Driving Intelligence Validation Platform

Research Result Report FY2018-2022

Weather Forecast

AD safety Assurance*

For Validation & Verification Methodology

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.

* AD : Automated Driving

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This report is summarized.
Please contact DIVP® consortium for detail.

Background and purpose

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

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

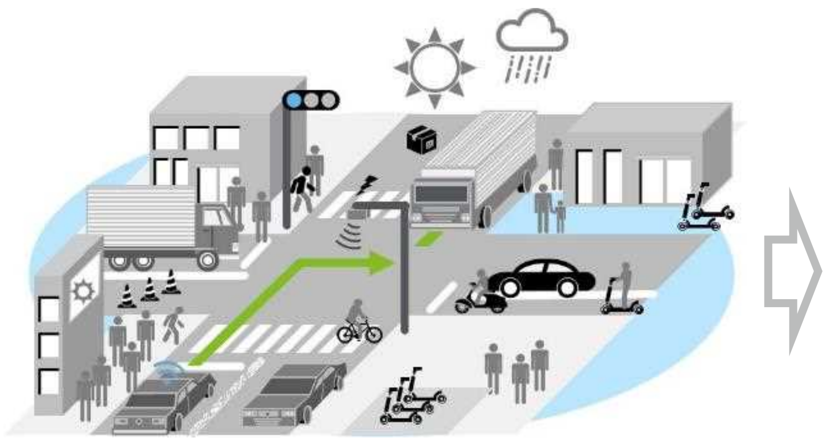
Highly Consistent Sensor Model

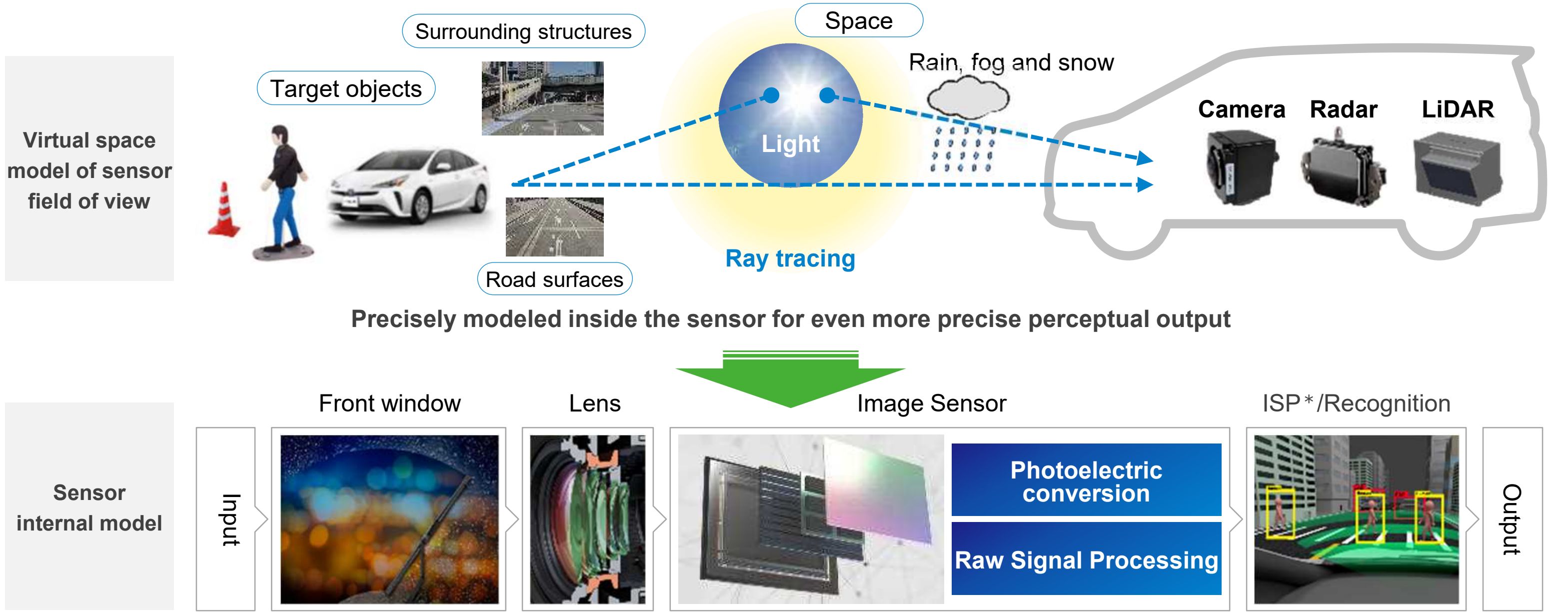
Source : Kanagawa Institute of technology, MITSUBISHI PRECISION CO.,LTD., DENSO Corporation, Pioneer Smart Sensing Innovations Corporation, Hitachi Automotive Systems, Ltd.

Constructing a virtual space simulation platform that is highly consistent with actual phenomena contributing to the safety assessment of automated driving

Purpose and characteristics of DIVP®

- Simulation model consistent with real phenomena
- Platform capable of consistently evaluating scenario generation, recognition performance validation, and vehicle control verification
- Enhancing connectivity with existing simulations





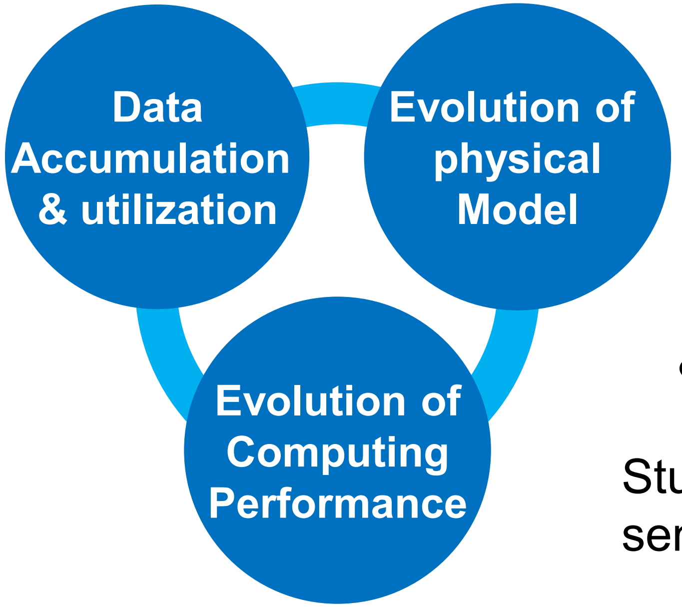
Real space → To virtual space model of sensor field of view, sensor internal model

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

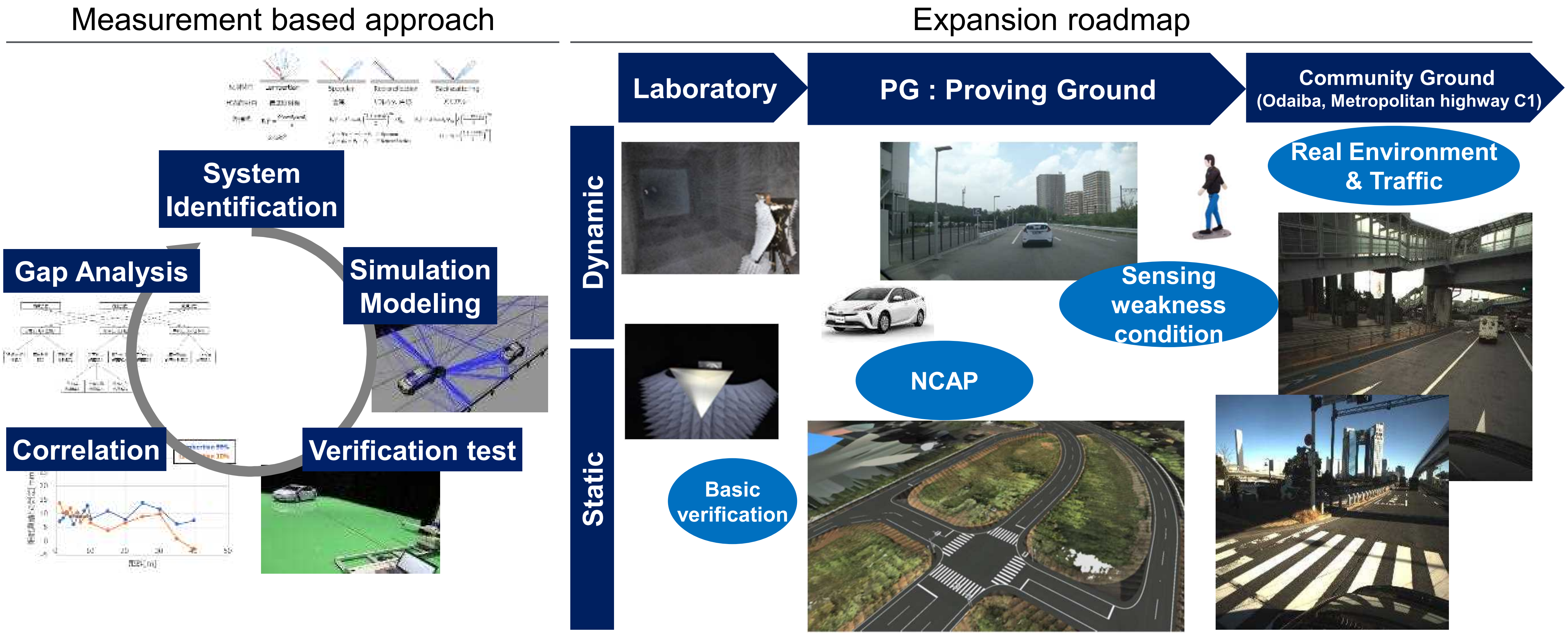
Source :FY2020 Year-end report

Summary of research findings

- Research Results
- Future Initiatives

We have built a virtual evaluation environment for sensor validation in NCAP and other assessments, sensing weakness environments, and actual traffic environments by reproducing physical phenomena in detail

Validation framework



Source : DENSO Corporation, SOKEN, INC, MITSUBISHI PRECISION CO.,LTD.

For safety assessment, it is essential to materialize scenarios, tools and indicators that enable validation of the two indicators

Safety validation system to be aimed at

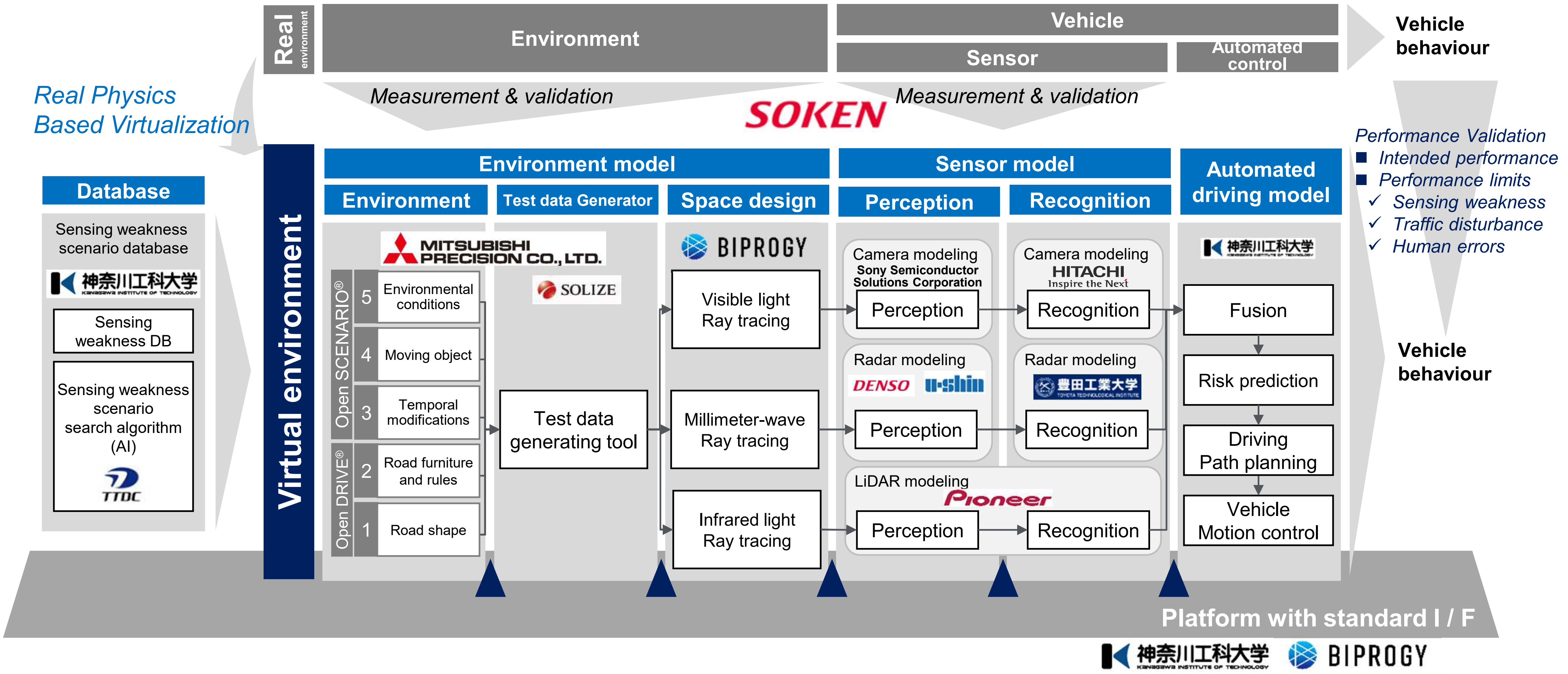
	Assessment Scenario	Validation Tool (Verification)	Metrics (Metrics)
Won't you bump into me? Evaluating	■ Geometric **traffic flow scenarios** based on analysis of accident data, etc. 	**Consistent** sensor models: Camera , RADAR , LiDAR  → Automated driving control model 	■ Accurate prediction of vehicle position allows **margin for accident** and determination 
Can you see it? validation of.	■ **Sensing weakness scenarios** based on expert knowledge 	*Simulation* *HILS / VILS* *PG / Public road*	■ **Virtual Validation of Recognition Performance** Based on a Consistency Model of Measurable Perceptual Outputs 

■ **Tool chain** according to validation purpose and target

DIVP

In AD technology, which consists of cognition, judgment, and behavior, the rule of safety can be said to be sensor technology that "recognizes the outside world," so external information for evaluating and learning sensor performance as well as the technology of the sensor itself is essential

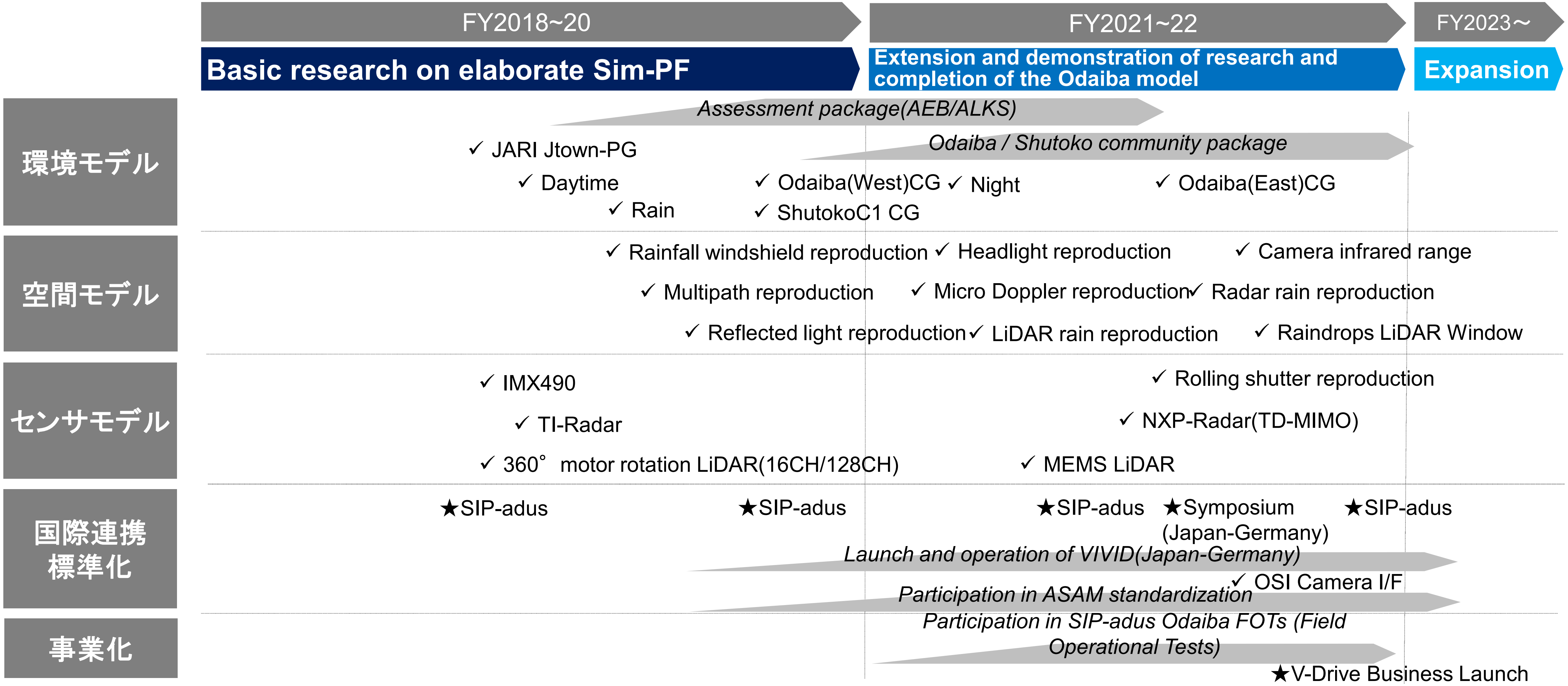
DIVP® project design



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

Through research starting in 2018, Virtualization of assessments and public road validations, proposal of Virtual-based safety assurance methods to international standards, etc., in 2021, DIVP® started business offerings.

DIVP® research results



AD-SA has so far started to connect Prjs and to disseminate and coordinate the SA framework internationally, and has received a certain amount of approval
In the future, we will accelerate global standardization through standardization through VIVID, ASAM, etc., and collaboration with the United States

Initiatives by the Joint Promotion Committee

～FY21 | *FY 22 Achievements* | *FY23～*

～FY21
- DIVP®/AD-URBAN/Sakura Begins Collaboration Between Three Projects
  - ➢ First, connect each other's achievements

FY 22 Achievements
- Launched a strategic review team to standardize AD Safety assurance
  - ➢ Drafting a framework and starting international communication and collaboration
  - ➢ Create a road map for realization

FY23～
- Lead international standardization
- Contributing to social implementation through collaboration with other research PRJ

jama

Presentation of expectations and joint examination of technical issues

SAKURA — Scenario

AD-URBAN — System

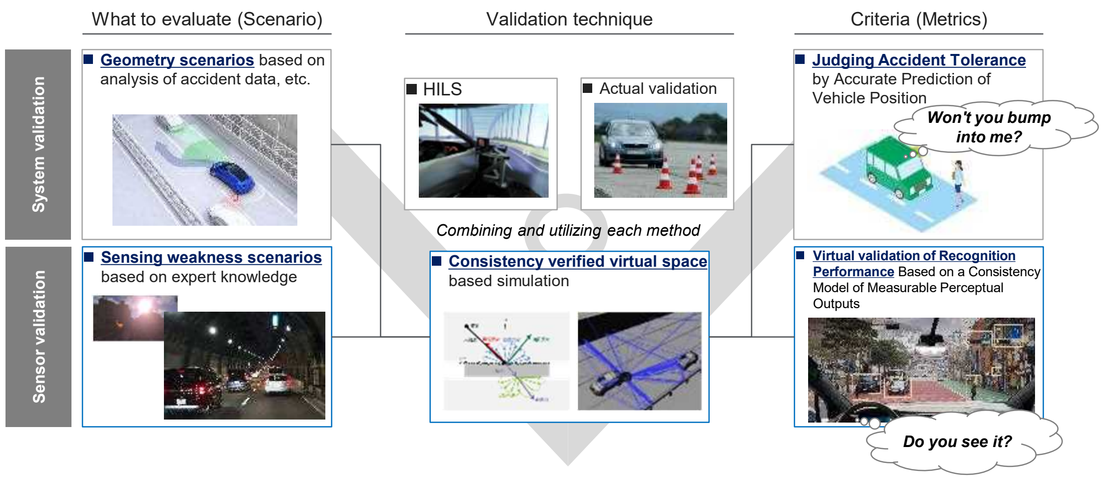
DIVP — Sim validation base

Strategy

R&D

Implementation standardization

AD Safety assurance framework



- ➢ Continuation of Japanese-German VIVID

PEGASUS
VVM
SETLevel ・・・

- ➢ Standardization based on collaboration

ASAM, ISO ・・・

- ➢ Expanding cooperation with the United States

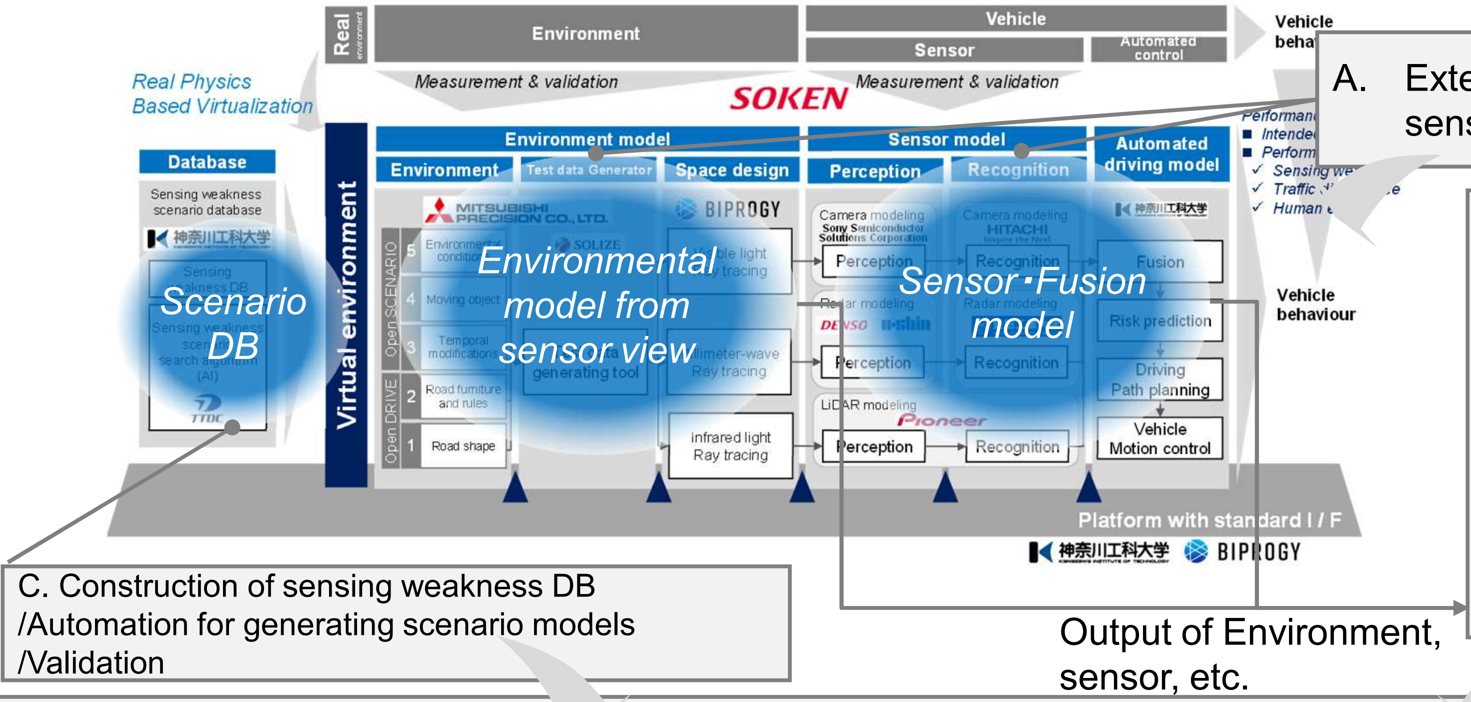
SAE, UL, IEEE ・・・

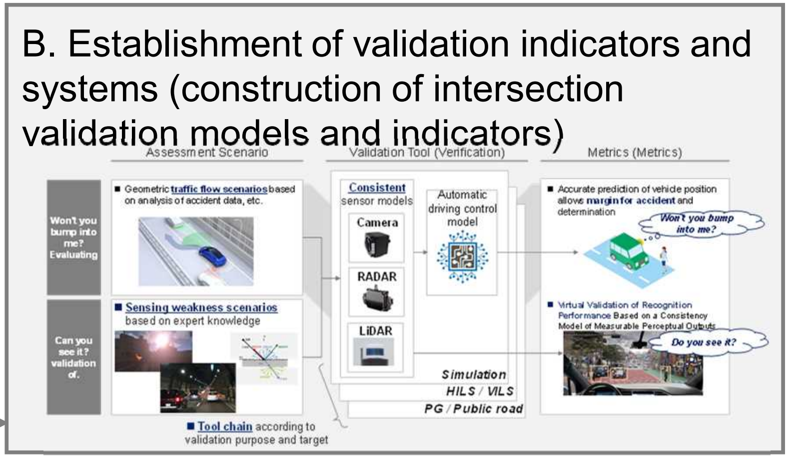
Source: 2022 Team 0 report

Further apply and utilize the results of research to achieve international standardization of safety assurance in FY23.

Approach to research themes of FY23

- DIVP® aims to establish Closed SILS in AD-Safety assurance*, and the results are to be used in RtL4, etc.
  - Need to consider the connection to VILS, etc. and to compete with Real time Sim.
  - Incorporation of evaluation protocols based on actual driving validations on public roads is an ongoing issue.





D. International Collaboration and Standardization

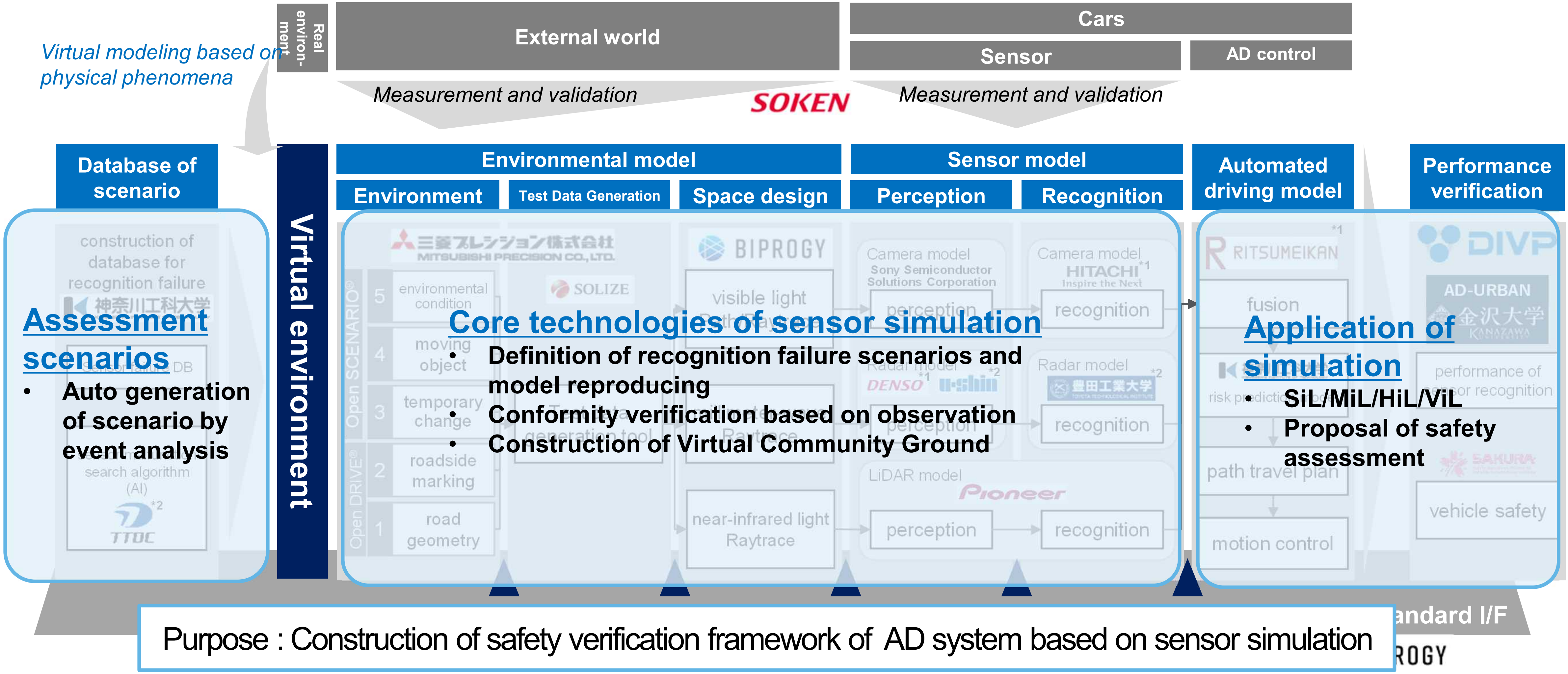
＊安全性評価をVirtualで実施できること

Summary of research findings

- Research Results
- Future Initiatives

To construct safety verification framework of AD system based on the minute physical sensor technologies, DIVP® research the core technologies of simulation, assessment scenarios and safety assessment

Positioning and purpose of research topics



Assessment scenarios

- Auto generation of scenario by event analysis

Core technologies of sensor simulation

- Definition of recognition failure scenarios and model reproducing
- Conformity verification based on observation
- Construction of Virtual Community Ground

Application of simulation

- SiL/MiL/HiL/ViL
- Proposal of safety assessment

Purpose : Construction of safety verification framework of AD system based on sensor simulation

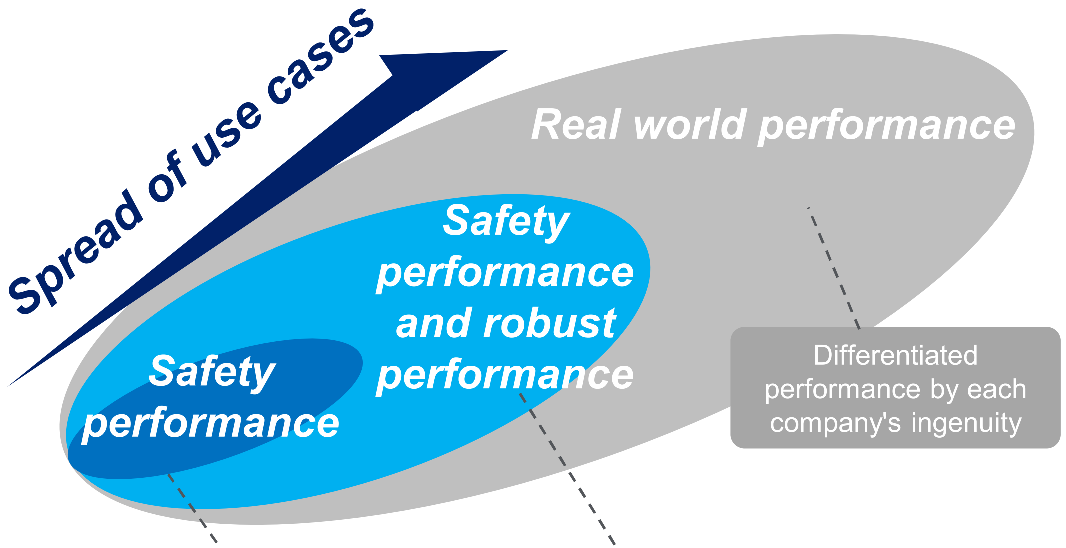
Source : Kanagawa Institute of Technology

DIVP® improve simulation accuracy based on consistency verification and develop Virtual-PG (Proving ground) to construct simulations to evaluate the limitation of sensor performance evaluation

Virtual-PG Expansion Policy

Roadmap of use case spreading

- 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 automated 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.
  - Generating simulation based on accident analysis (Especially casualties, general roads)
  - Generating simulation based on highway (automated driving) driving state data

Prioritize from investigation of Euro-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

Source : Kanagawa Institute of Technology

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

DIVP® Scenario Package

	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 (July - June FY2022)						
		ALKS (July - December FY2022)					
Daiba Community Package Robustness assessment scenario	Sensing weakness scenario (April FY2021 - December FY2022)						

Euro NCAP

ALKS

Sensing weakness scenario

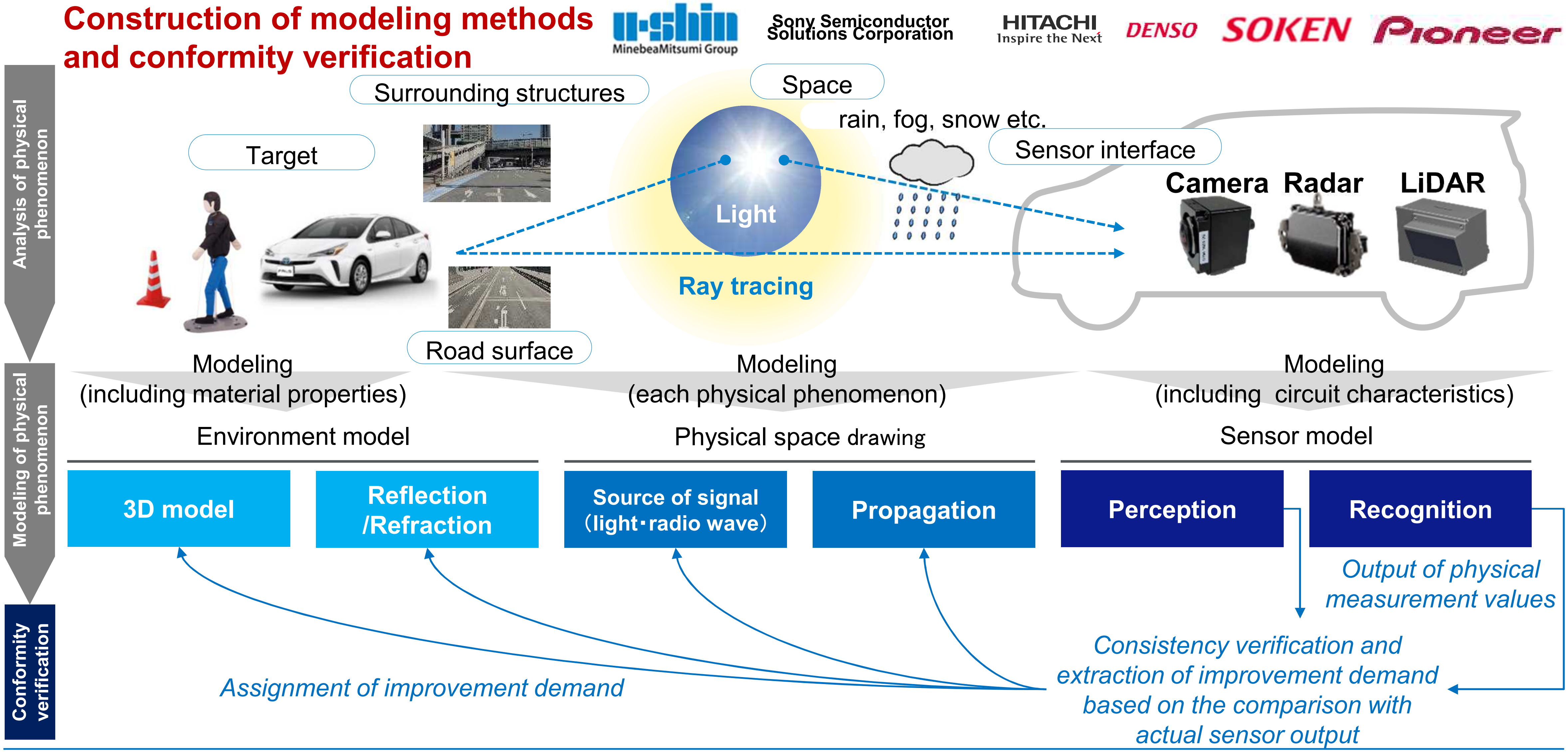
A faded white line / Thermal barrier coated road surface / Backlight / Tunnel / Rain / Snow

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

DIVP

Principle of detection and physical phenomena of electromagnetic wave in used frequency band are modeled to reproduce sensor output precisely. Consistency was verified by comparing with the actual vehicle test results.

Construction of modeling methods and conformity verification



Source : DENSO, INC, HitachiAutomotiveSystems, INC, PIONEER CORPORATION, MITSUBISHI PRECISION CO.,LTD.

DIVP

Reproduce not only normal scenes but also scenes that sensors are not good at(sensor-weakness) by the physical models. Model structures are divided into “environment", “space-drawing”, and “sensor-interface" and implemented as independent and precise models.

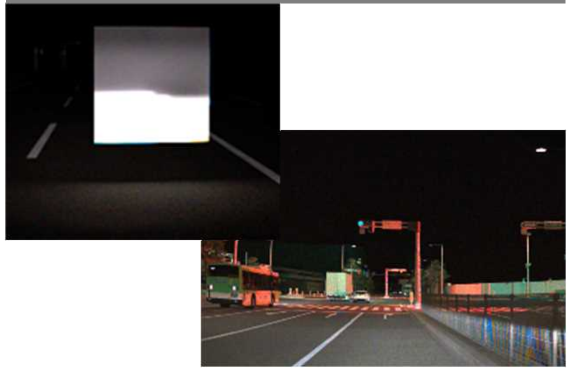
Reproduction of sensor-weakness scenes（Camera）

Sony Semiconductor Solutions Corporation SOKEN 三菱プレシジョン株式会社 MITSUBISHI PRECISION CO.,LTD. BIPROGY

Phenomena induced by environment models

Mirrored surfaces(luster materials･puddle)

Light sources(head light･traffic signal)



Phenomena induced by sensor-interface models

Rain drops on glass

Moving windshield wipers

Phenomena induced by spatial model

Dark places (e.g., tunnels)

Backlighting･Head light flare

Motion blur

Blur ON

Blur OFF

※60km/h

Source :Kanagawa Institute of Technology, Sony Semiconductor Solutions Corporation

【Camera Consistency Verification（Camera perception model + Environment model）example】 Verification of "At night＋Head light irradiation" scene was performed based on the perception outputs

The results of the camera consistency verification

Sony Semiconductor Solutions Corporation

When highly accurate data is applied to the environment model(Light source distribution, reflectance ratio of the assets) , it was confirmed that the consistency accuracy within about 20% can be achieved as simulated results.

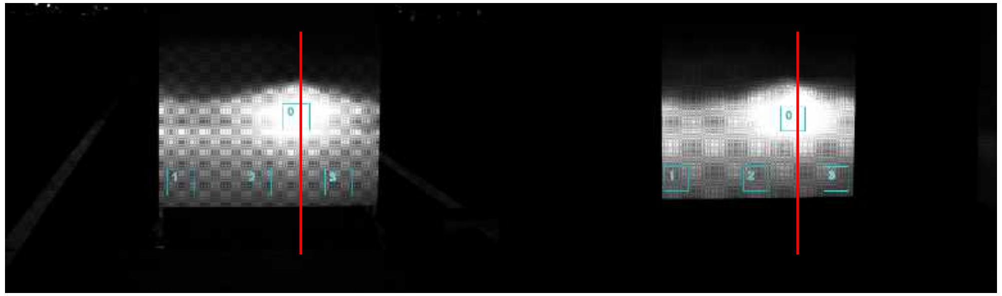
Ex. Verification results when Lambert reflector is irradiated by headlights (High beam)

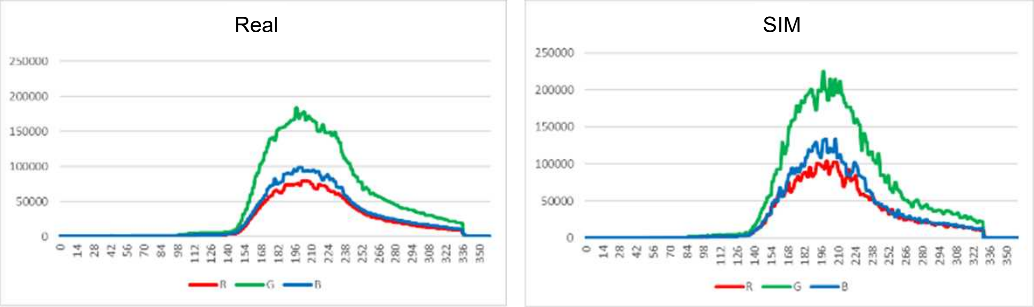
Evaluated scene（Jtown）

- At night, Lambert reflectors are placed 5m in front of the vehicle, and headlight from the vehicle are irradiated.
- In the simulation, the measured data were applied to the distribution characteristics of the light sources.

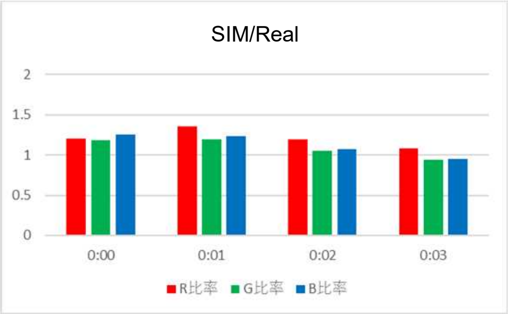
Comparison by RAW data

Actual camera result   SIM result





Signal intensity profile of pixels（Red line）



Signal intensity ratio for each area

	SIM / 実機
R	1.21
G	1.09
B	1.13

Average of signal intensity ratio

Source： Sony Semiconductor Solutions Corporation

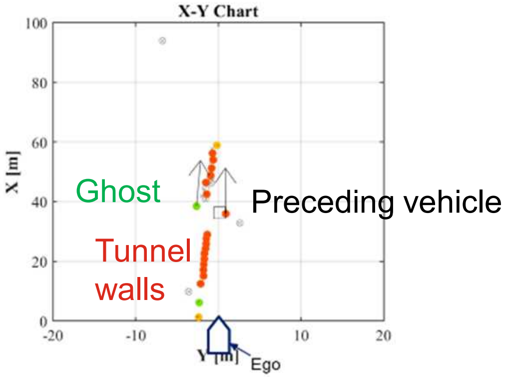
Reproduced not only normal conditions but also sensing weakness conditions using a physical model
The model is divided into “Environment”, “Space design”, and “Sensor boundary” and implemented as independent and sophisticated model

Reproduction of sensing weakness (Radar)

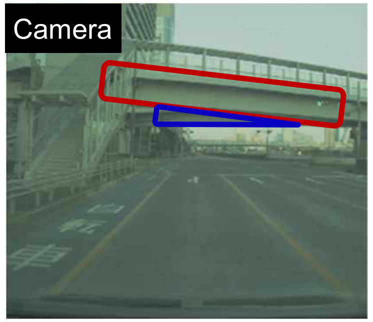
MinebeaMitsumi Group SOKEN 三菱プレシジョン株式会社 MITSUBISHI PRECISION CO.,LTD. BIPROGY

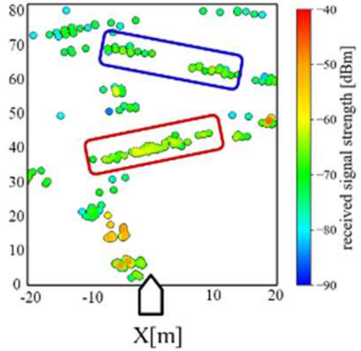
Phenomena caused by environmental model

Radar : Multipath ghost of preceding vehicle due to tunnel walls



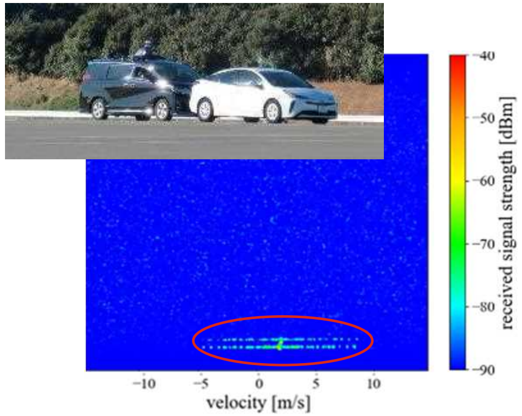
Radar : Special structure



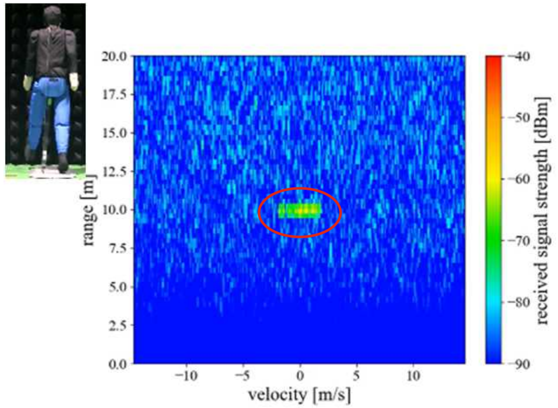


Phenomena caused by environmental model

Tire rotation of the preceding vehicle

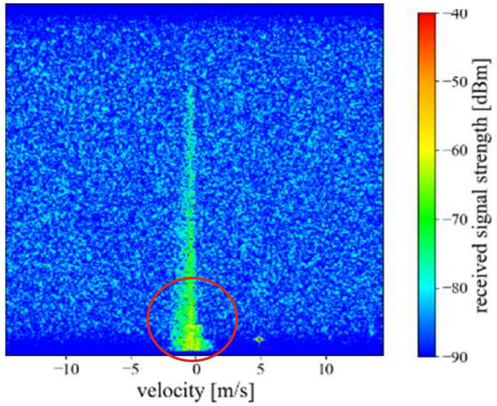


Pedestrian leg and arm swings

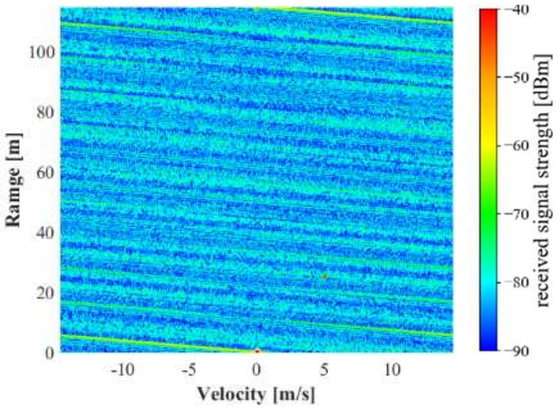


Phenomena caused by space design model

Clutter from rainfall



Interference from other sensors



Source :Kanagawa Institute of Technology, SOKEN

Reproduced not only normal conditions but also sensing weakness conditions using a physical model The model is divided into “Environment”, “Space design”, and “Sensor boundary” and implemented as independent and sophisticated model

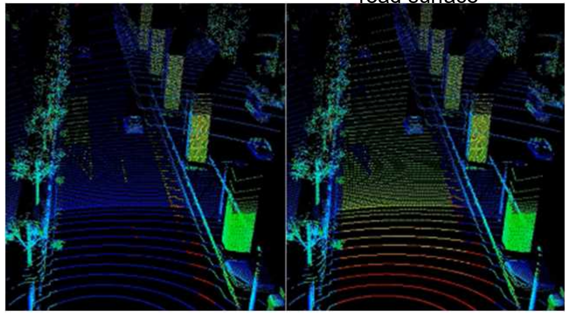
Reproduction of sensing weakness (LiDAR)

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

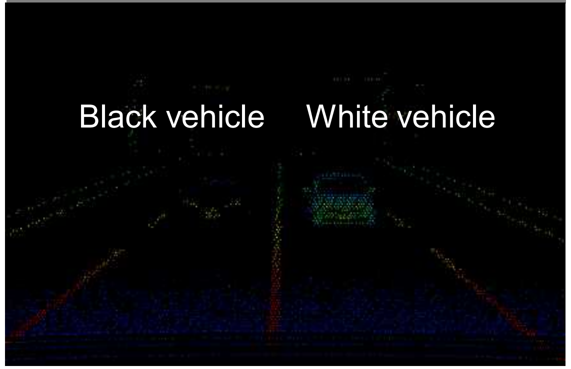
Phenomena caused by environmental model

Thermal barrier coating road surface (high reflection)

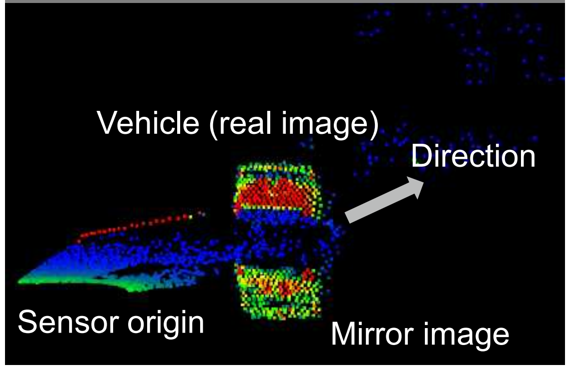
General road surface | Thermal barrier coating road surface



Black vehicle (low reflection)

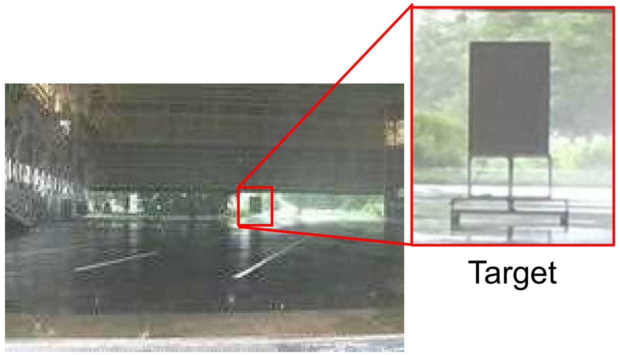


Mirror image by mirror surface (puddle)



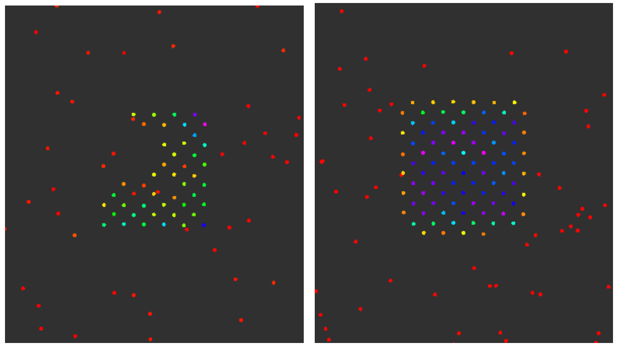
Phenomena caused by sensor boundary model

Noise due to raindrop adhesion



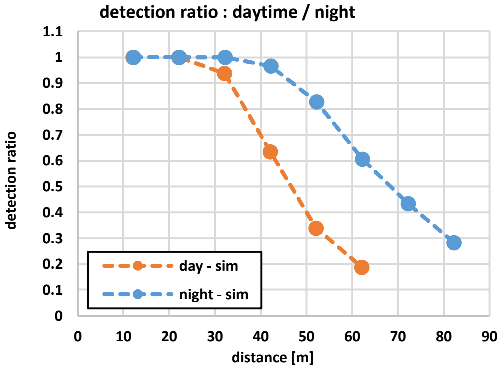
Rainfall facility

Wet | Dry

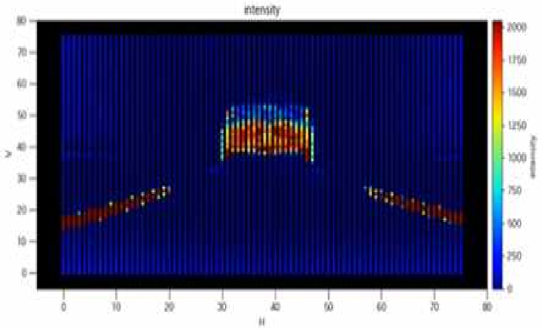


Phenomena caused by space design model

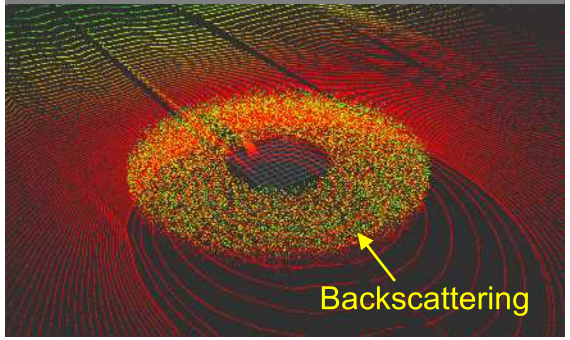
Detection performance degradation due to sunlight effect



Rain attenuation



Backscattering



Source :Kanagawa Institute of Technology, PIONEER CORPORATION

DIVP

Confirmed consistency by comparing the environmental, space design and sensor model with the results of real vehicle measurements
The results from laboratory validation to real traffic environment validation are compiled in the catalog

Simulation consistency validation

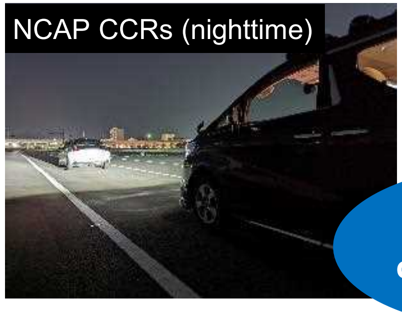
SOKEN 神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

DIVP® Consistency validation step

Lab → Proving Ground → Community Ground (Tokyo Waterfront Subcenter Odaiba, Metropolitan expressway C1)

Dynamic validation


Anechoic chamber


NCAP CCRs (nighttime)

Environment conditions causing system malfunctions

Real traffic environment


Tokyo Waterfront Area

Static validation


Radar target

Basic principle validation

NCAP

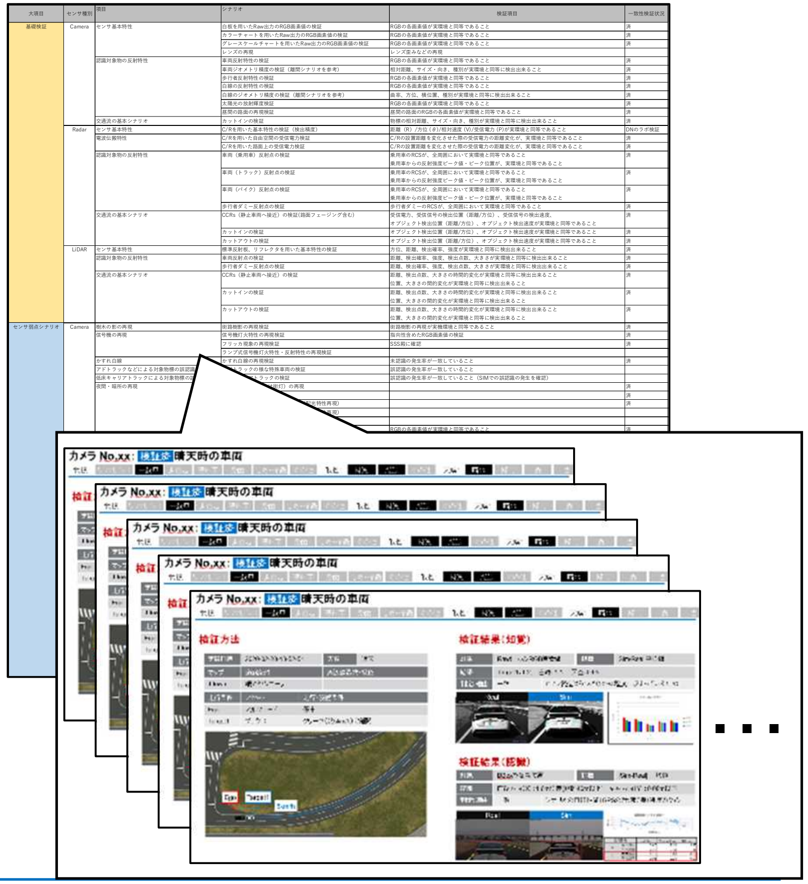

NCAP CPNA


Rainfall facility


Winter Proving Ground in Hokkaido

Validation results catalog

Organize the results of more than 90 validation items with a set of test methods and metrics



Source : Kanagawa Institute of technology, DENSO Corporation, SOKEN, INC

DIVP

Confirmed consistency in normal and major sensor weaknesses conditions, and expect to be able to use it to evaluate AD system
We will focus on reproducing snow phenomena and completing the main model of sensor weakness

Summary of consistency evaluation status

	Conditions		Status	Evaluation Items	Consistency Evaluation Results	Remarks
Camera	Normal	Outdoor Sunny	Done	Brightness of each asset	0.9 ~ 1.2 times brighter than real camera	20% error is about the variation of real camera
	Sensing weakness	Rainy	Done	Impact on recognition	Consistent trend of performance decline	Trial in collaboration with AD-URBAN
		Nighttime	Done	Brightness of each asset	1.1 ~ 1.4 times brighter than real camera	
		Fast motion effect	Done	Motion blur	Blur to velocity matches	
		Fog	Partially done	Brightness of each asset	Modeling completed	**Calculation time is an issue**
LiDAR	Normal	No background light	Done	Number of target point cloud, Intensity distribution, Detection probability	Confirmed	Error less than 2.5m resolution
	Sensing weakness	With background light	Done	Number of target point cloud, Intensity distribution, Detection probability	Confirmed	
		Attenuation and scattering by rain and fog	Done	Intensity distribution, Percentage of backscattering	Characteristics consistent with rainfall	Rainfall attenuation has been verified
		Water splash	Not Yet	Number of target point cloud, Position, Intensity distribution	Under consideration for modeling	Analyzing experimental data
Radar	Normal	Vehicle	Done	Intensity distribution, Distance attenuation	Average ±5dB	
	Sensing weakness	Wall-Multipath	Done	Reproduction of ghost, Intensity distribution from wall	Peak occurrences coincide Signal peak level error of 5 dB or less	
		Attenuation and scattering by rain	Done	Spatial attenuation, Clutter distribution	Less than 20% error in estimation of spatial attenuation Confirmation of clutter occurrence	
		Upper structure	Partially done	Signal strength distribution	Support for some structures	Continuing research for generalization

Source :Kanagawa Institute of Technology

Reproducing snow is a major goal for FY23 and beyond

We conducted a verification of principles and a reproduction experiment for simulation-based evaluation of the 9 items extracted from perception evaluation on public roads. 8/9 items have been verified, and the effectiveness of DIVP®-Sim. has been confirmed.

Verification of perception failure for AD safety assessment

■Outline

<Verification Item definition>
Plans for verification of principle for reproducible evaluation by simulation of perception failure items for each sensor extracted from the public road evaluation.

<Basic principles verification>
Clarification of basic principles, modeling and verification for simulation reproduction through experiments to reproduce perception failure phenomenon.

<Reproducibility verification>
Reproducibility verification through simulation by conducting reproducible experiments and measurements on a test course, taking into account the actual traffic environment.

■Outcome

Category	Vilification items (see JAMA guideline)	Results
LiDAR	① Attenuation of signal ② Noise	① Similar verified ② Experiments using actual solar light and simulation to verify reproducibility. **★See below【C】**
Radar	③ Large difference of signal ④ Low D/U (road surface multipath) ⑤ Low D/U (change of angle) ⑥ Low S/N (direction of a vehicle)	③ Verification of the principle and implementation of specific conditions for perception failure using an actual vehicle. **★See below【B】** ④ Similar verified ⑤ Reflection intensity measurement and analysis as verification of principle. **★See below【A】** ⑥ Similar verified
Camera	⑦ Hidden (image cut out) ⑧ Low spatial frequency / low contrast ⑨ Overexposure	⑦ Similar verified ⑧ Modeling on fog, and rain and snow roll-up is needed. ⑨ Similar verified

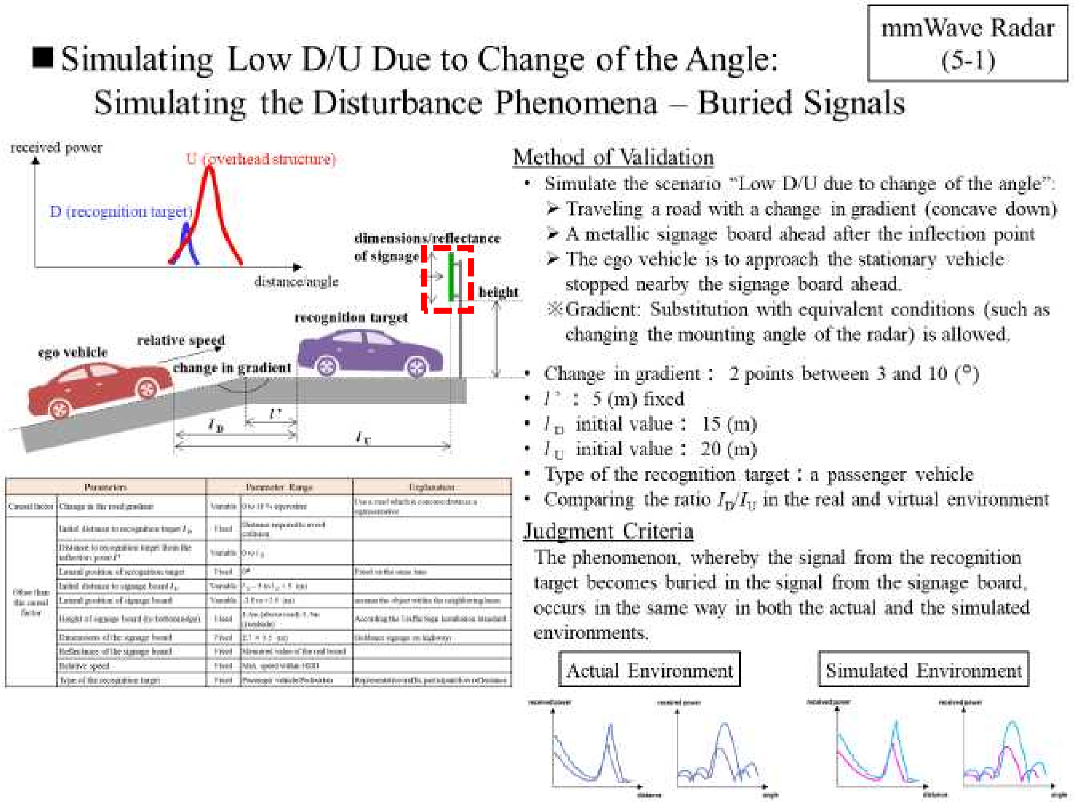
8/9 items have been verified.
Confirmed that critical use cases for each sensor can be evaluated with DIVP®-Sim.

Source : Kanagawa Institute of technology

【A】Example of basic principles verification

Measure and analyze the reflection intensity depending on the position and orientation of Radar and signage to determine the specific conditions for the occurrence of strong reflections.

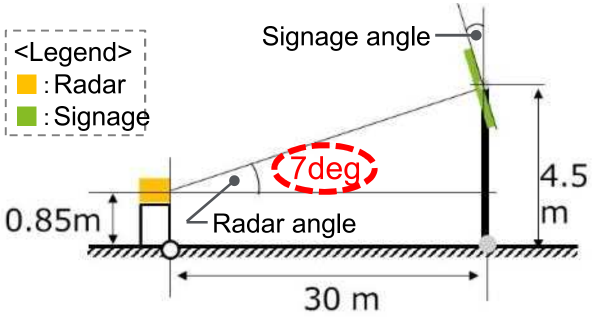
Radar - Low D/U (change of angle) <Basic principles verification>

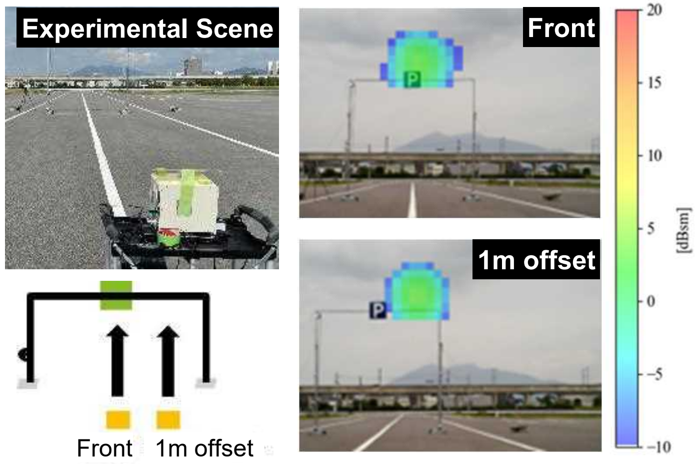


JAMA guideline

■Experiment overview

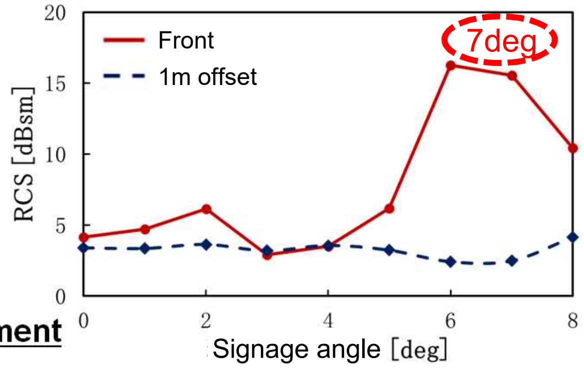
- Verify conditions for measuring strong reflections that may cause signal buried by changing the angle of the sign.





■Experiment results

- When facing forward, strong reflections were observed around 7 degrees, which is the tilt angle at which Radar and the sign are directly opposite each other.
- At 1 m offset, constant regardless of tilt angle (reflection from horizontal pole is dominant).



DIVP® experiment

Confirmed that radar and signage must be directly opposite each other for strong reflections be occurred.

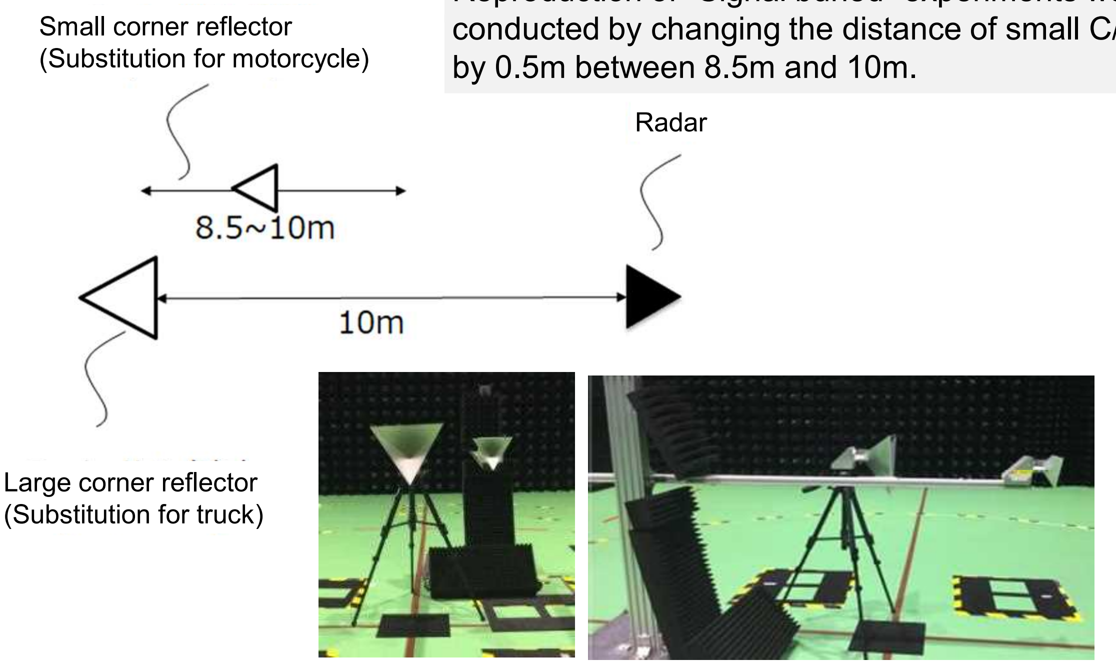
Source : Kanagawa Institute of technology

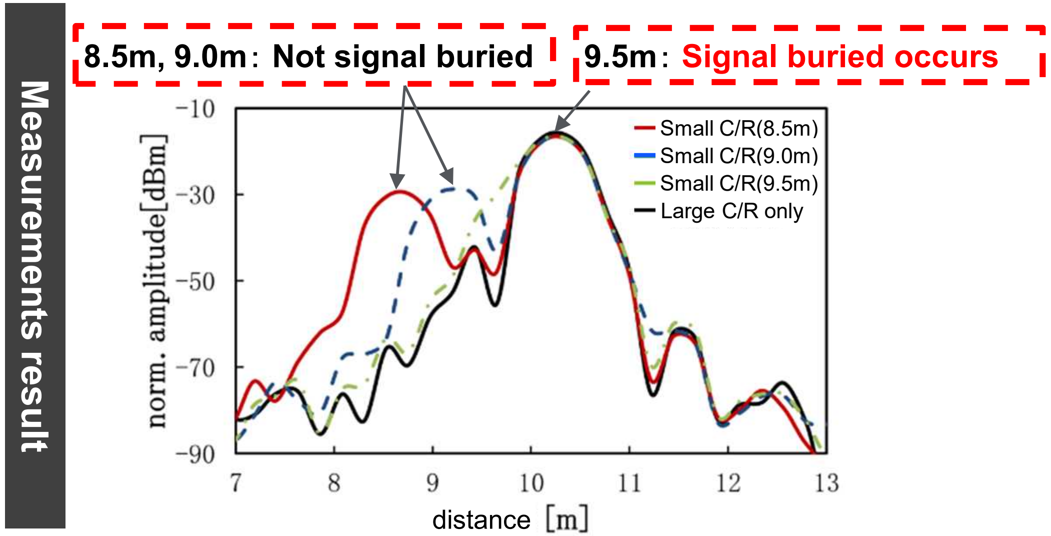
【B】Example of basic principles verification
Reproduction of "Signal buried" in the laboratory confirms reproduction by simulation at the principle level.

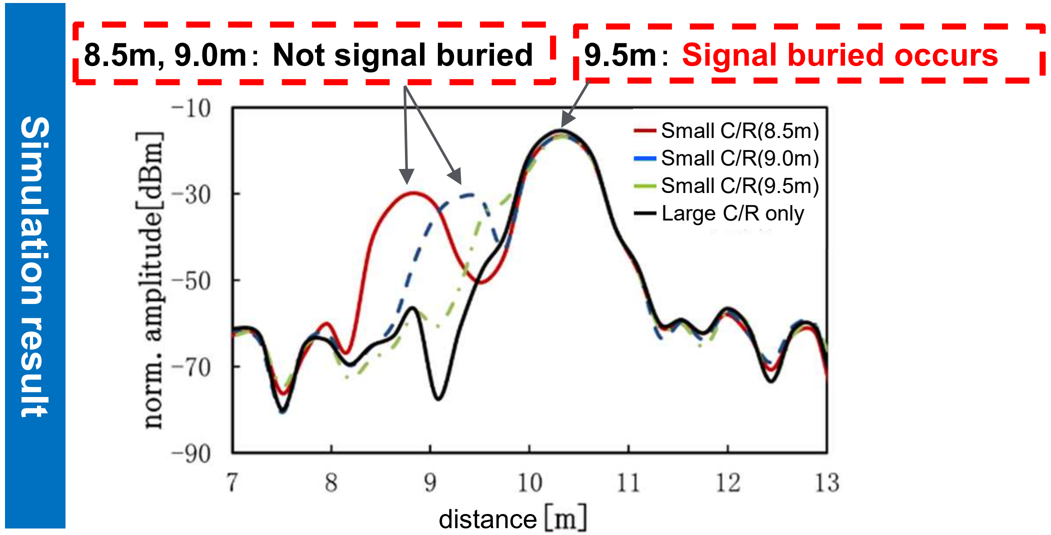
Radar - Large difference of signal <Basic principles verification>

■Experiment overview

■Note:
Reproduction of "Signal buried" experiments were conducted by changing the distance of small C/R by 0.5m between 8.5m and 10m.







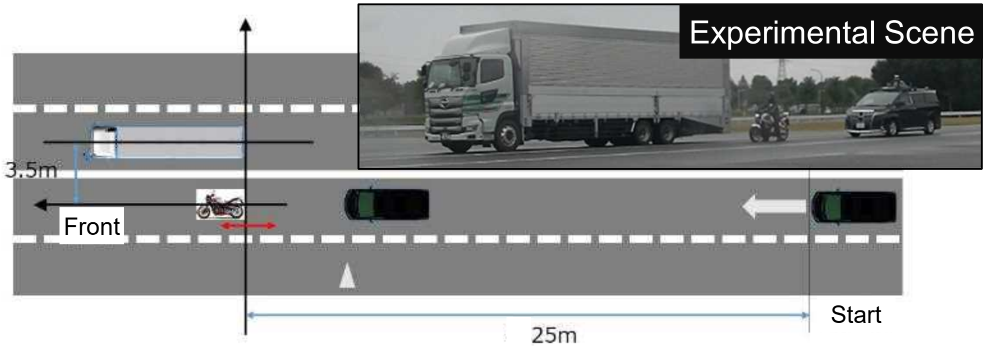
Confirmed that actual measurement and simulation results are consistent and that the "Signal buried" phenomenon can be reproduced.

Source : Kanagawa Institute of technology

【B】Example of Reproducibility verification
Reproduction experiments using trucks and motorcycles on a test course were conducted, and the specific conditions for the occurrence of sensor weakness phenomenon were completed.

Radar - Large difference of signal <Reproducibility verification>

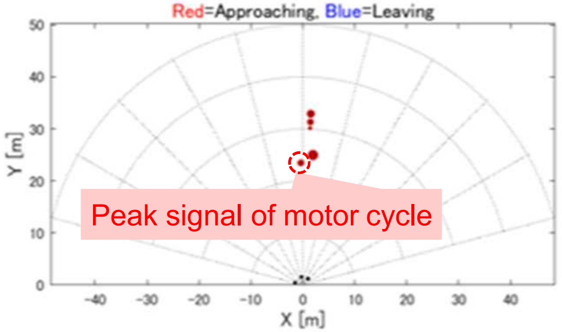
■Experiment overview

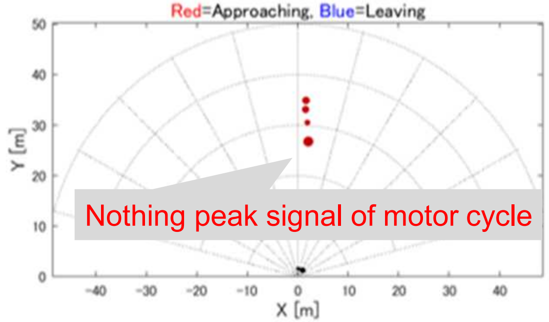


- Trucks and motorcycles are to be stationary for safety reasons.
- Analyzes the conditions that cause "Signal buried" by measuring multiple patterns of truck and motorcycle positioning.

> - Based on the analysis of the experimental data, the conditions for the occurrence of "Signal buried" by trucks and motorcycles have been specified.
> - By creating scenarios for these conditions and modeling the reflective characteristics of trucks and motorcycles, it is possible to reproduce "Signal buried" for the real objects.

■Experiment results

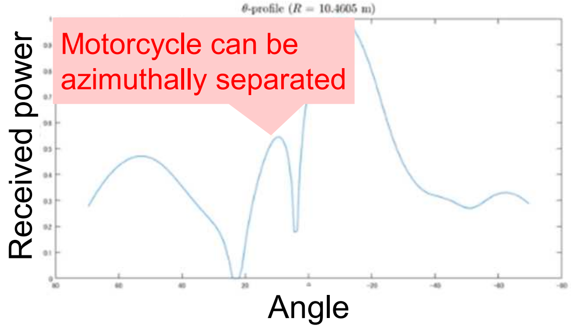


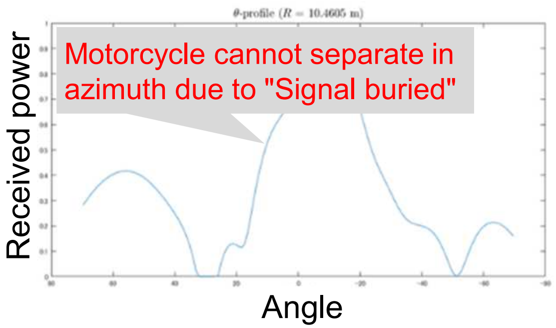


Distance between truck and motorcycle end				
+0.5m	0.0m	-0.5m	-1.0m	-1.5m
×	×	△	○	○

<Legend (about peak signal of motor cycle)>
× : Nothing
△ : Existing but flickering
○ : Existing

Specified the conditions of "Signal buried" occurs by the angle profiles.





Source : Kanagawa Institute of technology

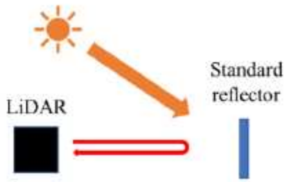
【C】Example of Reproducibility verification
Reproduction of “Noise in reflected light” using actual sunlight on a test course.

LiDAR - Noise in reflected light <Reproduction experiment>

■ **Noise：Average error and dispersion of the range**

LiDAR (F.2.4.2.1)

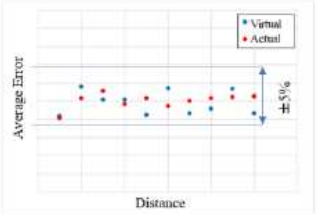
This validation corresponds to the evaluation scenario of ‘disturbance light originated in reflected light’ written in E.3.2.2.2.

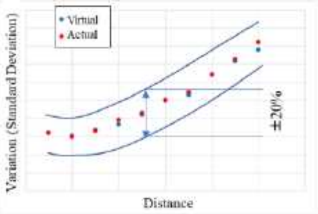


Method of Validation
Place a standard reflector in front of the LiDAR and vary the distance to measure the average error and standard deviation, to ensure the difference to the actual measurement falls within the judgment criteria.

Causal Factors			Causal Factor Parameter	Range	Basis (or reasons)
Space	Light source	Halogen lights, etc.	Elevation angle	20 to 90 degrees	i.q. Annex.E
			Azimuth angle	-180 to -150, 150 to 180 degrees	± 30 deg in the rear of the ego vehicle (traveling direction = 0 deg)
			Brightness	XX～YY W/mm²	The irradiance value on the target surface within the angular condition of the sun above is used in case of using a Halogen light etc. The parameter range is set within the LiDAR’s wavelength range.

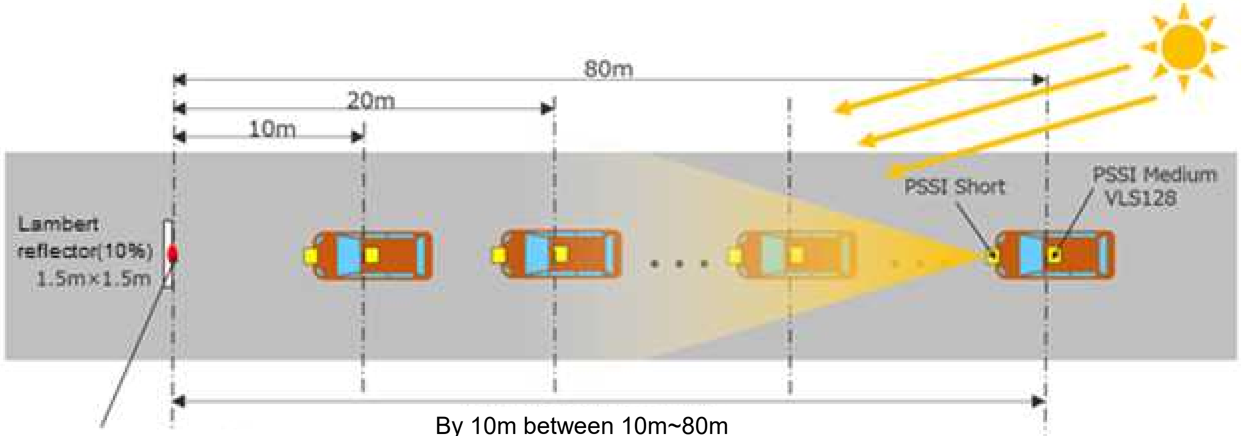
Judgment Criteria
Average error : within ±5% of distance to a target
σ : within ±20%





- The validation should be carried out in the condition of the maximum irradiance on the target surface within the parameter range above.
- A validation with fixed incidence is also acceptable if the noise level is properly reproduced.

JAMA - guideline



Light power on the target surface is measured with an optical power meter.

■Note:
- [1]: Daytime: 10:00 - 15:00 (several hours before and after the sun is in the south)
- [2]: Night time: After sunset（Obtained for comparison with [1])
- Weather: Clear sky
- Sun position: hitting the target from behind LiDAR

DIVP® - experiment

Source : Kanagawa Institute of technology

【C】Example of Reproducibility verification
Comparison of actual measurement and simulation evaluation results was conducted to confirm the reproducibility of the simulation.

LiDAR - Noise in reflected light <Reproducibility verification>

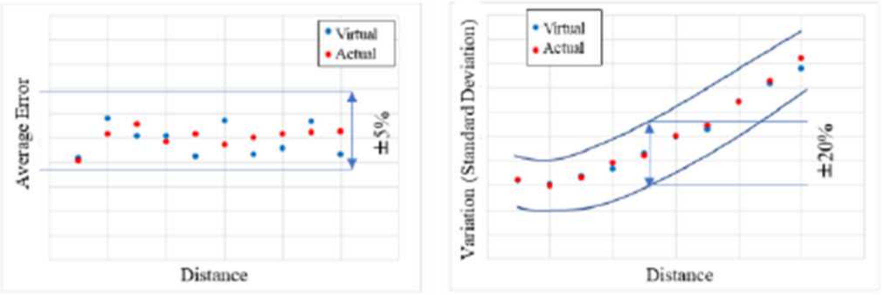
■Noise: Average error and dispersion of the range

Method of Validation

Place a standard reflector in front of the LiDAR and vary the distance to measure the average error and standard deviation, to ensure the difference to the actual measurement falls within the judgment criteria.

Judgment Criteria

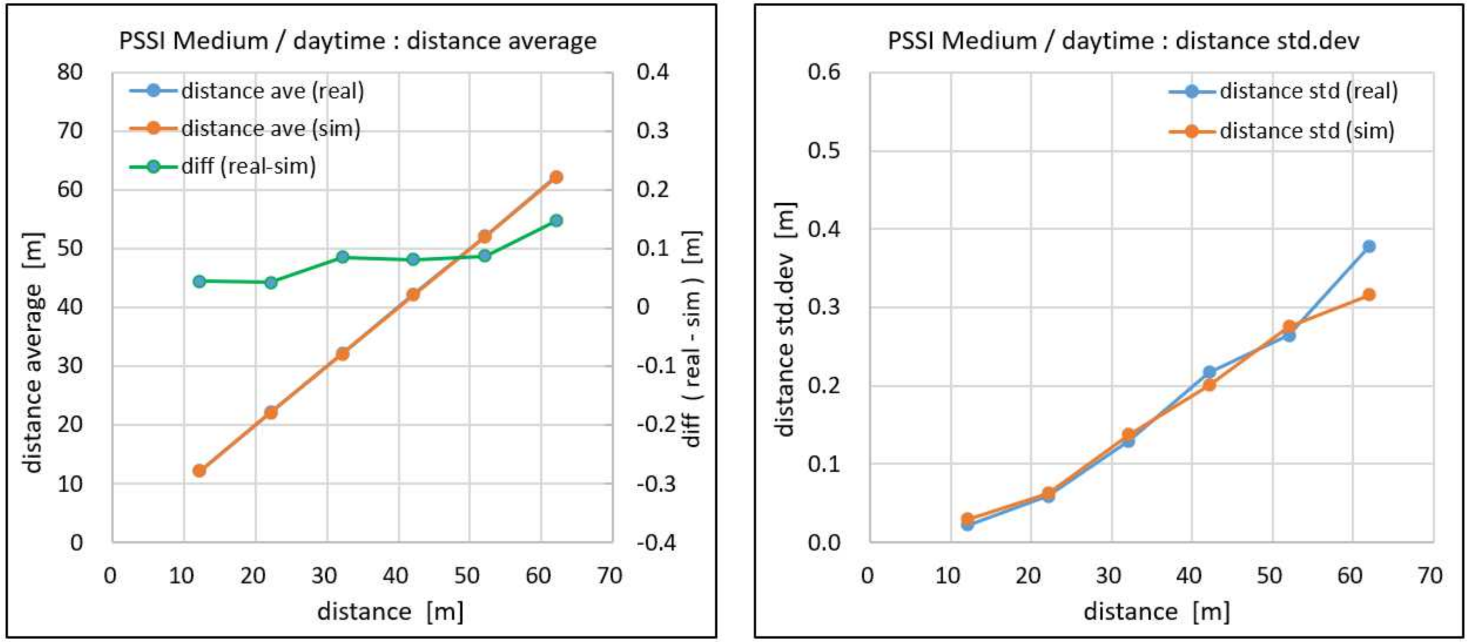
Average error : within ±5% of distance to a target
σ : within ±20%



JAMA - guideline

Distance: Average

Distance: Standard deviation



DIVP® - Simulation reproducibility verification results

- Average error: +0.38% at most.
- Standard deviation: -16.4% at most.

➡Both items were within the judgment criteria, reaffirming the effectiveness of DIVP®'s feature of precise skylight reproduction.

Source : Kanagawa Institute of technology

For simulation reproduction of sensor weakness phenomenon, verification by stepping up from basic principles to reproducibility and narrowing down scenario conditions are important. In addition to recognition performance limit evaluation, we will continue to study its use in AD/ADAS system design and ODD verification.

Simulation Reproduction Process of Sensor weakness phenomenon.

F/B to AD/ADAS system design.

Experimental vehicle

AD/ADAS system

Sensor: Camera, LiDAR, Radar

Recognition Software

FOT data

- Sensor weakness phenomenon

ODD requirements

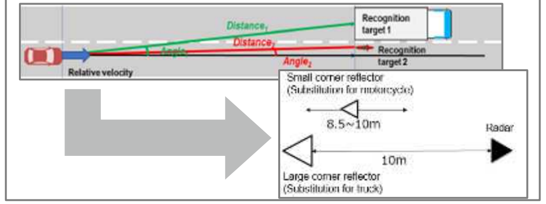
- Requirement to avoid sensor weakness phenomenon.

F/B to ODD requirements

Identification of problem phenomenon

■**Action items/output**

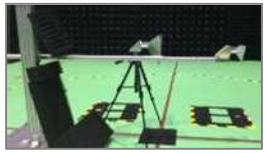
- Principle analysis of sensor weak phenomenon (environment/spatial/sensor)
- Concretization of experimental and measurement methods for verification of principle.

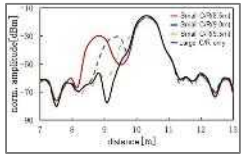


Basic principle model construction and verification

■**Action items/output**

- Conducting experiments and measurements, and analyzing results
- Basic principle model building and validation of environment/spatial/sensor.
- Concretization of experimental and measurement methods to verify reproducibility in actual vehicles.





Reproducibility verification

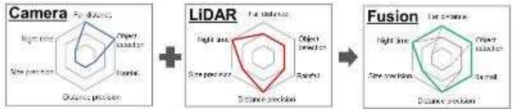
■**Action items/output**

- Conducting experiments and measurements, and analyzing results
- Narrowing down the conditions of sensor weakness phenomena, and scenario implementation.
- Model extensions that take into account the actual traffic environment (e.g., measurement of reflection characteristics)
- Reproducibility verification

Sensor weakness assessment and countermeasures.

■**Action items/output**

- Recognition performance limit evaluation of AD/ADAS systems in sensor weakness conditions.
- Study of sensor performance requirements and sensor Fusion.
- Vilification of ODD requirements.



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

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

Test course

Daiba

Metropolitan Expressway C1

Passenger vehicles

Traffic signal

Pedestrians and their belongings

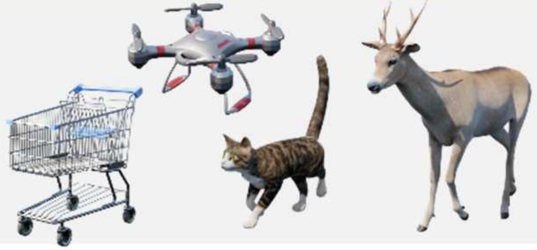
Motorcycles and special vehicles

NCAP dummies

Traffic signs and construction equipment

Large vehicle (including towing)

Obstacles and animals

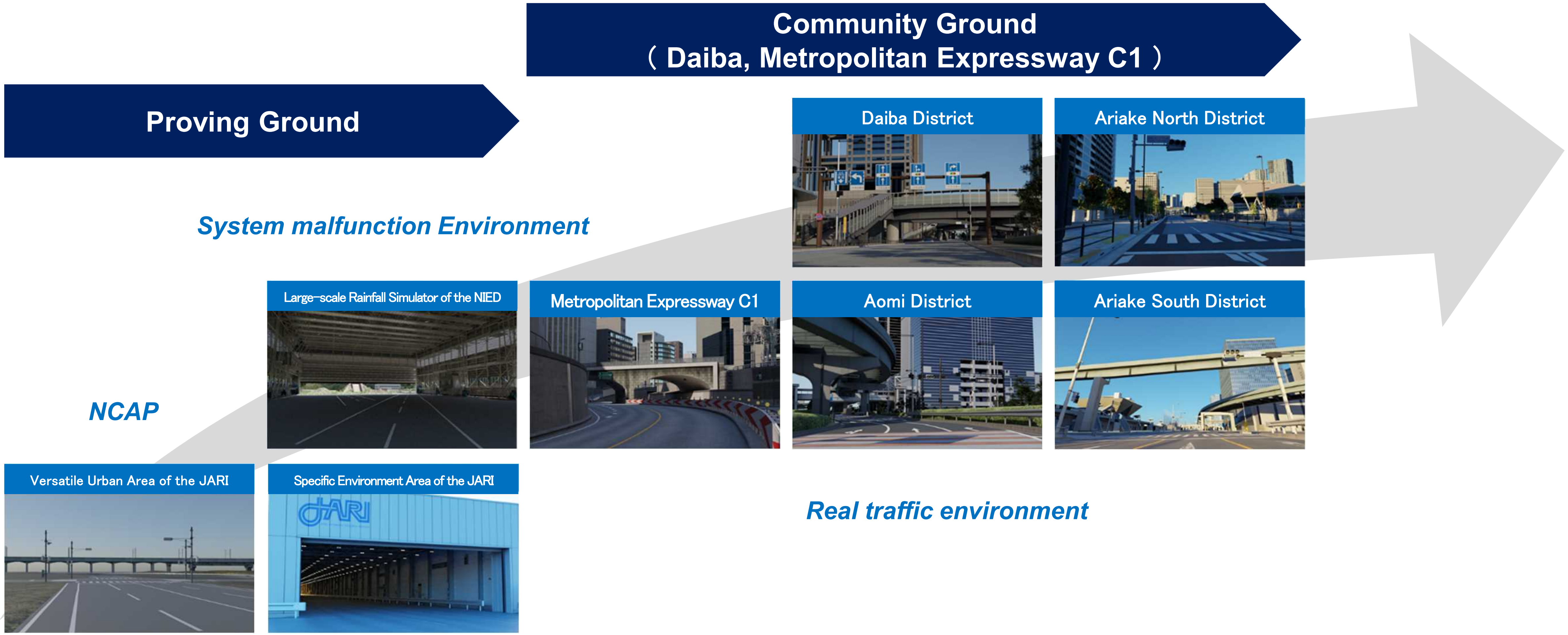


Source : MITSUBISHI PRECISION CO.,LTD.

Virtual Community Ground to be constructed to evaluate sensor malfunctions in a real traffic environment. It reproduces sensor malfunctions due to surrounding structures.

Development Virtual PG/CG

MITSUBISHI PRECISION CO.,LTD.

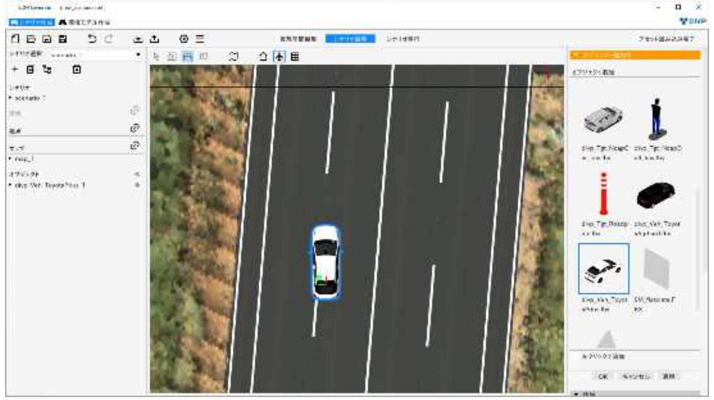


Source : MITSUBISHI PRECISION CO.,LTD.

Space Design Model Generator (SDM Generator) creates and manages scenarios for DIVP® simulators and assign a DIVP® material (reflectance property) to an asset.

Key Features of SDM Generator

MITSUBISHI PRECISION CO.,LTD.

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

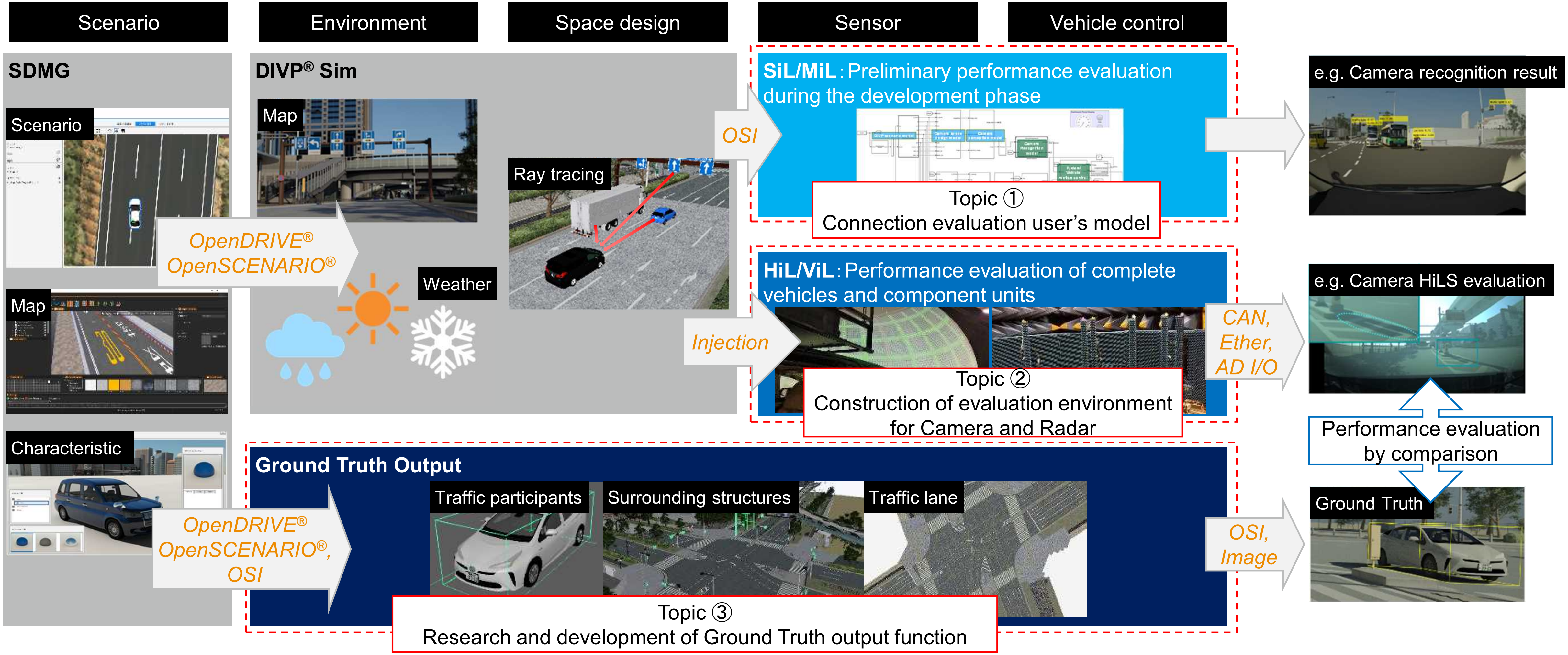
SDM Generator creates environment models and scenarios for DIVP® simulators by placing vehicles and targets in virtual space environments.

Source : MITSUBISHI PRECISION CO.,LTD.

DIVP

Conducted research on SiL/MiL/HiL/ViL※ and Ground Truth to systematize AD system evaluation system Developed DIVP® standard I/F and validated their practicality along with I/F studies such as ASAM

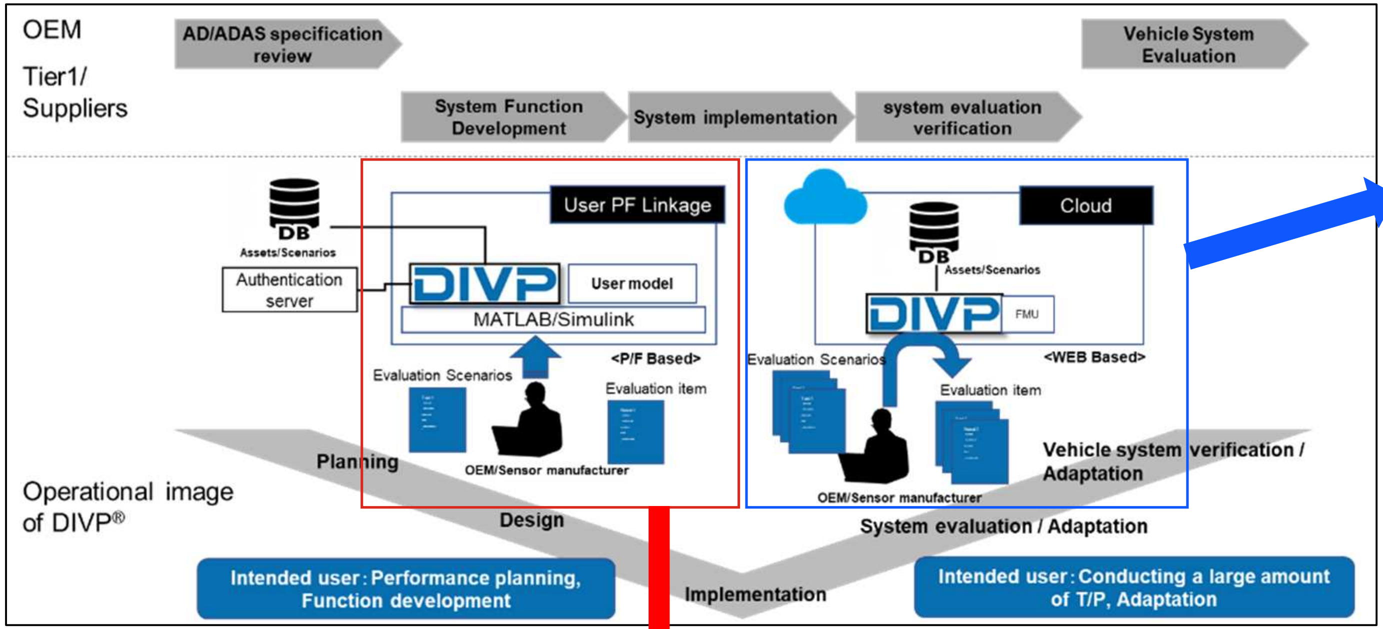
Overview of evaluation system based on Simulation

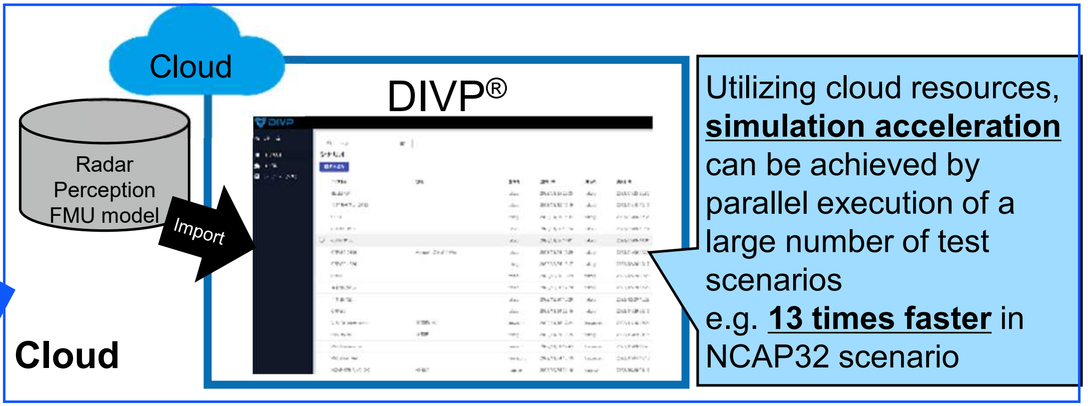


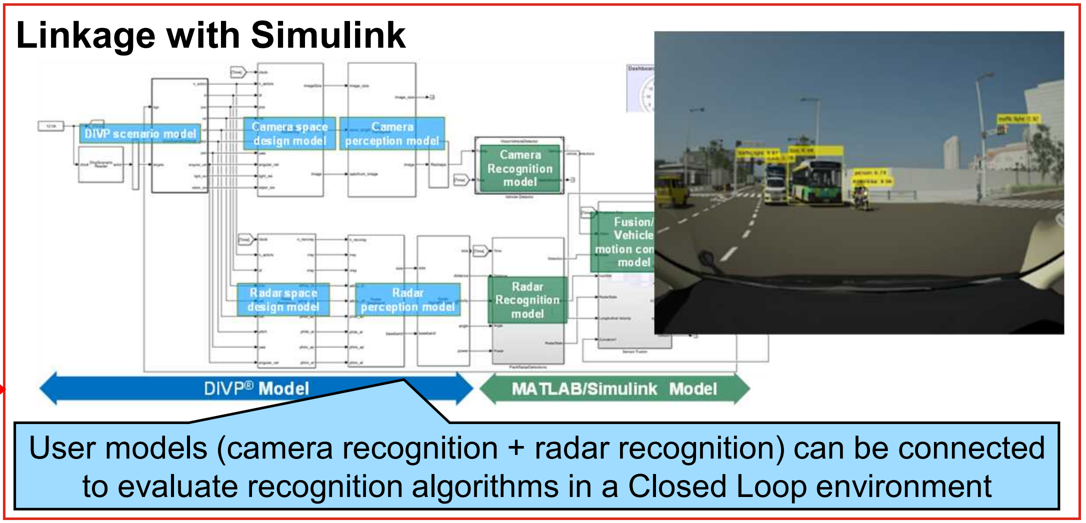
Source :Kanagawa Institute of technology, MITSUBISHI PRECISION CO.,LTD, VIVALDI ※SiL: Software in the Loop, MiL: Model in the Loop, HiL: Hardware in the Loop, ViL: Vehicle in the Loop

Verified connectivity in MATLAB Simulink and cloud environment (FMU models) to improve connectivity with user models such as sensor recognition and Fusion models

SiL/MiL simulator system according to development phase





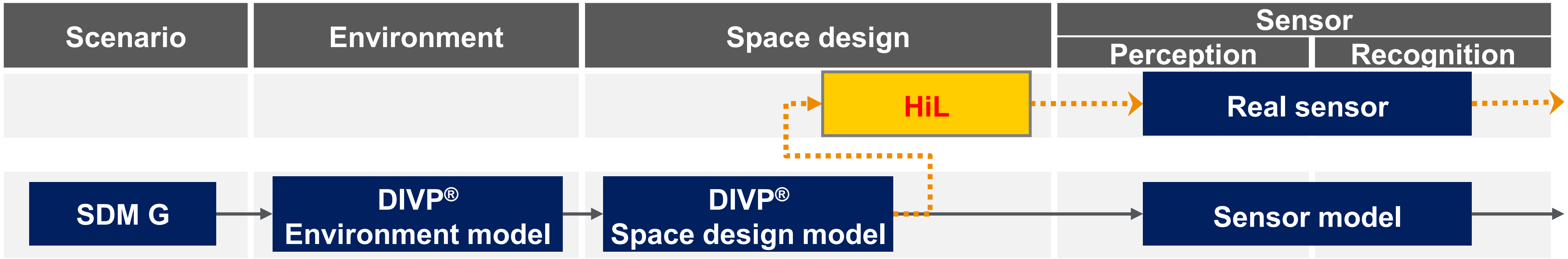


Verified that simulation evaluation including Closed Loop is possible by connecting Simulink and FMU model to DIVP®
Utilizing cloud computing resources, we have achieved simulation acceleration for a large number of test patterns

Source :Kanagawa Institute of technology

Constructed and evaluated HiL environment that can be evaluated while mounted on an actual vehicle Mono camera evaluation has been completed and Radar will be promoted in Japan-Germany collaboration

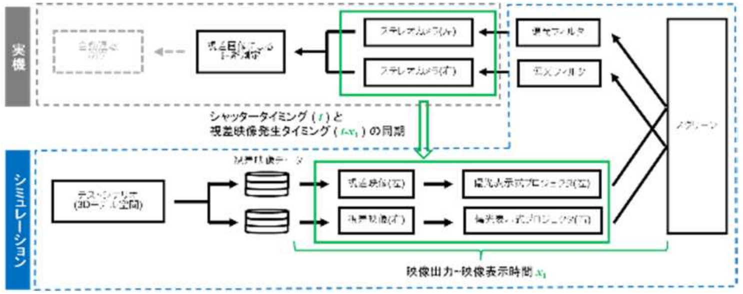
Establish Camera and Radar HiL/ViL environment



Camera HiL

Constructed a spherical wide-angle screen that allowed evaluation of mono camera, and completed evaluation of consistency with the actual mono camera

Considering a system where actual stereo camera can be evaluated



Radar HiL

AVL(Germany)

Constructing a system where horizontal targets can be evaluated

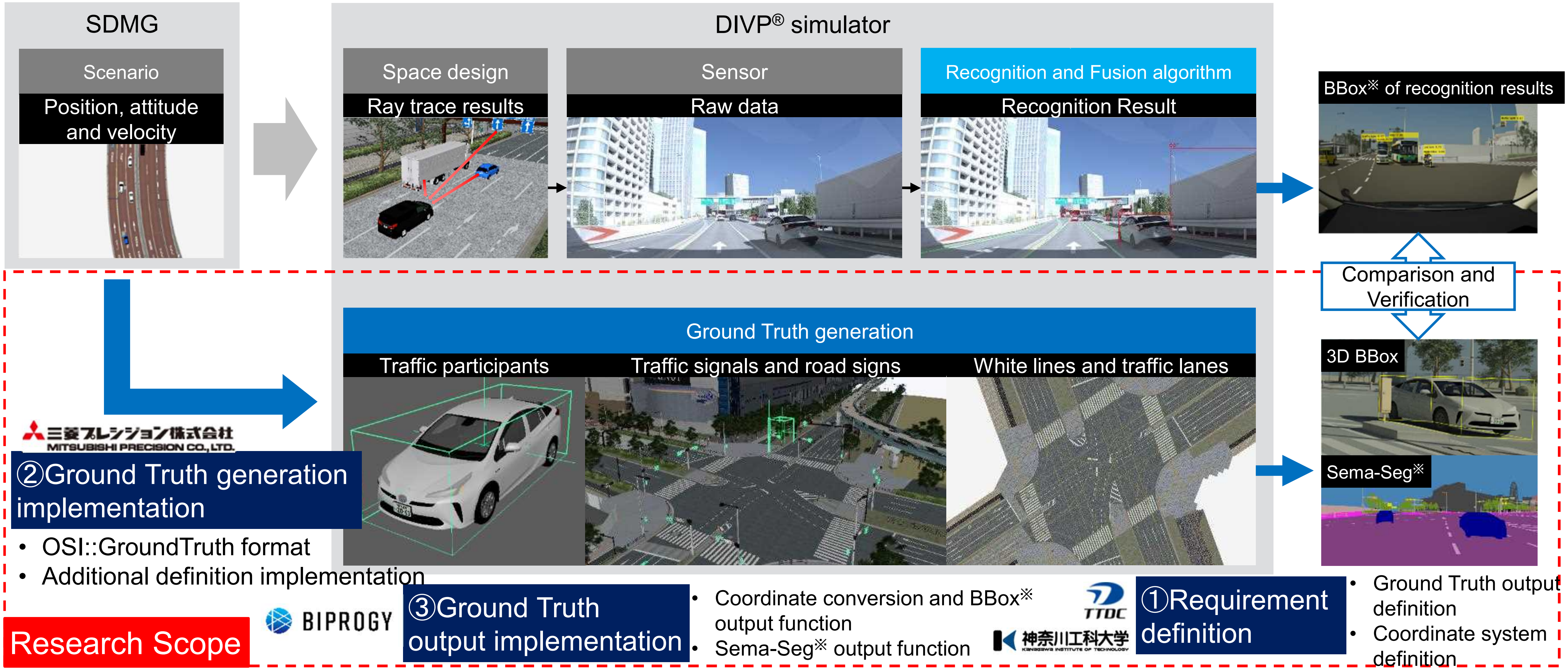
TU Ilmenau

Constructing a system where horizontal and vertical targets can be evaluated

Source :Kanagawa Institute of technology, MITSUBISHI PRECISION CO.,LTD, VIVALDI

Conducted research on Ground Truth output to efficiently evaluate recognition and Fusion algorithms using Simulator Conducted ①Requirement definition, ②Ground Truth generation implementation and ③Ground Truth output implementation based on a survey of international standards

Extension of Ground Truth -Research Scope-

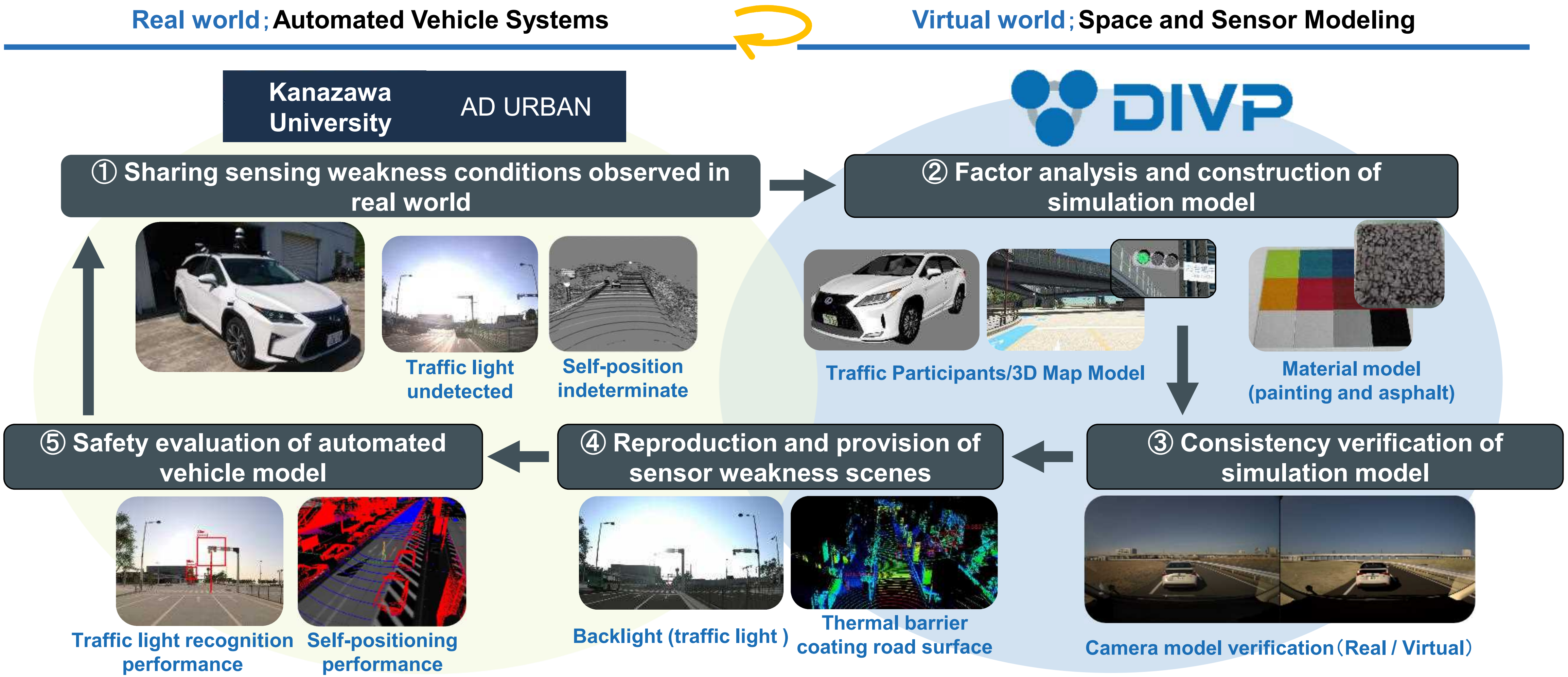


Source : Kanagawa Institute of technology, Toyota Technical Development Corporation, MITSUBISHI PRECISION CO.,LTD. , BIPROGY Inc. ※BBox: Bounding Box, Sema-Seg: Semantic Segmentation

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 research collaboration between DIVP® and AD URBAN projects

AD URBAN 神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY



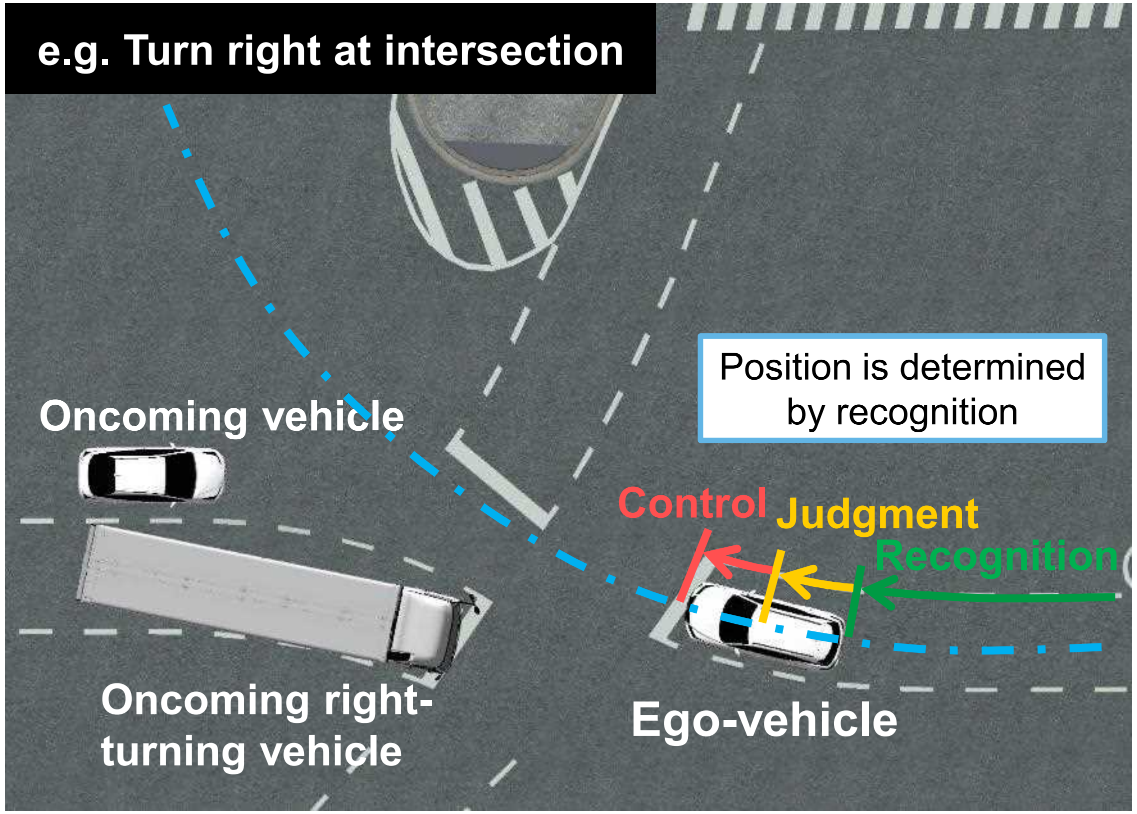
Source : Kanagawa Institute of technology, AD URBAN
*Research on the recognition technology required for automated driving technology (Lv. 3 and 4)

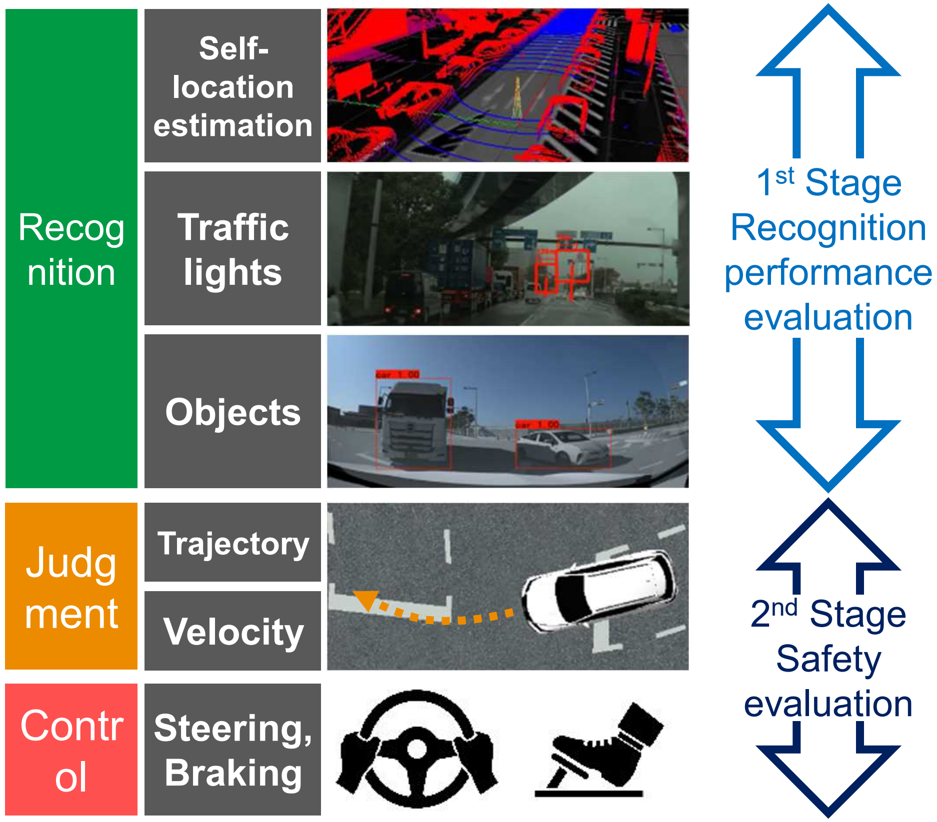
DIVP

Propose a process and metrics based on 2Stage evaluation for intersection right-turn scenario

Importance of 2Stage evaluation

AD URBAN





It is important to evaluate both "Where the recognition was possible (Recognition performance evaluation)" and "Where it was possible to stop (Safety evaluation)"

Source : Kanagawa Institute of technology, AD URBAN

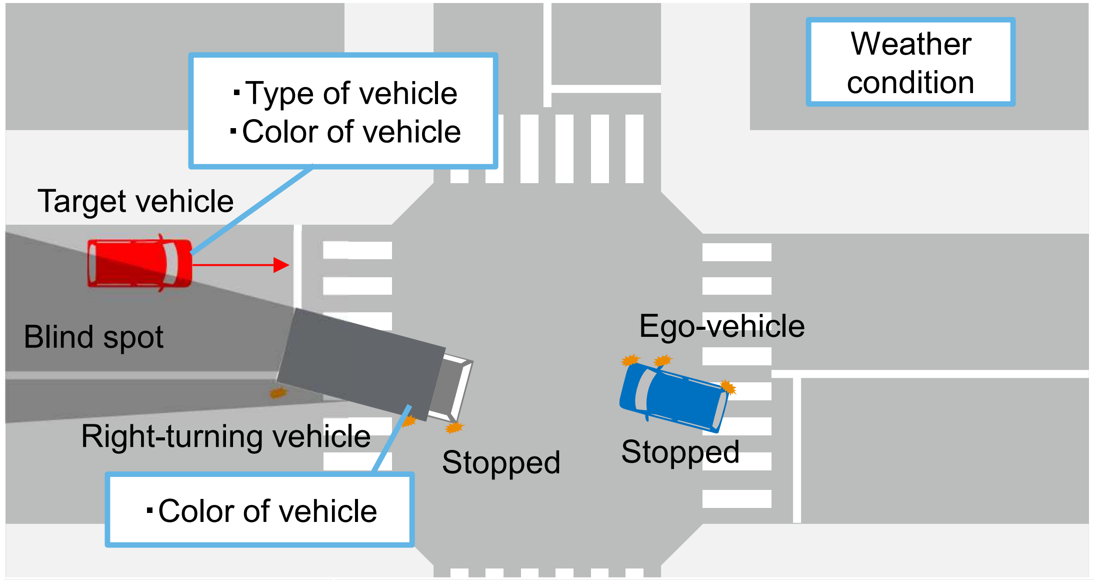
1st-Stage Sensor recognition performance evaluation：Conducted single sensor and Fusion evaluation in a scene where there is a blind spot caused by an oncoming right-turning vehicle, and proposed scenario conditions and metrics

Recognition performance evaluation in intersection scenario

AD URBAN

神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

Scenario image and parameters

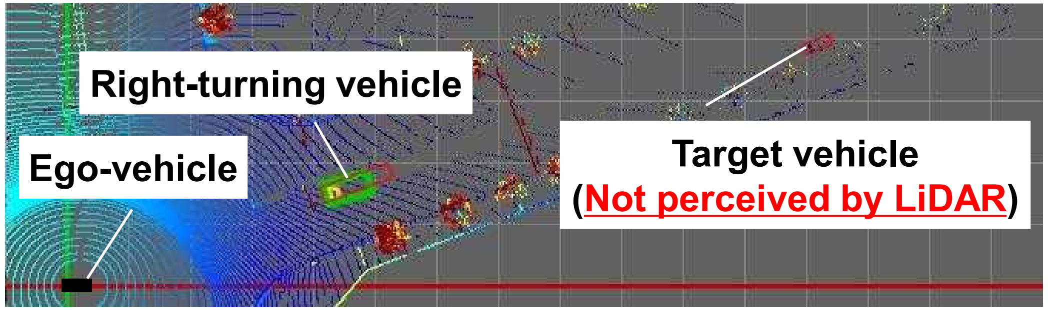


Item	Parameter range
Shield ratio	0~100[%]：Adjusted by the position of target vehicle and right-turning vehicle
Distance	~200[m]：Distance to target vehicle
Target vehicle	9 types of vehicle/8 colors：passenger car, bus and taxi
Weather condition	Sunny(noon and evening), cloudy, rainy and nighttime

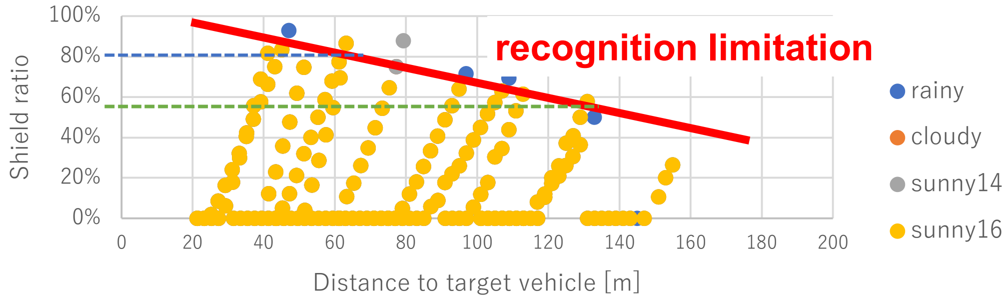
Recognition results by sensor Fusion

Camera

LiDAR



Verification result



Source : Kanagawa Institute of technology, AD URBAN

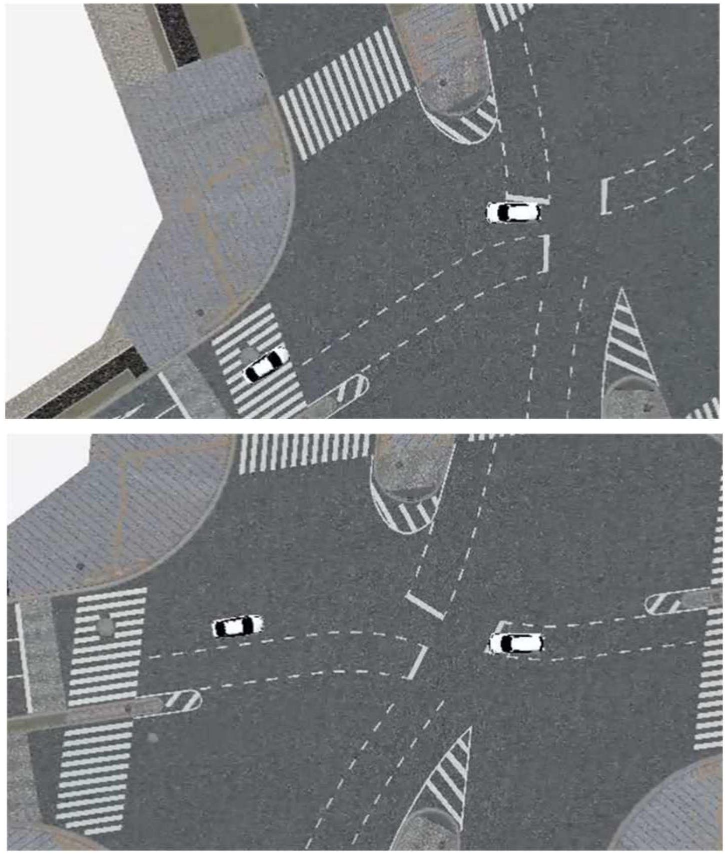
2nd-Stage Vehicle safety evaluation：PET※, which indicates the time margin against collision, was considered as an indicator of safety
Organized metrics for the real traffic environment by making safety implications of PET

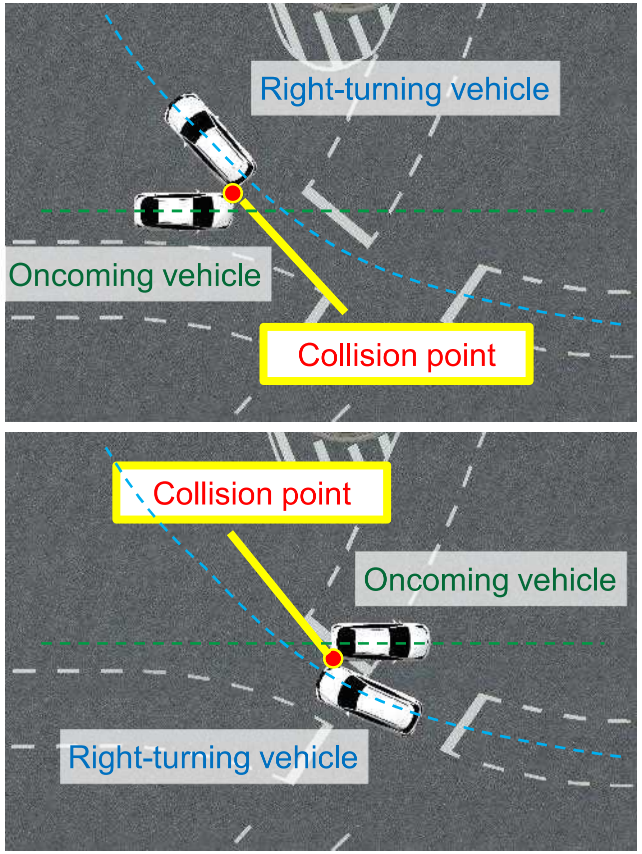
※Post Encroachment Time

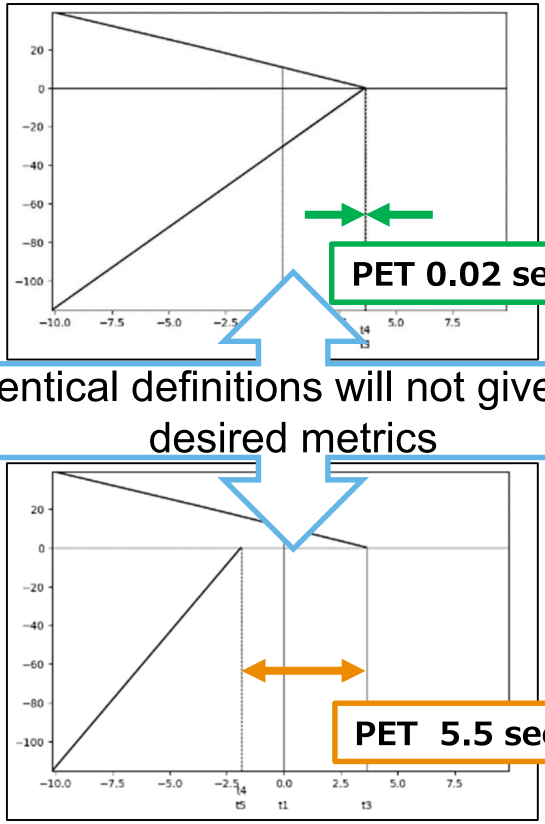
Differences in PET due to traffic conditions

SAKURA | AD URBAN | 神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

Right-turning car	Vehicle movement (DIVP)	Trajectory and Collision point	PET
Goes first			PET 0.02 sec
Goes after			PET 5.5 sec





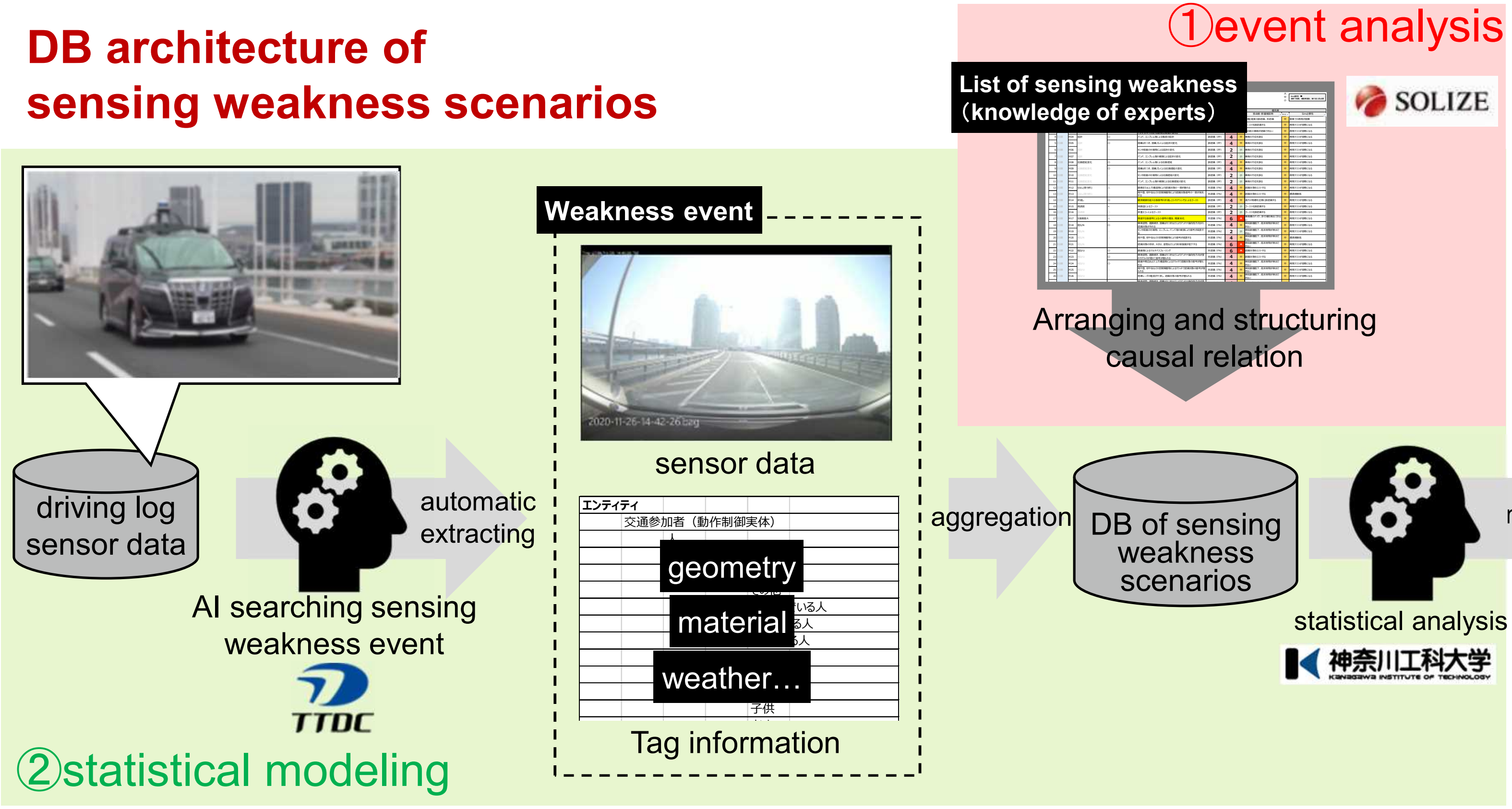


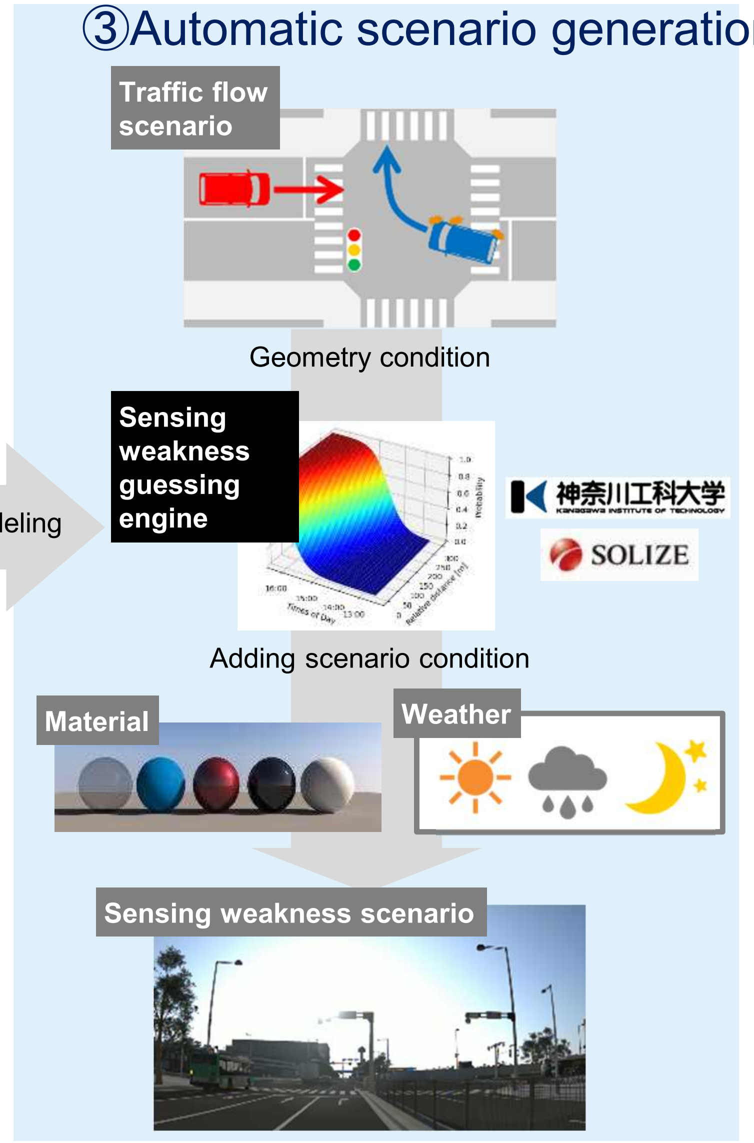
Identical definitions will not give the desired metrics

We will organize the definition of the metrics according to the situation and validate them using Sim

Source : Kanagawa Institute of technology, AD URBAN, SAKURA

Scenarios to evaluate sensor : sensing weakness scenarios are automatically generated based on event analysis and statistical model, not but wisdom of experts or trial-and-error of measurement experiences





Issue : Scenario generation to evaluate sensors properly is difficult.

Solution : Automatic scenario generation method based on sensor weakness event analysis and modeling is constructed.

Source : Kanagawa Institute of technology, Toyota Technical Development Corporation, SOLIZE Corporation

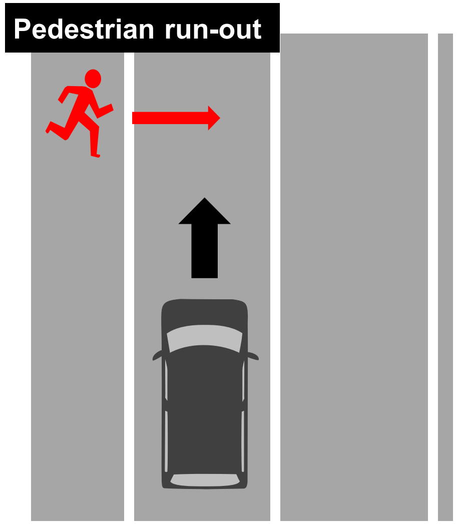
DIVP

The function to create sensing weakness scenarios under disadvantageous environmental condition and condition of target using traffic flow scenarios (including pedestrian behavior, vehicle behaivior, road shape etc.) as input is studied.

e.g.) Generating sensing weakness scenario under back light condition using sensing weakness event DB.

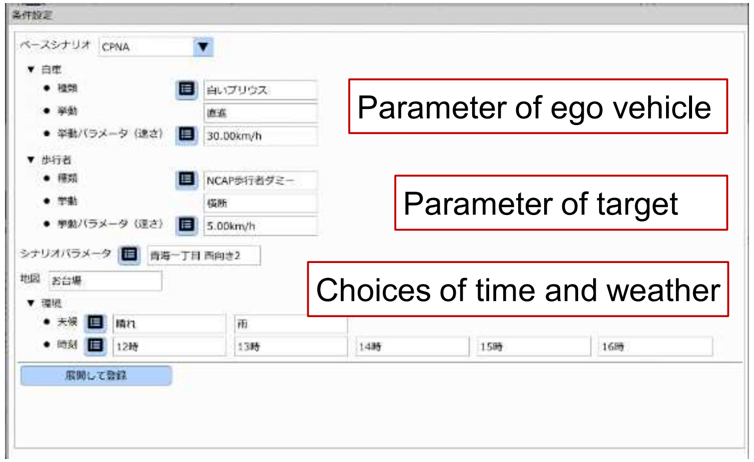
TTDC SOLIZE 神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

Traffic flow scenario



Setting of geometric condition

Sensing weakness guessing engine + Scenario generator

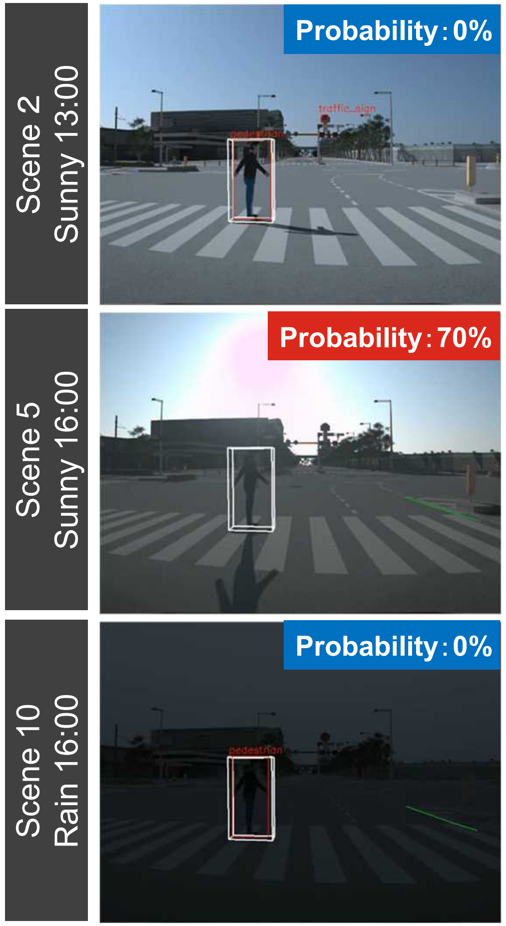


詳細	シーン名	自車	自車速度	交通参加者	交通参加者...	環境	衝突点	白飛び（halation）...
	シーン 1	黒いアルファー	30.00km/h	NCAP歩行者ダミー	5.00km/h	晴れ 12時	青海一丁目 西向き	0%
	シーン 2	黒いアルファー	30.00km/h	NCAP歩行者ダミー	5.00km/h	晴れ 13時	青海一丁目 西向き	0%
	シーン 3	黒いアルファー	30.00km/h	NCAP歩行者ダミー	5.00km/h	晴れ 14時	青海一丁目 西向き	1%
	シーン 4	黒いアルファー	30.00km/h	NCAP歩行者ダミー	5.00km/h	晴れ 15時	青海一丁目 西向き	11%
	シーン 5	黒いアルファー	30.00km/h	NCAP歩行者ダミー	5.00km/h	晴れ 16時	青海一丁目 西向き	70%
	シーン 6	黒いアルファー	30.00km/h	NCAP歩行者ダミー	5.00km/h	雨 12時	青海一丁目 西向き	0%
	シーン 7	黒いアルファー	30.00km/h	NCAP歩行者ダミー	5.00km/h	雨 13時	青海一丁目 西向き	0%
	シーン 8	黒いアルファー	30.00km/h	NCAP歩行者ダミー	5.00km/h	雨 14時	青海一丁目 西向き	0%
	シーン 9	黒いアルファー	30.00km/h	NCAP歩行者ダミー	5.00km/h	雨 15時	青海一丁目 西向き	0%
	シーン 10	黒いアルファー	30.00km/h	NCAP歩行者ダミー	5.00km/h	雨 16時	青海一丁目 西向き	0%

Probability of halation

Output of sensing weakness scenario

Results of DIVP® Sim



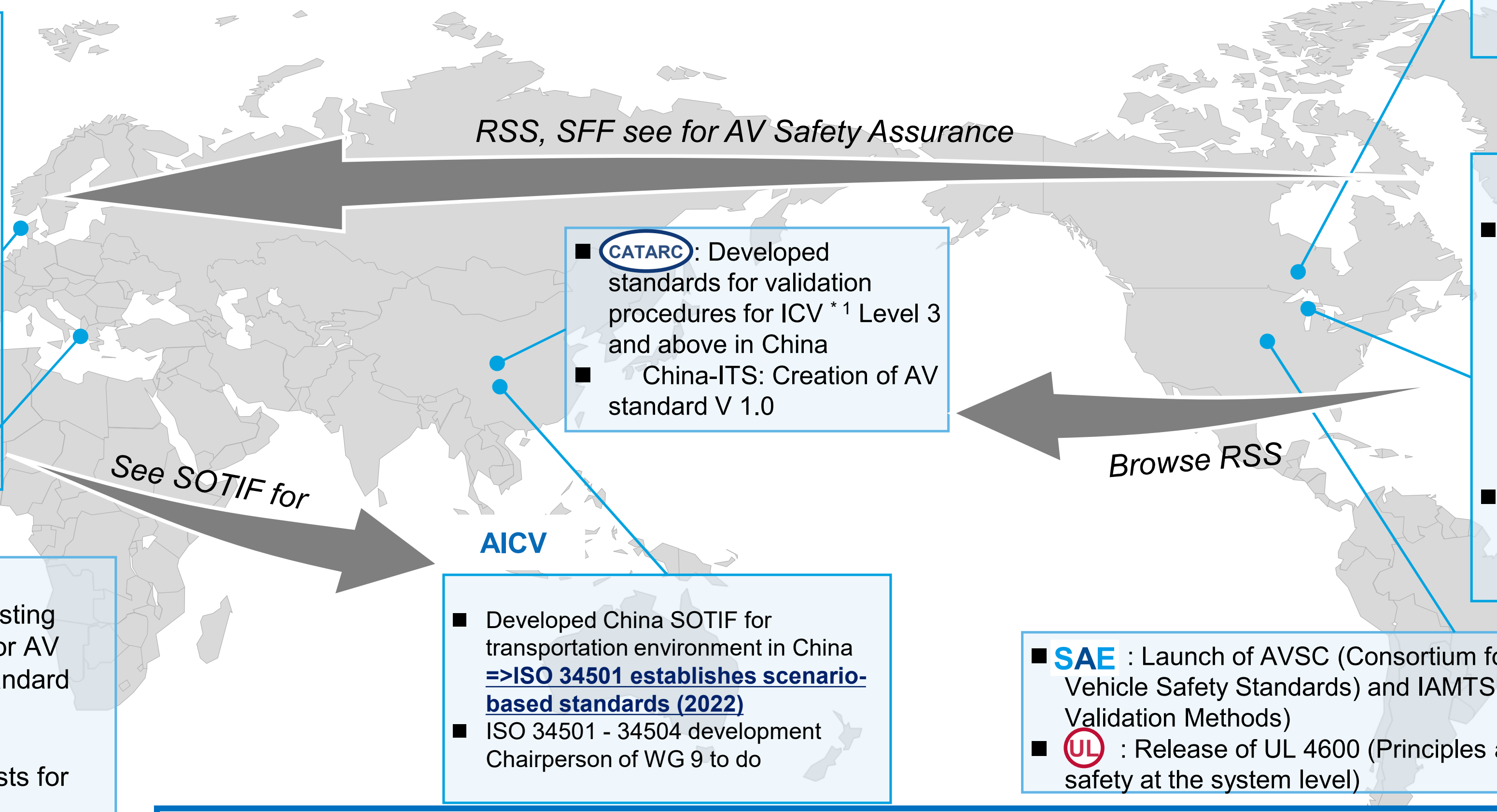
Source : Kanagawa Institute of technology, Toyota Technical Development Corporation, SOLIZE Corporation

DIVP

International collaboration and standardization

Various methods of AD safety assurance have been proposed in Europe and the United States, and the appearance of a crowd competition
In SIP-adus, cooperation with the Pegasus family of Germany on a practical level takes shape, and cooperation with the United States is mentioned

Global standards and standardization (related to Safety Assurance)



PEGASUS ASAM SETLevel 4to5 VVM Project

- EU: Consideration of AV Safety Envelope e-Approach to EC
- Germany:
  - Germany as chair **leads ISO 21448 (SOTIF) and ISO 5083 development (continuation of SaFAD's ISO 4808)**
  - Government-led projects: PEGASUS and ongoing V & VM and Set Level 4 to 5. Collaborating with Japan to promote ASAM standardization at VIVID

Third Party Appraisers

- TUV: Developed related testing methods and standards for AV
- ASAM : Developing a standard for scenario-based safety reasoning
- EURO NCAP : Conduct rating tests for LKA and ACC

- CATARC: Developed standards for validation procedures for ICV *1 Level 3 and above in China
- China-ITS: Creation of AV standard V 1.0

AICV

- Developed China SOTIF for transportation environment in China **=>ISO 34501 establishes scenario-based standards (2022)**
- ISO 34501 - 34504 development Chairperson of WG 9 to do

- NHTSA : Creating "Framework for Automated Driving System Safety"
- IEEE : IEEE P 2846 (RSS-based standard) released

Consider RSS

- intel: Move forward with the release of SaFAD based on RSS and various rulemaking
  - Development of SaFAD **=>ISO 4804** released
  - Development of RSS **=>IEEE P 2846** Released **=>See FRAV and VMAD under GRVA in WP 29**
- NVIDIA : Development of the Safety Force Field (SFF)

- SAE : Launch of AVSC (Consortium for Development of Self-Driving Vehicle Safety Standards) and IAMTS (Alliance for Standardization of Validation Methods)
- UL : Release of UL 4600 (Principles and processes for assessing safety at the system level)

In addition, an Industry Communication activity was launched to organize the jumble of standard proposals in the IEEE.

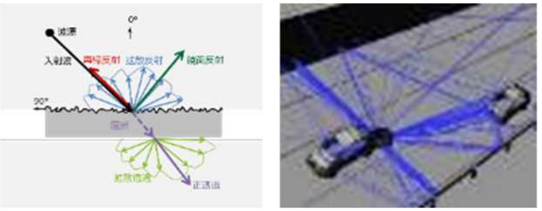
Source: Report of the 2022 regular meeting of Team 0

DIVP

When aiming for two validations, a physical Sim that evaluates the perception and perception of sensors, etc., a true Sim that evaluates the position of the vehicle, and their linkage are the essence of safety validation, DIVP® focuses on physical Sim and produces research results

Validation system required for AD safety assessment

Tool Structure	What to evaluate (Scenario)	Validation technique	Criteria (Metrics)
DIVP Physical Sim	■ **Sensing weakness scenarios** based on expert knowledge	■ **Consistency verified virtual space** based simulation	■ **Virtual Validation of Recognition Performance** based on a Consistency Model of Measurable Perceptual Outputs
True value Sim	■ **Geometry scenarios** based on analysis of accident data, etc.	*Combining and utilizing each method* ■ HILS ■ Actual validation	■ **Judging Accident Tolerance** by Accurate Prediction of Vehicle Position
Essence	*Weighting scenarios based on risk x frequency x detectability*	*Replacing and streamlining real-world validation using congruent verified Simulation*	*Vehicle behavior and output and judgment of sensor perception which is a rule of AD system*



DIVP® Elaborate Physics Sim pioneers, can lead in international standardization

Source: Fiscal 2021 year-end report

In this fiscal year, the study and standardization activities based on the framework of VIVID were conducted based on the collaboration between Japan and Germany
In 23 and beyond, we plan to expand our partnership with the United States and continue activities to foster social acceptance and implement AD in society

Trends and prospects for standardization of AD technology

Current

	2021	2022	From 2023

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Japan-Europe Partnership — Europe HEADSTART and White Paper published

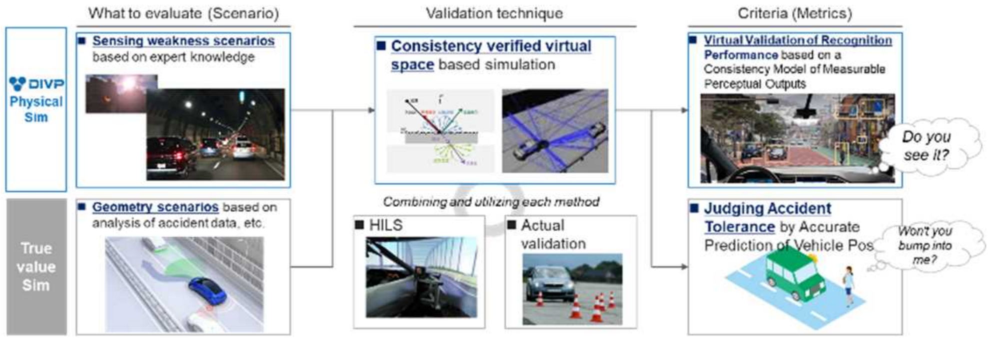
ISO34501 — Presenting a series of safety assessment flows

ISO34502 — **Development of a scenario-based safety assessment framework (led by Japan)**

Framework for AD assessment

ViViD PJ — DIVP & Vi

Reorganized validation framework to ensure "Can you see it or not hit it?" and **Ready to standardize virtual environment I/F** in AD safety assessment



Continuation of Japanese-German VIVID

International cooperation

PEGASUS、VVM

Expanding cooperation with the United States

SAE、UL、IEEE、IHS

Promotion of AD society implementation through collaboration with other research PJ

SAKURA、金沢大学 DIVP SUNRISE

Standardization activities

Initiatives for Standardization Organizations

Started **cooperative activities with standards bodies** such as ASAM

ASAM

- OSI 3.0: Camera sensor I/F — Standardized
- OSI 4.0: Radar I/F — Acceptance of Proposal
- Open SCENARIO®, Open Label — ViViD Agreement

Standardization based on collaboration

ASAM、ISO

Based on our research findings, we participated in various international symposiums and promoted discussions to strengthen international communication and systematize AD-SA. In October, SIP-adus was conducted to share information on international collaboration efforts, results, and market trends

ViViD PJ

Summary of Activities during the Year

★ ***June SafeCAD***

★ *July ARTS2022*

★ *Sept ITS world congress*

★ ***Oct SIP-adus workshop***

★ *Nov International Conference*

ASAM

SIP-9th closure & Next generation

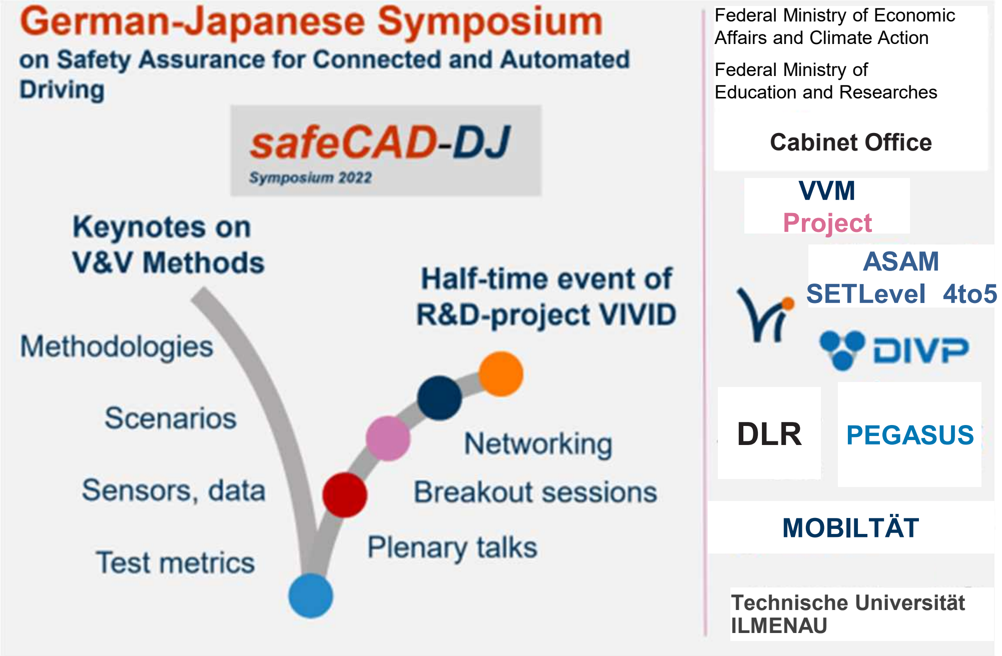
PEGASUS, ASAM, VVM, SETLevel, SAE, bast …

Review the concept of safety assessment through an international symposium with key players from Japan and Germany

ViViD PJ

SafeCAD Symposium (Berlin, June)

German-Japanese Symposium on Safety Assessment of Connected and Automated Vehicles



Sponsor representatives, keynote speakers for related projects, event participants

Mr. Seigo Kuzumaki
SIP-Adus Program Director

Mr. Shigekazu Fukunaga
Director, ITS and Autonomous Driving Promoting Office, METI

Dr. Stefan Mengel
Head of division, electronics and automated driving, **BMBF**

Mr. Reinhold Friedrich
Deputy Head, electronics and automated driving, **BMBF**

Ernst Stöckl-Pukall,
Head of Unit Digitisation and Industry 4.0, **BMBK**

Mr. Benjamin Engel
Global technology manager, **ASAM**

	Japan		Germany
Ministries and Departments	経済産業省	内閣府 Cabinet Office	Federal Ministry for Economic Affairs and Climate Action, Federal Ministry of Education and Research
PJ	DIVP	SAKURA	PEGASUS, ASAM, VVM, SETLevel
Research institutes	神奈川工科大学	TOKYO Univ,	DLR, Univ. Braunschweig, Univ. Darmstadt, Univ. Ilmenau, HAW Hamburg, Hochschule Kempton, Fraunhofer, KIT
OEM			BMW, Mercedes Benz
Megasap			BOSCH, Continental
Vendor	BIPROGY, MITSUBISHI PRECISION CO., LTD.	SOLIZE, TTDC	IPG, AVL, VDI･VDE･IT, Blickfeld

Source: 2022 Team 0 report

DIVP

Many experts and government officials participated from Japan, the U.S. and Europe. Sharing a wide range of information from an overview to specific discussions about regional trends and activities at VIVID

ViViD PJ

SIP-adus: Summary of Plenary Breakout Session

Summary

JAMA TOYOTA NISSAN HONDA DIVP SAKURA	DAIMLER Continental IPG AVL DLR Blickfeld KIT	Univ. ilmenau Hochschule Kempton Univ. Darmstadt Bast PEGASUS VVM SETLevel Univ. Braunschweig Fraunhofer	TRB SAE Automated Vehicle Safety Consortium Berkeley Univ.

- **58 experts and government officials from Japan, the United States and Europe** participated in the Breakout Session
- Japanese and German team leader reports on Keynote Sessions by regional representatives and VIVID activities

Breakout Session

Dr. Hideo Inoue

JP Research approach towards AD-safety assurance

DIVP
神奈川工科大学

- Working with **scenarios, assessment methods, and metrics frameworks** in safety assessment is important to promote standardization at ASAM

Dr. Matthias Hein
Dr. Henning Mosebach

German Research approach towards AD-safety assurance

DLR
VVM
Univ. Ilmenau

- Standardization at ASAM is functionning smoothly by clarifying points that the both commonly have or complement one another through this Japanese-German cooperation

Dr. Steven Shladover

Automated Driving Safety Assurance in the Broader Societal Context

Berkeley Univ.

- It is key for improvement of social acceptance in the US to have evaluation methods and parameters highly consistent with the real driving environment as a result of safety argument based on social needs

- Other lectures on German VV Method, regulatory trends in Europe and Germany, and standardization trends in the United States

DIVP

Safety assessments are becoming more important for the social implementation of automated driving Assessment methods and indicators that are highly congruent with the actual environment play an important role in fostering social acceptance

ViViD PJ

SIP-adus: Validation comments to VIVID

	JAMA, HONDA	Berkeley Univ.
Profile	 Kunimichi Hatano Mr. Chairperson of the Japan Automobile Manufacturers Association	 Dr. Steven Shladover California PATH Program Research Engineer
Summary of remarks	■ The stage for social implementation of automated driving is approaching. In the validation of the safety of automated driving, where the **validation index** is set and where to start is very important because it will be accepted by the traffic society. ■ In order for automated driving and other components of a transportation society to coexist in a transportation society, we need to think about a way in which we can contribute to and cooperate with not only automated driving itself but also the components around it. It is also important to **make rules** for this purpose. ■ **We ask that you contribute to the formulation of validation methods and indicators for automobiles and** contribute to the creation of a society in which automated driving can coexist **in order to realize a transportation society that includes safe automated driving.**	■ **Improving social acceptance** is an essential element in the social implementation of automated driving. **Assessment methods and tools that are highly consistent with the actual traffic environment** It is important to lay the groundwork for making a case for the safety of automated driving through construction ■ For the development of a transportation society, transportation-related databases are being developed in each region, but the databases themselves are very large, difficult to handle, and limited in scope, and are not fully utilized. ■ Is there a need for **educational efforts to publicize the risks and benefits of automated driving** in order to improve social acceptance?

DIVP

VIVID has 4-Joint research team as “Scenario”, “Sensor model”, “Toolchain” and “Framework & validation metrics”, towards AD-safety assurance validation methodology

Break out sessions overview

Legend ● JT activity

	2 - Scenario -	3.x - Sensor Model -	1 - Toolchain -	4 - Framework & metrics-
VIVID	KIT, IPG	Hochschule Kempton, Continental	AVL	Univ. Darmstadt, Univ. Ilmenau
DIVP	三菱プレシジョン株式会社, SOLIZE	神奈川工科大学, BIPROGY	神奈川工科大学	神奈川工科大学
Outcome	■ Exchanged sensing weakness scenario ■ Agreed standard for Open-material	■ Succeed mutual data exchange between DIVP® environmental model and VIVALDI sensor model ■ Ready for I/F standardization joint study	■ Established VILS with DIVP® environmental model-data injection into VIVALDI Radar stimulator thru OTA ■ Ready for joint study of data format & I/F standardization	■ Compared & reached mutually understand of process & methodology ■ Next step is to define & uniform the AD-Safety assurance standard as “VIVID”

DIVP

Thru VIVID collaboration, DIVP®'s precise environmental data input has successfully connected to VIVALDI's sensor model, as a foundation for further I/F, etc standardizations

Outcome from VIVID collaboration

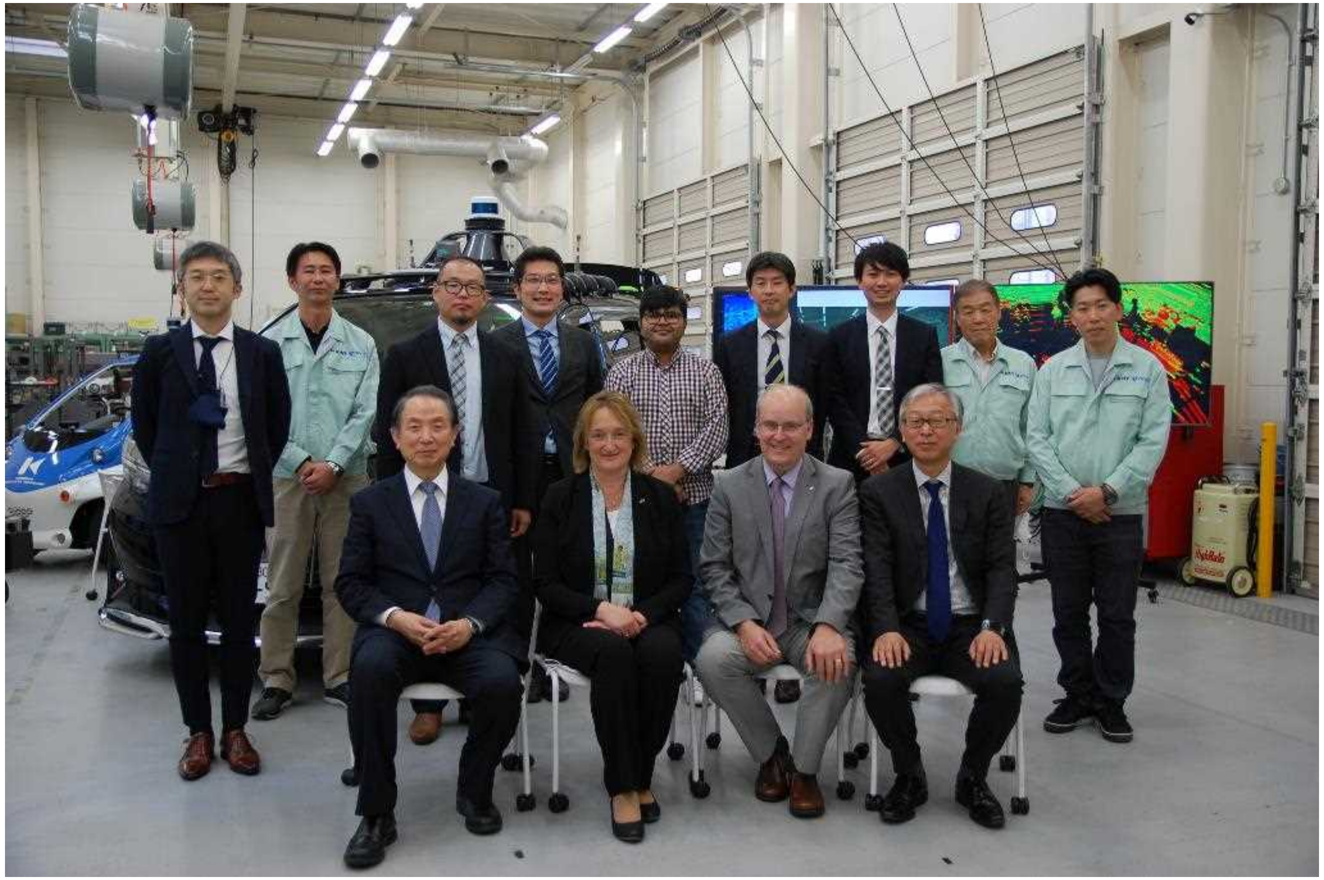
Fundamental study

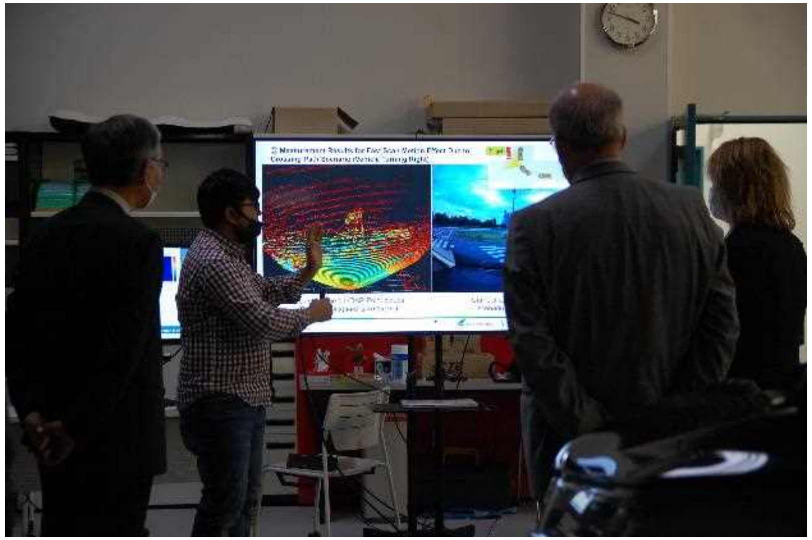
Space design Out put

Comments that he highly values AD-SA's efforts as a successful example of German-Japanese collaboration

ViViD PJ

German BMBF Schieferdecher visits KAIT (10/27)





Agenda

- DIVP® activity introduction, lab tour
- VIVID (VIVALDI- DIVP®) Japan-Germany collaboration introduction

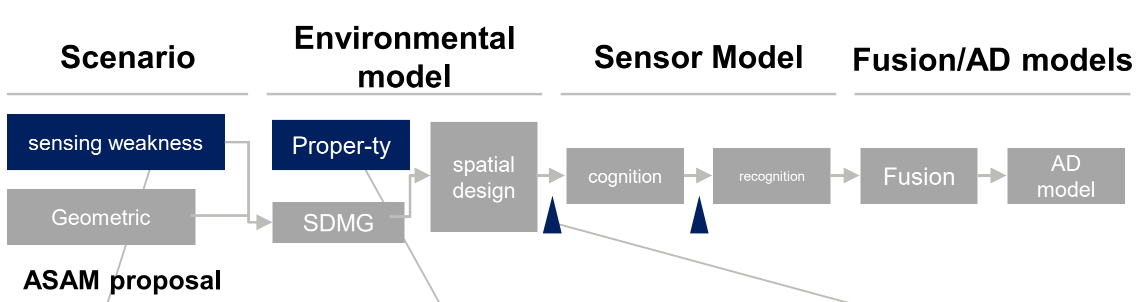
In this fiscal year, we organized the framework for international cooperation and promoted activities. Standardization begins with camera I/F

ViViD PJ
Initiatives for Standardization Organizations

SIP-adus: Structure for promoting activities this fiscal year

Advantages of VIVID

■ Discussions to standardize scenarios, materials and I/F



(1) Scenario
In accordance with the following
- ➢ OpenSCENARIO®
- ➢ OpenDRIVE®

Standardization of scenario format in senssing weakness
- ➢ OpenSCENARIO®
- ➢ OpenLabel

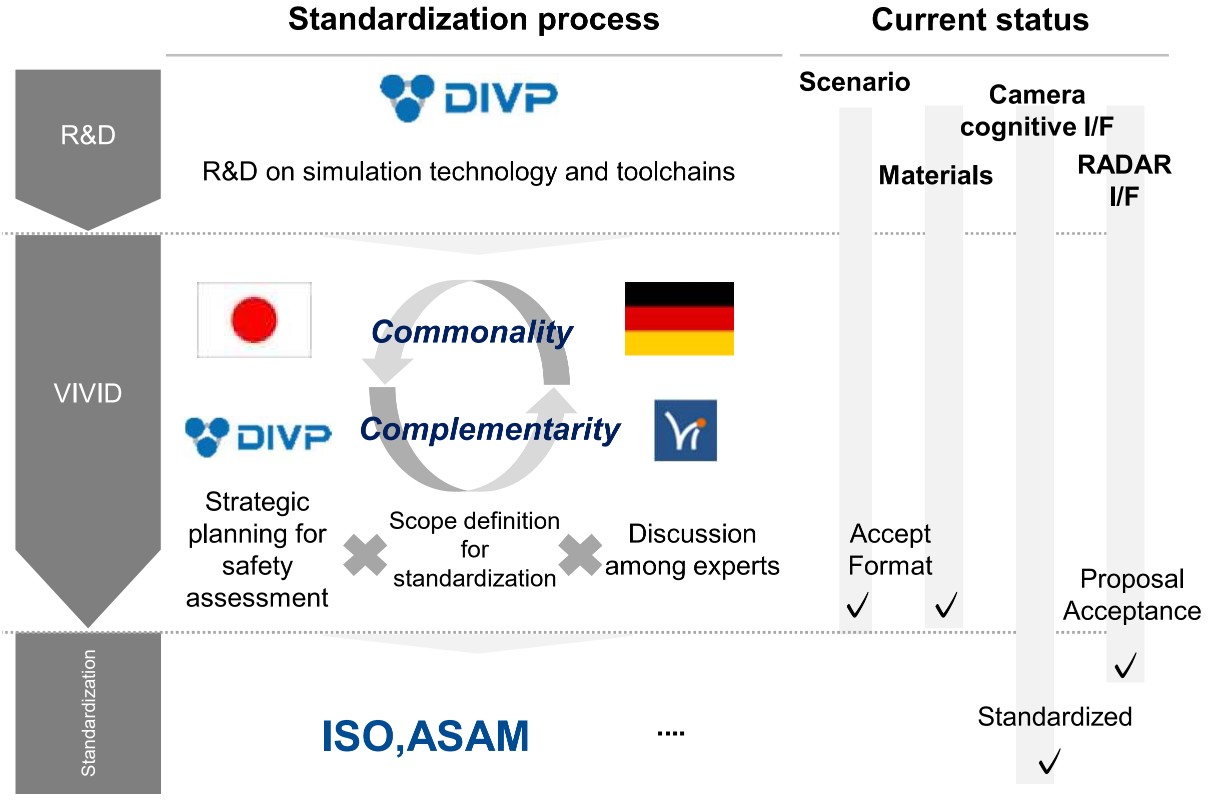
(2) Materials
Standardization of reflective properties of object surfaces for sensor validation
- ➢ OpenMaterial

(3) Camera cognitive I/F
Spectral I/F for camera input
- ➢ OSI3.0

(4) RADAR I/F
Standardization of sensor model I/F to ensure spatial design integrity
- ➢ OSI4.0

International Collaboration System and Standardization at ASAM

■ Overview of standardization activities through collaboration at VIVID



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ViViD PJ — DIVP & Vi

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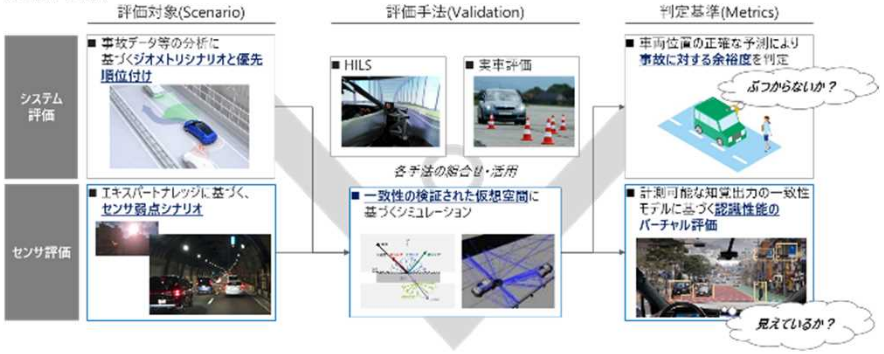

Standardization activities

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From 2023

Expanding cooperation with the United States

PEGASUS、VVM

International cooperation

Continuation of Japanese-German VIVID

SAE、UL、IEEE、IHS

Promotion of AD society implementation through collaboration with other research PJ

SAKURA、金沢大学 DIVP SUNRISE

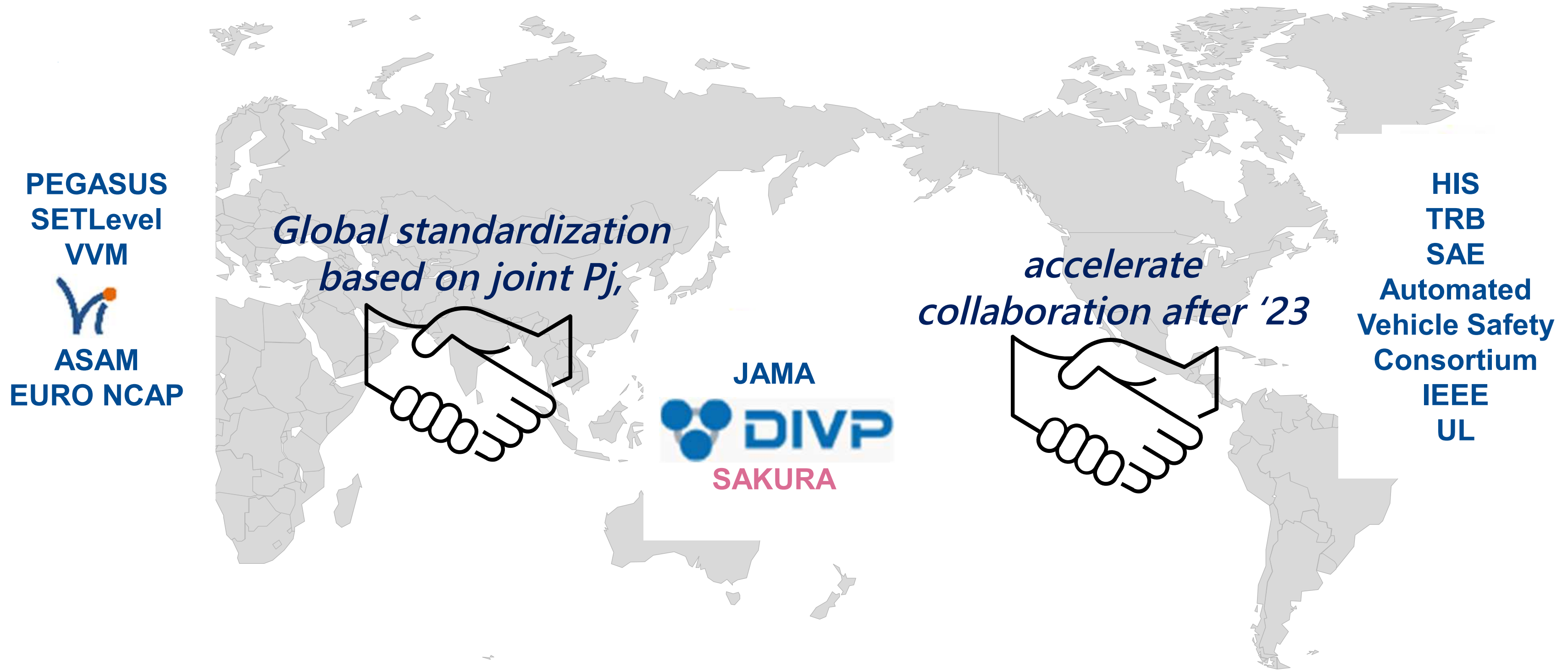
Standardization based on collaboration

ASAM、ISO

DIVP

Until ‘22, promote global standardization based on joint German-Japanese Pj,
After ‘23, accelerate collaboration with the U.S. and lead the making rules of global safety assessment.

Current status of international collaboration



Business provision

Established a new company, V-Drive Technologies, with investment from BIPROGY, and began one-stop offering of DIVP® products and services on September 22

Overview of the new company V-Drive Technologies

BIPROGY commercializes world's highest performance DIVP® simulation

New company

V-Drive Technologies

Established on July 1, 2022

BIPROGY 100% owned

Address: 1 -1 -1 Toyosu, Koto-ku, Tokyo
Representative: Toshimasa MIYAJI

- **VISION OF THE BUSINESS**

  Promote the arrival of a more reliable and safe automated driving society by providing an automated driving simulation platform that is highly consistent with real-world physical characteristics

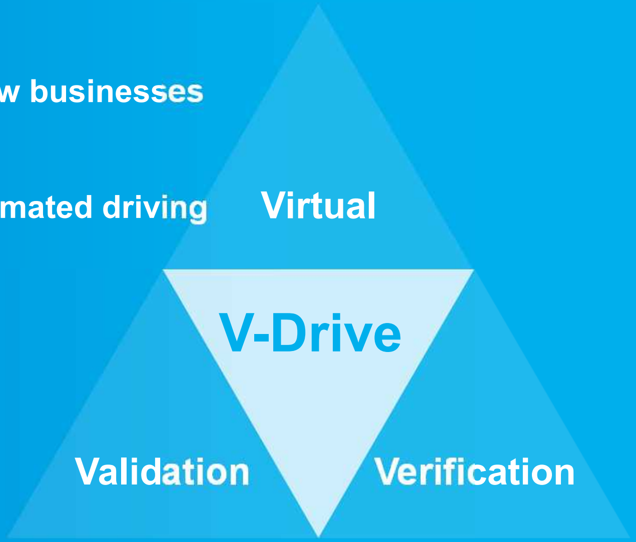
- **Origin of the company's name**

  V-Drive Technologies' Key Word aims
  a new company that drives and develops new businesses

  V-DRIVE：Vehicle ／（Autonomous）
  DRIVE -- > Automobile and automated driving

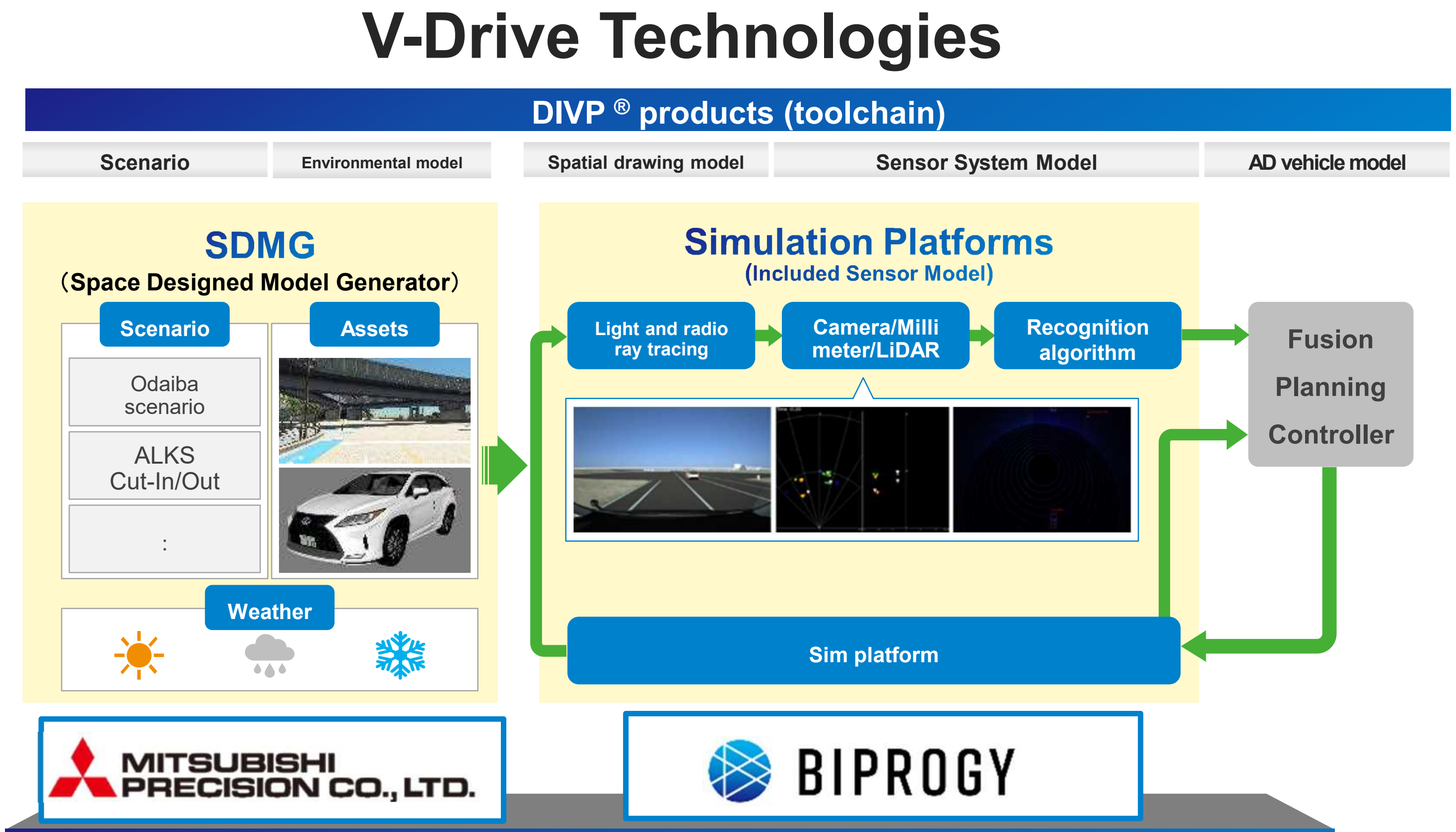
  V：Virtual ／Validation／Verification

Leverage advanced simulations to assess/verify and certify



DIVP® through a business alliance with Mitsubishi Precision ® One-stop delivery of the first wave of products and services
Provides a toolchain from scenario creation to simulation execution in two forms on cloud

Products offered by V-Drive Technologies



V-Drive Technologies provides one-stop DIVP® products and services in collaboration with Mitsubishi Precision and BIPROGY

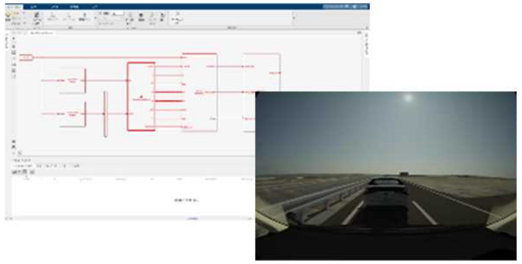
Source : Kanagawa Institute of technology, MITSUBISHI PRECISION CO., LTD.,

Cloud sales

- Build the required modules in Cloud and see simulation results

On-prem module sales

- Buy the necessary modules and install and connect them to your environment



Simulink(R), the standard platform for model-based development,· Toolbox, runs as.

Link with other simulation SWs

STEP 1 and STEP 2 of the FOTs in Tokyo waterfront area have been conducted since fiscal 2021
As a follow-up, we started a trial run with users. As of March 2023, prototypes are being evaluated at 17 sites

User trial efforts

The FOTs in Tokyo Waterfront Area — ***Follow-up***

Monitor validation → Step1 → Step2 → **Prototype Validation**

Initial understanding of needs

- *Understanding customer needs based on trial of research results*

Simulation Experience (STEP 1) Portal

(November 2, 2021 to end of February 22)

- *Widely appealing DIVP®.*
- *Ascertaining diverse needs. Brushing up products*

Hands-on version (STEP 2): Unique scenario and usage environment

(Mid-January 2022 to end-April 22)

- *DIVP ® Validating Value*
- *Pilot User Deployment Trial*

(From mid-May 2022: ongoing)

- ***The effect was confirmed by using the prototype in the user's real environment.***
- ***Proposing transition to products***

Participating companies (results)

- **Follow-up**: Introduce DIVP®-PF (SimuLINK version) and SDMG to user environment and conduct trial validation of prototype version

Trial validation using actual equipment is being conducted at 16 companies and 17 sites

- **STEP 2**: Individual scenarios, individual models, algorithms and connection validations, etc., focusing on OEMs, sensor manufacturers and tool vendors

Conducted by 5 companies

- Conducted DIVP® assessment with several auto companies

- **STEP 1**: Dedicated Portal Site Experience
  - DIVP® simulation video: NCAP/Odaiba
  - Consistency verification results introduction, scenario creation viewer experience

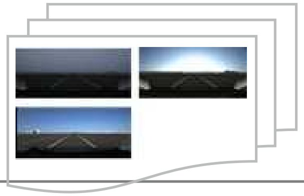
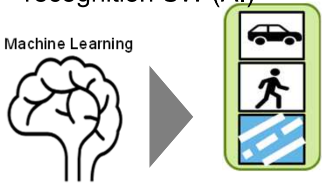
81 entries, 56 participants

- Domestic and overseas automotive OEMs, suppliers, and suppliers that conduct AD R & D
- Related systems and tool vendors
- A corporation such as a university
- Research institutions, certification bodies, etc.

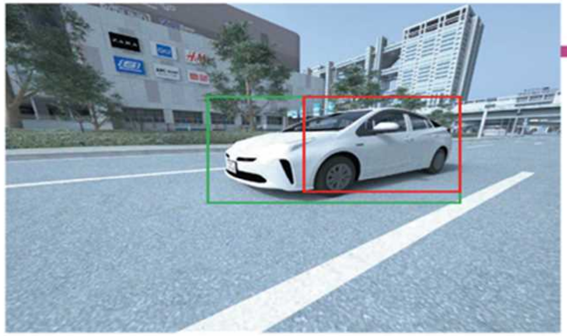
DIVP

(Reference example) Through user validation, we are grasping the expectations of OEMs, suppliers and others regarding simulation
In some validations, it was also confirmed that the DIVP® simulation output was comparable to the actual data

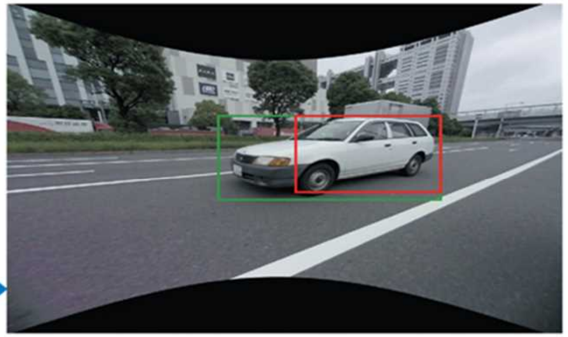
Potential application identified in STEP 2 (Practical version) (1) Application to deep learning

Applied Scene	Sensors	DIVP® Virtual Space Output	Validation	Summary
■ **Generating data for cognitive AI learning with multiple cameras** ➢ Generating large amounts of teacher data for deep-learning, changing conditions and scenarios	Camera	■ Performs cognitive learning of multiple surveillance cameras using simulation results Scenario 	■ Development and validation of recognition SW (AI) Machine Learning  Improved performance and efficiency with recognition SW	■ Simple scenario learning checks recognition rates and trends on par with machine learning recognition SWs using live-action data ■ Improves reliability by replacing annotations with simulated correct values ■ Rare cases can be made arbitrarily, so data acquisition period is not limited and efficient * Heavy rain, special vehicles, etc.

Right rear monitor



Training data
(Virtual space of DIVP®)



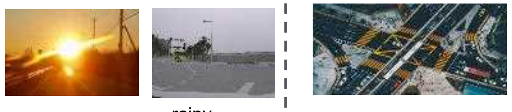
Result of recognition

Confirmed similar level of recognition ratio to learnt by real image for recognition SW (AI).

(Recognition of the case passing by vehicle on highway)

(Reference case) It is possible to freely change the validation conditions such as weather conditions, various kinds of traffic participants and their movements, and to evaluate the sensor recognition performance at each time, and there is a great expectation for the effect of the simulation with a high degree of freedom of environmental change

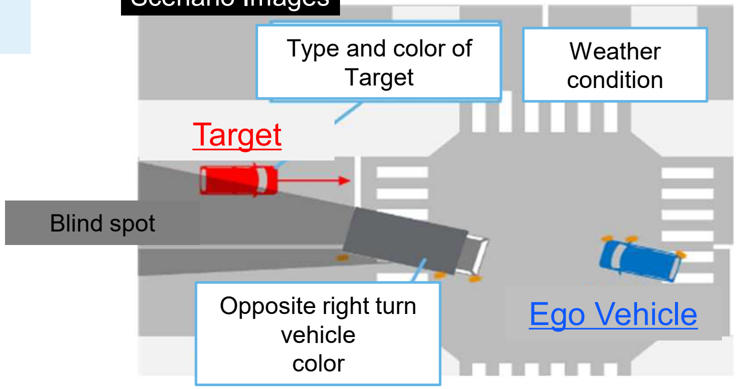
Possible application identified in STEP 2 (Practical version) (2): Application to safety assessment

Applied Scene	Sensors	DIVP® Virtual Space Output	Validation	Summary
■ **Sensor Fusion performance recognition validation** ➢ Conditions such as rain and backlight, and large numbers of traffic participants are prepared. Evaluate recognition performance	Camera Millimeter Wave LiDAR	■ **Simulated representation of adverse conditions and traffic participants that are difficult to set up in real life**  backlight / rainy weather / Multiple vehicles	■ **Validation of various sensor recognition performance under each condition** 	■ A variety of preliminary assessments can be done before the actual machine is completed, allowing front-loading of development. ■ Weather conditions and other conditions can be reproduced freely, making it possible to clearly compare sensing performance.

Performance validation of oncoming vehicle recognition by blind spot of truck waiting for right turn (Camera & LiDAR)

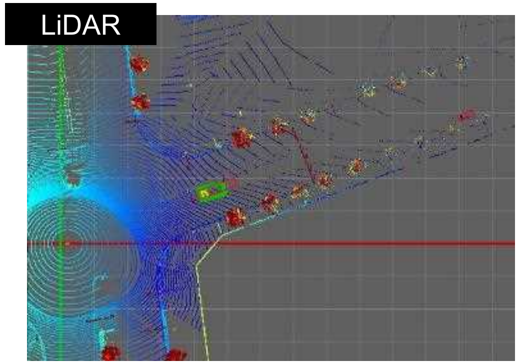
Environment model scenario setting

Sim implementation, sensor output acquisition



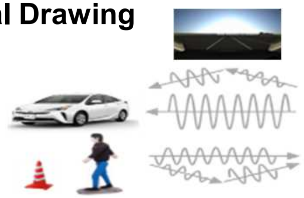
Camera

LiDAR



(Reference cases) It is expected that the validation of original sensor models and recognition models in conjunction with the output of DIVP® simulation results will contribute to the improvement of development efficiency. It also aims to convince sensor manufacturers of the performance of their products to OEMs

Possible application identified in STEP 2 (practical version) (3): Proprietary model validation through cooperation between OEMs and sensor manufacturers

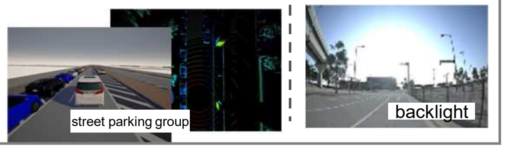
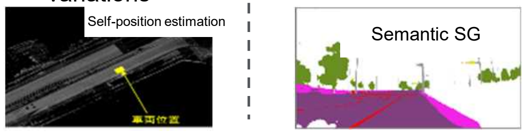
Applied Scene	Sensors	DIVP® Virtual Space Output	Validation	Summary
■ **In-house sensor recognition model validation** ➢ Evaluating the performance of sensor and recognition models owned by OEMs and suppliers with spatial draw output data	Camera millimeter-wave radar	■ **DIVP® (Camera Millimeter Wave) Spatial Drawing** 	■ Proprietary camera recognition model, millimeter-wave model performance validation (OEMs, Suppliers) 	■ Camera recognition: Although it is a qualitative validation, it is confirmed that the recognition rate and recognition accuracy are at the same level and trend as the recognition rate and recognition accuracy of real camera images. ■ Millimeter wave: In a simple scenario, the expected value in the scenario matches the model output. A validation was also conducted by comparing the results with actual equipment in a city environment.

Case in point: original sensor model validation conducted jointly by OEM and supplier

(Validation requirements: OEM + model provision & verification: supplier)

Conducted in the environment of Metropolitan Utaka

Application potential identified in STEP 2 (Practical version) (4): Verification and development efficiency through SW and algorithm linkage

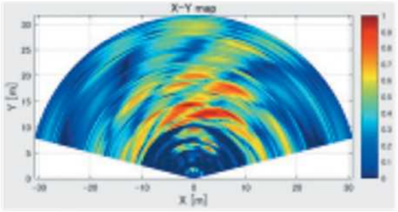
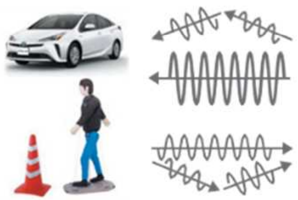
Applied Scene	Sensors	DIVP® Virtual Space Output	Validation	Summary
■ **SW linkage on Simulink** ➢ Create a variety of spatial drawing environments and apply them to closed-loop models linked with cognitive models and evaluate them	Camera millimeter-wave radar	■ **DIVP® (Camera/Millimeter Wave) Space Drawing/Perception (Various Scenes))** 	■ SW linkage is realized, and various DIVP® outputs and various simulations are coupled. Other company's SW → DIVP® → Other company's SW (Scenario) (Recognition)	■ DIVP® performs various patterns of simulation coupling on a Simulink basis using spatial drawing and perception ■ Ongoing validation based on complex scenarios in urban areas
■ **Algorithmic validation such as self-location estimation** ➢ Evaluating algorithms such as self-position estimation and trajectory generation in a virtual environment	LiDAR (+IMU)	■ **Simulate bad conditions that are difficult to set in reality** 	■ Algorithmic validation of self-location estimation and recognition with DIVP® output variations 	■ DIVP® spatial drawing and perceptual output is used to couple with other algorithms (self-location estimation, semantic segmentation). ■ Ten strings for validation in various scenes

AD-URBAN linkage: SIP/Kanazawa University

MAZDA, Furukawa Electric and Furukawa AS connected unique radar models with the DIVP® simulator in coordination among companies. We implemented verification by comparing simulation outputs with actual measurement values.

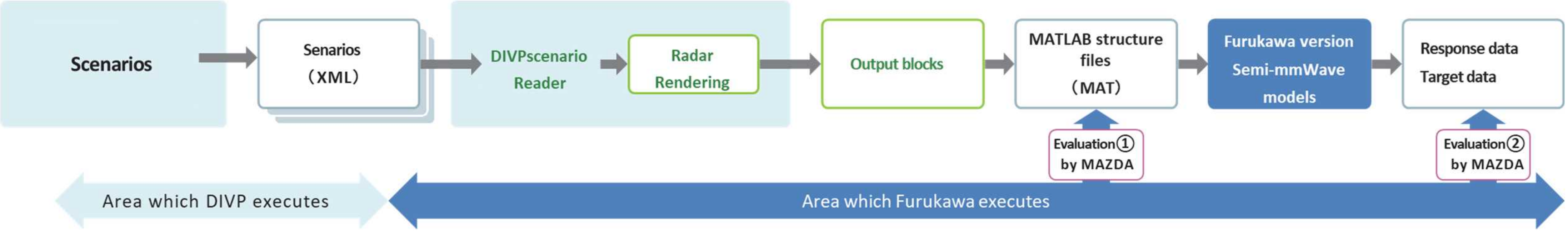
Aims of Validation

Confirmed that principles of mmWave works right in the rendered space of DIVP® with multiple scenarios. Validation was executed in the rendered space with actual mmWave models.

Use Scenes	Sensors	DIVP® Virtual Space Output	Validation	Points of Validation
Evaluate Own Company's Sensors and Recognition Models Validate performance of sensors and recognition models held at OEMs and supplies by spatial drawing output data	mmWave 	DIVP®（mmWave）Space Rendering 	Evaluate performance of unique radar models （by OEMs and suppliers） Furukawa Semi-mmWave Model （24Ghz Peripheral Monitor Radar）	①mmWave environment Results of rendering ②mmWave processing results

Method for Implementing Validation by Actual Equipment

Division of Roles are as follows.



Source :FURUKAWA AUTOMOTIVE SYSTEMS INC.

As for basic validation and simple-scenario validation, we validated output results of radar models connected to the DIVP® simulator performing in accordance with basic scenarios of targets coming closer. We confirmed the appropriateness of radar models.

Basic validation: Evaluation Summaries

We evaluated distance amplitude characteristics.

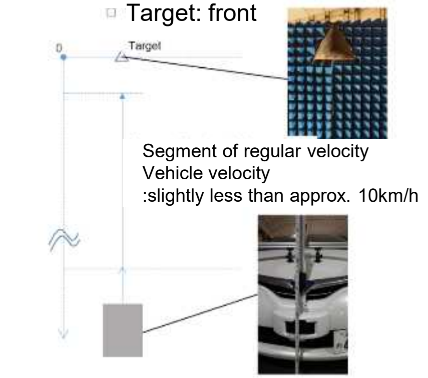
	Targets	SIM Results	Comments
Basic validation 1	Corner reflector 10dBsm Confront Directly	○ +3～+10dB approx.	Real-virtual consistency was mostly confirmed for targets of RCS regulations. Appropriateness was confirmed with both of DIVP and radar models.
Basic validation 2	Corner reflector 10dBsm 45 deg	+10dB or more approx.	《Reference》
Basic validation 3	Planar metal 5dBsm	○ +3～+6dB approx.	Real-virtual consistency was mostly confirmed on a PO basis. Appropriateness was confirmed with both of DIVP and radar models.
Simple scenario 4	Actual vehicles	−10dB or less approx.	《Reference》 Actual ego vehicle is CX-5. No configuration for simulation.

It is considered that computation performances about point targets, under good conditions, and DIVP ray tracing (incl. multipaths) are appropriate. The results about Actual Vehicles is varied. It suggests that simulating/modelling targets and scenarios is difficult.

Validation Scenarios

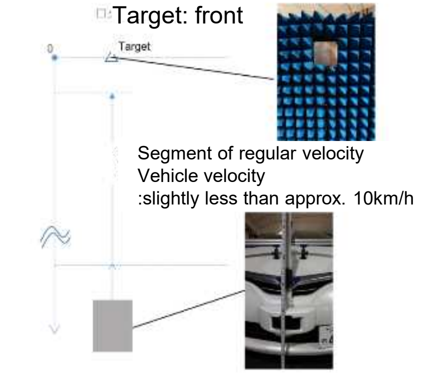
Basic Validation 1

Scenario



Basic Validation 3

Scenario

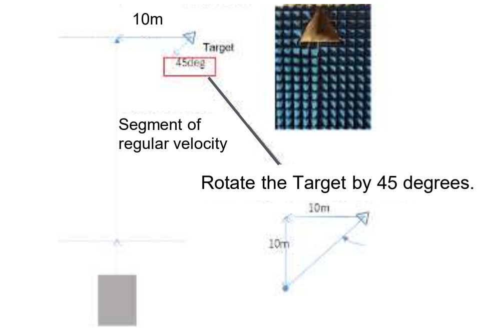


《Reference Validation》

*Feature of 45deg is not modelized.

Basic Validation 2

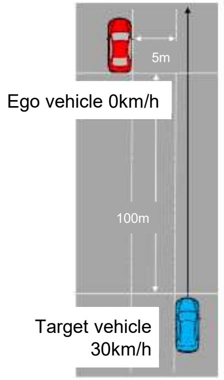
Scenario Target : 10m distant, 45 deg



*Different vehicle model is used.

Simple Scenario 4

Scenario

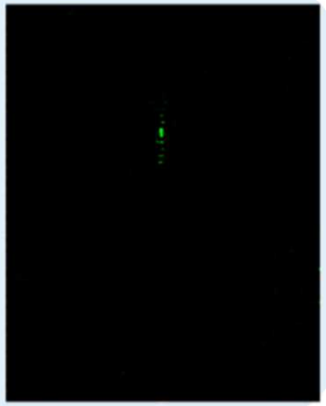


Source :FURUKAWA AUTOMOTIVE SYSTEMS INC.

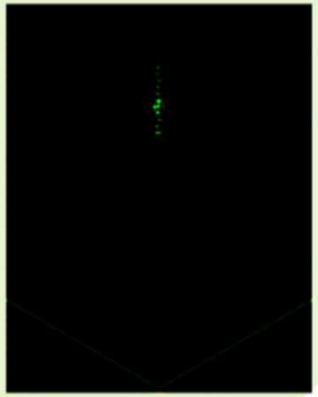
We compared the Simulator with an actual vehicle through the use of basic targets.
As a result, the Simulator indicated the same tendencies as indicated in the measurement results via actual vehicle, and its margin of error was in the order of magnitude 3 dB to 10 dB approx.（Basic Validation1,2）

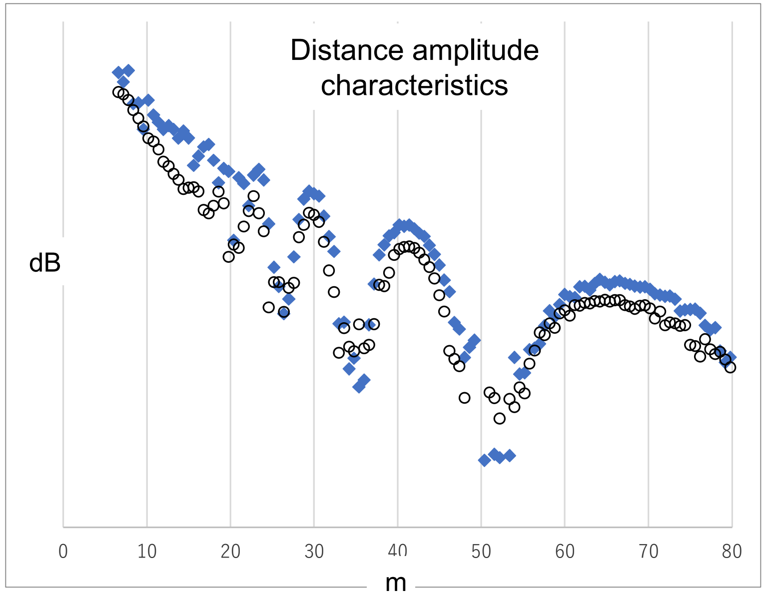
Basic Validation1

Measurement Via actual vehicle



Simulator



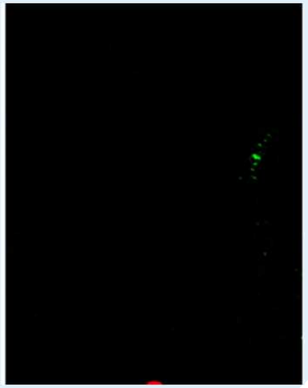


○Actual Vehicle
◆Simulator

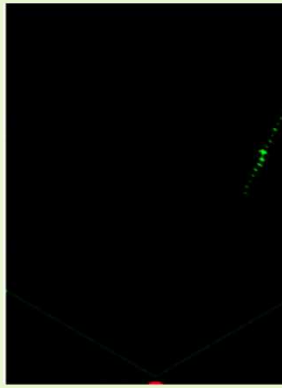
The amplitude difference between the measurement results via Actual Vehicle and the Simulator is approx. 3dB in the distance, and approx. 10dB max. in the neighborhood.
The Simulator traces the tendency of Peak Null about Ground Multipath.

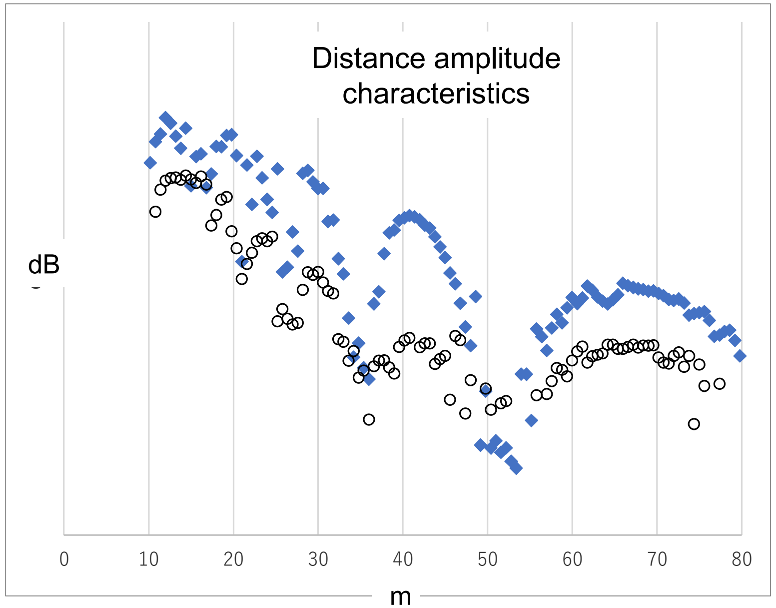
Basic Validation 2《Reference data》

Measurement Via actual vehicle



Simulator





○Actual Vehicle
◆Simulator

In this reference case, there are significant amplitude differences between the measurement results via Actual Vehicle and the Simulator.
It is presumed that Corner Reflector is not simulated well enough in light of the characteristics about a rotation of 45 degrees.

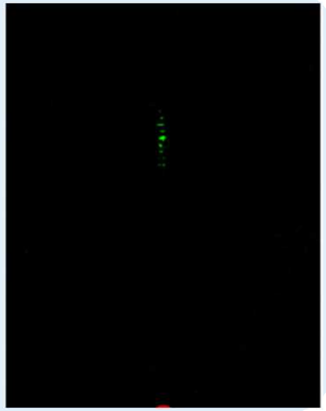
Source :FURUKAWA AUTOMOTIVE SYSTEMS INC.

We compared the Simulator with an actual vehicle through the use of basic targets.
As a result, the Simulator indicated the same tendencies as indicated in the measurement results via actual vehicle, and its margin of error was in the order of magnitude 3 dB to 10 dB approx.（Basic Validation3, Simple Scenario 4）

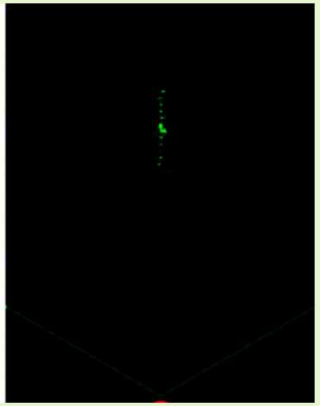
※Simple Scenario 4 is reference because tested targets are not modelized yet.

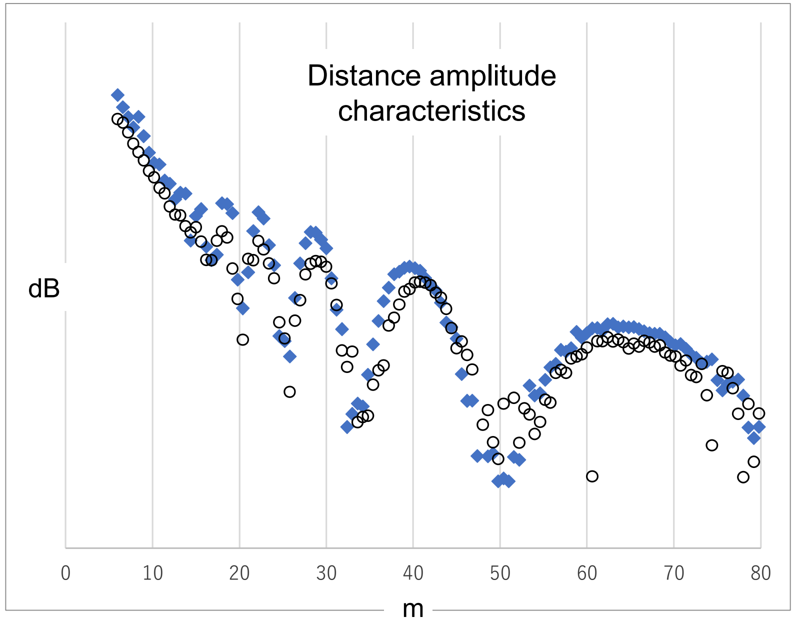
Basic Validation 3

Measurement Via actual vehicle



Simulator



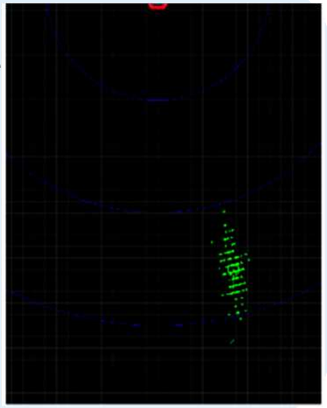


○Actual Vehicle
◆**Simulator**

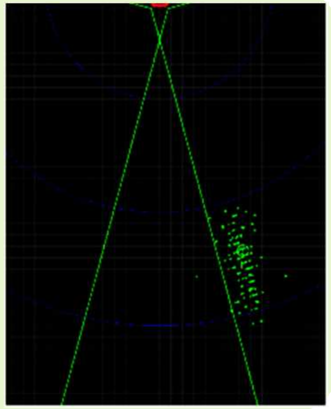
It seems that PO computed correctly intensity.
The amplitude difference between the measurement results via Actual Vehicle and the Simulator is approx. 3dB in the distance, and approx. 6dB max. in the neighborhood.
The Simulator traces the tendency of Peak Null about Ground Multipath.

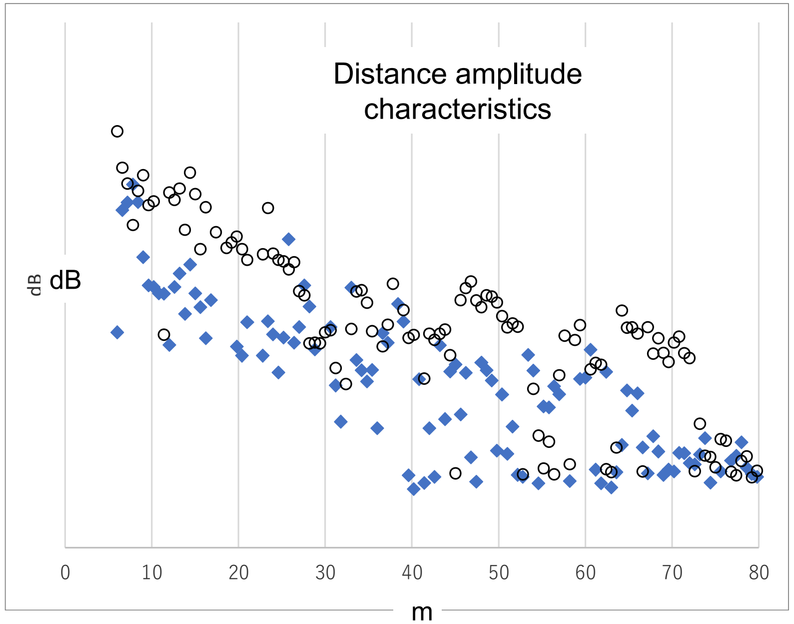
Simple Scenario《Reference data》

Measurement Via actual vehicle



Simulator





Examined by right behind radar.

○Actual Vehicle
◆**Simulator**

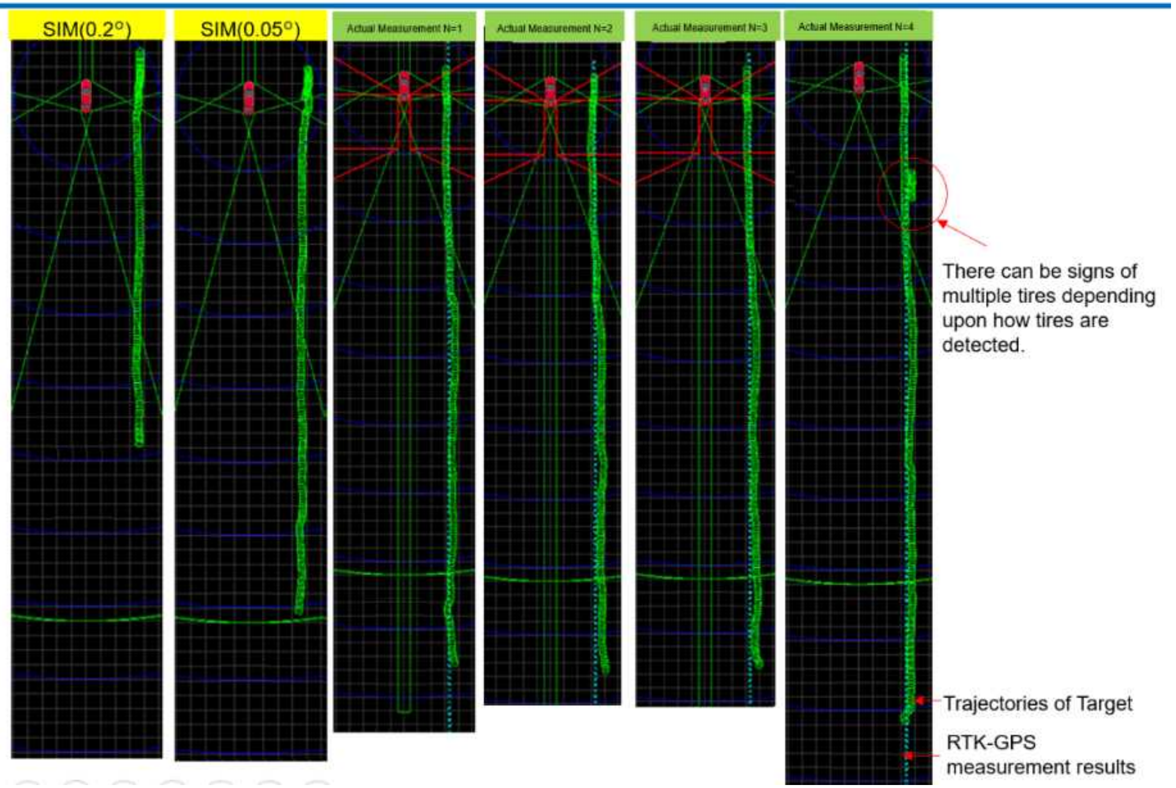
The Simulator's amplitude level is generally lower by 10dB or more, compared with the measurement results via Actual Vehicle .
The Peak Null appearance for Ground Multipath is not regulated in comparison with it being as indicated in Basic validation 1 and Basic validation 3, to the extent that an expanding target is concerned.

Source :FURUKAWA AUTOMOTIVE SYSTEMS INC.

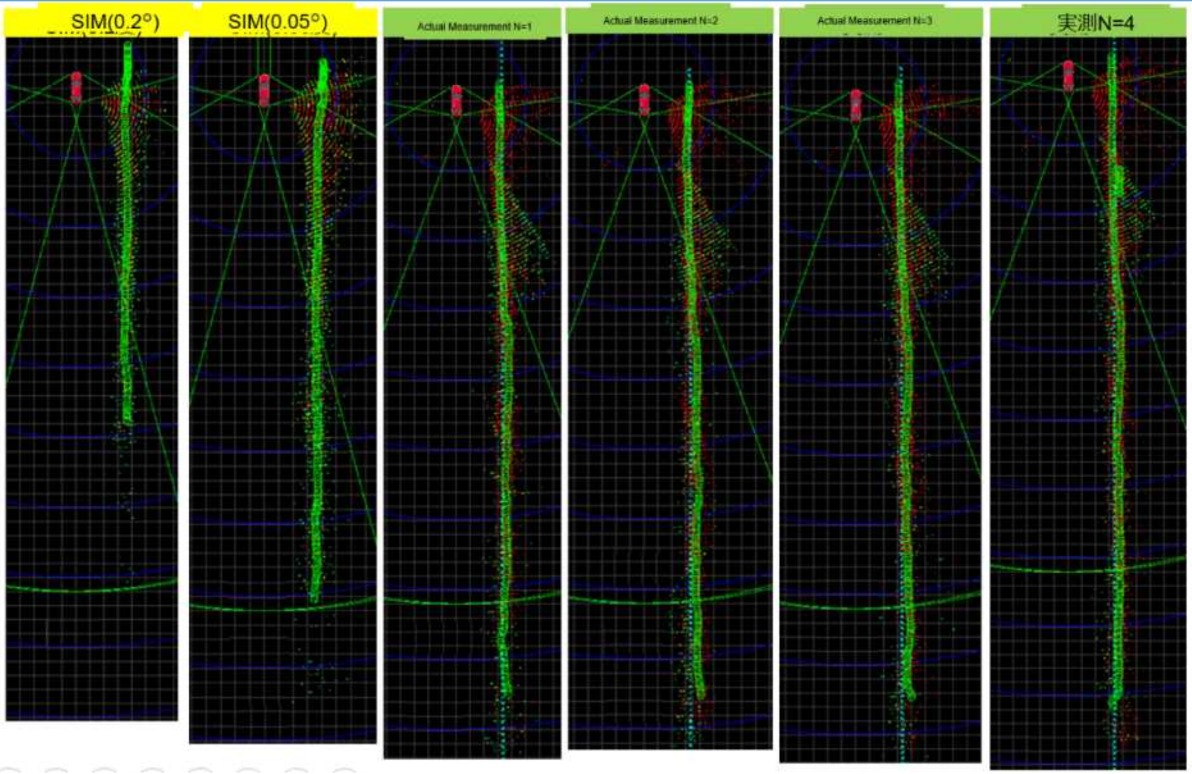
DIVP

No specific issues were identified about positions of targets travelling on the basis of a simple scenario about vehicles coming closer. However, there were differences in the detection distances.
It might be due to differences in the actual vehicle target and the simulated vehicle target.

Positions and Detection Distances for Targets



Responses (Reflection Intensity of 500 or more in red)



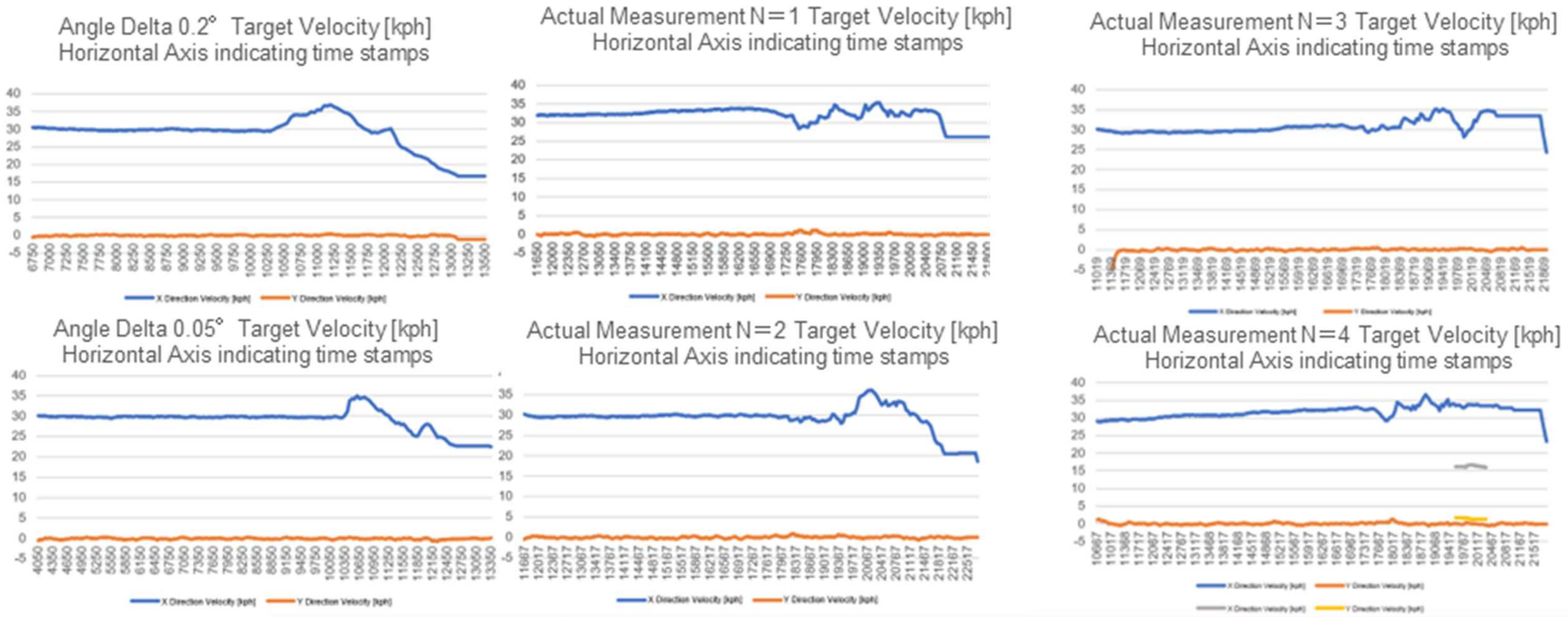
Target positions	○	Interval of scanning angle (on horizontal/vertical plane）(hereinafter : angle delta = no remarks on both degrees of 0.2 and 0.05
Maximum Detection Distances Angle delta 0.2	×	50 m for 80 - 90 m actually measured. This is improved by using the Angle Delta=0.05 degrees.
Maximum Detection Distances Angle delta 0.05	△	70 m for 80 - 90 m actually measured. It is considered to be due to a low reflection intensity in response.

Source :FURUKAWA AUTOMOTIVE SYSTEMS INC.

No specific issues were identified about velocities of targets travelling on the basis of a simple scenario 4 about vehicles coming closer.

Target Velocities 1/2

Target Velocities 2/2



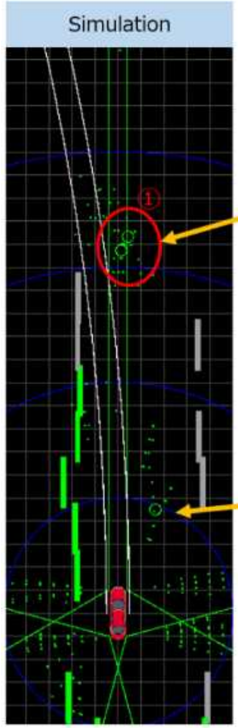
Target velocities Angle delta 0.2	○	If a target is far away by more than 20 m, the detected value is 30kph as indicated in the scenario. If it is near less than 20 m, velocities are varied as in the case of Actual Vehicle Measurements.
Target velocities Angle delta 0.05	○	If a target is far away by more than 20 m, the detected value is 30kph as indicated in the scenario. If it is near less than 20 m, velocities are varied as in the case of Actual Vehicle Measurements.

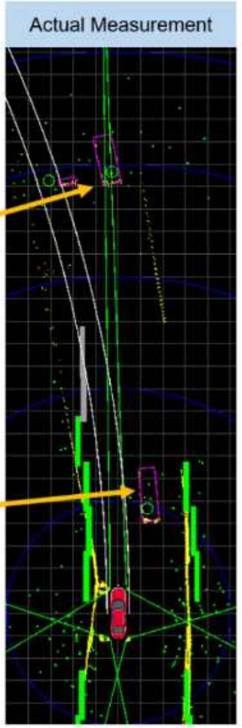
Source :FURUKAWA AUTOMOTIVE SYSTEMS INC.

《Reference-1》Comparison of the simulation result and measurement by actual radar in the simulated Tokyo metro highway C1 with passing by scenario (30 sec.).（simulated with angle delta = 0.2）

※Travelling positions, own vehicle’s velocity and target vehicle’s velocity are not strictly same conditions.

Scene （14.2 sec after Start, w. Vehicle 2 travelling 10 m ahead)

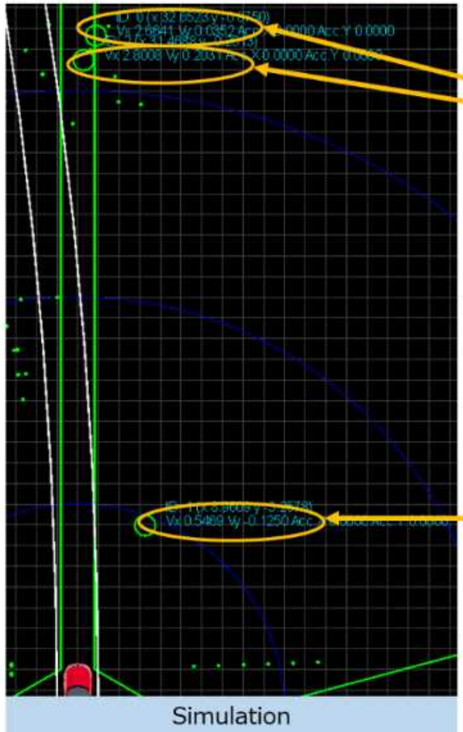


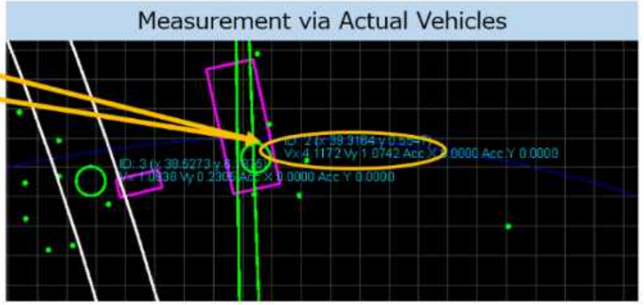


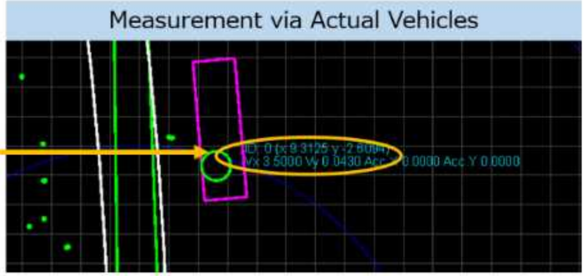
Comparison Results

[1] The response around the Target Vehicle spreads leftward and rightward.
As a result, the Target Vehicle is detected as two targets.
Although this actual measurement result did not experience this phenomenon, the phenomenon can occur in cases of actual measurement, as well.

Scene　Target Velocity







When detecting a target going off in the distance, DIVP recognizes that the velocity of target is lower than the actual velocity.

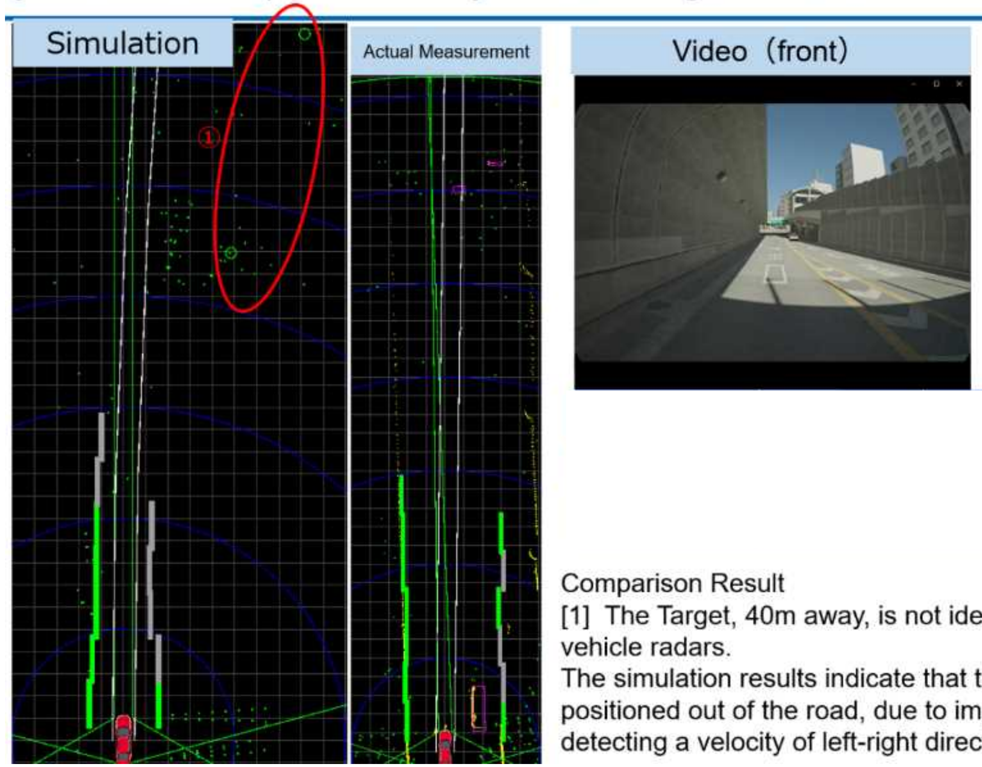
Vehicle data	△	A sudden change in the yaw rate impacts target positions and target velocities, in comparison with actual AD vehicles.
Target detection	○	A target is detected as two targets. This phenomenon is witnessed about actual AD vehicles capabilities (such as tire detection).
Roadside detection	○	Reflection Intensity (supplementary info.): An angle becomes smaller and decreases response q'ty in accordance with the distance becoming longer. Thus, it is presumed that the reflection intensity impacts the roadside detection results. (A concrete roadside disadvantages due to weak responses.) Conversely, response q'ty increases in a short distance, and thus, reflection intensity does not pose much problems. From the viewpoint of relationship with a target vehicle, the target vehicle is processed as a cloud of points of different velocity. Thus, it is presumed that there will be no mutual impacts.

Source :FURUKAWA AUTOMOTIVE SYSTEMS INC.

《Reference-2》Comparison of the simulation result and measurement by actual radar in the simulated Tokyo metro highway C1 with passing by scenario (30 sec.).（simulated with angle delta = 0.2）

※Travelling positions, own vehicle's velocity and target vehicle's velocity are not strictly same conditions.

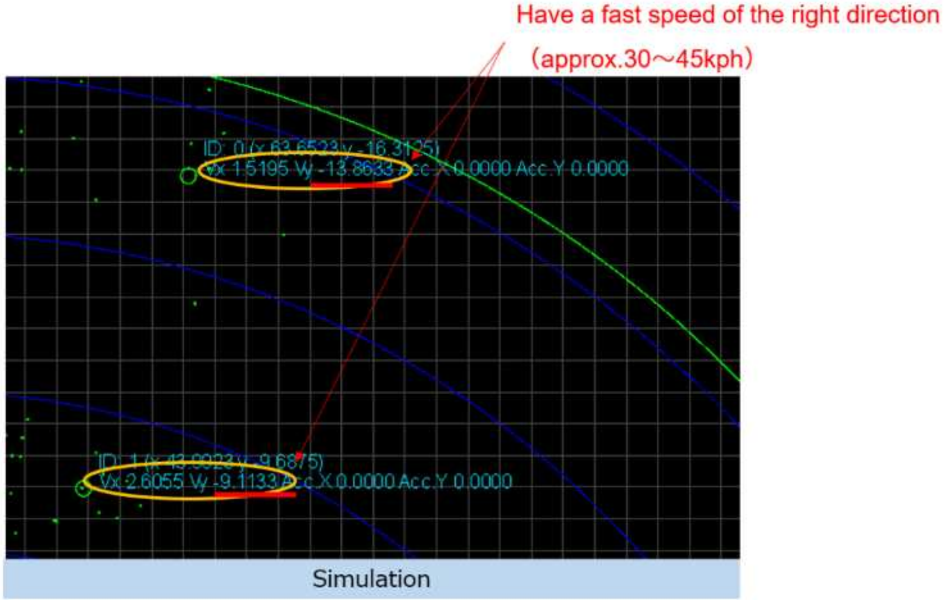
Scene (24.2 after Start, Immediately after Passing under an Elevated Structure)



Comparison Result

[1] The Target, 40m away, is not identified by actual vehicle radars.
The simulation results indicate that the Target is positioned out of the road, due to impacts of detecting a velocity of left-right direction.

Scene　Target Velocity



(*) Actual vehicle radars failed to identify a target.
Therefore, we have no actual measurement results in light of velocity.

Vehicle data	△	A sudden change in the yaw rate impacts target positions and target velocities, in comparison with actual AD vehicles.
Target detection	○	DIVP® detects Targets farther in the distance than actual AD vehicles.
Roadside detection	○	Reflection Intensity (supplementary info.): An angle becomes smaller and decreases response q'ty in accordance with the distance becoming longer. Thus, it is presumed that the reflection intensity impacts the roadside detection results. (A concrete roadside disadvantages due to weak responses.) Conversely, response q'ty increases in a short distance, and thus, reflection intensity does not pose much problems. From the viewpoint of relationship with a target vehicle, the target vehicle is processed as a cloud of points of different velocity. Thus, it is presumed that there will be no mutual impacts.

Source :FURUKAWA AUTOMOTIVE SYSTEMS INC.

Safety validation of AD requires verification of operation control based on real sensor output and simulation that can be evaluated in various environments as well as real environments, and there is a great expectation for construction of virtual space for real validation

AD safety assessment challenges and Sim requirements

Challenges in Evaluating the Safety of Self-Driving Cars

#01

Safety assessment of self-driving cars = **Sensors** Camera/Radar/LiDAR + Vehicle control software

·Does the sensor see the object or surroundings?
Are there false positives (false positives) and false negatives (oversights)?
·Are you driving safely with autonomous controls?

#02

Safety assessment of self-driving cars = **Requires validation under harsh conditions in various environments**

·Evaluating all the various phenomena reproducibly only in the actual vehicle
It's difficult and takes a lot of time and effort.
->Needs simulation that can be evaluated as in a real environment

Required simulation requirements

Real simulation environment: Virtual space Example: Shuto High C1, Odaiba

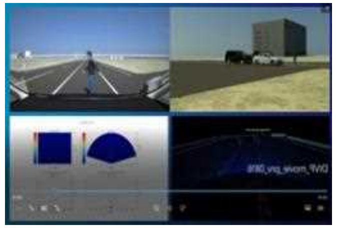
Metropolitan Expressway

Odaiba

- We will continue to develop safe and secure automated driving in various traffic scenes by adding various scenarios in many validation environments

OEM Development

Validation of driving system equivalent to actual vehicle
Example:Sensor representation in NCAP validation example



Validation when environmental conditions change
Example:Backlight, night and rainy weather

…

*All DIVP® Simulation Examples

DIVP

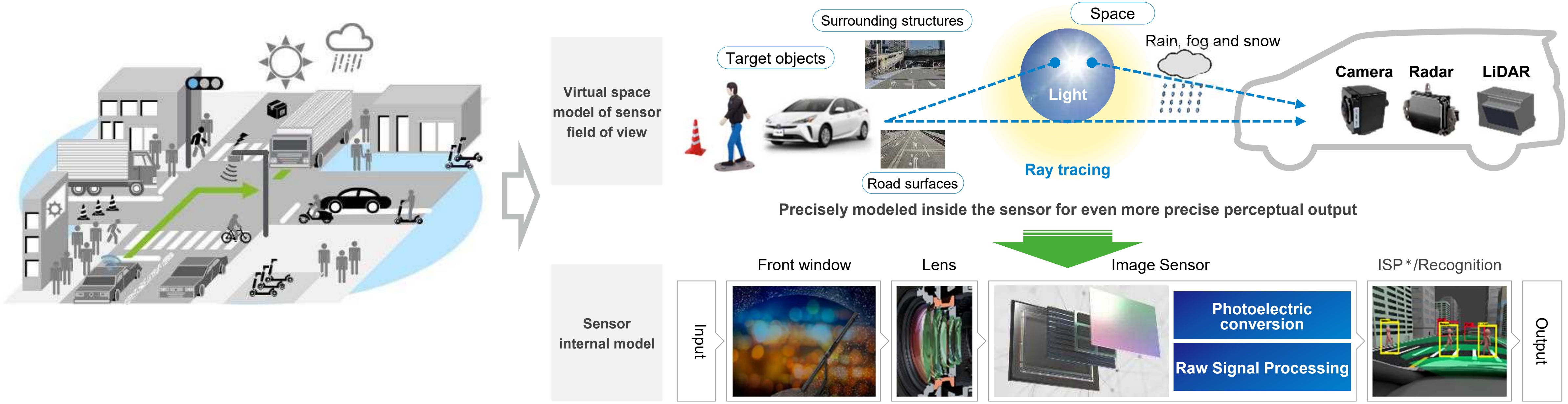
GBM

- Summary of validation results
- Validation results for each item
- Future Initiatives

Constructing a virtual space simulation platform that is highly consistent with actual phenomena contributing to the safety assessment of automated driving

Purpose and characteristics of DIVP®

- Simulation model consistent with real phenomena
- Platform capable of consistently evaluating scenario generation, recognition performance validation, and vehicle control verification
- Enhancing connectivity with existing simulations



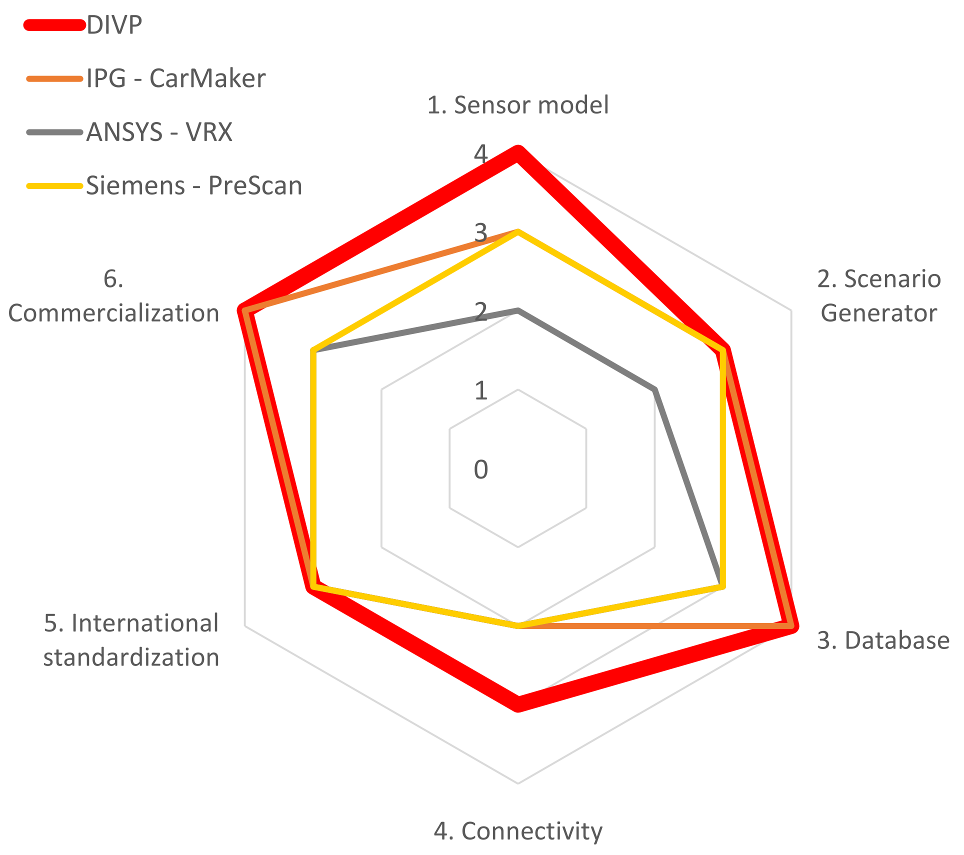
Real space → To virtual space model of sensor field of view, sensor internal model

Source : Kanagawa Institute of technology

We confirmed the superiority of "sensor model" and "connectivity" over competitors. In addition, the validation point was added to "database" and "commercialization," and BMC was conducted to confirm that it is sufficiently competitive.

Benchmark Results

->Achieved virtual space simulation PF construction that contributes to global competitiveness!



***Deficit Portion: FY 22 Update**

No	Validation axis	Validation perspective	Competitive Comparison and Validation Results
1	sensor model	• Reproducibility of sensing weakness phenomenon	**dominance** ✓ Have a virtual space model of property definition ✓ Consistency verification
2	Scenario Generator	• Usability • Scenario creation efficiency	**Equal** ✓ Features integrated physical and material properties
3	Database	• Enrichment of driving environment assets • Scenario model enrichment	**Equal** ✓ The number of driving environment assets has been increased and other simulation assets are available ✓ Differentiate by providing assessment/Odaiba packages featuring DB implementation of scenario models
4	Connectivity	• General Scenario Connectivity • Reflection property data connectivity • Sensor model connectivity	**dominance** ✓ Connectivity with reflective property data is dominant
5	international standardization	• Compliance with international standards	**Equal** ✓ Support for ASAM-OpenX ✓ DIVP® -I/F proposal to ASAM-OSI * 4.0
6	commercialization	• Responding to user use cases • Feature configuration and pricing	**Equal** ✓ MATLAB/Simulink environment, FMI/FMU supported ✓ Define competitive pricing through competitive comparisons

Source : Kanagawa Institute of technology

GBM

- Summary of validation results
- Validation results for each item
- Future Initiatives

A comparative study focused on DIVP® features (scenario creation and sensor simulation) to define a price structure that allows DIVP® to demonstrate its advantage

Commercialization; product price benchmark

*BIPROGY Summary as of July 2022

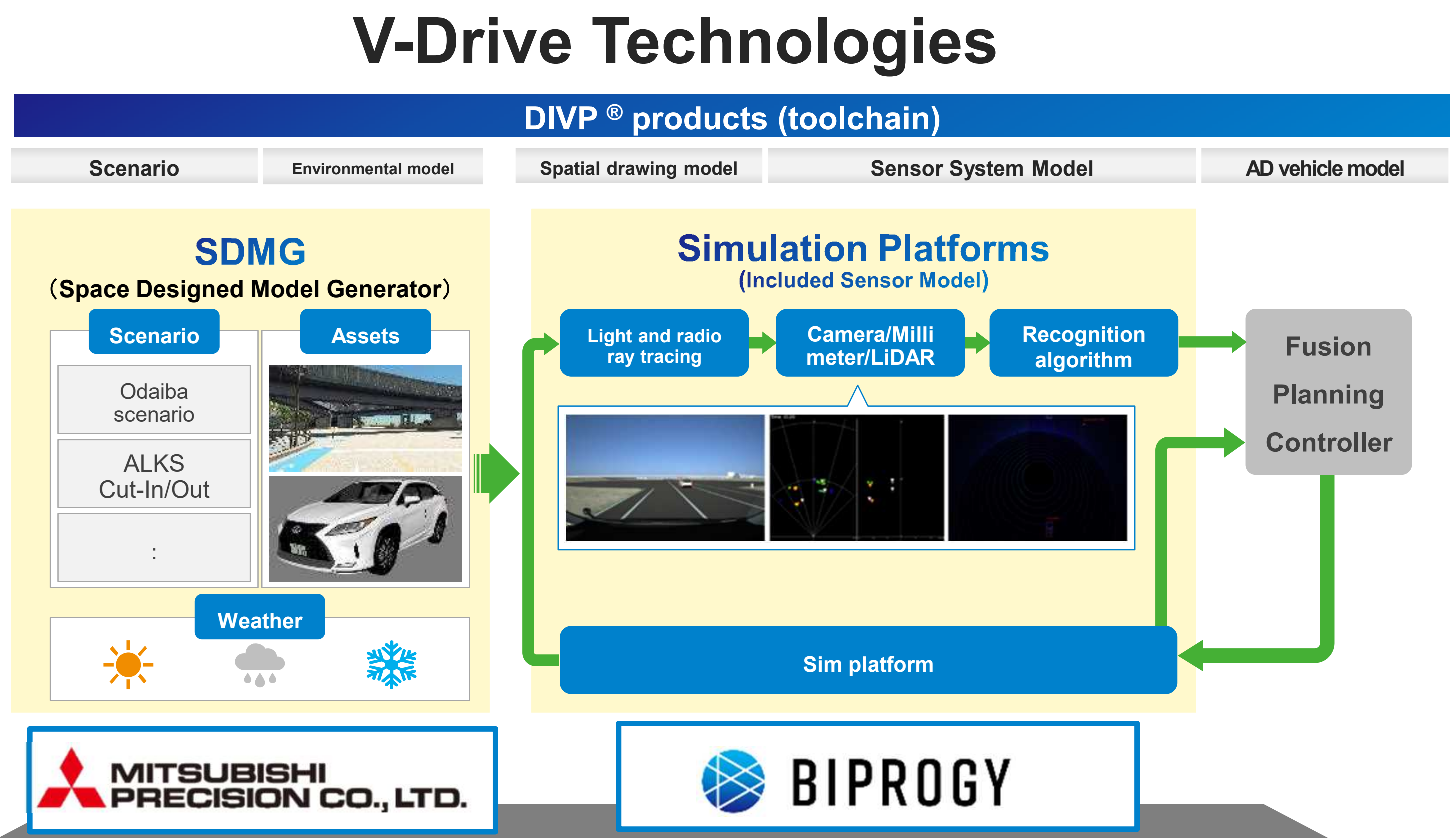
Products	Price Millions of yen	Price per function			Remarks
		Scenario Creation	Sensor simulation	Vehicle model	
DIVP®	Price	Base price(lump sum) + 30% (annual amount)	Base price(lump sum) + 30% (annual amount)		・SDMG (including basic assets) ・Sim-PF (including reference sensor model)
	Functional validation	◎	◎	None	
IPG CarMaker	Price comparison with DIVP®	DIVP® dominates	Almost equal (but including vehicle models)		・Scenario creation + sensor simulation (including vehicle models)
	Functional validation	○	△	○	
ANSYS VRX	Price comparison with DIVP®	DIVP® dominates	DIVP® dominates		
	Functional validation	○	○	None	

・CarMaker is about the same on price (DIVP® dominates the scenario department). The sensor simulation function is DIVP® -dominant.
・VRX featuring sensor simulation (camera) is more expensive than DIVP®

Source : Kanagawa Institute of technology

As for the product structure, we have studied both the on-prem version (Simulink environment) and the cloud version, and as of the end of July 22, 15 companies have started prototype trials at 16 sites, and we are in the process of adapting to the needs of our users

Commercialization; Progress



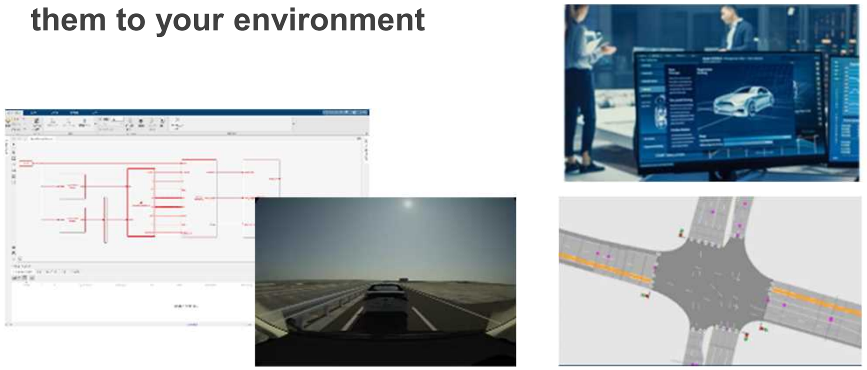
V-Drive Technologies provides one-stop DIVP® products and services in collaboration with Mitsubishi Precision and BIPROGY

Cloud sales

- Build the required modules in Cloud and see simulation results

On-prem module sales

- Buy the necessary modules and install and connect them to your environment



Simulink(R), the standard platform for model-based development, Toolbox, runs as.

Link with other simulation SWs

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

We've augmented the 3D assets we need. You can also use 3D assets from other simulations via format conversion

MITSUBISHI PRECISION CO., LTD.

Database ; 3D asset has been expanded

Test course

Daiba

Metropolitan Expressway C1

Passenger vehicles

Traffic signal

Pedestrians and their belongings

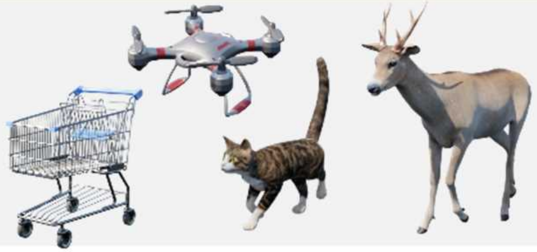
Motorcycles and special vehicles

NCAP dummies

Traffic signs and construction equipment

Large vehicle (including towing)

Obstacles and animals

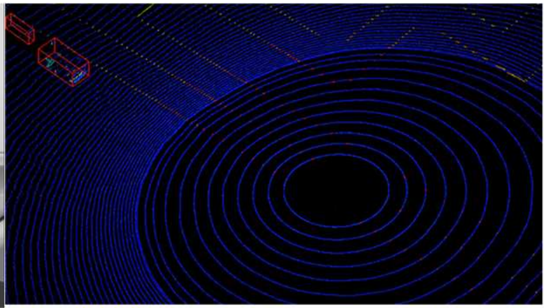


Source : MITSUBISHI PRECISION CO.,LTD.

Euro-NCAP simulation with Virtual-PG.
->Completed modeling of existing protocol 30 Scenario. Began providing users with a database of scenario models.

Database; Assessment, Odaiba sensing weakness, database as scenario model package

No	Euro-NCAP Test Protocol	Scenario
1	**AEB* VRU* Test Protocol** (Tests on Automatic Emergency Braking, etc., for Traffic Vulnerable Persons)	Car-to-Pedestrian Farside Adult 50% (CPFA-50)
2		Car-to-Pedestrian Nearside Adult 25% (CPNA-25)
3		Car-to-Pedestrian Nearside Adult 75% (CPNA-75)
4		Car-to-Pedestrian Nearside Child 50% (CPNC-50)
5		Car-to-Pedestrian Longitudinal Adult 25% (CPLA-25)
6		Car-to-Pedestrian Longitudinal Adult 50% (CPLA-50)
7		Car-to-Pedestrian Turning Adult 50% (CPTA-50)
8		Car-to-Pedestrian Reverse Adult 50% (CPRA-50)
9		Car-to-Pedestrian Reverse Adult stationary (CPRA-s)
10		Car-to-Bicyclist Nearside Adult 50% (CBNA-50)
11		Car-to-Bicyclist Nearside Adult Obstructed 50% (CBNAO-50)
12		Car-to-Bicyclist Farside Adult 50% (CBFA-50)
13		Car-to-Bicyclist Longitudinal Adult 25% (CBLA-25)
14		Car-to-Bicyclist Longitudinal Adult 50% (CBLA-50)
15		Car-to-Motorbike Rear Stationary(CMRs)
16		Car-to-Motorbike Rear Braking(CMRb)
17		Car-to-Motorbike Front Turn-Across-Path(CMFtap)
18		Car-to-Motorbike Front Straight-Cross-Path Left (CMFscp-L)
19	**AEB* Car-to-Car Test Protocol** (Tests on Automatic Emergency Brakes, etc., against Cars)	Car-to-Car Rear stationary(CCRs)
20		Car-to-Car Rear moving(CCRm)
21		Car-to-Car Rear braking(CCRb)
22		Car-to-Car Front turn-across-path(CCFtap)
23	**LSS* Test Protocol** (Test on Lane Keep, etc.)	Emergency Lane Keeping - Road Edge
24		Emergency Lane Keeping - Solid Line
25		Emergency Lane Keeping - Outcoming vehicle
26		Emergency Lane Keeping - Overtaking vehicle
27		Lane Keep Assist - Dashed line
28		Lane Keep Assist - Solid line
29		Oncoming vehicle(PTW)
30		Blind spot(PTW)

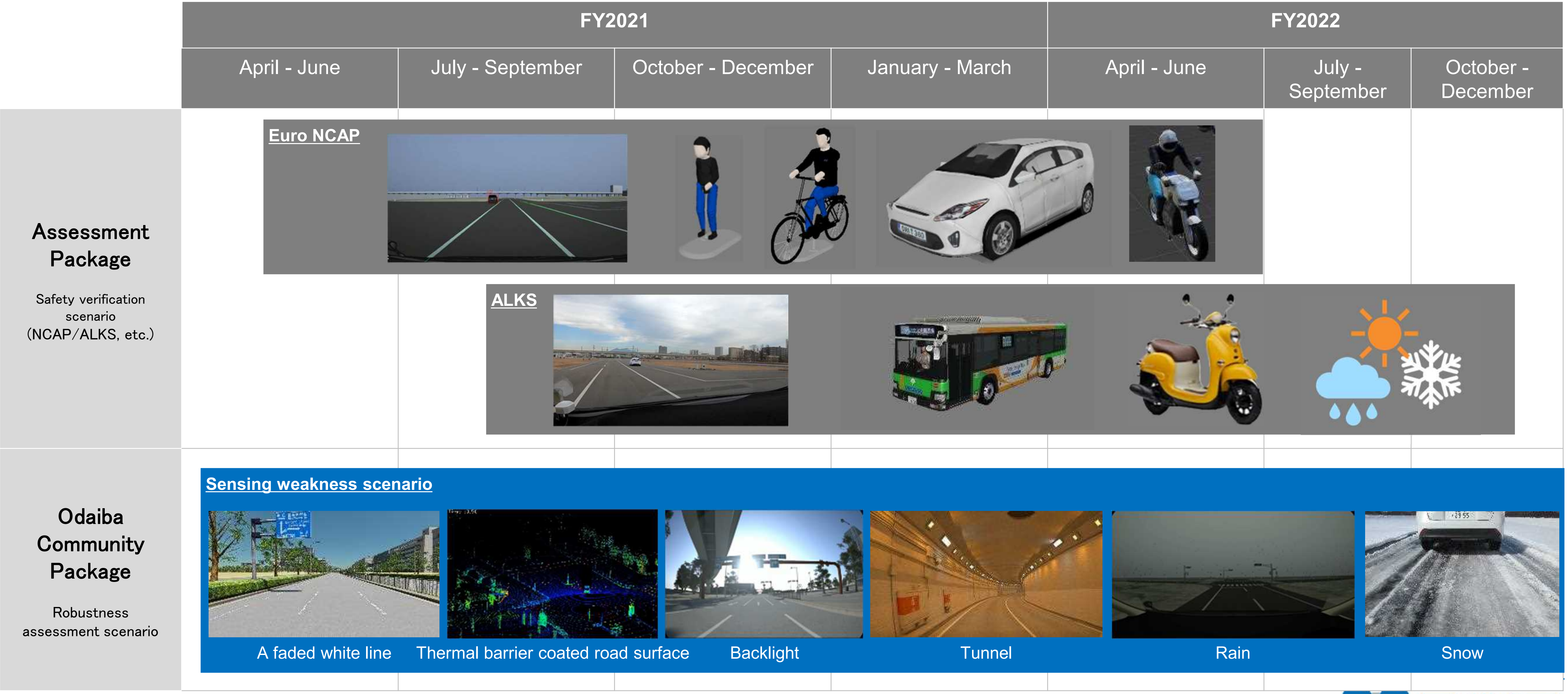


*AEB: Autonomous Emergency Braking, *VRU: Vulnerable Road User, *LSS: Lane Support Systems
Source : Kanagawa Institute of technology

DIVP

Scenario modeling of assessment and sensing weaknesses of Odaiba, each packaged as a database

Database；Assessment，Sensing weaknesses of Odaiba，Scenario modeling packaged

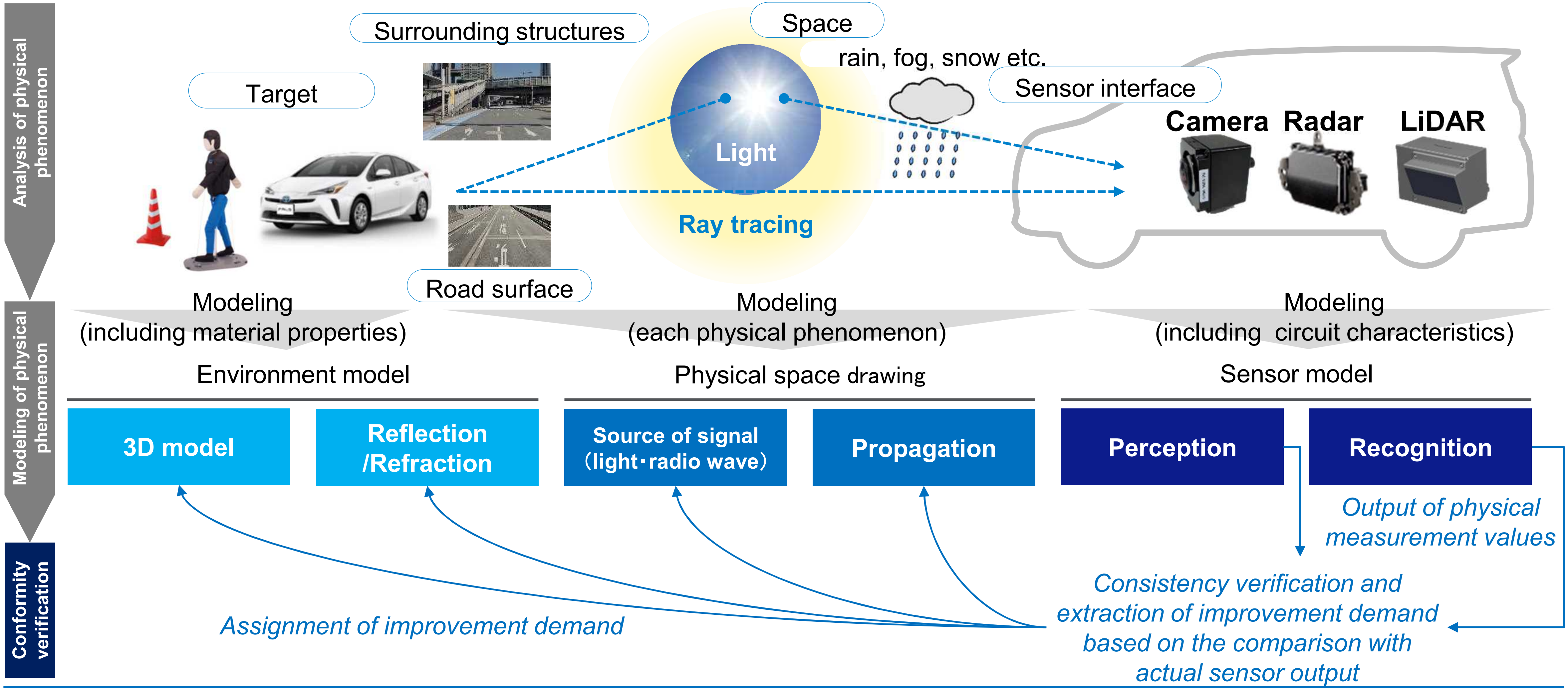


Source: MITSUBISHI PRECISION CO., LTD., Kanagawa Institute of Technology

DIVP

In order to accurately reproduce the sensor output, we measured and analyzed physical phenomena in the electromagnetic wave band used by the sensor, constructed a virtual space model with defined physical properties, combined it with the sensor model, and verified the consistency by comparing the actual vehicle with the Sim

Sensor model;
DIVP-Sim model and consistency verification



Source : DENSO, INC, HitachiAutomotiveSystems, INC, PIONEER CORPORATION, MITSUBISHI PRECISION CO.,LTD.

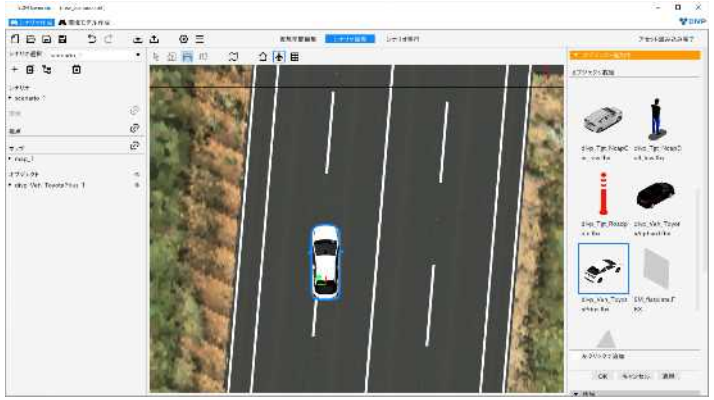
Expanded the functions of scenario editing and generation tools, developed highly novel functions for combining physical properties and materials, and built a flexible architecture that enables connections with other existing simulators in addition to static and dynamic traffic environment generation functions

Scenario Generator; SDM-Generator Features

screen example

Environment model creation function

Scenario creation function



Asset editing features

Key Features

Environment model creation function

- Optional Road Model Creation
- Arrangement of road markings, road signs, buildings, etc.
- Arrangement of blurred lines
- OpenDRIVE® import/export

Scenario creation function

- Arrangement of own vehicle, other vehicles, persons, etc.
- Control settings related to event/condition judgment
- OpenSCENARIO® import/export
- Import of driving log data by GPS or IMU

Asset editing features

- Assign a DIVP® material to an asset
- Reviewing Asset Control Information
- Asset confidentiality

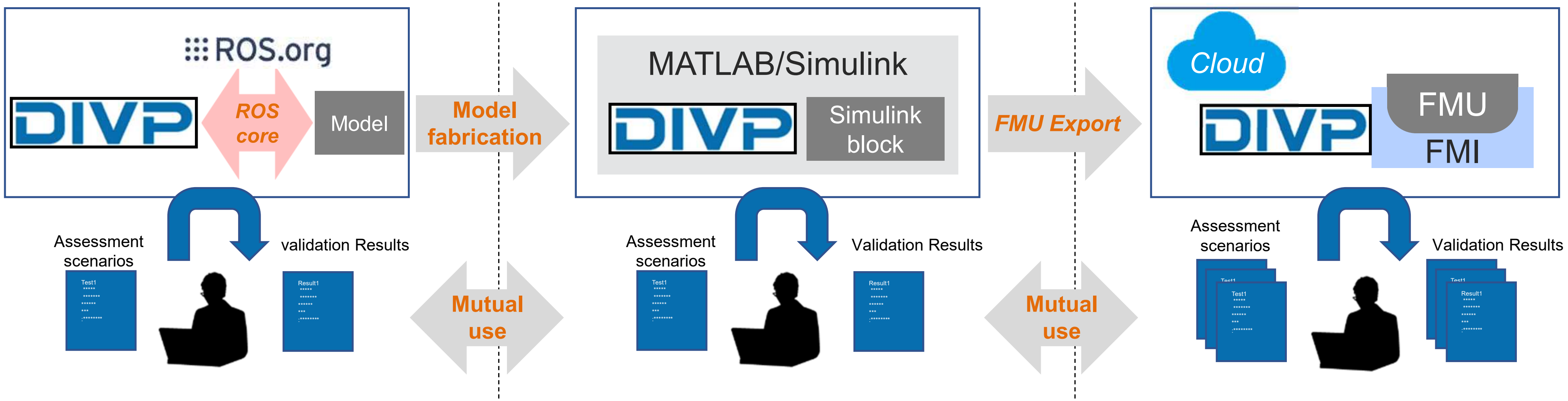
SDM Generator creates environment models and scenarios for DIVP® simulators by placing vehicles and targets in virtual space environments.

Source : MITSUBISHI PRECISION CO.,LTD.

With I/F for each environment, DIVP® simulation P/F adaptable to user needs environment can be provided

Connectivity; Flexible delivery format supporting standard IF (cloud format/module delivery to user environment)

Use case	Lapit Proto	Prior development and product development	product validation
Output Format	1. ROS	2. Simulink	3. FMU
Operational image	(see figure)	(see figure)	(see figure)
Advantage	Leveraging Open Source Software	Diversion of existing assets such as valuation tools	Multi-Condition, Fast Validation Using Cloud Resources



Connect ROS-mod, Simulink and FMU models with DIVP ® and confirm that SIM validation is possible

Source : Kanagawa Institute of technology

Proposed standardization to ASAM-OSI and OpenX while confirming the pioneering of DIVP® through collaboration between Germany and Japan VIVID

International standardization; Development of DIVP® Features into ASAM Standards Developed

ASAM OSI/OpenX Scope of Standardization activities

■ Discussing room for standardization regarding scenario/ material /I/Fs

Scenario | **Environmental model** | **Sensor Model** | **Fusion/AD models**

sensing weakness
Geometric
Proper-ty
SDMG
spatial design
cognition
recognition
Fusion
AD model

ASAM proposal

(1) Scenario
In accordance with the following
- OpenSCENARIO®
- OpenDRIVE®

Standardization of scenario format in senssing weakness
- OpenSCENARIO®
- OpenLabel

(2) Materials
Standardization of reflective properties of object surfaces for sensor validation
- OpenMaterial

(3) Camera cognitive I/F
Spectral I/F for camera input
- OSI3.0

(4) RADAR I/F
Standardization of sensor model I/F to ensure spatial design integrity
- OSI4.0

Approaches towards global standard

■ Collectively working on global standardization via VIVID collaboration

Standardization process | **Current status**

R&D
DIVP
R&D on simulation technology and toolchains

VIVID
Commonality
Complementarity
DIVP
Strategic planning for safety assessment
Scope definition for standardization
Discussion among experts

Standardization
ISO,ASAM ....

Scenario
Materials
Camera cognitive I/F
RADAR I/F
Accept Format ✓ ✓
Proposal Acceptance ✓
Standardized ✓

Source : Kanagawa Institute of technology

GBM

- ■ Summary of validation results
- ■ Validation results for each item
- ■ Future Initiatives

From the benchmark results, work on further strengthening of "scenario generator," "connectivity" and "international standardization"

Virtual Space Simulation PF Enhancement Points

No	Validation axis	Reinforcement points	Policy for Initiatives
2	Scenario Generator	• Expansion toward safety assessment on open roads • Establishing sensing weakness scenario DB	• Scenario modeling based on real traffic data at intersections (local roads) • Developing a Traffic Participant Behavior Model =>Joint development with the SAKURA Project ・Expansion of sensing weakness scenario and establishment of automatic generation technology
4	Connectivity	• Response to sensor Fusion validation • Development of the latest radar model	• Virtual performance verification of sensor Fusion (Camera, radar) • Building data analysis functions to improve validation efficiency =>Promote collaboration with AD-URBAN and SAKURA projects
5	international standardization	• Step up with safety assessment (Scenario, Verification, Metrics) by VIVID • Extend the scope of international cooperation to the US and EU	• Building a consistent safety assessment platform from Scenario to Verification to Metrics • Accelerating standardization through collaboration with VIVID • Study of SAE and ISO

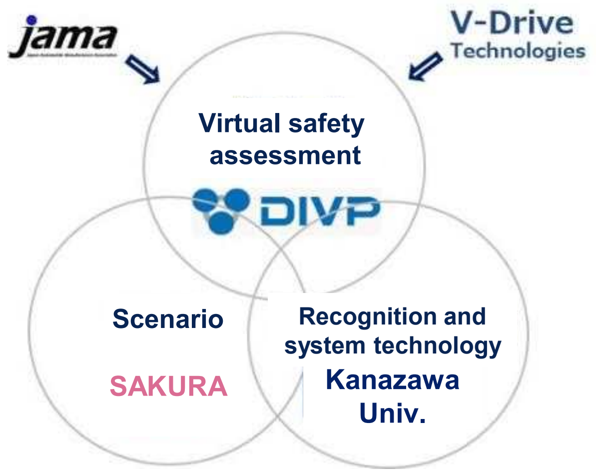
Source : Kanagawa Institute of technology

"Automated Driving Safety Assessment" sublimated to an all-Japan project structure
->Aim to improve the actual safety of Roadto L4 and contribute to international standardization

Initiatives for the Future

Initiatives after FY 23

- **Collaborate with JAMA to** aim for **the establishment of AD safety assessment**
- Promote consistent validation and international collaboration from scenario to simulation to system.



All-Japan system

First semester: 2018-2020
- Sim Evaluability Verification

Late study: 2021-2022
- Construction and commercialization of sensor and virtual space Sim.P/F

(Promotion of safety assessment in virtual space through collaboration between Japan and Germany)

After SIP (FY23~)
- Promotion of research to **establish safety assessment**

Role sharing after FY 23 (draft)

Conception	Strategy, international standardization	D. International Collaboration and Standardization, Planning and Promotion of Research Strategies
	DIVP	A. Extend and utilize environmental, spatial, and sensor models into tool chains B. Establishment of validation indicators and systems (construction of intersection validation models and indicators) C. Construction of sensing weakness DB and automation technology for generating weakness scenario models
Implementation	SAKURA	E. Development/implementation of safety assessment framework for AD vehicles F. Expanded Scenario DB G. Building a continuous safety assessment system
	金沢大学	H. Examination of safety validation index during crossing I. Investigation of an efficient AD system safety validation method utilizing a virtual environment
Expand	GL Update	D. GL update and publication by JAMA

Source : Kanagawa Institute of technology

External call

Actively disseminated information to both domestically and internationally, mainly through research presentations.

Results of external dissemination and other activities

（unit : number）

	2018	2019	2020	2021	2022	Total
■ Presentation	—	4	7	12	21	44
■ Paper	—	—	—	—	2	2
■ Press release	—	1	1	2	1	5
■ Patent application*	—	—	—	2	2	4

* : it includes applications in preparation in 2022

The official website of SIP-adus has a page for information on priority themes for international collaboration, and the volume of information on Safety Assurance was larger than that of other themes, and the number of accesses to the page was also higher.

Number of Accesses by Priority Themes for International Collaboration

テーマ	Number of accesses 2021*1	Number of accesses 2022*2
Safety Assurance	865	643
Human Factors	382	405
Dynamic Map	353	668
Connected Vehicles	313	565
Impact Assessment	171	326
Cyber Security	―	282

*1：May/2021～May/2022
*2：April/2022～April/2023

Source：For 2022, based on information provided by Congrès Inc.

DIVP

Appendix

In fiscal FY2019, we gave presentations on research and gave lectures on a number of issues

Results of research presentations and lectures

No.	Presenter	Affiliation	Title	Names of academic societies and events	Date of announcement
1	Hideo Inoue	Kanagawa Institute of Technology	Introduction of "Driving Intelligence Validation Platform (DIVP™) project" on SIP-adus	EUMW2022_Virtual Validation of Automotive Sensors	2019/9
2	Hideo Inoue	Kanagawa Institute of Technology	Driving Intelligence Validation Platform	Euro NCAP-JAMA Meeting, AD-Safety assurance session	2019/11
3	Hajime Kumabe	Kanagawa Institute of Technology	Denso Group's Future Mobility Initiatives	AUTOMOTIVE DIGITAL PROCESS Seminar 2019	2019/11
4	Koji Nagase	Kanagawa Institute of Technology	Presentation：SIP Phase2 AD: Development of AD validation environment improvement method in virtual space	6th Automotive Software Frontier 2021	2020/2

In fiscal FY2020, we gave presentations on research and gave lectures on a number of issues

Results of research presentations and lectures

No.	Presenter	Affiliation	Title	Names of academic societies and events	Date of announcement
1	Hideo Inoue	Kanagawa Institute of Technology	DIVP® Research outcome	SIP committee member visit	2020.10.20
2	Hideo Inoue	Kanagawa Institute of Technology	Driving Intelligence Validation Platform	SIP-adus Workshop 2020	2020.11.10
3	Hideo Inoue	Kanagawa Institute of Technology	Presentation	Workshop for virtual simulation on VIVID	2020.11.13
4	Hideo Inoue	Kanagawa Institute of Technology	Interview: The theory of evolution of cars that do not collide (article)Future sensor simulation system in autonomous driving, p074-077, Is the ADAS / AD technology working properly? Establishment of quantitative validation method for vehicles and its significance, p078-081	MotorFan illustrated Volume 171, (2021.1.28 published)	2020.11.25
5	Hideo Inoue	Kanagawa Institute of Technology	–VIVID Virtual validation –Technological progress	VIVID expert workshop, 4th Bilateral expert workshop on connected and automated driving Virtual meeting, German-Japan joint virtual validation methodology for intelligent driving systems	2020.11.25
6	Hideo Inoue	Kanagawa Institute of Technology	Presentation：SIP Phase2 AD: Development of AD validation environment improvement method in virtual space	8th Automotive Functional Safety Conference	2020.12.10
7	Koji Nagase	Kanagawa Institute of Technology	Presentation：SIP Phase2 AD: Development of AD validation environment improvement method in virtual space	6th Automotive Software Frontier 2021	2021.02.17
8	Hideo Inoue	Kanagawa Institute of Technology	Presentation：SIP Phase2 AD: Development of AD validation environment improvement method in virtual space；About DIVP® Proj	[Automotive Technology Association] 14th Automobile Control and Model Division Committee	2021.03.23

In fiscal FY2021, we gave presentations on research and gave lectures on a number of issues

Results of research presentations and lectures 1/2

No.	Presenter	Affiliation	Title	Names of academic societies and events	Date of announcement
1	Kazushi Takeda	Mitsubishi Precision	OpenDRIVE® Concept Project and Other OpenX Projects From a Tool Vendor Perspective	ASAM Regional Meeting Japan 2021	2021.6.29
2	Hideo Inoue	Kanagawa Institute of Technology	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 -	Safety Engineering Symposium 2021	2021.7.1
3	Hideo Inoue	Kanagawa Institute of Technology	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-	Gunma University Next Generation Open Innovation Council	2021.7.26
4	Hitachi Astemo Shōji Muramatsu	Hitachi Astemo	Development of technologies for automotive products that support autonomous driving	CASE workshop seminar	2021.9
5	Shotaro Koyama Kenichi Uehara Hideo Inoue	Kanagawa Institute of Technology	VALUATION OF APPARENT RISK BY USING HARDWARE-IN-THE-LOOP SYSTEM	FAST-zero '21	2021. 9.21
6	Hideo Inoue	Kanagawa Institute of Technology	Developmemt of Driving Intelligence Validation Platform (DIVP®) for Automated Driving Safety Assurance, p91-p97(JP), p.89-94(EN)	SIP 2nd Phase: Automated Driving for Universal Services -Mid-Term Results Report (2018-2020),	2021.9.30(JP) 2021.12.6(EN)
7	Tokihiko Akita	Toyota Technological Institute	Smart Vehicle Research Center Activity Status Report	The 11th Toyota Technological Institute Smart Vehicle Research Center Symposium	2021.10.21

In fiscal FY2021, we gave presentations on research and gave lectures on a number of issues

Results of research presentations and lectures 1/2

No.	Presenter	Affiliation	Title	Names of academic societies and events	Date of announcement
8	Hideo Inoue	SIP-adus Workshop 2021	Driving Intelligence Validation Platform for Automated Driving Safety Assurance Report on research results	SIP-adus Workshop 2021	2021.11.10
9	Hideo Inoue	Kanagawa Institute of Technology	Development of automated driving validation environment improvement method in virtual space; DIVP® Project	9th Autonomous Driving Safety Conference 2021	2021.12. 8
10	Hideo Inoue	Kanagawa Institute of Technology	Development of automated driving validation environment improvement method in virtual space	Invited lecture at CAE Forum 2022, Hideo Inoue	2022.2.10
11	Shunichi Takagi	Kanagawa Institute of Technology	Development of automated driving evaluation simulator in virtual space and application to practical education	Kanagawa Institute of Technology Educational Research Symposium Utilizing IT	2022/3

In fiscal FY2022, we gave presentations on research and gave lectures on a number of issues

Results of research presentations and lectures 1/3

No.	Presenter	Affiliation	Title	Names of academic societies and events	Date of announcement
1	Hideo Inoue	Kanagawa Institute of Technology	Development of Virtual Validation Platform ;DIVP® for Automated Driving Safety Assurance	EUMW2022_Virtual Validation of Automotive Sensors	2022/4/7
2	Hideo Inoue	Kanagawa Institute of Technology	Development of Virtual Validation Platform ;DIVP® for Automated Driving Safety Assurance	Euro NCAP-JAMA Meeting, AD-Safety assurance session	2022/5/16
3	Hideo Inoue	Kanagawa Institute of Technology	Development of Self-Driving Safety Assessment Simulation in Virtual Space - Co-sim. Collaboration between DIVP® and MATLAB/Simulink -	MATLAB Expo. 2022 lecture	2022/5/22
4	Hideo Inoue	Kanagawa Institute of Technology	Driving Intelligence Validation Platform for Automated Driving Safety Assurance	Safe-Connected and Automated Drive German-Japan workshop, Keynote	2022/6/1
5	Hideo Inoue/Hidesuke Sato	Kanagawa Institute of Technology/Toyota Motor Corporation	Safety Validation of Automated Driving Systems	Safe-Connected and Automated Drive German-Japan workshop, Keynote	2022/6/1
6	Hideo Inoue	Kanagawa Institute of Technology	Development Driving Intelligence Validation Platform - Status overview -	Safe-Connected and Automated Drive German-Japan workshop, Day 2	2022/6/2
7	Shotaro Koyama, Hideo Inoue	Kanagawa Institute of Technology	Development of Driving Intelligence Validation Platform (DIVP®) for ADS Safety Assurance	Automated Road Transportation Symposium 2022	2022/7
8	Hideo Inoue	Kanagawa Institute of Technology	Development of autonomous driving safety validation simulation focusing on virtual space and sensor physical model	Usable Sensor Symposium 2022	2022/7/2
9	Hideo Inoue	Kanagawa Institute of Technology	Development of Driving Intelligence Validation Platform(DIVP®) for ADS	ITS World Congress 2022	2022/9/
10	Hideo Inoue	Kanagawa Institute of Technology	Introducing DIVP® Products	V-Drive Technologies Press Release	2022/9/6

In fiscal FY2022, we gave presentations on research and gave lectures on a number of issues

Results of research presentations and lectures 2/3

No.	Presenter	Affiliation	Title	Names of academic societies and events	Date of announcement
11	Hideo Inoue	Kanagawa Institute of Technology	Development of Driving Intelligence Validation Platform (DIVP®) for ADS Safety Assurance	FINAL Project EVENT of RELAI, EDI GmbH	2022/9/29
12	Hideo Inoue	Kanagawa Institute of Technology	Driving Intelligence Validation Platform (DIVP®) for ADS Safety Assurance	SIP-adus Workshop 2022, Safety assurance, Keynote	2022/10/12
13	Hidesuke Sato/Hideo Inoue	Toyota Motor Corporation/Kanagawa Institute of Technology	JPN Research Activities Towards AD Safety Assurance - DIVP® Application -	SIP-adus workshop 2022, Safety Assurance, Breakout session, Keynote	2022/10/13
14	Hideo Inoue	Kanagawa Institute of Technology	Driving Intelligence Validation Platform (DIVP®) for ADS Safety Assurance	Visit to KAIT by Prof. Dr. Ina Schieferdecker, Director General, BMBF	2022/10/27
15	Hideo Inoue/Matthias Hein	Kanagawa Institute of Technology	German-Japan joint virtual validation methodology for intelligent driving systems-VIVID	Visit to KAIT by Prof. Dr. Ina Schieferdecker, Director General, BMBF	2022/10/27
16	Hidehiro Toyoda	Hitachi Astemo Co., Ltd.	Autonomous Driving System -Overview of Autonomous Driving System, System Architecture, Sensing, Simulation Verification Environment-	University of Electro-Communications Academic special course	2022/10
17	Mohamed Shouman/Tokihiko Akita	Toyota Institute of Technology (KAIT subcontractor)	Development of detection method for millimeter-wave radar using DIVP® simulator (English Title: Development of Detection Techniques for Millimeter - Wave Radar Using DIVP® Simulator)	Academic Lecture Meeting of Society of Automotive Engineers, Fall 2022	2022/10
18	Hideo Inoue	Kanagawa Institute of Technology	On safety assessment of autonomous vehicles - Development of simulation platform (DIVP®) in virtual space -	Symposium sponsored by the Active Safety Division Committee of the Society of Automotive Engineers, Japan, and initiatives for the social implementation of technologies and services for the spread of autonomous driving in Japan	2022/11/15

In fiscal 2022, we gave presentations on research and gave lectures on a number of issues

Results of research presentations and lectures 3/3

No.	Presenter	Affiliation	Title	Names of academic societies and events	Date of announcement
19	Kimiya Yamaashi	Hitachi Astemo Co., Ltd.	Efforts to develop environmental and safety technologies at Hitachi Astemo	Cadence Private Lecture	2022/11
20	Hideo Inoue	Kanagawa Institute of Technology	Self-Driving Safety Assessment Simulation in Virtual Space: DIVP® and International Collaboration	Lecture at the 10 Annual Automotive Function Safety Conference	2022/12/8
21	Tokihiko Akita	Toyota Institute of Technology	Application of the Automated Driving Safety Evaluation Platform (DIVP®) to research and development of millimeter-wave radar recognition logic)	CAE Forum on Automotive Technology 2023 Online	20223/2