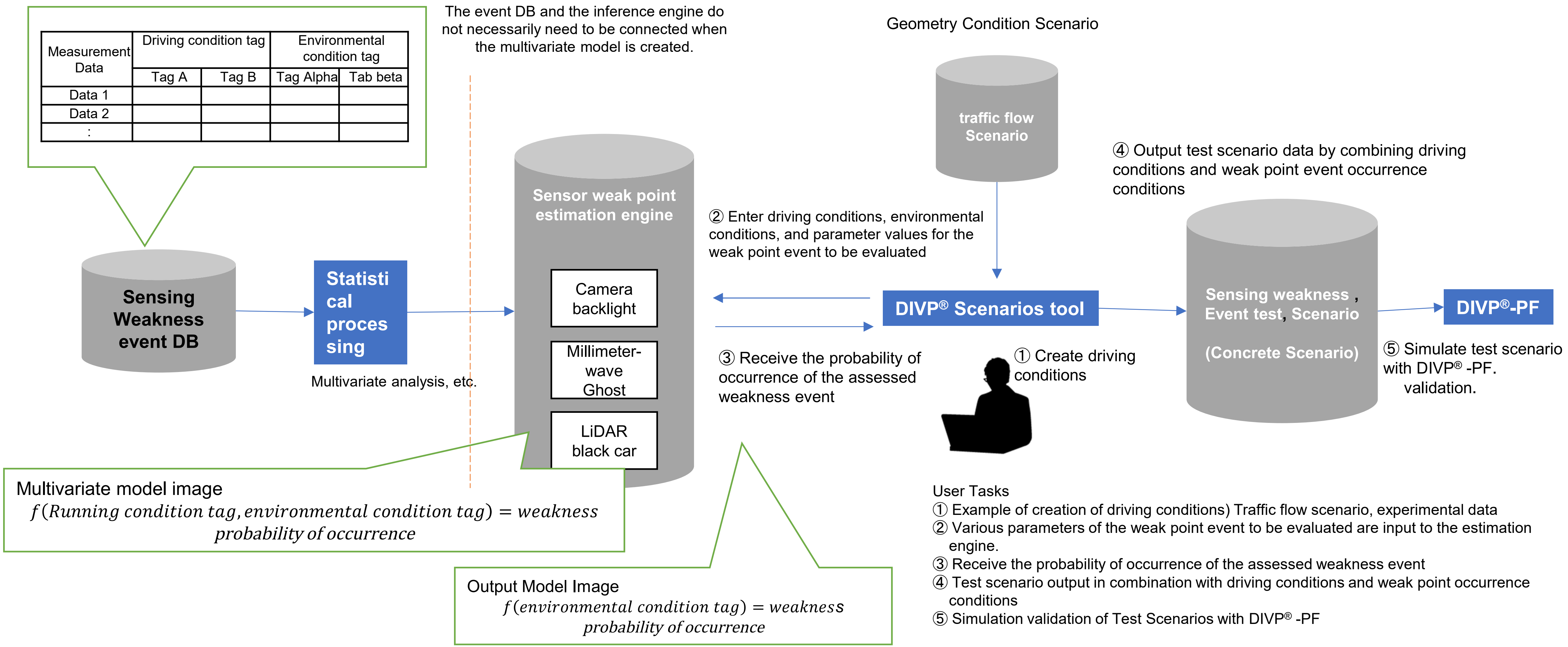
Attempting to find location of sensing weakness using semantic segmentation. Identify similarities via learning model,assuming that errors occur when contrast is insufficient

Estimation of Sensing Weakness by Semantic Segmentation



System for generating logical scenario combining traffic flow scenario specified by user and sensing weakness scenario obtained from database were devised.

Sensing Weakness Scenario Generation Flow



Measurement Data	Driving condition tag		Environmental condition tag	
	Tag A	Tag B	Tag Alpha	Tab beta
Data 1				
Data 2				
:				

User Tasks
① Example of creation of driving conditions) Traffic flow scenario, experimental data
② Various parameters of the weak point event to be evaluated are input to the estimation engine.
③ Receive the probability of occurrence of the assessed weakness event
④ Test scenario output in combination with driving conditions and weak point occurrence conditions
⑤ Simulation validation of Test Scenarios with DIVP® -PF

Source : Kanagawa Institute of Technology

Created sensing weakness event DB and I/F for input/output of database after examining content and structure of tags necessary to represent sensing weakness scenarios

Sensing Weakness Event DB and Surrounding System Structure

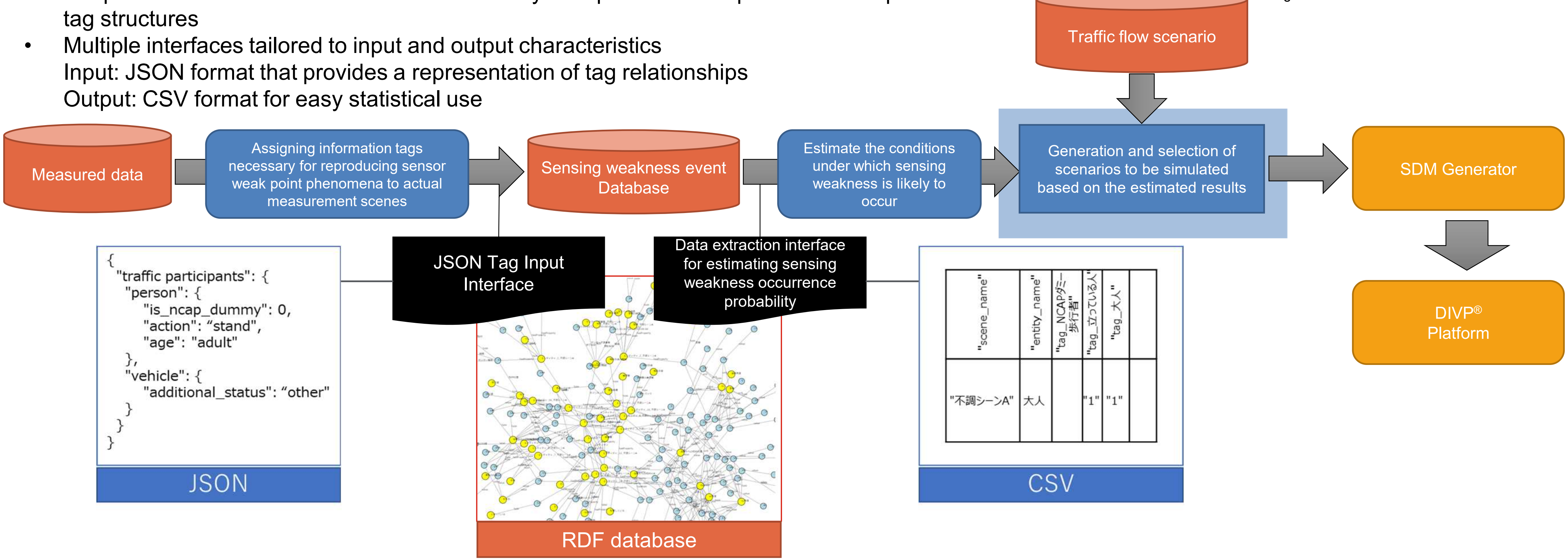
SOLIZE

Based on the tag structure examined, the prototype of the sensor weak point event DB system was mounted.

Features

- Adoption of an RDF database that makes it easy to express the complex relationships of tag structures
- Multiple interfaces tailored to input and output characteristics
  Input: JSON format that provides a representation of tag relationships
  Output: CSV format for easy statistical use

The following traffic scenarios are assumed
- DIVP® Existing Scenarios
- SAKURA Scenario Database
- Capture scenarios with external scenario generation tools



The algorithm (the sensing weakness estimation engine) that extracts the condition in which sensing weakness occurs is defined by regression model learned from sensing weakness event DB.

Sensing Weakness Estimation Engine Image

Weakness event scene to be evaluated
Driving conditions and environmental condition parameter values

Sensing weakness event DB

Tag Information

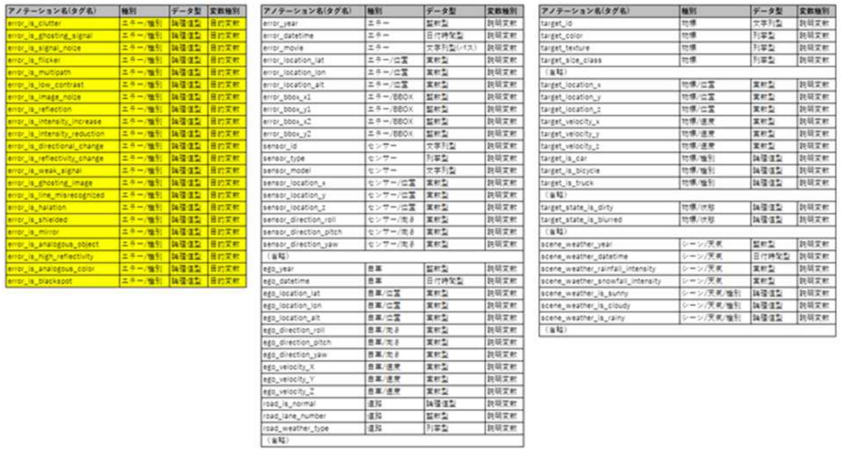
Logistic regression analysis

Regression model

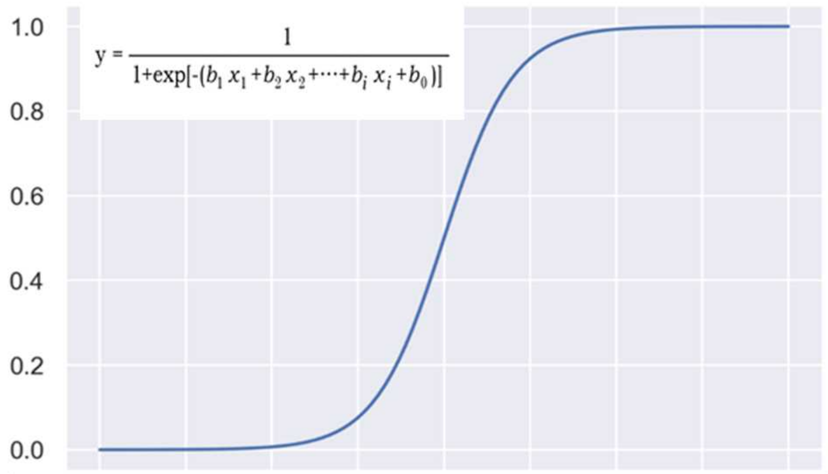
Probability of occurrence of assessed weak events (0~10%)

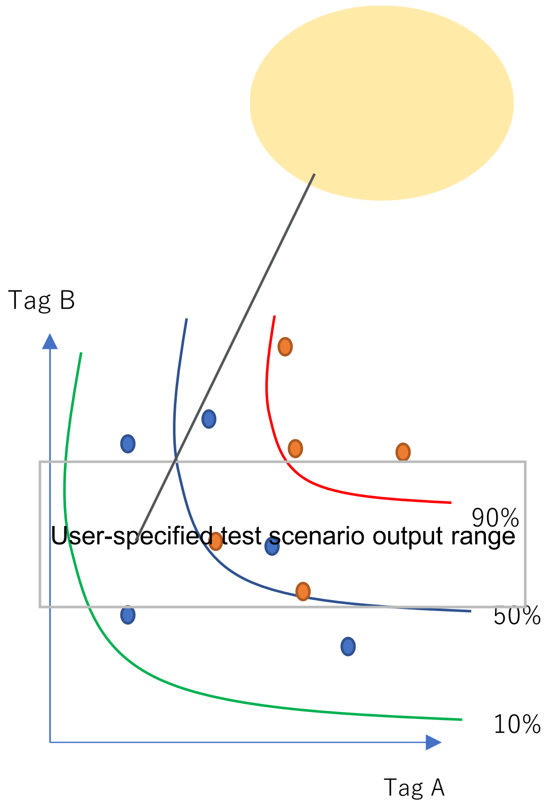
Narrow down relevant explanatory variables (Backward Stepwise Method)

Tag information (target and explanatory variables)



Partial regression coefficient, p-value/z-value, AIC (Akaike Information Criterion), ・・・





A prototype GUI application was developed to efficiently create sensing weaknes scenarios in tandem with sensor weakness scenario database using traffic flow scenarios as input.

Scenario Generator

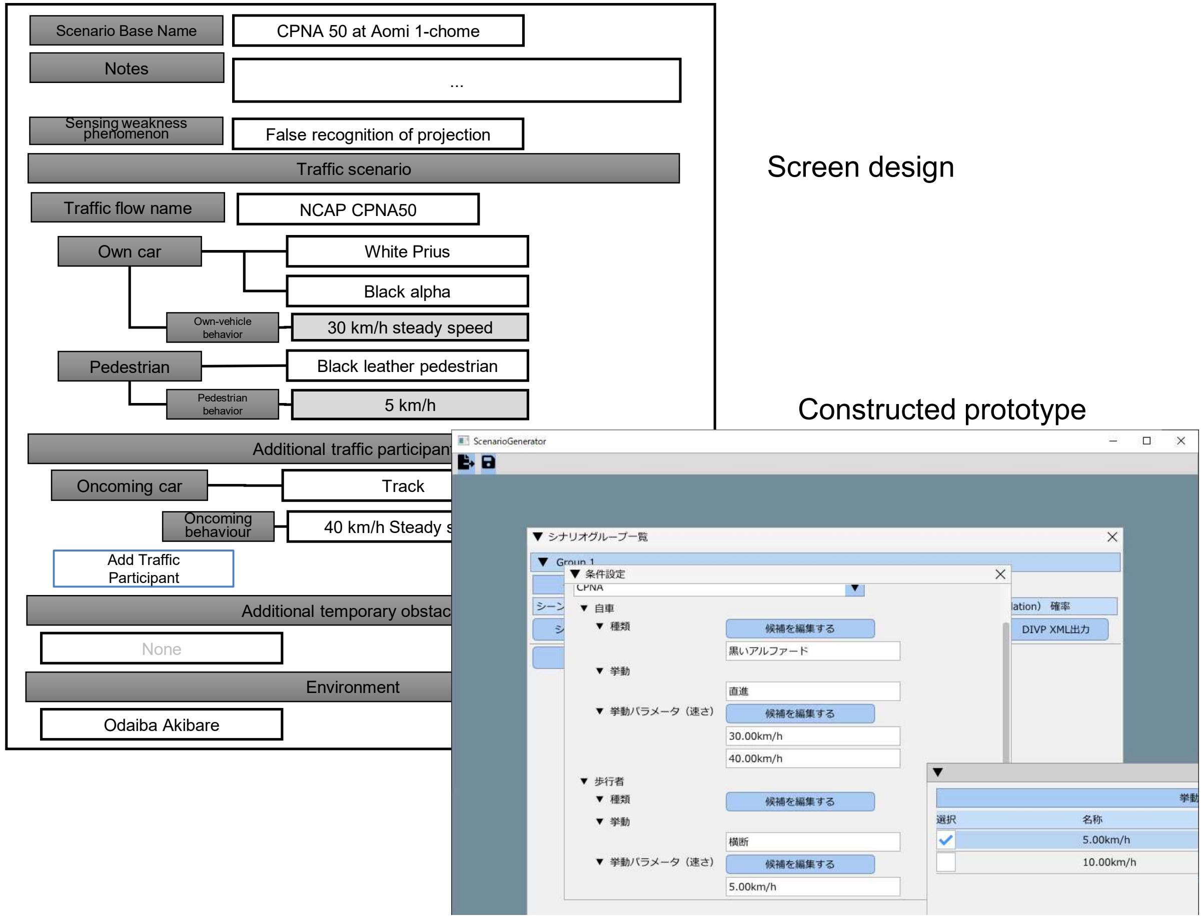
SOLIZE

Base scenario creation (user initial conditions)

Grouping of scenarios and confirmation of the probability of sensing weakness occurrence

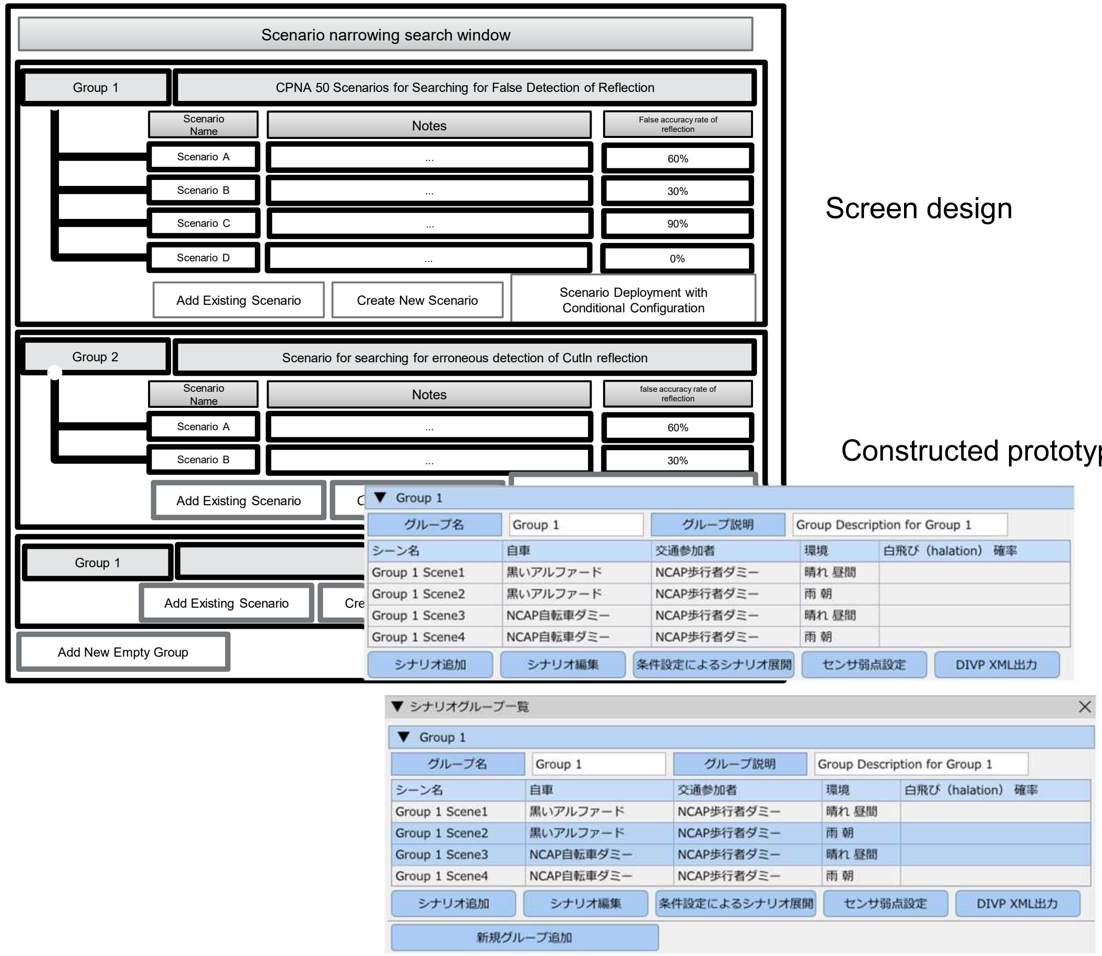
Screen design

Constructed prototype



Screen design

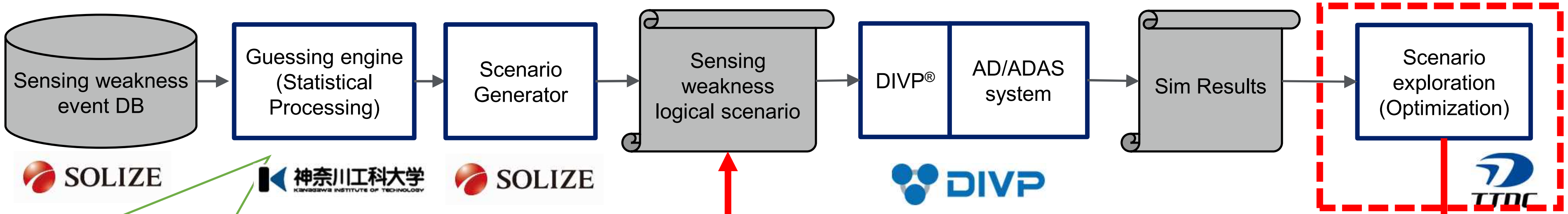
Constructed prototype



Source :SOLIZE Corporation

Designed, prototyped, and validated application searching boundary conditions (edge case scenario) within the scope of the generated sensing weakness logical scenario

Scenario Exploration (Optimization)



Multivariate model image

$f(running\ conditions, environmental\ conditions) =$
$weakness$ probability of occurrence

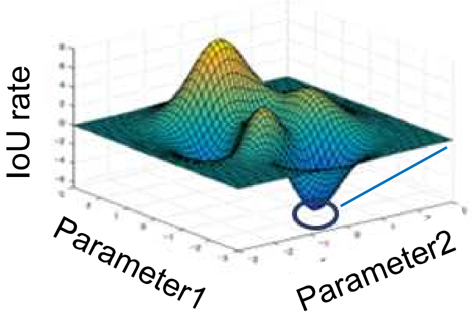
Example)Camera weak point "Halation phenomenon"
Conditions (**Driving conditions and their ranges,** where the occurrence of halation is high,
Estimate environmental conditions and their range)

Scenario Exploration (Optimization)

An optimization method is used.
DIVP® scenario for generating sensing weakness phenomena for validation indicators
Automatic search for (**values for driving conditions, values for environmental conditions**)

Example of scenario exploration (optimization)

Purpose	: Probe a scenario in which the camera recognition “IoU rate ” becomes low due to the weak point phenomenon“ halation ”
Seek Parameters	: Determined by the inference engine (Driving conditions and ranges, environmental conditions and ranges)
Validation index	: Camera recognition IoU rate (calculated from Sim result)



diagram

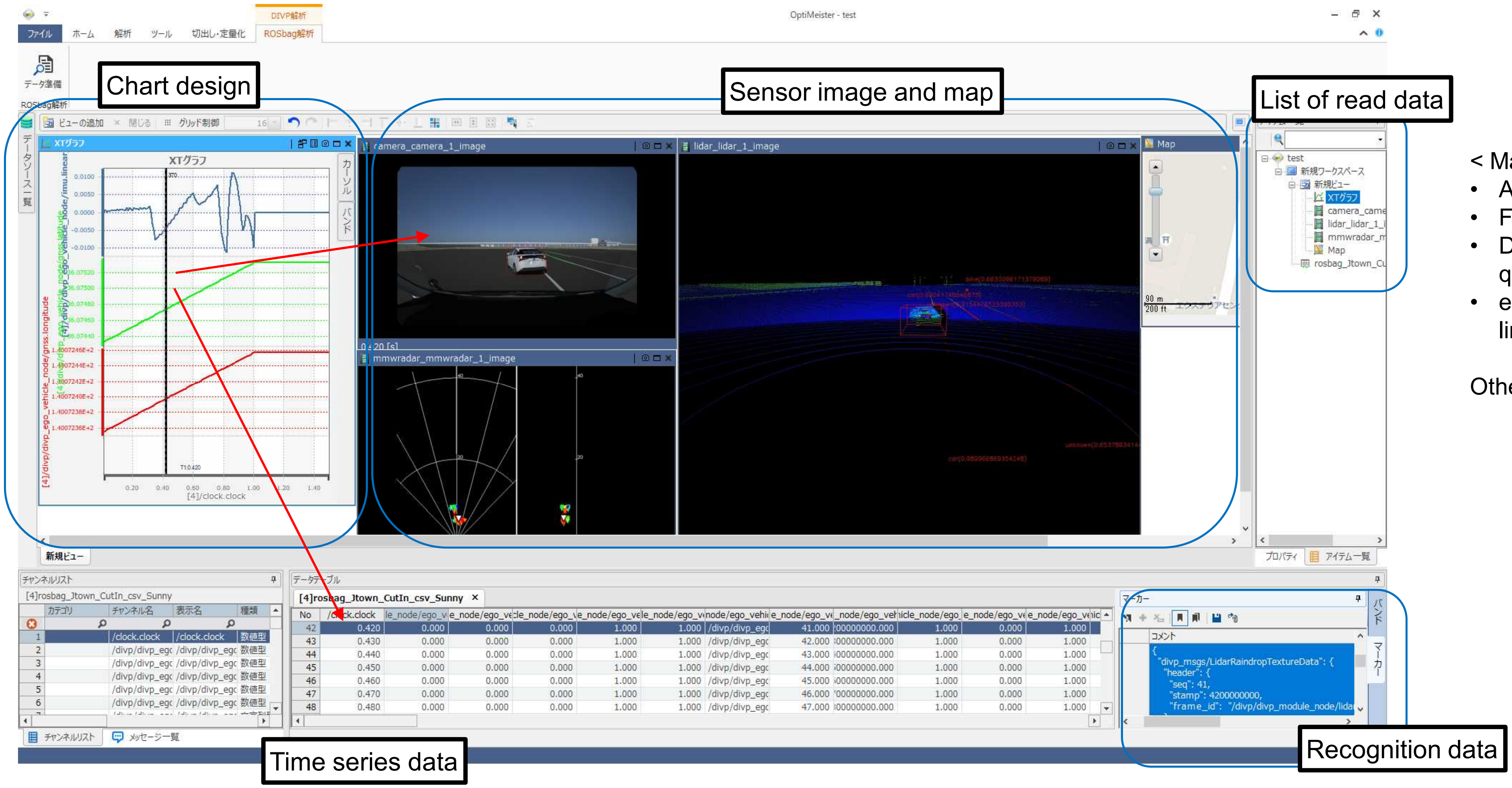
Identify the worst conditions quickly and accurately

Source : Toyota Technical Development Corporation

Data analysis tool equipped with display/analysis function of DIVP® output and function to derive effective scenario condition based on user-defined validation function was examined

Data Analysis Tools (TTDC OptiMister)

Can be checked in conjunction with chart cursor, movie, and data time.



< Main analysis functions >

- Arithmetic
- Filter
- Data range extraction and quantitative value calculation
- external script (Python) linkage

Others

Source : Toyota Technical Development Corporation

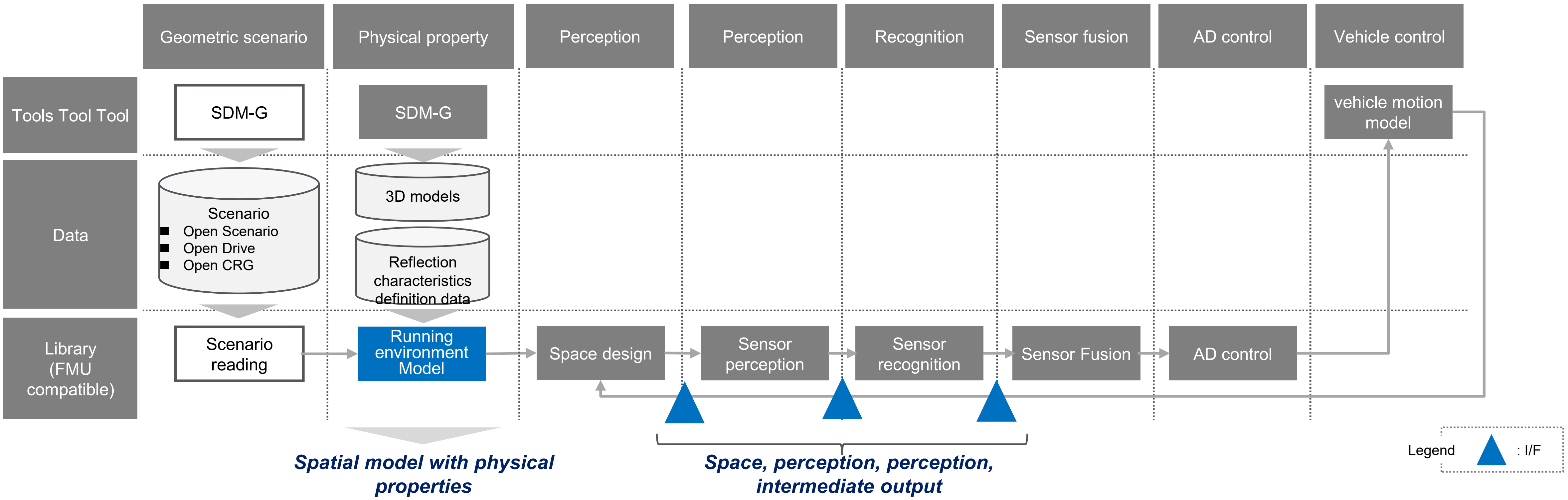
Outcome

- I ■ "Scenario package" for sensor validation
- II ■ Space and sensor model highly consistent with actual phenomena
- III ■ Measurement and validation methods that support consistency
- IV ■ Scenario DB for sensor validation
- V ■ Platform with standard I/F and connectivity to diverse assessment environments
  - ■ STANDARD I/F CONSIDERATION (D1 PART)
  - ■ Establishing a Diverse Validation Environment (Part B0)
  - ■ Combined Platform Validation (B0 Part)

DIVP® has detailed environmental model with physical properties, and the sensor's intermediate output enables safety assurance focusing on the sensor. International collaboration efforts sublimates necessary I/Fs to international standards.

Uniqueness of DIVP® compared to existing international standards

Nihon Unisys, Ltd



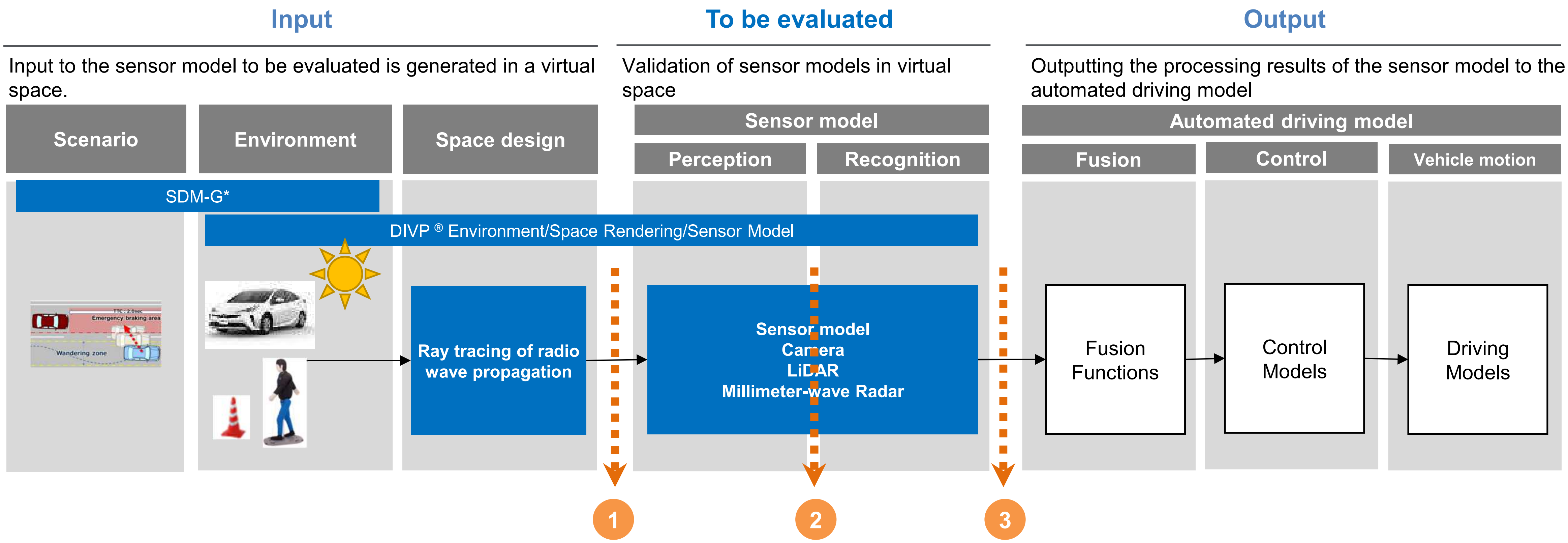
Validity of the sensor intermediate output was verified by experts of each sensor.

Source : Nihon Unisys, Ltd.

Extended platform connectivity on the basis of OSI through international cooperation project VIVALDI with Germany VIVALDI

DIVP® Organizing I/F from the viewpoint of the sensor model under validation

Nihon Unisys, Ltd



Discussions with German VIVALDI on IF connectivity via OSI as a standard IF for sensor models

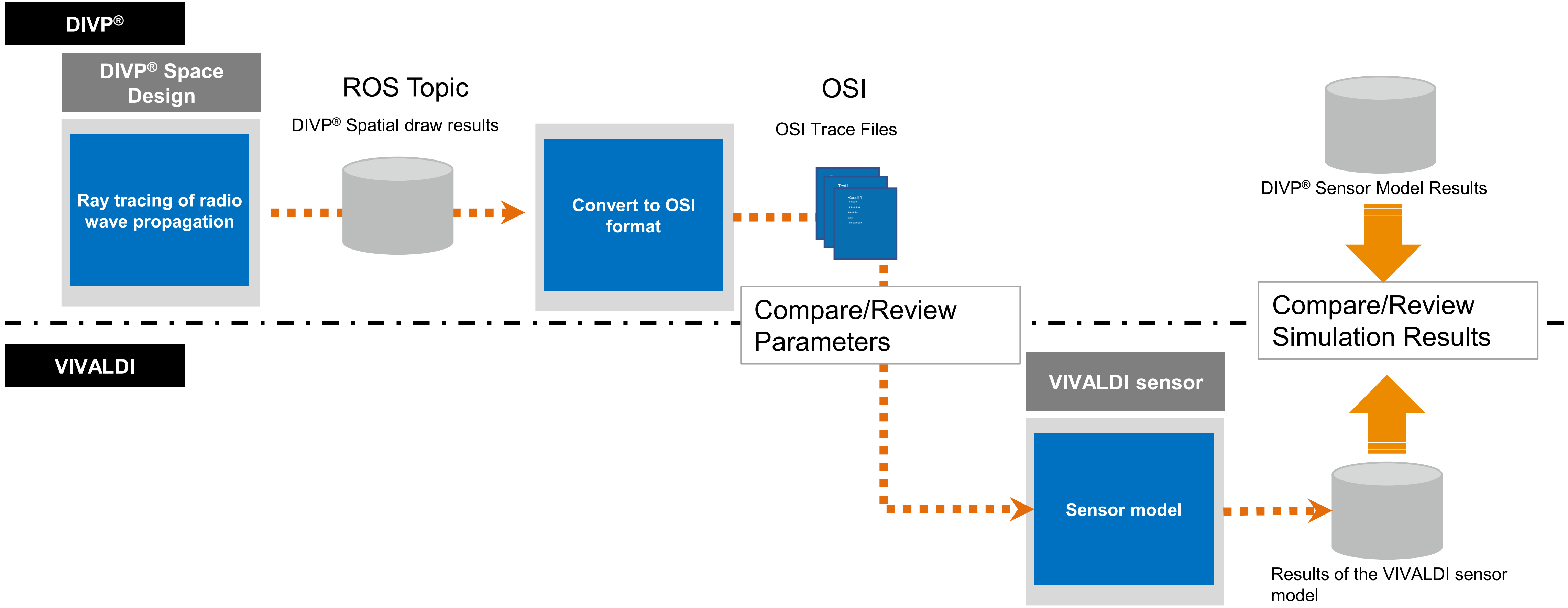
Source : Nihon Unisys, Ltd.

Extended platform connectivity on the basis of OSI through international cooperation project VIVALDI with Germany VIVALDI

Conversion of DIVP® Space Design to OSI Format

Nihon Unisys, Ltd

The result (ROS) of space design of DIVP® is converted into OSI format, and the result is provided to the German VIVALDI side for verification/consultation.
Through this activity, we will identify standard parameters to be proposed and incorporated into OSI as standards.



Source : Nihon Unisys, Ltd.

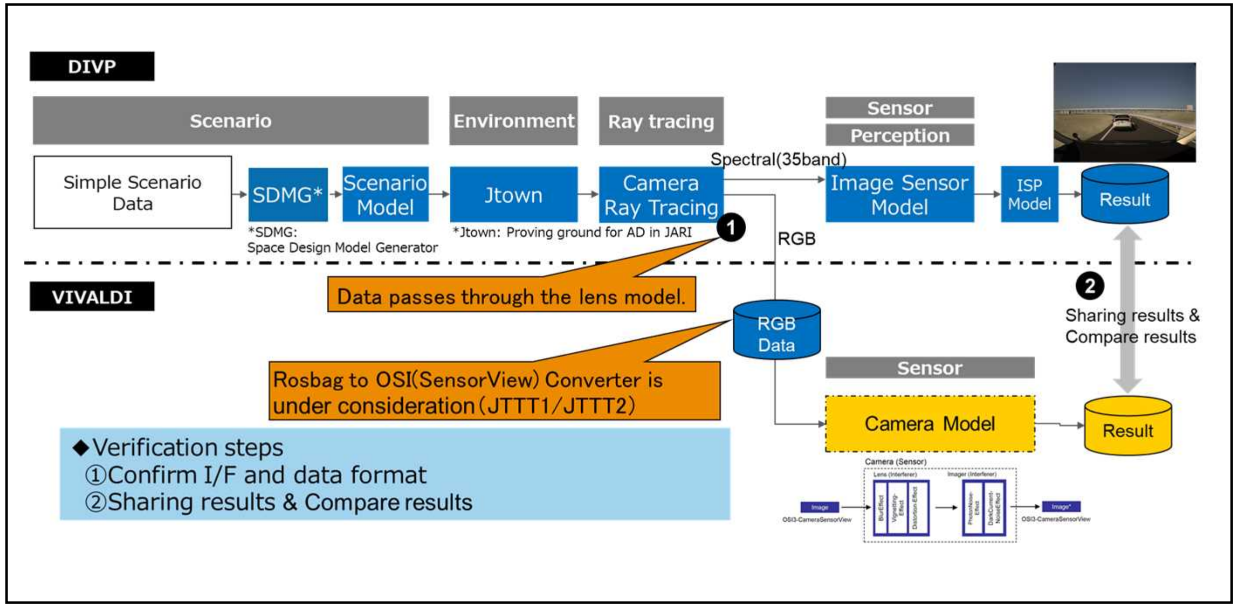
Exchange information and discuss usefulness of I/F connectivity, consistency verification methods, and detailed physical models based on camera data exchange, and deepen mutual understanding of ideal simulation environment.

Proposed two-step data exchange

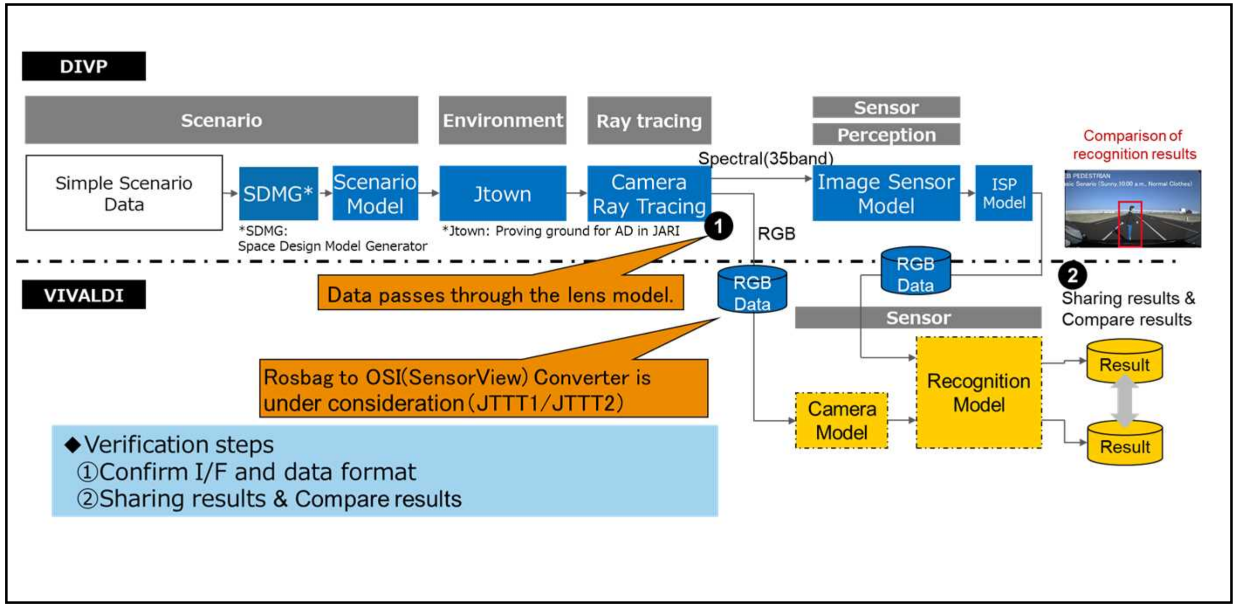
Sony Semiconductor Solutions Corporation

- Proposed two-step data exchange to better understand both platform (PF) environments
  - STEP1: Space design after RGB Provide image data and check I/F connectivity of output data
  - STEP 2: Provide sensor physical model output data to promote mutual understanding of the usefulness of a detailed physical model
- STEP 1 currently preparing supplied data for

STEP 1: Data Format, Verify I/F Connectivity



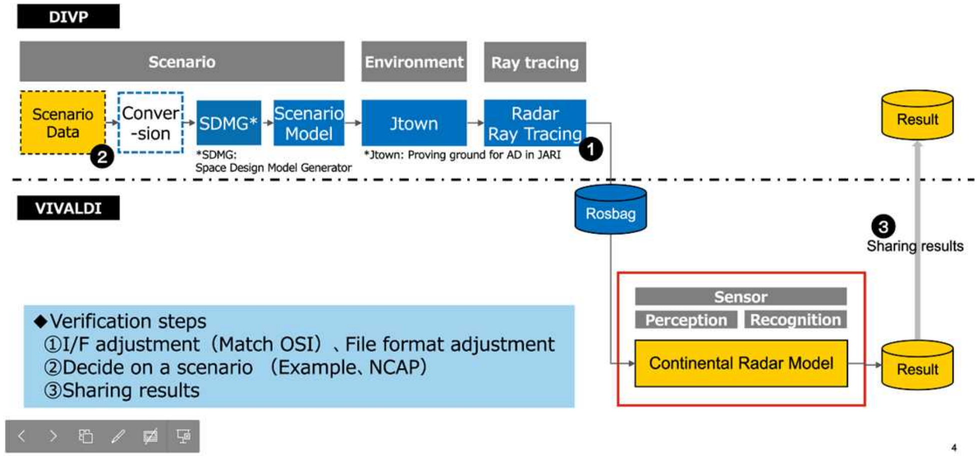
STEP 2: Verify the usefulness of the sensor physical model



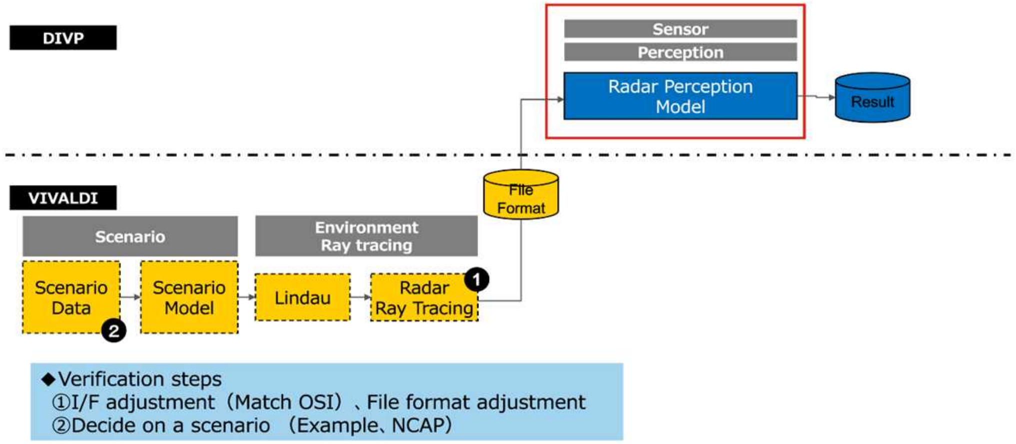
Source: Sony Semiconductor Solutions Corporation

Extension of platform connectivity on the basis of OSI through international cooperation project VIVID with Germany VIVALDI. The output data of the millimeter-wave space model is planed to be exchanged to evaluate the model IF validity. After the evaluation, the model IF will be established and be proposed to OSI as a standard IF.

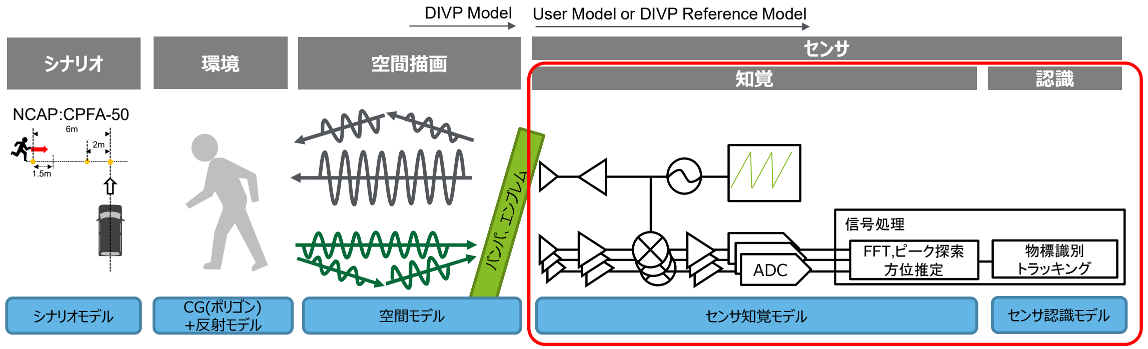
①The spatial rendering output data of DIVP® is input to Conti's Radar model and evaluated.



②Conti's spatial rendering output data is input to the Radar model of DIVP® and evaluated.



Exchanging spatial rendering output of each other and IF validation



・Policy to standardize the output of space model and propose it to OSI
・This year, we have:
1) Agreement on data exchange policies
2) Determining Common Scenarios
3) Presentation of a list of data to be provided to VIVALDI (agreement completed)
4) DIVP® Determining Data Format When Providing Data to VIVALDI (CSV)
5) Obtained VIVLADI data list (OSI extension) and checked specifications

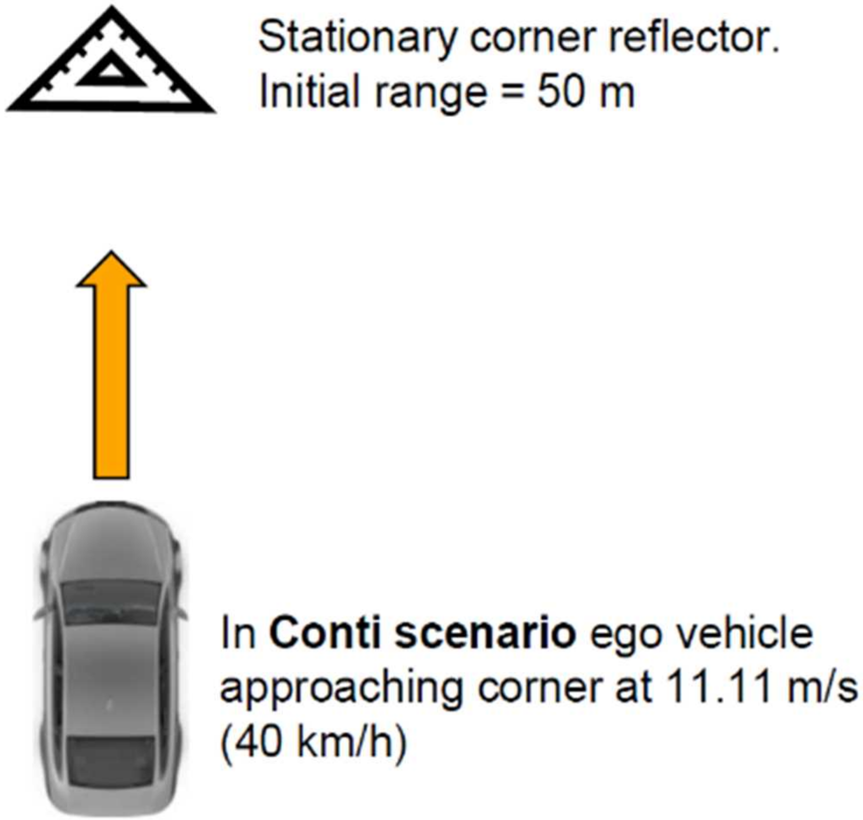
Supplemental information on 2) 3) 5) should be provided from the next page.

Extension of platform connectivity on the basis of OSI through international cooperation project VIVID with Germany VIVALDI

Supplementary information on 2) 3) 5) above will be provided from this page.

2)Determining Common Scenarios

Place 1 corner reflector 50 meters in front of the vehicle. The vehicle approaches the corner reflector at a constant speed of 40 km/h.



Source :Toyota Technical Development Corporation

3) Presentation of data list to be provided to VIVALDI (agreed)

The table below shows a list of data to be provided to VIVALDI.
This is the data list used by the Radar model on the DIVP® side and the data list to be obtained from the VIVALDI side.
We have agreed to provide this.

List of data to be provided to VIVALDI

No	Data	English notation
1	Total propagation distance	Ray propagation distance in total [m]
2	Relative velocity between reflection points	Sum of relative velocity between reflection points [m/s]
3	Propagation attenuation of the horizontal polarization component	Sum of propagation attenuation of horizontal polarization
4	Vertical propagation attenuation of polarization component	Sum of propagation attenuation of vertical polarization
5	Receiving horizontal angle	DOA in azimuth angle [deg]
6	Receiving vertical angle	DOA in elevation angle [deg]
7	Transmit horizontal angle	DOD in azimuth angle [deg]
8	Transmit vertical angle	DOD in elevation angle [deg]

Source :Toyota Technical Development Corporation

Extension of platform connectivity on the basis of OSI through international cooperation project VIVID with Germany VIVALDI

5)Obtain VIVLADI data list and check specifications

- As a result of comparing the required data list of DIVP® and VIVALDI, OSI® was found to have insufficient number of signals.
- VIVALDI is considering upgrading OSI ® in the form of OSI ® extension

Comparison verification results for DIVP® output, OSI, and VIVALDI output

No	Data	DIVP®	OSI extension by VIVALDI	OSI 3.0 RadarSensorView:: Reflection
1	Signal intensity	--	--	Signal_strength [dB]
2	Total propagation distance	Ray propagation distance in total [m]	Path_length	Time_of_flight [s]
3	Relative velocity between reflection points	Sum of relative velocity between reflection points [m/s]	Relative_velocity	Doppler_shift [Hz]
4	Propagation attenuation of the horizontal polarization component	Sum of propagation attenuation of horizontal polarization	Power in dBm(in H-pol)	--
5	Vertical propagation attenuation of polarization component	Sum of propagation attenuation of vertical polarization	Power in dBm(in V-pol)	--
6	Receiving horizontal angle	DOA in azimuth angle [deg]	Horizontal_angle	Source_horizontal_angle [rad]
7	Receiving vertical angle	DOA in elevation angle [deg]	Vertical_angle	Source_vertical_angle [rad]
8	Transmit Horizontal angle	DOD in azimuth angle [deg]	--	--
9	Transmit vertical angle	DOD in elevation angle [deg]	--	--
10	Reflectance point	Private	Number_of_interaction	--
11	Reflection point coordinates	Private	HitPoint as Vector3D x,y,z	--
12	Reflection phase shift	Private	Phase	--

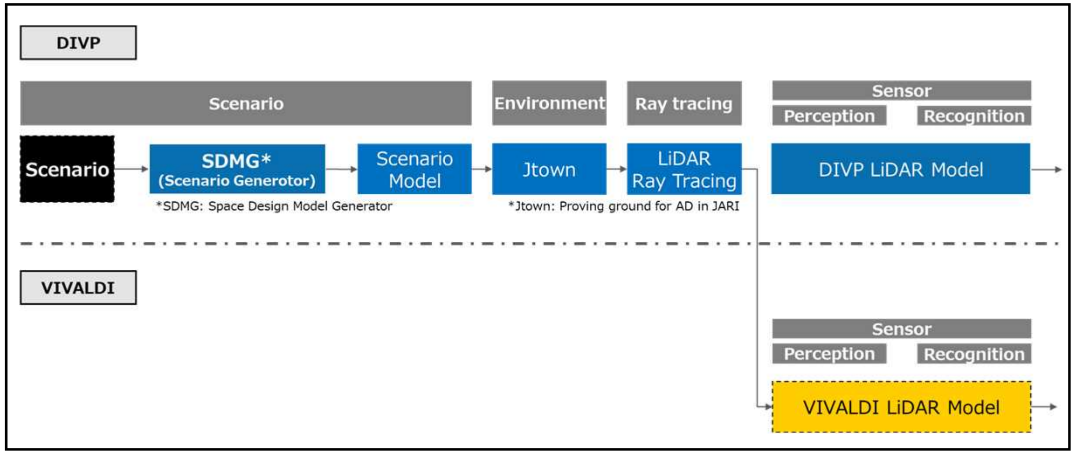
Signals that are same or convertible between DIVP® and VIVALDI models' output.

DIVP® model has some private data that can not be used for data exchange. Discussions are ongoing.

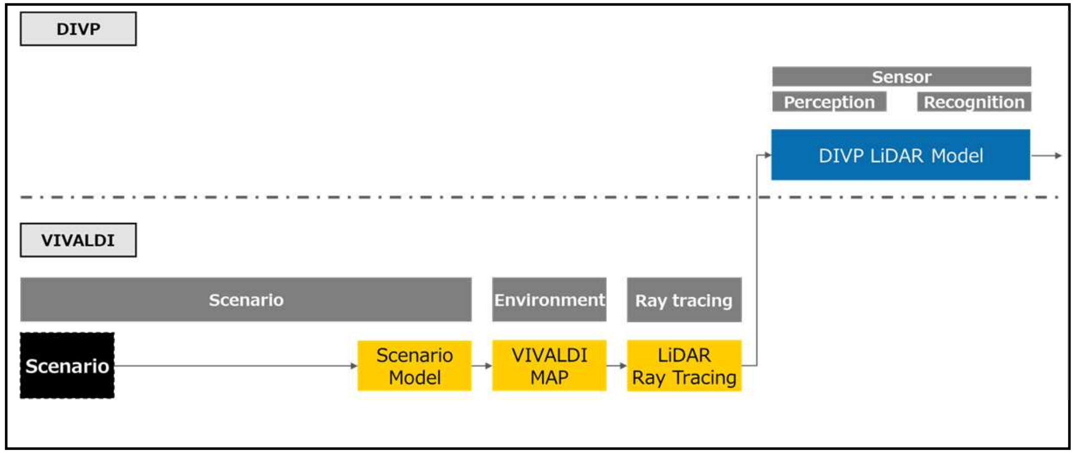
Source :Toyota Technical Development Corporation

Extended platform connectivity on the basis of OSI through international cooperation project VIVALDI with Germany VIVALDI. Exchanges LiDAR spatial rendering output and evaluates IF validity. Policy to submit proposals to OSI as a standard IF.

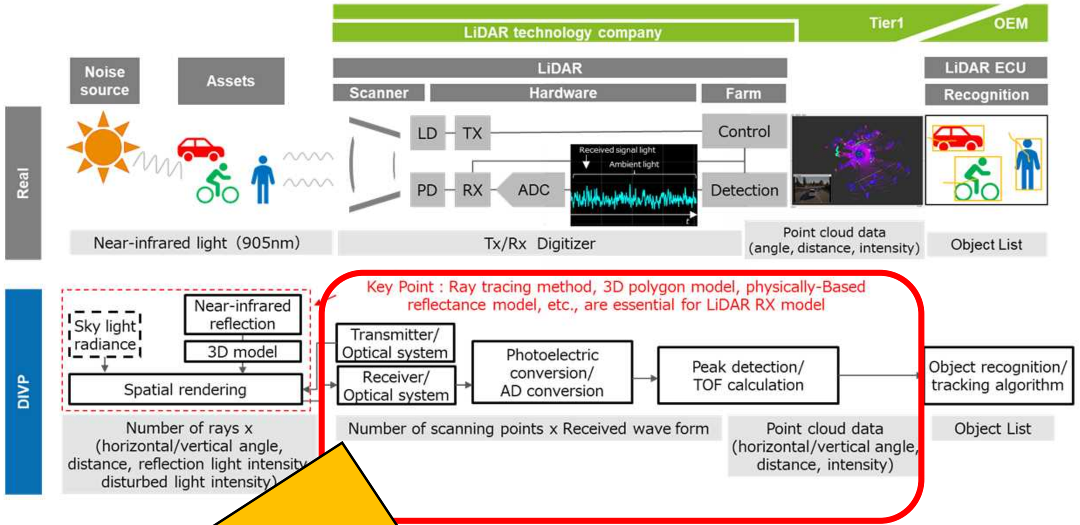
① The space design output data of DIVP® is input to the LiDAR model of VIVALDI and evaluated.



②The space design output data of VIVALDI is input to the LiDAR model of DIVP® and evaluated.



Exchanging space design output of each other and IF validation



- Policy to standardize the output of space design and propose it to OSI
- In FY 2022, we will discuss the latter stage of the perceptual output IF and the perceptual output IF by the exchange of the LiDAR model.

Source : Kanagawa Institute of Technology, PIONEER SMART SENSING INNOVATIONS CORPORATION, PIONEER CORPORATION

Outcome

- I ■ "Scenario package" for sensor validation
- II ■ Space and sensor model highly consistent with actual phenomena
- III ■ Measurement and validation methods that support consistency
- IV ■ Scenario DB for sensor validation
- **V ■ Platform with standard I/F and connectivity to diverse assessment environments**
  - ■ STANDARD I/F CONSIDERATION (D1 PART)
  - **■ Establishing a Diverse Validation Environment (Part B0)**
  - ■ Combined Platform Validation (B0 Part)

① Discussed connection of DIVP® simulator to MathWorks Fusion reference model to improving connectivity with AD/ADAS systems②Considered using OpenSCENARIO /OpenDRIVE to reuse user assets (scenarios, assets) and improve connectivity

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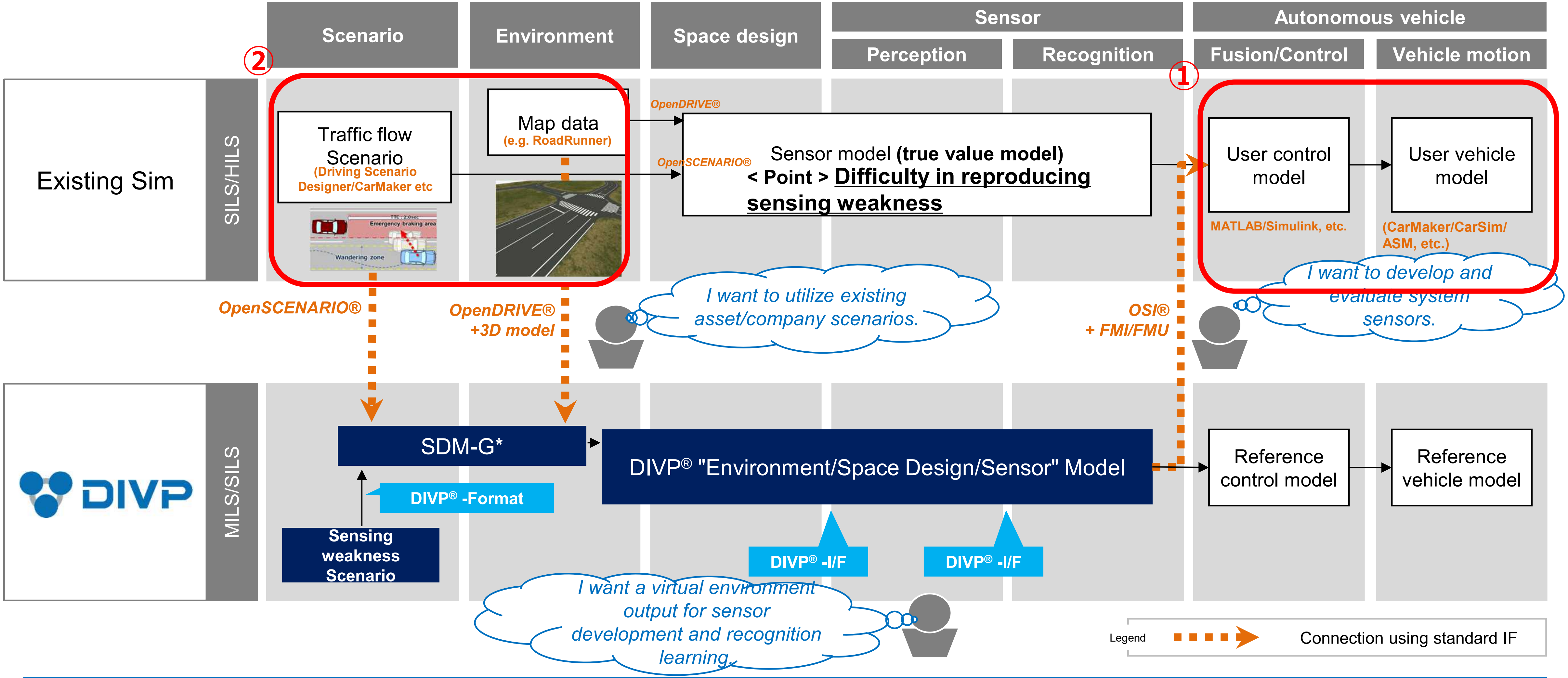
Connectivity to various validation environments - DIVP® Initiatives to enhance connectivity -



Source : Kanagawa Institute of Technology

DIVP

Examination of connectivity issues existing user models and scenario assets

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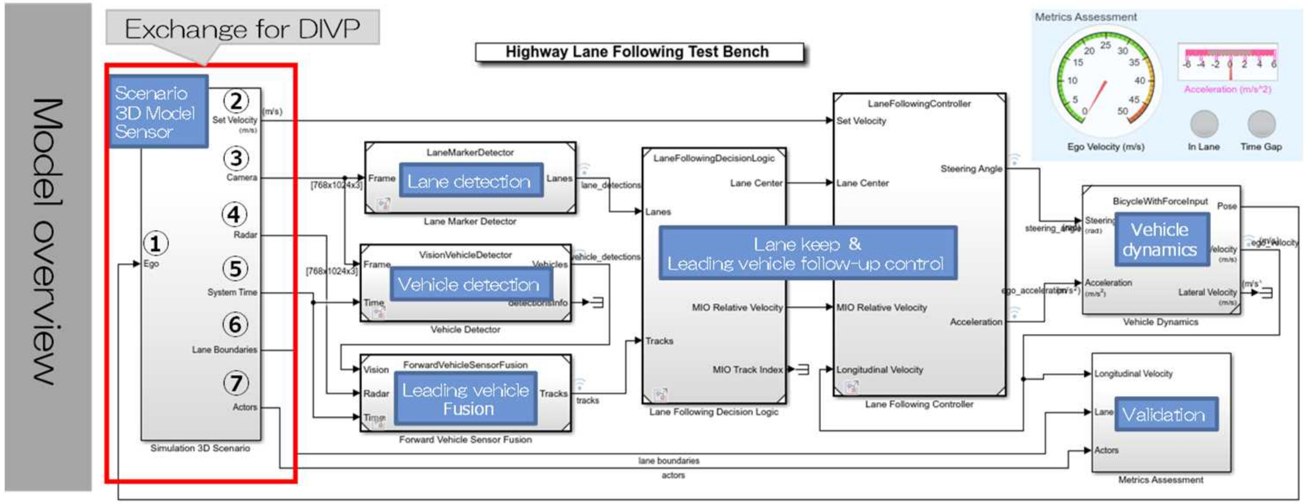
Connectivity to various validation environments - DIVP® Initiatives to enhance connectivity -

No	DIVP® Connectivity Issues	Content of the issues	Initiatives to Enhance Connectivity
① -1	Connecting to AD/ADAS Systems	Different Simulation Platform **Environments** and DIVP® must be connected	Constructing Co-SIM Environment Based on ROS
① -2		Application of DIVP® model in de facto standard environment for model-based development is mandatory	Model connectivity on MATLAB/Simulink platforms
① -3		I/F which enables simulation based on actual vehicle is required.	AD/ADAS system (AD-URBAN Proj) to DIVP®
① -4		Requires International Standard Model I/F	DIVP® Connection for FMI/FMU Models
②	Connecting to User Scenarios/Road Data	Requires an environment where user assets (scenarios,road data) can be reused	Enter OpenSCENARIO/OpenDRIVVE data based on NCAP cut-in scenario and verify DIVP® -SIM operation

Source : Kanagawa Institute of Technology

Closed loop simulation conducted by connecting environment model/sensor model part simulated by Unreal Engine 4, based on Mathwork's preceding car following model sample, to DIVP® simulator.

① -1: MathWorks Fusion Reference Connection Consideration



Copyright 2019-2021 The MathWorks, Inc.

MW Model Module | DIVP® module

	Scenario	Environment	Space design	Sensor: Pperception	Sensor: Recognition	Autonomous vehicle: Fusion/Control	Autonomous vehicle: Vehicle motion
MW model	Scenario model (Driving Scenario Designer)	3D models Asset (UE4 Linkage)	Space design Model (UE4 Linkage)	Camera perception (UE4 Linkage); Radar Model (UE4 Linkage)	Camera recognition; Radar Model (UE4 Linkage)	Leading car Fusion Lane Keep & Follow Ctrl	Vehicle dynamics
	DIVP® Scenario	3D models Asset	Space design Model	Camera perception; Radar Model (Dummy used during development)	I F; Camera recognition	leading car Fusion Lane Keep & Follow Ctrl	Vehicle dynamics; I F

Source : Kanagawa Institute of Technology

Constructed a Co-Sim environment using ROS communication to realize cooperative simulation between different OSs

① -1: MathWorks Fusion Reference Connection Configuration

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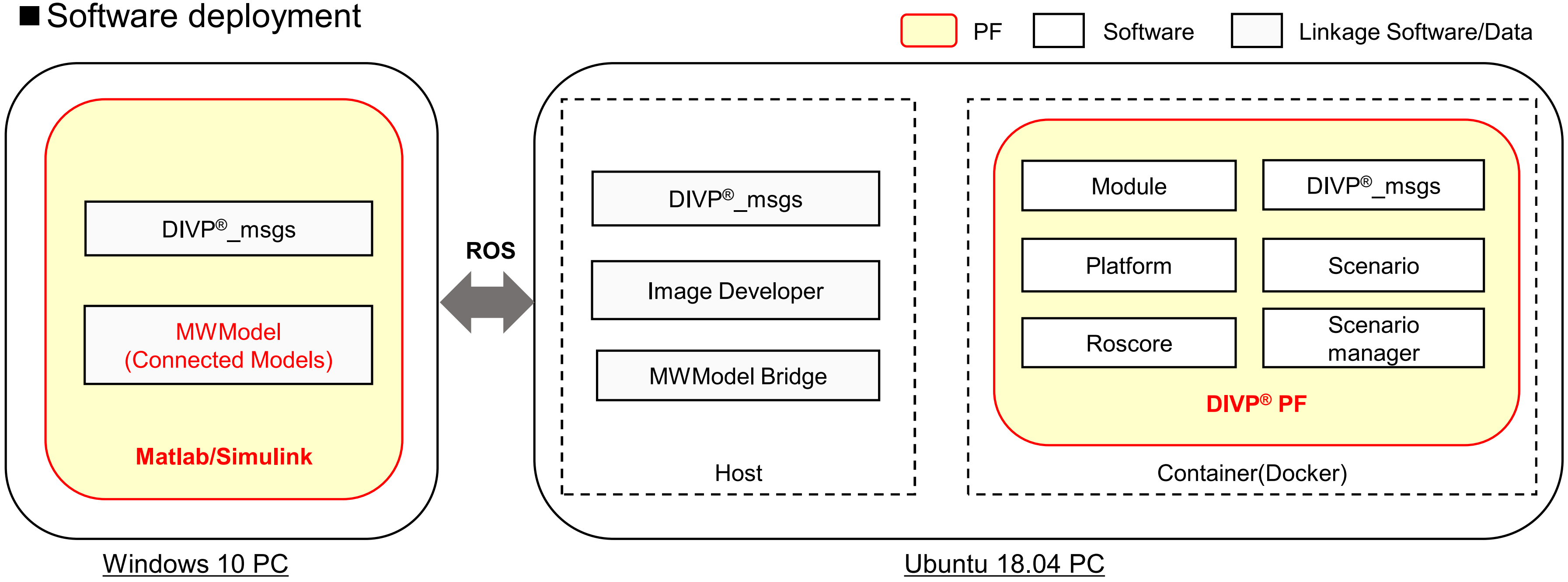
■ Software deployment



Linkage Software/Data	Contents
MWModel (Connected Models)	Mathworks provides an example of a high-speed car-following model in the Automated Driving Toolbox. The DIVP® sensor output is connected to the recognition input of this model, and the vehicle motion output of this model is connected to the DIVP® space design input.
MWModel Bridge	DIVP® Bridge Node Reflects MWModel Vehicle Motion Output in PF.
Image Developer	Development node.
DIVP®_msgs	DIVP® ROS Messages Provided by PF.

Source : Kanagawa Institute of Technology

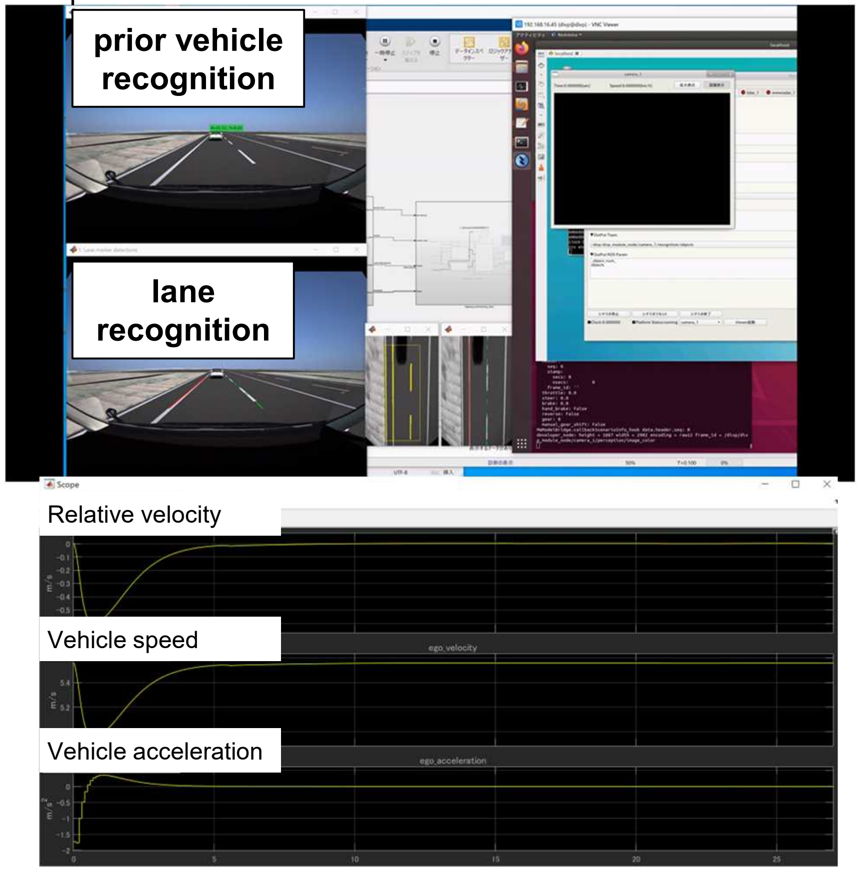
Connected Fusion Reference model to DIVP® simulator and confirmed that white line recognition and preceding/ following vehicle recognition are possible.

① -1: MathWorks Fusion Referense Connection Result

Own car　Other vehicle

No	Scenario (Jtown/Sunny)	To be evaluated: Recognition – Vehicle recognition	To be evaluated: Recognition – White line recognition	To be evaluated: Judgment and control – Vehicle following	Result
1	Straight line/No preceding vehicle/Constant speed 20km/h		○		○
2	Straight line/With preceding vehicle/Constant speed 20km/h　20km/h 30m	○			○
3	Straight line/With preceding car/Catching up with own car 55km/h　40km/h 50m			○	○

No2. Straight line/With leading vehicle/Result of constant speed scenario



DIVP® (Ubuntu) and Simulink model (Windows) connected with ROS for cross-OS CoSIM environment

Source : Kanagawa Institute of Technology

Connected DIVP® environment, spatial rendering, and sensor models (Simulink blocks) with Fusion reference models. DIVP® confirmed to be simulatable on the Simulink platform

① -2: Fusion reference model connectivity on MATLAB/Simulink platforms

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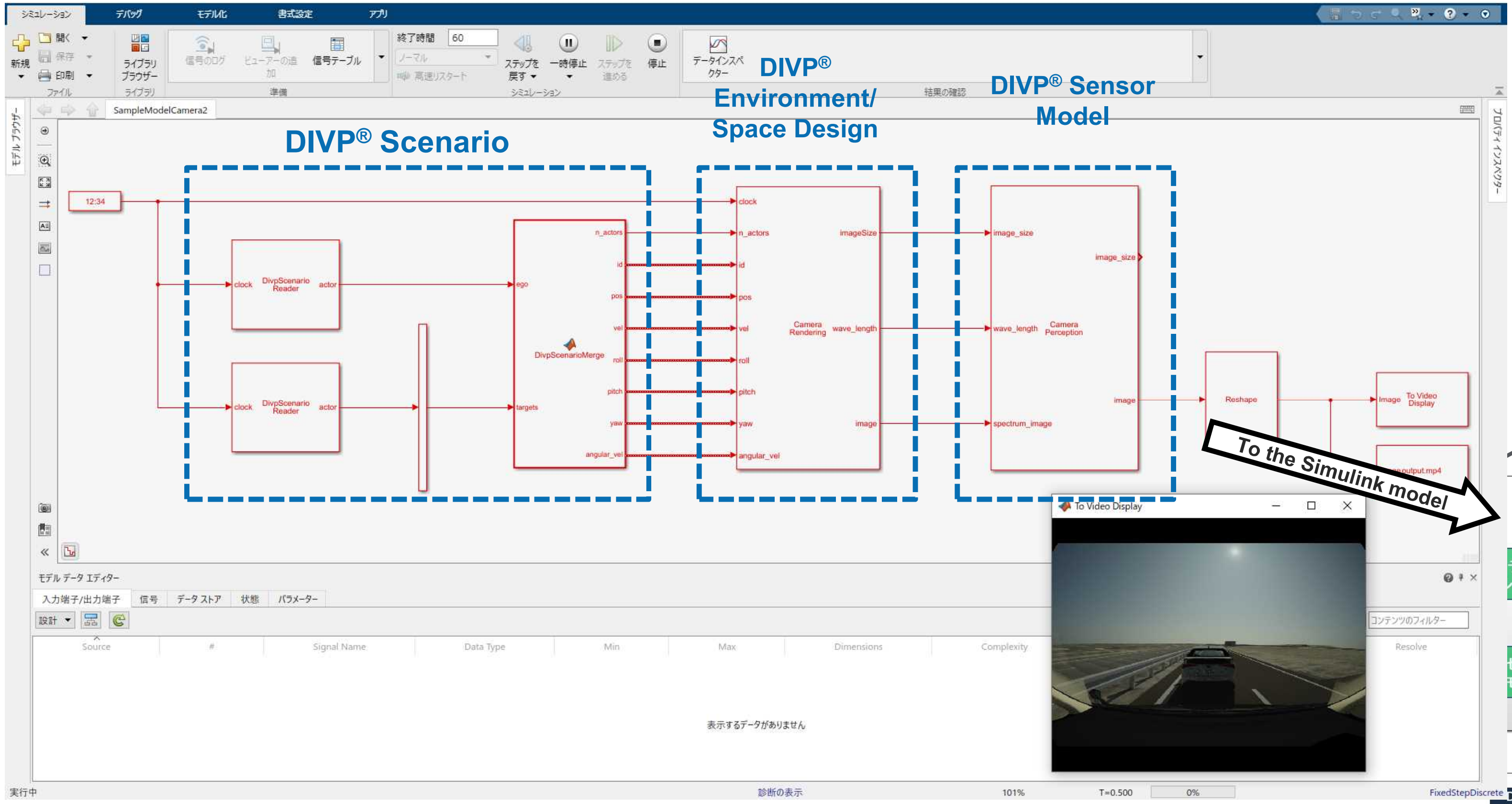
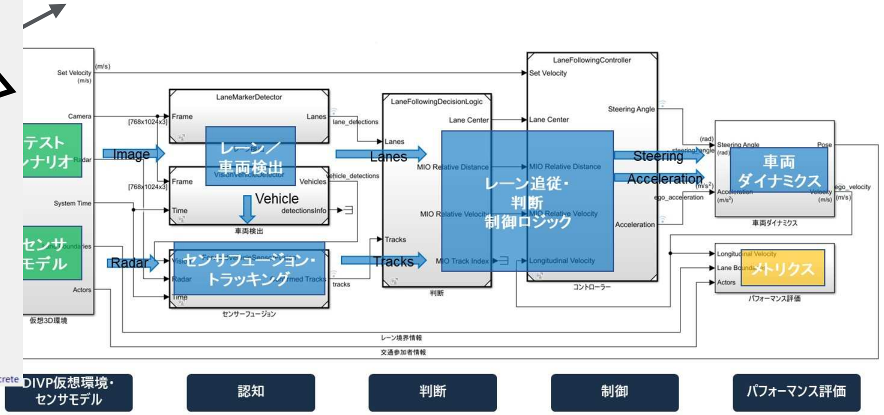
MathWorks ® Simulink screen

To Video Display block output video





Autonomous driving Simulink model

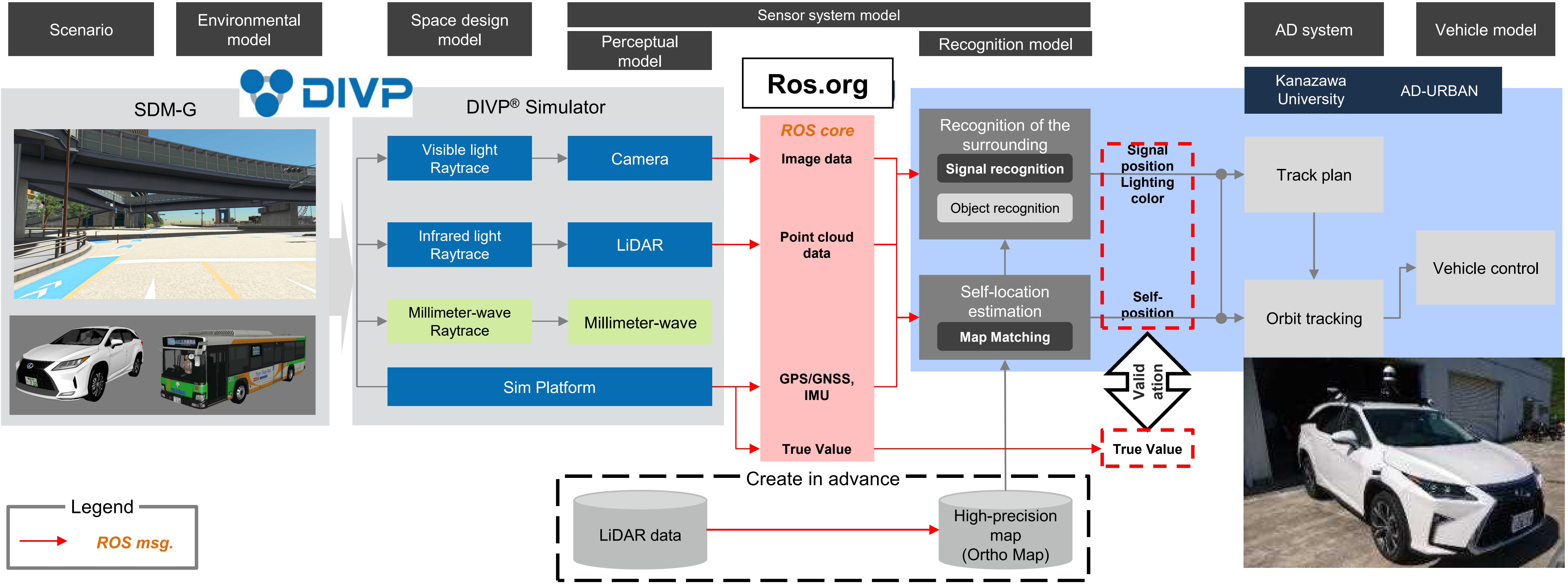
MATLAB/Simulink models and DIVP® - easy SIM connection, check CoSIM operation

Source : Kanagawa Institute of Technology

DIVP

① -3: Connected with AD/ADAS systems and clarified connection requirements with autonomous driving systems

Connection between DIVP® and AD-URBAN automated driving system

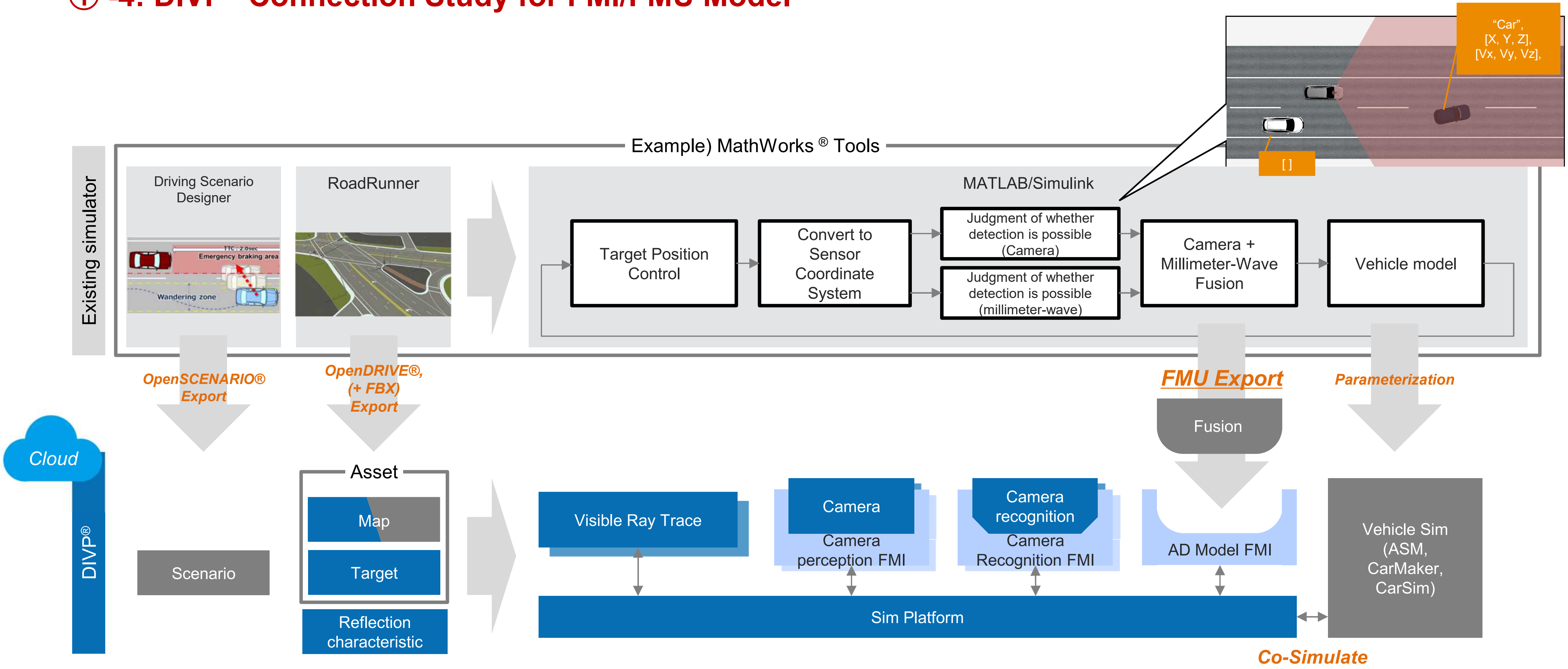


Enhancement of true value output required for validation of autonomous driving system and confirmation of synchronous simulation function were made.

Source : Kanagawa Institute of technology, AD-URBAN

MATLAB/Simulink's FMU Export allows to import developed models into DIVP®

① -4: DIVP® Connection Study for FMI/FMU Model



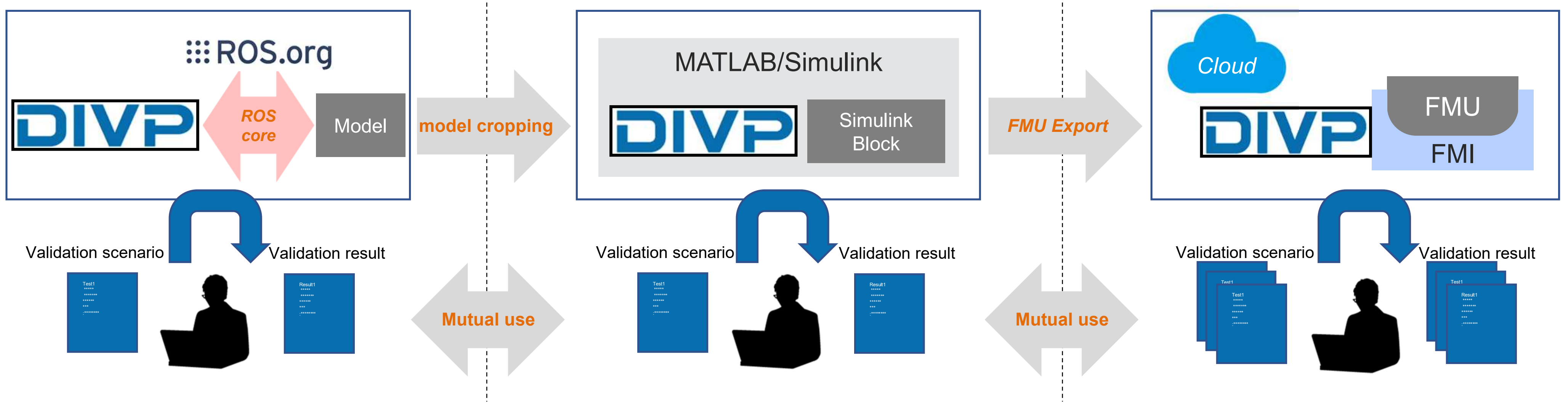
Source : Kanagawa Institute of Technology

Confirmed that simulator can be applied to a variety of validation environments considering appropriate connection I/F differs depending on user, development phase, and existing environment.

Simulator system for development phase

Use Case	Rapid Proto	Advanced development and product development	Product validation
Output format	1. ROS	2. Simulink	3. FMU
Advantage	Leveraging Open Source Software	Diversion of existing assets such as validation tools	Multi-Conditional and Rapid Validation Using Cloud Resources

Operational image

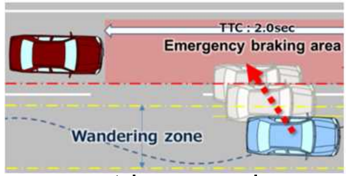


Connect the ROS module, Simulink model, and FMU model to DIVP® and confirm that SIM validation is possible.

Source: Kanagawa Institute of Technology

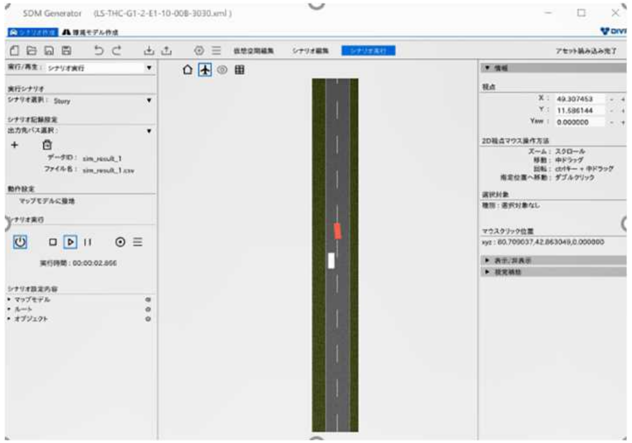
Conduced feasibility study on cut-in scenarios (OpenSCENARIO/OpenDRIVE)

② : Consideration of OpenSCENARIO/OpenDRIVE connection



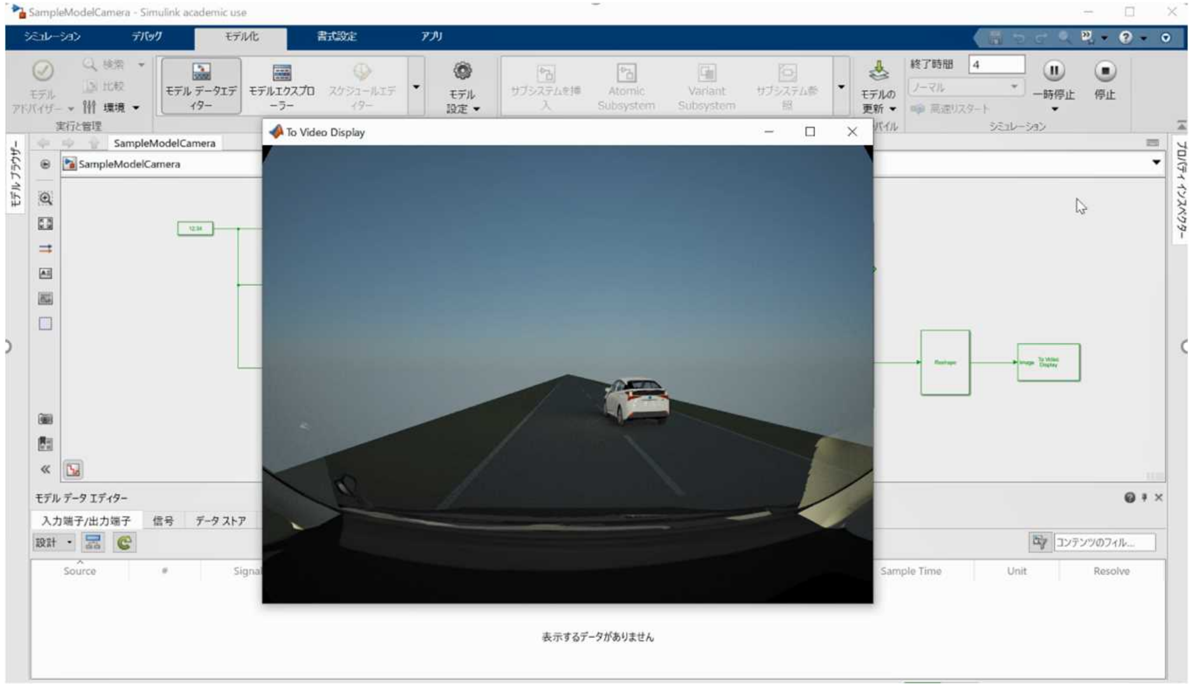
cut-in scenario

Import OpenSCENARIO/OpenDRIVE



Verifying Scenario Operation in SDM-Generator

INPUT TO DIVP® PF



Reproduction of cut-in scenario in DIVP® PF

Input OpenSCENARIO/OpenDRIVE data and confirm that SIM is possible with DIVP®.

Outcome

- I ■ "Scenario package" for sensor validation
- II ■ Space and sensor model highly consistent with actual phenomena
- III ■ Measurement and validation methods that support consistency
- IV ■ Scenario DB for sensor validation
- V ■ Platform with standard I/F and connectivity to diverse assessment environments
  - ■ STANDARD I/F CONSIDERATION (D1 PART)
  - ■ Establishing a Diverse Validation Environment (Part B0)
  - ■ Combined Platform Validation (B0 Part)

Version 0.8, a platform for research and development, has been released at Kanagawa Institute of Technology. Detailed specifications are established and knowledge accumulated.

DIVP® Extension status (join validation status)

神奈川工科大学
KANAGAWA INSTITUTE OF TECHNOLOGY

Ver	Release Contents	Environmental model	Sensor model	Automated driving model
V0.1	Coupling Validation PF (First Edition)	■ MAP Jtown reenactment	■ Combine all sensor (Camera, Radar, LiDAR) base models	■ -
V0.2	Pre-Verification PF	■ Add Asset ✓ Alphard	■ CUDA Radar Sensor Model (Distance and Speed FFT)	■ Construction of reference automatic operation model by correct value sensor
V0.3	PF for basic verification	■ MAP Jtown (10 cm increments) reproduced ■ Sky light cloudy, light cloudiness reproduced ■ Add Asset ✓ NCAP Pedestrian/Bicycle Dummy ✓ Alphard Interior Parts Added (windshield, mirror, etc.)	■ Function addition ✓ Camera space design changed to IMX 490 equivalent ✓ Add an Optix library model for LiDAR space design ✓ Change Radar space design to PO approximation model	■ Combine Camera/Radar/LiDAR recognition models
V0.4	-	■ Unify Scenario Coordinate System to Right Hand System	■ LiDAR space design updates (for example, vehicle position interpolation)	■ Added external vehicle model linkage function (CarMaker linkage)
V0.5	PF for NCAP, ALKS verification	■ reproduction of JARI specific environmental test site ■ Sky light September 12, 2020 Clear, light cloudiness, additional cloudiness ■ Add Asset ✓ GST (NCAP dummy vehicle); ✓ NCAP dummy vehicle balloon ✓ Alphard Black (Target, for Obstacles)	■ Works with Sony IMX 490 models (SSS needs to provide a model)	■ Construction of an automated driving model environment including recognition models
V0.6	For sensing weakness validation Release	■ Add Asset ✓ Alphard (light source) ✓ Prius (Light source, black) ✓ NCAP Dummy (Black Leather) ✓ Manhole and corrugated board	■ PSSI LiDAR models (Short Range) are operational (PSSI must provide a model)	■ -
V0.7	Metropolitan Expressway C1/Odaiba Scalability Validation Release	■ MAP Metropolitan Expressway C1/Odaiba reproduction ■ Sky light November 25, 2020 Clear, light cloudy, cloudy Add December 23, 2020 Clear, slightly cloudy, and cloudy weather added	■ Add specular component to LiDAR reflectivity	■ -
V0.8	Marine demonstration test release	■Addition of structures (such as bus stops) adjacent to the MAP travel path ■Alphard (light source) with Type A light distribution characteristics	■ PSSI LiDAR models (Medium Range) are operational (PSSI must provide a model)	■ -

*For details of each model (environmental model, sensor model, automated driving model), refer to the specifications of each company.
Source : Kanagawa Institute of Technology

DIVP

International collaboration and Global standardization

“Perceiving?” & ”Risk for accidents?” are the fundamental safety for human behavior

Fundamental safety

For validating 2-type of criteria, 2-type of Simulations are needed for Sensing physics validation & system validation, and DIVP® concentrate Sensing physics simulation so far

Total validation strategy for AD-safety assuarance

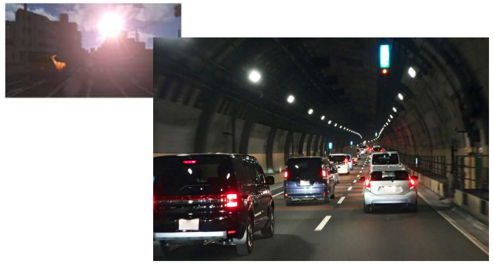
Tool structure

Scenario | Validation | Judgement

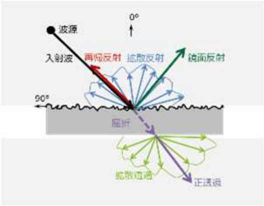
DIVP

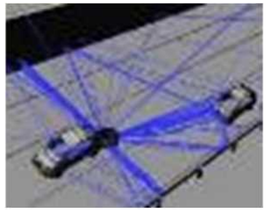
Sensor Sim

■ **Sensing Weakness Scenario** based on expert knowledge

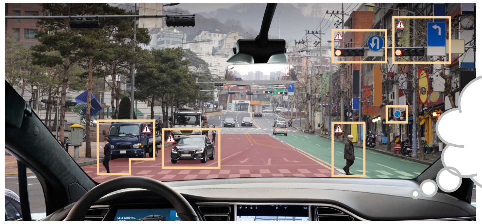


■ **Verifeid consistency based** Virtual space





■ **Virtual Validation of Cognitive Performance** Based on a Concordance Model of Measurable Perceptual Output

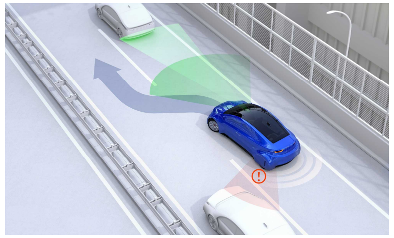


Percepting ?

Combination and application of each method

System Sim

■ **Geometric scenario** based on analysis of accident data, etc.



■ HILS

■ Actual vehicle validation

■ Accurate prediction of vehicle position to determine **margin for accident** and.

Risk for accident?

Essence

Weighting scenarios based on risk x frequency x detectability

Alternative and efficient validation of actual vehicles using simulation verified for consistency

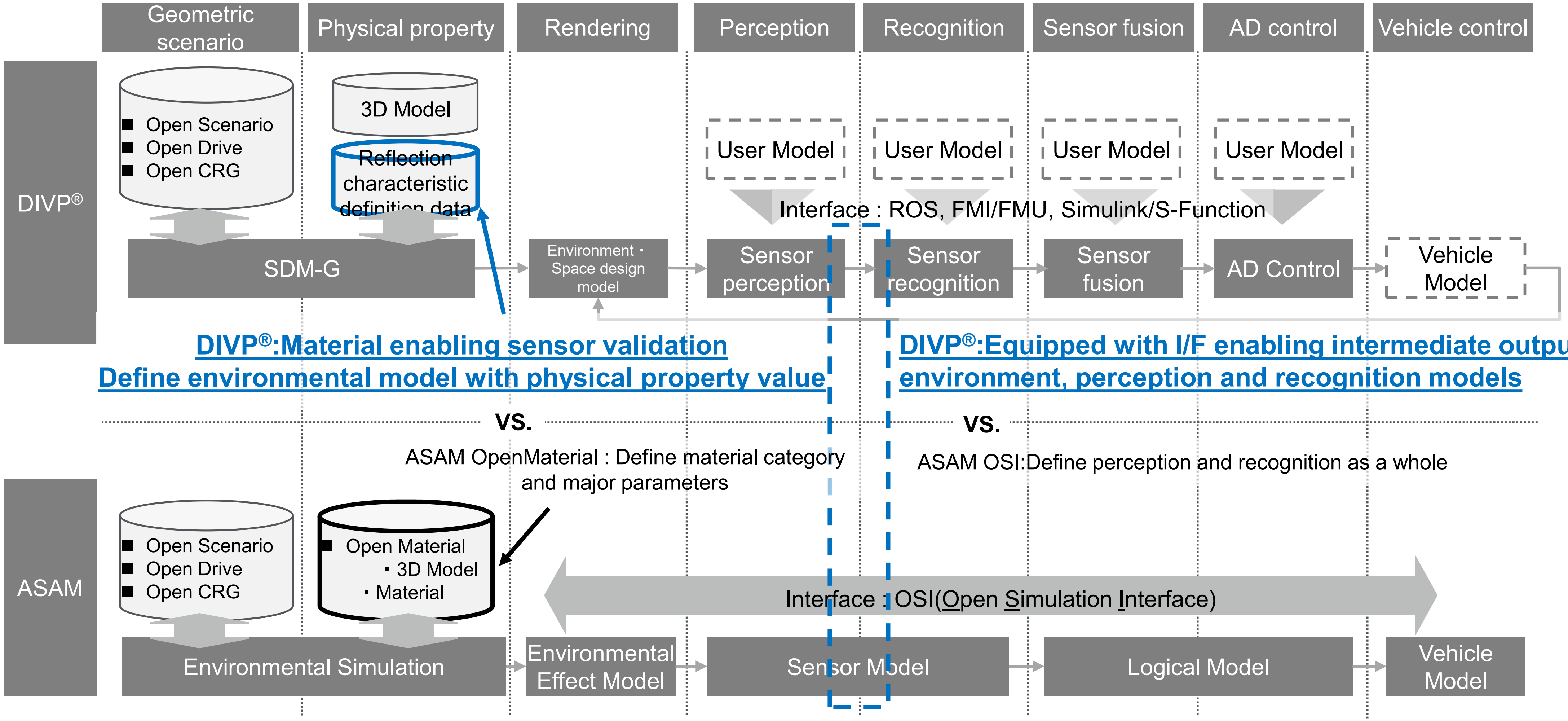
Vehicle behavior and sensor perception output and judgment as a rule of AD system

*SDM – Generator ; Space Design Model - Generator

DIVP

Referring de-facto discussion in ASAM, DIVP®'s Physical property owned environmental modeling & sensor small module based I/Fs could lead global standardization

Major differences of DIVP® compared to ASAM OSI



DIVP® will lead International collaboration and Global standardization by collaborating with domestic AD-Safety assurance research activity with JAMA Sakura, etc.

Safety Assurance global activities（VIVID (GER-JPN)/ASAM）organizational structure

SIP-adus International Collaboration Safety Assurance

SIP SIP-adus Innovation of Automated Driving for Universal Services

Leader: JAMA ← SIP

Sub-leader: DIVP

*EU Collaboration:Discussed @ SA members and international collaboration WG

ASAM DIVP

DIVP

Open X Activities (Environment) DIVP 三菱プレシジョン株式会社 **JARI**

OpenScenario2.0（Scenario generation）
OpenDrive（Space Feature）
CityGML（City Space）
OpenX Ontology
Open Material（sensor property）
Open Label（ScenarioDB）

OSI (Sensors)

OSI(v4.0)（Geometry model）
OSI Extension ← VIVID（Sensor physical model etc.）
OSC etc.

DIVP VIVID JTTTs: Leading Institutions and Meeting Activities

	Topic	DIVP®(JPN)	VIVALDI(GER)	Target (under discussion)
JTTT1 (I/F)	Comparison of simulation toolchains	Nihon Unisys, Ltd	AVL	■ Exchange information on perception/recognition model output, testbed and hardware interfaces ■ Provide OSI trace file output to JTTT 3.x activities
JTTT2 (Environmental Data)	Modelling, geometries and materials	三菱プレシジョン株式会社	KIT	■ Exchange map assets and material database
JTTT3.1 (Camera)	Reference data, test methods and metrics	神奈川工科大学 SONY	Hochschule Kempten	■ Exchange DIVP® ray tracing output (OSI trace file with dummy data) and study outcome on VIVALDI camera model
JTTT3.2 (LiDAR)	Reference data and model metrics	神奈川工科大学 Pioneer	Hochschule Kempten	■ Exchange DIVP® ray tracing output using simple static scenario and study outcome on VIVALDI LiDAR model
JTTT3.3 (RADAR)	Validation, performance simulation and reference data	神奈川工科大学 SOKEN	Continental	■ Comprehend differences in parameters and study outcome on VIVALDI RADAR model
JTTT3.4 (V&V Testing Framework)	Sensor testing and test metrics	神奈川工科大学	Technische Universität ILMENAU	■ Exchange information on measurement methods, and discuss reflectivity measurements
JTTT5 (Scenario Structuring)	Modularity, criticality, sensor-specific weakness	SOLIZE	IPG	■ DIVP® proposed communalization of scenarios*1
JTTT6 (Simulation Validation)	Scenario generation process, test campaign	神奈川工科大学	Technische Universität Darmstadt	■ Both sides proposed to focus on scenario generation and comparative studies of measurement results*1

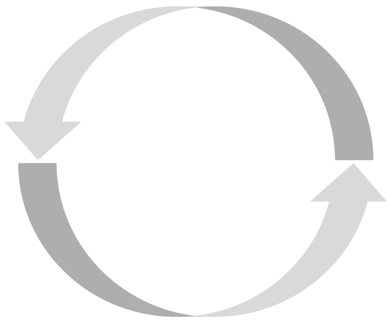
Thru VIVID collaboration, engineering Gemba based commonalities & complementation finding could accelerate AD-safety assurance and lead global standardization

Key finding from VIVID collaboration

Give & Take based Competitive collaboration

DIVP

Commonalities



Complementarities

AD safety assurance strategy reinforcement	Specify standardization scope	Key person identification

Global standardization leading

ISO ASAM ....

DIVP® will propose to ASAM initiatives on OSI extension, city GML and Open Material via VIVID, and lead standardization by determining key contact and working with global projects on safety assurance

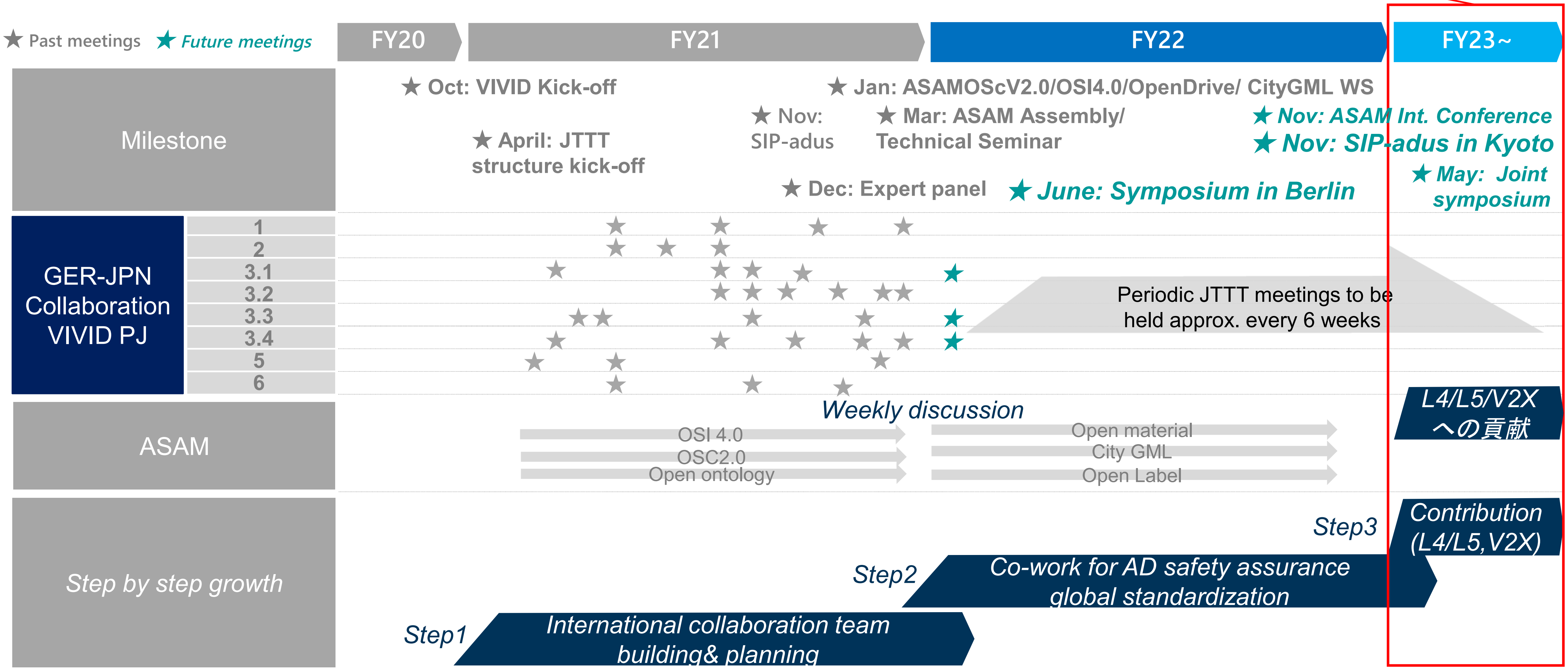
DIVP®'s understanding of issues related to international collaboration

	1 Systematize Assurance	2 Determine Standardization Scope	3 Determine Key Contact
Issues from DIVP® Viewpoint	■ Consider collaboration with other safety assurance framework such as the **UL** (US) and **V4V** (EU, succeeding HEADSTART PJ) other than German projects	■ **Submit proposal to ASAM initiatives such as OSI extension, CityGML and Open Material**	■ Clarify ideal counterpart for submission of proposal and method regarding global standardization effort
DIVP® Action Plan	■ DIVP® to pay **close attention to developments** and **collaborate** where applicable	■ OSI extension, CityGML and Open Material are initiatives on which DIVP® and VIVID should work together, and thus DIVP® will **actively discuss and draft proposal via VIVID**	■ Determine **key contact** via **VIVID** discussions to establish direct line of communication with ASAM

【International Collaboration】VIVALDI（GER)is willing to continue collaborative efforts beyond FY23, and continuation of DIVP® beyond FY23 is necessary to spearhead standardization (ASAM) activities

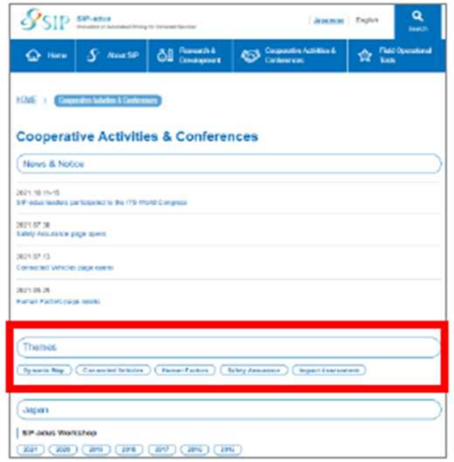
International collaboration/ standardization schedule

VIVALDI willing to continue efforts beyond FY23



Safety Assurance grabbed most attention at SIP-adus 2021, indicating participants' interest in the subject

【Cf】2021 SIP-adus responses



国際連携＆イベントページ
「Themes」に掲載

テーマ別アクセス数
期間：2021年5月～2022年1月

テーマ	公開日	アクセス数
Safety Assurance	2021/7/30	704
Human Factors	2021/5/25	373
Dynamic Map	2021/3/25	331
Connected Vehicles	2021/7/13	279
Impact Assessment	2021/11/11	165

Safety Assuranceへのアクセス数が最大

Source : Congrès Inc.

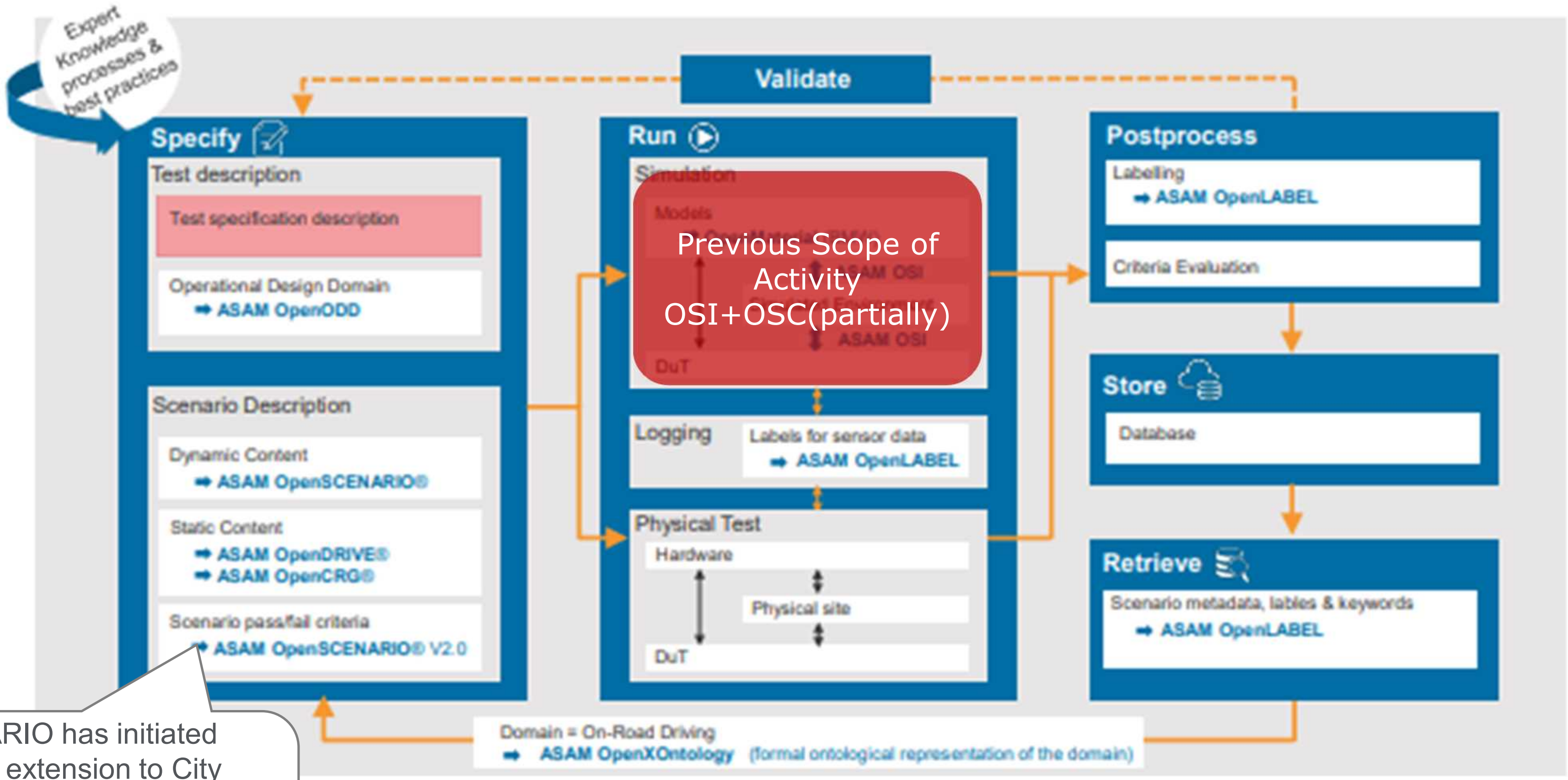
International collaboration and Global standardization

- International standardization via ASAM(GER)
- Acceleration of JPN-GER collaboration project VIVID

While previously concentrating on OSI activities, DIVP®'s avant-garde achievements can lead ASAM standardization given increased attention allocated to physical property value

ASAM OpenX Structure

ASAM



- OpenSCENARIO has initiated discussion of extension to City GML and OpenMaterial
  - ➢ *Activities on physical properties pertaining to environment models are growing in number*

Source：“ASAM Open Simulation Interface ASAM Open X”(ASAM Technical seminar, October 8th 2020)

DIVP

Active discussions on physical property are observed across the OpenX landscape. Aside from DIVP® actions, JARI's contribution is needed for OpenLabel pertaining to real vehicle verification

ASAM OpenX Status/ Issues/ DIVP® action plan

ASAM

	Recent Topics	Hypothetical issues from DIVP®(including Sakura) perspectives		Action Plan
OSI (v4.0)	■ Contemplation of **Google FlatBuffers** introduction ■ Discussion on **Road Model definition (physical sim)** ■ Sensor Modeling WP: managing perception data (sensor view) and environment conditions	■ Active discussion regarding interface necessary for sensor validation. **DIVP® could lead debate based on cutting-edge activities**	Nihon Unisys, Ltd	■ **Compare OSI/DIVP®** ■ Discuss Road Model definition within VIVID ■ **Cooperate with VIVALDI on OSI extension**
Open Drive	■ **Discussion on extending to area model (CityGML)** ■ **Discussion on OpenMaterial for sensor materials** ✓ **BMW submitted proposal, may become OpenX** ■ TU Munich to compile use case data	■ Discussion on OpenMaterial, presumably eyeing to define physical property required for sensor sims, launched. **Monitoring required to ensure universality of DIVP® values**	Nihon Unisys, Ltd 三菱プレシジョン株式会社 神奈川工科大学	■ **Issue extraction based on OpenMaterial Proposal review** ■ Monitor CityGML status
Open Scenario 2.0	■ Opinions to **support definition** of **static objects** for **efficient run of large number of tests** observed ■ Final revision of **environment condition** and action ongoing	■ Discussion on efficient run of sims ongoing. Inconvenient format needs rooting out **for standard alignment of DIVP® products (SDM Generator)**	三菱プレシジョン株式会社	■ Monitor activities
Open X Ontology	■ Discussion taking the vantage point of positioning Open X Ontology as **the top domain that connects other OpenXs such as OSI/OSC** to proceed ■ **Only true value defined**, no class definition related to sensing weakness	■ Open X Ontology to connect other OSI/OSC as top domain. **Definitions of physical property and sensor output need to be addressed.**	SOLIZE TTDC	■ Prepare learning sessions to inform members of recent Ontology/ Label status ■ **Cooperation request for JARI in terms of real vehicle verification**
Open Label	■ Standardization ongoing regarding motion pictures, dots, sensor data, sim data annotation and tagging format ✓ **Definition of sensing weaknesses vacant**	■ Standardization of DIVP® tagging format may be required for **scale-up of business based on data inter-operability**		

*"Environmental Condition" handles weather (rain, fog, etc.) and is inserted into OSI's Sim I/F. The first scenario is written in OpenSCENARIO, and the definitions are implemented in Ontology, etc., which are connected across OpenX.

International collaboration and Global standardization

- International standardization via ASAM(GER)
- Acceleration of JPN-GER collaboration project VIVID

VIVID is German funded VIVALDI & Japanese CAO funded DIVP® joint project since November 2020, targeting Simulation based AD-Safety assurance Global standardization

VIVID key objectives

How realistic is realistic enough?

How safe is safe enough?

Multi-sensor platforms
: Radar + LiDAR + Camera

Complementary methods from simple to realistic: SiL, HiL, ViL, FOT

Open standards & interfaces thru ASAM OpenX
Scenario, sensor, environment, OpenX-Ontology

Fidelity metrics of simulation and test chains

Knowledge base created from a reference architecture

Harmonisation & globalisation:
German-Japanese "joint topical task teams" (JTTTs)

Technische Universität ILMENAU
KIT
Hochschule Kempten
Technische Universität Darmstadt
Mercedes-Benz
Continental
DIVP
AVL
IPG
Blickfeld
DLR

Source : German-Japan Joint Virtual Validation Methodology for Intelligent Driving Systems – VIVID, 5. Expert workshop "CAD"

VIVALDI-DIVP® assigned individual leaders to each JTTT for small team based discussion to define commonality & complementary toward AD-safety assurance Global standard

JTTT(Joint Topical Task Team) structure

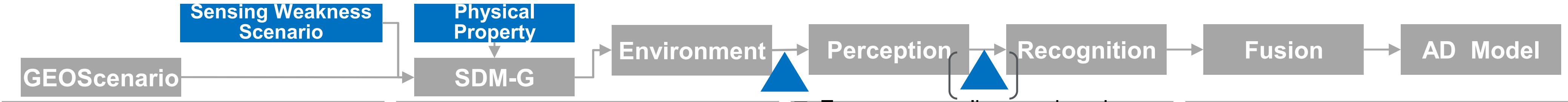
	Topic	DIVP®(JPN)	VIVALDI(GER)	Expected Outcome
JTTT1 (I/F)	Comparison of simulation toolchains	Nihon Unisys, Ltd	AVL	■ Exchange information on perception/recognition model output, testbed and hardware interfaces ■ Provide OSI trace file output to JTTT 3.x activities
JTTT2 (Environmental Data)	Modelling, geometries and materials	三菱プレシジョン株式会社	KIT	■ Exchange map assets and material database
JTTT3.1 (Camera)	Reference data, test methods and metrics	神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY Sony Semiconductor Solutions Corporation	Hochschule Kempten	■ Exchange DIVP® ray tracing output (OSI trace file with dummy data) and study outcome on VIVALDI camera model
JTTT3.2 (LiDAR)	Reference data and model metrics	神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY Pioneer	Hochschule Kempten	■ Exchange DIVP® ray tracing output using simple static scenario and study outcome on VIVALDI LiDAR model
JTTT3.3 (RADAR)	Validation, performance simulation and reference data	神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY TTDC SOKEN u-shin	Continental	■ Comprehend differences in parameters and study outcome on VIVALDI RADAR model
JTTT3.4 （V&V Testing Framework)	Sensor testing and test metrics	神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY TTDC	Technische Universität ILMENAU	■ Exchange information on measurement methods, and discuss reflectivity measurements
JTTT5 (Scenario Structuring)	Modularity, criticality, sensor-specific weakness	SOLIZE	IPG	■ DIVP® proposed communalization of scenarios *1
JTTT6 (Simulation Validation)	Scenario generation process, test campaign	神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY	Technische Universität Darmstadt	■ Both sides proposed to focus on scenario generation and comparative studies of measurement results *1

*1：Consensus on expected outcome between JPN-GER has yet to be confirmed

DIVP

DIVP® prioritize & propose JTTT collaboration for Sensing performance validation-ability with Sensing weakness, Physical property owned environmental models & sensor I/Fs

JTTT scope from DIVP® perspective



	Scenario	Environment Model	Sensor Model	Fusion/AD model
Issues From DIVP® Perspectives	■ Standardized prioritization of scenarios necessary for sims require clarification. Current JAMA strategy is not practical and needs rethinking.	■ Current format is unable to attach property info required for sensor sims, and rule making is at risk of proceeding on true-value＋α basis	■ European suppliers are keeping environment ~sensor models folded as black box, and I/F between these models is called for ■ Perception output proposed by DIVP® has been standardized	■ Validity definition of sim accuracy based on connectivity beyond sensor output and fusion is yet to be determined
VIVID Action Policy	■ Sort **prioritized scenarios** for sensor validation (critical scenario (GER), sensing weakness scenarios (JPN))(using PerCollECT)	■ Study validity of true value output ■ Consider standardization of 3D model format **to add property** ■ Prepare for **map exchange** from VIVALDI	■ Appeal positives of I/F node between **environment/sensor models** via exchange/validation of output and sensor modeｌｓ ■ Consider perception output action	■ Discuss **reference to VIVALDI's sim accuracy** ■ Spur **all-Japan consensus building** by including JAMA (Sakura)
JTTT area of expertise/ Leader	**JTTT5** （SOLIZE）	**JTTT2** （MPC/NUL）	■ JTTT3.1 Camera ■ JTTT3.2 LiDAR ■ JTTT3.3 Radar	■ JTTT6
	■ NUL to handle all I/F related issues in JTT1. **Spearhead international harmonization via ASAM** while establishing VIVID I/F standard in response to all JTTT activities.			
	■ JTTT3.4 to **discuss toolchain including HILS/VILS**, and to cover fundamental technology pertaining to measurement and validation criteria. JTTT3.4 also looking to include weather conditions in scope of business.			

International collaboration and Global standardization

- International standardization via ASAM(GER)
- Acceleration of JPN-GER collaboration project VIVID
  - JTTT1
  - JTTT2
  - JTTT3.1~3.3
  - JTTT3.4
  - JTTT5
  - JTTT6

JTTT1 Interface
DIVP® Simulation and data interfaces

JTTT1 scope

Nihon Unisys, Ltd

Input

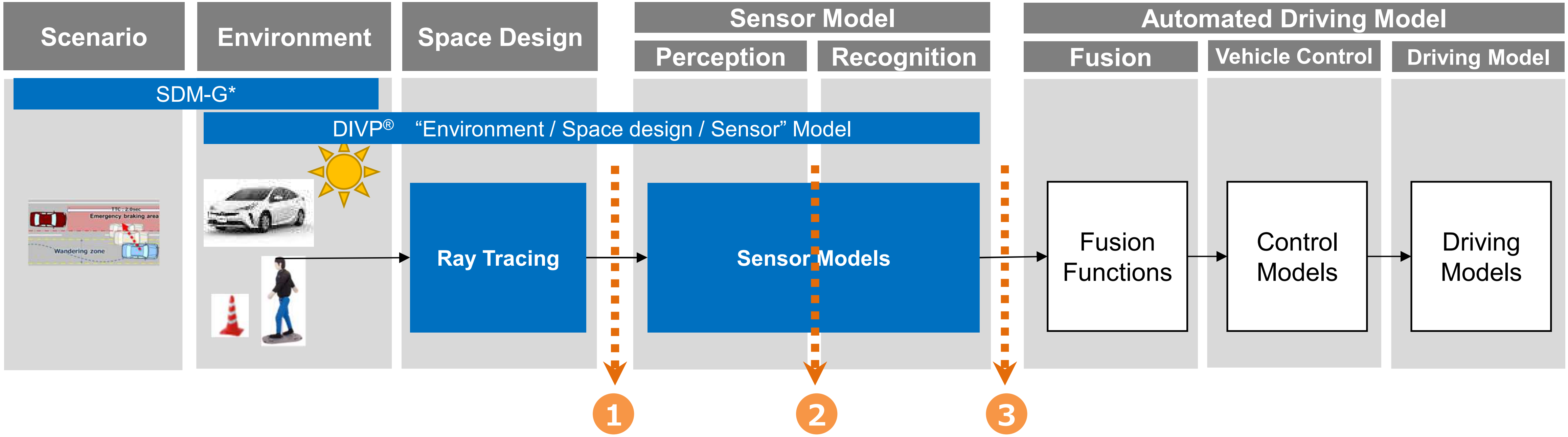
Generate sensor input data made by precise physical simulation with environment data that actual sensor could receive

Validation target

Execute sensor model simulation in virtual space

Output

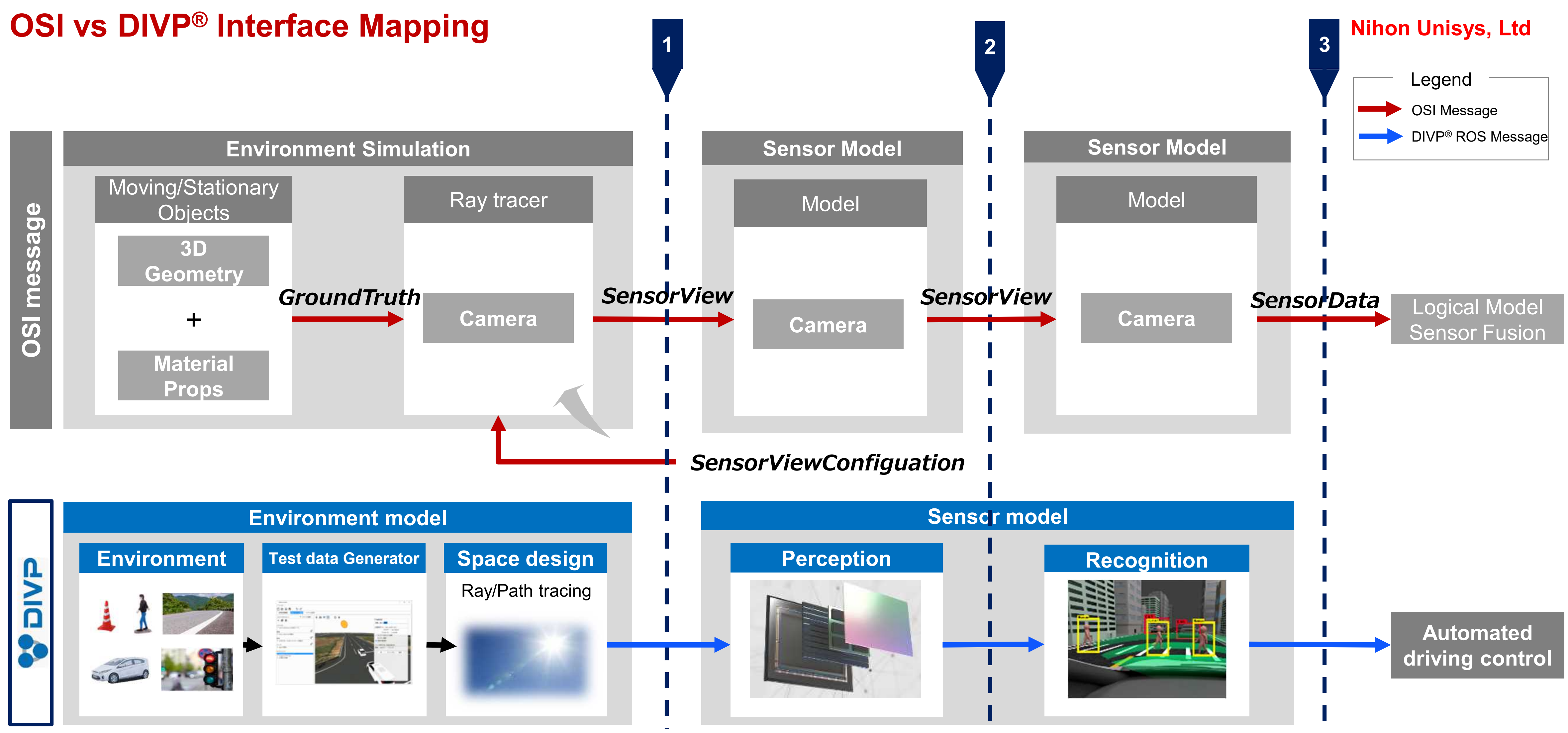
Output results of sensor model simulation to automated driving models



*SDM-G : Space Design Model Generator

DIVP

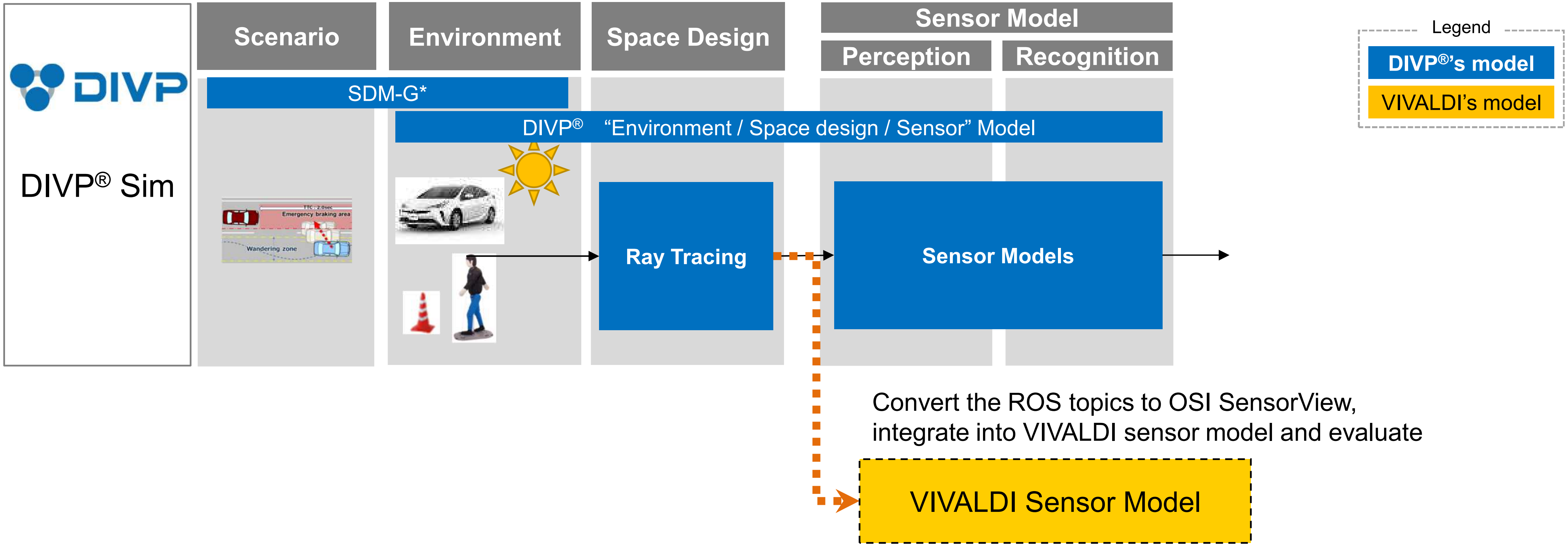
Actualize format proposal towards standardization through comparison between DIVP® and quasi-de-facto OSI standard



Convert DIVP® spatial design output to OSI format, and integrate into VIVALDI sensor model

Proposal：Exchange the input of sensor model

Nihon Unisys, Ltd



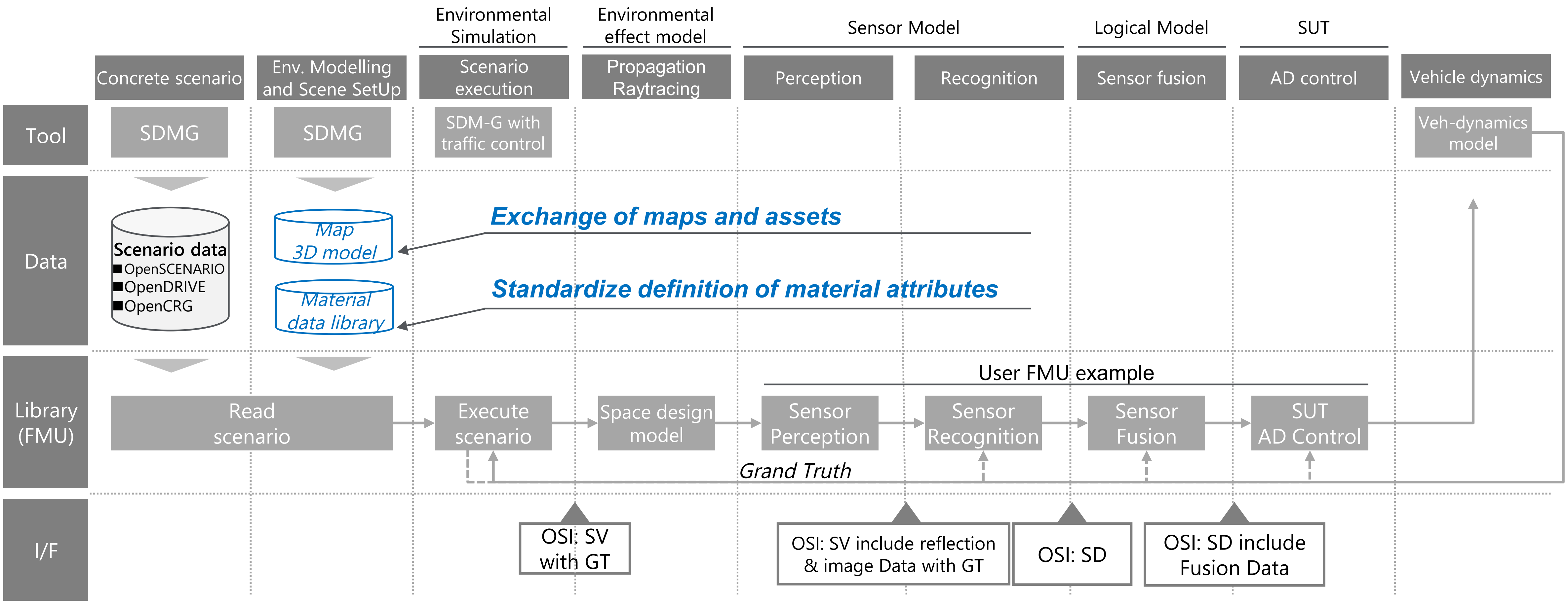
Verify I/F connectivity and extension by exchanging/ verifying input data to sensor models

International collaboration and Global standardization

- International standardization via ASAM(GER)
- Acceleration of JPN-GER collaboration project VIVID
  - JTTT1
  - JTTT2
  - JTTT3.1~3.3
  - JTTT3.4
  - JTTT5
  - JTTT6

DIVP® proposed to exchange maps & assets & material attribution standardization

Proposed collaboration scope



Note SDM-G: Space Design Model Generator, SV: Sensor View, SD: Sensor Data, GT: Grand Truth

JTTT2 aims to standardize precise simulations and discuss standards for material data

Purpose and expected achievement in JTTT2

三菱プレシジョン株式会社

Purpose and benefits of exchanging map data with VIVALDI

- ✓ Verify effectiveness of data compatibility.
- ✓ First in ASAM, data formats can be discussed in DIVP® and VIVALDI.
- ✓ DIVP® enables verification using VIVALDI data.

As an asset DIVP®, achievement goals and motivation (intention)

- ✓ Standardization through precise simulations and discussions regarding standards for material data.
- ✓ We aim to reduce costs by standardizing material information measurement methods and sharing data with VIVALDI.

Source : MITSUBISHI PRECISION CO.,LTD.

DIVP

The table compares DIVP® assets item and UE4 assets item in general, and DIVP® look to confirm VIVALDI's assets

DIVP® assets VS. General assets (UE4)

三菱プレシジョン株式会社

Item	DIVP® assets	UE4 based assets
■ Asset format	■ FBX Format	■ FBX Format or ■ Uasset format （depend on UE4 version)
■ Geometry	■ Polygon	■ Polygon
■ Control method	■ Bone control ■ Partially original control	■ Bone control ■ Original control
■ Material	■ External definition （Refer to material using mesh name as key）	■ Texture or ■ UE4 defined by blueprint (depend on after process)

DIVP

International collaboration and Global standardization

- International standardization via ASAM(GER)
- Acceleration of JPN-GER collaboration project VIVID
  - JTTT1
  - JTTT2
  - JTTT3.1~3.3
  - JTTT3.4
  - JTTT5
  - JTTT6

Toward Sim-based AD Safety assurance, DIVP® proposes sensor In/Out and intermediate I/F for physical measured based perception validation

Camera I/Fs example

Legend ▲ : I/F ▲ : DIVP® Proposed I/F

Environment model		Sensor model		Fusion
Environment	Spatial drawing	Perception	Recognition	

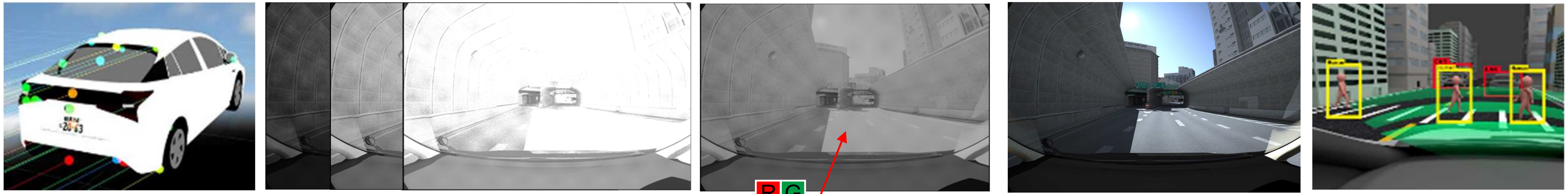
Sensor signal flow

Lens → Spectral ① (DIVP® Proposed I/F) → Image sensor block: Photoelectric conversion x N times → (I/F) → HDR Synthesis → 24bit → PWL compression → 12bit ② (DIVP® Proposed I/F) → Control block: Development process (ISP Processing) → 8bit (I/F) → Object recognition DNN → ③ (DIVP® Proposed I/F) → Fusion → (I/F) *Sensor output received by the current OEM (CAN-FD, etc.)*

I/F out put

Spatial input (①)	Multiple exposure output	*RAW (Bayer array) image* (②)	Color image	*Target recognition information* (③)
■ Output of the Ray tracing of the space ■ Multiband spectral irradiance (W/m^2/nm)	■ Taking multiple low-bit images with different exposure conditions ■ Combine into high-bit images by HDR synthesis	■ Images with a wide dynamic range and communication capability ■ ***It is possible to judge whether a large amount of information was perceived.***	■ Image with a color or a single color of 8 bits in the development process ■ Information may be lost due to processing methods.	■ Information such as the type, position, and size of the object

Example output



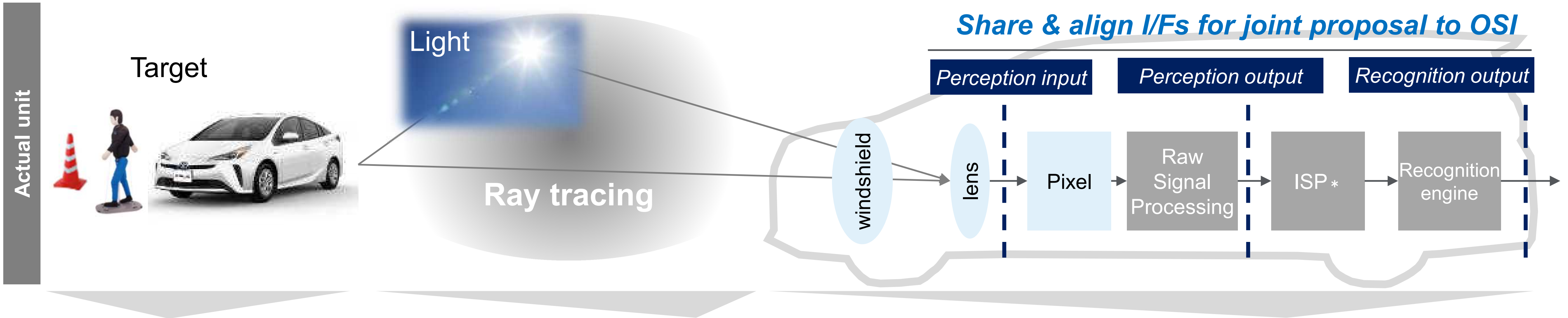
R G G B *Color filter array(Bayer array)*

* Example of output is different from the reference example and actual output.
Source : SOKEN,INC

DIVP® proposed 3-I/Fs, share & align I/Fs for joint proposal to OSI

JTTT3.1 scope

Kanagawa Institute of Technology 神奈川工科大学 · Sony Semiconductor Solutions Corporation



Environmental model	*Space design*	*Sensor model*

The Key for modeling

Environmental model

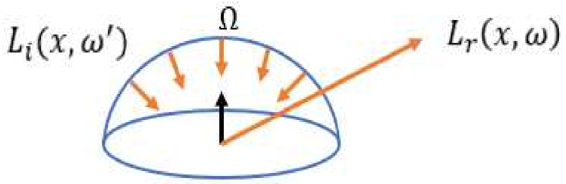
- Precise reproduction of object shape
- Reproduction of reflection characteristics of visible light spectrum

Space design

- Precisely reproduce propagation, reflection, etc. from the light source

Calculate reflected waves using rendering equations

$$L_r(x,\omega) = \int_\Omega f_r(x,\omega,\omega')L_i(x,\omega')(\omega',n)d\omega'$$

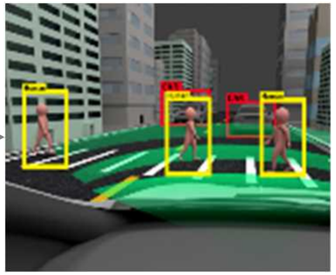


Sensor model

Camera perception model

- Photoelectric conversion
- Raw Signal Processing

Recognition model

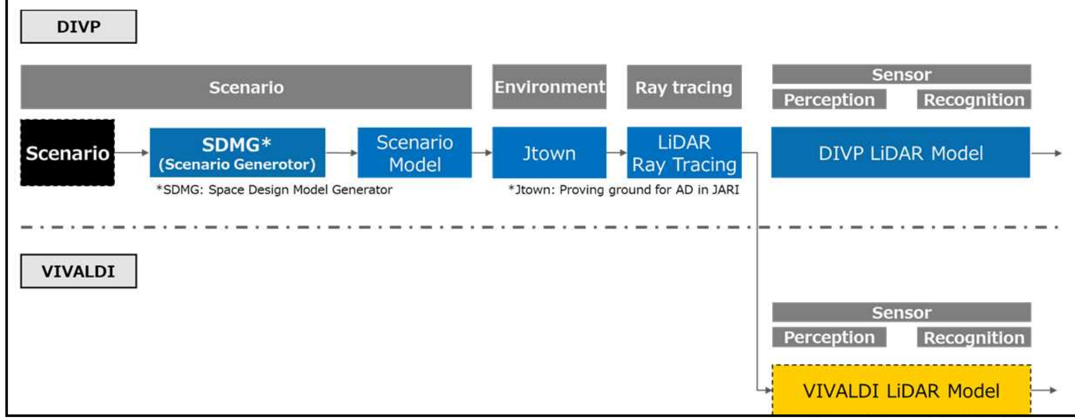


DIVP

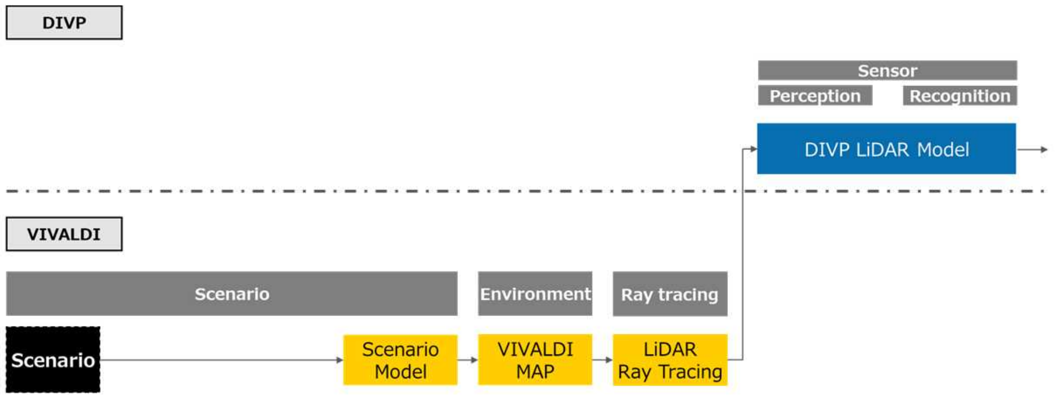
Extension of platform connectivity on the basis of OSI through international collaboration project VIVID with Germany VIVALDI

JTTT3.2 Scope

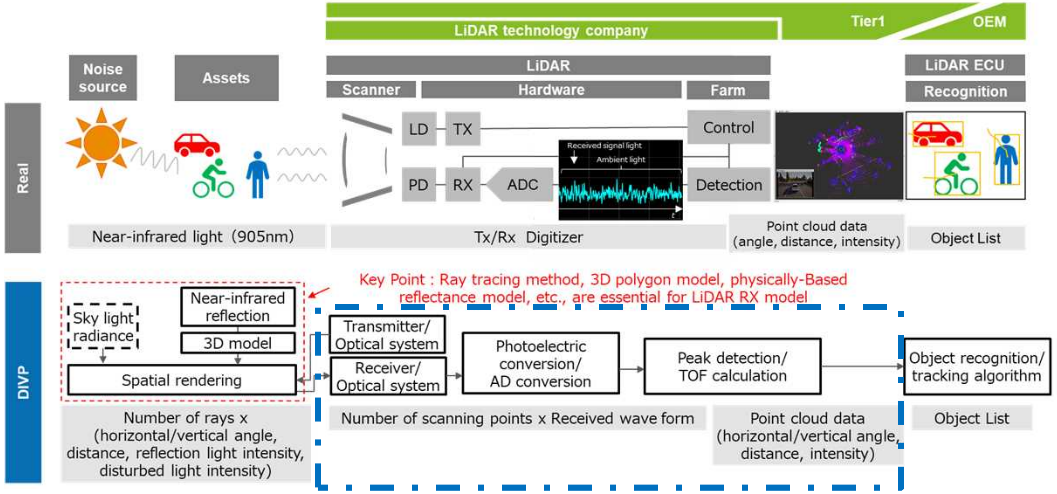
① Input DIVP® space design output data into VIVALDI LiDAR model



② Input DIVP®space design output data into VIVALDI LiDAR model



Exchange models and joint validation



- Policy to standardize the output of space design and propose it to OSI
- In FY 2022, we will discuss the latter stage of the perceptual output IF and the perceptual output IF by the exchange of the LiDAR model.

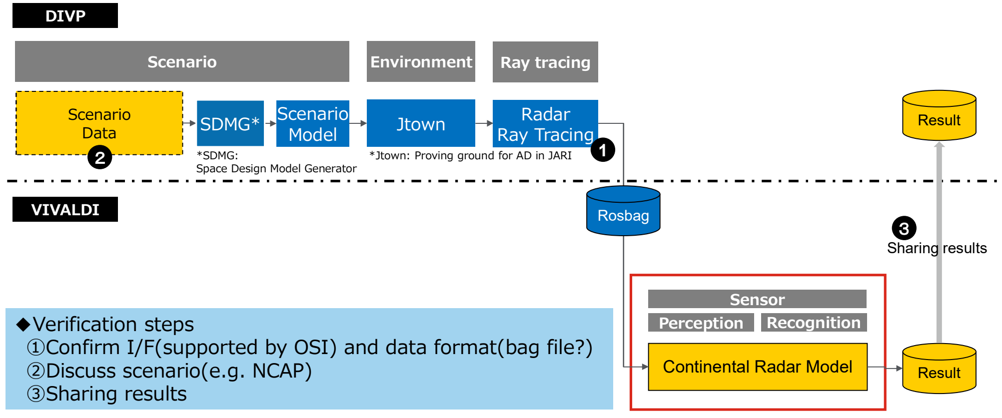
Source : Kanagawa Institute of Technology, PIONEER SMART SENSING INNOVATIONS CORPORATION, PIONEER CORPORATION

Evaluate validity of I/F through exchange of Radar ray tracing data, and propose to OSI as standardized I/F

JTTT3.3 Scope

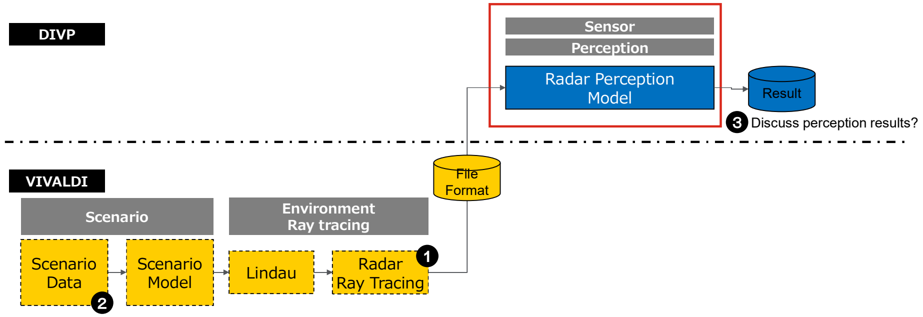
神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY / SOKEN / 豊田工業大学 TOYOTA TECHNOLOGICAL INSTITUTE / TTDC

① Input DIVP® radar ray tracing data into Continental radar model.



◆Verification steps
①Confirm I/F(supported by OSI) and data format(bag file?)
②Discuss scenario(e.g. NCAP)
③Sharing results

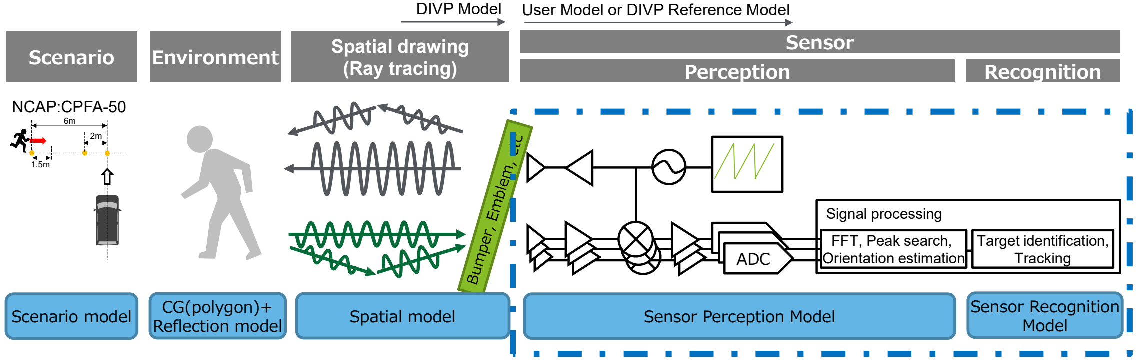
② Input Continental radar ray tracing data into DIVP® radar model.



◆Verification steps
①Confirm I/F(supported by OSI) and data format
②Discuss scenario(e.g. NCAP)
③(Discuss radar perception results)

Exchange models and joint validation

Share & align I/Fs for joint proposal to OSI



- Standardization and validation of Environment Ray tracing I/Fs
- Expected outcome :OSI proposal

DIVP

International Collaboration/Standardization

- International standardization via ASAM(GER)
- Acceleration of JPN-GER collaboration project VIVID
  - JTTT1
  - JTTT2
  - JTTT3.1~3.3
  - JTTT3.4
  - JTTT5
  - JTTT6

[JTTT3.4 V&V testing framework] Aim for joint proposal on metrics and toolchains through discussion on measurement methodology from modeling to consistency verification and HiLS/ViLS validation methodology

神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

Joint study topics

① Measurement methodology from modeling to consistency verification

Modeling
- 3D model shape
- Light, millimeter wave reflection
- Sensor noise
- RCS

Consistency verification
- Static test in lab-condition
- Static & Dynamic test in Proving Ground
- Sensing weakness condition verification on Community Ground(Odaiba, Tokyo-C1)

② HiLS validation methodology

Validation methodology
- Each sensor models'
- Multiple Camera
- Injection & OTA technology research

Topic	FY2021/2022	
	① Modeling	① Consistency verification
	② Validation methodization	② Injection / OTA

	Test environments	Sensors: Camera	Radar	LiDAR
①	SiLS	○	○	○
②	HiLS	With Injection △	×	×
②	HiLS (ViLS)	With Screen △	×	×
②	Car driving test (NCAP)	△	△	△

Source : Kanagawa Institute of Technology

DIVP

International collaboration and Global standardization

- International standardization via ASAM(GER)
- Acceleration of JPN-GER collaboration project VIVID
  - JTTT1
  - JTTT2
  - JTTT3.1~3.3
  - JTTT3.4
  - JTTT5
  - JTTT6

DIVP

Summary and proposals

SOLIZE

Proposals

Share parameters are to be set in each environmental model

[Parameters in typical traffic scenario]

- Driving behavior of ego vehicle
- Driving behavior of other vehicles
- Pedestrian path, speed
- Road path
- Traffic signals, lane marks, road markings
- Road geometry(slope/ cant)

[Candidate Parameters in sensor weakness scenario]

- The attitude of traffic participants
- Control behavior of the ego vehicle components
  - ✓ Wiper
  - ✓ Sensor mounting position, attitude
  - ✓ Behavior of sensors
- Reflective Properties of traffic participants
- Reflective Properties of road surface
- Reflective properties of surrounding structures
- Detailed weather, atmosphere conditions

Goals (under consideration [*1])

- Standardize relevant physical parameter and extend DIVP®'s virtual environment
  - ✓ Exchange parameter with VIVALDI, aiming to globally standardize DIVP®'s environmental parameter structure
  - ✓ Exchange sensor weakness scenario with VIVALDI, gain more information on user interface, and remaster scenario interface to satisfy global user demands

Steps

- The next step towards harmonization would be to understand the similarities and discrepancies between GER/JPN:
  - ✓ Exchange list of relevant-cum-open parameters of models, containing names/ types and without value
  - ✓ Investigate if the exchanged parameters can be directly used in each side's model
  - ✓ Conduct comparative study of the used parameters

*1: Goals yet to be confirmed

DIVP

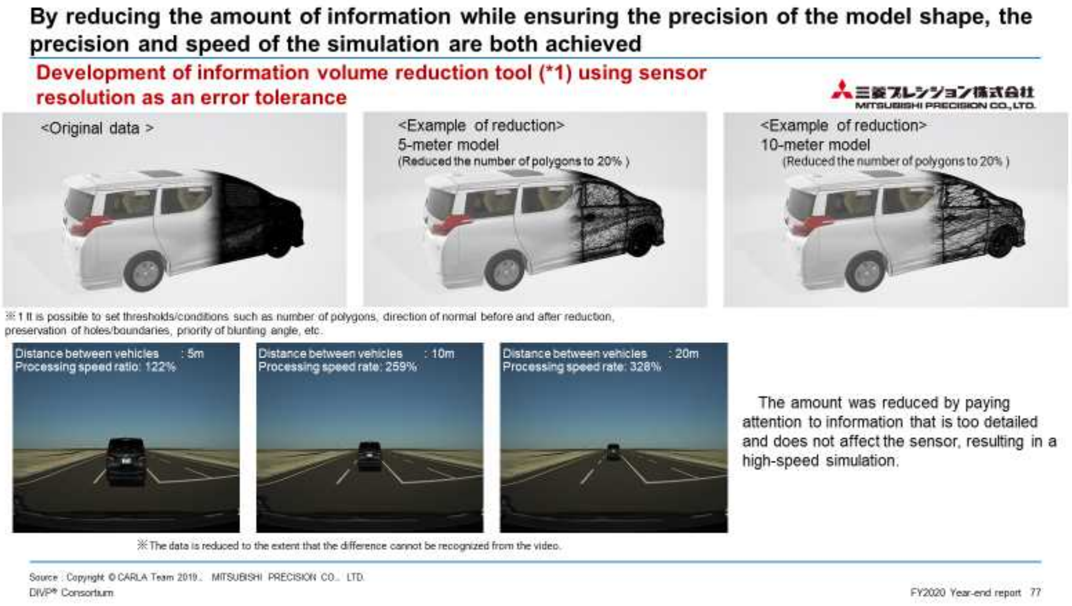
Traffic participant models and 3d map models have accurate 3D shapes and reflective properties obtained by measuring the actual objects

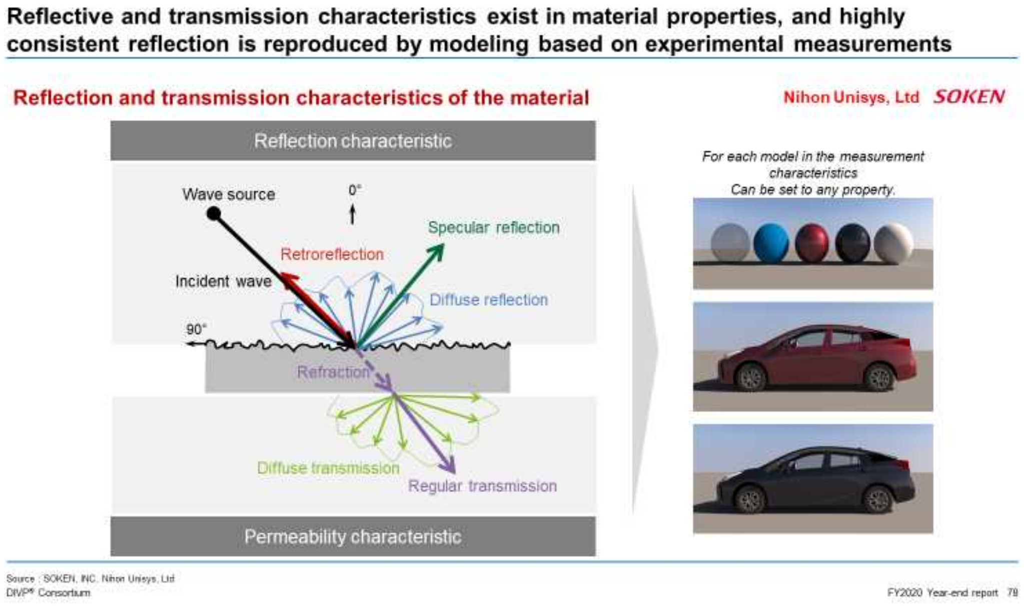
【Cf】3D shapes and reflective properties in DIVP® models

SOLIZE

Accurate 3d shape：
Compared to typical CG models, DIVP® 3d models has much accurate shape in order to minimize the angular errors of ray tracing

Reflective properties：
BRDF of each surface material type has been measured with the actual object sample
Additional conversion of surface conditions (e.g. wet surface) and extrapolation are also performed as needed





DIVP

DIVP® project scenarios were selected based on the criteria of whether scenario proves to be "simulatable" and "high impact to safety assurance"

【Cf】Scenario selection in DIVP® project

SOLIZE

DIVP® "sensor weakness scenarios" are selected for proving that DIVP® platform is "able to perform verification related to the sensor output under the autonomous driving situations"

Remark: In Japan, as a comprehensive safety assurance framework, "Automated Driving Safety Evaluation Framework" has been discussed and published by JAMA. In VIVID framework, it would be discussed in JTTT6.

The scenario selection criteria is based on the expert knowledge on the following:

"Simulatable"

Is the real phenomena modeled by DIVP® simulation which is mainly implemented with ray-tracing?

Does the verification with the simulation have more advantages than actual vehicle verification?

"High impact to safety assurance"

First, some prior phenomena were selected based on the expert knowledge of the sensor maker experts.

After that, some scenarios in which the selected phenomena are supposed to be occurred were chosen.

(It means "the sensor weakness scenarios" are not necessarily critical scenarios in the traffic situations.)

Example sensor weakness scenarios in DIVP®:

Sensor	Phenomena	Scenario
LiDAR	• Blackspot caused by the objects with low near-infrared reflectance, such as black leather jacket	CPNA like scenario with a pedestrian who wears a black leather jacket
Radar	• Multipath caused by the wall, such as tunnel wall • Difficulty in identification of the objects with the same speed	Driving in a tunnel Driving behind two vehicles in parallel at the same speed
Camera	• Halation due to the backlighting • Blurred lane marks (while lines)	Driving west in the evening Driving on the road with blurred lane marks
Other environment	• Rain • Snow	Driving in the rain Driving in the snow

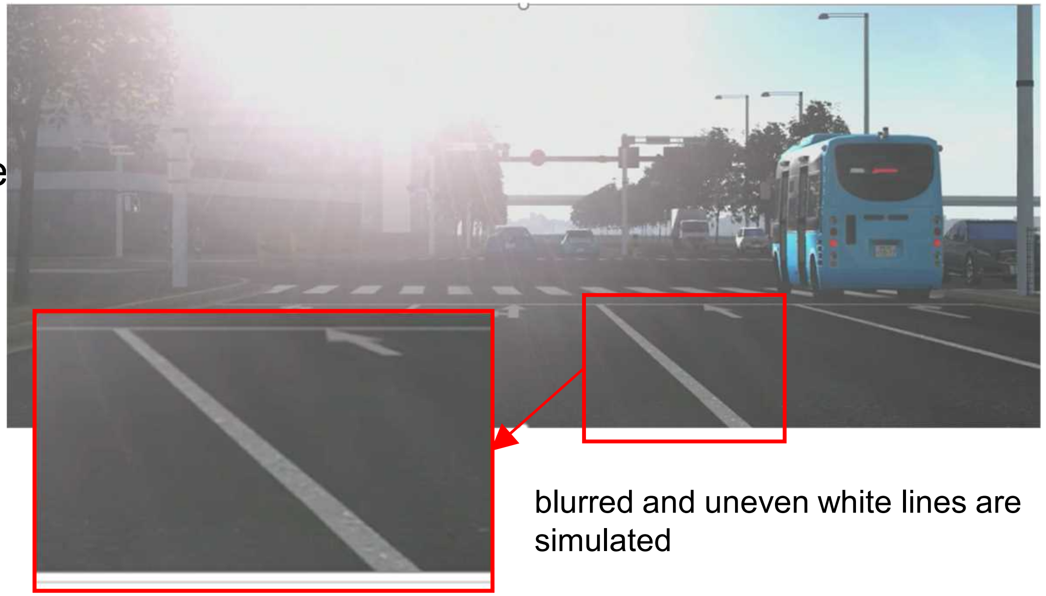
DIVP

In current DIVP® scenarios, we choose environmental parameters and 3D models with detailed properties. Other environmental parameters are only in module settings

【Cf】DIVP® scenario parameters

SOLIZE

- Environmental and physical phenomenon related parameters which can be set in scenario
  - ✓ Date, traffic participants models, 3D map models (with latitude/longitude),weather(sunny/cloudy/rainy/snowy), precipitations
    - Sun altitude / azimuth
      - ➢ DIVP® environmental module calculate position of the sun based on the date parameters and latitude/longitude parameters of selected 3D map model
    - Traffic participant models with accurate 3D shape and reflective properties
      - ➢ Select ego vehicle model because its shapes and its properties affect phenomena
    - 3D map models with accurate 3D shape and reflective properties of all structures of the town including roads, traffic signals, blurred lane marks, buildings…
    - Ego vehicle / sensors settings
      - ➢ type/model/number of sensors, front/brake lamp lighting



blurred and uneven white lines are simulated

DIVP

International collaboration and Global standardization

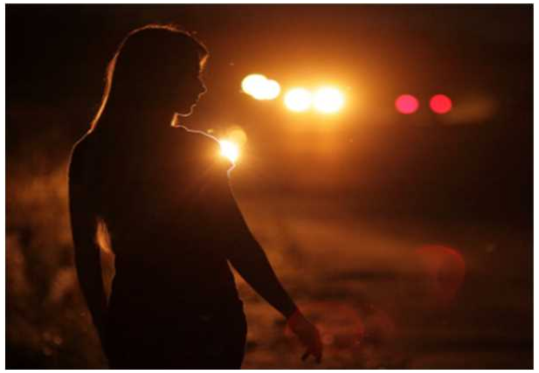
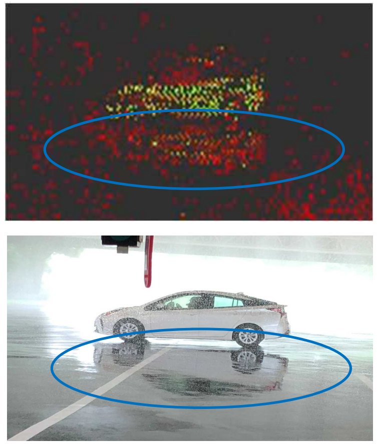
- International standardization via ASAM(GER)
- Acceleration of JPN-GER collaboration project VIVID
  - JTTT1
  - JTTT2
  - JTTT3.1~3.3
  - JTTT3.4
  - JTTT5
  - JTTT6

DIVP

Sensing weakness scenario validates 4-state of perception

Perception cases

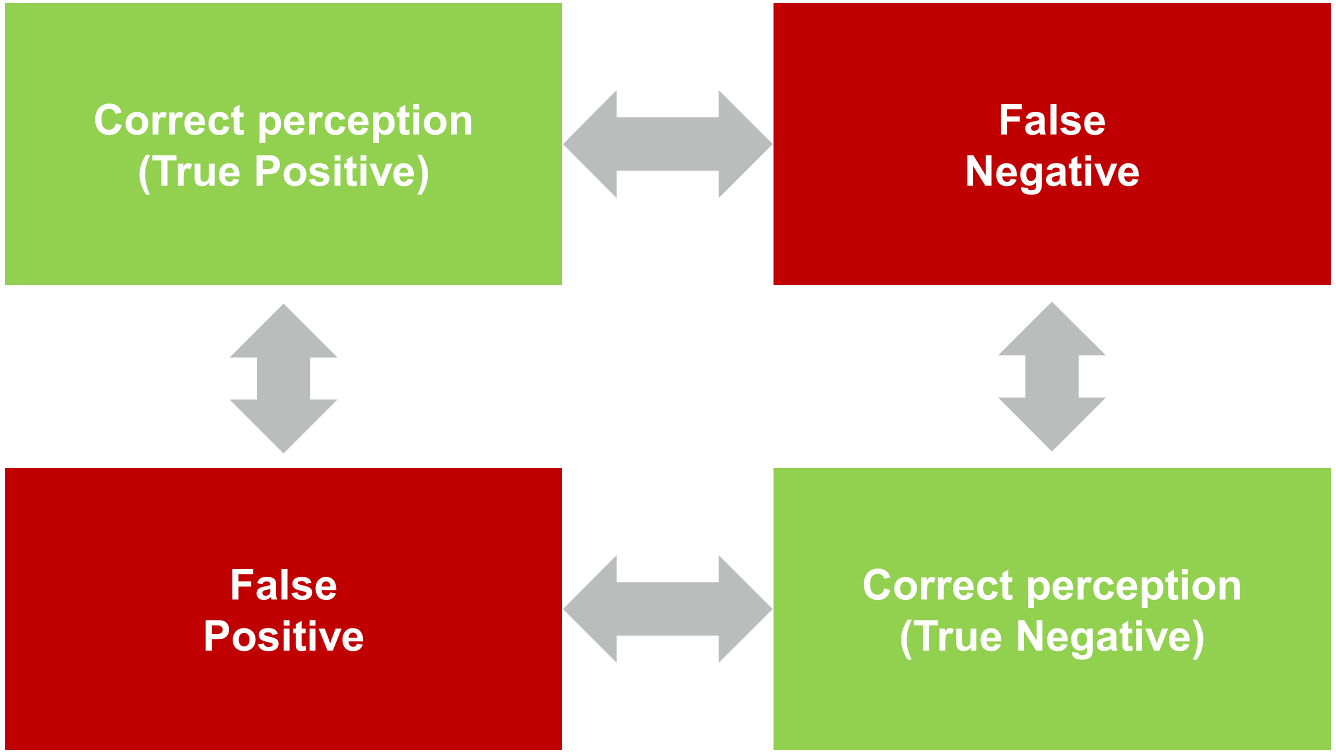
Target		Sensor perception: Exist	Sensor perception: Not
	Exist	Correct perception (True / Positive)	False Negative
	Non exist	False Positive	Correct perception (True Negative)

Camera	Radar	LiDAR
Object not visible due to darkness & backlight	Multiple objects are not able to be segmented & percept as one object	Not able t percept due to wearing black leather.
		
Flare or ghost could be percept as objects	Reflection of the gradient path leads to false perception of non-existent objects	False perception due by miller reflection
		

Source : MITSUBISHI PRECISION CO.、LTD.、 SOKEN,INC, Pioneer Smart Sensing Innovations Corporation

During the scenario transition, perception state will be fluctuating in time being

Perception state variance with “specific” sensor performance

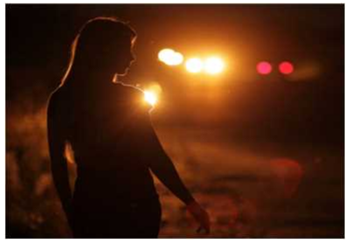


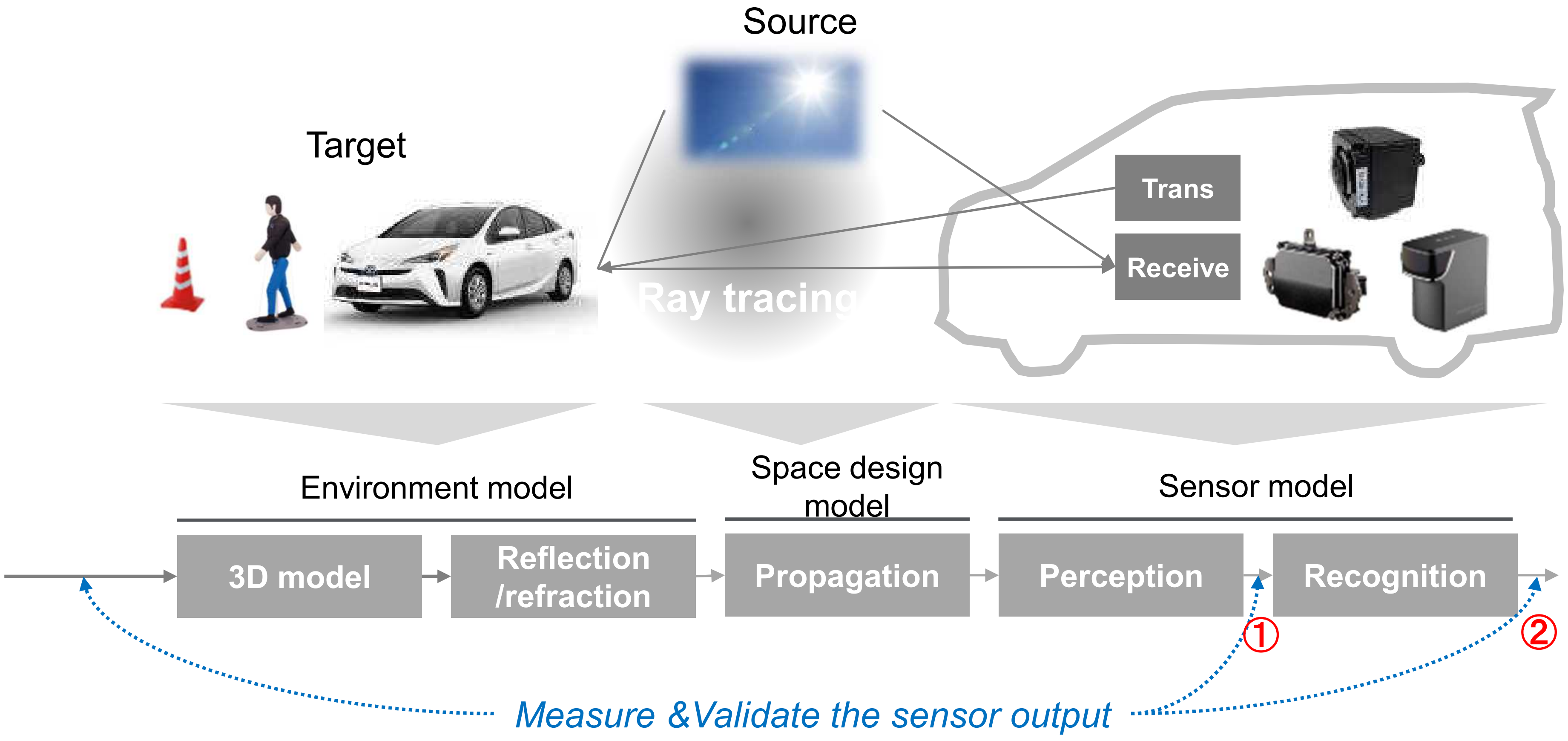
“Correct perception” , “False positive” , “False negative”
3-state is needed to validate & define the sensing perception status

For the perception validation, sensor output "Measure-ability" is the mandatory threshold

Validation procedure

Sensing weakness scenario



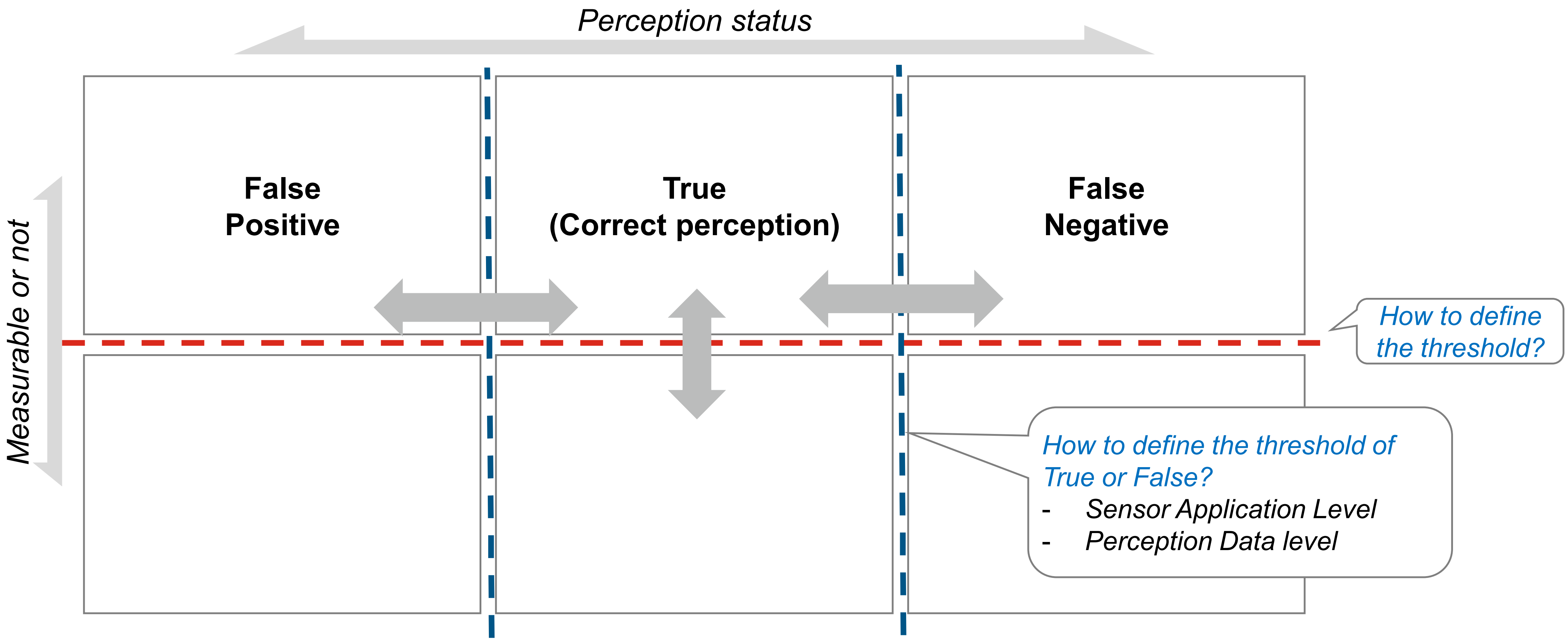


Measurable or not is also the key feature for sensing limit definition

Source : DENSO, INC, HitachiAutomotiveSystems, INC, PIONEER SMART SENSING INNOVATIONS CORPORATION

DIVP® would like to propose Scenario portfolio for sensing performance validation

Scenario portfolio



SIP Coastal Area Demonstration Test and External Collaboration

The plan is to implement the Tokyo Waterfront Area FOT, a DIVP® Evaluation Program, in two stages, STEP 1 (Simulation based upon Portal Site Scenarios) from November 2, 2021 and STEP 2 (Simulation based upon Participants' Scenarios) from the middle of January 2022

Provided Environments

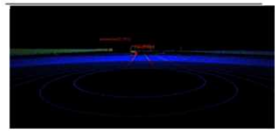
- ■ **We provided virtual environments for evaluation at J-Town and the Tokyo Waterfront Area as well as evaluation patterns**
  - ➢ **Scenario patterns: Simulate evaluation scenarios based upon actual measurements data**
  - ➢ **Sensor failures: Digitally reproduce sensor weaknesses that surface depending upon combinations of environmental factors**

J-town/Eur-NCAP Test Protocols

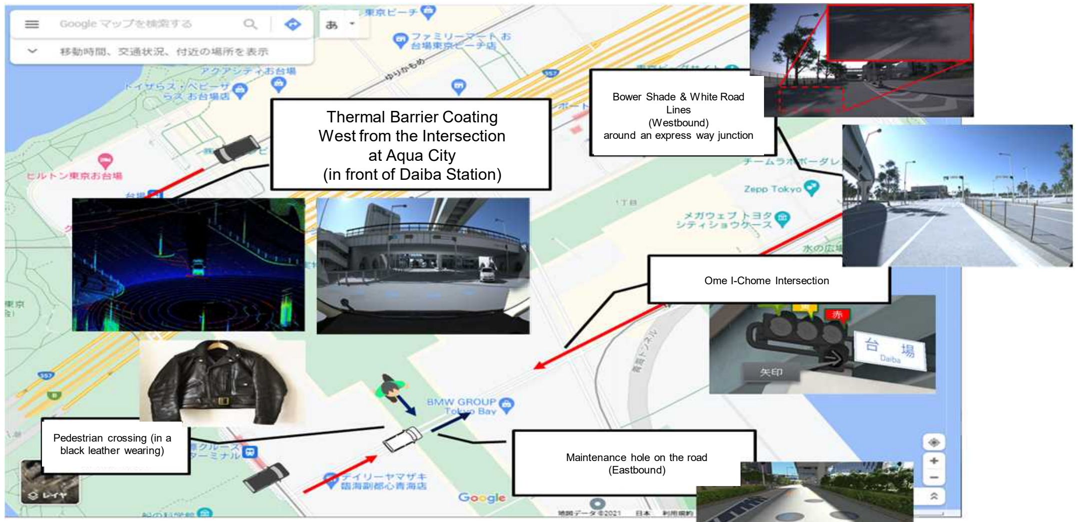
AEB Pedestrian crossing

Camera output

LiDAR output



Scenes at the Odaiba Environment where Sensor Weaknesses are Exposed



Summaries and Schedules

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Contents Experienced by Participants

■ **STEP1【 Simulation based upon Portal Site Scenarios 】** :
Nov 2, 2021 to End of Jan 2022
Access to the dedicated Portal Site
Appreciate usability of tools and simulation results

■ **STEP2【 Simulation based upon Participants' Scenarios 】** :
Middle of Jan 2022 to Middle of Apr 2022
Validate through own environments connected to DIVP®

Scheduled Participants

The participants listed below at home and abroad engaged in AD R&D

- ■ Automobile OEMs and suppliers
- ■ Vendors of related systems and tools
- ■ Juristic persons such as universities
- ■ Research institutes, certification authorities, etc.

Time Schedule

8/4 — Recruitment begins
'21/1
'21/Apr :Business launch (planned)

STEP 1 (Simulation based upon Portal Site Scenarios)
(November 02 '21— End of January '22)

(Preparations)
(November '21 – January '22)

STEP2 (Simulation based upon Participants' Scenarios)
(Mid-January.'22 – April '22)

Source : 「About Application for Participating in the Tokyo Waterfront City Area Field Operational Test (through simulation) for Strategic Innovation Promotion Program (SIP) Phase Two - Automated Driving (Expansion of Systems and Services) (Building a safety evaluation environment in Virtual Space)」 (NEDO HP, August 4th 2021)

**We provided protypes based upon R&D and panelist testers evaluations.
Also, we enabled broad acknowledgement for DIVP® through STEP 1 [Simulation based upon Portal Site Scenarios], and promoted the solution implementation at pilot users through STEP 2 [Simulation based upon Participants' Scenarios]**

Position of the Tokyo Waterfront Area FOT

■ Tokyo Waterfront City Area Field Operational Test

Nihon Unisys, Ltd

Waterfront City Area Field Operational Test

Panelist Tester Evaluation → Step1 → Step2

Simulation based upon Participants' Scenarios（STEP2）
（Mid-January 2022 – End of April '22）

- *Verify the value of DIVP®*
- *Implementation at pilot users for trial use*

Simulation based upon Portal Site Scenarios（STEP1）
（November 3, 2021- End of February, 2022）

- *Entice customers more by calling attention to deliverables broadly*
- *Polish products as a result of grasping various types of needs*

Grasp Needs in the early stage

- *Grasp customers needs based upon using research deliverables on a trial basis*

Participant Companies （Result）

■ STEP1：Simulation experience through a dedicated portal site
- ➢ DIVP® simulation videos : NCAP, Odaiba
- ➢ Briefings about faithfulness (real-actual verification) results
- ➢ Experiencing the Viewer function for creating scenarios

Applicants：81 entries, 56 companies

The participants listed below at home and abroad engaged in AD R&D
- ■ Automobile OEMs and suppliers
- ■ Vendors of related systems and tools
- ■ Juristic persons such as universities
- ■ Research institutes, certification authorities, etc.

■ STEP2：Implement safety evaluations about actual sensor systems through cooperative efforts mainly by OEMs, sensor makers and tool vendors

Applicants：8 companies

- ■ Evaluations are being made by cooperating with several automotive business operators as panelist testers

We implemented FOT in accordance with the time schedule below
STEP 2 [Simulation based upon Participants ' Scenarios] will continue to the end of April 2022. It will be followed by a phase of evaluation by pilot users.

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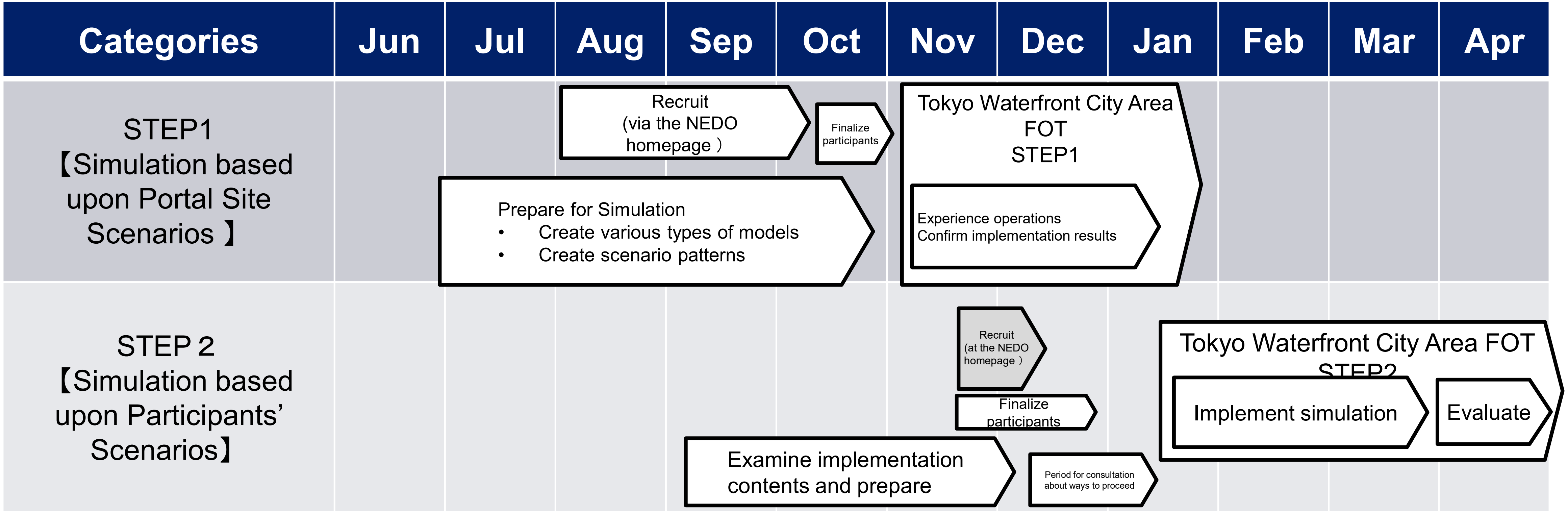
Schedule (Draft) for the Tokyo Waterfront Area Field Operational Test



SIP Coastal Area Demonstration Test and External Collaboration

■STEP1 outcome

■STEP2 status of implementation

■Analysis Results Discussions and Future Direction

Address for the contents of
FOT STEP1【Simulation based upon Portal Site Scenarios】
https://demo.monitor-divp.net/
ID: User01 Pass:User01@AWS

In STEP 1[Simulation based upon Portal Site Scenarios], we enabled verifications through a combined use of packaged scenarios and various environmental factors that could expose sensor weaknesses.
Efficient verifications for guaranteeing AD systems were implemented.

STEP1

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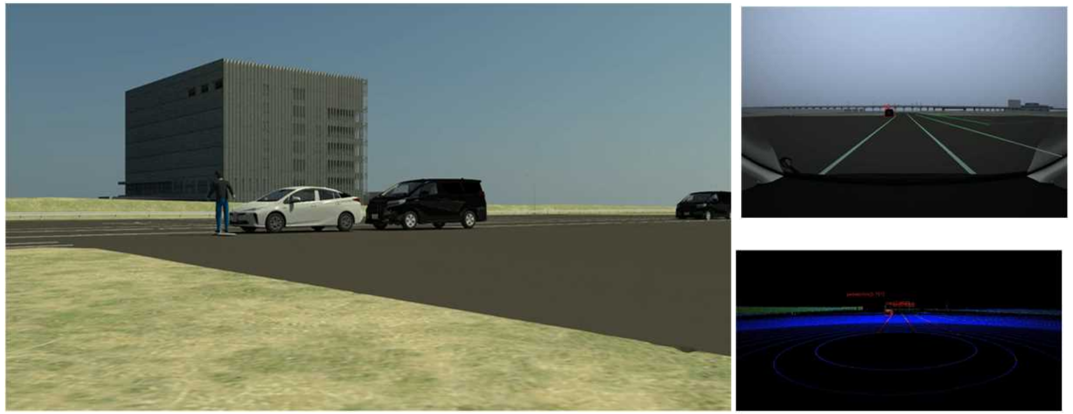
The Provided Simulation Environments：STEP1【Simulation based upon Portal Site Scenarios】

Packaged Scenarios

Eur-NCAP Test Protocols



Odaiba Environment

Various Scenes where Sensor Weaknesses may Be Surfaced

Objects that are difficult to be Detected

Targets at the same distance and at the same relative velocity

Black leather jacket

Black-color vehicle

Upward structures

Things of low reflection on the road

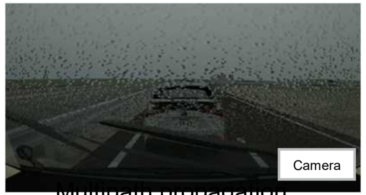
Things of high reflection on the road (maintenance hole)

Environments that may affect reflections and propagations

Backlight, background light

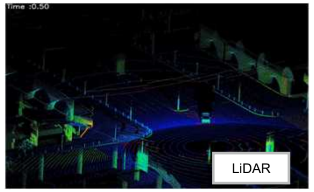
Reflections in the windshield

Rain

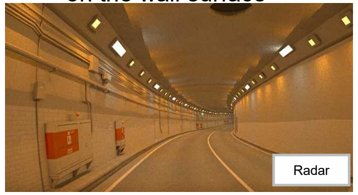


Blurry white lines

Thermal barrier-coated road surface



Multipath propagation on the wall surface



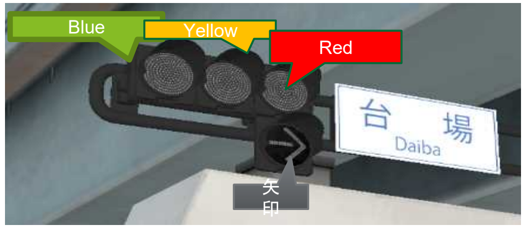
Source：「About Application for Participating in the Tokyo Waterfront City Area Field Operational Test (through simulation) for Strategic Innovation Promotion Program (SIP) Phase Two - Automated Driving (Expansion of Systems and Services) (Building a safety evaluation environment in Virtual Space)」（NEDO HP, August 4th 2021）

Scenes where sensor weaknesses are exposed were digitally reproduced and organized into a package for the Field Operational Test. The scene data was collected by actual vehicle journeys at/through Odaiba and the Inner Circular Route. The approx.20 scenario packages were subject to acceptability examination by users in the FOT of Tokyo Waterfront Area.

Scenario Example that Exposes Sensor Weaknesses (Basic Physical Model: Camera)

To Be Provided at FOT in the Tokyo Waterfront Area : approx. 20 patterns (including variations)

STEP1 **Nihon Unisys, Ltd**

Layers	Misrecognitions about white lines due to roadside tree shades	Reproductions of distributed lights through traffic lights	Low-floor/platform carriers that cannot be recognized
Sample			■ Misrecognitions about inter-vehicle distance due to backward viewpoints 
L1: Road Shapes	Neighborhood of Odaiba Ome Station（Westward） 	Odaiba Ome 1-Chome Intersection 	North Side of Tokyo International Exchange Center (TIEC), Odaiba 
L2: Targets, Traffic Rules	White lines, roadside trees	Traffic lights (red, blue, yellow, arrows), Pedestrian crosswalk signals	Straight road
L3: Temporary Changes	-	-	-
L4: Moving Objects	-	-	Low-floor/platform carrier travelling ahead of the own vehicle
L5: Environmental Conditions	Daytime	Daytime/Nighttime	-

Source : Kanagawa Institute of technology, Google map, AD-URBAN

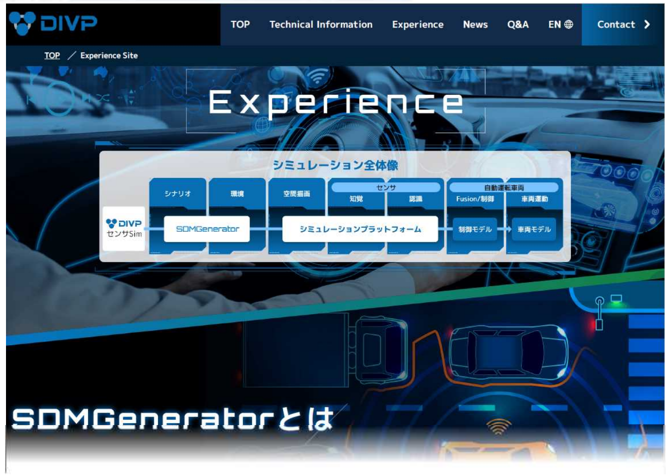
Through a dedicated portal site established for the FOT STEP1 [Simulation based upon Portal Site Scenarios], the DIVP® simulator demonstrated a significant fidelity in simulating actual measurements data of physical phenomena, as endorsed by faithfulness verifications. It was recognized broadly among participants.

Nihon Unisys, Ltd

Information Offered at the Dedicated Portal Site

URL : **ID : User01 Pass : User01@AWS**

(*) This is a portal site for the DIVP® information about the Field Operational Test in the Tokyo Waterfront Area. The section "Technical Information" contains plenty of videos.



The DIVP® solution's technical features that enable faithful simulation are the focus in the Portal Site descriptions with simulation result videos

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Structure for Providing Information at the Portal Site

URL：https://demo.monitor-divp.net/ID：User01 Pass：User01@AWS

Page Structure	Page Contents	Description Contents
Top	Concept	Streamline verifications about reliability and safety of autonomous driving
	Vision	DIVP® simulator's features • Exquisite simulations enabled through combining environmental models x spatial models x sensor models
	Aim for this FOT	Promote the appeal of the DIVP® simulator's usefulness for AD system development and evaluation as evidenced through the use of packaged scenarios (NCAP, Odaiba and Inner Circular Route C1)
Technical Information	Descriptions about fidelity	Describe various types of sensor models and fidelity evidences
	Materials and videos about simulation examples	• Scenario packages • Sensor failures witnessed in the Odaiba and Inner Circular Route C1 environments
	Under development	Failure patterns of sensors that are under development
	Development roadmap	Research plan for the period from FY2021 to FY 2022
Experience (simulations in obtainable environments)	SDMGenerator （Function to create scenarios)	• Functions descriptions • Videos for operation manuals
	Simulation platform	• Functions descriptions • Browser Viewer operation experiences

Information was offered at a dedicated portal site to 56 companies (or entries of 81 persons) .
We plan to keep the participants in the communication loop where they will continue to receive the DIVP® information.

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Companies that Applied for Portal Site Access

【Total】 56 companies（81entries）applied

- A webinar-style meeting was held on January 17, 2022.
- The plan is to keep the participants in the communication loop. They will continue to receive the DIVP® Information.

(Random order)

OEM (13 companies)

Toyota Motor Corporation
Matsuda
Mitsubishi
SUBARU
Yamaha Motor
Isuzu Motors
Mitsubishi Fuso Truck and Bus Corporation
Suzuki
Daihatsu
Honda Motor
Nissan
Woven Core

Automotive-related Companies (suppliers, etc.) (28 companies)

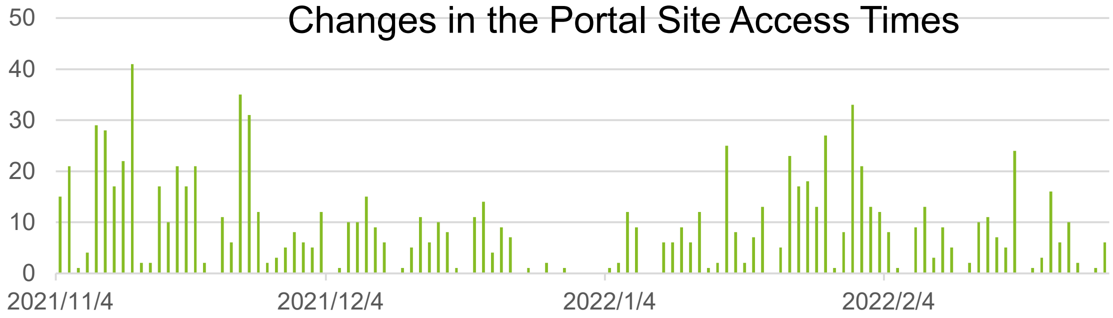
Tier IV
Kanazawa Univ.
Nagoya Univ.
Valeo Japan
Canon
Randstad
Toyota Systems
Nippon Koei
TOYOTA Body Seiko
Tsukuba Univ.
Denso
Aisin
Kyocera
Furukawa Electric
Furukawa AS
Sumitomo Electric Industries
Mitsubishi Heavy Industries Machinery Systems
TOYOTA INDUSTRIES IT SOLUTIONS
AVL Japan
Toyota Technical Development
Automobile Laboratory of Aioi Nissay Dowa Insurance
Sompo Japan
Pacific Consultants
AISAN TECHNOLOGY
J-QuAD DYNAMICS
Toyota Technological Institute
MathWorks Japan
Continental Automotive
Hitachi Astemo
Toyota Industries Corporation
NXP Japan

IT (3 companies)

IBM Japan
Shin-Norinsha
Serio

Related to DIVP®
(12 companies)

The portal site received 1,032 accesses during the period from November 4, 2021 to February 28, 2022. (or 18 times of access per company)



Information was sent via a Webinar-style seminar for the FOT STEP 1 [Simulation based upon Portal Site Scenarios].75 persons participated including parties concerned.

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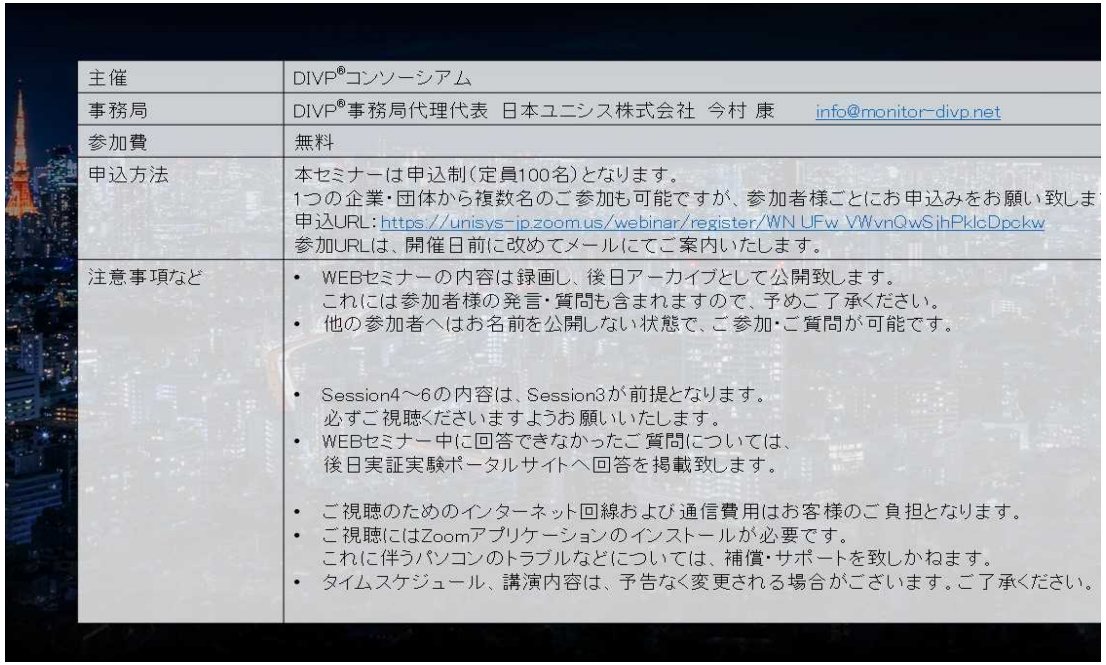
A webinar-style seminar was held on January 17, 2022

Participants75 in total

- OEM: 6 companies, 1 1 persons
- Car -related companies: 19 companies, 38 persons
- IT: 1 company, 1 person

Others

- 17 persons related to the sponsors
- 9 panelists
- 3 moderators/administrators



主催	DIVP®コンソーシアム
事務局	DIVP®事務局代理代表 日本ユニシス株式会社 今村 康 info@monitor-divp.net
参加費	無料
申込方法	本セミナーは申込制(定員100名)となります。 1つの企業・団体から複数名のご参加も可能ですが、参加者様ごとにお申込みをお願い致しま 申込URL：https://unisys-jp.zoom.us/webinar/register/WN UFw VWvnQwSjhPklcDpckw 参加URLは、開催日前に改めてメールにてご案内いたします。
注意事項など	• WEBセミナーの内容は録画し、後日アーカイブとして公開致します。 これには参加者様の発言・質問も含まれますので、予めご了承ください。 • 他の参加者へはお名前を公開しない状態で、ご参加・ご質問が可能です。 • Session4～6の内容は、Session3が前提となります。 必ずご視聴くださいますようお願いいたします。 • WEBセミナー中に回答できなかったご質問については、 後日実証実験ポータルサイトへ回答を掲載致します。 • ご視聴のためのインターネット回線および通信費用はお客様のご負担となります。 • ご視聴にはZoomアプリケーションのインストールが必要です。 これに伴うパソコンのトラブルなどについては、補償・サポートを致しかねます。 • タイムスケジュール、講演内容は、予告なく変更される場合がございます。ご了承ください。

The webinar-style meeting contained briefings by DIVP® participant companies' experts mainly on DIVP® simulator features, simulation scenario creation functions, environment models and fidelity of sensor

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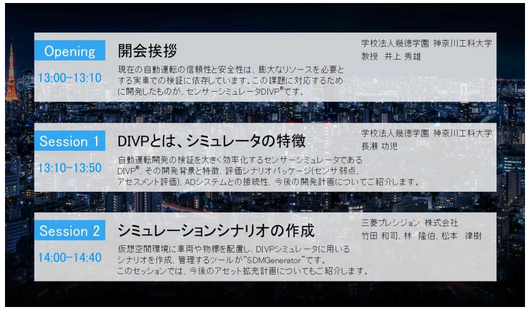
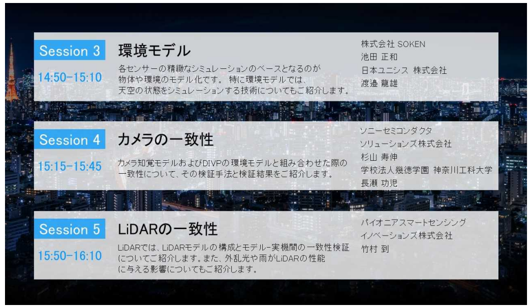
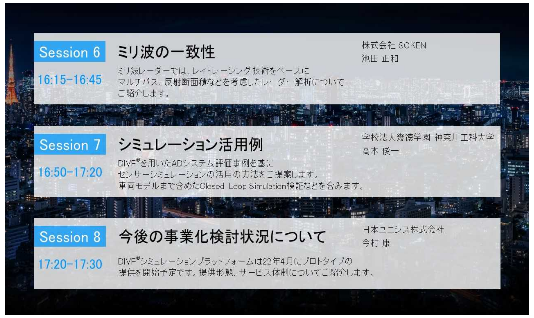
Implementation of the Webinar-style Seminar

Date & Time: Monday, January 17, 2022 13:00-17:30
Style: Zoom (Webinar)
Seminar Contents: Based upon the Field Operational Test Portal Site contents
Focused mainly upon OEMs after considering the FOP participant composition ratios

Session	Lecture Title	Speakers
Opening Session	Opening Remarks	Professor Inoue, KAIT
Session 1	What is DIVP®? DIVP® Simulator Features	Mr. Inomata, NUL Mr. Nagase, KAIT
Session 2	Create Simulation Scenarios	Mr. Takeda, Mr. Hayashi, Mr. Matsumoto, MPC
Session 3	Environment Models	Mr. Ikeda, SOKEN, Mr. Watanabe, NUL
Session 4	Camera Fidelity	Mr. Sugiyama, SSS, Mr. Nagase, KAIT
Session 5	LiDAR Fidelity	Mr. Takemura, PSSI (via video)
Session 6	Millimeter-wave Radar Fidelity	Mr. Ikeda, SOKEN
Session 7	Simulation Use Examples	Mr. Takagi, KAIT
Session 8	Situations of Future Commercialization Considerations	Mr. Imamura, NUL







Follow-ups after the Seminar
Friday, January 21: The video recording of the seminar was available.
Monday, January 31: The Q&A session contents were uploaded

33 participants in the Webinar-style seminar answered to a questionnaire.
80% or more respondents indicated that they are (very) satisfied with each of the Sessions. Thus, the seminar was conducive in efficiently complementing the information shared via the portal site.

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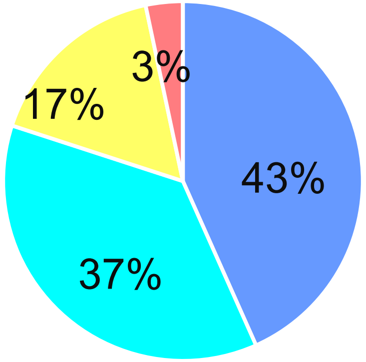
The Webinar-style Seminar Questionnaire Results

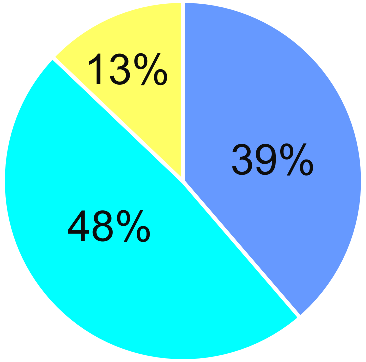
【Legend】
Common to the sessions

- Very satisfied
- Satisfied
- Neutral
- Dissatisfied
- Very dissatisfied

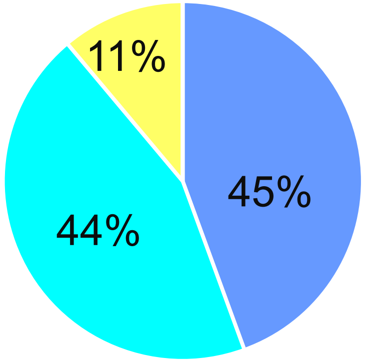
Session1
:What is DIVP®?
DIVP® Simulator Features



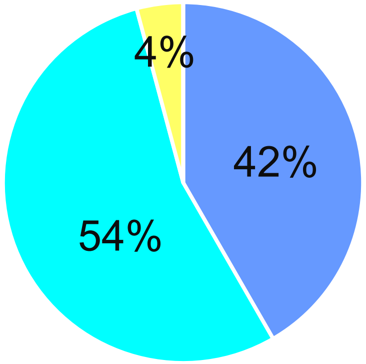
Session2
: Create Simulation Scenarios



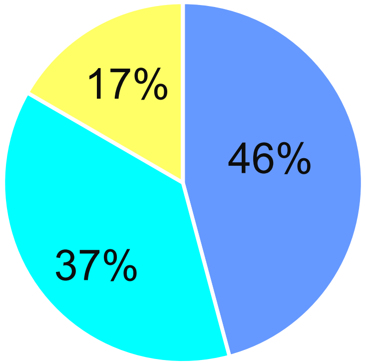
Session3
:Environment Models



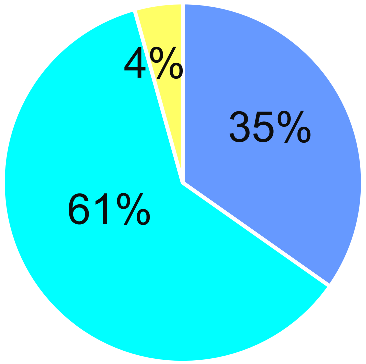
Session4
:Camera Fidelity



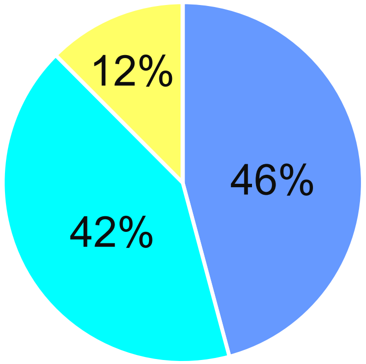
Session5
:LiDAR Fidelity



Session6
:Millimeter-wave Radar Fidelity



Session7
: Simulation Use Examples



44 participants (as of the end of February) answered to a questionnaire of the Tokyo Waterfront Area FOT STEP 1 [Simulation based upon Portal Site Scenarios]. The DIVP® simulator was appreciated more highly than other simulators mainly from the viewpoints of simulation reliability and asset adequacy.

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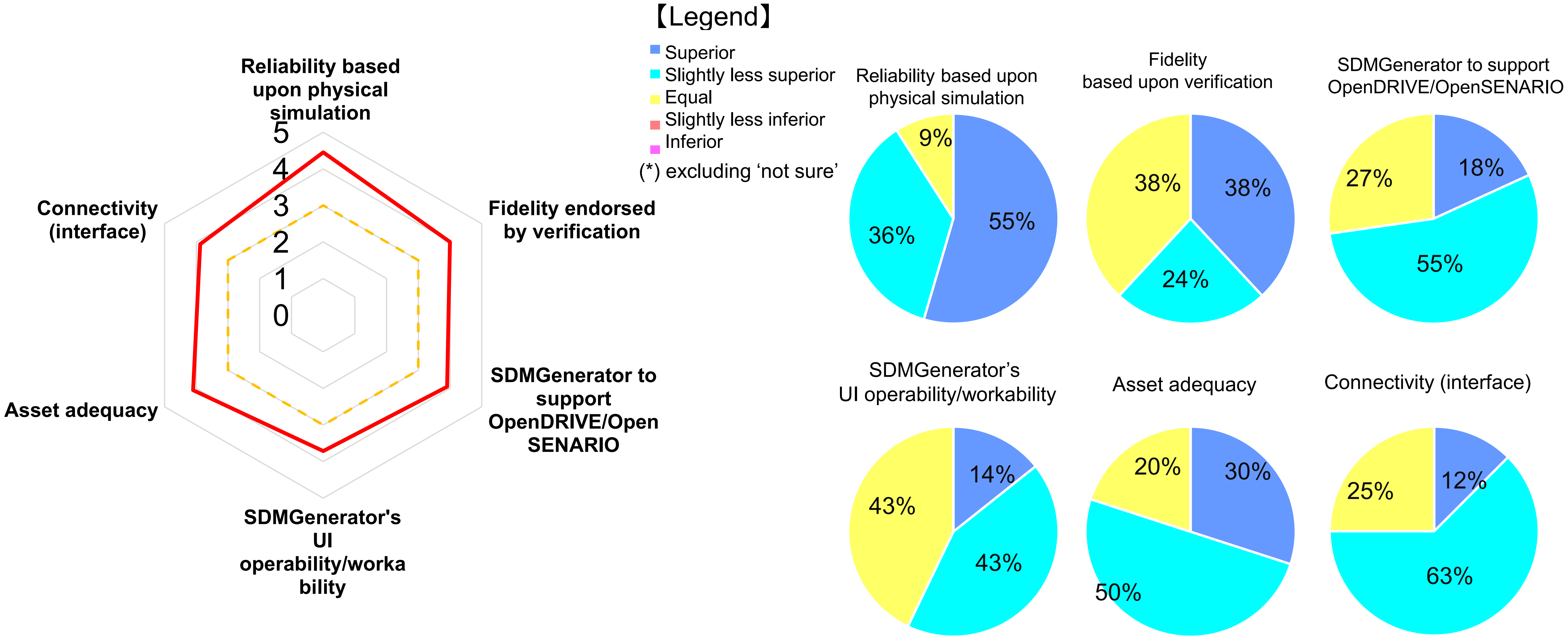
The FOT STEP1【Simulation based upon Portal Site Scenarios】Questionnaire Result



A questionnaire survey was conducted about the possibility of using the DIVP® simulator for services during the Tokyo Waterfront Area FOT STEP 1 [Simulation based upon Portal Site Scenarios]

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[FOT Questionnaire] Use the DIVP® Simulator for Services

Q: Please tick service items for which the DIVP® simulator can be used below. Include services other than those performed by the respondents. Multiple answers were allowed. 44 responded.

	Research	Business Plan	Vehicle Development/Design	Vehicle Sales	Vehicle Use
OEMs / Suppliers	•New sensor algorithm research •New sensor system considerations •Sensor /system evaluations	•RFQ preparation Sourcing evaluation	• Safety evaluation • Prediction of results of evaluation by external certifiers partly pursuant to NCAP • Adaptability of sensors and systems • Considerations of evaluation plans composed of various types of evaluation environments • Sensor/system requirements definition • Sensor/system evaluations	• Safety evaluation • Prediction of results of evaluation by external certifiers partly pursuant to NCAP	•Safety evaluation •Support for analyzing sensor failures in the market through the use of the DIVP® Simulator
Organizations for evaluation, research and certification	N/A	N/A	N/A	•Evaluate sensors. Prepare (automatically) scenarios to expose sensor weaknesses	N/A
Others (insurers, etc.)	N/A	• Sensor/system requirements definition	•Safety evaluation •Evaluate sensors. Prepare (automatically) scenarios to expose sensor weaknesses •Considerations about plans for evaluating the DIVP® Simulator on public roads • Adequacy of sensors and systems • Sensor/system requirements definition	N/A	•Safety evaluation, premium calculation •Evaluate sensors. Prepare (automatically) scenarios to expose sensor weaknesses

There are expectations that SDMGenerator can be more useful for 'vehicle development /design' than for 'research'. The expectations may reflect that simulation is prevalent in actual development practices. Also, it was confirmed that SDMG is at a level that it can be used with an eye toward practical use.

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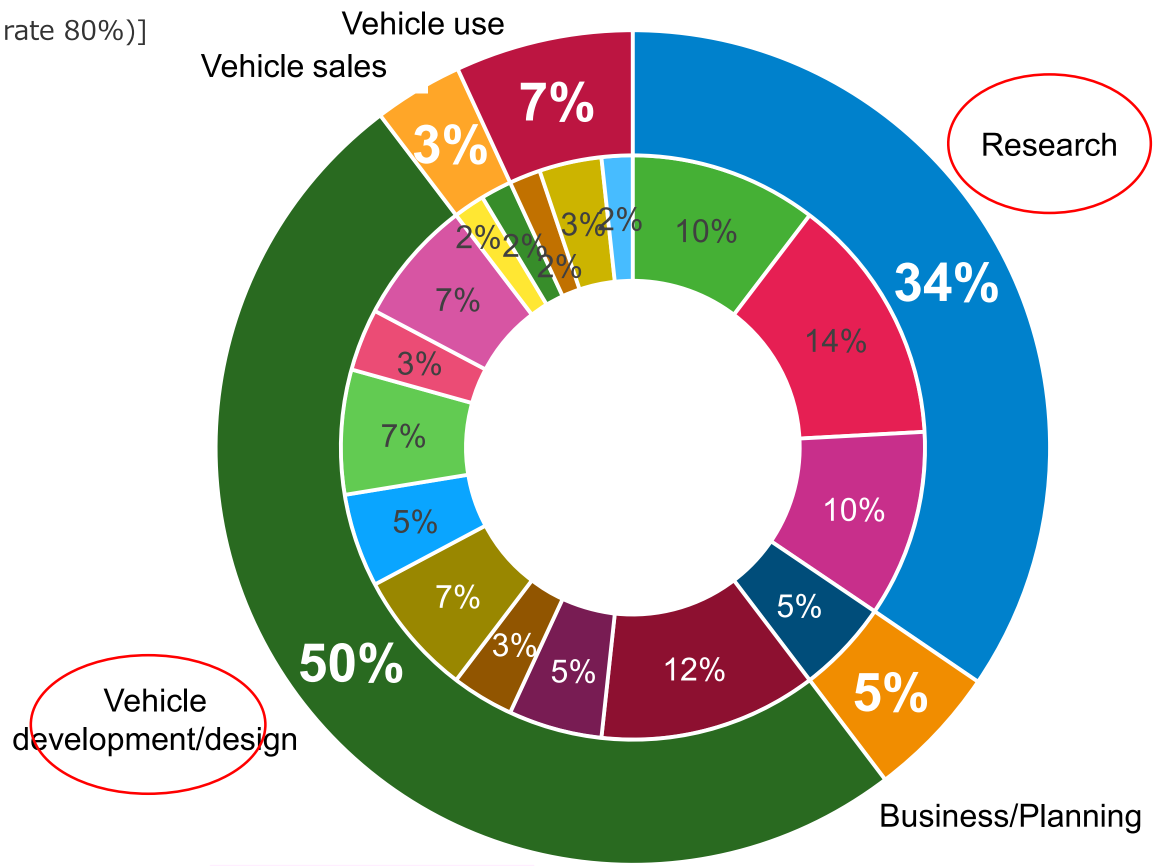
【FOT Questionnaire Survey】services for which SDMGenerator can be used

[Multiple answers were allowed. 44 respondents answered (out of 56 in total: response rate 80%)]

【Legend (for Inner Circle)】 Related to safety evaluation

Research	:	Sensors/systems evaluation
Research	:	New sensors/systems considerations
Research	:	New sensors/algorithm research
Business/Planning	:	RFQ preparation/sourcing evaluation
Business/Planning	:	Sensors/systems requirements definition
Vehicle Development/Design	:	Sensors/systems evaluation
Vehicle Development/Design	:	Sensors/systems requirements definition
Vehicle Development/Design	:	Considerations on evaluation plans through the use of combinations of various types of evaluation environments
Vehicle Development/Design	:	Sensors/systems adequacy
Vehicle Development/Design	:	Prediction of evaluation results by external certifiers partly pursuant to NCAP
Vehicle Development/Design	:	Safety evaluations
Vehicle Development/Design	:	Considerations on plans for evaluating the DIVP® Simulator on public roads
Vehicle Development/Design	:	Evaluate sensors. Prepare (automatically) scenarios to expose sensor weaknesses
Vehicle Sales	:	Prediction of evaluation results by external certifiers partly pursuant to NCAP
Vehicle Sales	:	Safety evaluations
Vehicle Sales	:	Evaluate sensors. Prepare (automatically) scenarios to expose sensor weaknesses
Vehicle Use	:	Support for analyzing sensor failures in the market through the use of the DIVP® Simulator
Vehicle Use	:	Safety evaluations
Vehicle Use	:	Evaluate sensors. Prepare (automatically) scenarios to expose sensor weaknesses
Vehicle Use		Safety evaluations, premium calculations



On the other hand, we received less expectations about using the DIVP® solution for 'safety evaluation' or specifically a related item of 'Evaluate sensors. Prepare (automatically) scenarios to expose sensor weaknesses' than we had expected. Safety evaluation is the key for promoting the social acceptability of autonomous driving, and it is the crucial aim of DIVP®. (This result may be due to respondents representing a wide variety of industries including non-life insurance and IT.)

DIVP

Expectations about Simulation PF are almost of the same degree for 'Research' and 'Vehicle Development/Design'. Simulation PF is appreciated specifically: it would be useful for 'new systems/algorithm research' in the 'Research' field, and for a series of processes from evaluation to adaptation in the field of 'Vehicle Development/Design' field.

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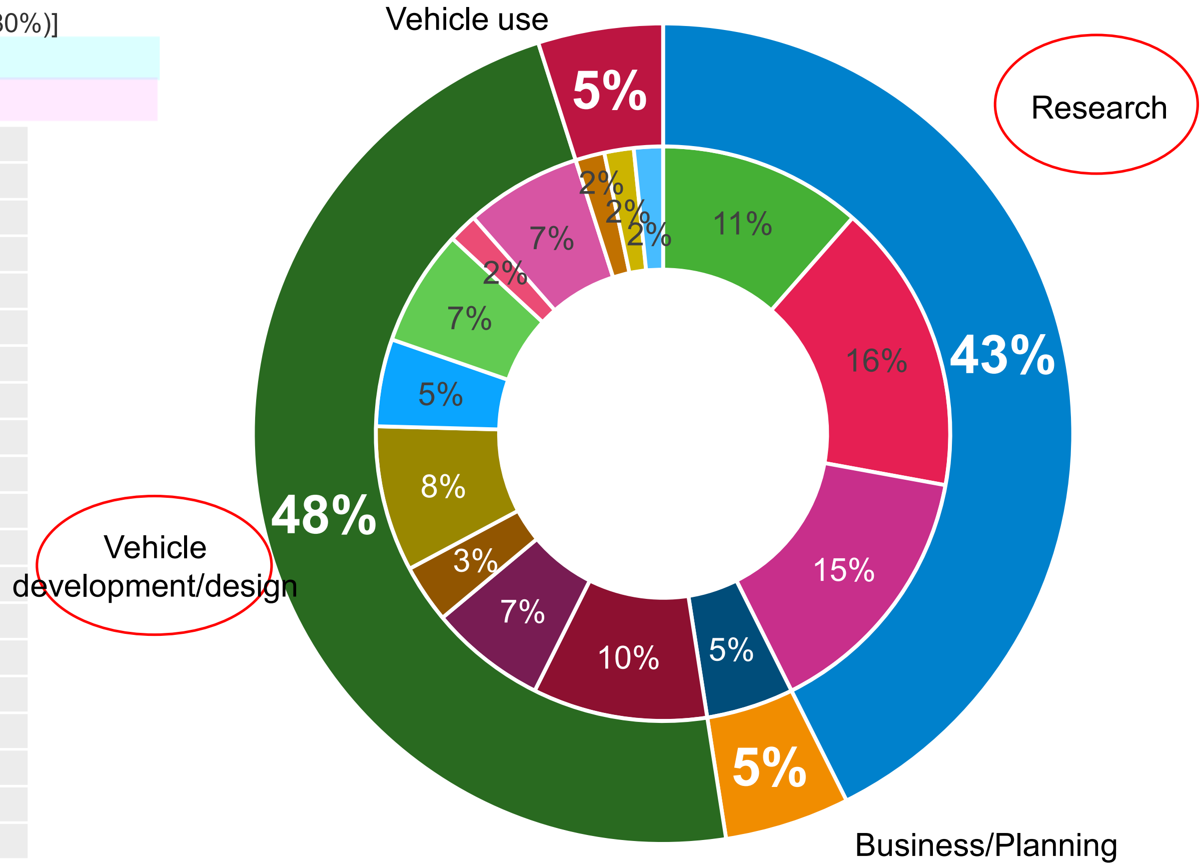
【FOT Questionnaire Survey】 services for which Simulation PF can be used

[Multiple answers were allowed. 44 respondents answered (out of 56 in total: response rate 80%)]

【Legends (for Inner Circle)】

Related to the use of Simulation PF
Related to safety evaluation

Research	:	Sensors/systems evaluation
Research	:	New sensors/systems considerations
Research	:	New sensors/algorithm research
Business/Planning	:	RFQ preparation/sourcing evaluation
Business/Planning	:	Sensors/systems requirements definition
Vehicle Development/Design	:	Sensors/systems evaluation
Vehicle Development/Design	:	Sensors/systems requirements definition
Vehicle Development/Design	:	Considerations on evaluation plans through the use of combinations of various types of evaluation environments
Vehicle Development/Design	:	Sensors/systems adequacy
Vehicle Development/Design	:	Prediction of evaluation results by external certifiers partly pursuant to NCAP
Vehicle Development/Design	:	Safety evaluations
Vehicle Development/Design	:	Considerations on plans for evaluating the DIVP® Simulator on public roads
Vehicle Development/Design	:	Evaluate sensors. Prepare (automatically) scenarios to expose sensor weaknesses
Vehicle Sales	:	Prediction of evaluation results by external certifiers partly pursuant to NCAP
Vehicle Sales	:	Safety evaluations
Vehicle Sales	:	Evaluate sensors. Prepare (automatically) scenarios to expose sensor weaknesses
Vehicle Use	:	Support for analyzing sensor failures in the market through the use of the DIVP® Simulator
Vehicle Use	:	Safety evaluations
Vehicle Use	:	Evaluate sensors. Prepare (automatically) scenarios to expose sensor weaknesses
Vehicle Use	:	Safety evaluations, premium calculations



Simulation PF received the same expectation tendencies as SDMG in light of 'Evaluate sensors. Prepare (automatically) scenarios to expose sensor weaknesses' and 'safety evaluation'. (This result may be due to respondents representing a wide variety of industries including non-life insurance and IT.) It is necessary to fulfill highly-rated physical simulation functions of Simulation PF about scenarios to expose sensor weaknesses. Also, a tool chain composed of the solution and SDMG needs to be pitched as the last recourse for safety evaluation.

We received the free voices below as a result of the survey. Respondents gave us specific opinions saying that they look forward to certifying via simulation, referring to other simulators that they are interested in connecting with, and talking about a vision of how to use the DIVP® solution for their companies.

[FOT Questionnaire]

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Opinions freely voiced such as those about the FOT management

Q. Freely express opinions and requests if you have.

- Needless to say, model accuracy is indispensable for a simulation product. Pursuant to our past experiences, we feel that it is crucial for a simulation product to define how it is used. **If the DIVP® Simulator can be used for certification as well as development and evaluation, it will be conducive to accelerating the social advance of AD. Thus, we would like to see furthermore development of the DIVP® Simulator as a standard tool.**
- We would appreciate a **place for consulting** on test scenarios and maps that can be prepared, as well as time and costs for the preparation.
- At this point in time, we hardly witness vehicles referred to as autonomous driving (AD) cars. In the future we will see some. Then, we would appreciate it if we can **simulate for each type of AD cars**.
- We would appreciate a connection with IPG CarMaker in light of vehicle model, and Simulink in light of control model
- Please provide at a low price
- We would appreciate it if the mechanism can be considered to be **upward compatible for CARLA** mainly in light of connectivity, sensor models, and API.
- We would appreciate it if we have **roadside trees assets (including millimeter wave radar features) and spatial drawing functions** that would help us study roadway infrastructural radars.
- We feel that this simulator is **fidelity-verified and will be extremely useful for us**. The current model does not have **fish-eye cameras and sonar functions** that we use for ourselves. We would appreciate it if the functions would be mounted in order to **enhance the sensor functions**. Also, please **include simulation scenes on parking lots (ground/multistorey/underground parking facilities)** as well that would expand the opportunities of use.
- **Plenty of feedbacks will return from the perspectives of users in the system development field** in response to a commercial release of the Simulator product in FY2022. We would appreciate it if **the information is shared with us as needed about examples of the Simulator use considerations mainly in the advanced development areas.**
- The DIVP® Simulator needs to **accumulate track records at OEMs in Japan** in order to have competitive advantage over overseas tool makers/suppliers.
- We appreciate the organization for sharing many types of information. We pay close attention to the DIVP® Simulator mainly in light of **costs; if the DIVP® Simulator can enable us to quickly perform as we wish; connectivity through interfaces; and customizability/tweakability**. Please let us receive and collect information continously.

SIP Coastal Area Demonstration Test and External Collaboration

- ■STEP1 outcome
- ■STEP2 status of implementation
- ■Analysis Results Discussions and Future Direction

What is attempted through STEP 2 [Simulation based upon Participants' Scenarios] is to connect the DIVP® Simulator execution result outputs with various types of models and systems owned by Participants through the use of scenarios adjusted and environments arranged in prepared virtual spaces.

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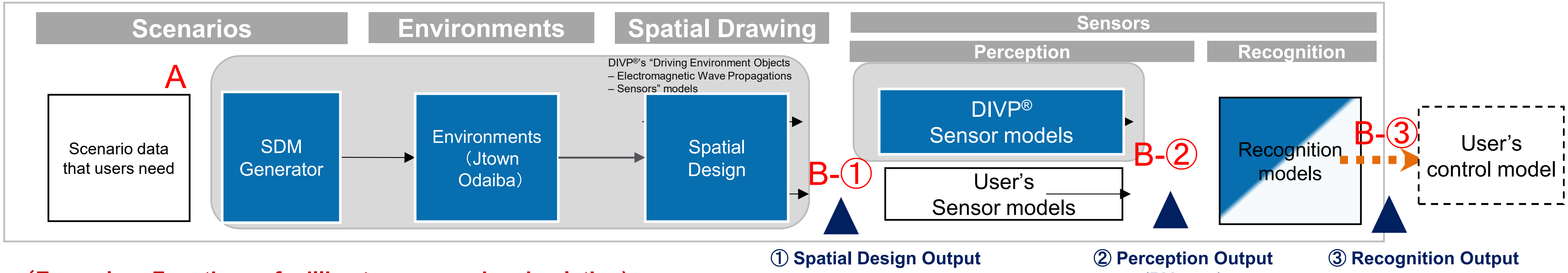
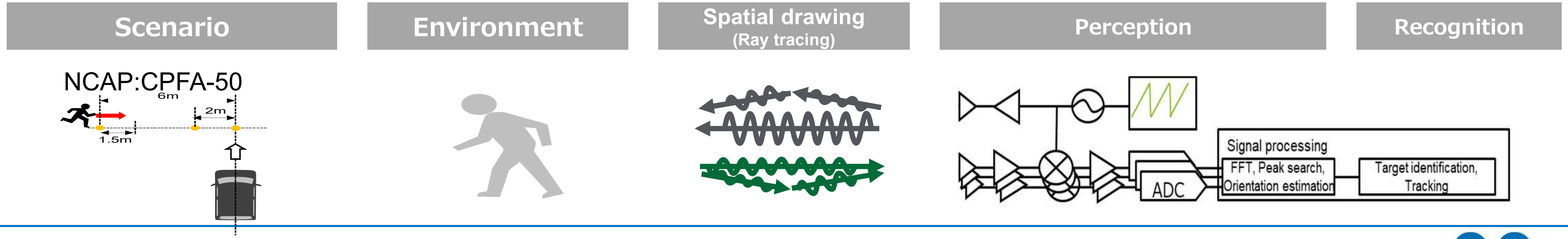
A. Simulation scenarios and environments can be individually arranged in accordance with needs of participants within the framework of virtual environments created on the DIVP® Platform.
B. Participants can connect various outputs (from cameras, millimeter wave radars and LiDAR devices) of results from virtually executing the "Driving Environment Objects – Electromagnetic Wave Propagations - Sensors" models with their own various types of models and systems. (The connection can be performed via csv files)

B_① Use outputs from a virtual environment : Transfer DIVP® spatial design outputs into user's sensor models
B_② Use outputs from a virtual environment : Transfer DIVP® sensor perception outputs into user's recognition models
B_③ Coordinate simulation results (Use simulation results (outputs) as inputs for another processing)

Provided by DIVP®
User's model



(Example : Functions of millimeter wave radar simulation)



Furthermore, we will attempt to ensure the DIVP® Simulator's connectivity (through interfaces) with existing multiple simulation environments with an aim towards enticing customers to implement the DIVP® Simulator

STEP2

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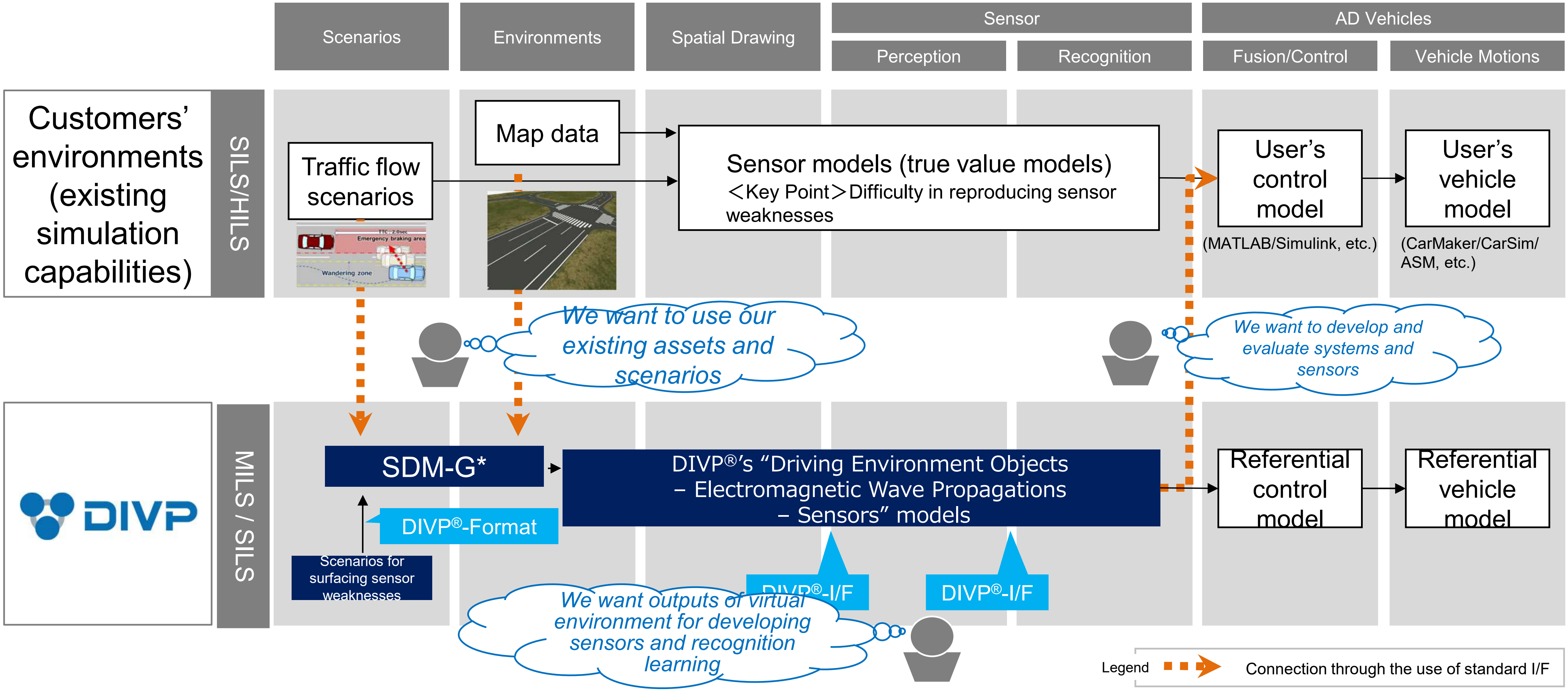
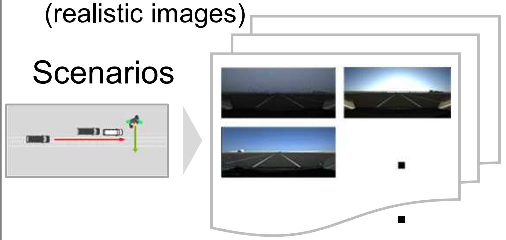
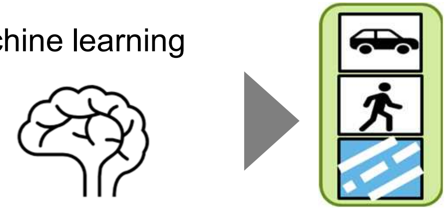
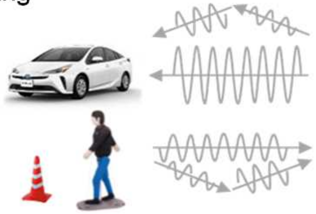
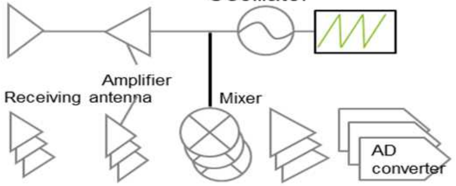
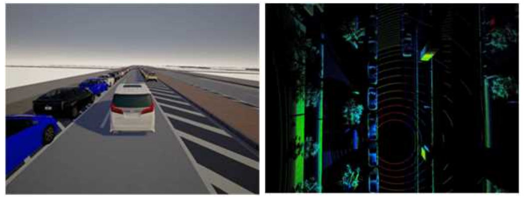
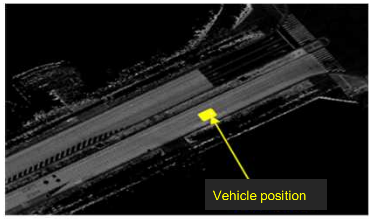
Attempt to Connect with Customers' Environments



Various types of system needs from customers' perspectives about using the DIVP® virtual environments and spatial drawing outputs were collected from the evaluation feedbacks mainly by OEMs, suppliers and universities.
Various types of evaluations were enabled in the DIVP® virtual spaces.

STEP2 **Nihon Unisys, Ltd**

Customers' Needs Examples Attempted at STEP2【Simulation based upon Participants' Scenarios】

Uses Needs Examples	Sensors	Create DIVP® Virtual Spaces	Output forms	Evaluations
■ **Create AI Learning Data** ➢ Mass produce Deep-learning Training Data under/of different conditions and scenarios	Multiple cameras	■ Create a significant amount of images (realistic images) Scenarios 	Camera Perception Output	■ Recognition SW（AI）development, evaluation Machine learning  Improve performance of recognition SW
■ **Evaluate Own Sensor Models** ➢ Evaluate performances of sensor models held by OEMs and suppliers through the use of spatial drawing output data	Millimeter Wave Radars	■ DIVP®（millimeter wave radar）spatial drawing 	Millimeter Wave Rader Spatial Drawing	■ Evaluation of own millimeter wave radar models performances (of OEMs and suppliers) 
■ **Evaluate algorithms of self-localization** ➢ Evaluate algorithms for self-localization and trajectory generation in a virtual environment *AD-URBAN coordination: Descriptions of the examples are on the next page*	LiDAR (+IMU)	■ Create virtually (simulate) bad conditions that are difficult to be set in a real world 	LiDAR Perception Output	■ Self-localization algorithm evaluation 

Source : Kanagawa Institute of technology, Mitsubishi Precision co., Ltd, AD-URBAN

8 persons entered in the Tokyo Waterfront Area FOT STEP 2 [Simulation based upon Participants' Scenarios]
The participants continue specific efforts for evaluating the DIVP® simulator in accordance with their own company's requirements up until the end of April.

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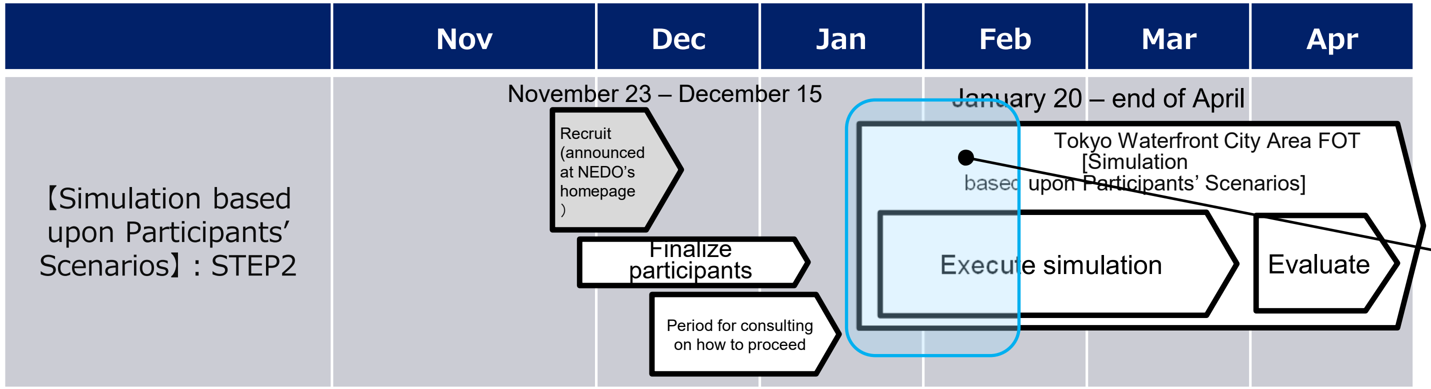
【Simulation based upon Participants' Scenarios】 :
STEP2 Application Situations

【Total】 8 companies entered
- Implement evaluation in accordance with own specific requirements. Use own specific scenarios, attempt to connect with own models
- Considerations were made in a direction towards permitting the applicant companies as much as possible to the extent that they turned in the entry form. Timing and contents were adjusted.

Business Categories		Sensor Types	Needs
OEMs	Company A	Camera	Examine the possibilities about creating DL learning data by using the DIVP® perception outputs (images)
	Company B	Camera, LiDAR	Compare output results generated by (Company B's) own recognition models grasping a real world with output results generated by the own models grasping a virtual world simulated by the DIVP® spatial drawing function in order to evaluate the DIVP® spatial drawing function.
	Company C	Millimeter Wave Radar	Evaluate own patterns through the use of the DIVP® spatial drawing function (millimeter wave radar)
Suppliers	Company D	Millimeter Wave Radar	Evaluate own patterns through the use of the DIVP® spatial drawing functions (millimeter wave radar)
	Company E	Camera	Evaluate own (stereo) camera (connecting with own recognition SW)
	Company F	Millimeter Wave Radar Camera	Use the DIVP® spatial drawing function in order to evaluate own sensor units
Sensor Maker	Company G	Camera, LiDAR	Aim to evaluate sensors developed by own company through the use of a realistic (highly faithful) environment simulated by the DIVP® spatial drawing function
Development Tool Maker	Company H	In General	Use DIVP® on the MBD development standard PF. Evaluate by coordinating DIVP® with other types of SW products.

【Simulation based upon Participants' Scenarios】 :
STEP2 Implementation Plan

・Contents and timings of support were considered flexibly.
Support resources were adjusted with the aim of basically permitting all applicants as long as they turned in the entry form.
・Each participant was interviewed before and after January 20, the FOT Step 2 launch date.
Aims and targets are varied depending upon participants.
Thus, workloads necessary for implementation and technical issues are not the same among them.
Requirements were narrowed down and resources were distributed accordingly in an approx. one month from January 20, as reflected into an implementation plan



【Duties during the Period】

① Execute NDA
Execution finished: 4 companies
NDA contents changed: 1 company
New execution finished: 2 companies
NDA contents being adjusted: 1 company

② Discuss on purposes and implementation contents, and finalize simulation-subject contents and schedules

【Simulation based upon Participants' Scenarios】 ：STEP2

Please find below the summary of implementation situations as of the end of February 2022.

・ Descriptions in blue indicate the current situations as of the end of February 2022 **Nihon Unisys, Ltd**

Business categories	Company Names	Sensors	Purposes	KickOff	Situations (implementation contents, progress situations)	NDA
OEMs	Company A	■ Cameras	▪ Verify the usability of DIVP® perception output as DL training data	■To continue from OEM Panelist Tester Evaluation	■ (Execution Contents): Adjust to an actual camera position. Generate simulation output images. Initiate verification by comparing with actual vehicle images partly in light of recognition % through the use of recognition algorithm ■ （Progress): Difference results were confirmed at the then current output level available at the end of February (after making adjustments of parameters, positions, etc.) Consider future targets and further implementations of scenarios.	■ Executed
OEMs	Company B	■ Cameras ■ LiDAR	▪ Verify the usability of DIVP® by comparing DIVP® perception output with actual sensors (data)	■ Jan 20	■ (Execution Contents): Cameras⇒ Compare actual camera outputs with DIVP® (RAW) output results through the use of own recognition algorithm and similar scenarios. LiDAR⇒ Compare actual LiDAR outputs with DIVP® outputs (point clouds) through the use of similar scenarios. (* Tendencies were looked to and checked about cameras and LiDARs, both.) ■ （Progress): Confirmations began about parameter setting items for sensors that will be used and implementation scenarios	■ Executed
OEMs	Company C	■ Millimeter Wave Radar	▪ Company C and Company D to verify the usability of DIVP® simulator by comparing own actual sensors and own sensor models with DIVP®'s mimic sensor models in the DIVP® simulation environment	■ Feb 10	■ (Execution Contents): Compare in a basic environment outputs from Company D's millimeter wave radar and outputs resulting from simulating the Company D's millimeter wave radar. (* Precision in light of reception level, angle, distance, speed, etc. was confirmed during examining traveling situations in a laboratory environment) ■ (Progress): Confirmations about DIVP® output contents and IF specifications began in cooperation with Company D Company C to prepare basic verification scenarios	■ Adjustments are being made due to partial changes
Suppliers	Company D Group					■ Executed
Suppliers	Company E	■ Cameras	• Verify whether or not the DIVP® Simulator can be used for developing and verifying stereo camera	■ Jan 12	■ (Execution Contents): Create a new PF environment at Company E. Connect it with own recognition SW environment. Apply a monocular camera evaluation method (DIVP® deliverable) for stereo camera, and verify. ■ (Progress): Preparations for creating the environment are finished	■Contents confirmations were finished (yet to be signed and sealed)
Suppliers	Company F	■Millimeter Wave Radar ■Cameras	▪ Share global coordination situations and examine the use of DIVP®	■ Share info. for now	■ Share information with the DIVP® consortium about global coordination activities. （Company F's subsidiary in Japan is interested in gradually making attempts of global coordination through the use of Company F's scenarios. ）	—
Sensor Makers	Company G	■ Cameras ■ LiDAR	▪ Enhance knowledge and expertise with the aim of evaluating own sensors through the use of simulation capabilities	■ Jan 12 （re. NDA）	■ Negotiations on NDA continue about purposes for using information. (Concurrently negotiations continue about using SIM in the SimuLINK environment)	■ Negotiations about contents continue
Development tool (software)	Company H	■ In General	▪ Create examples of coordination between DIVP® and various types of SW products on SimuLINK (that can be referred to as the standard PF for MBD development)	■ Jan 21	■ (Execution Contents): Specific examples of using the DIVP® simulator on SimuLINK are virtual scenes where sensors expose key weaknesses as focused on by DIVP®. Such scenes can be composed of digital combinations of the DIVP® mimic environments, MathWorks' recognition AI algorithm and Fusion algorithm. ■ (Progress): Discussions began on specific implementation by using output examples that can be mutually provided by Company H and DIVP®.	■ Contents yet to be confirmed

The aim of this FOT STEP 1 focuses on participants attempting to use DIVP® in their own environments. STEP 2 participants clearly indicate their desire to proceed with evaluations by simulating various scenarios about sensor weaknesses in virtual environments.

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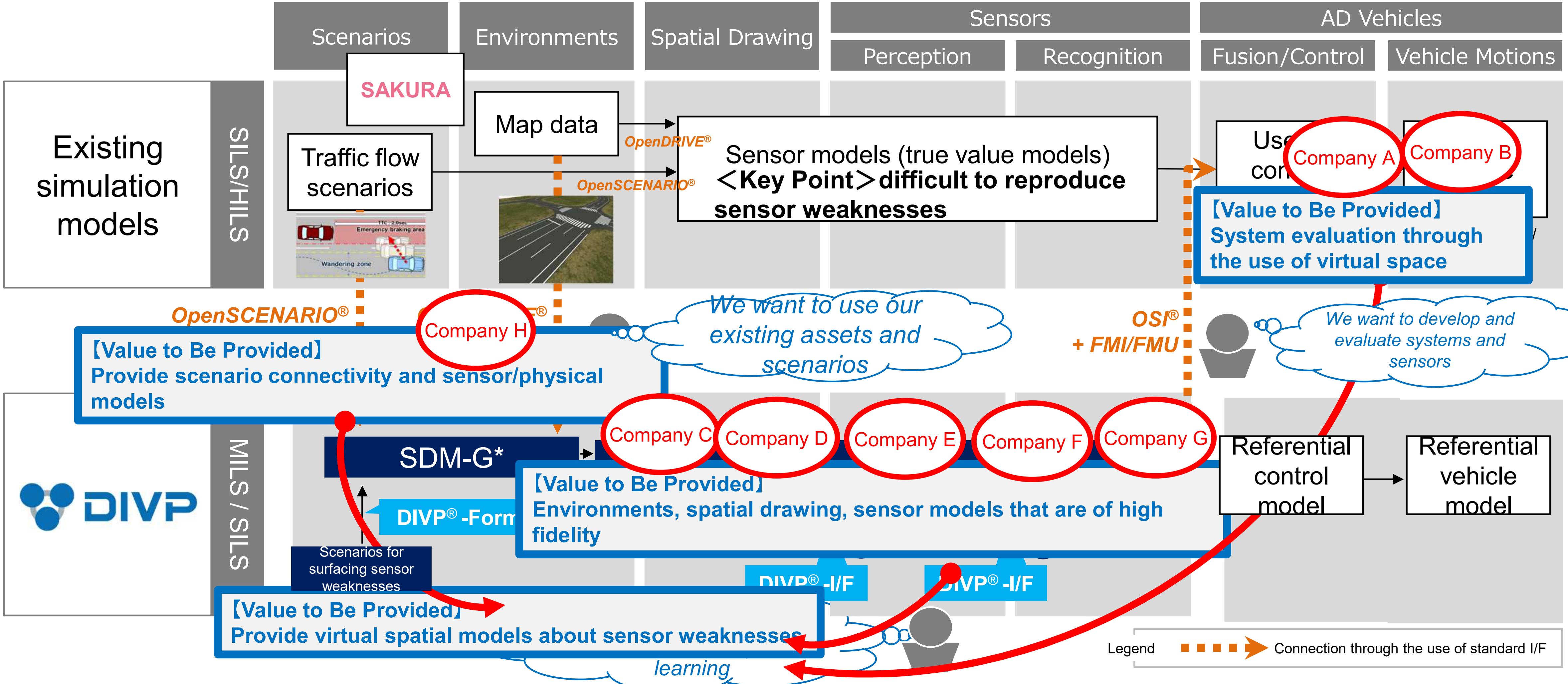
Organize simulation model types in accordance with purposes (Co-simulation) and what is aimed at FOT



* SDM-G : Space Design Model Generator

Expectations for the Next Step

SIP Coastal Area Demonstration Test and External Collaboration

- ■STEP1 outcome
- ■STEP2 status of implementation
- ■Analysis Results Discussions and Future Direction

The intention is to divide the requirements into R&D issues and commercialization issues and take specific actions. Also, we will proactively look for requirements through the on-going FOT Step 2 phase and future user surveys.

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Summary of Requirements Known through User Surveys(as considered for reflecting on future plans)

		Items of Consideration
R&D		・Digitally reproduce real environments - Road conditions: wet road surfaces, puddles, accumulated snow, sunlight reflections - Meteorological conditions: rain, fog, snow, moonlight - Sensors: impacts from sensors of oncoming vehicles and other vehicles, dirt and snow on sensors
		・Simulate scenes where sensors do not work properly -Evaporation of pedestrians, backlight on traffic signals, etc.
		・Simulate vehicles - Vibrations, posture changes of vehicles, etc.
Issues about Commercialization	**Products**	・Improve SDMGenerator functions - Fulfill furthermore functions for operability and creating routes and scenarios - Fulfill assets for reproducing real environments
		・Improve the simulation PF functions - Improve computation speed - Develop IF for connecting with other systems - Referential models (parameter settings)
	Schemes	・Create arrangements for coordinating with other vendors - Fulfill sensor models - Partners for co-simulation
		・Create arrangements for supporting for using the DIVP® simulator partly for services Simulator,

We obtained feedbacks about DIVP® evaluation as well as users' situations and expectations through the FOT STEP 1 and (ongoing) STEP 2.We considered the directions for the DIVP® products with an eye on users and markets.

Feedbacks from the FOT and Considerations on the Future Directions

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	FOT Summaries	Feedback: User Situations and Expectations	Feedback: DIVP® Evaluation (good)
FOT STEP1	■ 56 companies participated (OEMs, sensor makers, and other companies of different industries such as damage insurance) ■ The participants understood the DIVP® features through the use of Portal Site functions. We conducted surveys about their expectations and possibilities of using DIVP® for their businesses	■ AD development simulation prevails to some extent (specifically among OEMs) ■ Strong demands for fulfilling assets and supporting OPEN-X for creating simulation environments are witnessed ■ Need for scenarios exposing poor sensor performances is emphasized with. ⇒Awareness for safety evaluation is being developed. ■ Strong demands for connectivity is witnessed （desirous of connecting with simulation systems and models)	■ SDMG • Fulfill assets and support OPEN-X (scenarios and driving, both) • Operability ■ Simulation PF • Reliability proven by physical simulation, fidelity by verification (scenes to expose sensor poor performances) • Connectivity（prepare IF、support Simulink）
FOT STEP2	■ 5 companies (8 persons) evaluate DIVP® outputs through use cases ■ The participants attempt to connect DIVP® with their own models and environments after confirming the DIVP® performances and functions ■ We conducted interviews about specific methods of sensor evaluation	■ Actual vehicle evaluation through simulation cannot hold any longer. Desirous of examining how much simulation can serve ■ Strong demands for evaluating and developing in virtual environments (OEMs') own algorithm and (Suppliers') own models are witnessed	■ （Example: cameras） 32 colors x 32-bit superb capabilities of expressing realities ⇒ Simulating sensor poor performances, decisive for evaluating sensor performances ■ Environment × Scenes to expose sensor poor performances (packaged scenarios) enables variable evaluation environments ■ Flexible connectivity (specifically, SimuLINK is highly expected)

Reflect onto the Future Plans

<u>Expectations from users / markets（about using the DIVP® simulator）</u>

- ➢ Improve QCD furthermore in AD development
- ➢ Establish and obtain a methodology for safety evaluation

<u>DIVP®（Simulation PF＆SDMG）Products</u>

(*)
Establish the position as unrivalled simulator in the arena of AD development and safety evaluation

- ➢ Create environments for true value ＋ physical simulation
- ➢ Strengthen and develop scenes and scenarios to expose sensor poor performances
- ➢ Ensure connectivity (OPEN-X、simulation IF）

Promotion

Accelerate efforts to disseminate research results worldwide and promote use of intellectual property with eyes on commercialization

Promotion

Date	Presentation media	Presentation titles	Presenter
2021.6.29	ASAM Regional Meeting Japan 2021	OpenDRIVE Concept Project and Other OpenX Projects From a Tool Vendor Perspective	Mitsubishi Precision Kazushi Takeda
2021.7.1	Safety Engineering Symposium 2021	Safety and functional validation of autonomous driving (2) Construction of an automated driving safety assurance environment in a virtual space - DIVP® Introduction to the (Driving Intelligence Validation Platform) Project -	Hideo Inoue
2021.7.26	Gunma University Next Generation Open Innovation Council	Autonomous driving intelligence system to support the independence of the elderly and realize a safe and secure society -Evolution and validation of safety technologies in autonomous driving and driver support-	Hideo Inoue
2021.9	CASE workshop seminar	Development of technologies for automotive products that support autonomous driving	Hitachi Astemo Shōji Muramatsu
2021. 9.21	FAST-zero '21	VALUATION OF APPARENT RISK BY USING HARDWARE-IN-THE-LOOP SYSTEM	Kanagawa Institute of Technology Shotaro Koyama Kenichi Uehara Hideo Inoue
2021.9.30(JP) 2021.12.6(EN)	SIP 2nd Phase: Automated Driving for Universal Services -Mid-Term Results Report (2018-2020),	Devepmemt of Driving Intelligence Validation Platform (DIVP®) for Automated Driving Safety Assurance, p91-p97(JP), p.89-94(EN)	Hideo Inoue
2021.10.21	The 11th Toyota Technological Institute Smart Vehicle Research Center Symposium	Smart Vehicle Research Center Activity Status Report	Tokihiko Akita Toyota Technological Institute
2021.11.10	SIP-adus Workshop 2021	Driving Intelligence Validation Platform for Automated Driving Safety Assurance Report on research results	Hideo Inoue
2021.12. 8	9th Autonomous Driving Safety Conference 2021	Development of automated driving validation environment improvement method in virtual space; DIVP® Project	Hideo Inoue
2022.2.10	Invited lecture at CAE Forum 2022, Hideo Inoue	Development of automated driving validation environment improvement method in virtual space	Hideo Inoue

Paper presentation

Date	media	Titles	Authour
2022.2.1	Academic Trends February 2022 issue, VOLUME 27, NUMBER 2,	Simulation Technology for Safety Assurance of Autonomous Vehicles - DIVP® Project, p 87 -91	Hideo Inoue
2022.3.8	ICCVE2022 Coference, IEEE, Technical program: ADAS/AD System Development /Cybersecurity	Vehicle-in-the-Loop Testing – a Comparative Study for Efficient Validation of ADAS/AD Functions	Christian Schyr Hideo Inoue Yuji Nakaoka (AVL Deutschland GmbH/Kanagawa Institute of Technology/ AVL Japan K.K.)

IPs

Filing date	Accession Number	Title of the patent, etc. in the application	Applicant
2021.03.23	Japanese Patent Application No. 2021 048977	Consistency verification method and system for On-Vehicle camera simulator (At the time of preparation of last year's report, this year's report is included because the application was not filed.)	Sony Semiconductor Solutions Corporation

DIVP

END

Tokyo Odaiba → Virtual Community Ground

This report documents the results of Cross-ministerial Strategic Innovation Promotion Program (SIP) 2nd Phase, Automated Driving for Universal Services (SIP-adus, NEDO management number: JPNP18012) that was implemented by the Cabinet Office and was served by the New Energy and Industrial Technology Development Organization (NEDO) as a secretariat.