DIVP
Driving Intelligence Validation Platform

FY2020 Year-end report

Weather Forecast

AD safety Assurance*

For Validation & Verification Methodology

* AD : Automated Driving

Index

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

* PG : Proving ground, CG : Community ground

Project Design

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 DIVP

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

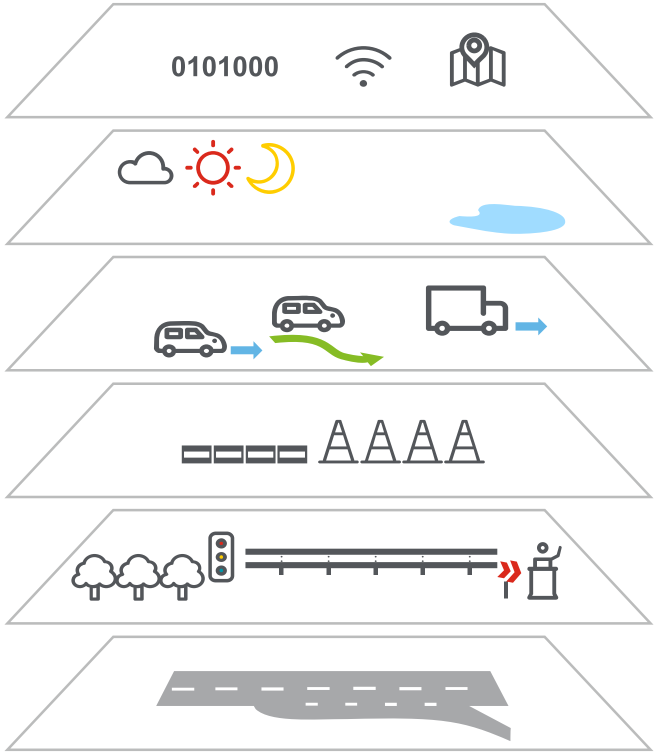
Source : Kanagawa Institute of technology, MITSUBISHI PRECISION CO.,LTD., DENSO Corporation, Pioneer Smart Sensing Innovations Corporation, Hitachi Automotive Systems, Ltd.

Simulation is the Key for total validation flame work for AD-Safety assurance

AD safety validation methodology

Traffic environment conditions

■ Generating test conditions by combining various conditions



Layer6	Digital information
Layer5	Environmental conditions
Layer4	Moving objects
Layer3	Temporal modifications & events
Layer2	Road furniture and rules
Layer1	Road shape

Total validation test system

■ Test management combining various experimental methods

Real vehicle test

Bench test (VILS*)

Simulation

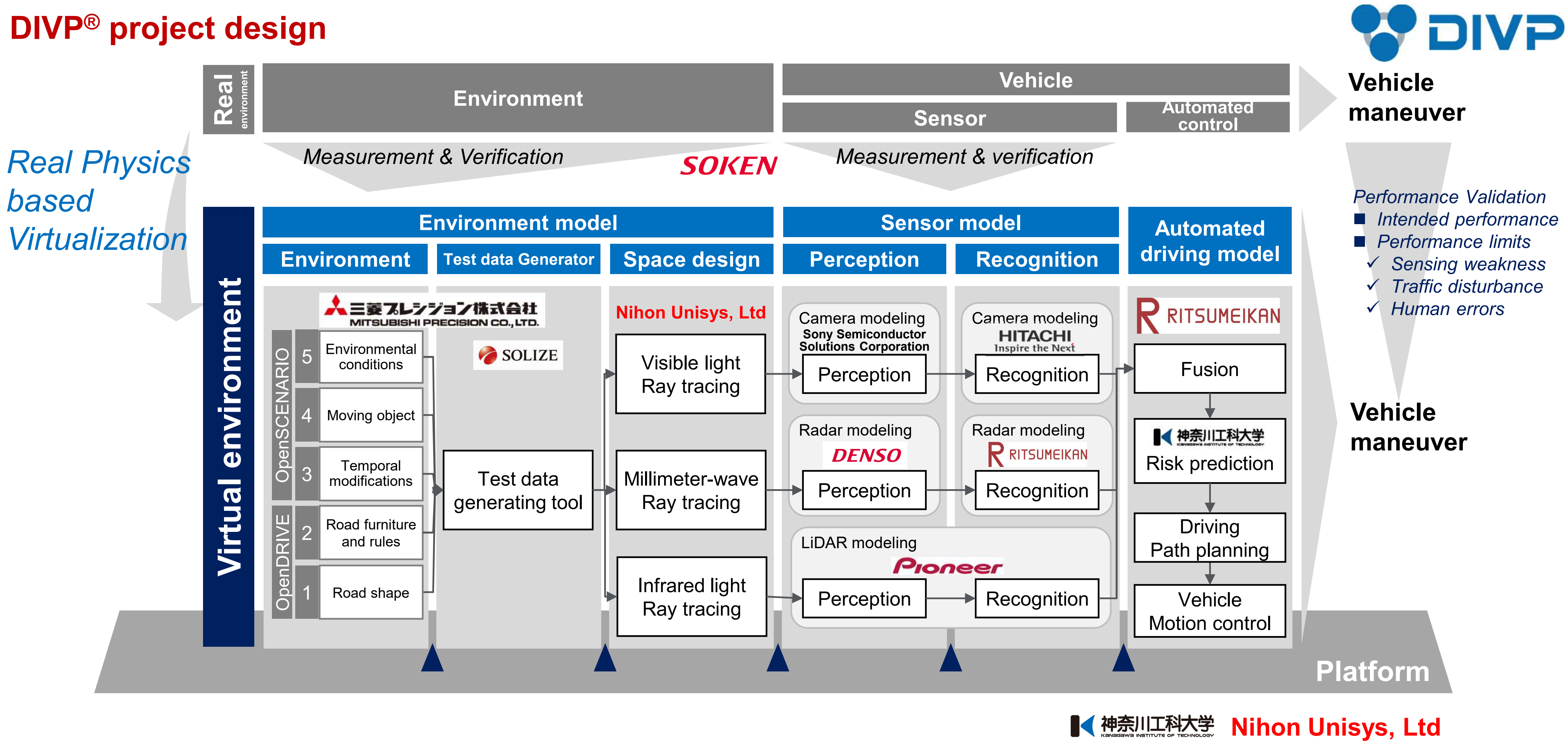
Consistency & numbers of available Environment conditions would be a key for Simulation implementation into the AD-Safety validation methodology

* VILS : Vehicle in the Loop

Source: Mitsubishi Precision Co. Ltd.

Designed project architecture, Precisely Duplicate from Real to Virtual, and Verification of consistency with real testing by 10-exparts as DIVP® Consortium

DIVP® project design

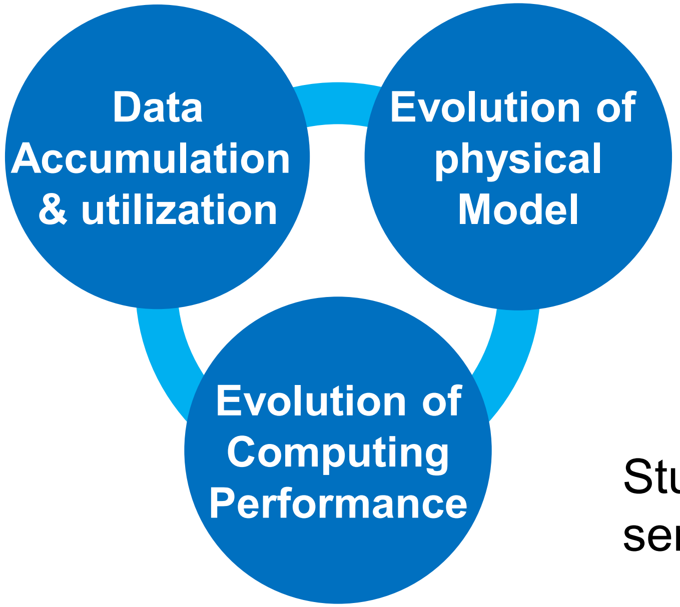


DIVP® scope covers “Physical Model” & “Computing Performance” in Trinitarian approach

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)

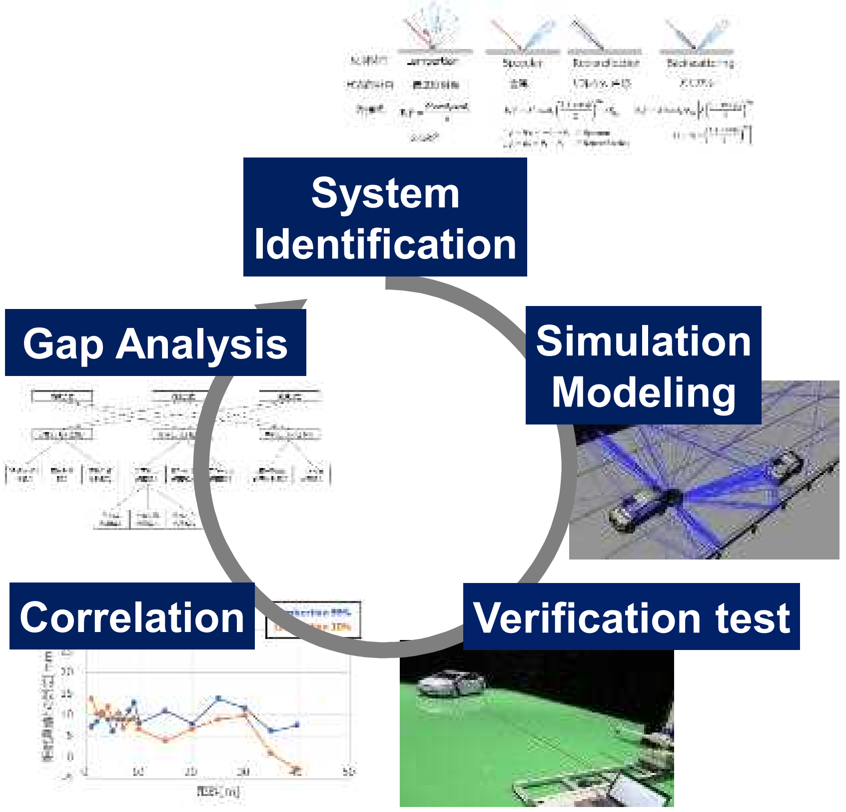
With project outcome DIVP® is to Improve Simulation based AD Safety validation for Consumer acceptable Safety assurance

FY2020 Outcome

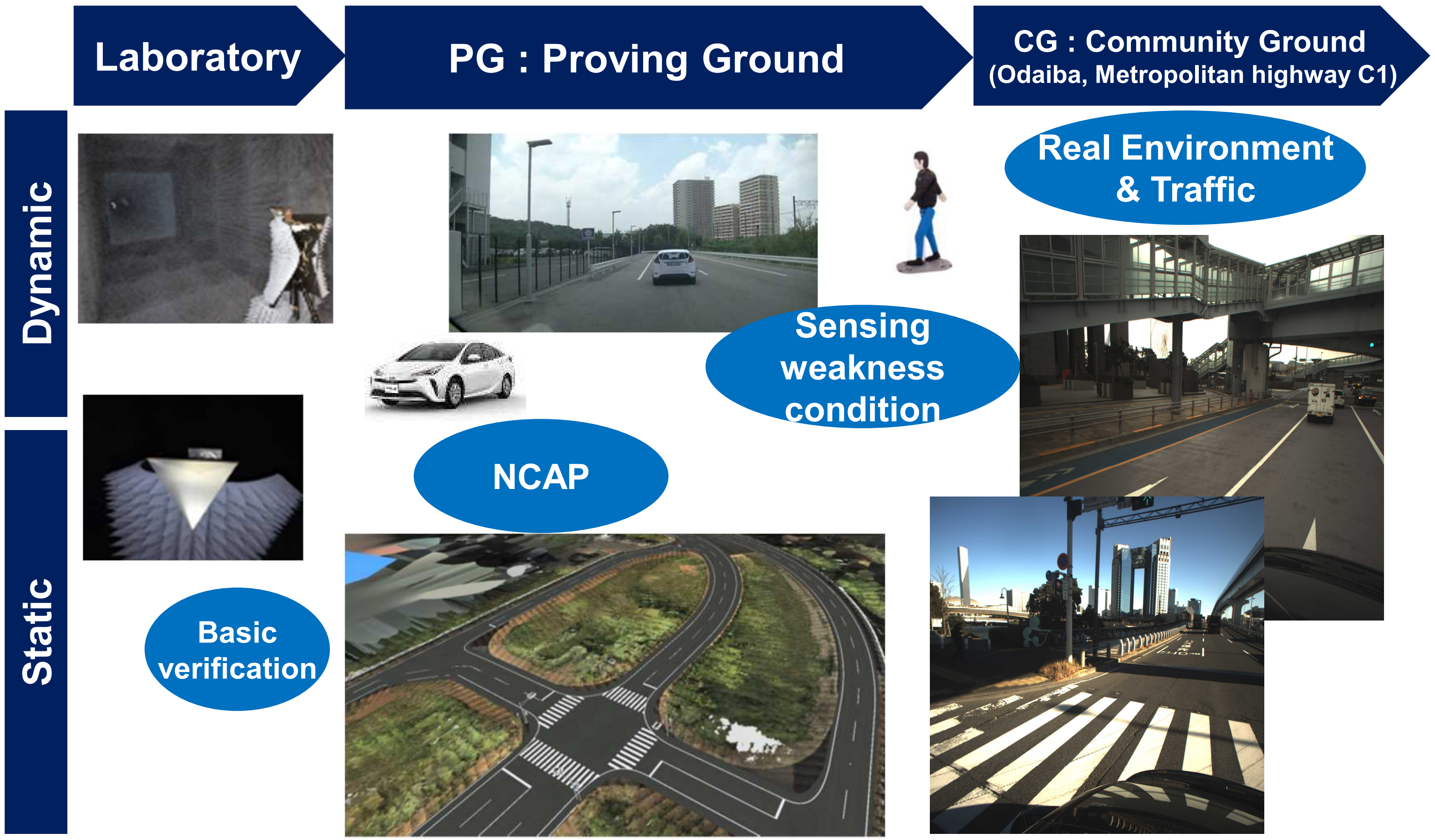
Modeling the sensing physics with measurement verification bases, and expanding validation field from Static Labo-condition to Dynamic Real condition as CG

Validation framework

Measurement based approach



Expansion roadmap

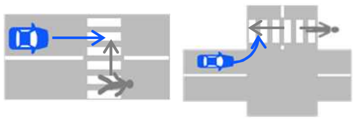
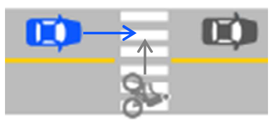
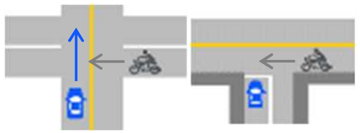
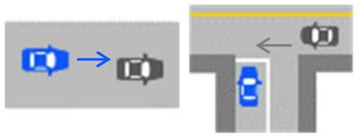
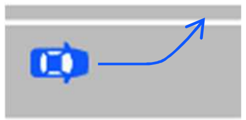
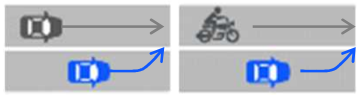


Source : DENSO Corporation, SOKEN, INC, MITSUBISHI PRECISION CO.,LTD.

Duplicated NCAP protocols and Structured & planed asset road map for NCAP2025

Virtual-PG for Eur-NCAP

Legend: Current plan / NCAP2025 forecast / Out of scope

	AEB*1				LSS*3	
	Pedestrian	**Cyclist**	**PTW**	**Car**	**White Lane**	**Car/PTW**
Objective	Emergency braking with forward Pedestrian detection (with Night condition)	Emergency braking with forward Crossing bike	Emergency braking with forward PTW	Emergency braking with forward & crossing Car detection	Lane keeping control with warning alert	Driving assist with lane merging
NCAP2025 forecast	■ Crossing Pedestrian ■ Backward Pedestrian in reverse ■ AEB/AES*2 cooperative control	■ AEB/AES*2 cooperative control	■ PTW in cornering ■ Jumping out stuff in insufficient visibility	■ Head on collision ■ Jumping out stuff in insufficient visibility	-	■ Oncoming PTW ■ Passing PTW
Overview						
Required assets: 5 Environmental conditions	Day (Current plan), Night (Current plan)	Day (Current plan), Night (Out of scope)	Day (NCAP2025 forecast), Night (Out of scope)	Day (Current plan), Night (Out of scope)	Day (Current plan), Night (Out of scope)	Day (Current plan), Night (Out of scope)
4 Moving object	Adult (Current plan), Child (Current plan), Bike (Out of scope), Car (Out of scope), Mot-cycle (Out of scope), Mopet (Out of scope)	Adult (Out of scope), Child (Out of scope), Bike (Current plan), Car (Out of scope), Mot-cycle (Out of scope), Mopet (Out of scope)	Adult (Out of scope), Child (Out of scope), Bike (Out of scope), Car (Out of scope), Mot-cycle (NCAP2025 forecast), Mopet (NCAP2025 forecast)	Adult (Out of scope), Child (Out of scope), Bike (Out of scope), Car (Current plan), Mot-cycle (Out of scope), Mopet (Out of scope)	Adult (Out of scope), Child (Out of scope), Bike (Out of scope), Car (Out of scope), Mot-cycle (Out of scope), Mopet (Out of scope)	Adult (Out of scope), Child (Out of scope), Bike (Out of scope), Car (Current plan), Mot-cycle (NCAP2025 forecast), Mopet (NCAP2025 forecast)
3 Temporal modifications	Stopped vehicle (Current plan)	Stopped vehicle (Current plan)	Stopped vehicle (Out of scope)	Stopped vehicle (Out of scope)	Stopped vehicle (Out of scope)	Stopped vehicle (Out of scope)
2 Road furniture and rules	Dividing lane (Current plan), Crosswalk (NCAP2025 forecast), Signal (NCAP2025 forecast), Side wall (Out of scope)	Dividing lane (Current plan), Crosswalk (NCAP2025 forecast), Signal (NCAP2025 forecast), Side wall (Out of scope)	Dividing lane (NCAP2025 forecast), Crosswalk (Out of scope), Signal (NCAP2025 forecast), Side wall (NCAP2025 forecast)	Dividing lane (Current plan), Crosswalk (Out of scope), Signal (Current plan), Side wall (NCAP2025 forecast)	Dividing lane (Current plan), Crosswalk (Out of scope), Signal (Out of scope), Side wall (Out of scope)	Dividing lane (Current plan), Crosswalk (Out of scope), Signal (Out of scope), Side wall (Out of scope)
1 Road shape	straight (Current plan), Crossroad (NCAP2025 forecast), T-junctin (Out of scope)	straight (Current plan), Crossroad (NCAP2025 forecast), T-junctin (Out of scope)	straight (NCAP2025 forecast), Crossroad (NCAP2025 forecast), T-junctin (NCAP2025 forecast)	straight (Current plan), Crossroad (Current plan), T-junctin (NCAP2025 forecast)	straight (Current plan), Crossroad (Out of scope), T-junctin (Out of scope)	straight (Current plan), Crossroad (Out of scope), T-junctin (Out of scope)

*1 AEB : Automatic Emergency Braking, *2 AES : Automatic Emergency Steering, *3 LSS : Lane Support System / PTW : Powered Two Wheeler

Source : EuroNCAP2025(https://cdn.euroncap.com/media/30700/euroncap-roadmap-2025-v4.pdf)

Duplicate Euro-NCAP AEB Pedestrian protocol in Virtual-PG & expanding toward NCAP2025

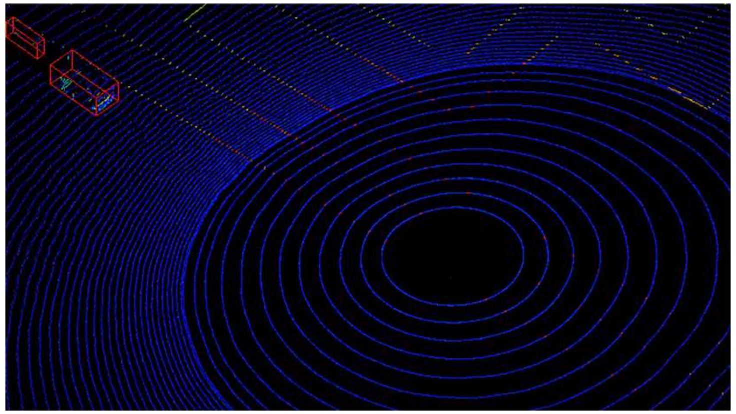
Euro-NCAP Simulation ; pedestrian darting out scenario

SOKEN

Pedestrian darting out scenario sim.

Camera sim.

LiDAR sim.



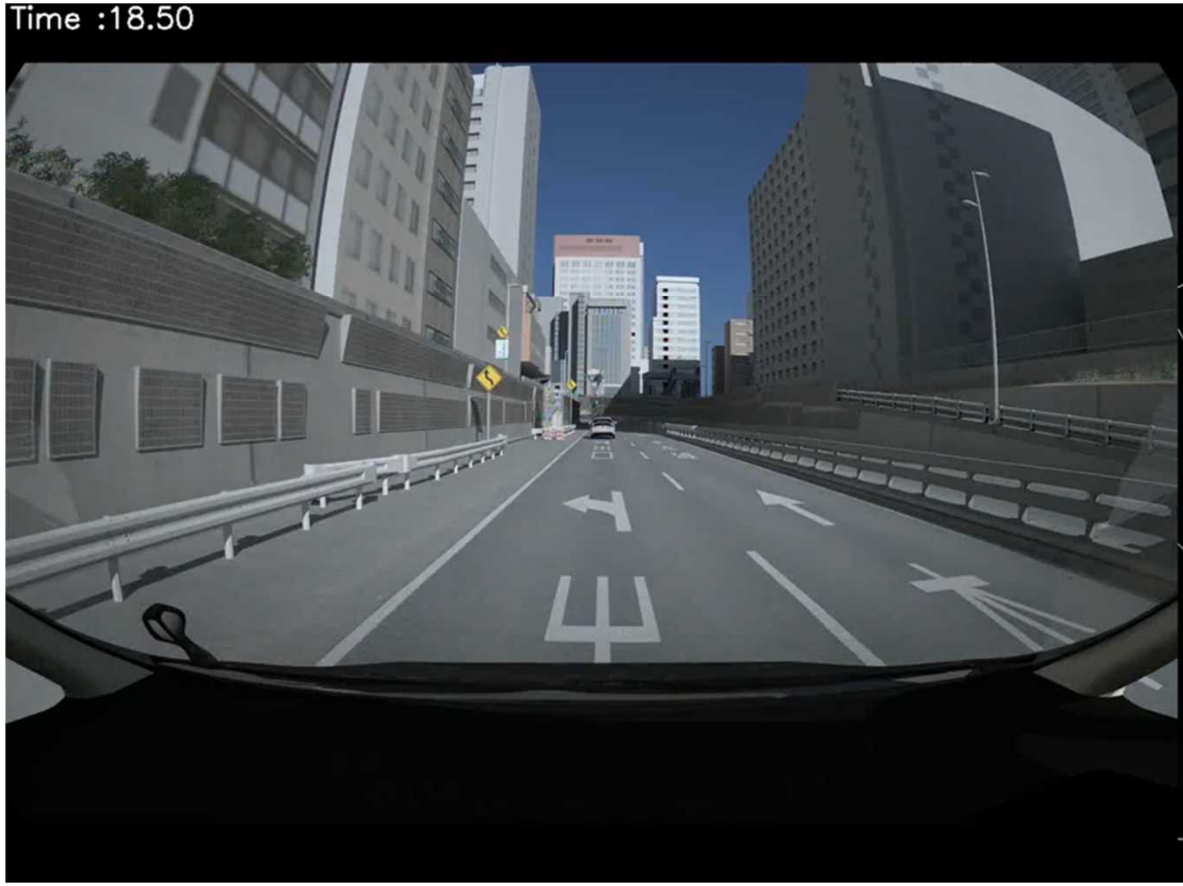
Source : Kanagawa Institute of technology

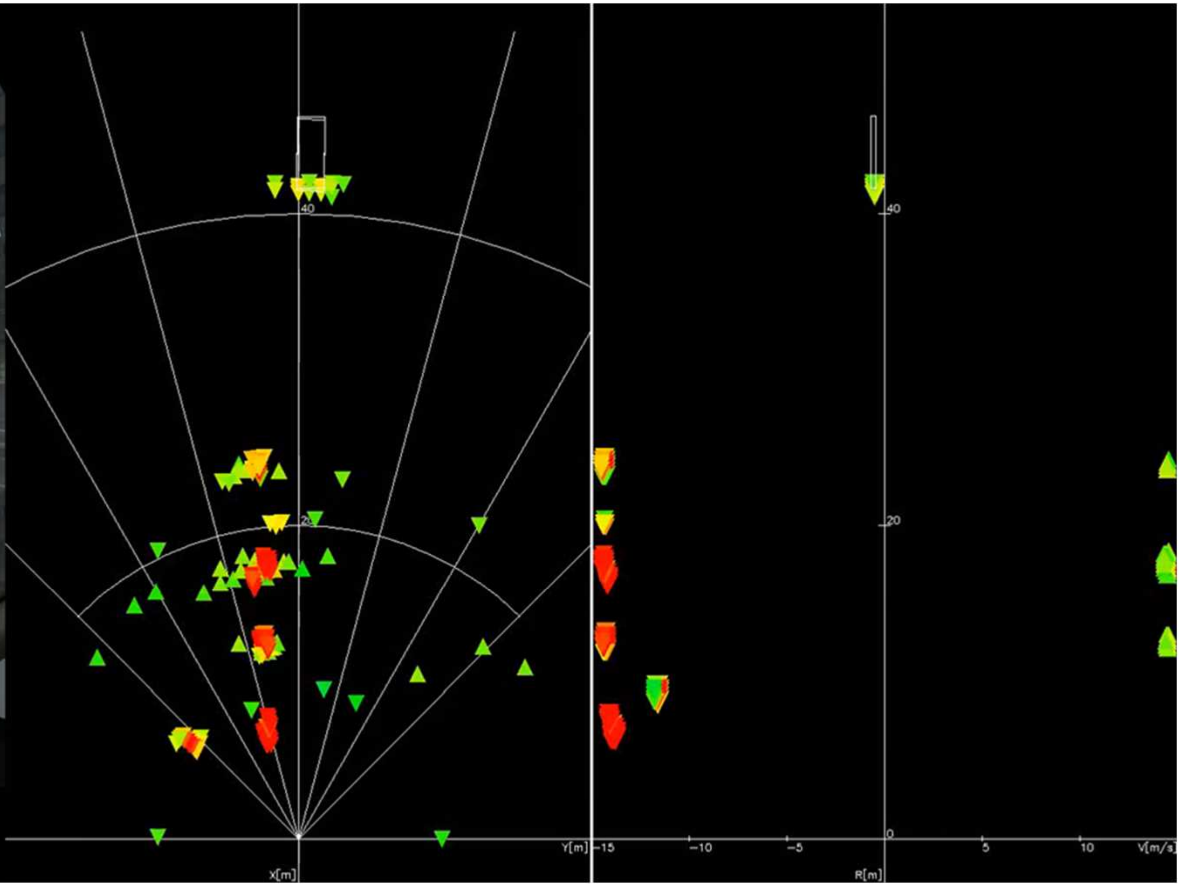
Duplicated Tokyo metro highway C1 & Odaiba as Virtual Community Ground for sensing weakness validation in Real traffic environmental conditions

<Example> C1 Simulation from Hamazaki bridge JCT to Edobashi JCT

神奈川工科大学
KANAGAWA INSTITUTE OF TECHNOLOGY

Camera output	Radar output



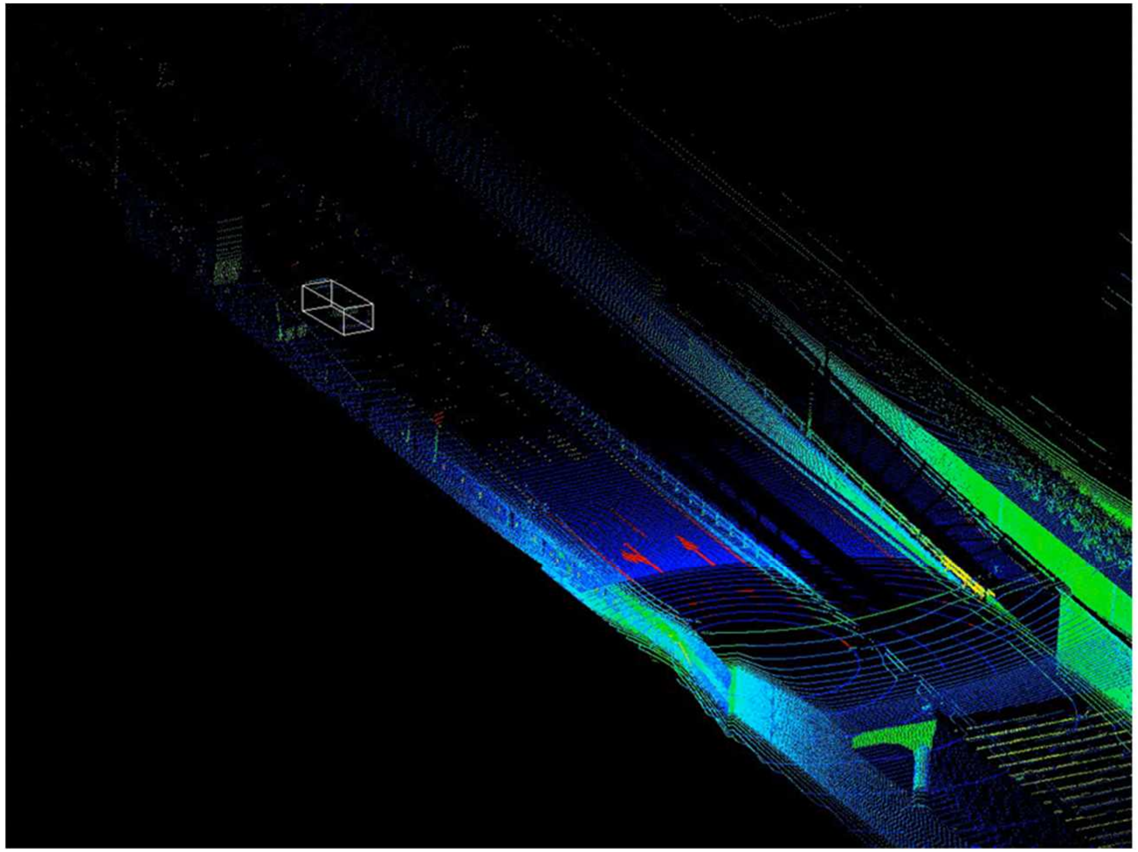
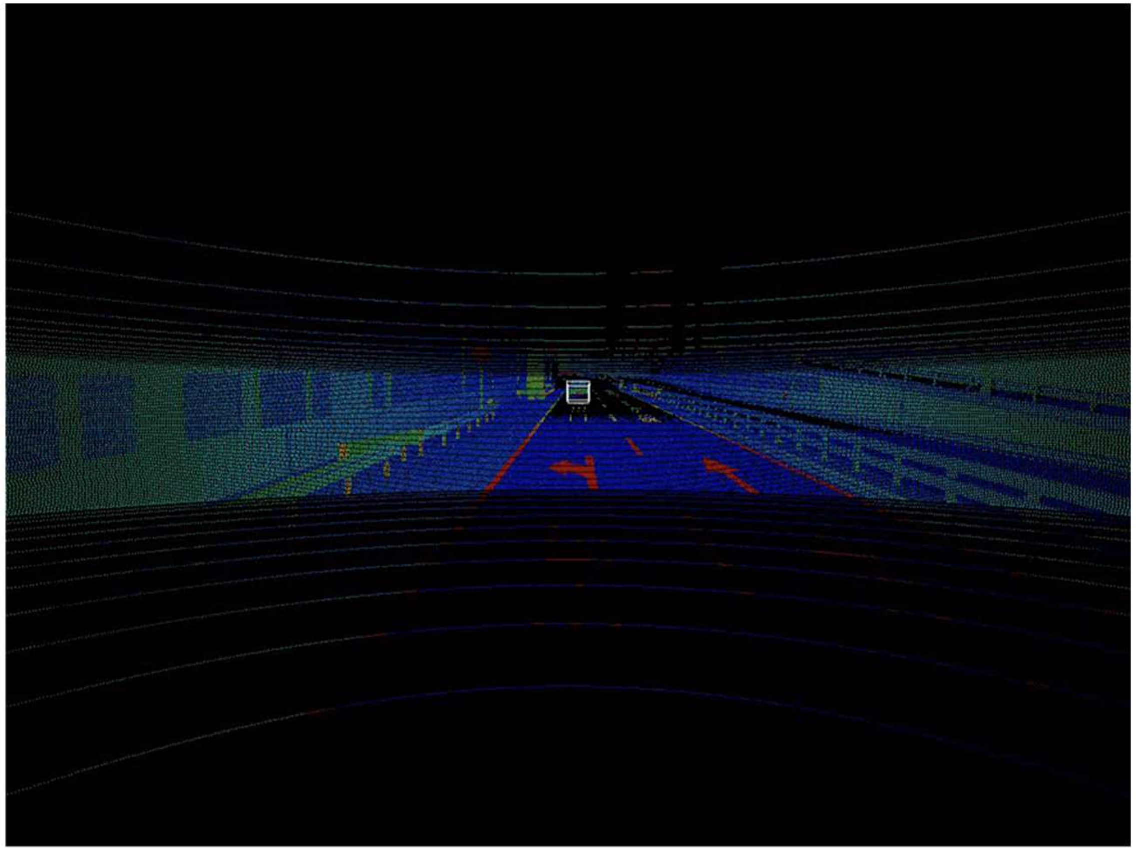


Source : Kanagawa Institute of technology

Duplicated Tokyo metro highway C1 & Odaiba as Virtual Community Ground for sensing weakness validation in Real traffic environmental conditions

<Example> C1 Simulation from Hamazaki bridge JCT to Edobashi JCT

神奈川工科大学
KANAGAWA INSTITUTE OF TECHNOLOGY

LiDAR output	LiDAR output
	

Source : Kanagawa Institute of technology

Duplicated Tokyo metro highway C1 & Odaiba as Virtual Community Ground for sensing weakness validation in Real traffic environmental conditions

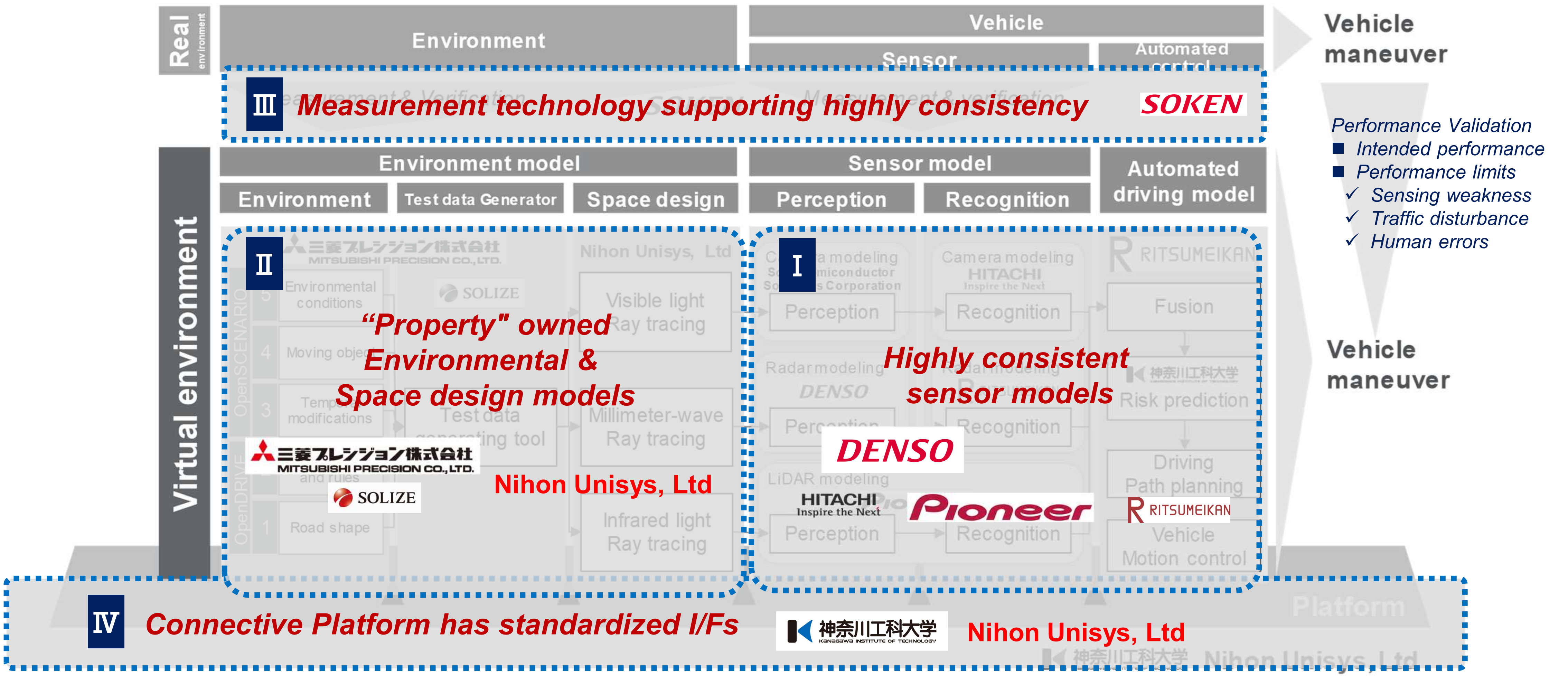
<Example> Simulation results in Odaiba

神奈川工科大学
KANAGAWA INSTITUTE OF TECHNOLOGY

Source : Kanagawa Institute of technology

DIVP® output Highly consistent Ⅰ Sensor & Ⅱ Environmental models with Ⅲ Sensing physics measurement bases, onto Ⅳ Connective Platform has standard I/Fs

FY20 Outcome



DIVP® is the only simulation with Highly Consistent Environment & Sensor "Pair modeling"

Benchmark result of Camera

神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

Classification	Phenomena	DIVP®	IPG CarMaker 9.0	Siemens PreScan 2020.1	VIRES VTD 2.2.0	ANSYS VRX R2.2020
Source	General light source(vehicle lamp, etc.)	◎	○	○	○	○
Source	Radiance of solar	◎	○	○	○	○
Source	Radiance of sky	◎	×	△	○	△
Source	Indirect light	◎	○	×	×	○
Optics	Reflection, diffusion, transmission on the object surface	◎	△	△	△	○
Optics	Aging of the object surface	◎(asphalt)	×	○	△	※
Optics	Fouling	×	△	△	×	※
Propagation	Scattering(Participating medium)	○(fog)	×	×	×	○
Sensor	Effect of vehicle dynamics	◎	△	△	△	△
Sensor	Effect of temperature characteristic	×	×	×	×	○
Sensor	Aging of the sensor	×	×	×	×	×
Sensor	Lens distortion	○	○	○	○	○
Sensor	Lens flare	×	×	×	×	×
Sensor	Ghost	×	×	×	×	×
Sensor	Fouling(windshield)	○ (raindrop)	△	×	×	×

①
②
③

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

Items that shows the superiority of DIVP®

① Only DIVP® is to verify the actual machine.
② CarMaker only supports reflection and transmission,
Prescan only supports reflection,
VTD unsupports a moving objects.
VRX partially supports radiance of sky.
③ Only DIVP® fully supports vehicle behavior.

※ Limit the range that can be completed within 2020 by prioritizing DIVP® functions based on frequency and criticality

DIVP® is the only simulation with Highly Consistent Environment & Sensor "Pair modeling"

Benchmark result of Radar

神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

Classification	Phenomena	DIVP®	IPG CarMaker 9.0	Siemens PreScan 2020.1	VIRES VTD 2.2.0	ANSYS VRX R.2020	
Source	Other vehicle light source(interference)	◎	×	×	×	△	②
Optics	Reflection, diffusion transmission on the object surface	◎	△	△	△	△	③
Optics	Aging of the object surface	○(asphalt)	△	×	×	×	④
Optics	Fouling	◎(raindrop)	△	×	×	△	
Optics	Phase/polarization change during reflection	◎	○	×	×	×	
Propagation	Diffraction	×	×	×	×	※	⑤
Propagation	Multi reflection/transmission	◎	△	△	×	×	
Propagation	Scattering(attenuation), interference in space	◎	○	○	×	×	
Propagation	Doppler	◎	○	○	×	○	
Propagation	Micro-Doppler	◎	○	○	×	※	⑥
Sensor	Own light source(reproduction of modulation method)	◎	○	○	×	○	
Sensor	Effect of vehicle dynamics	◎	△	△	△	△	
Sensor	Effect of temperature characteristic	×	×	×	×	×	
Sensor	Aging of the sensor	×	×	×	×	×	
Sensor	Fouling	×	×	×	×	×	
Sensor	Internal reflection	×	×	×	×	×	

① (bracket covering the highlighted rows from "Other vehicle light source(interference)" to "Effect of vehicle dynamics")

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

Items that shows the superiority of DIVP®

① Only DIVP® is to verify the actual machine.
② Only DIVP® is to support interference.
③ Only DIVP® supports reflection, scattering and transmission
④ Only DIVP® responds to the effects of extraneous matter and phase / polarization changes during reflection
⑤ Only DIVP® supports multiple reflection / transmission
⑥ Only DIVP® supports Effect of Vehicle dynamics

※ Limit the range that can be completed within 2020 by prioritizing DIVP® functions based on frequency and criticality

DIVP® is the only simulation with Highly Consistent Environment & Sensor "Pair modeling"

Benchmark result of LiDAR

神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

Classification	Phenomena	DIVP®	IPG CarMaker 9.0	Siemens PreScan 2020.1	VIRES VTD 2.2.0	ANSYS VRX R.2020
Source	Other vehicle light source(interferences)	×	×	×	×	△
Source	Other source(halogen lamp)	×	×	×	×	△
Source	*Radiance of solar*	◎	×	×	×	△
Source	*Radiance of sky*	◎	×	×	×	△
Optics	*Reflection, diffusion, transmission on the object surface*	◎	△	△	△	△
Optics	*Aging of the object surface*	◎(asphalt)	×	×	×	×
Optics	*Fouling*	◎(raindrop)	×	×	×	×
Propagation	*Multi reflection/transmission*	◎	△	×	△	×
Propagation	*The cross sectional area of a laser beam*	◎	○	※	※	×
Propagation	Scattering in space(attenuation)	◎	×	○	×	△
Sensor	*Own light source*	◎	×	×	×	○
Sensor	*Scanning*	◎	×	×	×	○
Sensor	*Effect of vehicle dynamics*	◎	△	△	△	△
Sensor	Effect of temperature characteristic	×	×	×	×	×
Sensor	Aging of the sensor	×	×	×	×	×
Sensor	*Fouling*	◎(raindrop)	×	×	×	×

①: Source rows (1–2) ②: Source/Optics/Propagation rows ③: Sensor rows ④: Sensor Fouling

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

Items that shows the superiority of DIVP®

① Only DIVP® is to verify the actual machine.
② Only DIVP® supports the radiance of sunlight, radiance of sky light, reflection / scattering / transmission on the object surface, influence of deterioration, attached matter, multiple reflection / transmission
③ Only DIVP® responds to the effects of its own light source, scanning and vehicle behavior
④ Only DIVP® responds to the effects of sensor deposits

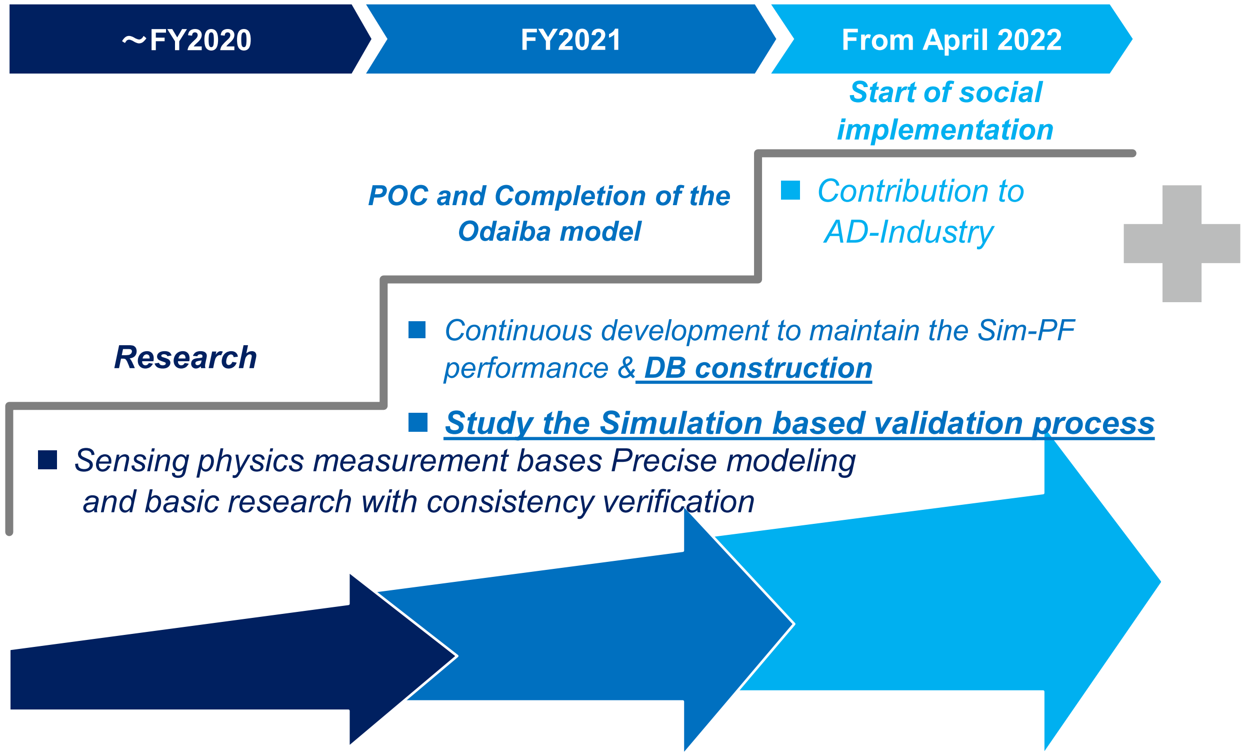
※ Limit the range that can be completed within 2020 by prioritizing DIVP® functions based on frequency and criticality

Toward social implementation on FY22, DIVP® will study the validation process utilizing the Sim-PF and expand the scope to constructing Data Base for realize Virtual-PG/CG

Further schedule

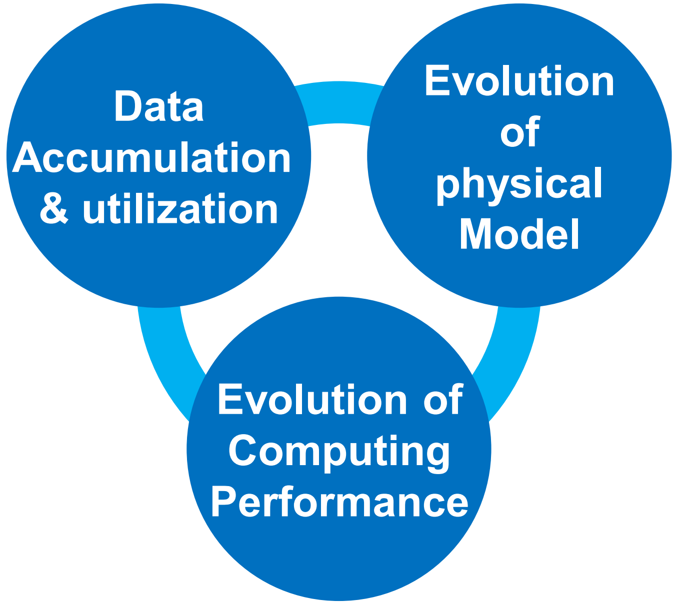
Road map toward social implementation

■ Improving the performance and processing of Sim-PF for social implementation toward FY2022



Research scope expansion

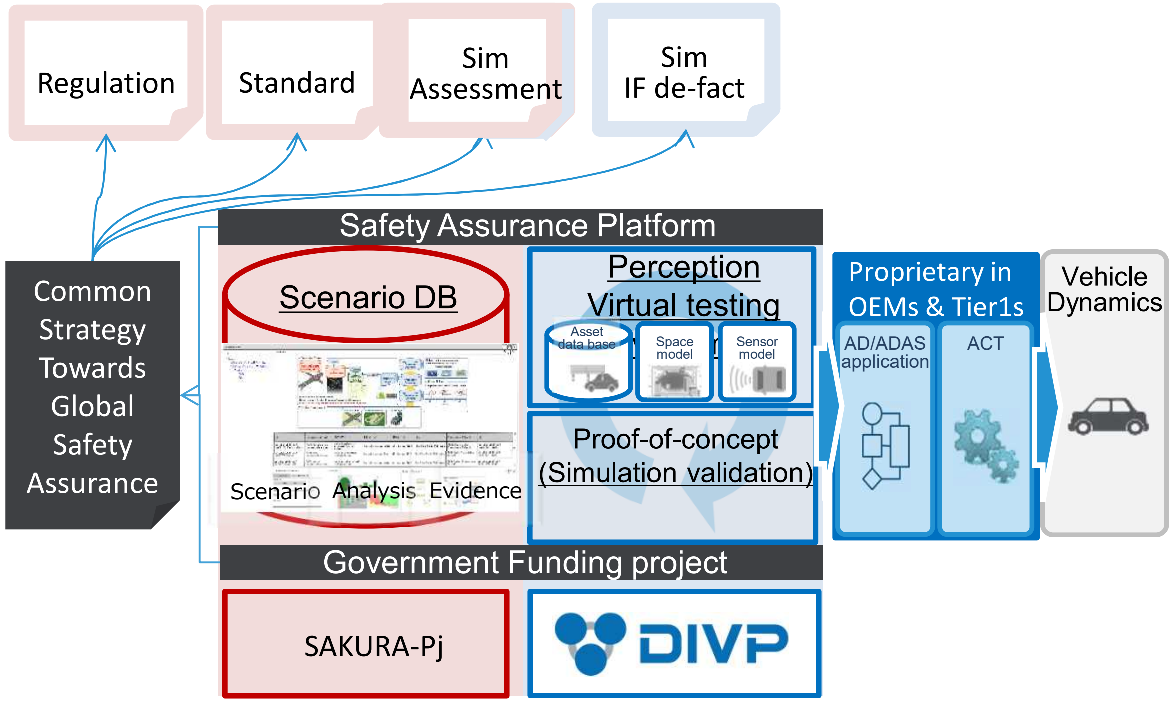
■ DIVP® expand the scope to Database(DB) construction for realize AD safety validation system with various drive scene in Virtual-PG/CG



Summary

- DIVP® in SIP-adus believes that sensing domain based approach leads AD/ADAS to safer mobility society.
- DIVP® in SIP-adus will contribute to the standardization of I/F, reference modeling procedure with respective global activities.

Position in AD-safety assurance



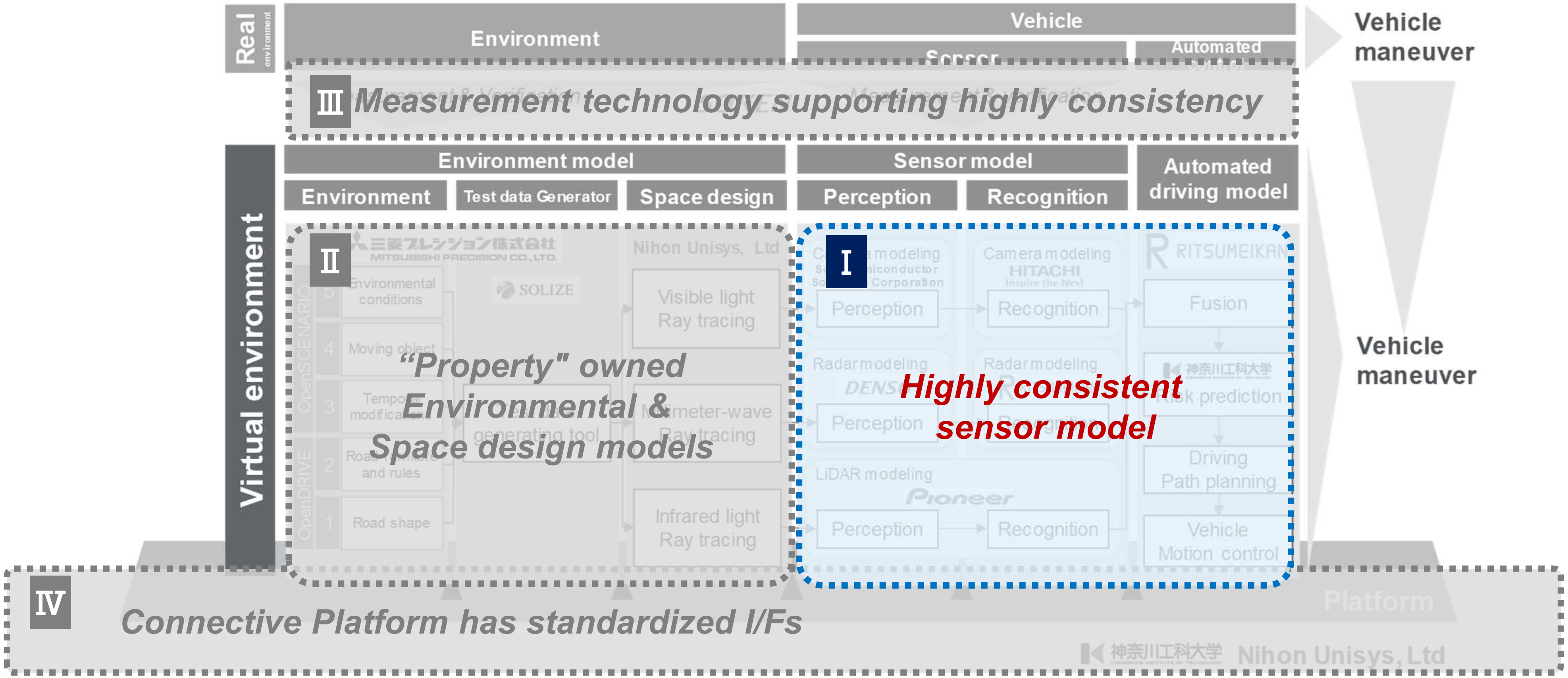
DIVP® Objectives

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

Source : JAMA presentation

FY2020 outcome

FY2020 outcome



Sensing physics precise modeling with real test validation & verification

Modeling procedure

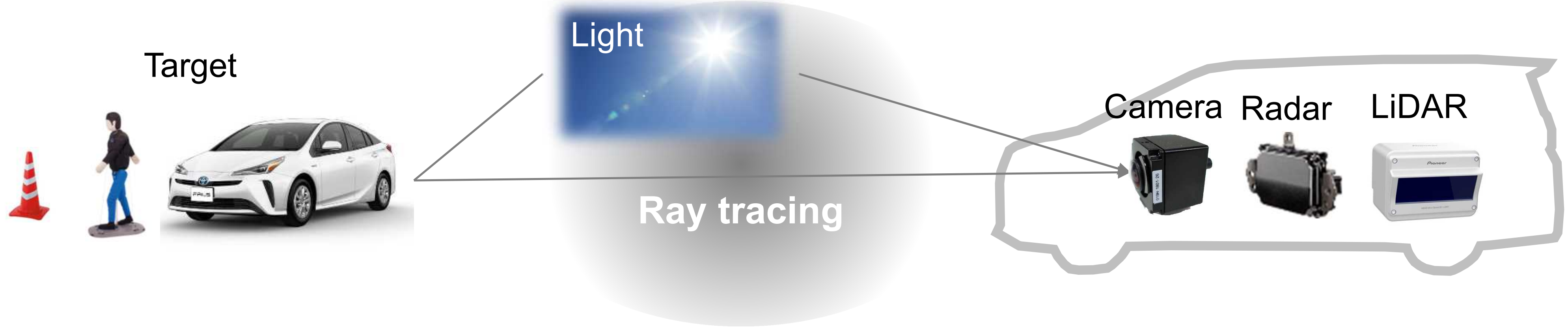
Steps	Action Details	Implementation steps
Step1	■ Real physics modeling ✓ Mathematical modeling of physical phenomena in the real world ✓ Interface design	Understanding of the principles of each sensor Function allocation of each part Interface design
Step2	■ Real physics based simulation model ✓ Simulation modeling of mathematical models ✓ Designing competitive advantages	Design of the simulation model Design the "Highly consistent sensor modeling" procedure
Step3	■ Verification & Validation ✓ Verification of consistency between Virtual and Real ✓ Verified modeling-based extrapolability verification	Basic operation verification Extended operation verification

Investigated modeling units and Interfaces based on light path from source to sensor output, and defined Environmental, Space design and Sensor perception & recognition models

Modeling procedure

HITACHI Inspire the Next | Sony Semiconductor Solutions Corporation | DENSO | SOKEN | Pioneer

Light path



Next Step is to Virtualize Image sensor for precise Perception

In-Camera detail

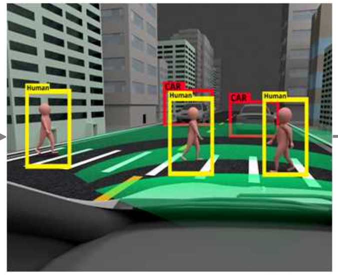
Input →

Front window

Lens

Image Sensor Sony Semiconductor Solutions Corporation

ISP*/Recognition



→ Output

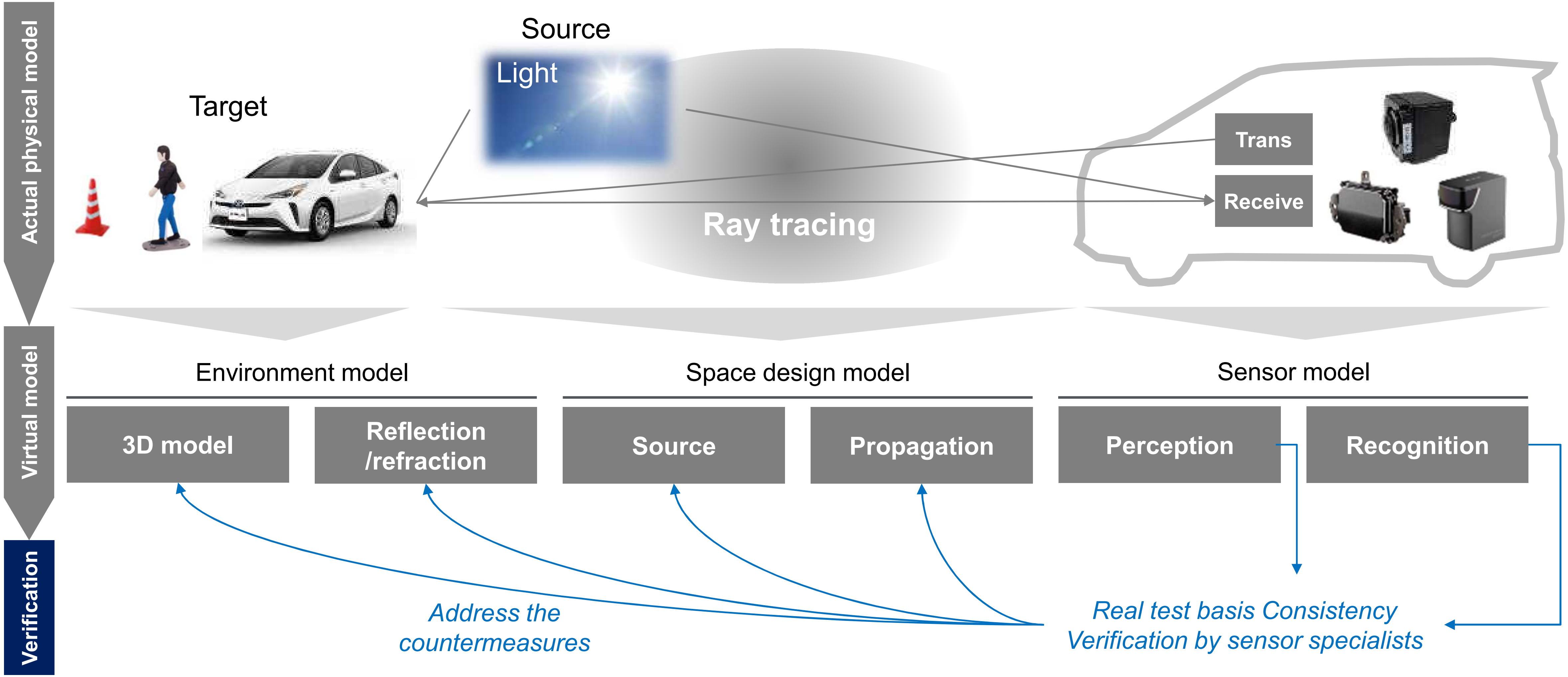
* Image Signal Processor

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

Verification of consistency between Real vs Virtual, sensor supplier as a sensor specialist will evaluate sensor output and address the countermeasures onto suspicious modules

Validation & Verification procedure

Sony Semiconductor Solutions Corporation HITACHI Inspire the Next DENSO SOKEN Pioneer

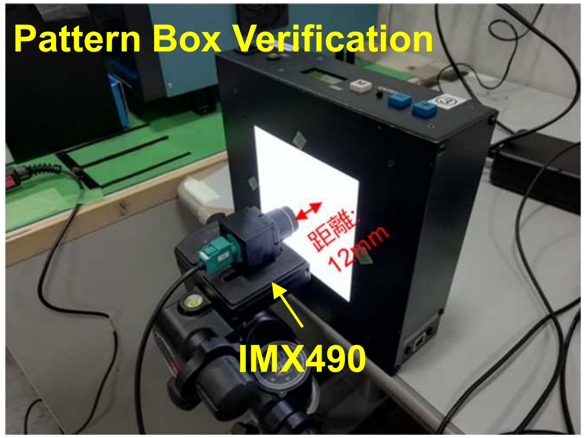


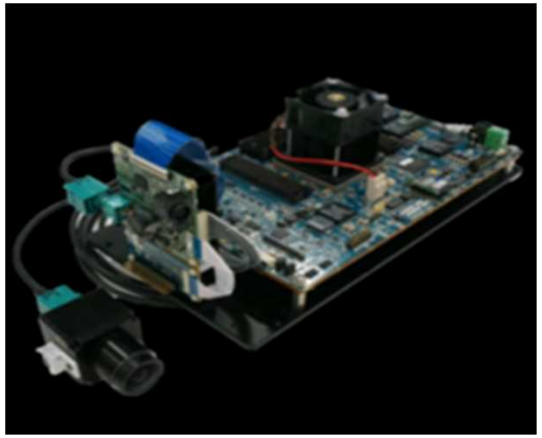
Source : DENSO, INC, HitachiAutomotiveSystems, INC, PIONEER SMART SENSING INNOVATIONS CORPORATION

As a 1st step, each sensor verified with Simple condition in Labo base

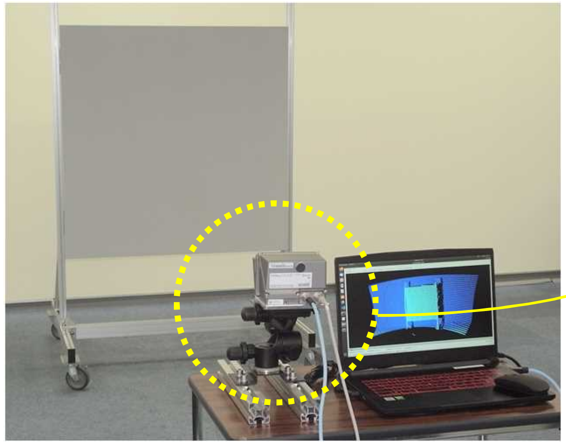
Basic verification

Camera verification
Sony Semiconductor Solutions Corporation

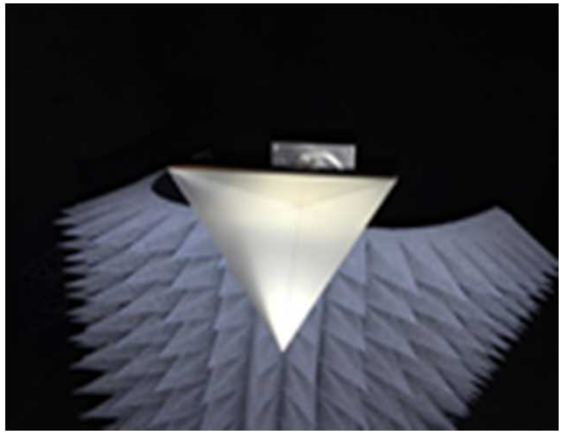


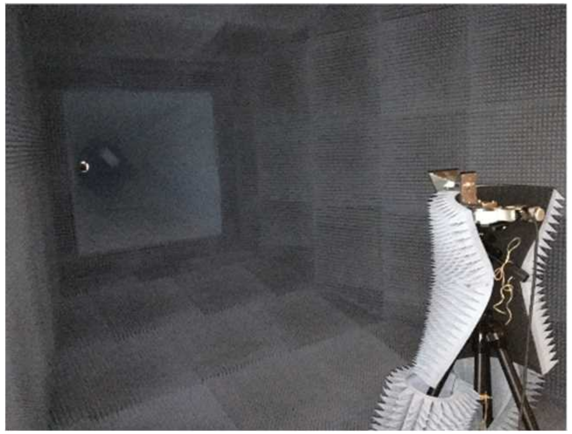


LiDAR verification
Pioneer



Radar verification
DENSO SOKEN





Vehicle verification
SOKEN

Source : Sony Semiconductor Solutions Corporation, DENSO Corporation, Pioneer Smart Sensing Innovations Corporation, SOKEN, INC

Highly consistent sensor model

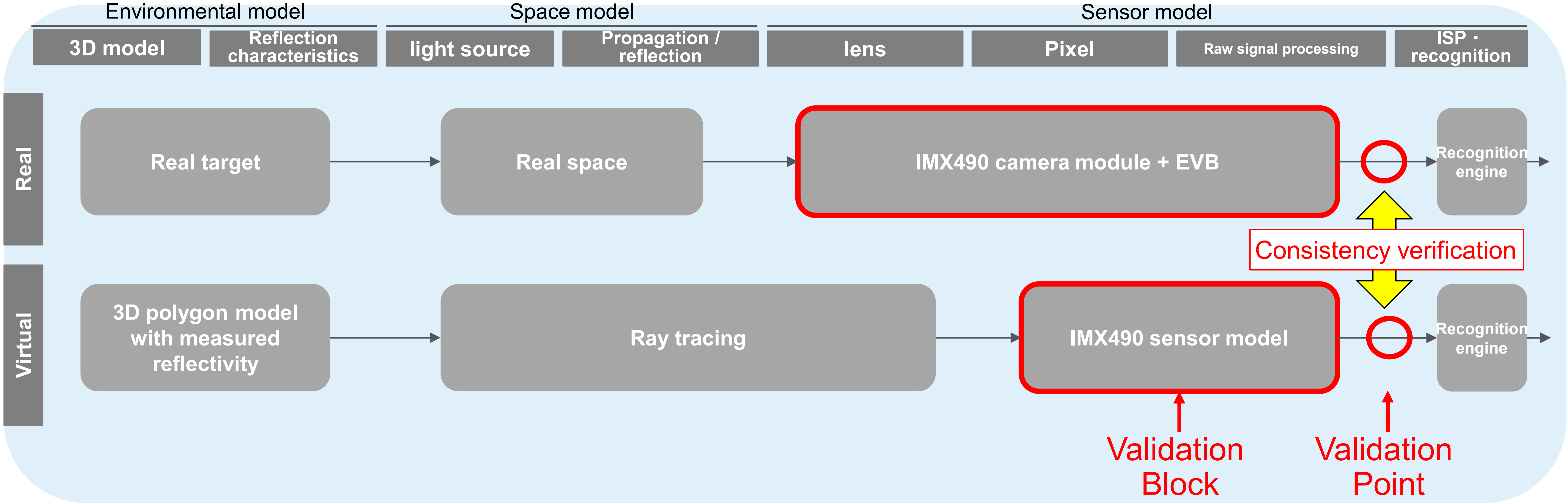
- Camera model
  - Perception
  - Recognition
- LiDAR model
- Radar model
- AD control model

【Camera consistency verification】 By comparing and verifying the perception output of the camera, the scenes and the places where the differences occur are identified, and the causes are clarified to rotate the cycle from consistency verification to improvement

Overview of consistency verification

Sony Semiconductor Solutions Corporation

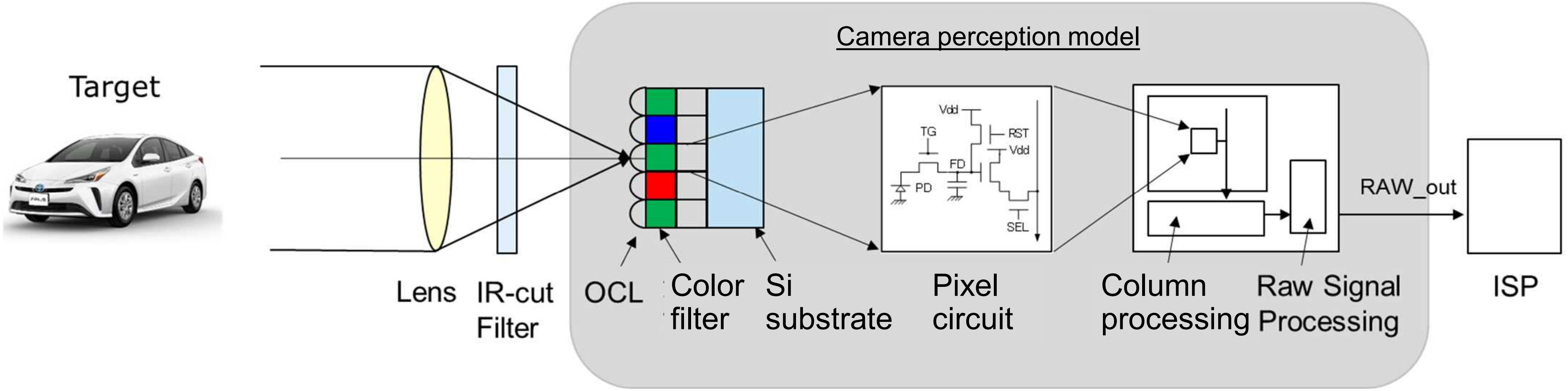
- Using the IMX490 sensor, compare the output result of the sensor model with the actual unit shooting data
- By comparing data, clarify the scenes and places where differences occur, and their causes



【Camera consistency verification】
Extract the factors that affect the verification of consistency and proceed with the validation of consistency based on these.

Configuration of camera perception model and error factors

Sony Semiconductor Solutions Corporation



	Input	OCL (On Chip Lens)	Color filter	Si substrate	Pixel circuit	Column processing	RAW Signal Processing
Error factors	■ Spectroscopy ■ Projection data ■ shading	■ Focusing rate	■ Spectral characteristics	■ Quantum efficiency ■ Light shot noise ■ Floor noise	■ Circuit in pixel	■ Analog gain	■ HDR synthesis ■ PWL compression
Influence point of error	■ Color reproduction ■ Pixel displacement ■ Brightness distribution	■ Brightness	■ Color reproduction	■ Brightness ■ Noise level	■ Signal level	■ Signal level	■ Gradation expression
Error influence	Large	Little	Large	Large	Little	Little	Large

Source : Sony Semiconductor Solutions Corporation

【Camera consistency verification】
Designing a verification method that compares the signal levels starting from a known object

Consistency verification procedure

Sony Semiconductor Solutions Corporation

- Verification process
  - ① Indoor (studio) validation
    - Verification using white plates
      - Confirmation by in-plane uniform level subjects
    - Verification using gray charts and color charts
      - Confirmation of contrast and color reproducibility
  - ② Outdoor validation
    - Actual environment scenes and weakness factor scenes

- Verification method
  - Histogram comparison
    - Extract for each whole screen or area (image height, color, distance, subject)
    - Comparison of mean (Signal), variation (Noise), and distribution shape
  - Analyze factors and provide feedback from areas with large differences.

According to the validation, the difference between SIM and actual data was about 20%, Therefore, the effectiveness of Camera performance validation is confirmed.

Camera Simulation Results*

Sony Semiconductor Solutions Corporation

Result of actual camera

SIM result (sky data: fine)

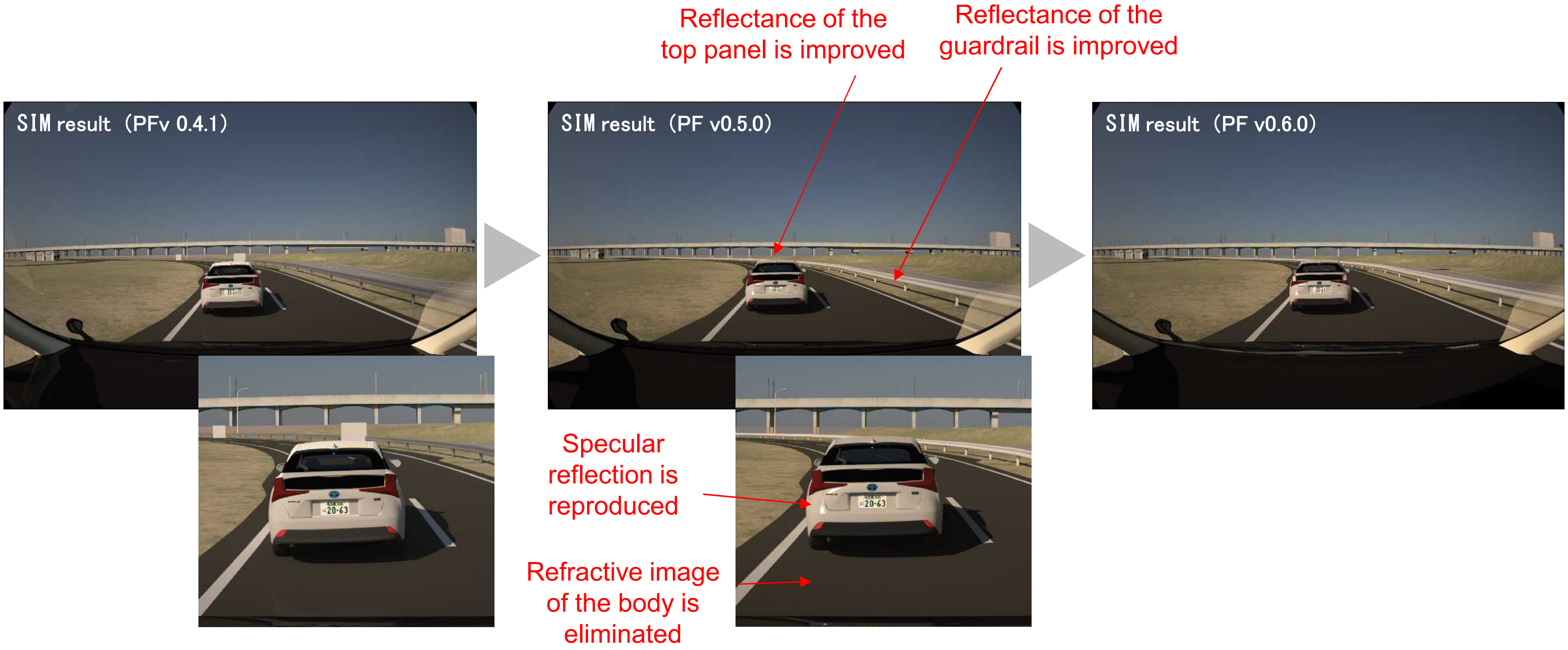
Mostly same Brightness

* 8 bits in 24 bits are displayed.
Source : Sony Semiconductor Solutions Corporation, SOKEN, INC

Results of basic consistency verification

Confirm consistency is improved for each version update.

Sony Semiconductor
Solutions Corporation



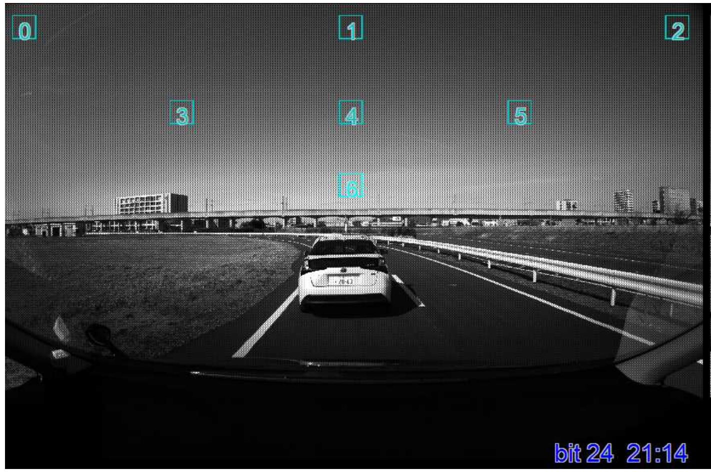
Source : Sony Semiconductor Solutions Corporation

Results of basic consistency verification: Example 1

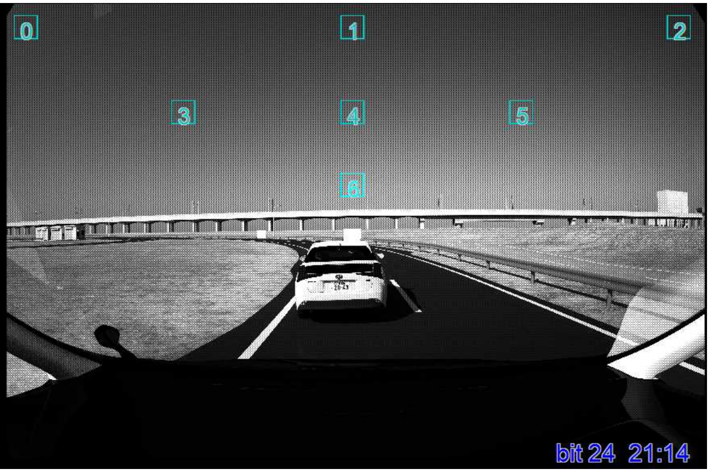
Sky Consistency Validation Results: Confirm high-level consistency

Sony Semiconductor Solutions Corporation

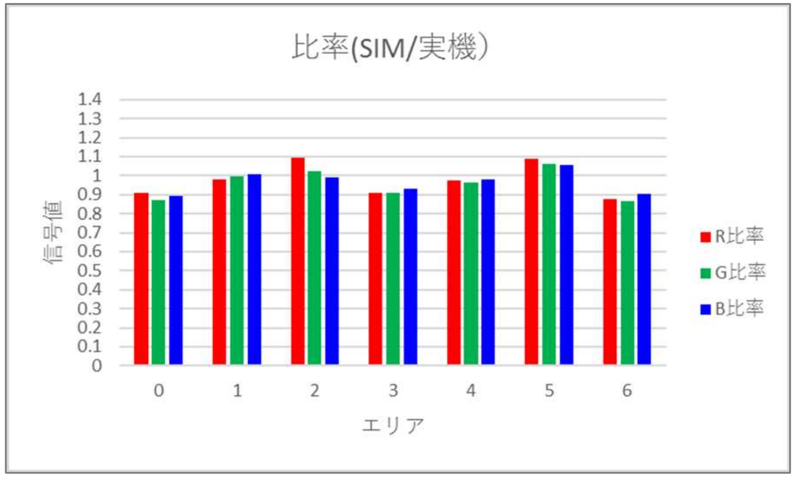
Image acquired on actual camera

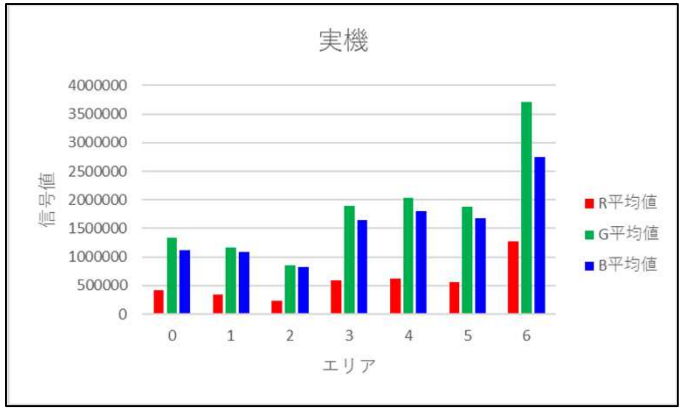


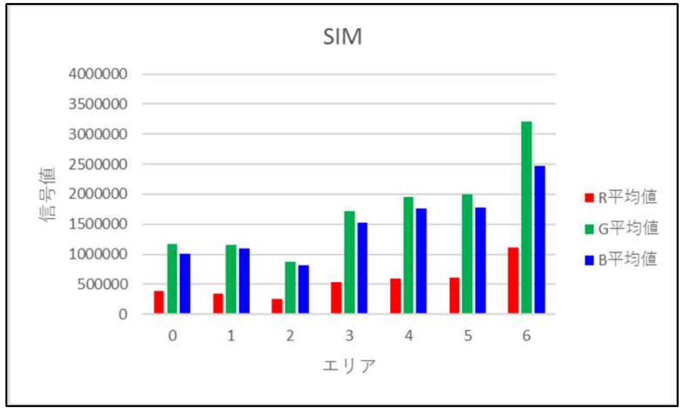
Simulation (SIM) result



Consistency of sky areas (Sim/Act)







Pixel	Ratio average (SIM/Act)
R	0.98
G	0.97
B	0.96

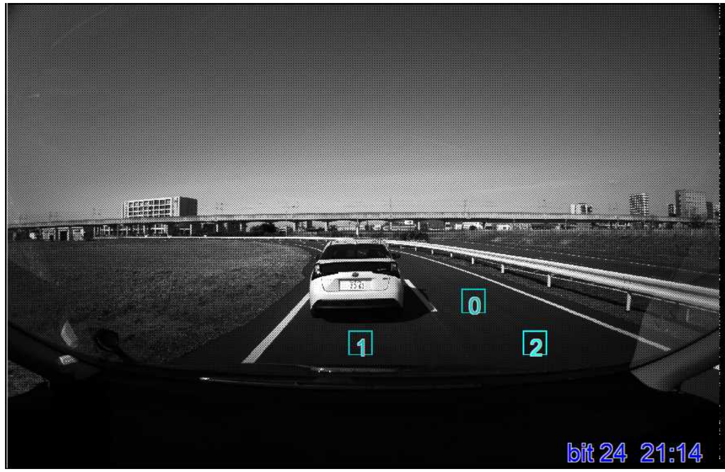
Source : Sony Semiconductor Solutions Corporation

Results of basic consistency verification: Example 2

Asphalt Consistency Validation Results: Confirm high-level consistency

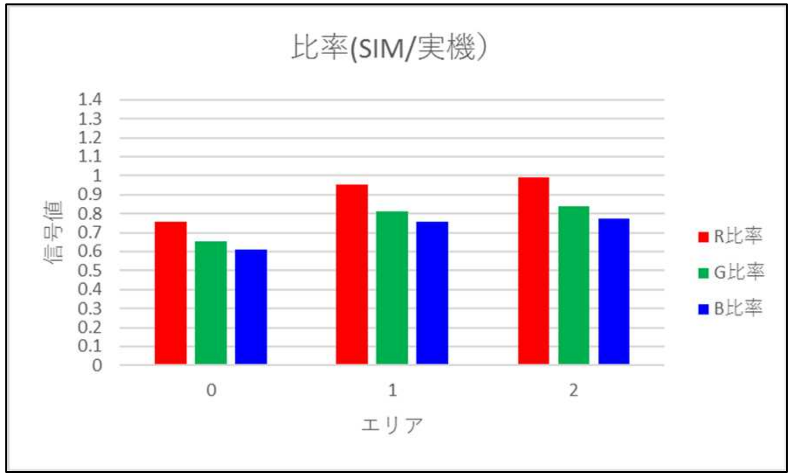
Sony Semiconductor Solutions Corporation

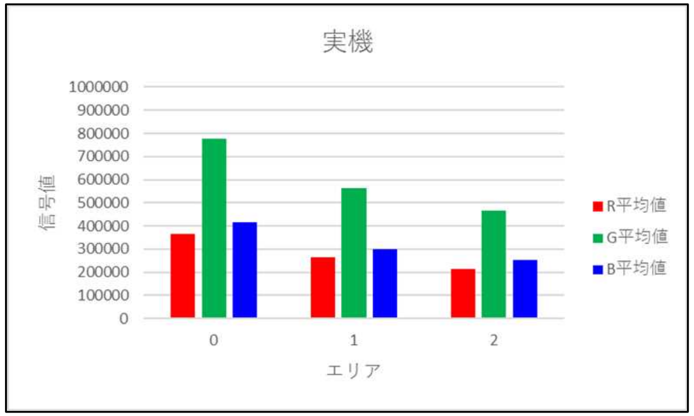
Image acquired on actual camera

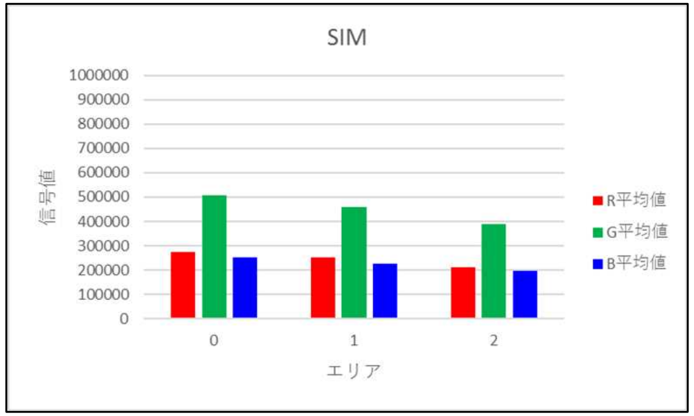


Simulation (SIM) result

Consistency of sky areas (Sim/Act)







Pixel	Ratio average (SIM/Act)
R	0.90
G	0.77
B	0.71

Source : Sony Semiconductor Solutions Corporation

Highly consistent sensor model

- Camera model
  - Perception
  - Recognition
- LiDAR model
- Radar model
- AD control model

Simulation based on a mathematical model, Verify the equivalence by comparing the actual sensor output and the simulation output.

Modeling approach

HITACHI
Inspire the Next

Steps	Item	Procedure
Step0	■ Real physics modeling ✓ Mathematical modeling of real-world physical phenomena ✓ Interface design ✓ Simulation based on a mathematical model	Grasp of principles for each sensor Interface design Simulation model design
Step1	■ simulation model check ✓ Check the interface ✓ Verification of recognition model	Combination verification Prior verification
Step2 Step3	■ Verification & Validation : Under Normal Condition ✓ Verify the equivalence between Real and Virtual	Basic verification
Step4	■ Verification & Validation : Under Bad Condition ✓ Verify the equivalence between Real and Virtual	Verification w/ recognition error factor
Step5	■ Verification & Validation ✓ Verification with changed parameter	Extended verification

When verifying consistency in camera recognition, it is necessary to accurately reproduce the position and orientation of the actual vehicle and the mounting position of the camera

Before removing the error component of the scenario

HITACHI
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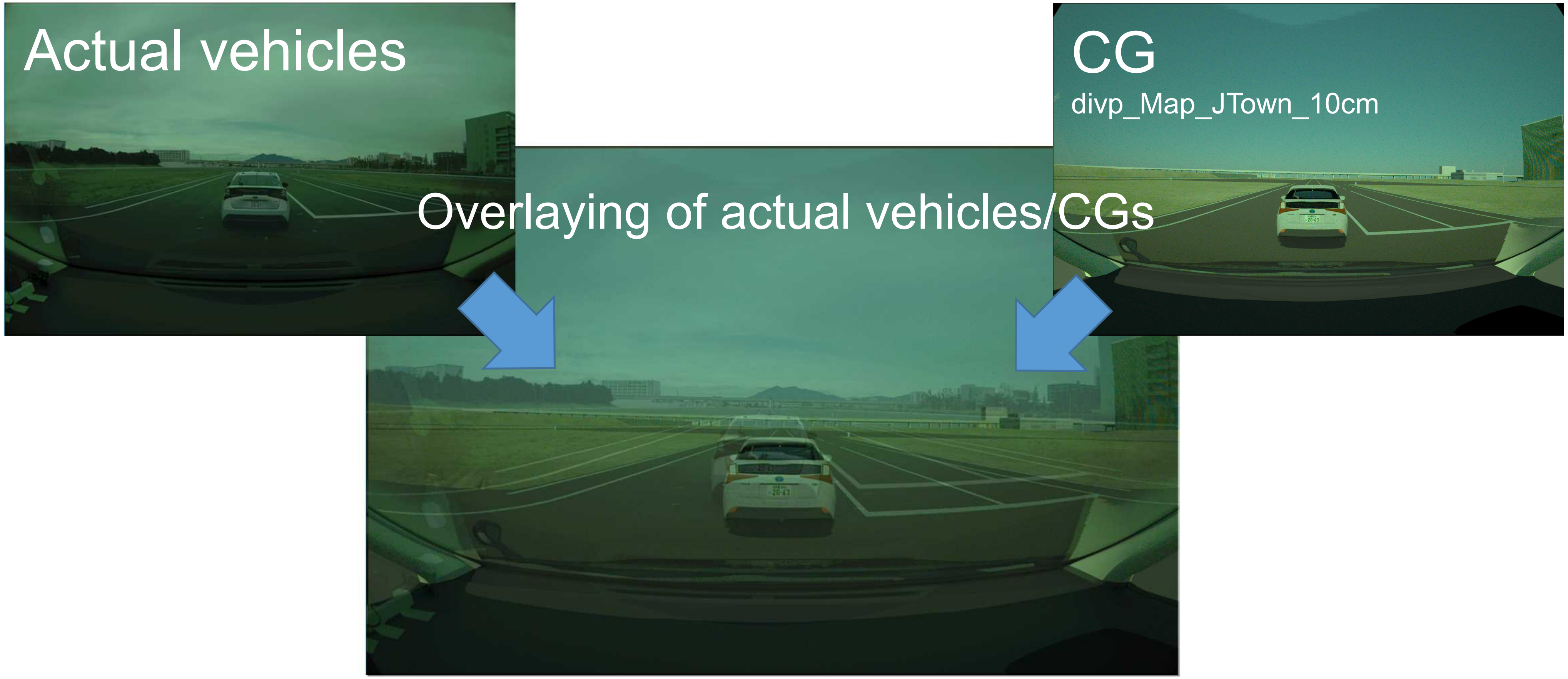

Source : Hitachi Astemo, Ltd.

When verifying consistency in camera recognition, it is necessary to accurately reproduce the position and orientation of the actual vehicle and the mounting position of the camera.

The largest error component

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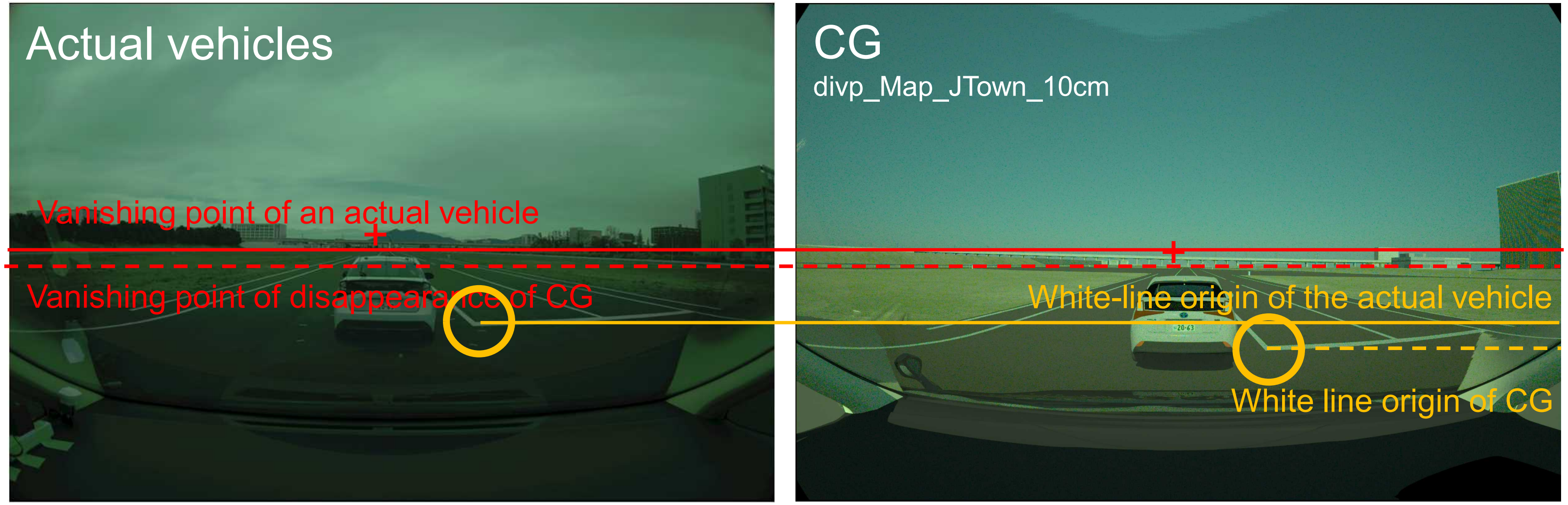
1.Difference in the vanishing point
2.Difference in white-line origin



Source : Hitachi Astemo, Ltd.

Adjustments from GPS information that cannot be simply reproduced are performed to eliminate the error component of the scenario

After removing the error component of the scenario

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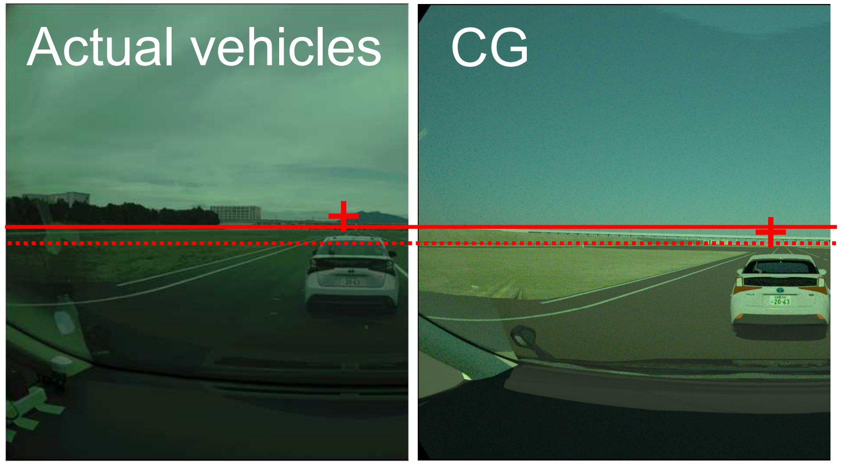
[Before removal]

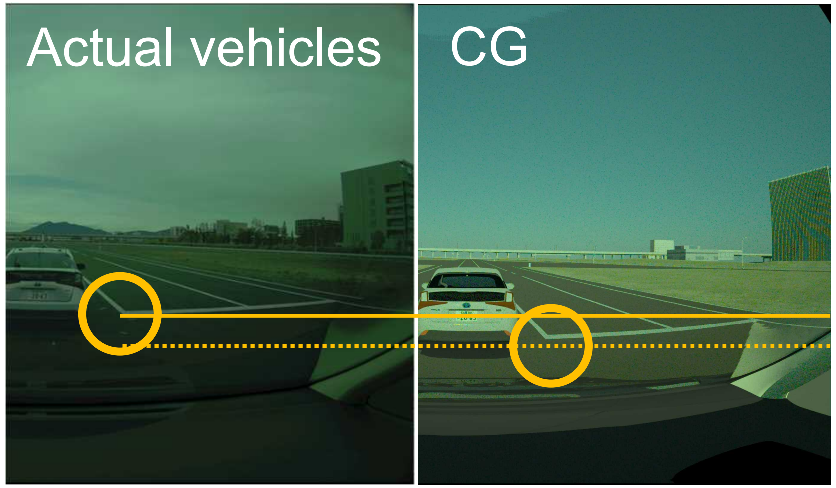


[Contents of change]

Pitch[deg]	
Before adjustment	-2.08459
After adjustment	0.21541

[After removal]

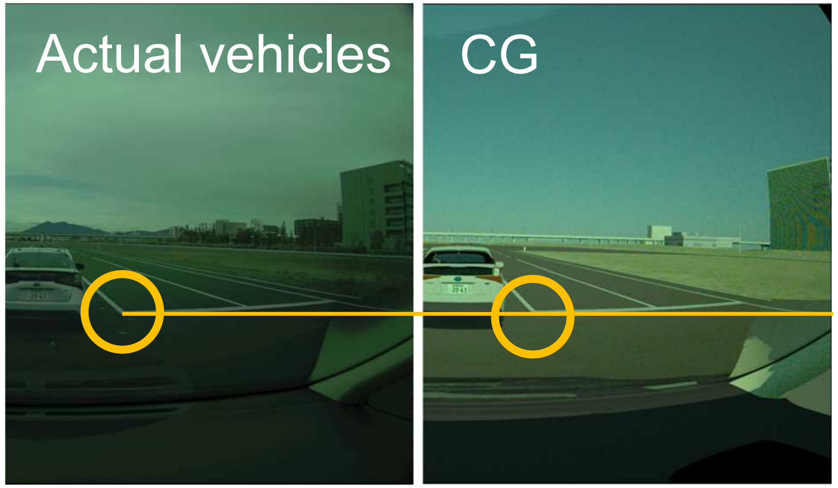
[Before removal]



[Contents of change]

Pos_x[m]	
Before adjustment	424.02715
After adjustment	423.12715

[After removal]



Source : Hitachi Astemo, Ltd.

Adjustments from GPS information that cannot be simply reproduced are performed to eliminate the error component of the scenario

Recognition results

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Object (essence)

Data			Actual vehicle	CG	Difference	Difference rate
Target size	Screen coordinates	X	381	368	-13	-3%
		Y	333	301	-32	-10%
	Sensor coordinates	X	0	0	0	0%
		Y	1.75	1.8	0.05	3%
		Z	1.52	1.48	-0.04	-3%
Target position information	Screen coordinates	X	1421	1424	3	0%
		Y	1132	1131	-1	0%
	Sensor coordinates	X	4.93	5.3	0.37	8%
		Y	0.14	0.13	-0.01	-7%
		Z	-0.83	-0.86	-0.03	4%
	World coordinate	Latitude	2147483648	2147483648	0	0%
		Longitude	2147483648	2147483648	0	0%
		Altitude	0.76	0.73	-0.03	-4%
Reliability	Normalization	-	99	99	0	0%
	Number detected	-	251	251	0	0%

■Validation results
Maximum error within ± 10%

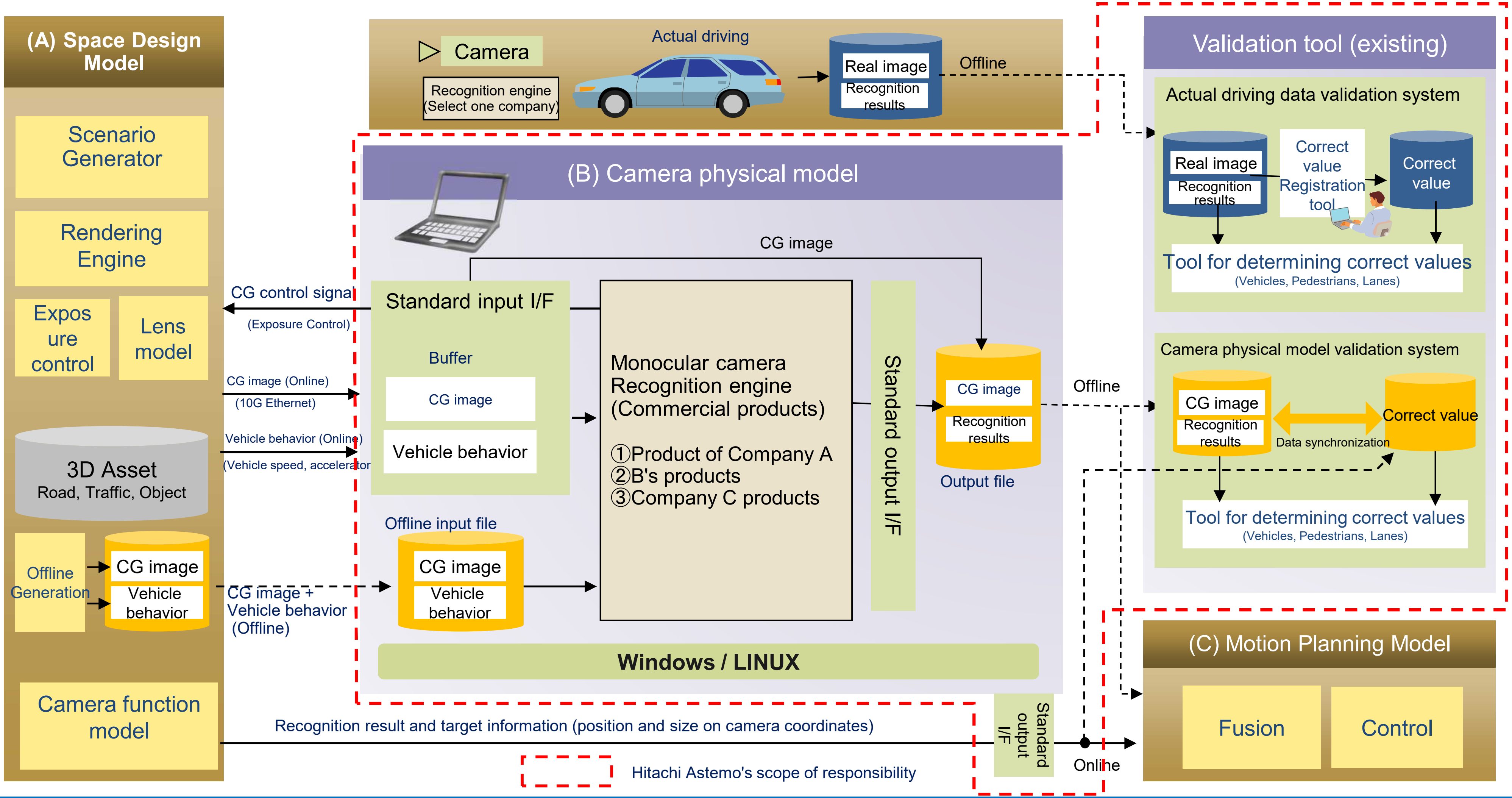
Comment It is considered that this environment can be used in a static state without recognition error factor. In the next step, the validation will be carried out in the dynamic state and the state in which the recognition error factor are added, and the practicality will be continuously examined.

Source : Hitachi Astemo, Ltd.

Develop a set of tools for ease of incorporation into the validation environment of each company (including facilitation of adaptation to standard I/F)

Camera verification environment

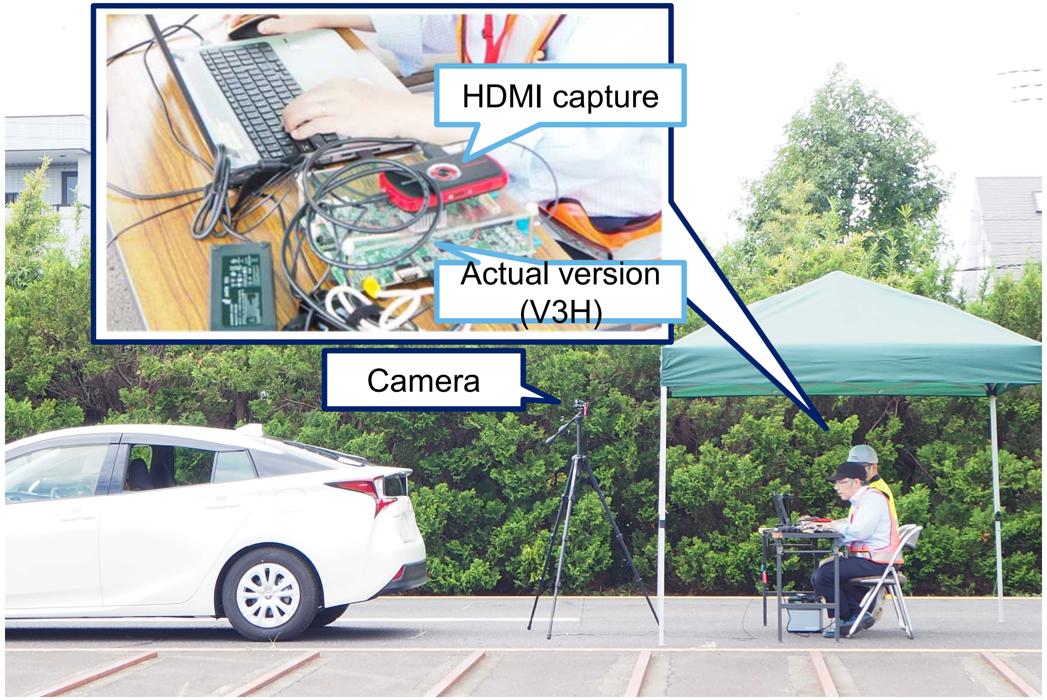
HITACHI Inspire the Next



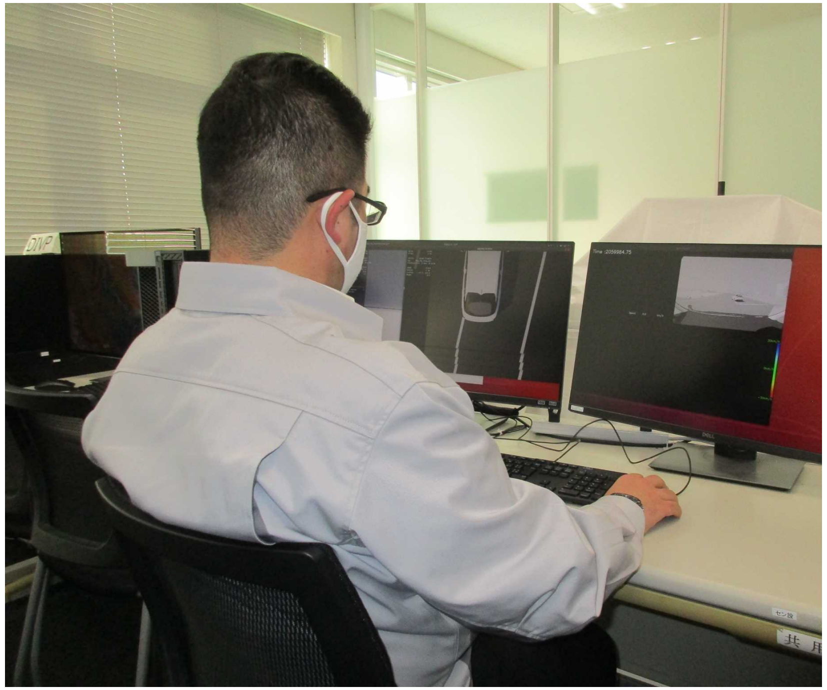
Source : Hitachi Astemo, Ltd.

Develop a set of tools for ease of incorporation into the validation environment of each company (including facilitation of adaptation to standard I/F)

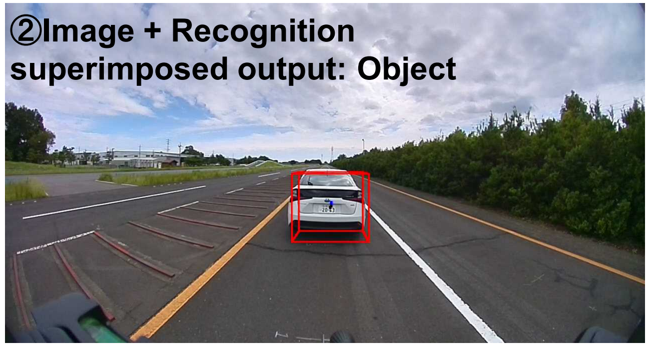
■Actual vehicle verification



■CG verification



■Actual vehicle verification results



Source : Hitachi Astemo, Ltd.

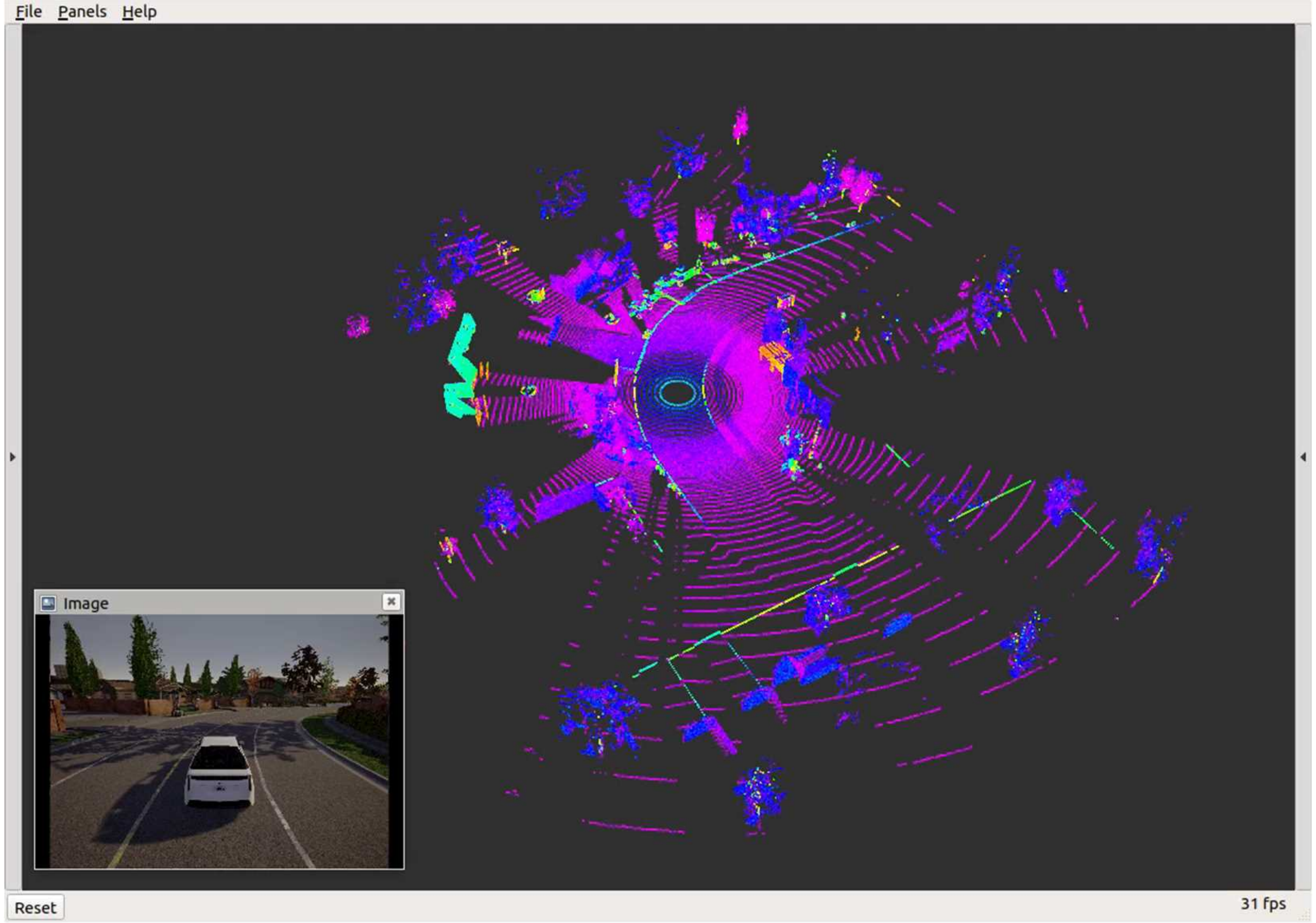
Highly consistent sensor model

- Camera model
- LiDAR model
- Radar model
- AD control model

LiDAR modeling & verification was implemented

LiDAR simulation

Nihon Unisys, Ltd



Source : Nihon Unisys, Ltd

[Consistency verification]
Verify the consistency effectively by eliminating error factors as much as possible at each step.

Consistency verification

Step	Purpose of Verification	Validation target	Validation parameters	Validation index
Consistency verification of LiDAR perception model	■ Assess the consistency of LiDAR perception models (scanning and ranging models) by eliminating errors caused by environmental, spatial propagation models and scenarios as much as possible.	■ RX model output (Only PSSI model)	■ Intensity distribution of received signal	■ Consistency of intensity distribution, mean, and variance at each distance of the target with known shape and reflection characteristics
			■ Noise intensity distribution	■ Consistency of noise intensity distribution, mean, and variance at each distance of the target with known shape and reflection characteristics
		■ Perception model output	■ Angle	■ Vertical resolution (elevation angle between adjacent lines) ■ Consistency of horizontal resolution (azimuth angle between adjacent points in the horizontal direction)
			■ Distance ■ Intensity	■ Consistency of accuracy and precision at each distance of the target with known shape and reflection characteristics
			■ Distance measurement limit	■ Consistency of detection probability of the target with known shape and reflection characteristics
Consistency verification of environmental model and LiDAR perception model	■ Assess the consistency of the environmental model and the LiDAR perception model (scanning model and ranging model) by eliminating errors caused by the spatial propagation model and scenario as much as possible.	■ Perception model output	■ Minimum distance to the target	■ Consistency of accuracy and precision of distance
			■ The number of points to hit the target	■ Consistency of accuracy and precision of the number of points
			■ Target size	■ Consistency of accuracy and precision of the target size
			■ Intensity of target point cloud	■ Consistency of intensity distribution
Impact validation on recognition model output	■ Evaluate the effect of the difference between the perception model output point cloud and the actual LiDAR output point cloud on the recognition model output.	■ Recognition model output	■ Long-range distance detection limit	■ Detection probability of the target
Malfunction reproduction verification				
Extensibility verification	*Continued verification in the future*			

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[Validation only with PSSI model]

In this year's research, we will evaluate the LiDAR manufactured by Company V and PSSI, verify that there is a certain degree of consistency under no sensor malfunction conditions for Company V model, and evaluate the PSSI LiDAR under sensor malfunction conditions that cause problems and extract some issues. We will resolve the issues in the activities for the following year.

Summary of Consistency Verification and Issues

Evaluation item		Company V LiDAR（b）	PSSI LiDAR
Consistensy verification for LiDAR Perception Model			
	Peak level of received signal		○
	Noise level		○ ※1
	Angle	○	Not experimenting
	Distance	○	○
	Intensity	△（Inconsistency in close range ）	○
	Distance measurement limit	Not experimenting	○
Consistensy verification for Environment model＋LiDAR Perception Model			
	Target size	○	Not experimenting
	Minimum distance to the target	○	Not experimenting
	The number of points that hit the target	△（Inconsistency in long range ）	○
	Intensity distribution of target point cloud	△（Inconsistency in close range）	○
Impact evaluation on recognition model output			
	Long-range detection limit	×（Confirmed that ambient point clouds affect the long Range detection limit）	○ ※2

※1 There is a challenge with the measurement method under conditions with disturbed light.
※2 Black leather jacket NCAP, which is a condition for malfunctioning, does not match.

[Consistency verification of Company V Model (b)]
The concordance of the intensity distribution in the distance was confirmed, and the number of points was inconsistent in the distance.

Environmental Model + LiDAR Perception Model Consistency Verification

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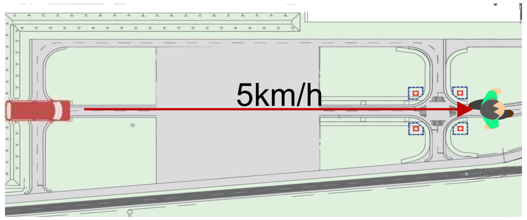
Verification scenario

- A scenario in which a vehicle equipped with a sensor runs at 5 km/h and approaches the measurement target.

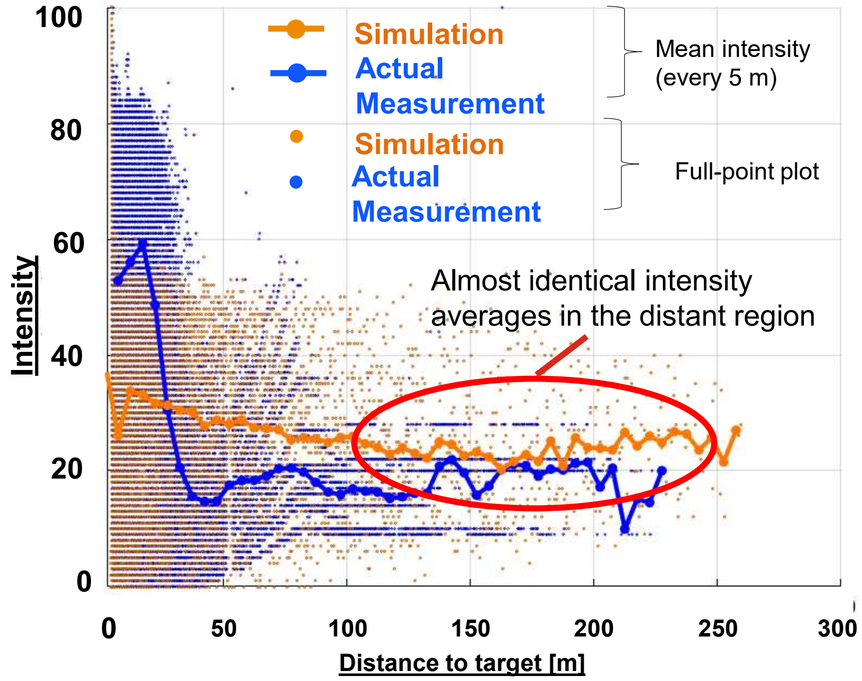
Sensor-equipped vehicle: Alphard

Target: Test dummy for NCAP



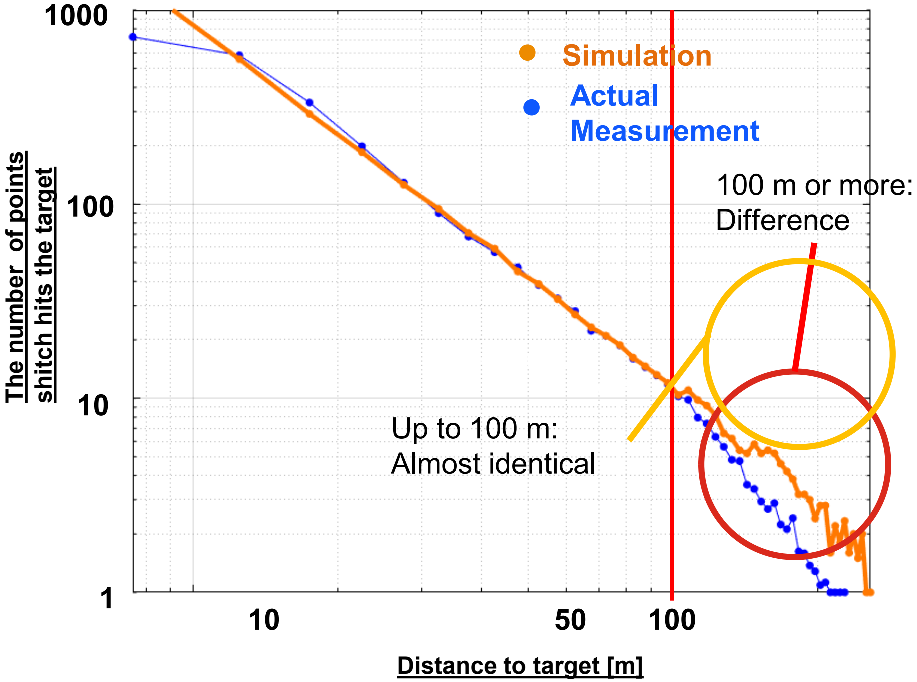
[Consistency of intensity distribution]

- Reflection intensity nearly matches in the distant region
- Although the near intensity distribution is very different, it is considered that there is no effect on the object detection/recognition unit.



[Consistency of number of points]

- Up to 100 m, the number of points which hits target is almost identical.
- The number of points differs at 100 m or more.



The reason for the discrepancy in the distant point number is considered to be the difference in the measurement distance limit of LiDAR.

Source : Pioneer Smart Sensing Innovations Corporation.

[Consistency Verification of Company V Model (b)]
At output of recognition model, detection limit of distant target differs 10 m or more

Validation of detection limit of the distant targets

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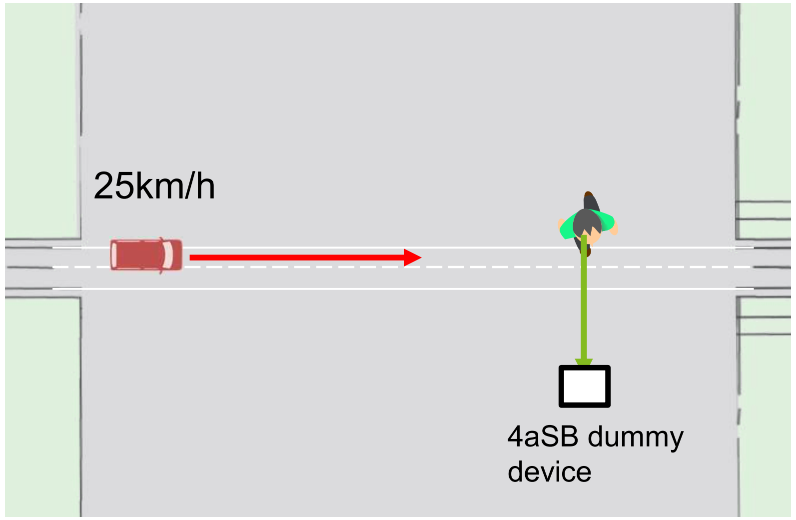
[Measurement Conditions]

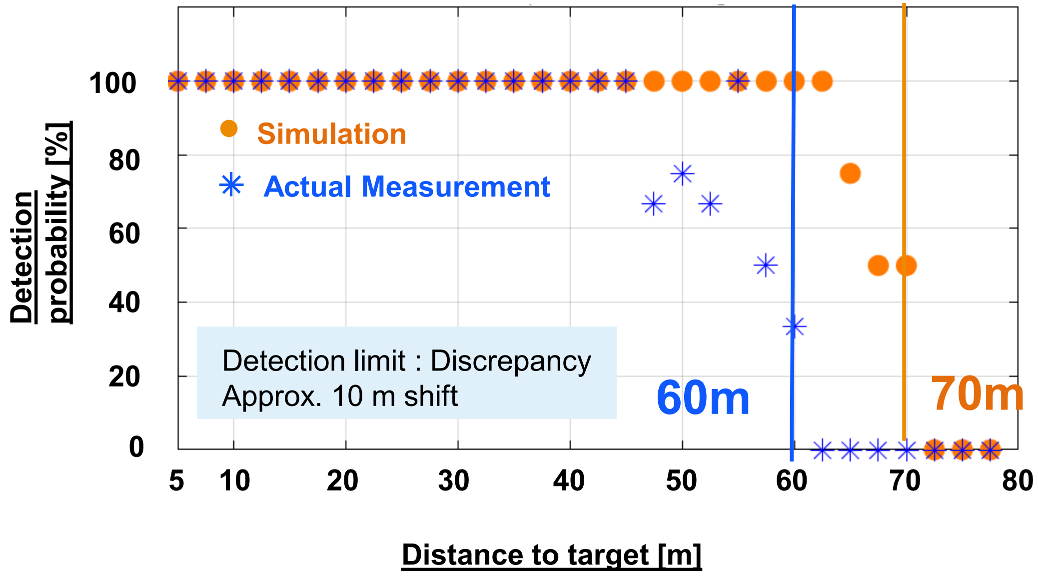
Validation conducted in pedestrian cross-cutting scenario



Sensor-equipped vehicle: Alphard

Target: Test dummy for NCAP

[Distance detection limit of target]



A large difference of 10 m or more was observed in the detection limit of the distant object of the actual measurement and the simulation.
(Detailed Causes of Variance: Next page)

Source : Pioneer Smart Sensing Innovations Corporation.

[Consistency Verification of V Company Model (b)]
Differences in the detection limit of distant targets

Detection limit of the target in long distance : Cause of difference

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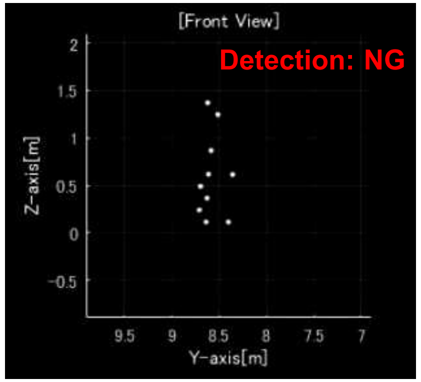
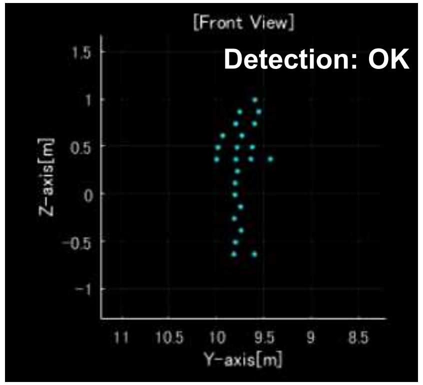
[Factor ①: Inconsistency in shape of target point cloud]

Comparison of 65m ahead target point cloud

Actual Measurement



Simulation

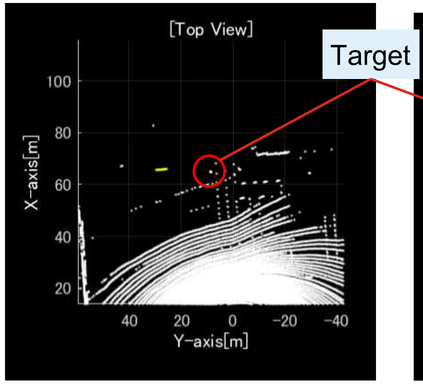


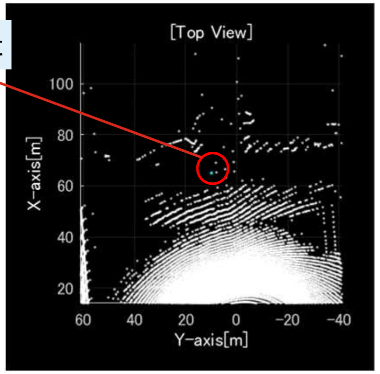
Differences in the shape of the target point cloud
⇒Possible cause of difference

[Factor ②: Effect of ambient point cloud]

Comparison of point cloud around the target
(target location: 65m ahead)

Actual Measurement **Simulation**





Differences in the shape of ambient point cloud of the target
⇒ Investigation of the effect of point cloud around the target
(next page)

Source : Pioneer Smart Sensing Innovations Corporation.

[Consistency Verification of Company V Model (b)]
Testing the hypothesis that "point cloud around the target affect the detection limit of the target"

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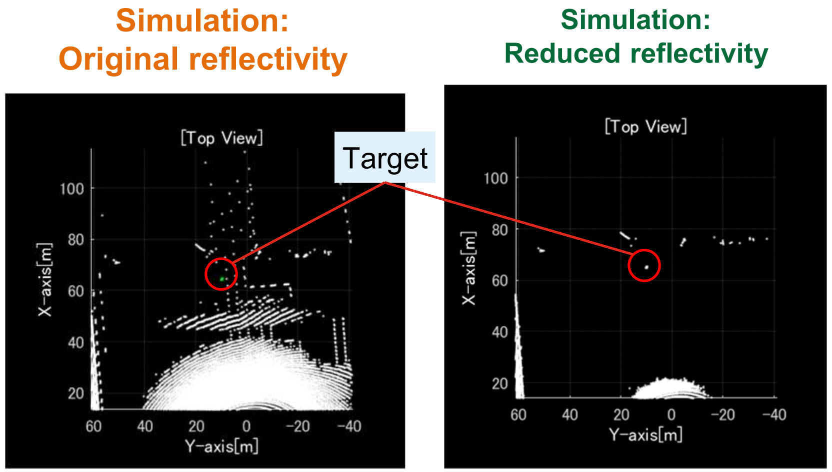
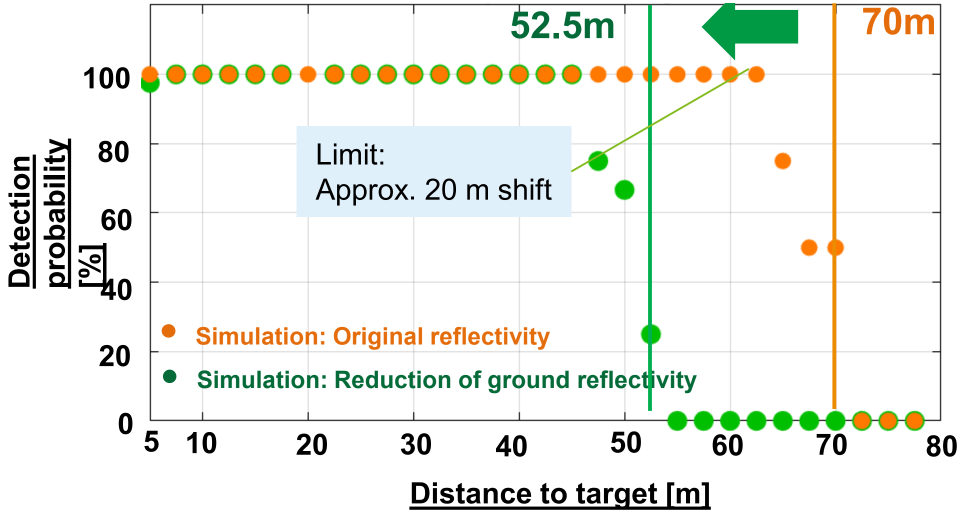
Long-distance detection limit of target: assessment of the effect of point cloud around the target

Difference in point cloud around the target (target location: 65m ahead)

- **Contents of verification:**
  Investigation whether intentional changes in the reflectivity of only the ground affect the detection limit of the target.



Differences in the detection limit of distant targets due to differences in point cloud around the target



Ground reflectivity differences around the target significantly reduce the target's detection limit for long distance.

It was confirmed that the target‘s long-range detection limit was affected by the point cloud around the target.

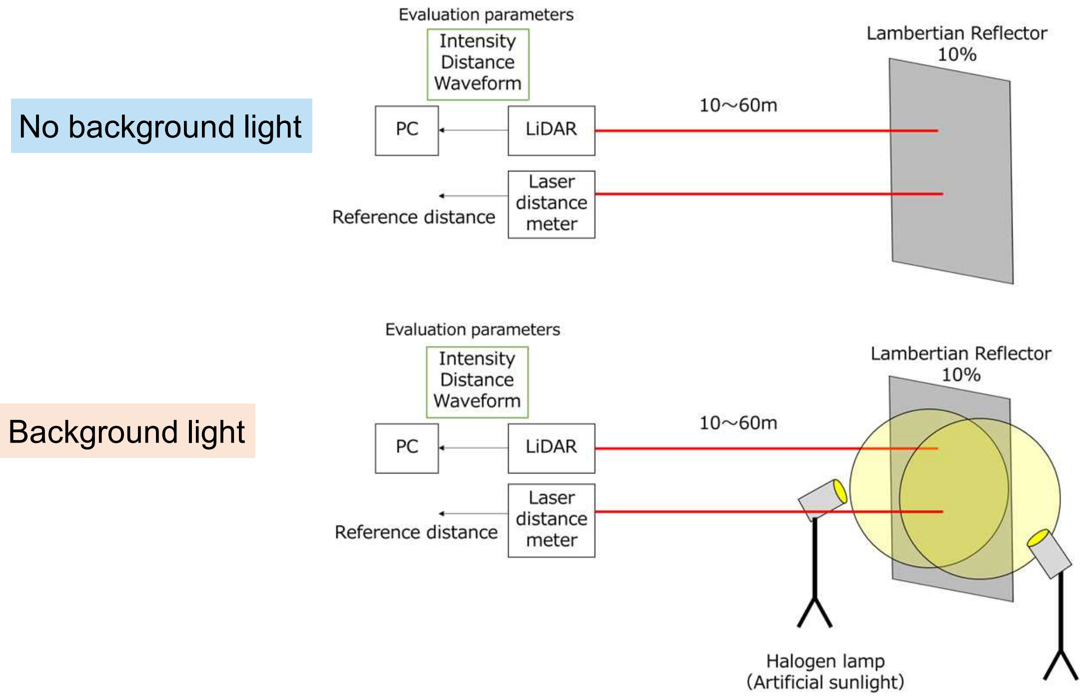
Source : Pioneer Smart Sensing Innovations Corporation.

[PSSI LiDAR Consistency Verification] The consistency of PSSI-LiDAR (Rx model/ranging model) was evaluated in the laboratory by eliminating errors caused by the environmental model and scenario as much as possible.

Consistency Verification of LiDAR perception model

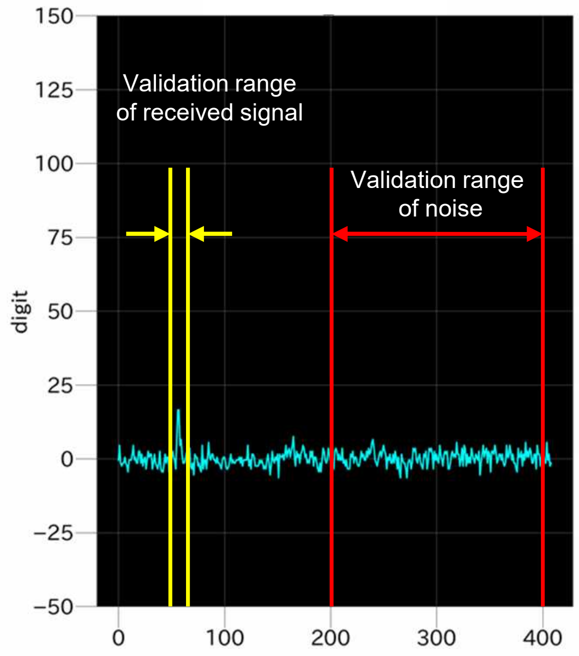
Validation environment in consistency verification of PSSI LiDAR

- Measurement by changing the distance between LiDAR and Lambertian reflector.
- The halogen lamp is used for the background light as simulated sunlight.



Rx model output (waveform) Validation

- For the noise waveform validation, the range that is not affected by the received waveform from the target is used.
- For the received signal waveform validation, the maximum peak in the predetermined range is used.



Source : Pioneer Smart Sensing Innovations Corporation.

[PSSI LiDAR Consistency Verification: Rx Model (Waveform) Validation]
Confirm consistency of Rx model (waveform) with no background light.

Consistency Verification of Rx Model (Waveform) (Verification Results)

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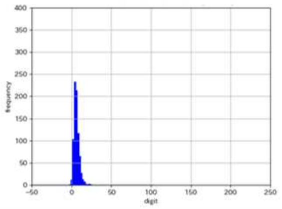
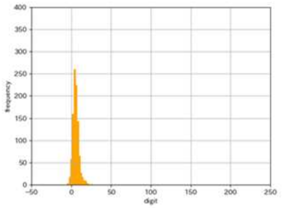
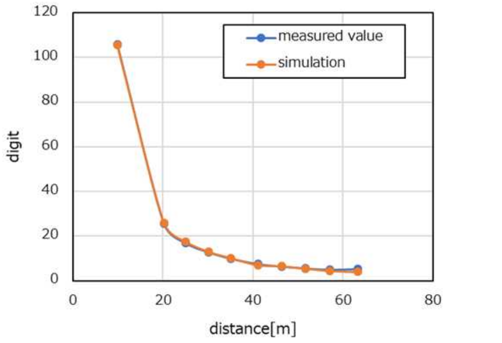
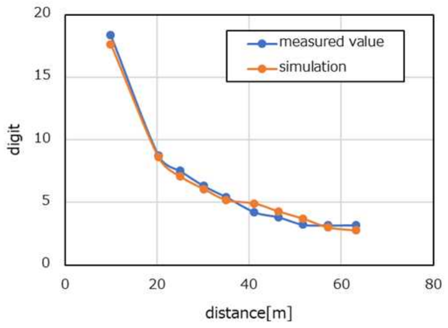
●Results of consistency verification of received signalpeak waveform intensity

	Object	Measured value	Simulation
	Number of data	1000	1000
	Bin width	2digit	2digit
Received signal peak intensity histogram	Distance to a target 52m		

Average of received signal peak intensity

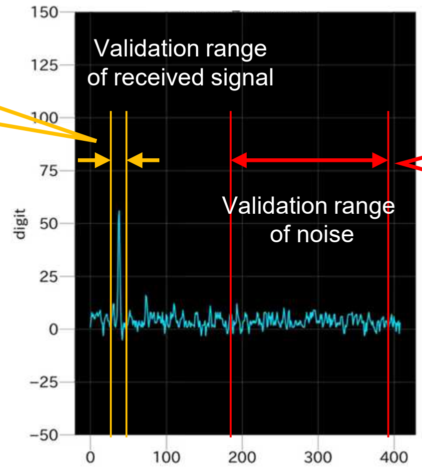


Standard deviation of received signal peak intensity

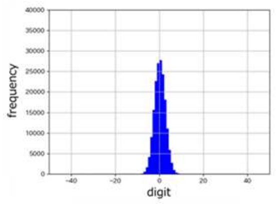
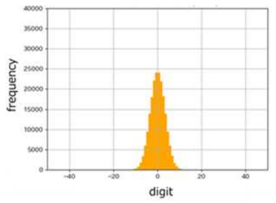


Confirm consistency of histogram, mean, and standard deviation of the received signal peak waveform intensity.

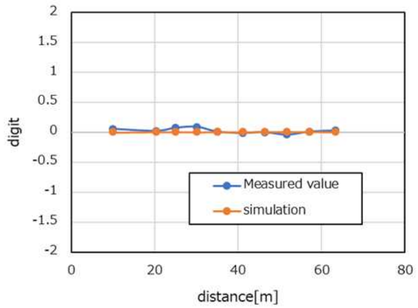
<Example of waveform>
No background light
Lambertian reflector (10%)
target position 20m



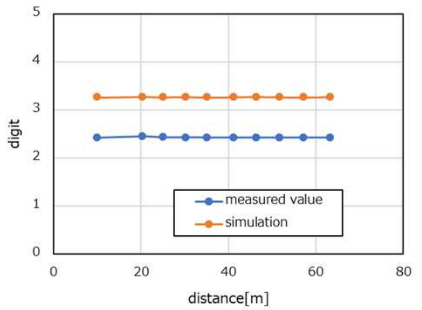
●Results of consistency verification of noise waveform intensity

	Measured value	Simulation
Object	Measured value	Simulation
Number of data	200000	200000
Bin width	1digit	1digit
Noise intensity histogram		

Average of noise intensity



Standard deviation of noise intensity



Confirm consistency of histogram, mean, and standard deviation for noise waveform intensity.

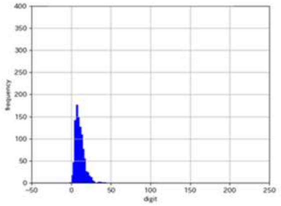
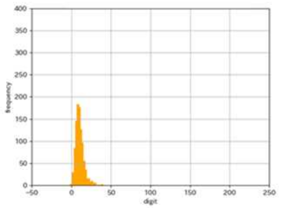
Source : Pioneer Smart Sensing Innovations Corporation.

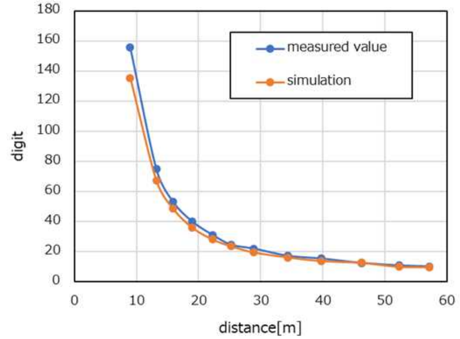
[PSSI LiDAR Consistency Verification: Rx Model (Waveform) Validation]
The noise component of the Rx model (waveform) is not matched with the background light.

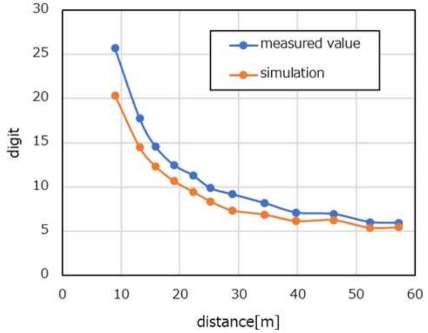
Consistency Verification of Rx Model (Waveform) (Verification Results)

Pioneer

●Results of consistency verification of received signal peak waveform intensity

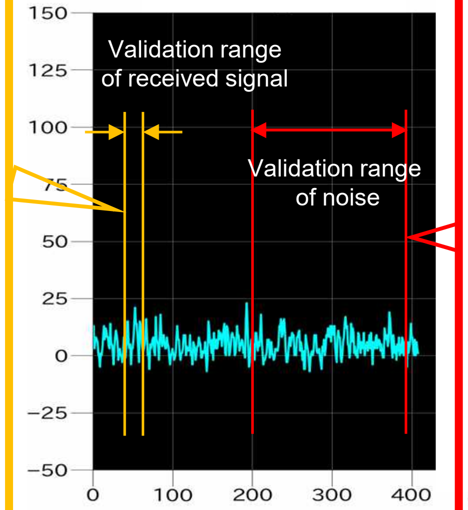
	Object	Measured value	Simulation
	Number of data	1000	1000
	Bin width	2digit	2digit
Received signal peak intensity histogram	Distance to a target 13m		



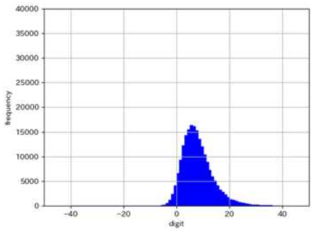
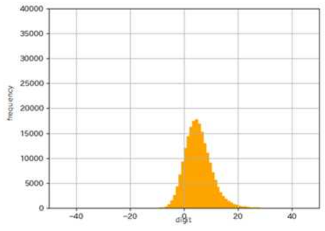


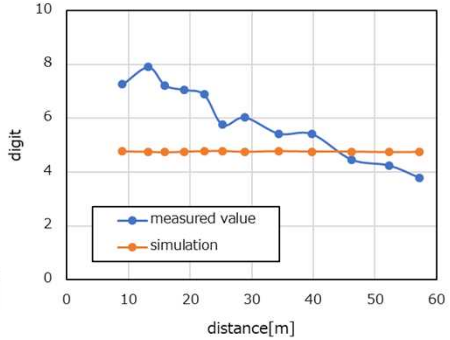
Confirm a certain degree of consistency with the peak of the received signal waveform, although the actual measurement was slightly larger than the model in both the mean and standard deviation of the peak intensity.

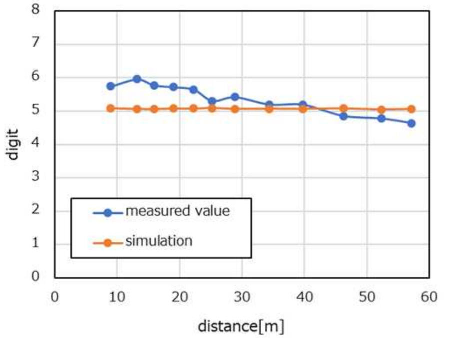
<Example of waveform>
With background light
Lambertian reflector (10%)
target position 13m



●Results of consistency verification of noise waveform intensity

Object	Measured value	Simulation
Number of data	200000	200000
Bin width	1digit	1digit
Noise intensity histogram		





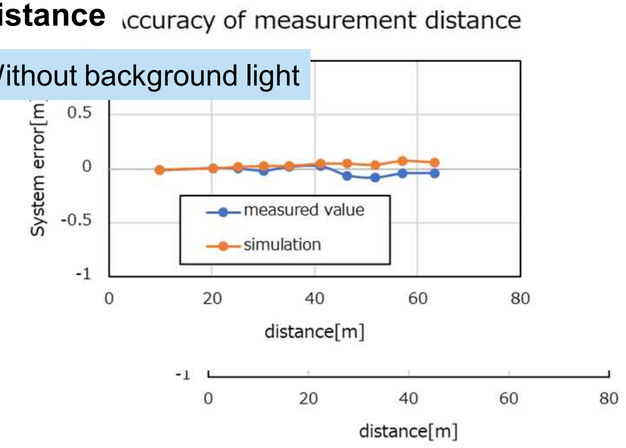
Regarding the noise waveform intensity,there is a challenge in the measurement method (reproduction of background light) . Since beam spot size increases with distance, halogen light is not uniformly irradiated on the target within the field of view, which is presumed to be the cause of the inconsistency.

Source : Pioneer Smart Sensing Innovations Corporation.

[PSSI LiDAR Consistency Verification]
Confirm consistency of the ranging model (point group) without background light.

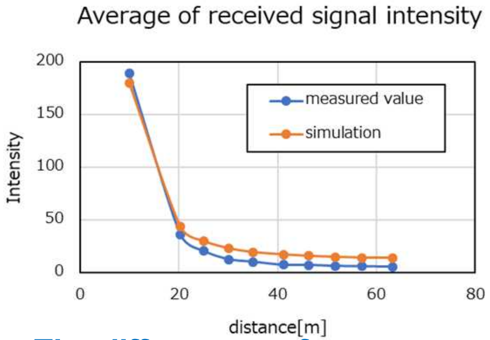
Consistency Verification (verification results) of output of ranging model (point cloud)

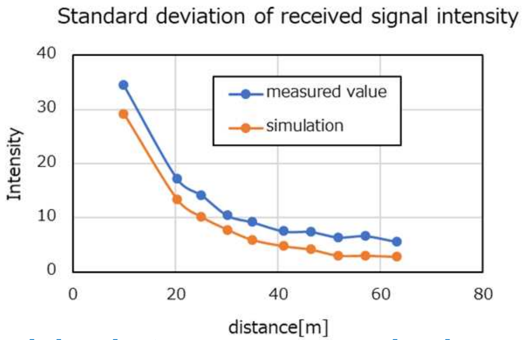
●**Consistency verification of distance**



Adequate consistency was confirmed for accuracy and precision.

●**Consistency verification of intensity**

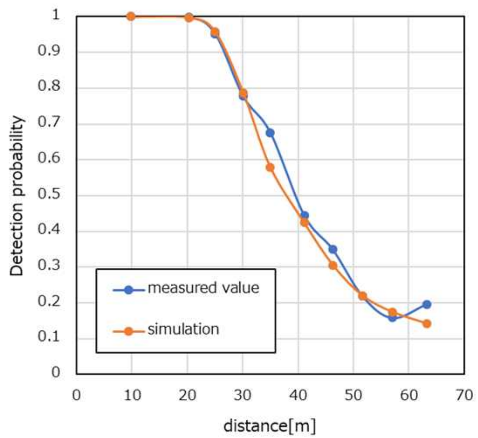




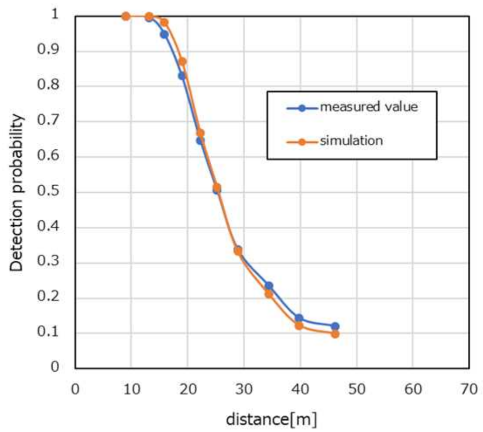
The differences of accuracy and precision between measured value and simulation are small,and the measured value tends to be higher than simulation.

●**Consistency verification of detection probabilities**

Without background light



With background light



Confirm consistency of ranging limit (detection probability) by both conditions without background light and with background light.

Source : Pioneer Smart Sensing Innovations Corporation.

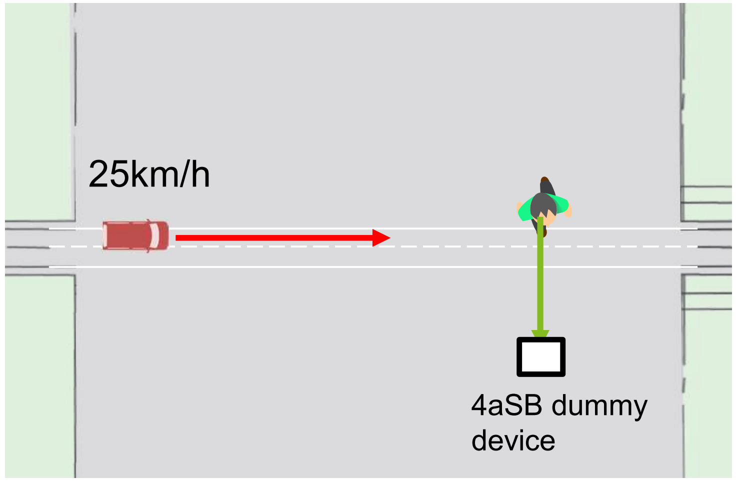
[PSSI LiDAR Consistency Verification] Confirm consistency between intensity distribution and number of target point cloud.

Consistency Verification for Environmental Model + LiDAR Perception Model

<<Measurement conditions>>

- **Validation conducted in nighttime scenario across pedestrians**

[Validation Conditions] No background light: Because sunlight is a cause of malfunction, it is evaluated without background light.



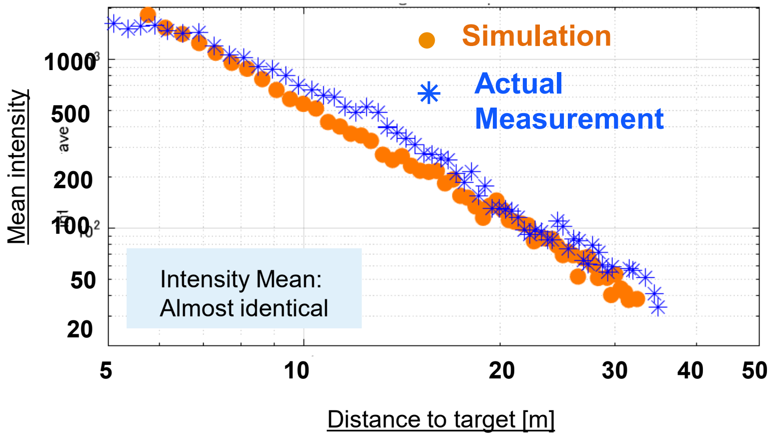
Sensor-equipped vehicle: Alphard

Target: Test dummy for NCAP

<<Validation results>>

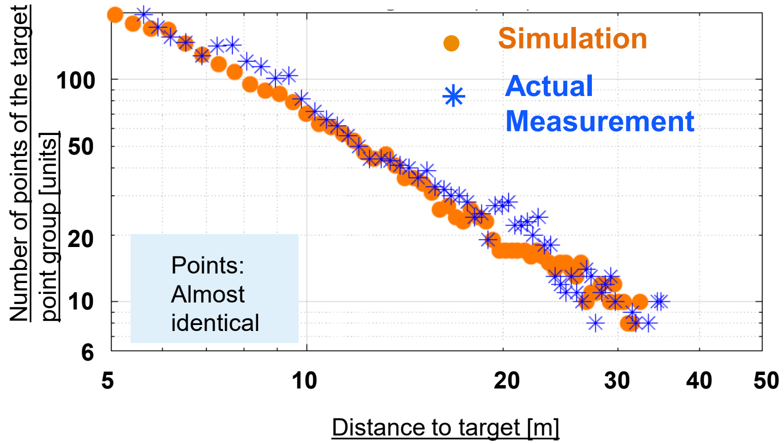
[Intensity distribution of target point cloud]

Mean intensity for each distance



[The number of target point cloud]

Number of points in the target point cloud for each distance



Confirm consistency in intensity distribution and number of target point cloud

Source : Pioneer Smart Sensing Innovations Corporation.

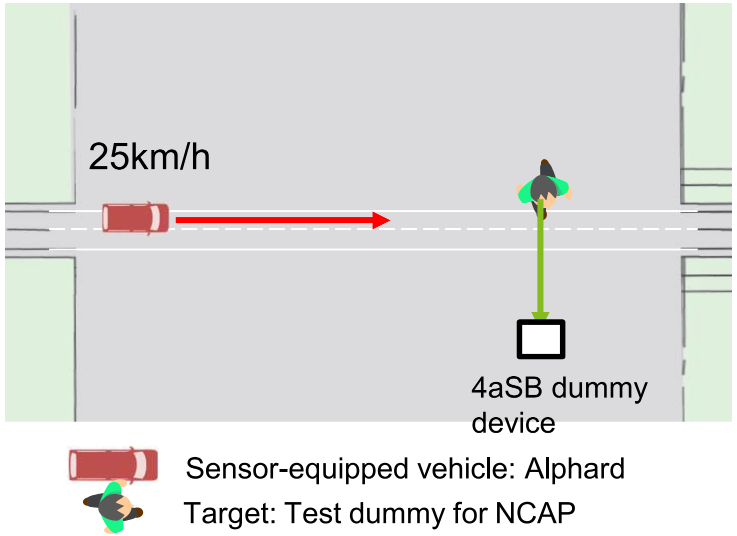
[PSSI LiDAR Consistency Verification]
In the case of black leather jacket NCAP dummy, there is a discrepancy in target long-distance detection limit.

Impact validation on Recognition Model Output

<<Measurement conditions>>

- **Validation conducted in nighttime scenario across pedestrians**

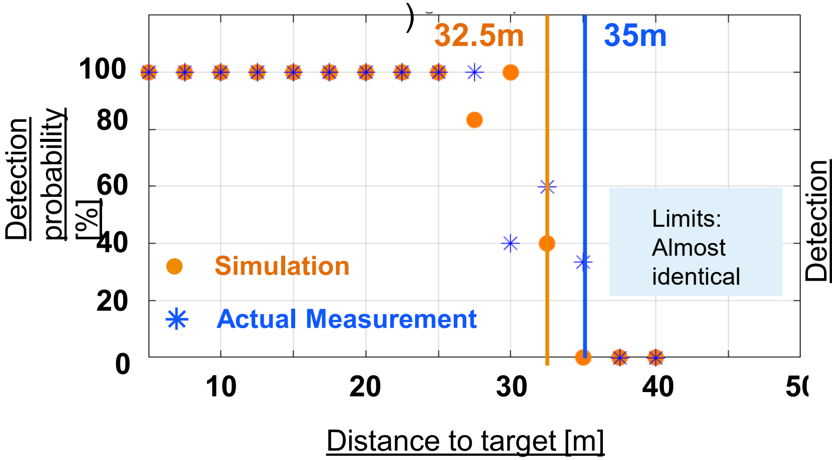
[Validation Conditions] No background light: Because sunlight is a cause of malfunction, it is evaluated without background light.



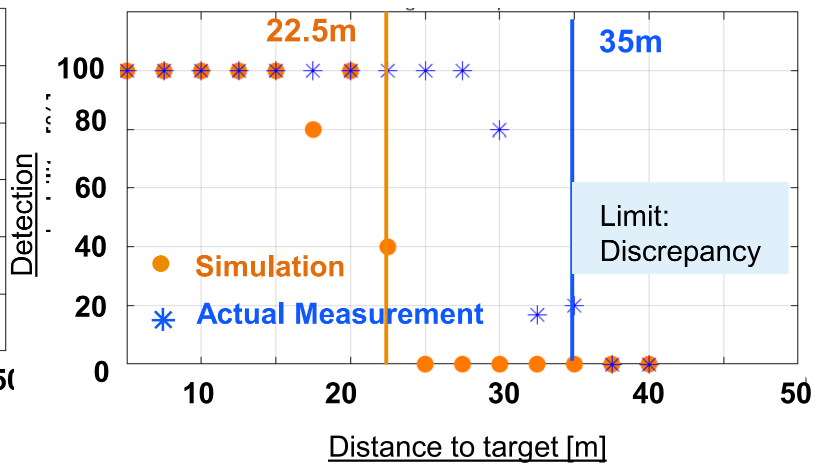
<<Validation results>>

- The target detection limit of the PSSI LiDAR recognition model depends on the number of points which hits the target.
- There are two main factors that determine the number of points.
  - Detection limit by target size and resolution of LiDAR ⇒ Confirmed with test dummy for NCAP
  - Detection limit by influence of target reflectance ⇒ Confirmed with test dummy with black leather jacket for NCAP

[Detection limit of target]
(Test dummy for NCAP)



[Detection limit of target]
(Test dummy with black leather jacket for NCAP)



Confirmed consistency of long-distance detection limit in test dummy for NCAP
Confirmed inconsistency of long-distance detection limit in test dummy with black leather jacket

Source : Pioneer Smart Sensing Innovations Corporation.

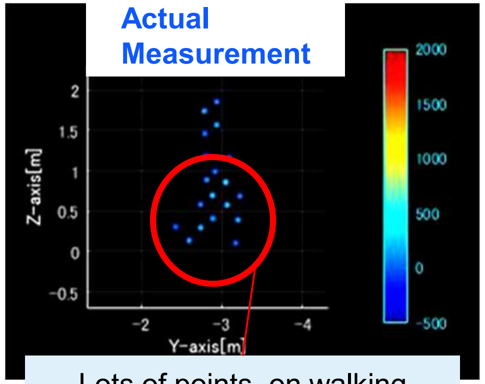
[PSSI LiDAR Consistency Verification]
Evaluate the effect of target point cloud shape and reflectance on the target long-range detection limit

[Detection limit of the target: Investigation of the cause of differences]
(Test dummy with black leather jacket)

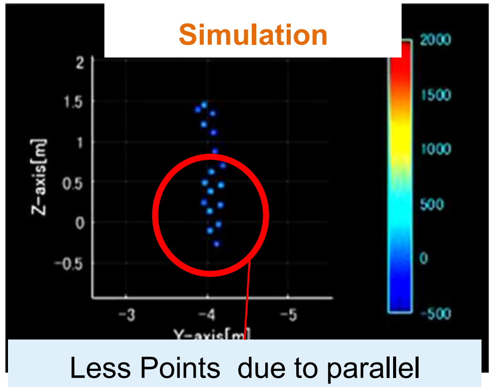
Pioneer

[Factor ①: Difference in the lower body point cloud shape]

Difference in the shape of the lower body point cloud



Lots of points on walking

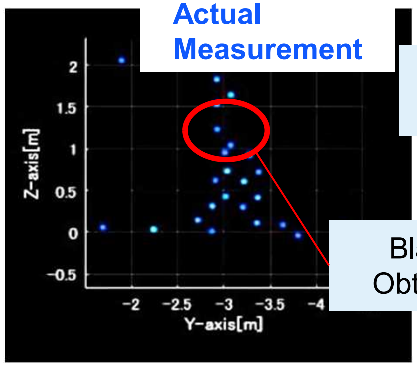


Less Points due to parallel movement of the feet together.

Large difference in the shape of the lower half of the target between actual measurement and simulation ⇒ Candidate of difference factor

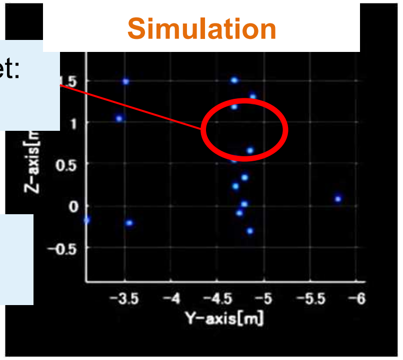
[Factor ②: Effect reflectance of black leather jacket]

- Difference in point cloud of black leather jacket (distance to target: 22 m)

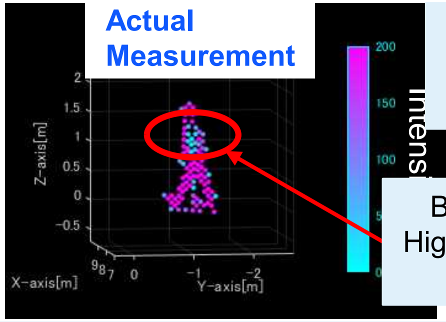


Black Leather Jacket: No point

Black Leather Jacket: Obtaining several points

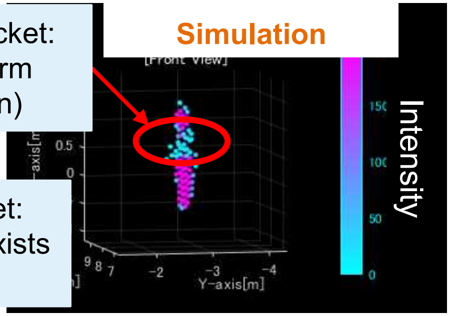


- Difference in intensity of a black leather jacket (distance to target: 8 m)



Black leather jacket: Low and uniform intensity (cyan)

Black leather jacket: High intensity part exists (magenta).



Although black leather jacket have specular components, they are not reproduced in the model ⇒ Candidate of difference factor

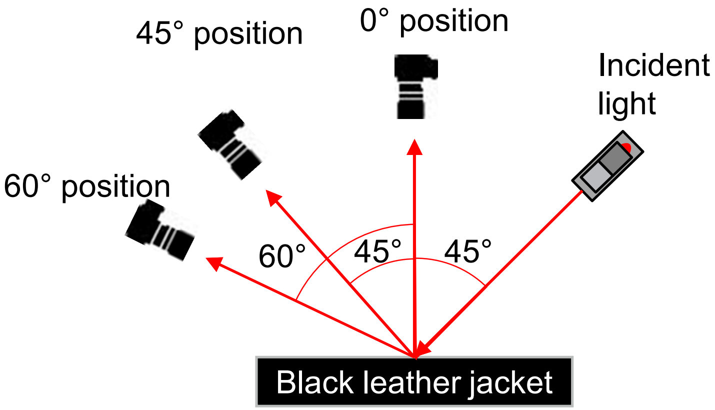
Source : Pioneer Smart Sensing Innovations Corporation.

[PSSI LiDAR Recognition Model Impact Validation]
Investigation of specular reflection characteristics of black leather jacket

[Distance detection limit of target (with test dummy with black leather jacket for NCAP): Investigation of the cause of difference]

[Factor ②: Effect of reflectance of black leather jacket]

Changes in the reflected light intensity of the black leather jacket when the camera angle is changed (the incident light is about 45°)



0° position

45° position

60° position

Confirm that the black leather jacket contains a specular reflection component significantly larger than the diffuse reflection component.

Source : Pioneer Smart Sensing Innovations Corporation.

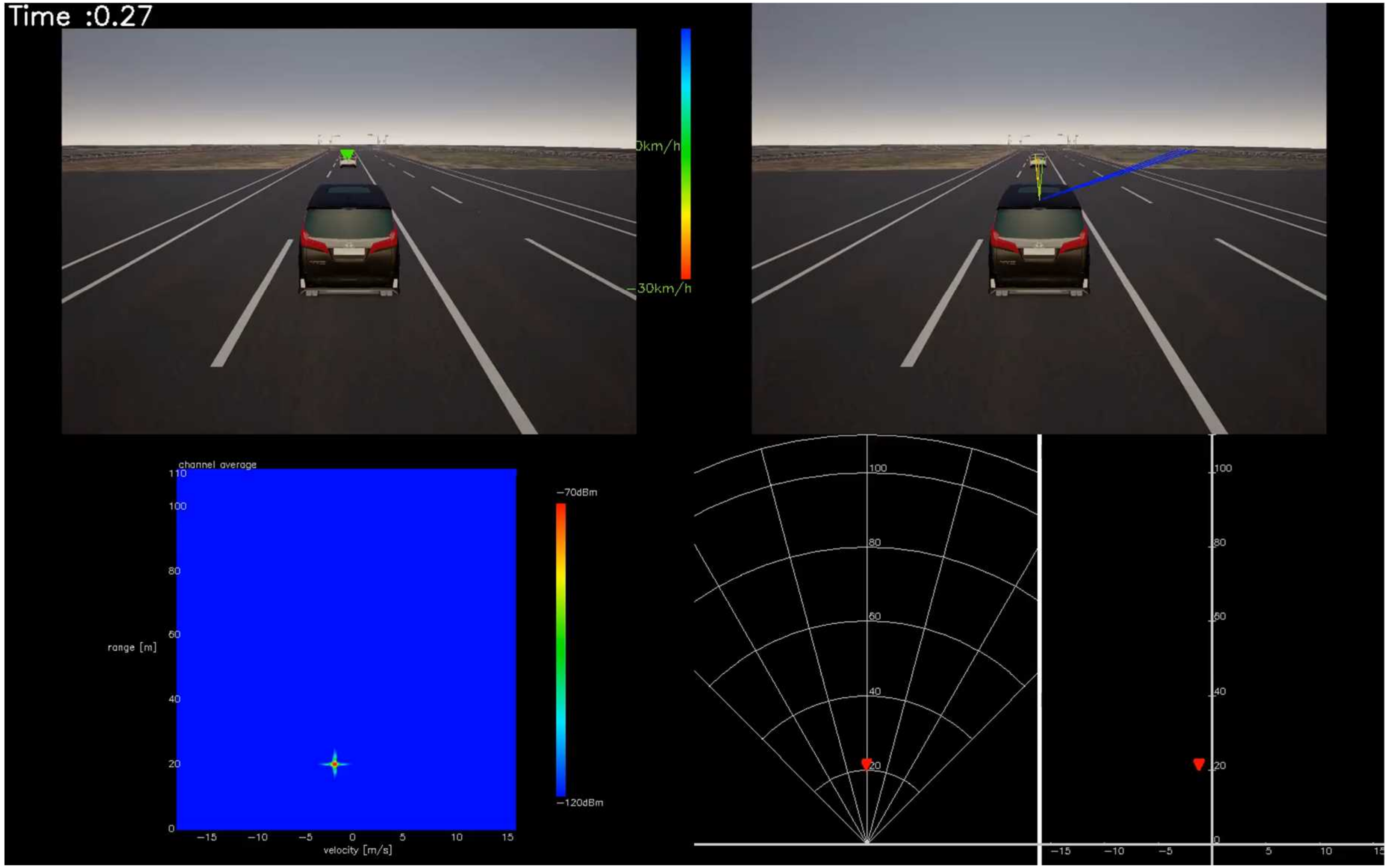
Highly consistent sensor model

- Camera model
- LiDAR model
- Radar model
  - Perception
  - Recognition
- AD control model

Radar model was implemented & under validation of Real vs Simulation consistency

Radar simulation

DENSO SOKEN Nihon Unisys, Ltd



Source : SOKEN, INC

Assessment of simulator function in stages to clarify issues for each layer (sensor model, asset model, propagation model)

Consistency verification

DENSO SOKEN Nihon Unisys, Ltd

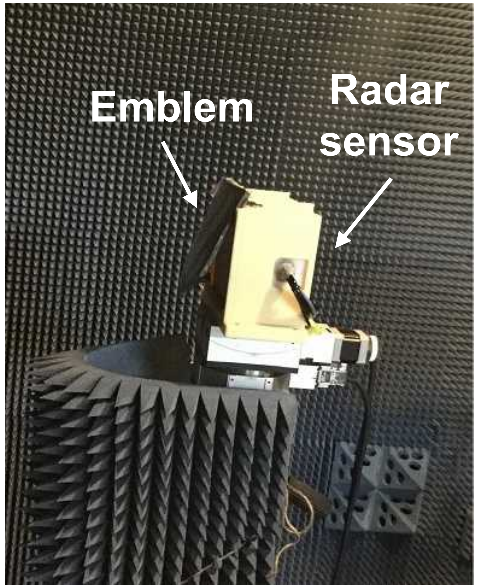
Step	Purpose of Verification	Confirmation characteristics	Validation index
Join operation check	■ Confirmation of the validity of the I/F defined and of the perception output to the point source (corner reflector)	■ Distance, speed, angle and signal intensity	■ Distance, speed, angle and signal intensity in anechoic chambers
		■ Antenna directivity and circuit noise	■ Directional dependence of signal intensity and noise intensity distribution
		■ Error due to the emblem	■ Angle estimation error
Preliminary verification (Static) / Basic verification (Dynamic)	■ Verification of basic single-object (Prius, NCAP dummy pedestrian and bicycle)	■ Reflection intensity, reflection point distribution	■ Signal intensity distribution for distance, speed and angle
		■ Road surface multipath	■ Distance dependence of corner reflector and Prius signal intensity
		■ Micro-Doppler	■ Signal intensity distribution in the speed direction by pedestrian leg movements and tire rotation
NCAP scenario verification	■ Verification of basic multi-objects(combinations of Prius, Alphard, NCAP dummies, etc.)	■ Multiple echo	■ Ghost echoes between the ego-vehicle and the Prius
		■ Shielding properties of objects	■ Time to start seeing the target behind the object
Malfunctions verification / Extensibility verification	■ Verification of objects (manholes and corrugated cardboard) that are subject to false positive or false negative using millimeter-wave radar ■ Verification in the actual traffic environment	■ Signal intensity	■ Signal intensity of manholes and corrugated cardboard
		■ Multipath with tunnel walls	■ Situation of ghost to the overtaking vehicle
		■ Reflection intensity and reflection point distribution of the surrounding structure	■ Signal intensity distribution for tunnel/bridge distance, speed and angle

Build a mechanism to reproduce malfunctions by incorporating sensor characteristics and error factors into the Radar model based on actual measurements

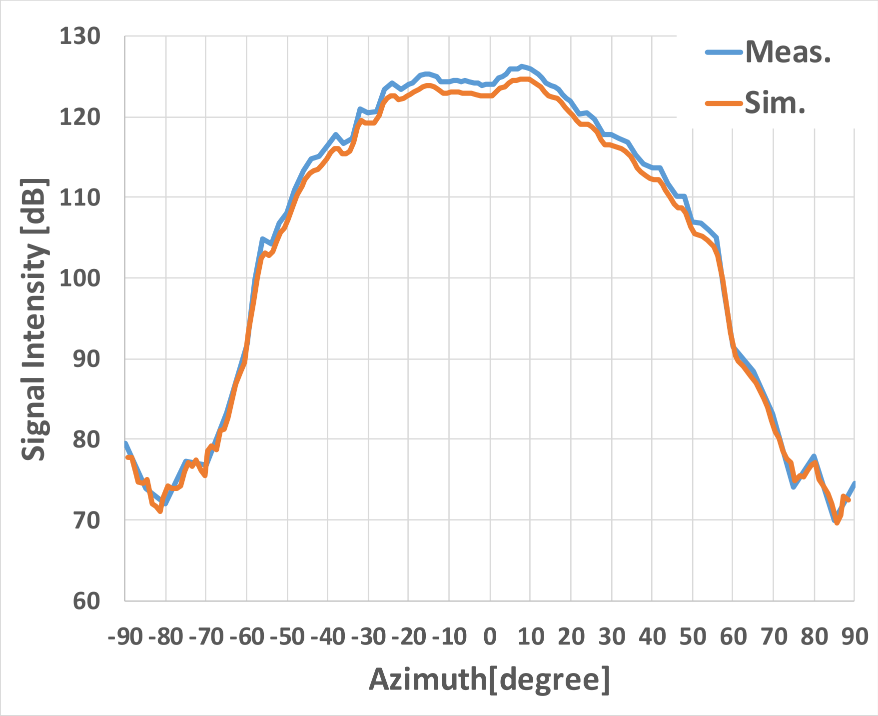
Azimuth dependence of signal intensity

DENSO SOKEN Nihon Unisys, Ltd

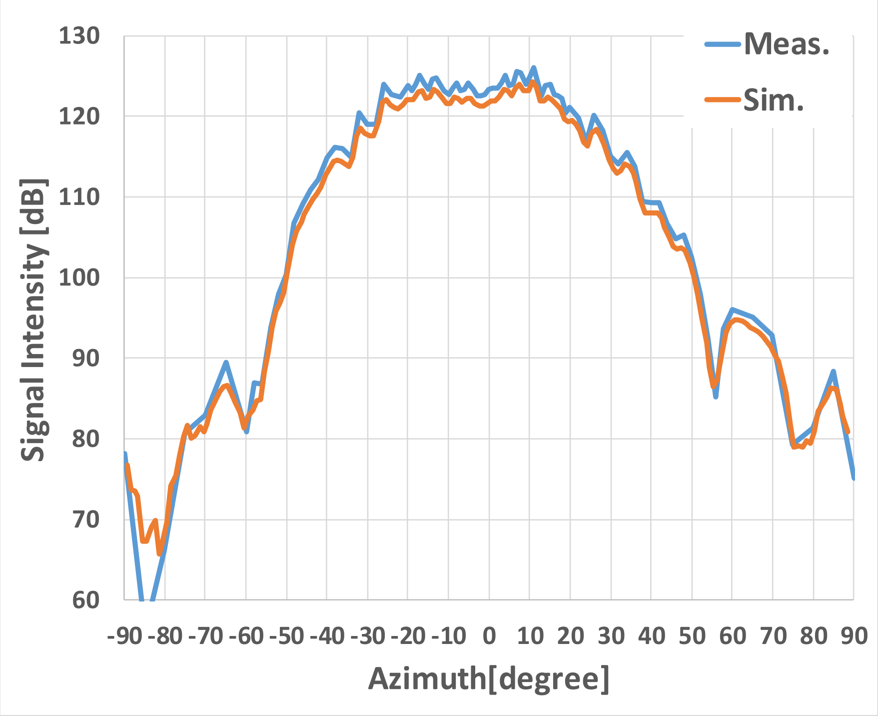
Measurement Environment



Without emblem



With emblem



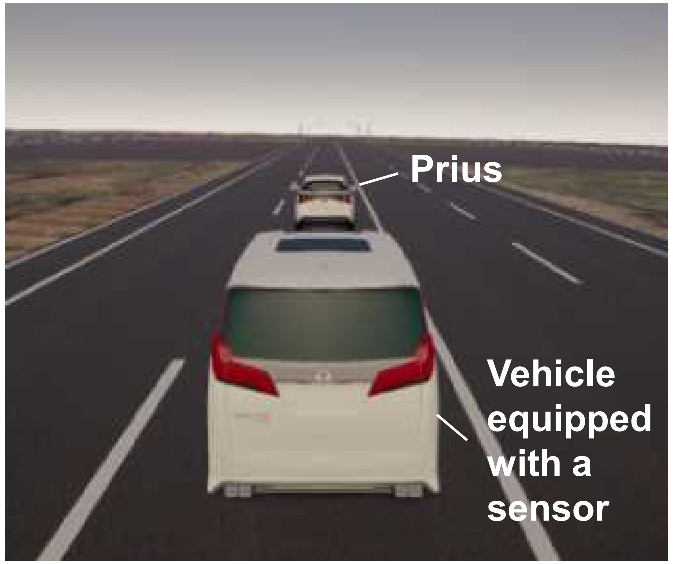
Source : DENSO, INC

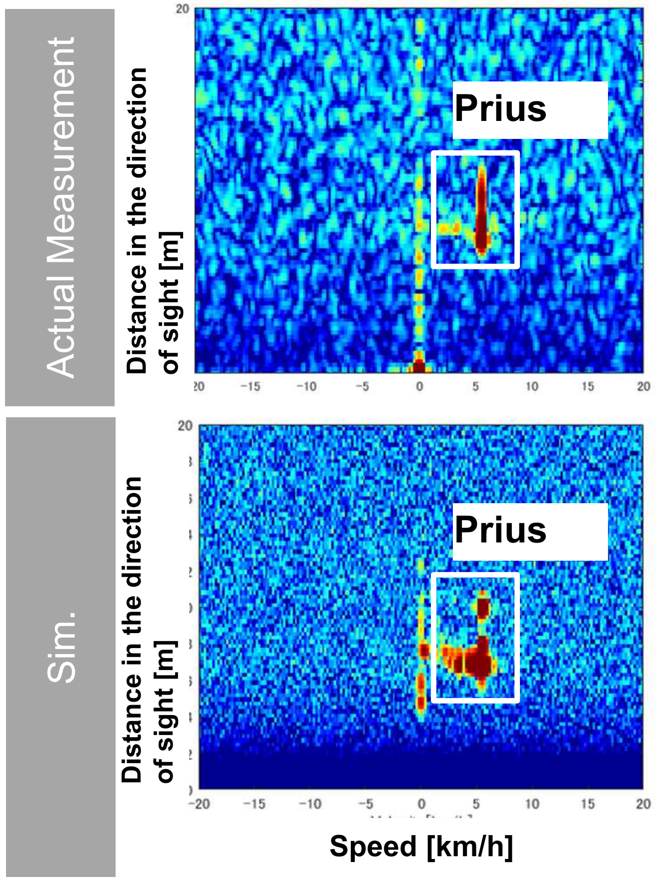
By applying PO approximation and using reflection rate based on actual measurement, it was confirmed that the signal intensity level and distance attenuation are largely consistent

Verification in the longitudinal departing scenario

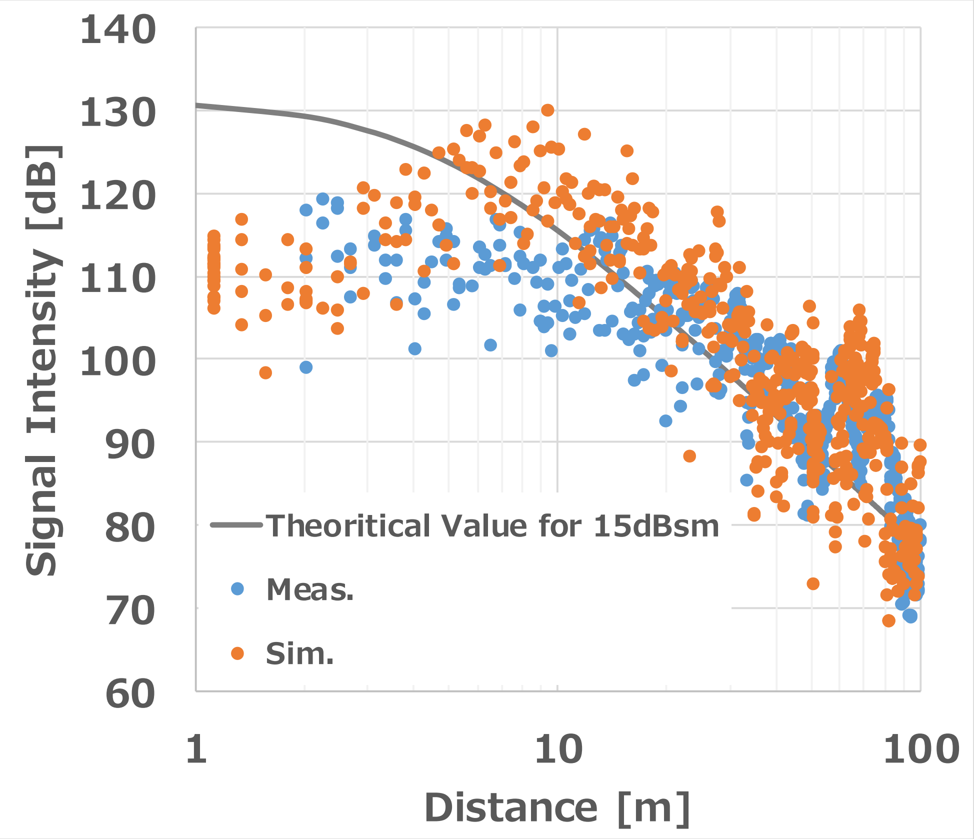
DENSO SOKEN Nihon Unisys, Ltd

Confirmation of consistency of perception data outputs(distance, speed, angle, signal intensity)





Comparison of signal intensities at the maximum reflection point



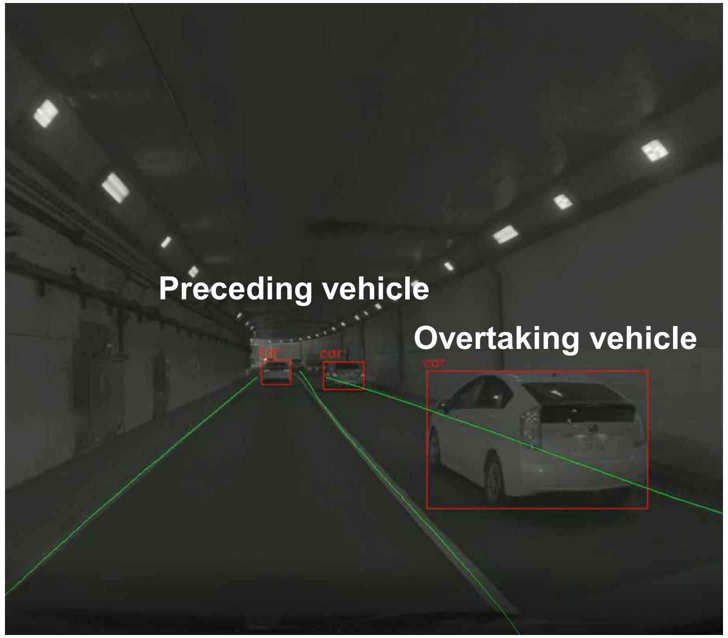
Source : DENSO, INC

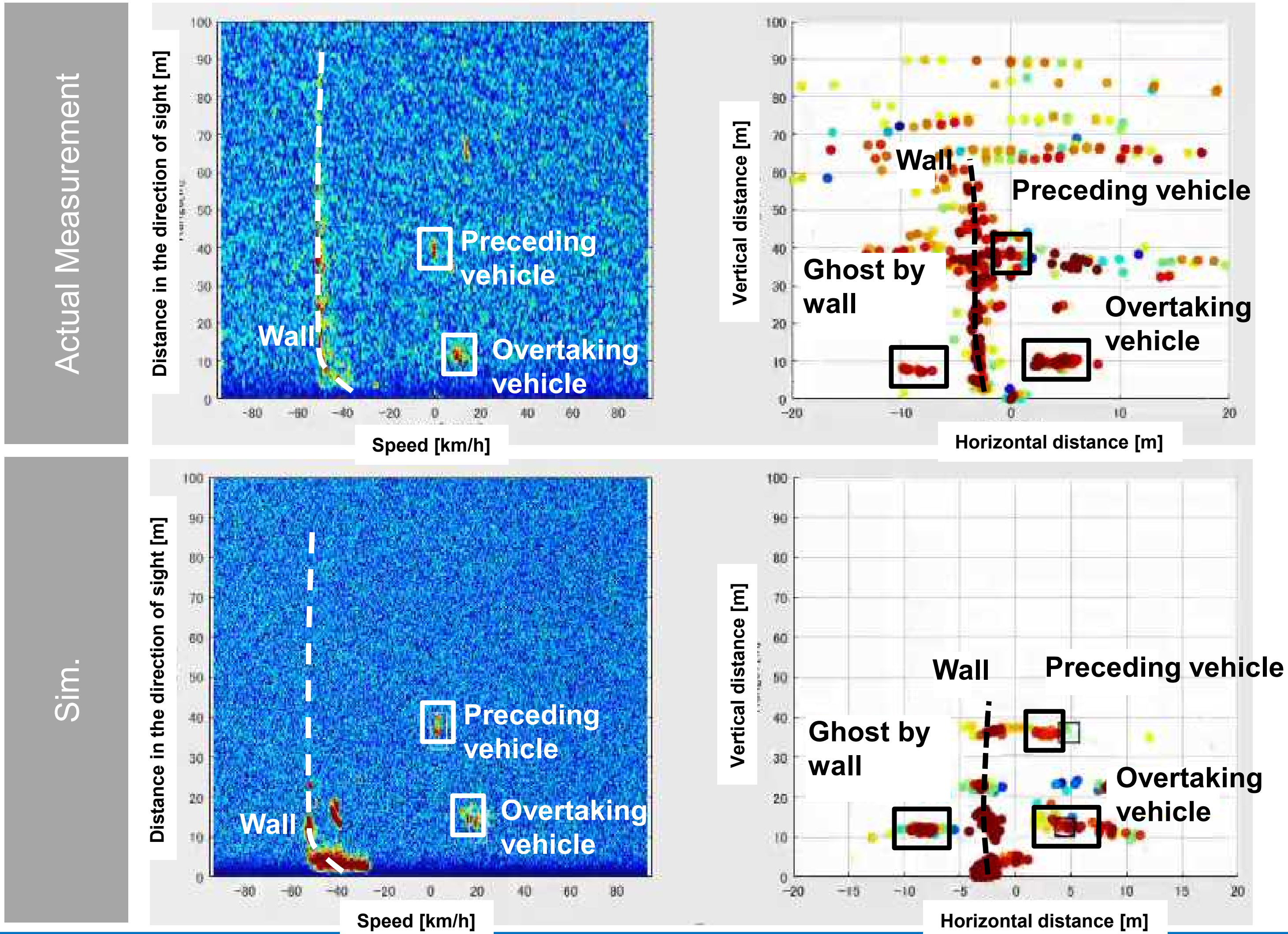
Establishment of the simulation environment and model construction method enabled simulation in complex actual driving scenes and enabled the extraction of problems.

Verification of consistency at C1 Metropolitan Expressway

DENSO SOKEN Nihon Unisys, Ltd

Verification scenario





Source : DENSO, INC

The consistency of the millimeter-wave Radar model was confirmed, and current issues were extracted.

Results of confirmation of conformity with Radar model

DENSO SOKEN Nihon Unisys, Ltd

Confirmation characteristics	Check item	Contents of the consistency confirmed	Current issues
Reflection characteristics of the target object	Perception data output for the Prius, pedestrians, corrugated products and manholes	■ The distance, speed and angle are almost the same. ■ The signal Intensity of the Prius, pedestrian and manhole is almost identical depending on the scene	■ Method of asset splitting and allocation of reflection characteristics ■ Modeling of irregular surface structures such as corrugated vehicledboard
Reflection characteristics of peripheral structures	Perception data output of tunnels and bridges	-	■ Reflection and reproduction of peripheral structures
Shielding properties of objects	Time to start seeing the target behind the object	■ The time to start seeing is almost the same.	■ Validation against the principles of diffraction and transmission
Multipath characteristic	Distance dependence of on-street corner reflector and Prius signal intensity	-	■ Reproduction of Road Surface Multipath Effects
	Ghost at the tunnel wall	■ Check for ghost.	■ Reproducibility check of signal intensity
Multiple echo characteristics	Multiple echo signals between the ego-vehicle and the Prius	■ Confirm signal generation by multiple echoes.	■ Reproducibility check of signal intensity
Influence of the environment in which the sensor is mounted	Angle estimation error by the emblem	■ The Angle estimation error is almost identical.	■ Modeling for each mounting environment
Micro-Doppler	Perception data output of tires to rotate and pedestrian foot movements	■ Generation of micro-Dopplers due to pedestrian foot movements	■ Optimization of asset split method and Ray parameter setting

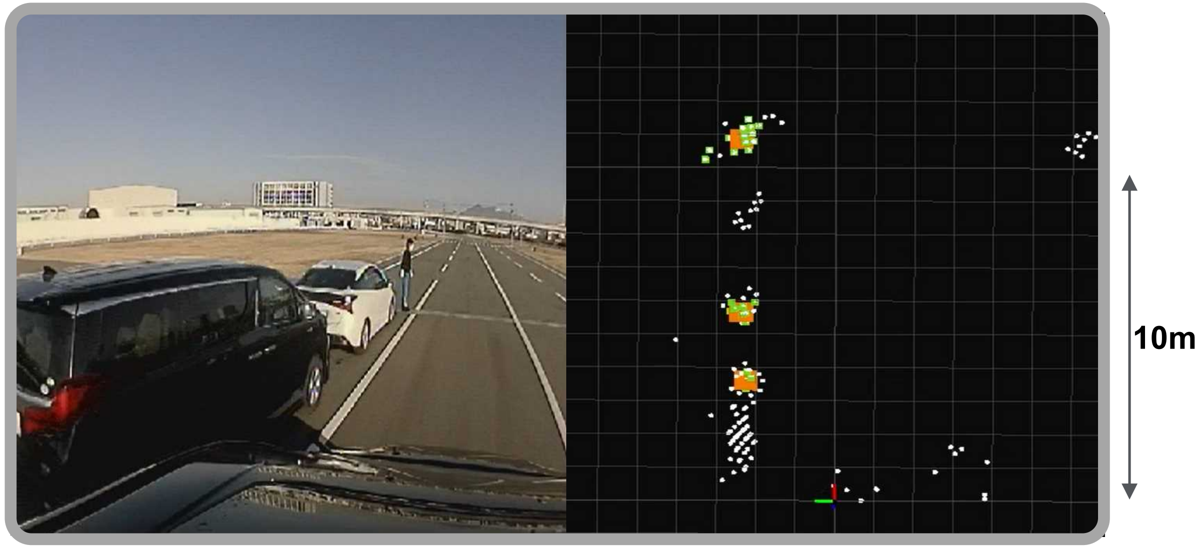
Highly consistent sensor model

- Camera model
- LiDAR model
- Radar model
  - Perception
  - Recognition
- AD control model

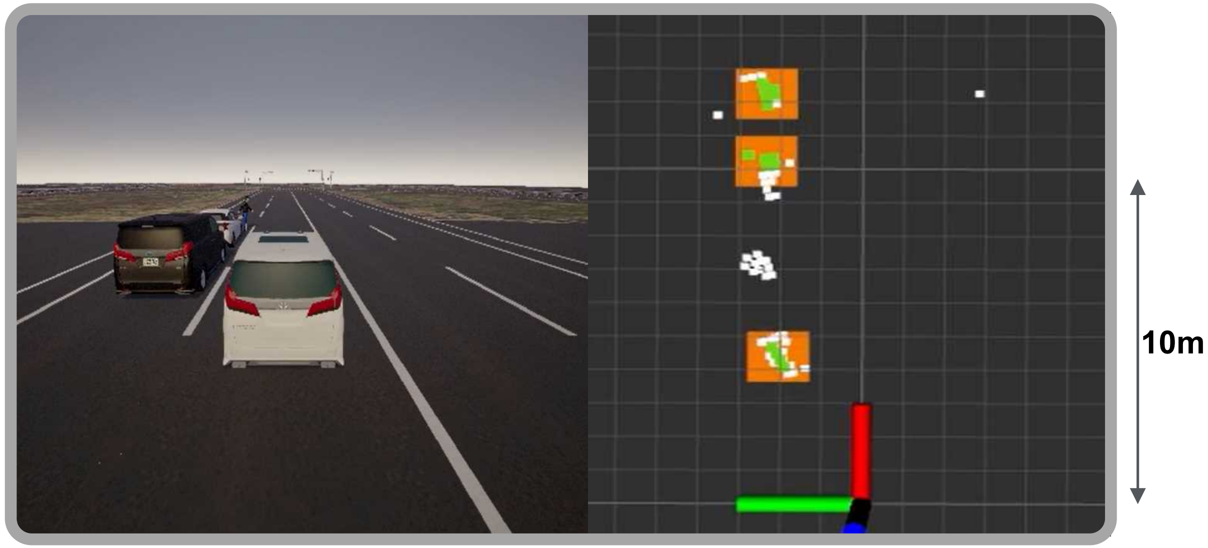
DIVP® platform contributes to the development and validation of radar recognition models.

Coordinates output of the radar recognition model (NCAP-AEB test : 25km/h)

Real



DIVP® simulation



※Simulation conditions : refrector OFF、number of refrection 1, maximum perception output 200 points

○ Perception output ■ Perception output after removing noise ■ Recognition output

- **The radar recognition model has some issues concerning the accuracy of coordinates estimation**
  - ➢ **The accuracy depends on "Method of asset splitting and allocation of reflection characteristics".**

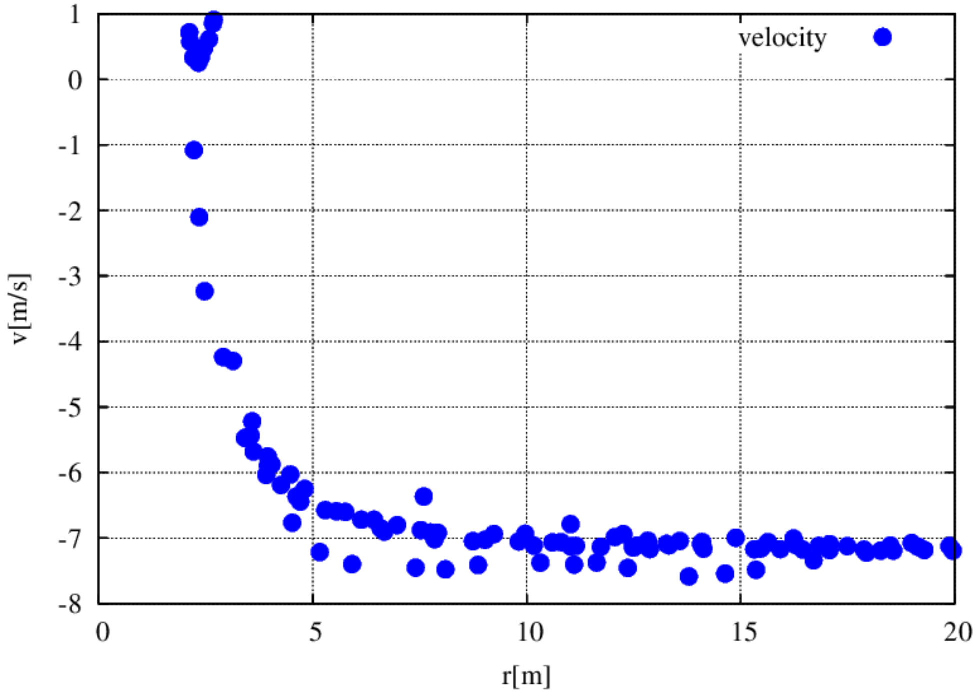
Source : Ritsumeikan University

DIVP® platform contributes to the development and validation of radar recognition models.

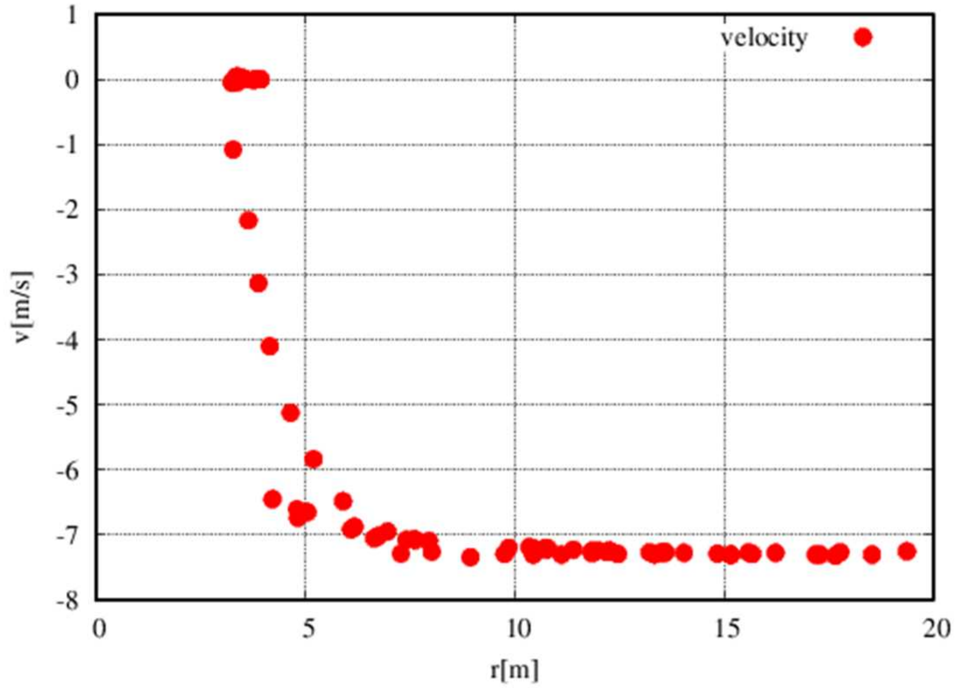
Relative velocity output of the radar recognition model (NCAP-AEB test : 25km/h)

RITSUMEIKAN

Real



DIVP® simulation



The above figures show that the actual measurement and the simulation are almost the same regardless of the distance.

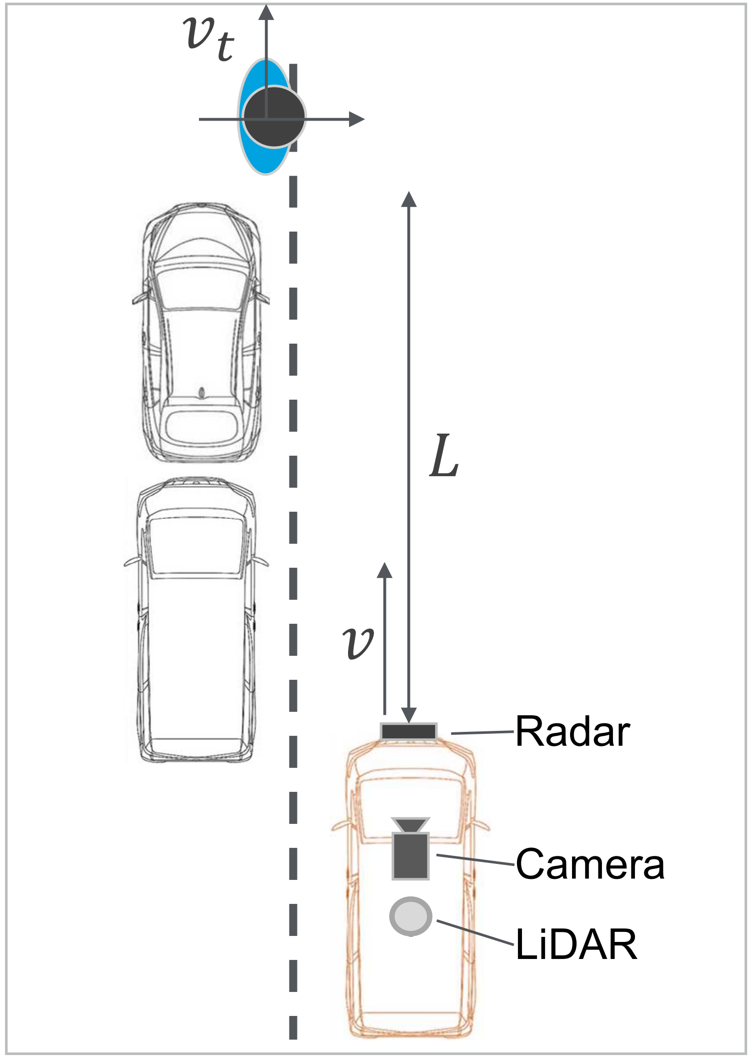
Source : Ritsumeikan University

Highly consistent sensor model

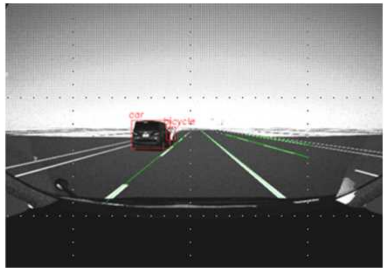
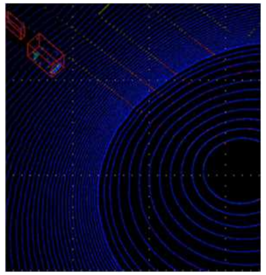
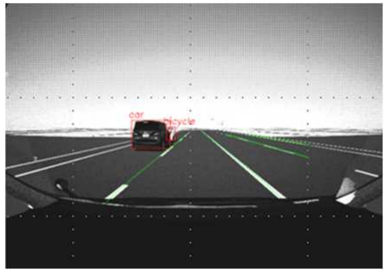
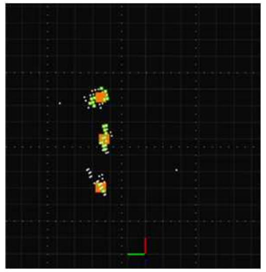
- Camera model
- LiDAR model
- Radar model
- AD control model

A fusion model combining camera, LiDAR and radar achieved highly accurate coordinates estimation to the target objects.

The fusion model combining camera, LiDAR and radar for the NCAP-AEB test



Role of each sensor and design of sensor fusion

	Camera	LiDAR or Radar
Role	Direction estimation Object Detection	Direction estimation Coordinates estimation
Camera+LiDAR		
Camera+Radar		

Design of AEB operation based on TTC (Time to Collision)

$$\mathrm{TTC} = \frac{L}{v - v_t}$$

Source : Ritsumeikan University

Steady experimental verification reflected real-world problems in the simulation, and the consistency of vehicle behavior was confirmed

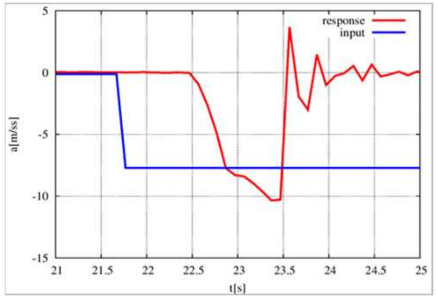
Verification of consistency in vehicle behavior

RITSUMEIKAN

Detect a pedestrian

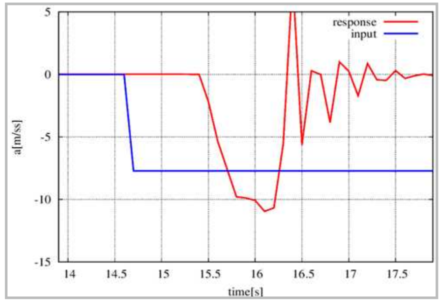
Real

Consistency in input delay of emergency brake



Input delay (Real)

sim.



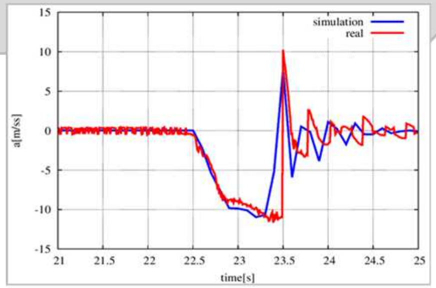
Input delay (Sim.)

Start braking

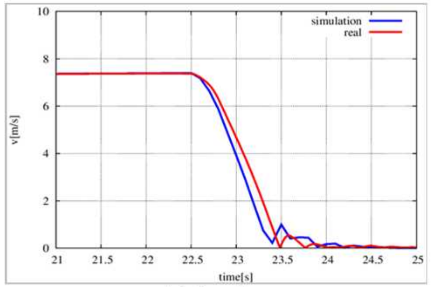
Real

Sim.

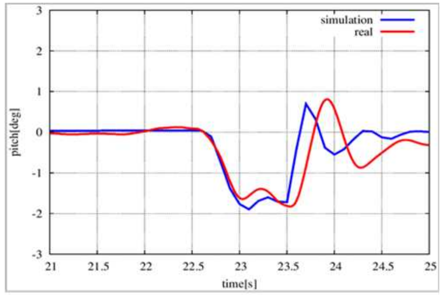
Consistency in vehicle behavior



Acceleration



Velocity



Pitch

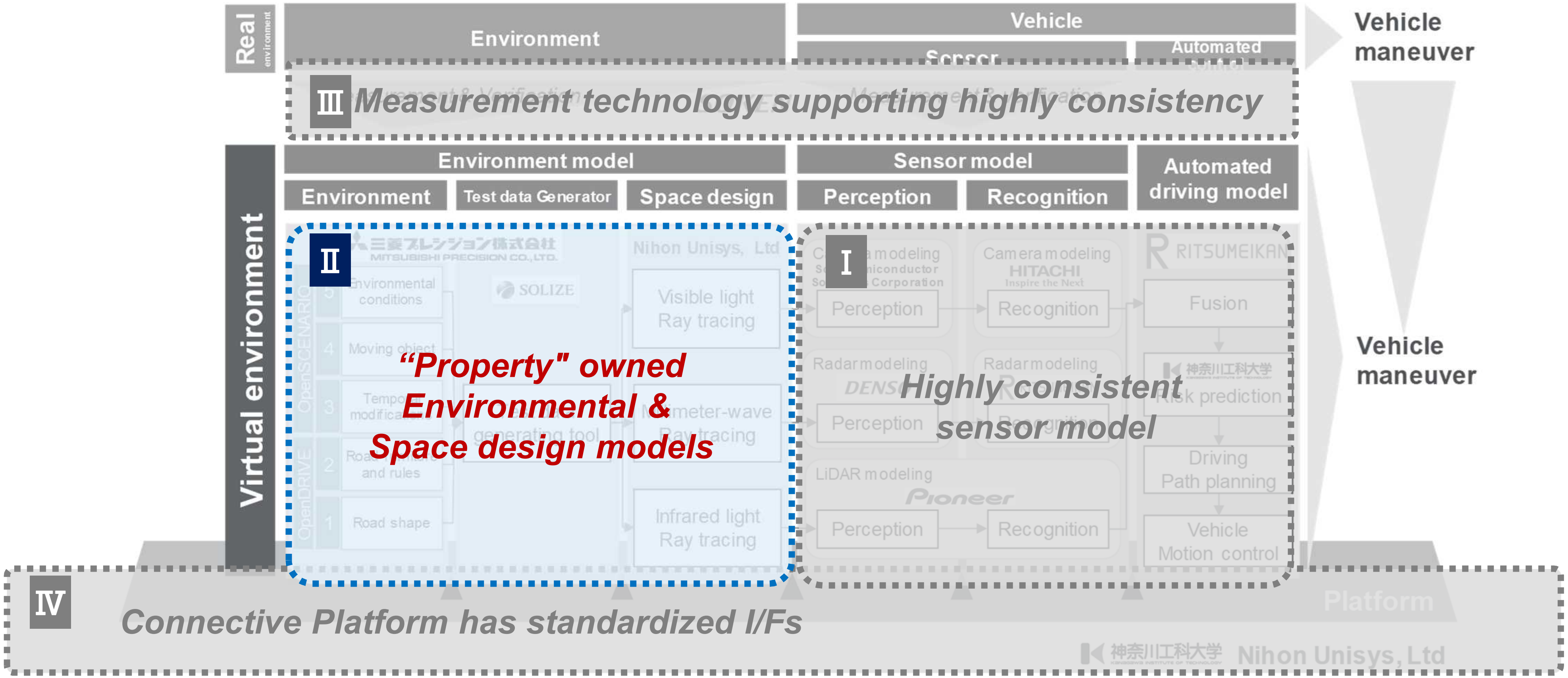
Stop

Real

Sim.

Source : Ritsumeikan University

FY2020 outcome

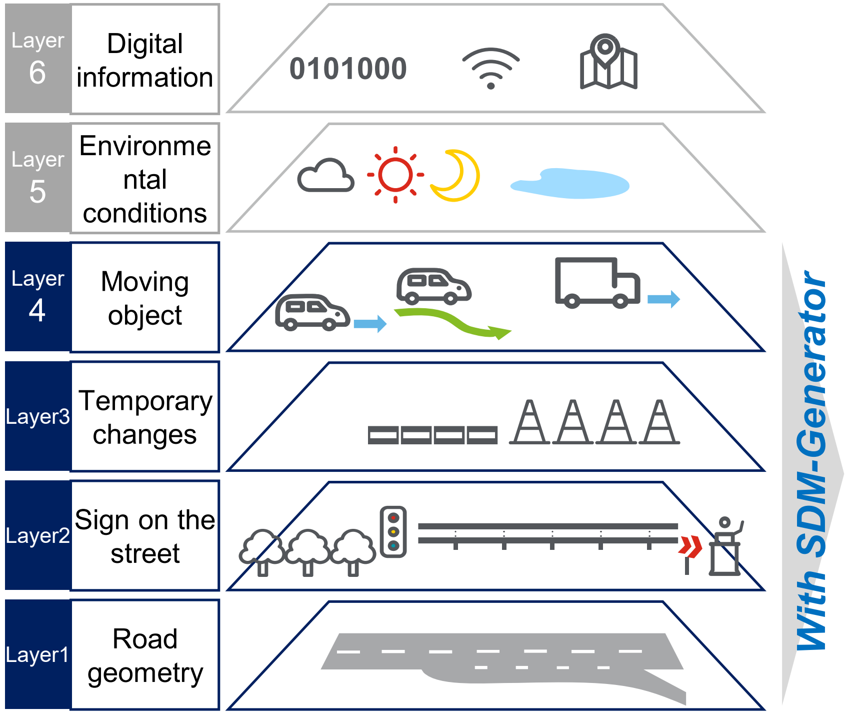


The SDM*-generator makes it possible to assemble the necessary traffic environment model freely at any time without being constrained by time, location, weather conditions, etc.

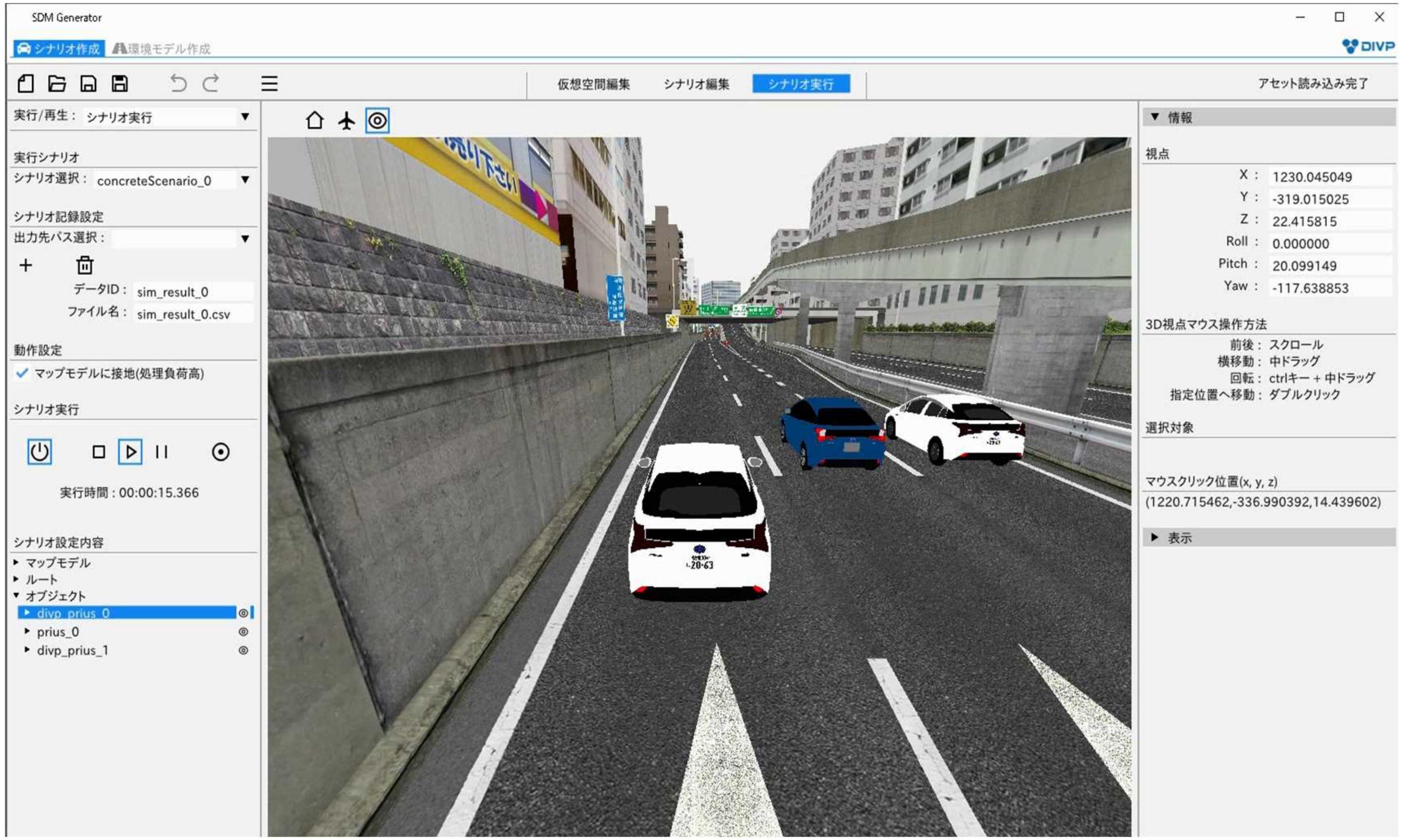
Convenient traffic environment modeling technology

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

Layer of the driving environment model



Creation of traffic environment models using SDM-generators



- **Large amount of experimental resources are required depending on weather conditions, time, and traffic environment of surrounding areas, and there are cases where it is difficult to reproduce in the experiment. It is difficult to comprehensively evaluate in the first place.**

Pengineer rom Japanese OEM

*: **S**pace **D**esign **M**odel

Source：MITSUBISHI PRECISION CO.、LTD.

It is possible to assemble any traffic environment such as road shape, placement of traffic participants, movement setting and also environmental factors such as rain and backlight.

Building Virtual Proving Ground

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

Simulation of traffic environment at J-town intersection

Rain

Backlight

* : Virtual Proving Ground
Source : MITSUBISHI PRECISION CO.,LTD.

“Property" owned Environmental & Space design models

- Precise Environmental & Space design models
- Sensing weakness domain modeling
- Sensing weakness scenario analysis

Each model of a property-bearing environment reproduces the internal structure with a high-definition polygon, allowing validation of millimeter-wave radar

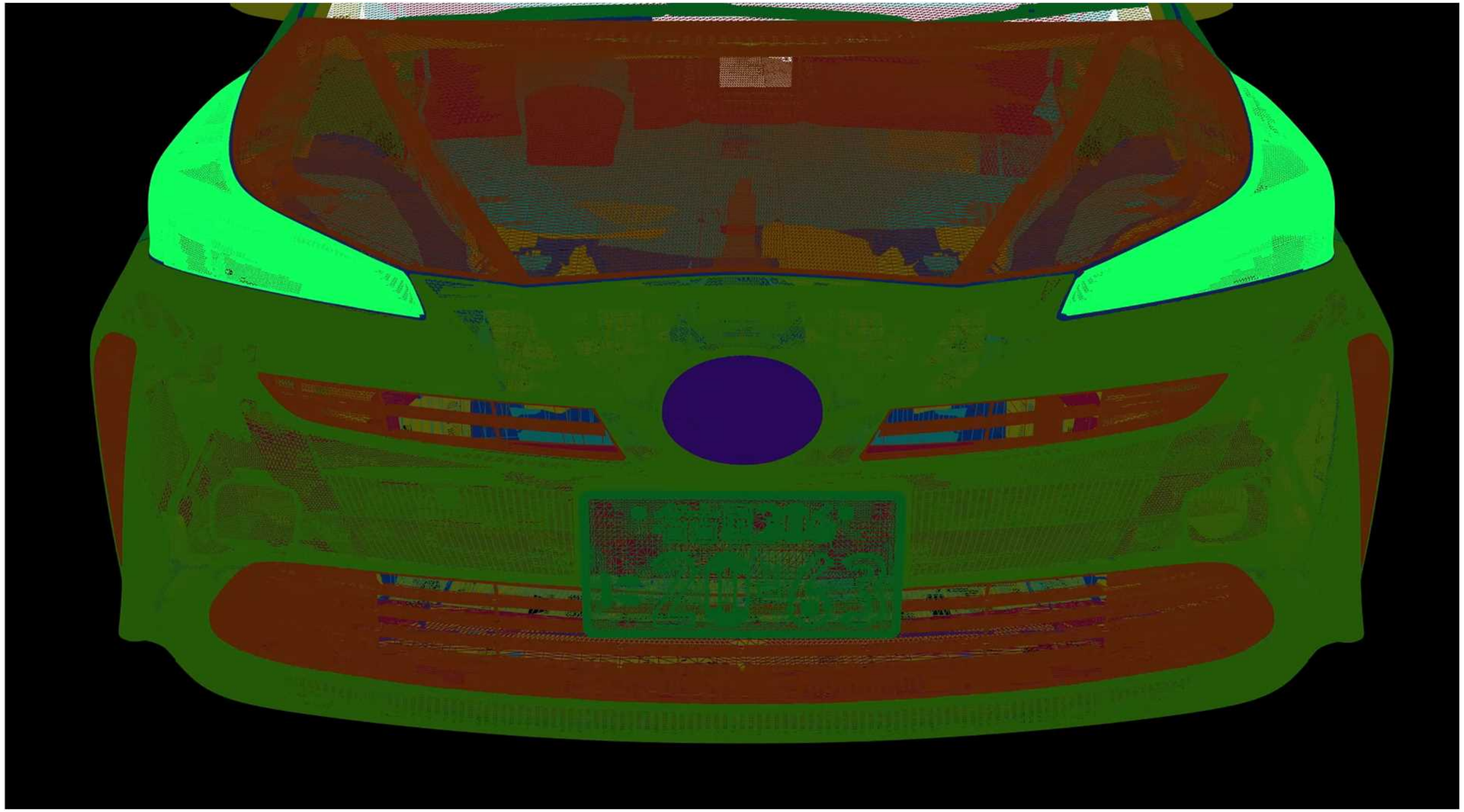
High-resolution polygon model

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

Laser measurement

Detailed modeling based on actual measurement

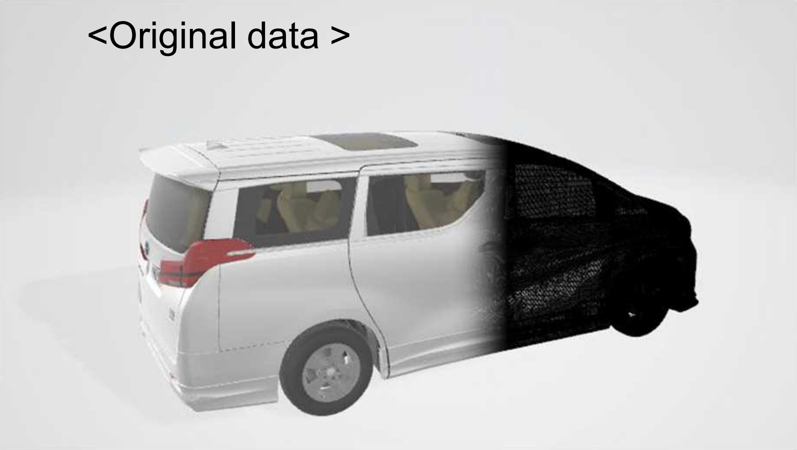
Polygon modeling

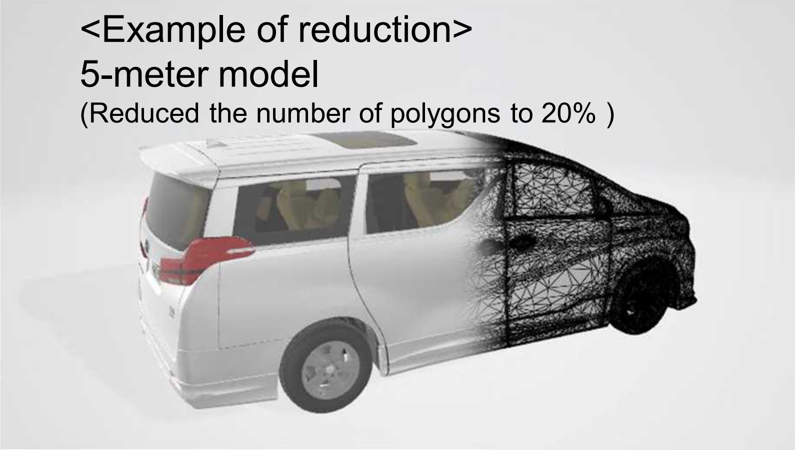


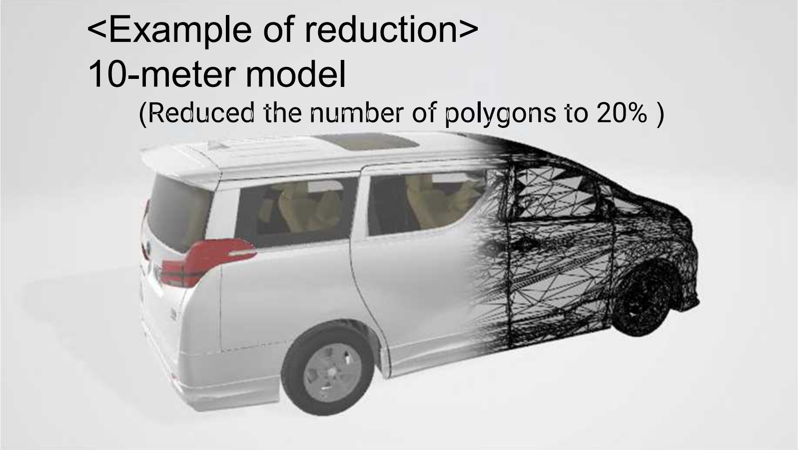
Source : SOKEN, INC, MITSUBISHI PRECISION CO.、LTD.

By reducing the amount of information while ensuring the precision of the model shape, the precision and speed of the simulation are both achieved

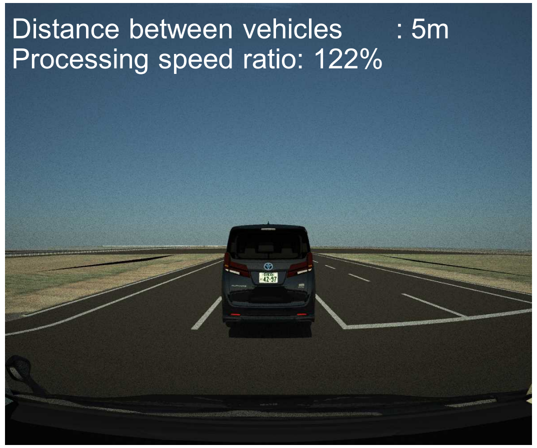
Development of information volume reduction tool (*1) using sensor resolution as an error tolerance

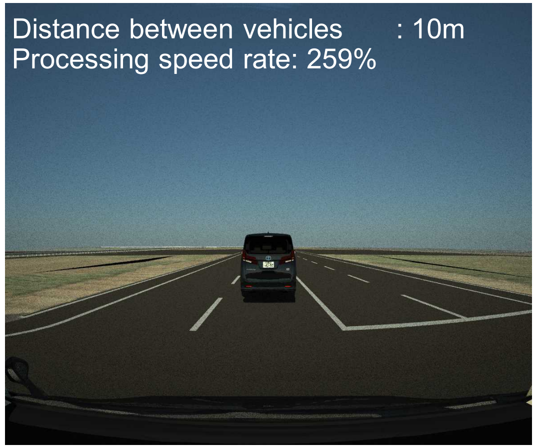


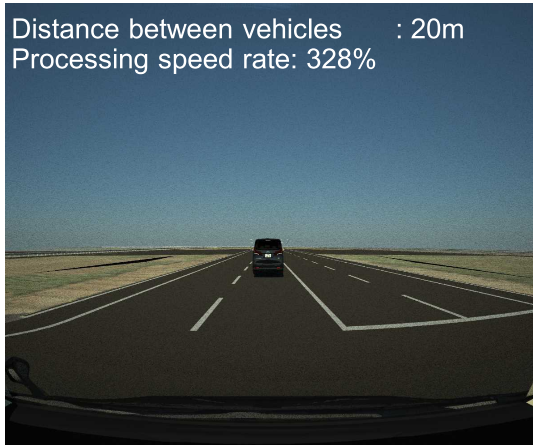




※1 It is possible to set thresholds/conditions such as number of polygons, direction of normal before and after reduction, preservation of holes/boundaries, priority of blunting angle, etc.







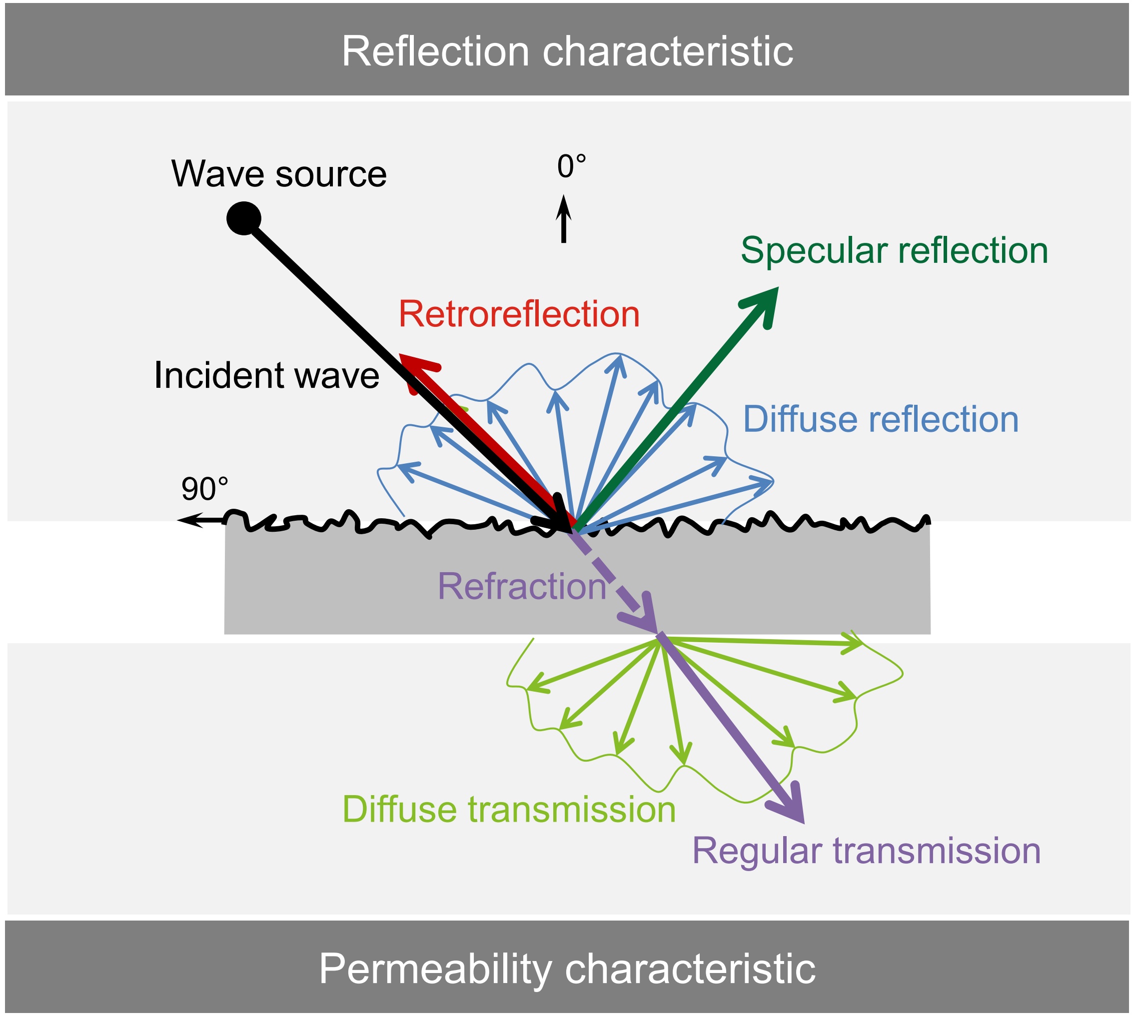
The amount was reduced by paying attention to information that is too detailed and does not affect the sensor, resulting in a high-speed simulation.

※The data is reduced to the extent that the difference cannot be recognized from the video.

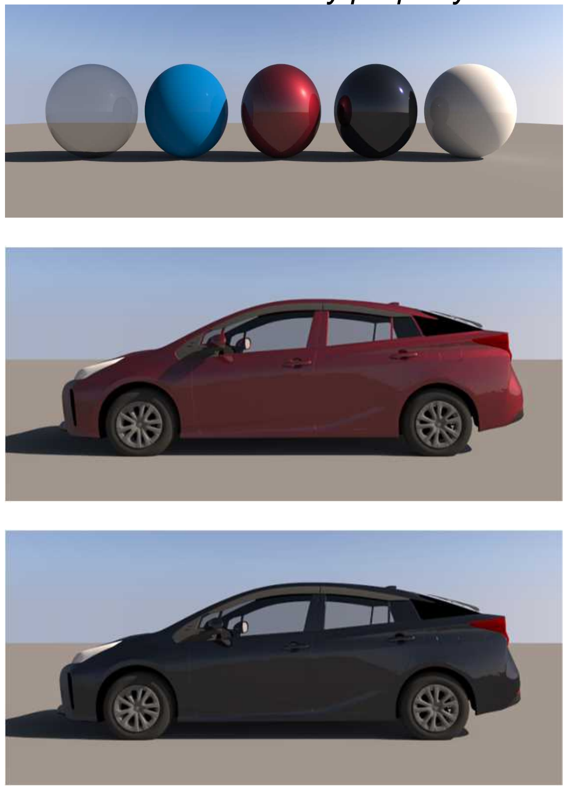
Reflective and transmission characteristics exist in material properties, and highly consistent reflection is reproduced by modeling based on experimental measurements

Reflection and transmission characteristics of the material

Nihon Unisys, Ltd SOKEN



For each model in the measurement characteristics
Can be set to any property.



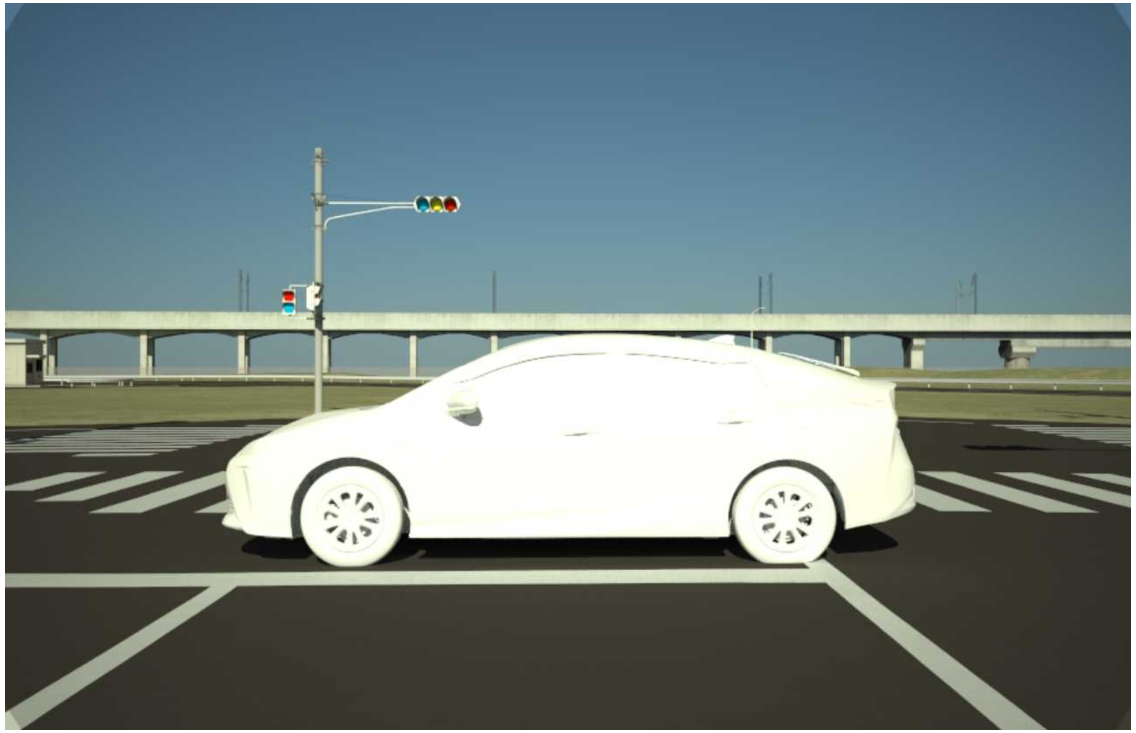
Source : SOKEN, INC, Nihon Unisys, Ltd

Application “Property” onto model surfaces realize precise objects in virtual environment

Properties to reproduce the delicate traffic environment

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

No Property	With Property
The result is flat with no color or texture.	The characteristics of the material are reproduced, and the strength and transparency of color and reflection can be reproduced.



Source : Copyright © CARLA Team 2019., MITSUBISHI PRECISION CO.,LTD.

Precisely reproducing the reflectance of visible light and the brightness of sunlight, and reproducing perception output of the camera close to the real environment

Spatial rendering of DIVP®

SOKEN Nihon Unisys, Ltd

DIVP®	Typical simulator (CARLA)
Precise environmental reproduction by sunlight and reflectivity of objects	Unrealistic spatial rendering with limited (RGB3 primaries) reflections

Source : Copyright © CARLA Team 2019.

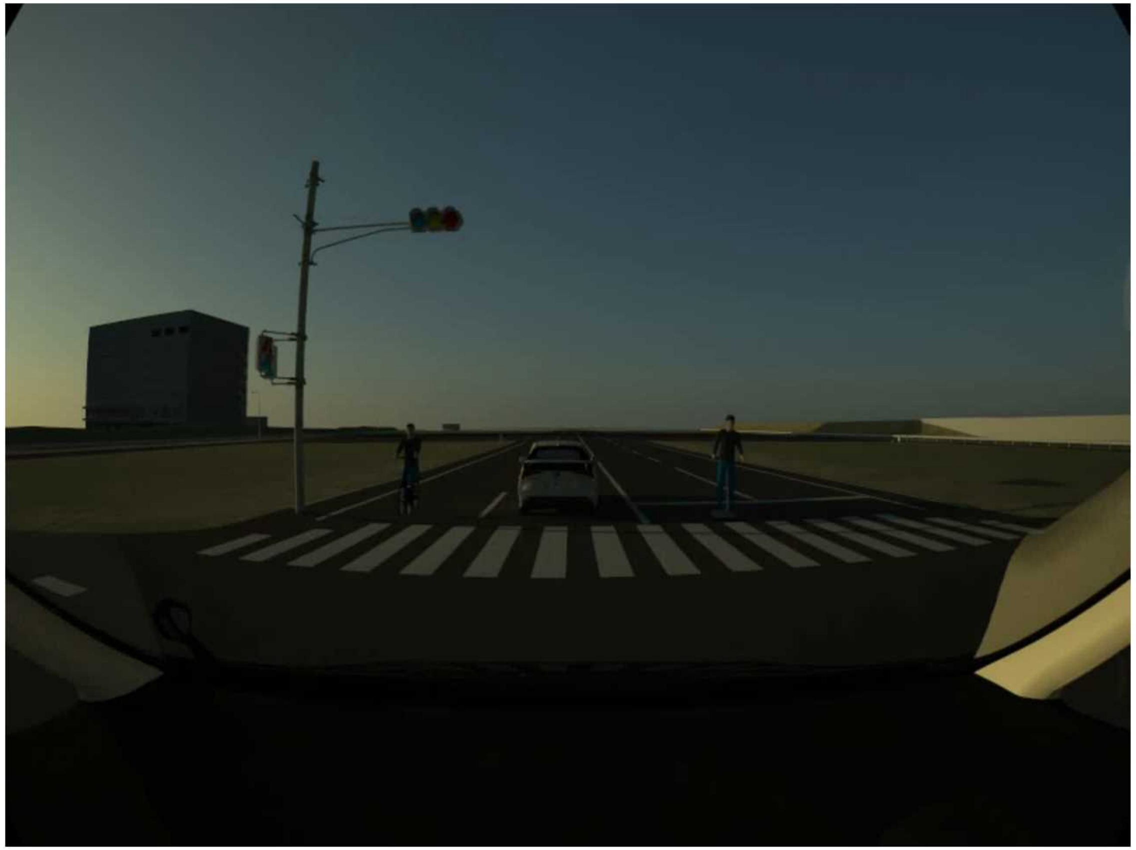
Simulating the actual movement of sunlight makes it possible to reproduce light equivalent to the actual environment

Sky light simulation

神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

Nihon Unisys, Ltd

From 07:00 to 17:00



Cloudy from 07:00 to 17:00

Source : Kanagawa Institute of technology

“Property" owned Environmental & Space design models

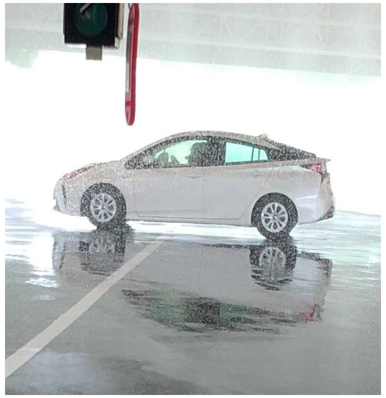
- Precise Environmental & Space design models
- **Sensing weakness domain modeling**
- Sensing weakness scenario analysis

To validate “Visible" & “Invisible", which are the essence of the AD safety verification, the scenario data of the sensing weakness scene is constructed

Example of sensing weakness condition

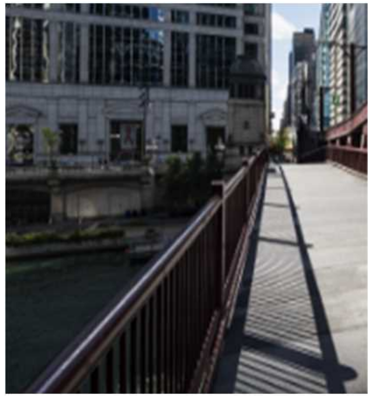
三菱プレシジョン株式会社
MITSUBISHI PRECISION CO., LTD.

Reflection of wet road surfaces



Disappearance of pedestrians due to facing lights

Multi-path by bridge pier structure



Multivehicle multipath

Attenuation of light and radio waves due to rainfall

Loss of objects due to backlight

False recognition due to high reflection paint

Underpass multipath

Motorcycles

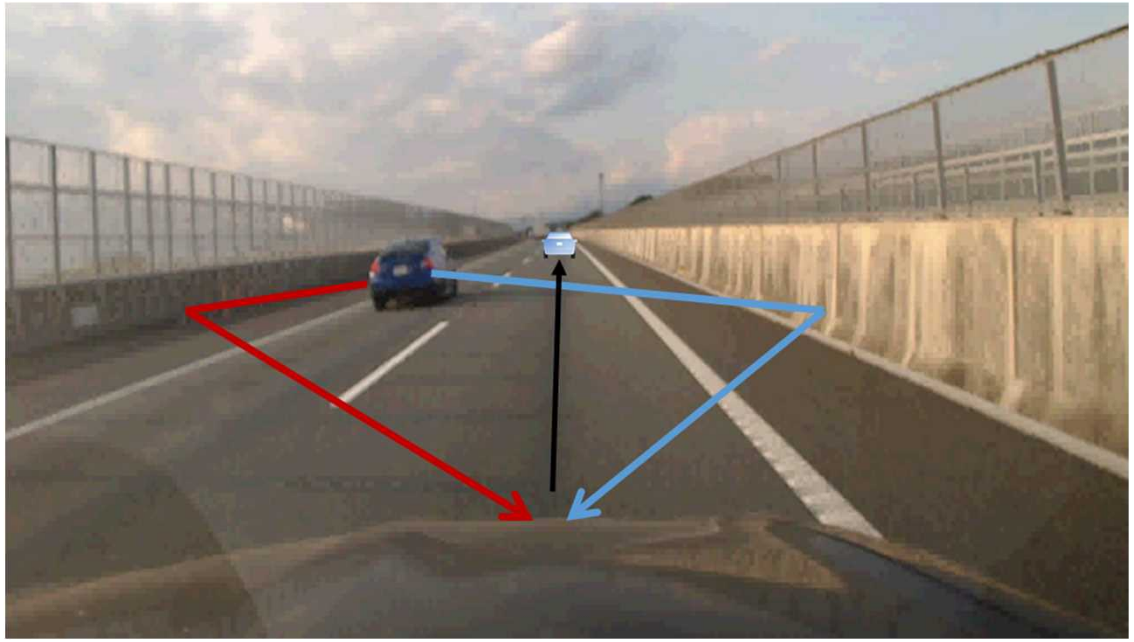
Source : SOKEN, INC

Radar recognizes objects by transmitting millimeter-waves and receiving reflections. Radar recognizes the problem of processing the reflection point because of the characteristics of millimeter-waves and low resolution. Radar contributes to research and development of these technical problems by reproducing precise phenomena in Sim.

Mechanism of the Radar slump

DENSO SOKEN

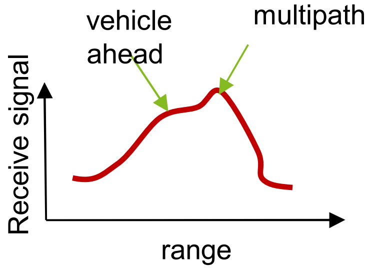
Multipath example 1 of Radar



- False recognition of the presence of the preceding vehicle due to multipath synthesis

Multipath case 2 of Radar

- The multi-pass signal of the construction pilot and the preceding vehicle signal cannot be separated and recognized, and the preceding vehicle is lost or mistakenly recognized as far away.

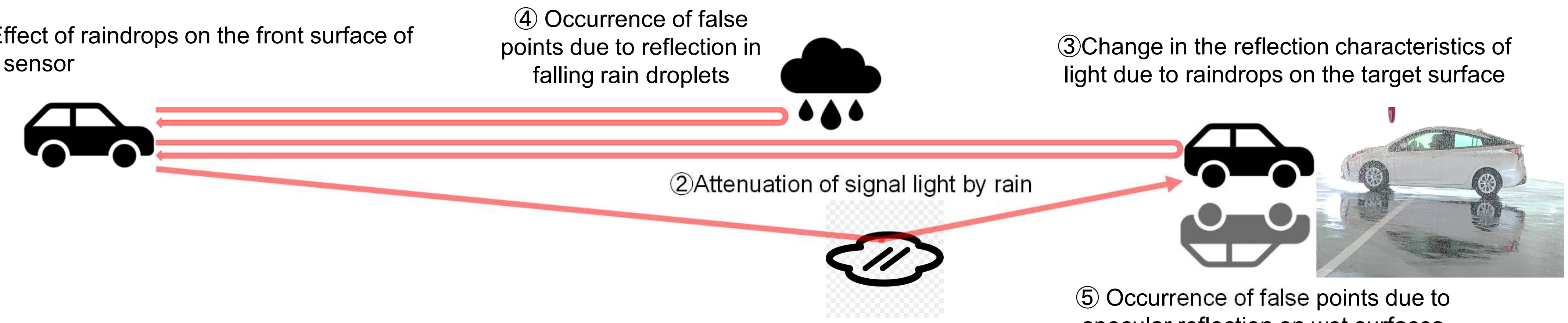


Source : SOKEN, INC

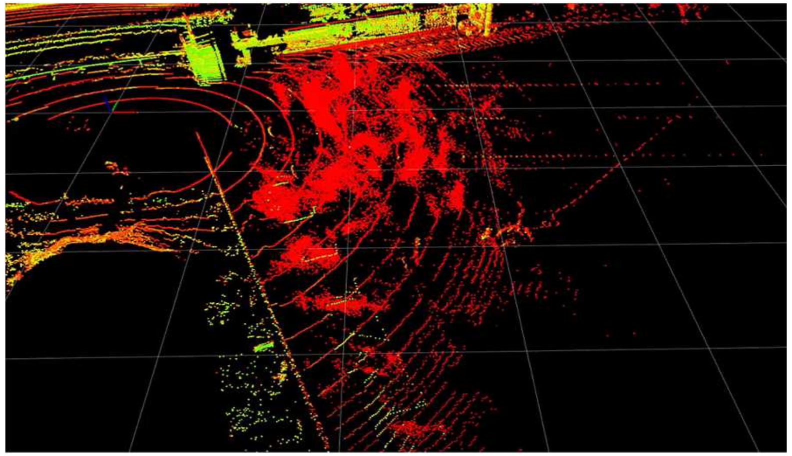
[Reproduction of Malfunction]
Impact of rain on LiDAR

Impact of rain on LiDAR

Pioneer



Measured point cloud data



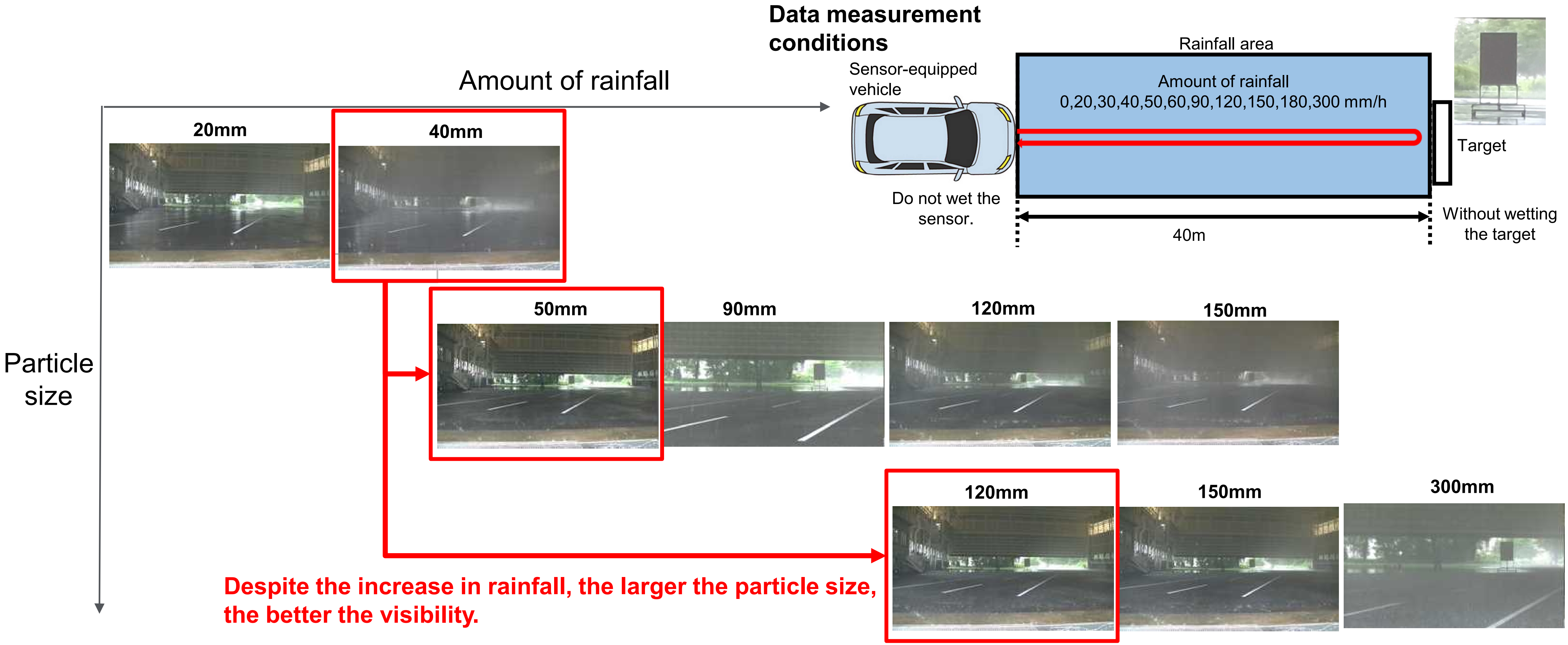
① Effect of raindrops on the front surface of the sensor : False Negative
②Attenuation of signal light due to rainfall:False Negative
③Change in the reflection characteristics of light due to raindrops on the target surface: False Negative
④Occurrence of false points due to reflection in falling rain droplets: False Positive
⑤Occurrence of false points due to specular reflection on wet surfaces : False positive

Source : Pioneer Smart Sensing Innovations Corporation. SOKEN, INC. Kanagawa Institute of Technology

[Reproduction of Malfunction] Investigate the signal intensity reflected at the target and the frequency of false points occurring in the space by changing amount of rainfall.

Understanding the phenomenon in rain experiment facilities

Pioneer

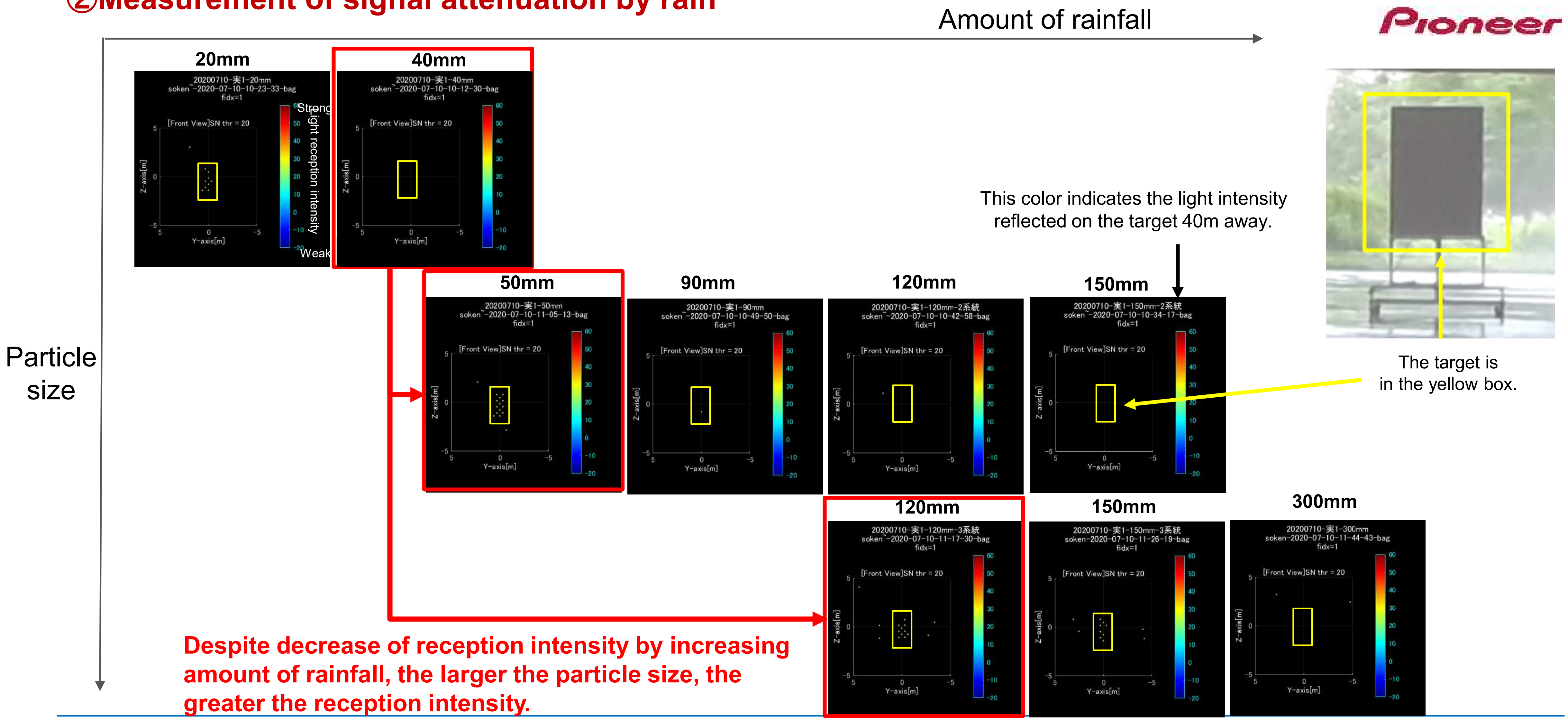


Despite the increase in rainfall, the larger the particle size, the better the visibility.

Source : Pioneer Smart Sensing Innovations Corporation. SOKEN, INC. Kanagawa Institute of Technology

[Reproduction of Malfunction]
Investigate the signal intensity reflected on the target by changing the amount of rainfall.

②Measurement of signal attenuation by rain



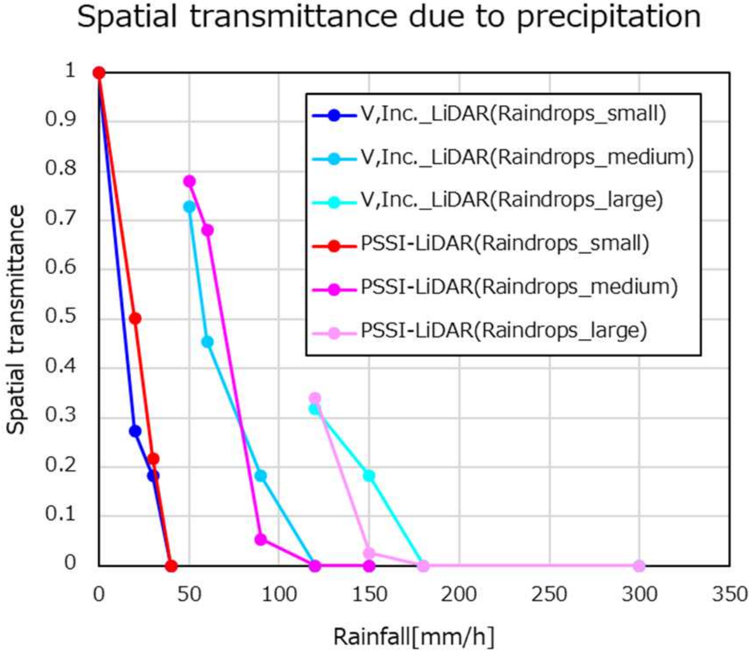
Despite decrease of reception intensity by increasing amount of rainfall, the larger the particle size, the greater the reception intensity.

Source : Pioneer Smart Sensing Innovations Corporation. SOKEN, INC. Kanagawa Institute of Technology

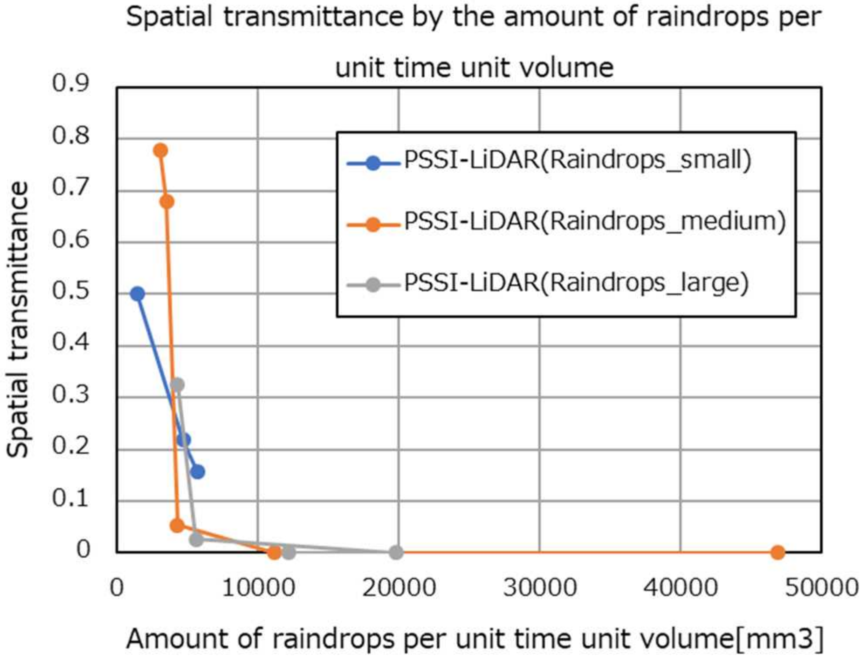
[Reproduction of Malfunction]
Modeling the signal light attenuation by rain.

Pioneer

Calculate the spatial attenuation rate of light from reflection intensity measured by LiDAR and the amount of rainfall



Statistical modeling of the relationship between the Raindroplet Space Density and the space transmittance rate of signal.



Calculate the amount of raindrops contained in unit time and unit volume (Raindroplet Space Density) based on the number of raindrops, particle velocity, and particle size measured by a distrometer.

Calculate the density of Raindroplet Space Density (D [mm3/m3]) from the flow velocity, particle size, and number of raindrops.

$$D = \frac{V}{S * t * v}$$

V:Volume of raindrops [m3]
S:Distrometer measured area [m2]
t:Measurement time [sec]
v:Particle velocity

Attenuation model of light due to rainfall in space

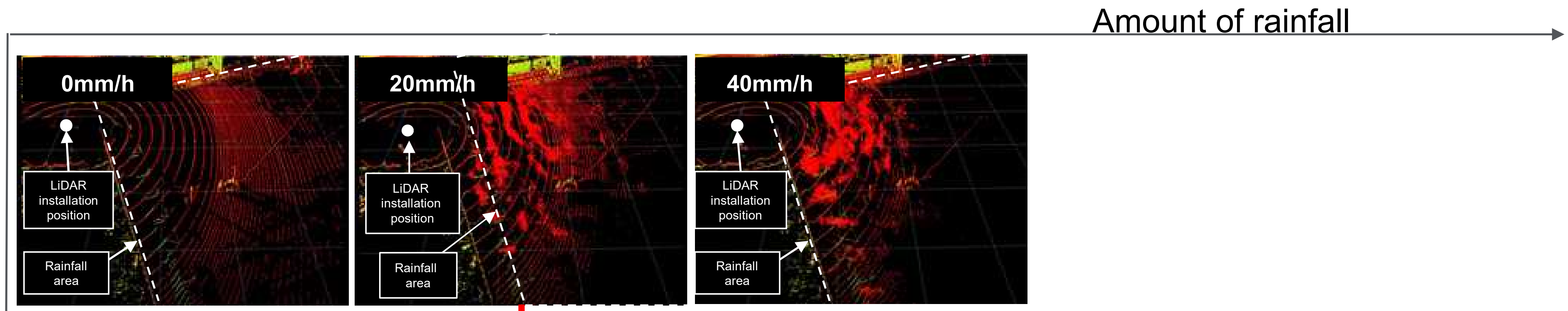
$$\rho = 10^{\left(\frac{-0.00003 * R * D}{10}\right)}$$

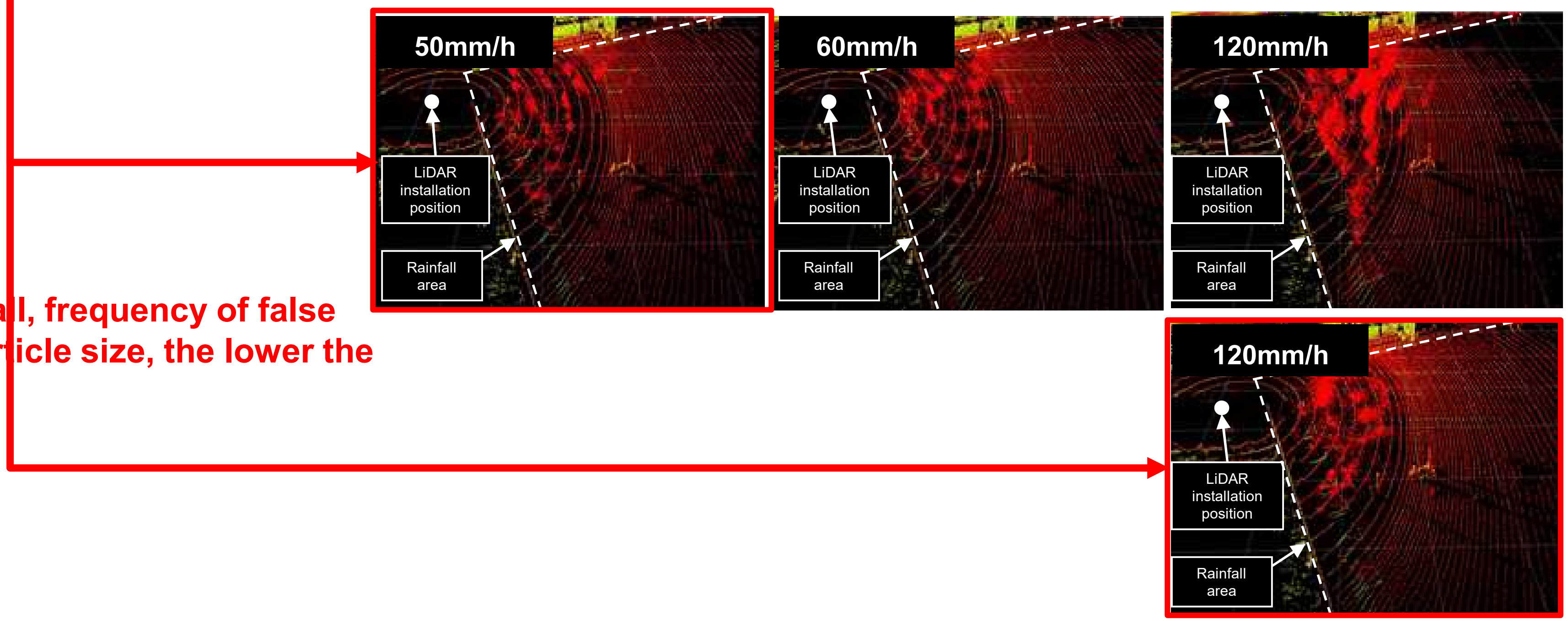
ρ: Spatial attenuation factor of received light intensity
R:Distance to the target
D:Raindrop space density

Source : Pioneer Smart Sensing Innovations Corporation. SOKEN, INC. Kanagawa Institute of Technology

[Reproduction of Malfunction]
④Occurrence of false points due to reflection in rain droplets

Investigate the trend of false points occurring in the space by changing the amount of rainfall





By increasing the amount of rainfall, frequency of false points increase. The larger the particle size, the lower the frequency of false points.

Particle size

Source : Pioneer Smart Sensing Innovations Corporation. SOKEN, INC. Kanagawa Institute of Technology

[Reproduction of Malfunction]
Consistency verification for pedestrian crossing scenarios at night

Result of NCAP doll crossing scenario (Jtown) under streetlight at night

Sony Semiconductor Solutions Corporation

Result of actual camera	Simulation result
	

- For the road surface and white lines, the signal levels of the simulation results are reproduced lower than the actual data.
- They are probably due to the accuracy of the streetlight and the ambient light. Give feedback to the environmental model part.

* * Display 8bit out of 24bit

Source : Sony Semiconductor Solutions Corporation, SOKEN, INC

“Property" owned Environmental & Space design models

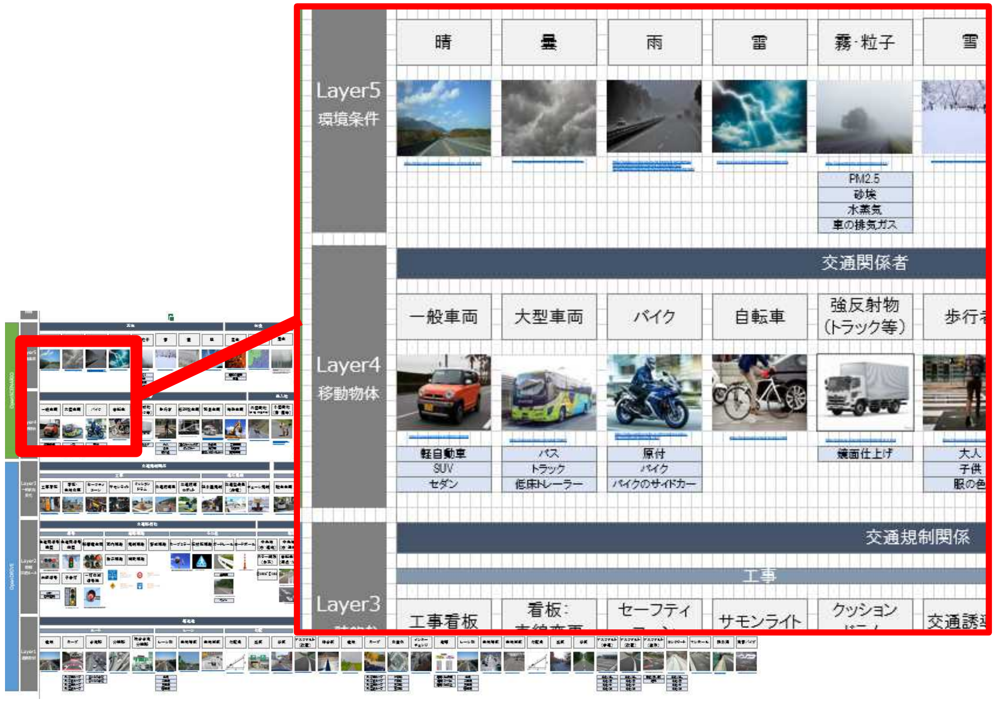
- Precise Environmental & Space design models
- Sensing weakness domain modeling
- Sensing weakness scenario analysis

Determine the weakness to be reproduced and the priority of the scenario using the FMEA approach after identifying factors that affect the occurrence of sensing weakness

Determination of priority reproduction scenarios of malfunctioning

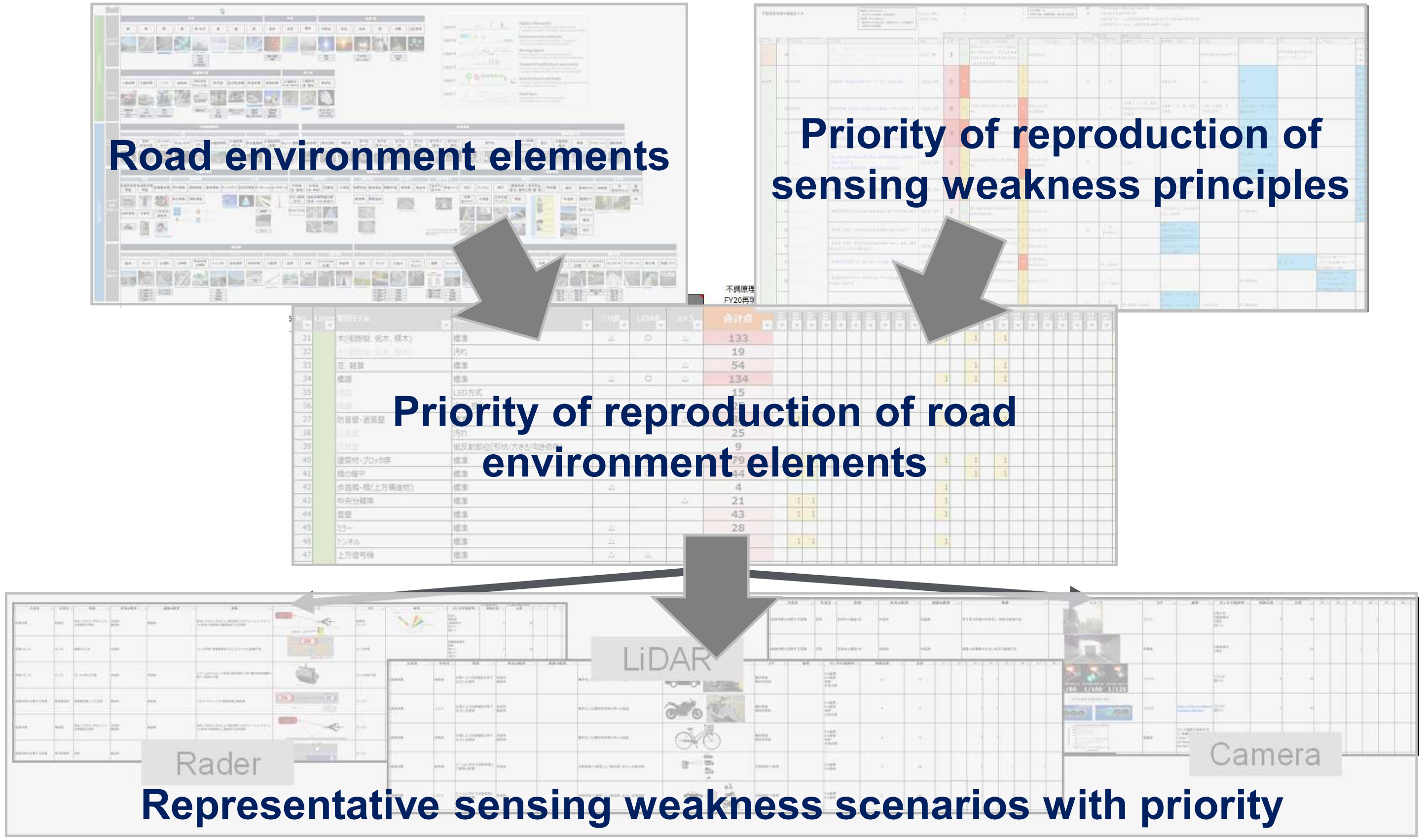
SOLIZE

① Identification of elements required for Japan's road environment



Based on the hierarchy of PEGASUS, we identified the elements of Japan's road environment, looked at scenarios and international cooperation.

② Determine sensing weakness scenarios for each sensor, which should be reproduces with priority. These scenario are based on estimation on the priority of the sensing weakness condition (see the next slide) and the result of ①.



Source : SOLIZE Corp.

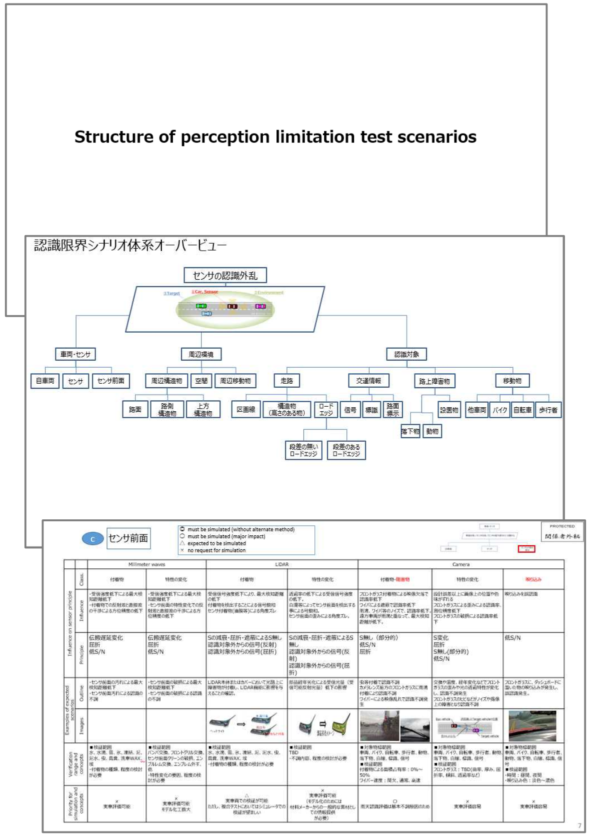
DIVP® is studying how to organize and reproduce the sensing weakness condition in cooperation with “Structure of perception limitation test scenarios” by JAMA

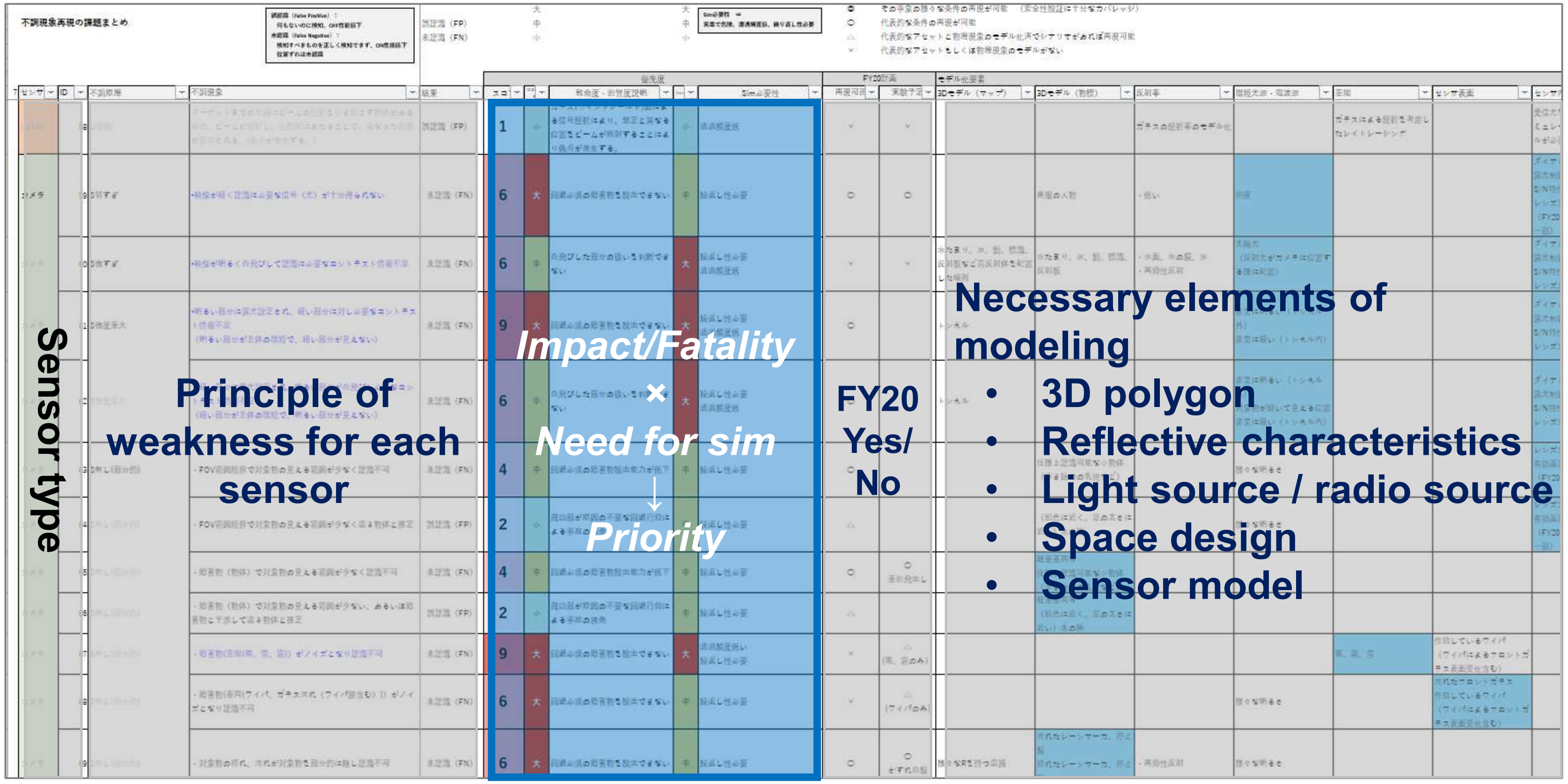
Arrangement of weakness principles that should be reproduced with DIVP®

SOLIZE

Structure of perception limitation test scenarios by JAMA ≅*FTA*

Examination of priority based on the degree of impact / fatality of each sensor and the necessity of simulation ≅*FMEA*





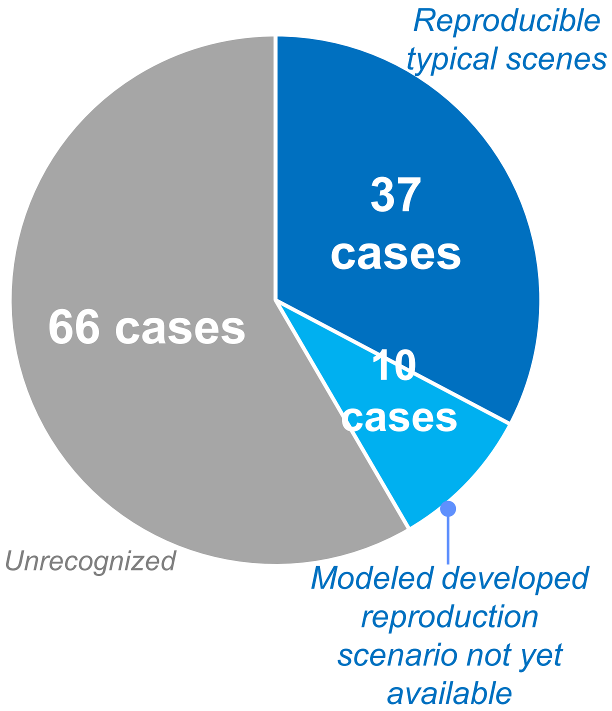
Source : JAMA white paper, SOLIZE Corp.

In FY20, 42% of the sensing weakness principle and 43% of the sensing weakness scenario can be reproduced.

Resurgence as of FY20

SOLIZE

Reproducibility of the sensor weakness principle



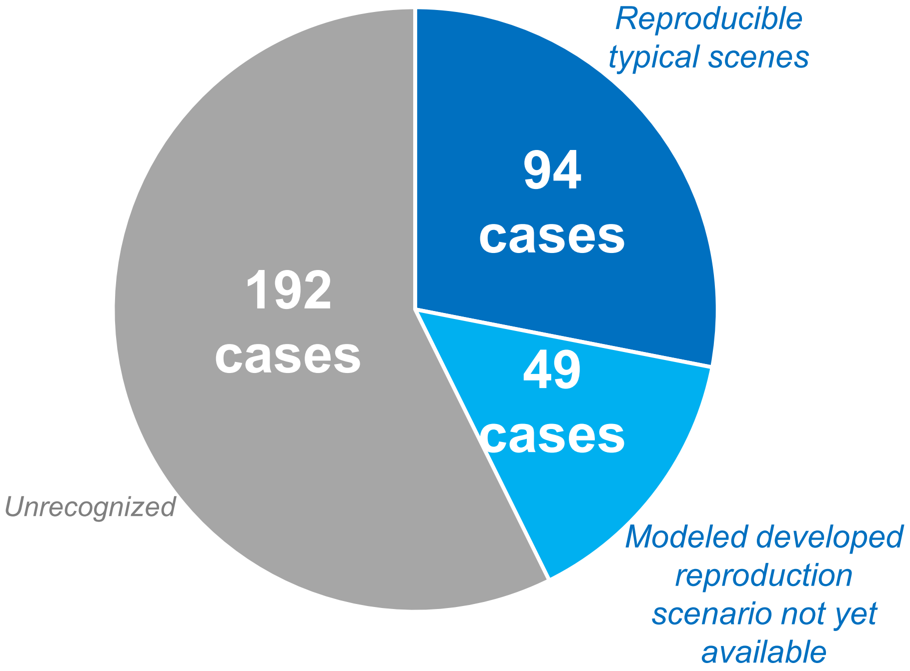
Reproducible
- **Camera: low contrast in darkness and marker color**
- **Radar: difficulty in separating ghosts from roadside walls, multi-object targets, etc.**
- **LiDAR: low-reflective, high-reflective, etc.**

	Reproducible	No scenario	Unrecognized	Total
Camera	11	7	37	55
Radar	14	3	13	30
LiDAR	12		16	28
Total	37	10	66	113

Remaining issues
- **Camera: flicker, flare, dirt, running water, etc.**
- **Radar: noise from obstacles in space, interference from other vehicle radar waves, etc.**
- **LiDAR: Transmission, specular reflection, interference with other vehicles' LiDAR lasers, etc.**

Planned to cover 42% of all weakness in FY20

Reproducibility of the sensor weakness scenario



143 (43%) of all 335 sensing weakness point scenarios are reproducible.

Source : Kanagawa Institute of Technology, SOLIZE Corp.

Investigate whether the methodology for comprehensive expansion and execution of driving condition scenarios can be applied to sensing weakness scenarios

Methodology for Expansion and Executing Driving Condition Scenario

We investigated whether the proposed methodology for comprehensive expansion and execution of driving condition scenarios can be applied to sensing weakness scenarios.

The target methodology is a method proposed by PEGASUS project. This methodology is a three-layered model which layers are functional scenarios, logical scenarios, and concrete scenarios. In this methodology, functional scenarios written in natural languages are converted into logical scenarios with parameter ranges, and finally logical scenarios are transformed into concrete scenarios which are executable in the simulator.

Concept image of PEGASUS scenario methodology

This methodology is a proposed method for comprehensive execution of driving scenarios by developing from abstract functional scenarios to concrete scenarios

Functional scenario	Logical scenario	Concrete scenario
Road network Maximum speed of 100 km/h, Curve of the vehicle road on one side of the three lanes	Roads. 3.5]m Curve radius [network] Lane width [2.3.0.6..0.9]m Signal position [0.200] m	Road network Lane width [3.2]m Curve radius [0.7] m Signal position [150]m
Stationary objects on the road	Stationary objects on the road	Stationary objects on the road
Animal bodies on the road Automobiles and traffic congestion Interaction: in a slow-moving traffic jam, your vehicle is moving to the middle lane.	Animal bodies on the road Length of traffic congestion [10.200]m Speed of traffic congestion [0.30] m Distance from vehicle [50,300]m Vehicle speed [80..130] m	Animal bodies on the road Length of traffic congestion [40] m Speed of traffic congestion [30]m Distance from vehicle [200]m Vehicle speed [100] m
Environment Summer and rain	Environment Temperature [10..40] m Rain particle diameter [20..100] m	Environment Temperature 20 m Rain particle diameter 100 m

Abstract "functional scenarios" written in a natural language ↔ **Appropriate parameter settings** ↔ **Feasible "concrete scenario"**

Source : SOLIZE Corp.

Investigate whether the methodology for comprehensive expansion and execution of driving condition scenarios can be applied to sensing weakness scenarios (cont.)

Trial to Apply the Scenario Expansion Methodology for Sensing Weakness Scenarios

SOLIZE

In order to explore the possibility to apply the methodology for sensing weakness scenarios, we developed a prototype of an ontology, terms and relations with them, and some syntax patterns for describing sensor malfunction scenarios.

	Functional				Logical	
Layer 1	道路	レイアウト	片側一車線道路		幅	[3.25m,3.5m]
			片側二車線道路		幅	
			片側一車線×片側一車線交差点		幅	
					なす角	
					半径	
		形状	直線		長さ	
			カーブ		曲線半径	
			平坦		勾配	[0%,1%]
			上り坂			
			下り坂			
		表面	アスファルト	均一		
				ひび割れ		
				穴（くぼみ）		
			コンクリート	均一		
				ひび割れ		
				穴（くぼみ）		
			実線		幅	
					色	
					残面積	

					時刻	
		服装	上半身	黒革	表面積	
			下半身	ジーンズ	表面積	
	vs他車	動作	先行			
			追従			
			追い越し			
Layer 5	環境	天候と時間帯	日中	晴れ	照度	[2000lux,∞)
					太陽高度	
					太陽方位角	
				曇り	照度	
				雨	降水量	(0mm,20mm)
				雪		
			夜間	晴れ	照度	
				曇り	照度	
				雨	降水量	(0mm,20mm)
				雪		
		気候	温暖		気温	[5℃,40℃]
		風	無風		風速	[0m/s,10m/s)
			強風		風速	
		光源				

Examples of ontologies for sensing weakness scenarios

センサ不調要因 からのアプローチ例

雨・急な上り坂・アスファルトのシナリオを作成したい場合

Layer 5	Layer 1	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4
雨の	片側一車線道路を	定速60km/hで	道なりに走る	他車を	定速55km/hで	道なりに走る	自車が	追従する。
	上り坂							
	アスファルト							
	均一							

指定されたセンサ不調要因について、単体で発生するものを加え、属性として発生するものを付与して作成

センサ不調原理 からのアプローチ例

マルチパスのシナリオを作成したい場合

Layer 2	Layer 1	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4
路側壁のある	片側一車線道路を	定速60km/hで	道なりに走る	他車を	定速55km/hで	道なりに走る	自車が	追従する。

Layer 1	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4
片側一車線道路を	定速60km/hで	道なりに走る	他車を	定速55km/hで	道なりに走る	自車が	追従する。
平坦							
アスファルト							
均一							

マルチパスを発生させるセンサ不調要因（単体/属性）をシナリオに加えて作成

センサ不調名称 からのアプローチ例

未検知のシナリオを作成したい場合

未検知を発生させるセンサ不調要因（単体/属性）をシナリオに加えて作成

逆光も同様

センサ不調要因 からのアプローチ

Layer 5	Layer 1	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4	Layer 4
日中・晴れ・逆光の	片側一車線道路を	定速60km/hで	道なりに走る	他車を	定速55km/hで	道なりに走る	自車が	追従する。

用語集・シナリオに登場する用語はすべて数値化される必要がある。

「逆光」はどのように数値化されるかが争点。

逆光になるタイミング（太陽の方位+自車の経路）と高度で定まる？

Examples of syntax patterns for sensing weakness scenarios

For sensing weakness scenario representation, more terms which are unnecessary for driving condition scenarios should be added consistently. Moreover, since one physical phenomenon which causes sensing weakness can affect many other phenomena, relationships between these phenomena should be expressed in the ontology. For example, “rain” affects wet road surface, wet sensor surface, puddles and splashes, etc.

Constructing an ontology containing these complex relationships needs correct understanding of the phenomena and many time-consuming tasks.

As the ontology becomes more complex, so does the scenario representation. The syntax pattens for it also become more complicated so that they tend to be difficult to function as syntax templates.

Source : SOLIZE Corp.

Implement a scenario expansion software in order to investigate whether the methodology for expansion and execution of scenarios can be applied to DIVP® platform

Implementing a prototype for scenario expansion

SOLIZE

We confirmed that scenarios written in natural language can be converted to executable scenarios with XML files simulating databases.

Example Functional Scenario Description (only Japanese)

夕方、雨の中を、ライトを点灯させて走行する自車の前を横切る歩行者に衝突しそうになる

Using natural language processing to extract asset information, operation, and environmental information described in a functional scenario.

driving condition database (Currently part of EURO NCAP and preferences)

Search the database of driving conditions for environment settings and driving routes that fit the extracted information.

Generate a specific scenario that covers the searched result

Extracted scenario information

Currently only in Japanese

Scenario execution (Execution with SDM Generator)

For supporting sensing weakness scenarios with this software, some information sources such as a database of parameters for sensing weakness phenomena would be needed.

Source : SOLIZE Corp.

Develop a convert program to convert real measurement data into executable scenarios for DIVP® platform, and convert and check all the scenarios

Develop a convert program and check all the result

SOLIZE

We developed a convert program which supports all types of measurement data measured in each verification phase, such as pre-verification, basic verification, sensor malfunction verification, and expandability verification.

IMU data

NCAP data

Other measurement data

Manual measurement data

Several correction depending on data collection method, data format, and , map information

DIVP® platform compatible scenarios

Source : SOLIZE Corp.

A prototype implementation of scenario development and generation tool is implemented This tool supports only a part of EURO NCAP based scenarios

Progress on Scenario Development function

SOLIZE

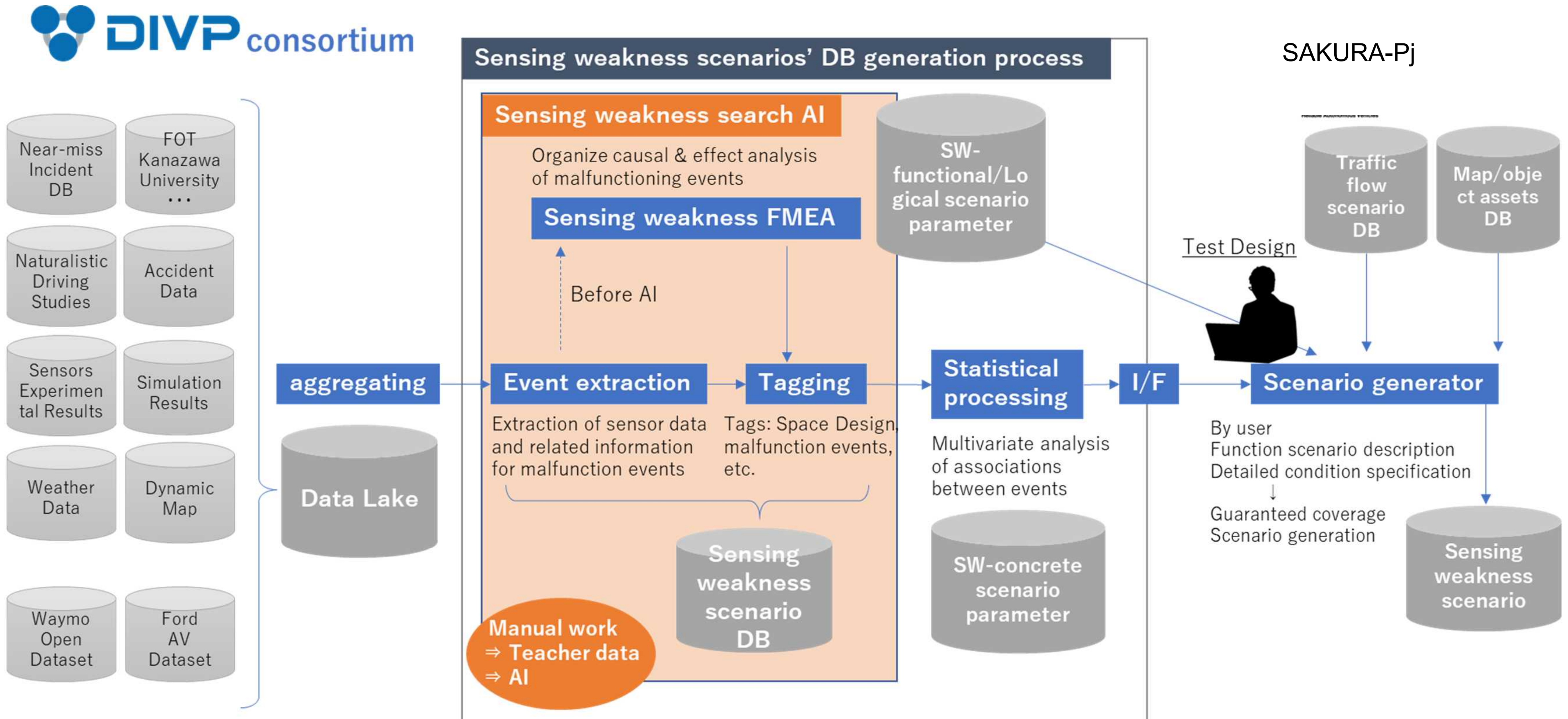
The scenario development function supports only a small part of EURO NCAP based scenario currently. And we need more effort to execute these scenarios on DIVP® platform

Action Item	Initial goal	Level of achievement
Requirement analysis on sensing weakness scenarios	List and prioritize sensing weakness scenarios and determine a validation method of scenarios	Completed on listing and prioritizing them, but more effort to determine a validation method is needed
Construction of a description method for sensor malfunction scenarios	Construct a method for prioritized scenarios	Completed on construction a method for a part of EURO NCAP scenarios without sensing weakness. More effort to describe sensor malfunction is needed, including radical change of the methodology
Implement a tool for generate sensing weakness scenarios	Implement a tool to convert measurement data into scenarios Implement a tool to develop prioritized scenario sensing weakness scenarios	Completed on implementation a tool to convert measurement data into scenarios Completed on construction a method for a part of EURO NCAP scenarios. More effort to describe more complex method is needed
Execute sensing weakness scenarios	Implement a binding tool between sensor generation tool and DIVP® platform	Completed implementing a tool with SDM generator. More effort to bind a scenario generator with DIVP® simulation platform

Source : SOLIZE Corp.

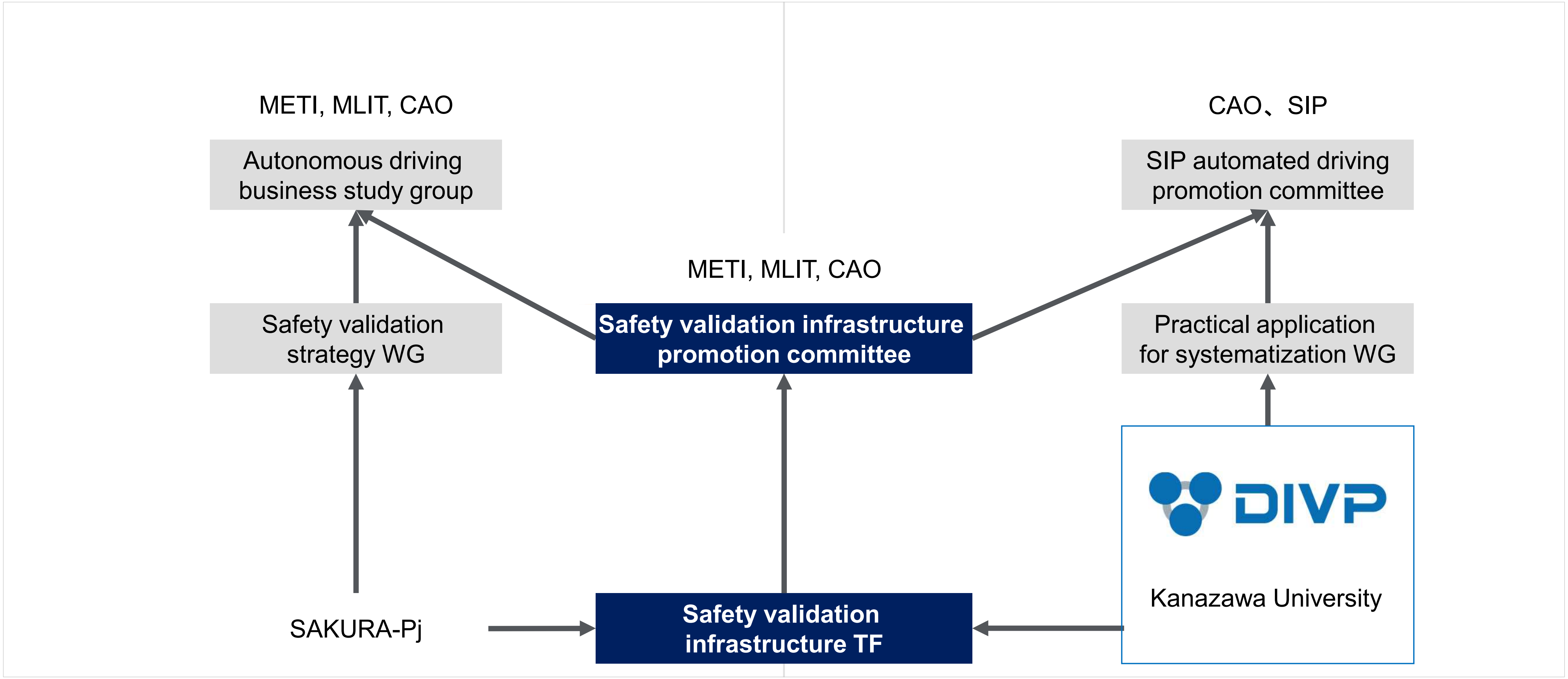
DIVP® promotes the construction of DB focusing on sensing weakness

DB generation process



Establish and deepen cooperation with other SIP projects and the SAKURA Project to review the safety validation infrastructure TF

Coordination system related to safety validation



Source : Excerpts from JAMA's document

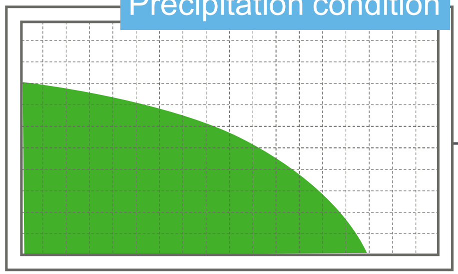
Construction of DB focusing on sensor weakness, and simulation based Validation combining traffic & recognition disturbance through collaboration with SAKURA-Pj

DB Collaboration（e.g. Precipitation & Cut-In Scenario Validation）

FY21 additional scope

Sensing weakness scenario DB

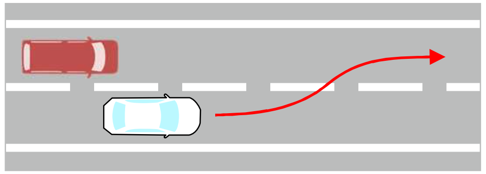
Precipitation condition



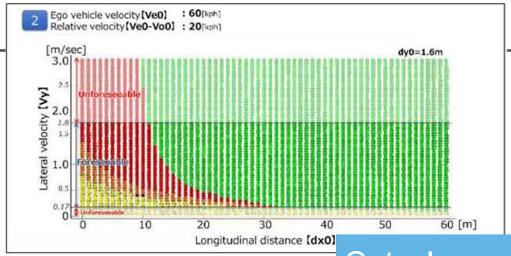
Recognition disturbance

SAKURA-Pj

Traffic flow scenario DB



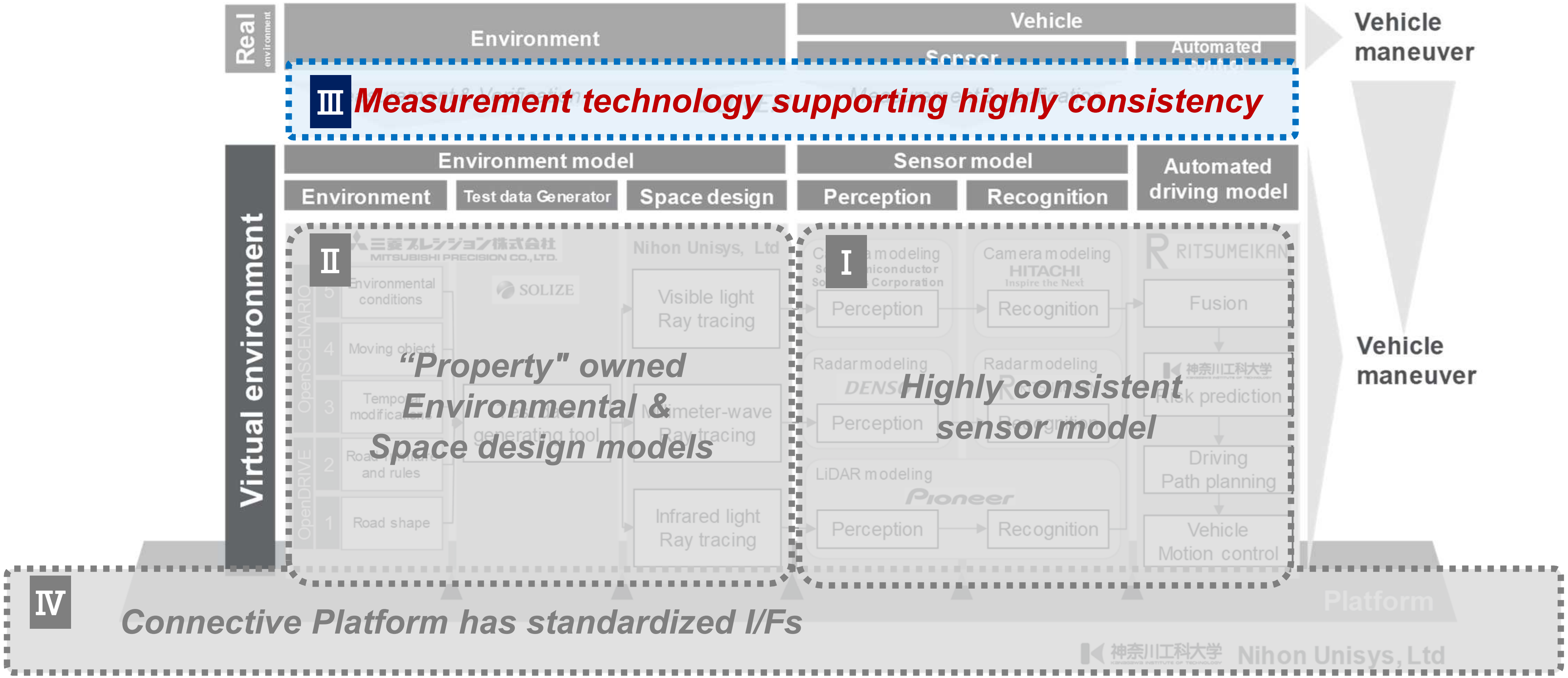
Traffic disturbance



Cut－In condition

Precipitation & Cut-In Scenario Validation (Simulation)

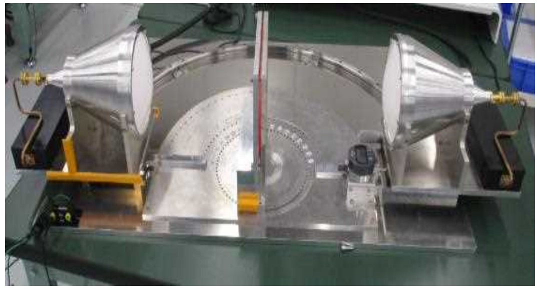
FY2020 outcome

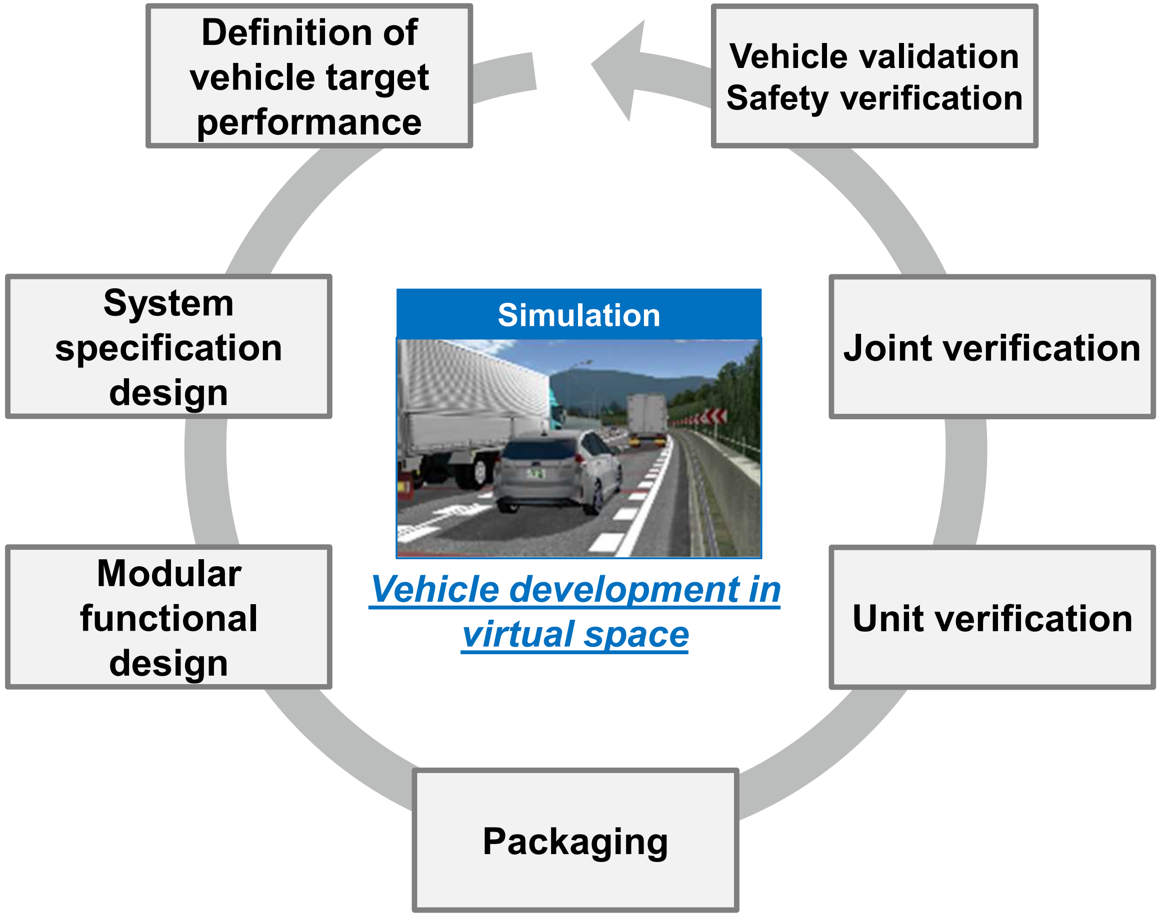


Process model generation through "modeling based on experimental measurement" and "model verification based on experimental validation"

Modeling process

Experimental measurement technology





Joint check & validation technology

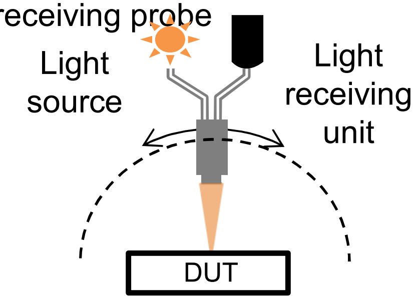
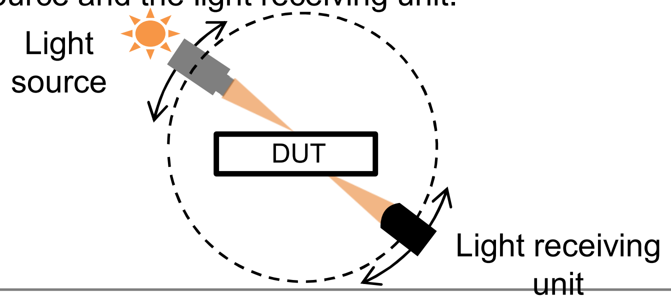
*1:API : Application Programing Interface.
Source : MITSUBISHI PRECISION CO.、LTD.、 SOKEN, INC

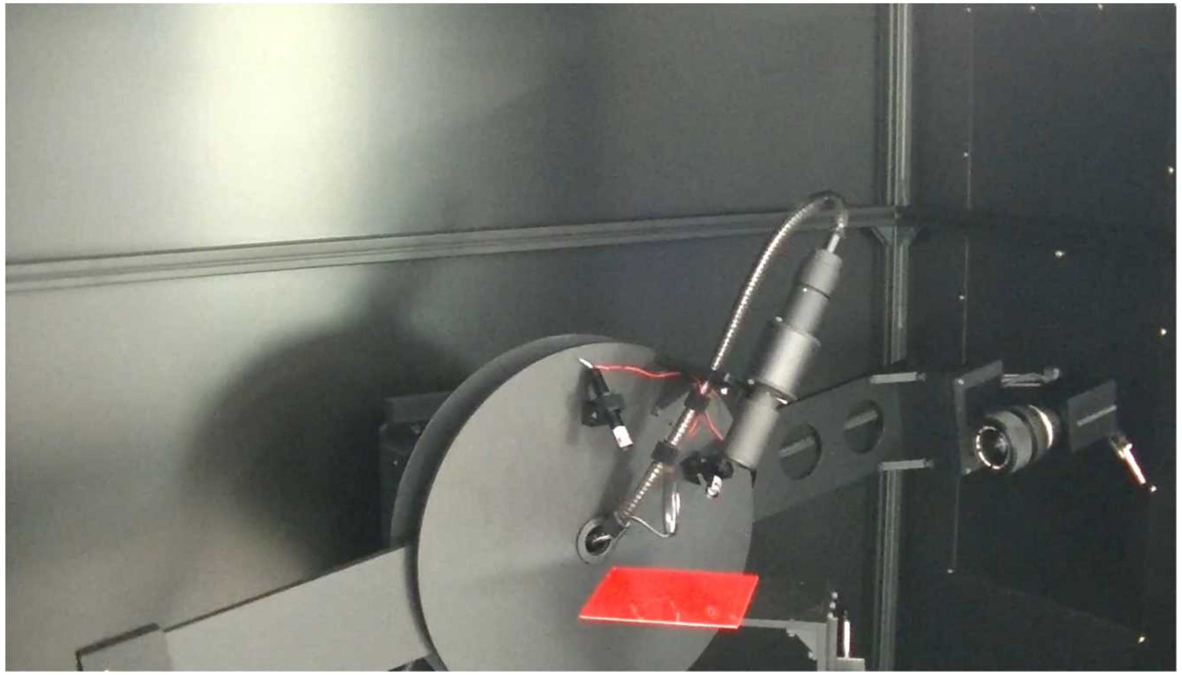
Each property model is guaranteed at a high level of realization and consistency by the advanced measurement technology of DIVP®

Measurement technology that guarantees a high level of consistency

SOKEN

System for measuring visible and infrared light

Measurement conditions		■ Measurement wavelength: 360-1000 nm ■ Measurement angle: 0 to 90 degrees for light source ■ 0° to ± 180° light reception ■ Light source/receiving angle > 10 degrees
Measurement method	Retroreflection	■ Direct measurement of retroreflection with integrated light source/light receiving probe 
	Diffuse reflection diffuse transmission	■ Measure diffuse reflection/transmission by rotating the light source and the light receiving unit. 



Source : SOKEN, INC

[Environmental Model Construction]
The measurement system was designed and manufactured on a trial basis, and measurement accuracy sufficient for verifying sensor consistency was achieved.

System for measuring visible and infrared light

SOKEN

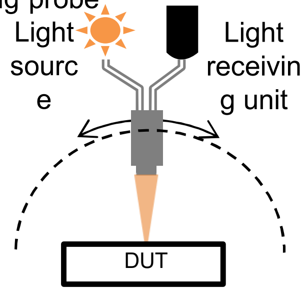
Measurement conditions

- Measurement wavelength: 360-1000 nm
- Measurement angle: 0 to 90 degrees for light source
- 0° to ± 180° light reception
- Light source/receiving angle > 10 degrees

Measurement method

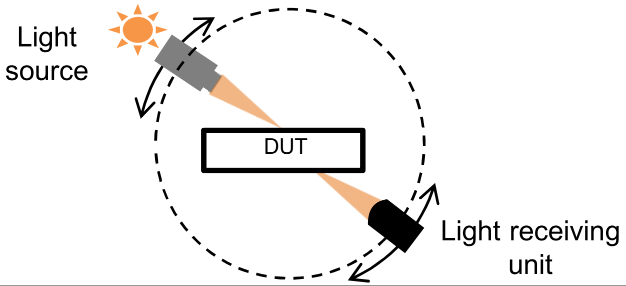
Retroreflection

- Direct measurement of retroreflection with integrated light source/light receiving probe

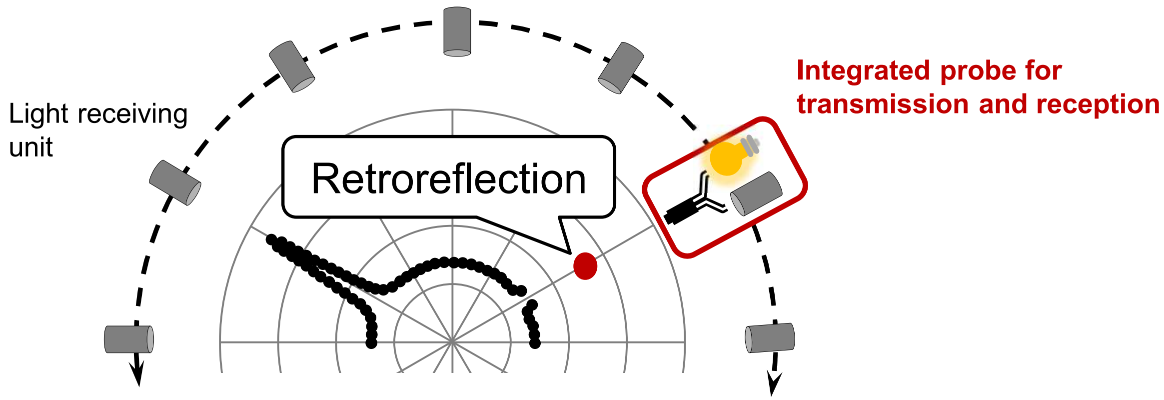


Diffuse reflection diffuse transmission

- Measure diffuse reflection/transmission by rotating the light source and the light receiving unit.

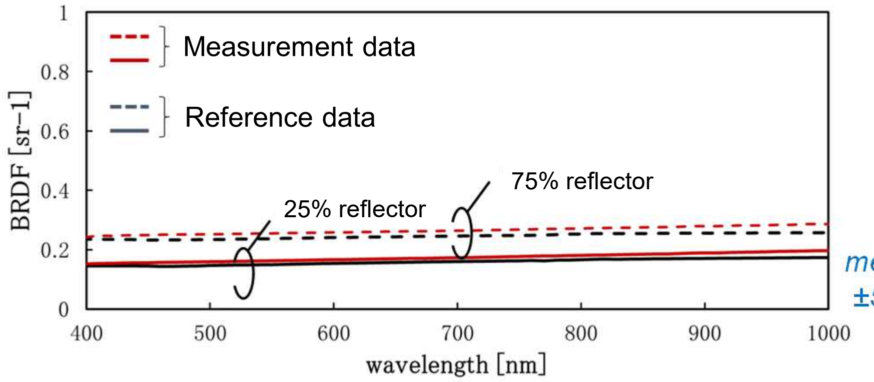


Angular characteristic measurement result image



Retrograde reflection, which was difficult to measure by the integrated transmission/reception probe, was measured.

Measurement results



Error of ±5% or less from baseline data

LiDAR required measurement accuracy of ±5% or less on reflection characteristics

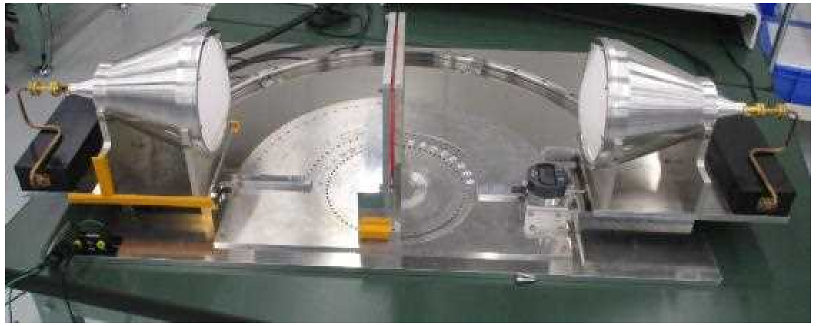
Source : SOKEN, INC

Achieves highly consistent environment modeling with reflection characteristics by experimental measurement compared with the conventional theoretical formula Sim.

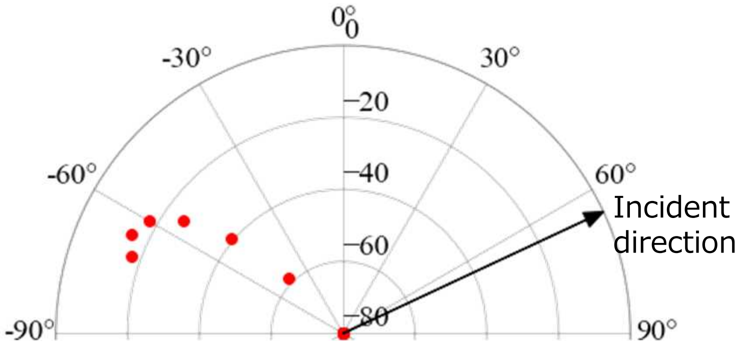
Efforts to create radar reflectance data

SOKEN

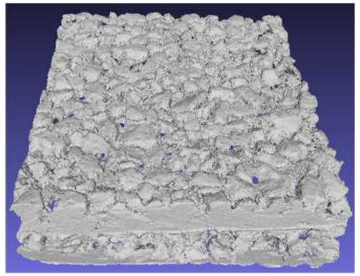
Experimental characteristic measurement



Reflection characteristic measurement

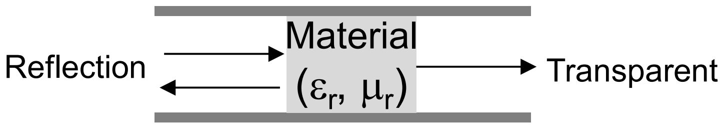


Interpolation processing of the theoretical formulas based on measurement results

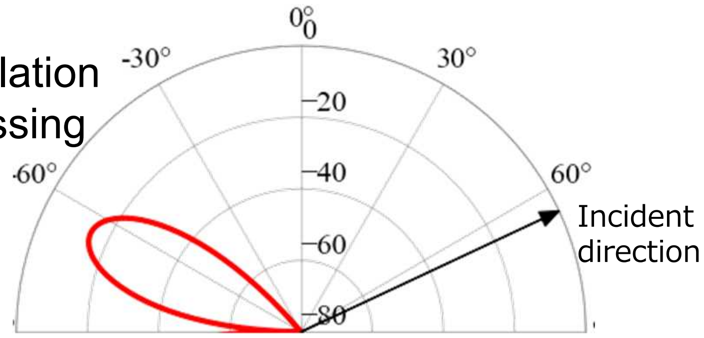


Surface roughness measurement

Transmission model



Interpolation processing



Measure surface and material characteristics as well as material reflection characteristics
Create reflection data for interpolation processing of the theoretical formulas

Source : SOKEN, INC

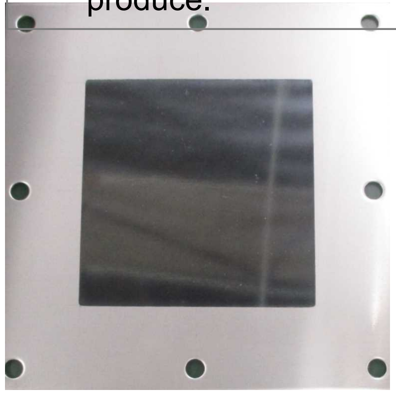
Manufacturing, measurement, and visualization technologies to "make invisible objects visible" play an important role

Measurement technology supporting DIVP®?

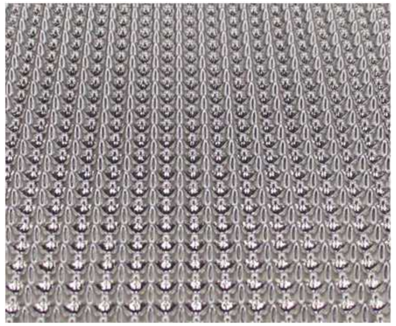
SOKEN

Manufacturing technology

- We have the world's highest level of precision processing skills and facilities, enabling us to produce original measuring instruments and test samples that other companies cannot produce.



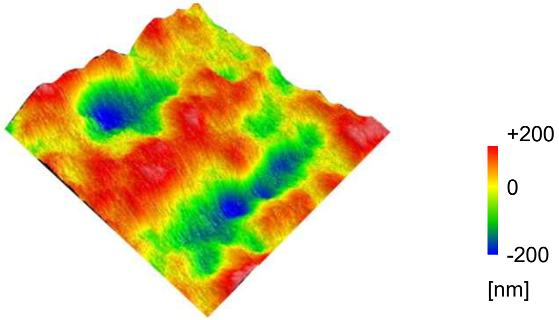
Surface treatment in nm



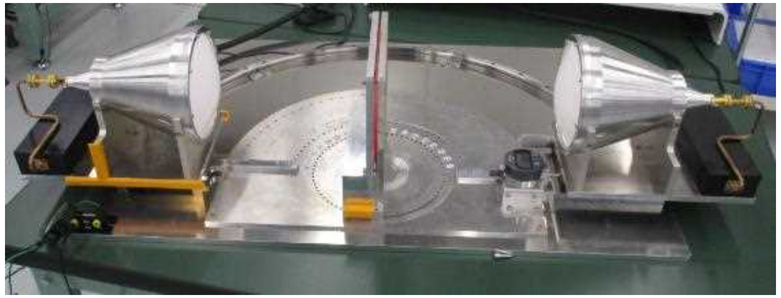
3D printer + plating process
Surface roughness sample for Radar

Measurement/visualization technology

- With high-precision measurement technology and original measurement equipment/sensors, it is possible to measure items that other companies cannot measure.



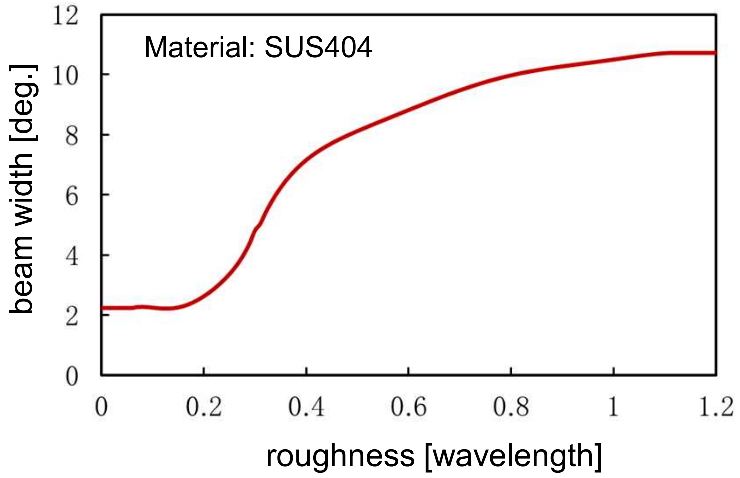
Surface roughness measurement in nm



Measurement of dielectric constant and magnetic permeability by free space method

Analysis and discovery

- Multifaceted analysis of measurement results to discover new knowledge and relevance not previously available



Example) Relationship between surface roughness and reflected beam width

measured the material reflection characteristics at each sensor wavelength (visible light region, infrared light region, millimeter wave band) to verify the simulation and measurement results.

Measured materials

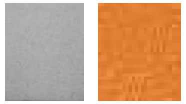
SOKEN

Road surfaces

Asphalt (permeable, non-permeable, Infrared reflective)
Concrete

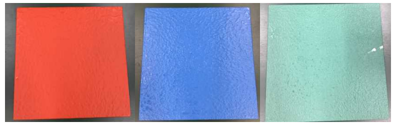
Road marking materials

White line, Orange line



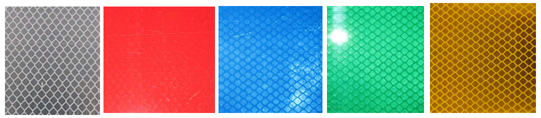
Road painting

Red, Blue, Green



Road sign (retroreflective)

White
Red
Blue
Yellow
Green



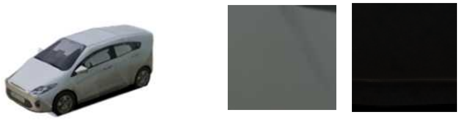
Delineator

White reflector
Orange reflector

NCAP Dummy

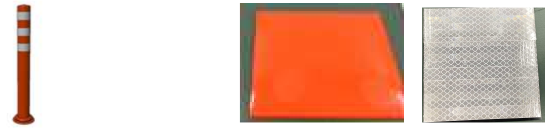
Black
Beige
Blue

Body part
Radio wave absorber



Road pole

Red resin
Reflector

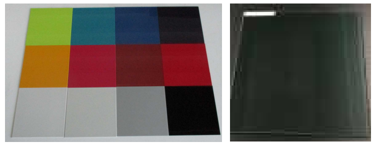


Road pylon

Red resin
Reflector

Vehicle parts

Painting (representative color)
Glass



Source : SOKEN, INC

Constructed an experimental vehicle for high-precision data measurement for verification of consistency of simulation from NCAP/ALKS validation

Measurement Technology Supporting DIVP® (Experimental Vehicles)

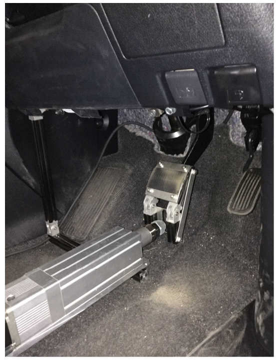
SOKEN

NCAP study

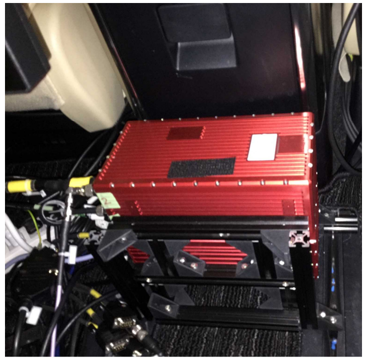
Measurement vehicle

sensing weakness simulation experiment on public roads

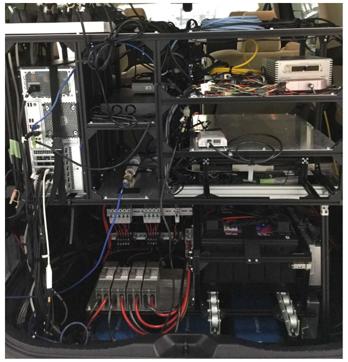
Asset enabled business experiments using vehicle dummies (GSTs)



Automatic brake control robot



High-precision GNSS vehicle inertial device IMU



Hi-speed, large-capacity measurement system

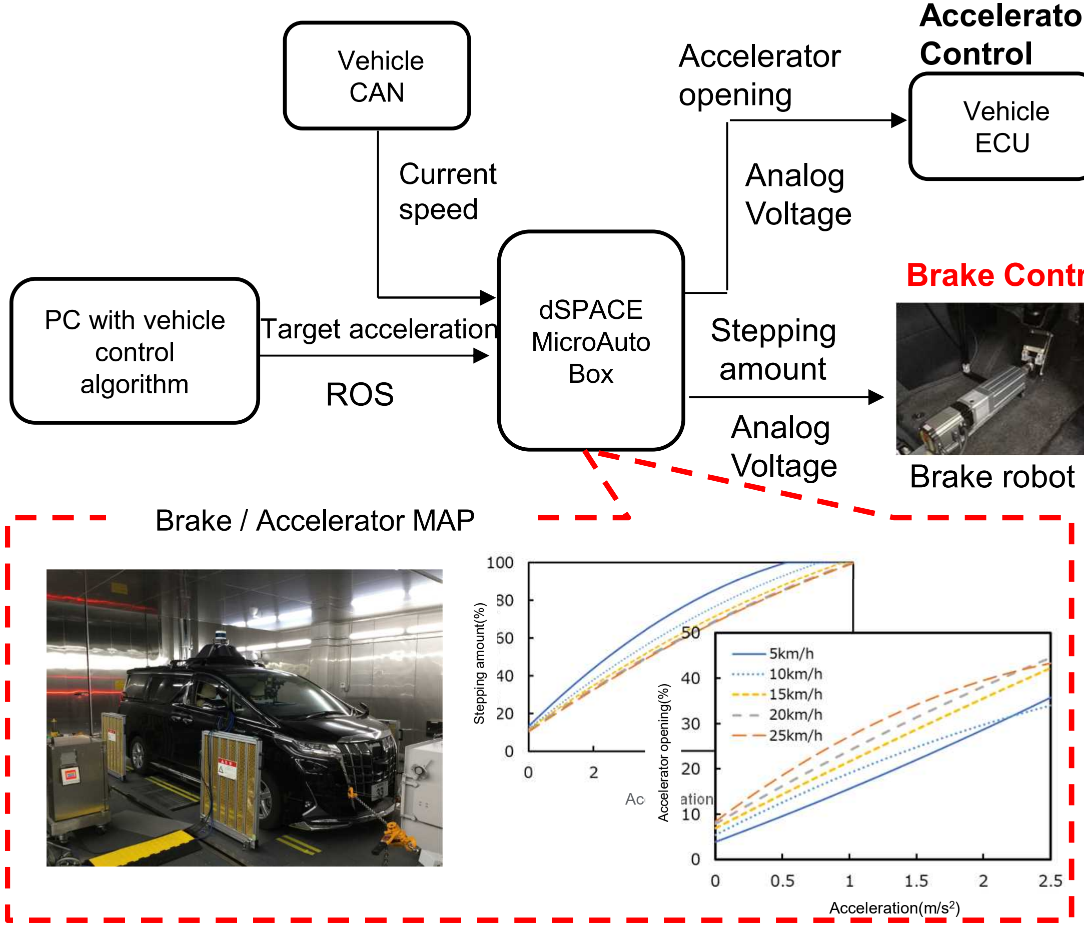
Sensor vehicle-mounted technology for vehicle inspection

Source : SOKEN, INC

Realized an automatic brake control system that can respond to actual emergency braking operating conditions and has a structure that is easy to install in a vehicle.

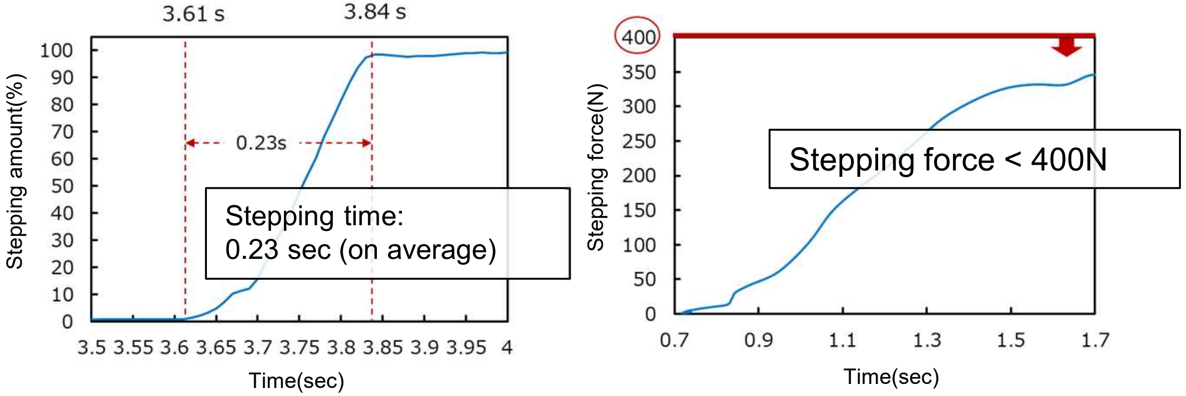
Measurement Technology Supporting DIVP® (Autonomous Brake control system)

SOKEN

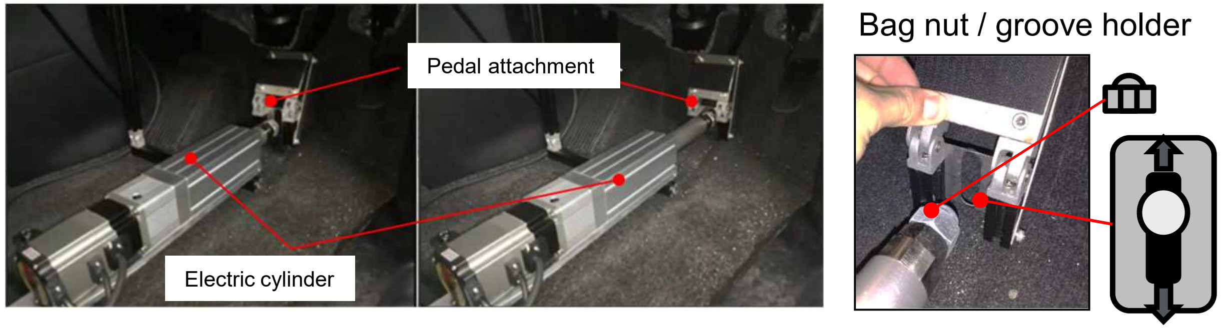


Configuration of automatic brake control system

Brake robot unit to reproduce the actual driver's movement

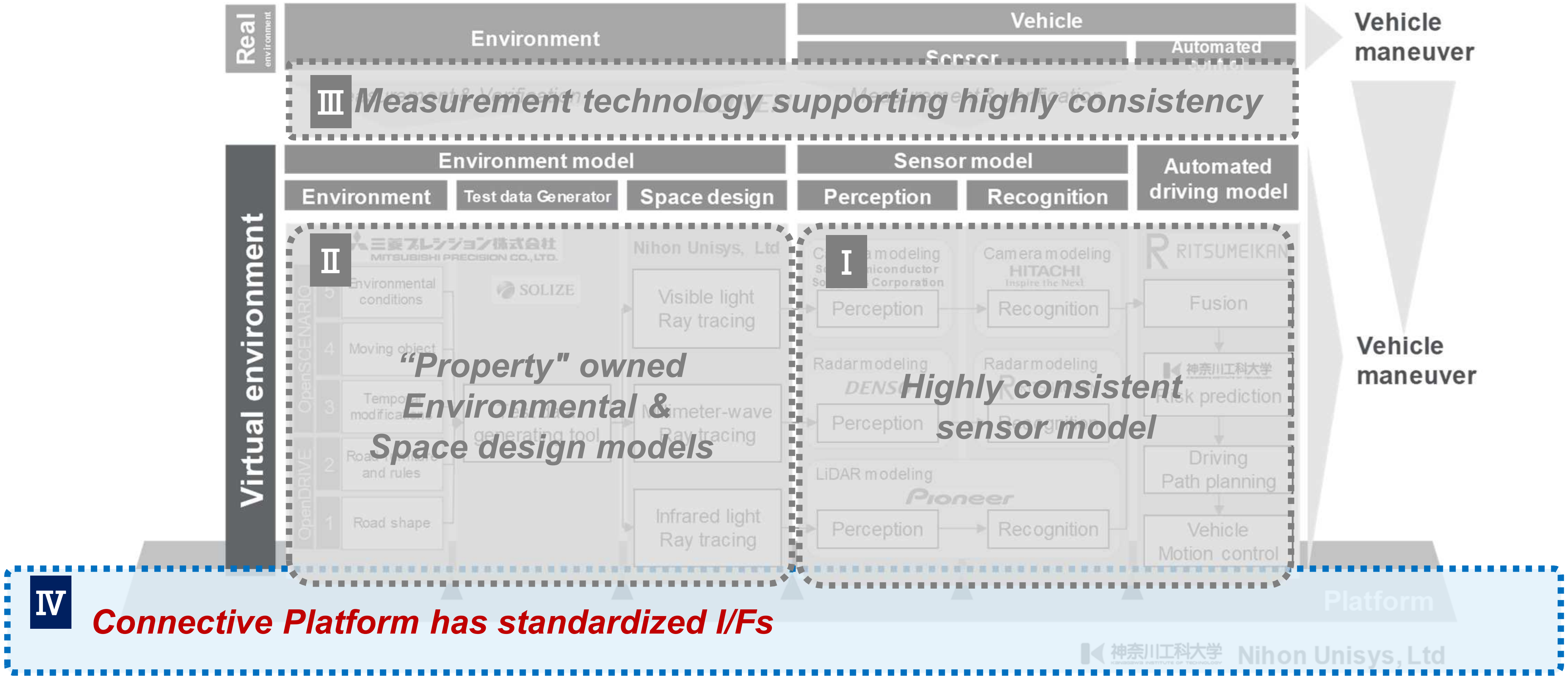


Relationship between human brake depression time and depression amount



(a) When stepping on (b) Normal Pedal attachment

FY2020 outcome



Simulation PF up to V0.7 has been released, specifications are written for detailed specifications, and knowledge is accumulated

DIVP® Status of Function Extension (Join Validation Status)

神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

Ver	Contents of the release	Environment model	Sensor model	Automatic operation model
V0.1	PF for integration validation (1st edition)	■ MAP JTown reproduction	■ Combine all sensor (Camera, Radar, LiDAR) based models	■ -
V0.2	Pre-verification PF	■ Adding assets ✓ Alphard	■ Adoption of CUDA (distance/speed FFT) for the Radar sensor model	■ Construction of a reference automatic operation model using a positive resolution sensor
V0.3	Basic verification PF	■ Reproduction of MAP JTOWn (10cm increments) ■ Reproduced sky light clouds and slight clouds. ■ Adding assets ✓ NCAP pedestrian/bicycle dummy ✓ Addition of parts to Alphard interior (windshields, mirrors, etc.)	■ Addition of functions ✓ Changing Camera space drawing to IMX490 equivalent ✓ Addition of Optix library model for LiDAR spatial drawing ✓ Radar space drawing changed to PO approximation model	■ Combine Camera/Radar/LiDAR recognition model
V0.4	-	■ Unify the scenario coordinate system into the right hand system.	■ Updating of LiDAR spatial drawing (e.g., vehicle position interpolation)	■ External vehicle model coordination function added (with CarMaker)
V0.5	NCAP, ALKS Verification PF	■ JARI Specific Environment Test Site Reproduction ■ Atmospheric light: September 12, 2020, light cloudy, light cloudy added ■ Adding assets ✓ GST (NCAP dummy vehicle), ✓ NCAP dummy vehicle balloon ✓ Alphard Black (for targets and obstacles)	■ Sony camera IMX490 model operable (The model must be provided by SSS.)	■ Construction of an automatic operation model environment including recognition models
V0.6	Sensing weakness validation release	■ Adding assets ✓ Alpha (light source) ✓ Prius (light source, black) ✓ NCAP dummy (black leather) ✓ Manholes and corrugated cardboard ✓ NCAP street lights at night	■ PSSI LiDAR model can be operated. (The model must be provided by PSSI.)	■ -
V0.7	Tokyo Metropolitan Highlands C1/Odaiba Scalability Assessment Release	■ Map Metropolitan Higher C1/Odaiba Reproduction ■ Atmospheric light, light clouds, sunny November 25, 2020 Weather, slightly cloudy, and cloudy on December 23, 2020	■ Addition of specular component to LiDAR reflectance	■ -

※For details of each model (environmental model/sensor model/automatic operation model), refer to the specifications of each company.

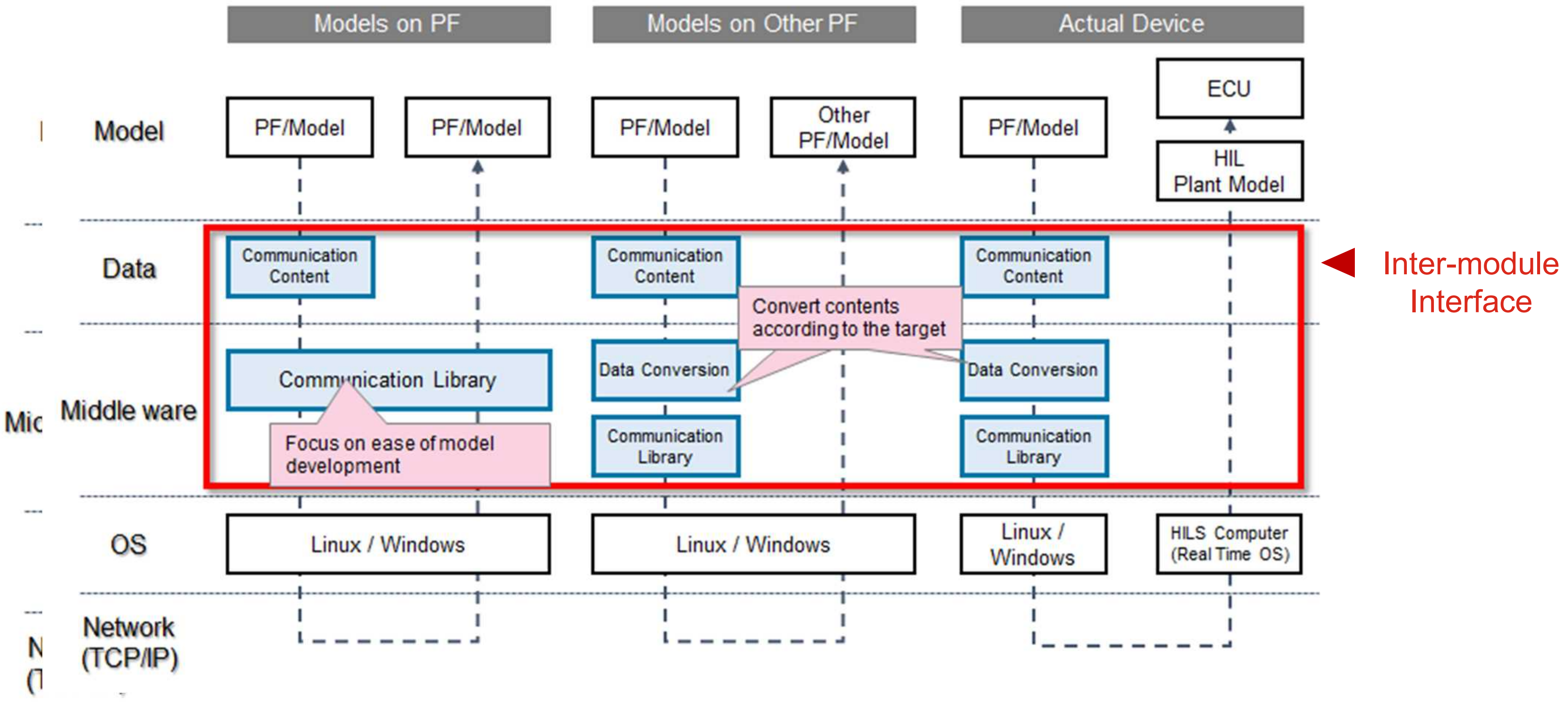
Connective Platform has standardized I/Fs

- Standard I/F study
- Comprehensive validation method study

Considering the compatibility and scalability of future elemental technology advances and the expansion of the use of simulated PF

Examination of specifications for inter-module interfaces that ensure scalability between various verification and validation environments

Nihon Unisys, Ltd



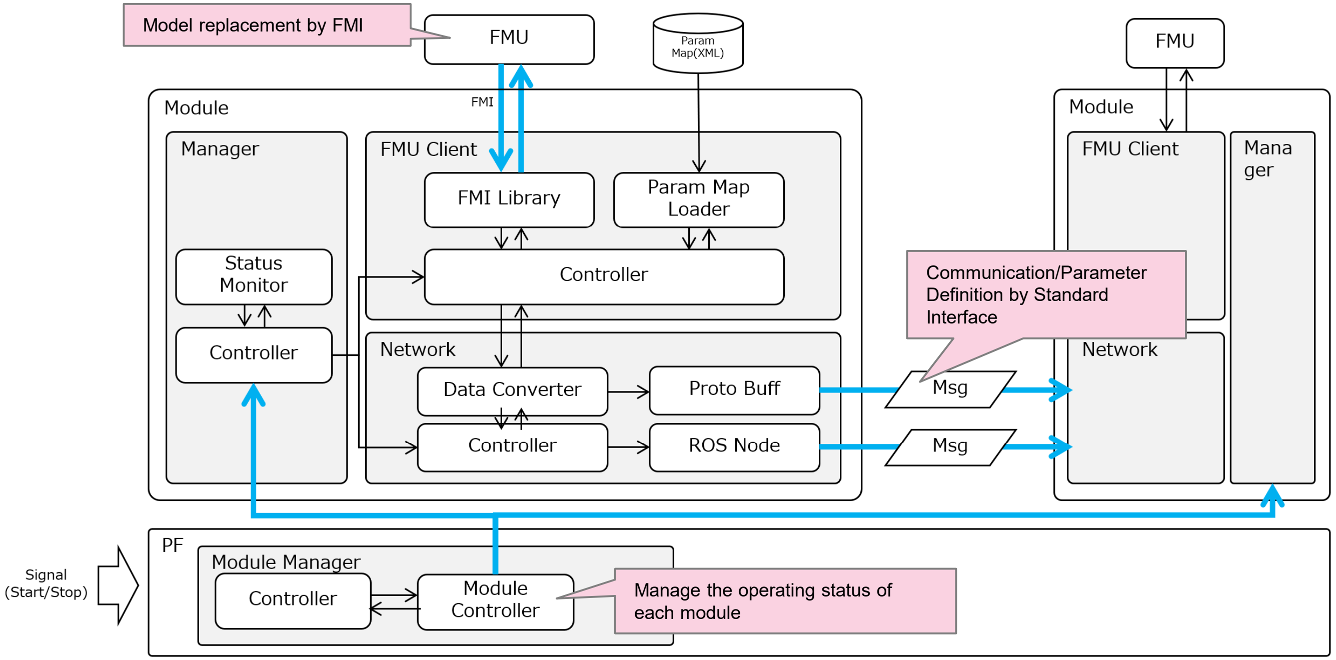
Creation of prototypes for communication/control between modules in consideration of specifications for inter-module interface

Prototype of the inter-module interface

Nihon Unisys, Ltd

Requirements for inter-module interface

- The model can be replaced independently of the simulation PF.
- Input/output parameters can be defined in a format independent of the simulation PF or communication method.
- Must be able to connect to modules distributed among multiple computers or modules on other systems via the network.
- When communicating with modules on other systems, communication from modules on the simulation PF should be possible without being aware of the difference.
- Operation status of each module shall be controlled (abnormal detection, vitality monitoring, start/stop).



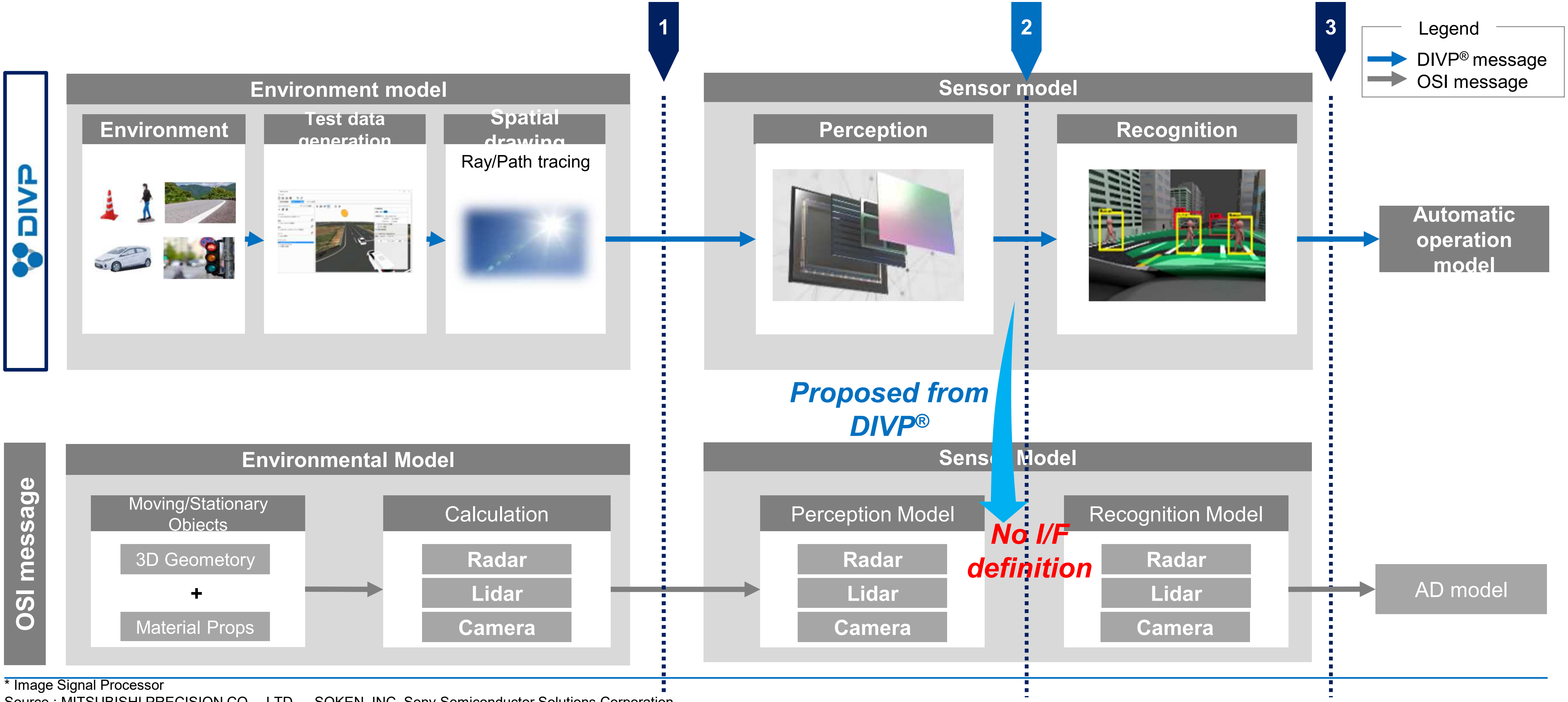
※Prototype schematic

Based on the knowledge gained in prototyping, the new module replacement mechanism will be reflected in future PF simulation development.

Through international collaboration projects with Germany's VIVALDI, and ASAM and proposed an interface specification for AD safety validation focusing on sensors

Activities for International Standardization of IFs

Nihon Unisys, Ltd



* Image Signal Processor

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

Connective Platform has standardized I/Fs

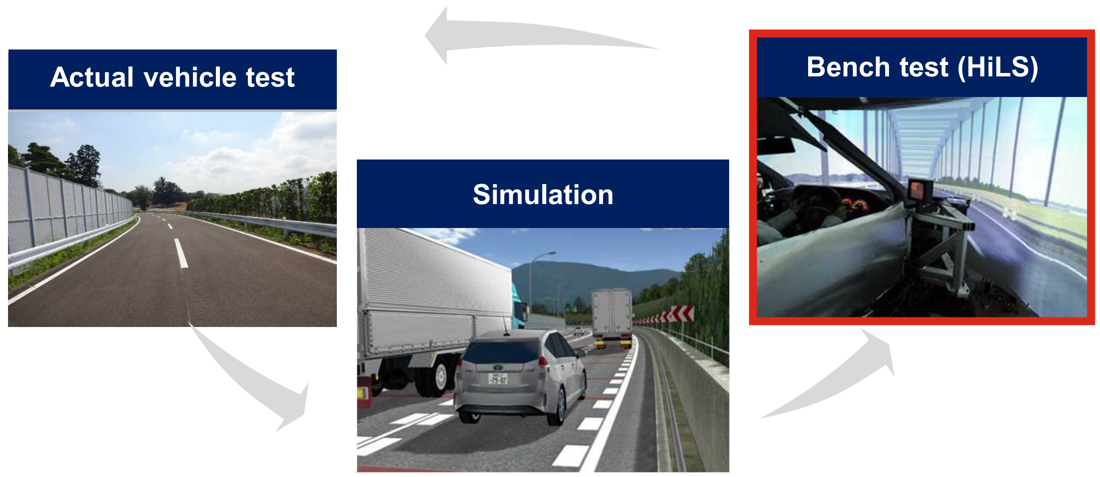
- Standard I/F study
- Comprehensive validation method study

Construct HiLS using injection technology for future black box validations, and study validation possibilities

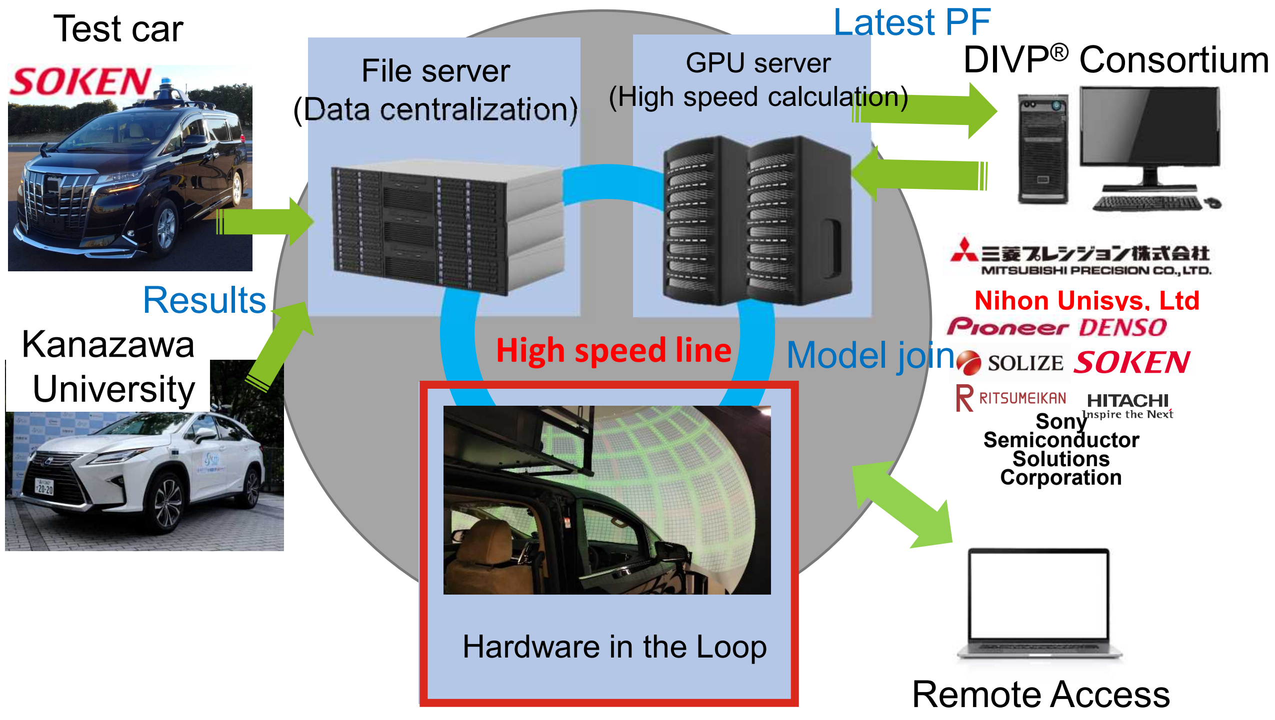
Camera HiLS Construction

神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

Automated Drive(AD)



DIVP® Project Overview

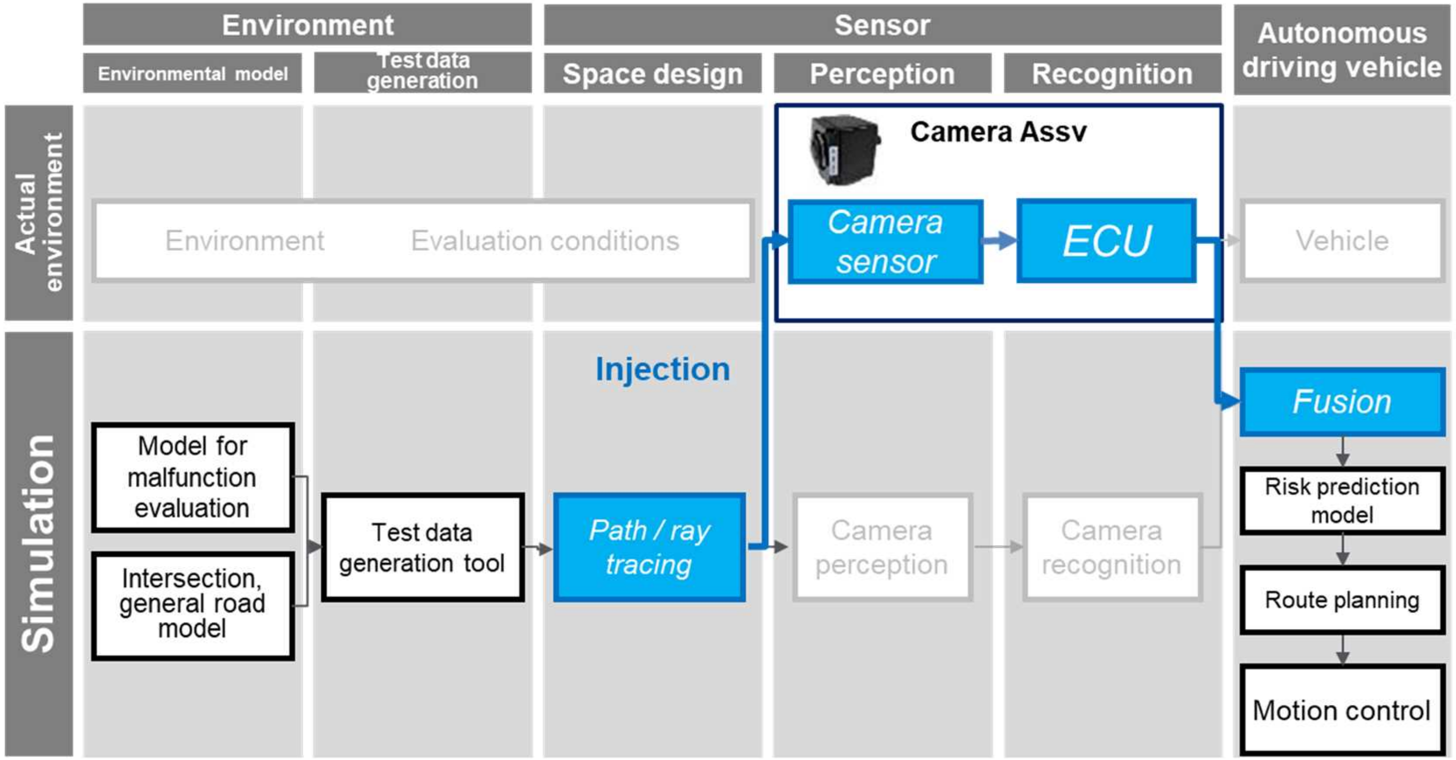


*HiLS ; Hardware in the loop Simulation
Source : MITSUBISHI PRECISION CO.,LTD., Kanagawa Institute of Technology,
DIVP® Consortium

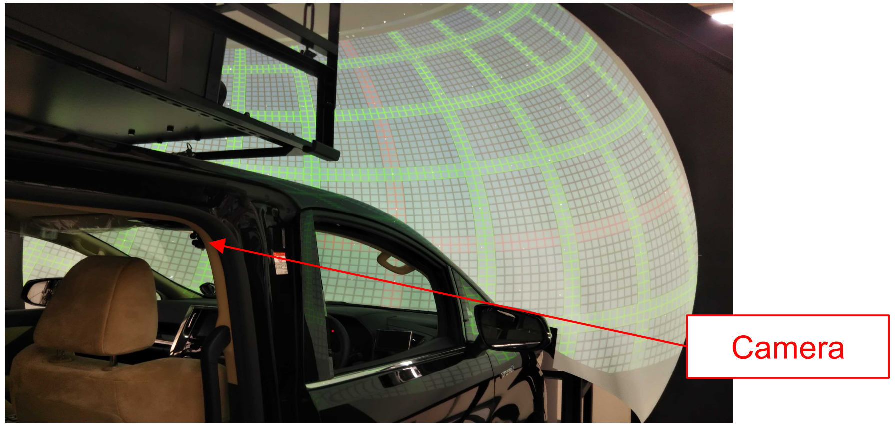
Construct HiLS using injection technology for future black box validations, and study validation possibilities

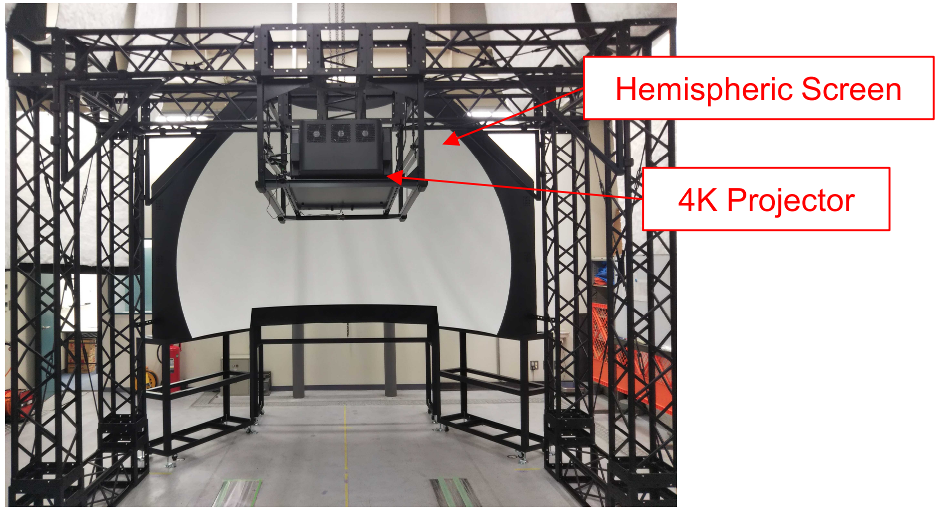
Camera HiLS Overview

HiLS Concept



HiLS Configuration





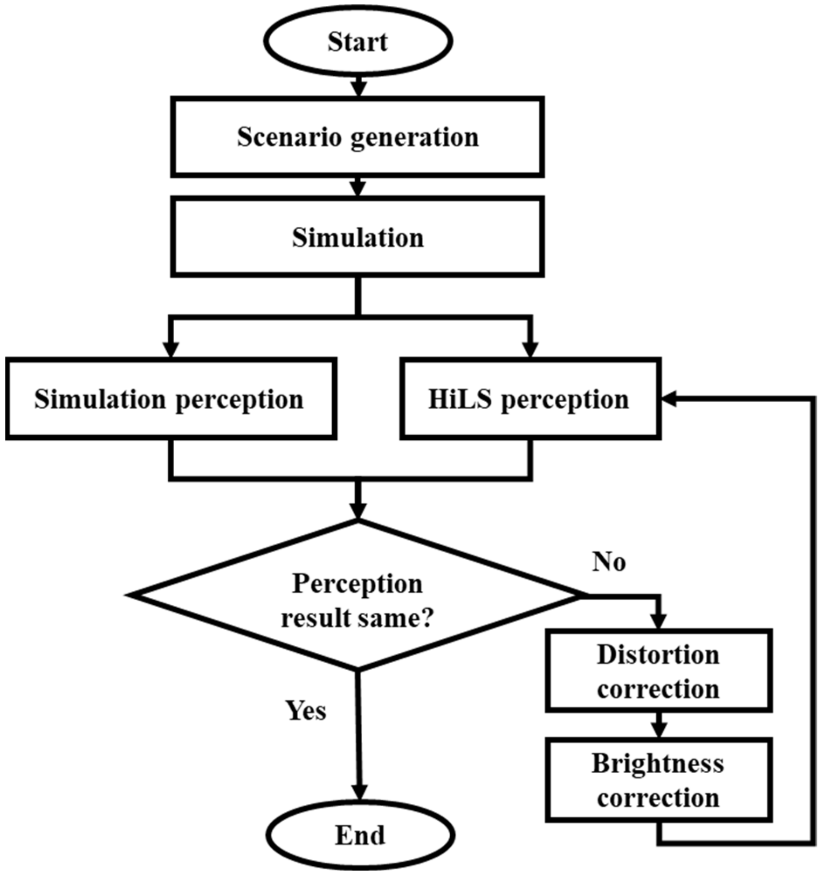
Source : Kanagawa Institute of Technology,

Verification of consistency by comparison between simulation and HiLS perception

Consistency verification of perception

神奈川工科大学
KANAGAWA INSTITUTE OF TECHNOLOGY

Test method



Distortion correction procedure

Phase	Overview
1	Detect intersection data from image data
2	Delete false points from intersection data
3	Add adjacent point data to intersection data
4	Add undetected point data to intersection data
5	Apply homography transformation
6	Detect intersection data from image data after distortion correction
7	Verify distortion correction

Brightness correction procedure

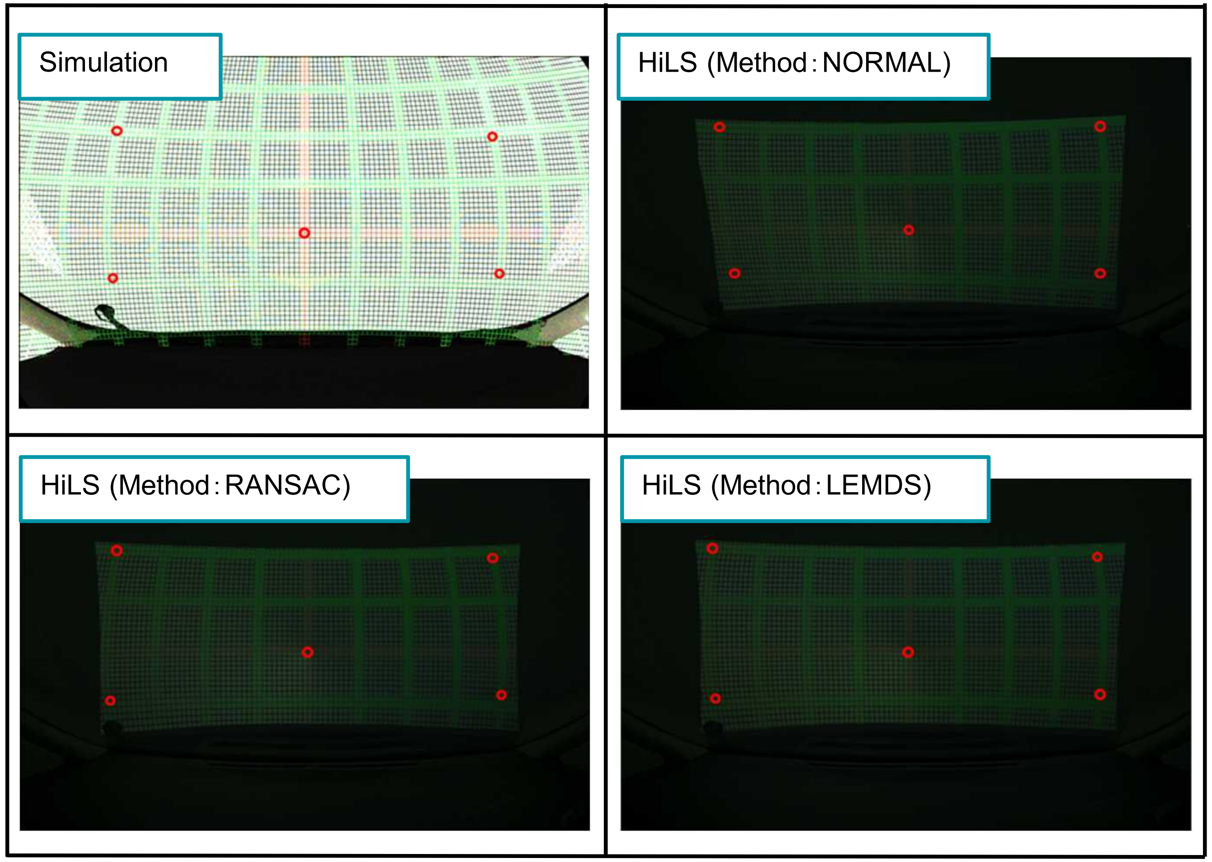
Phase	Overview
1	Get pixel-by-pixel RGB data from image data
2	Calculate gain error and offset error
3	Apply brightness correction formula
4	Get pixel-by-pixel RGB data from image data after brightness correction
5	Verify brightness correction

Distortion correction using RANSAC's robust estimation algorithm is well suited

Results (Distortion Correction)

神奈川工科大学
KANAGAWA INSTITUTE OF TECHNOLOGY

Comparing Distortion Correction Algorithm



Results of distortion correction

Position	Before correction	After correction (NORMAL)	After correction (RANSAC)	After correction (LEMDS)
Upper left	37	41	22	26
Lower left	41	17	16	113
Center	52	24	24	25
Upper right	46	20	9	61
Lower right	35	15	10	10

Error（unit：pixel）

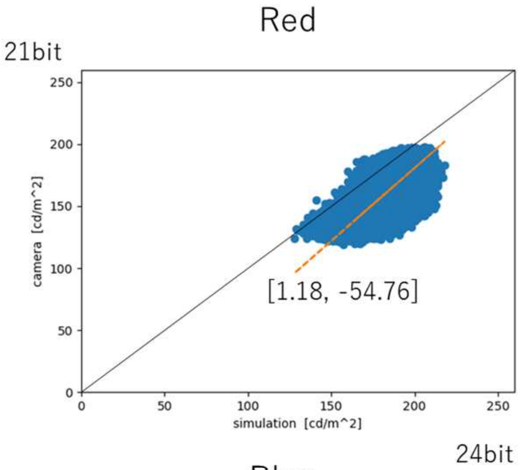
Correction using RANSAC's robust estimation algorithm is well suited to simulation data

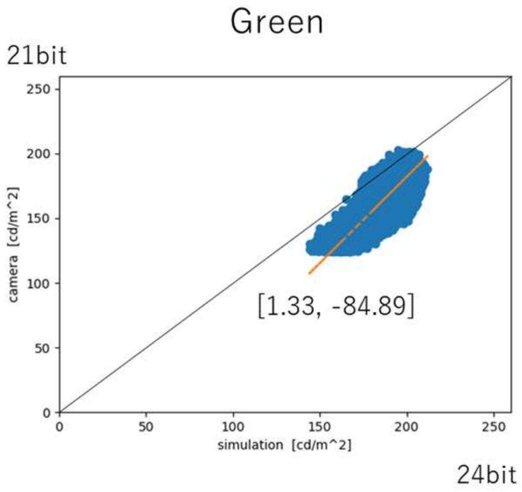
Source : Kanagawa Institute of Technology,
DIVP® Consortium

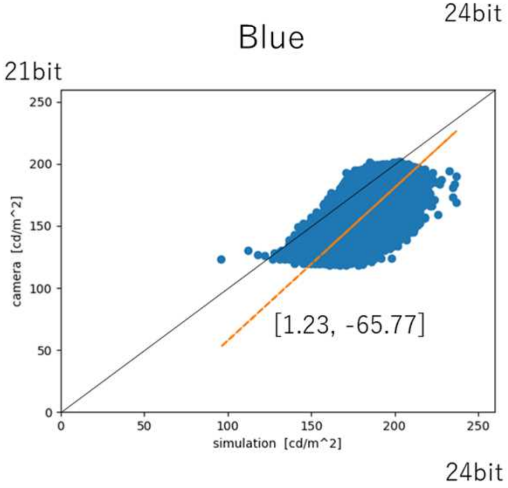
Correction formula can be applied to brightness correction

Results (Brightness Correction)

RGB data (pixel-by-pixel)







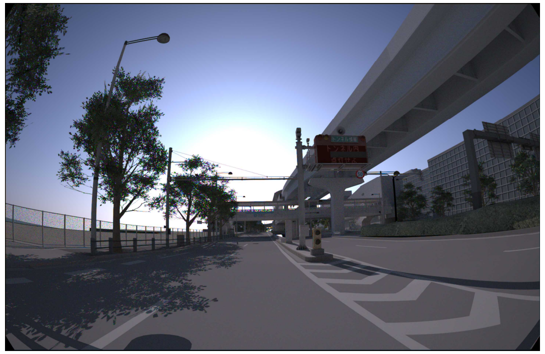
X-axis : Simulation brightness
Y-xis : HiLS brightness
[Gain, offset]

<Correction formula>

- Red : input * 2^3 / 1.17748 + 30
- Green : input * 2^3 / 1.33405 + 30
- Blue : input * 2^3 / 1.23260 + 30

Results of brightness correction

Simulation



HiLS

By getting pixel-by-pixel RGB data from image data, correction formula can be applied

Source : Kanagawa Institute of Technology,
DIVP® Consortium

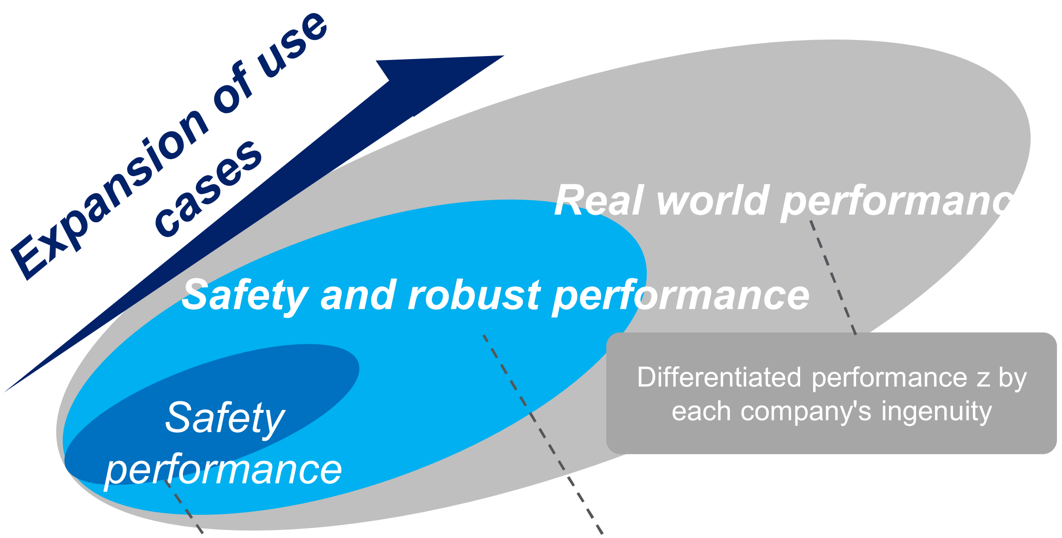
Virtual-PG / CG

In FY2020, along with improving the simulation accuracy based on consistency verification, we will develop a Virtual-PG (Proving Group) and reproduce some NCAP protocols

Virtual-PG Expansion Policy

Roadmap for Expanding Use Cases

- Raising recognition of platform effectiveness through "safety" assessments shared by all industry players



The basis of the safety performance that all automobiles must have in order to reduce serious accidents and fatalities

Basic safety features that will serve as the basis for automatic driving functions that consumers can feel comfortable

DIVP® scope

Advancing Virtual-PG Conversion with Two Pillars

1

Safety verification to reduce accidents

- Test protocols can be reproduced based on accident data, enabling safety assessment simulation.
  - Creation based on accident analysis (especially casualties, public roads)
  - Generation based on highway (automatic operation) running status data

Determine priorities from investigation of Eur-NCAP protocol generated from accident data

2

Verification of safety performance and robustness

- Reproducing bad input conditions of the sensor, enabling robustness simulation in real world
  - Weak environment due to the detection principle of each sensor and electromagnetic band used

Determine priorities from DIVP® Consortium participating suppliers and OEM communication content

Structing Asset Data based on European framework

Data base structuring

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

European Framework

DIVP® status

OpenSCENARIO

Layer4 — Moving object
Those existing in a condition where they are expected to move on the road surface where they can pass.

- Vehicle: Small vehicle, Large-sized vehicles, . . ., Powered motorcycle, Bicycle, . . .
- Pedestrians: Male, Female, Children, Old man, Wheelchair, Person pushing the baby carriage, Pet, . . .
- Other: Animal, Tram, Segway, Micro mobi, . . .

Layer3 — Temporary structures
Equipment temporarily fixed and installed

- Construction equipment: Pylon, Tiger fence, Signboard, Red light, Induction man, . . .
- Obstacle: Anything dropped, Parking Vehicle, Runner in the opposite direction, . . .

OpenDRIVE

Layer2 — Structures and markers
Fixed and installed

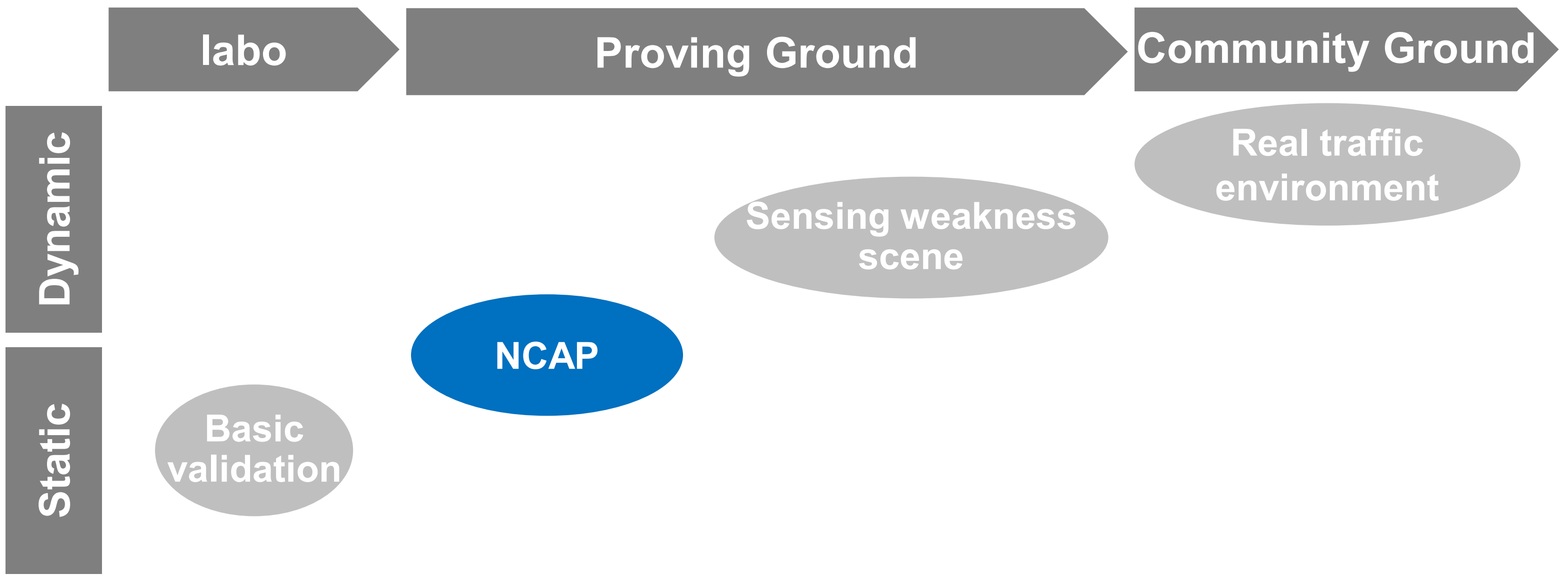
- Road signs: Indicator, Electronic bulletin board, . . .
- Traffic signal: Signal, Lighting apparatus for vehicles, Pedestrian lamps, . . .
- Structure: Tunnel, Pedestrian bridge, Bridge, Building structure, . . .
- Security equipment: Guard rail, Guard pipe, Curve mirror, . . .
- Natural objects: Planting, . . .

Layer1 — Road geometry
Reference plane on which a structure or moving object is installed

- Road surface: Carriage way, Side walk, Bicycle path, Road shoulder, Separation zone, Parking lot, . . .
- Road surface condition: Rain, Snow, Manhole, Cracking of white line, Cracks on roads, . . .
- Ground level: Ground (other than road), . . .
- Road marking: Demarcated line, Central line, Crosswalk, Channelizing strip, Zebra, Pause, No deployment, Speed, Stopping, . . .

Legend
- Implemented within FY2020
- Implemented from FY2021 onward
- Low Priority

Virtual-PG / CG



Based on the results of matching the priority of the weakness requirements with JAMA, experimental was carried out in September, and the test protocol of ALKS was added

Experimental Conditions for Cognitive Malfunctions (9/7 to 9/18)

SOKEN

weakness scenarios and assets addressed in the experiment

Travel protocol

AEB-Pedestrian	AEB-Cyclist	AEB-vehicle
■ Pedestrian cross-cutting scenarios	■ Bicycle following scenario	■ Right-right collision scenario

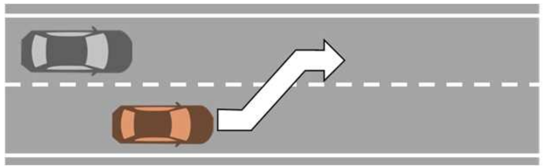
Asset

		Camera	Radar	LiDAR
5	Environmental conditions	Daytime, Nighttime, Rain/fog, Backlight, Forward light	Daytime, Nighttime, Rain	Daytime, Nighttime, Rain/fog, Backlight, Forward light
4	Moving object	ans in black, Black vehicle, NCAP dummy	Multiple vehicles	ans in black, Black vehicle
3	Temporary changes		ed cardboar, Manhole	
2	Object mark	Windshield, Dashboard, fulminan	Guard rail, Roadside wall	fulminan, Heat shielding paint asphalt
1	Road Shape	Straight line, Intersection point	Straight line, Intersection point	Straight line, Intersection point

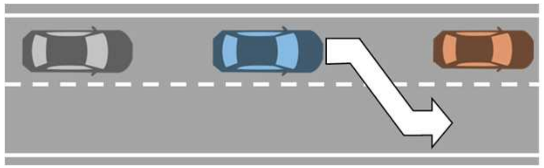
Legend
- Request for JAMA
- Sensor requirements
- Expansion plan

Addition of ALKS study protocol

Cut In



Cut Out



Test scene

Source : SOKEN, INC

Started to reproduce NCAP “Vehicle shadow darting out" by experimental measurement at Proving Ground

NCAP Vehicle shadow darting out

SOKEN

Source : SOKEN, INC

Started to reproduce NCAP “Vehicle shadow darting out" by experimental measurement at Proving Ground

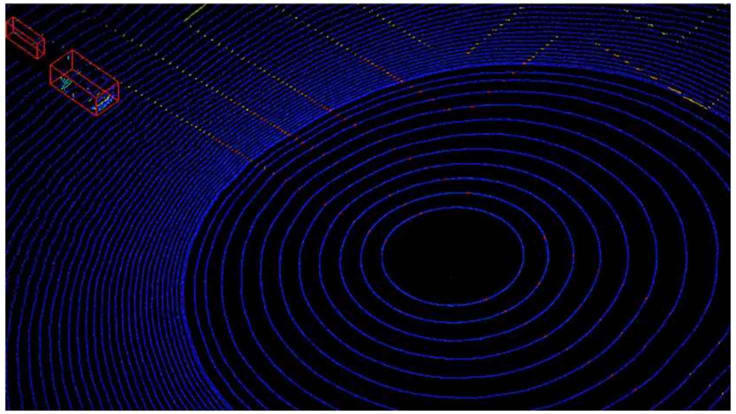
NCAP Vehicle shadow darting out（Simulation）

神奈川工科大学
KANAGAWA INSTITUTE OF TECHNOLOGY

Scenario of pedestrian darting out from vehicle shadow

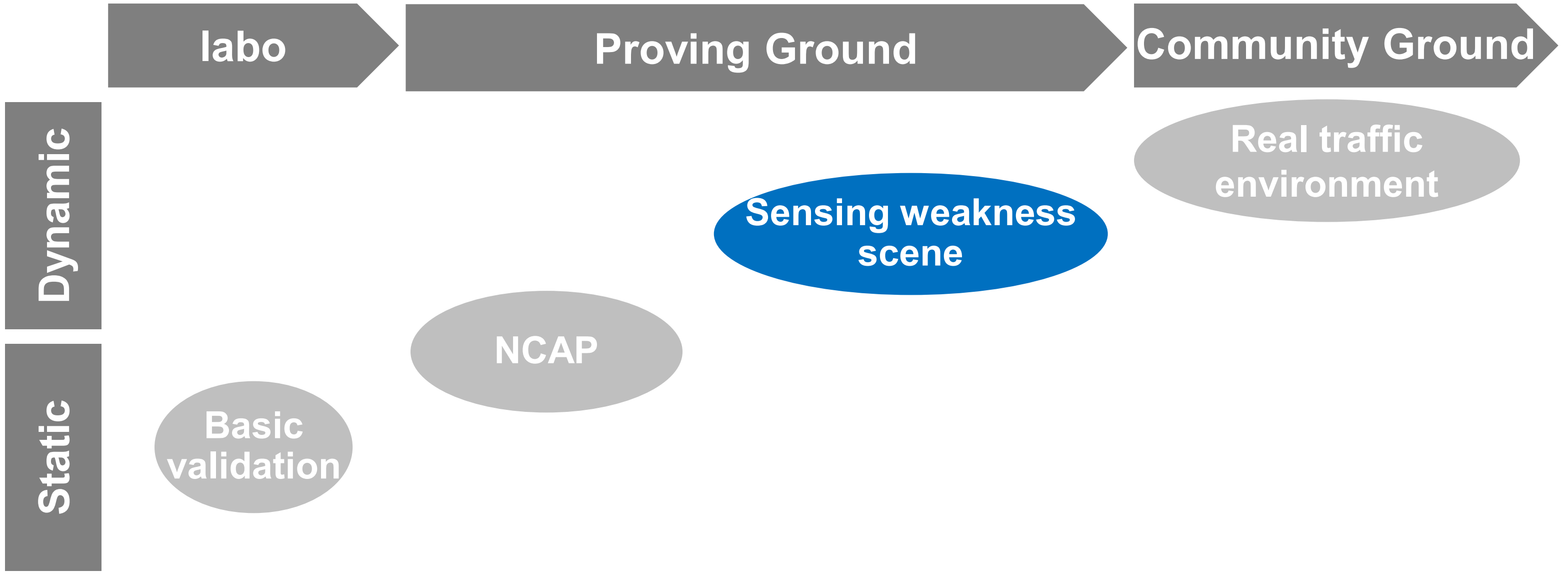
Camera Simulation

LiDAR Simulation



Source : Kanagawa Institute of technology

Virtual-PG / CG



Intended to construct Virtual-PG by acquiring sensor data in Euro-NCAP scenario in PG

Validation of Disability in PG

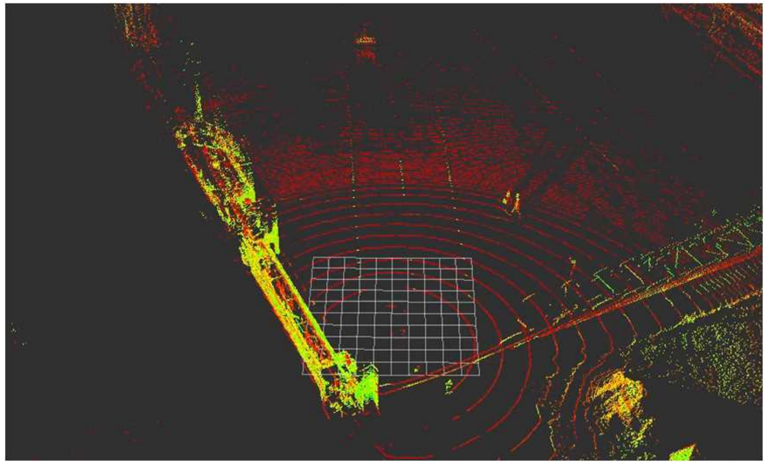
SOKEN

Source : SOKEN, INC

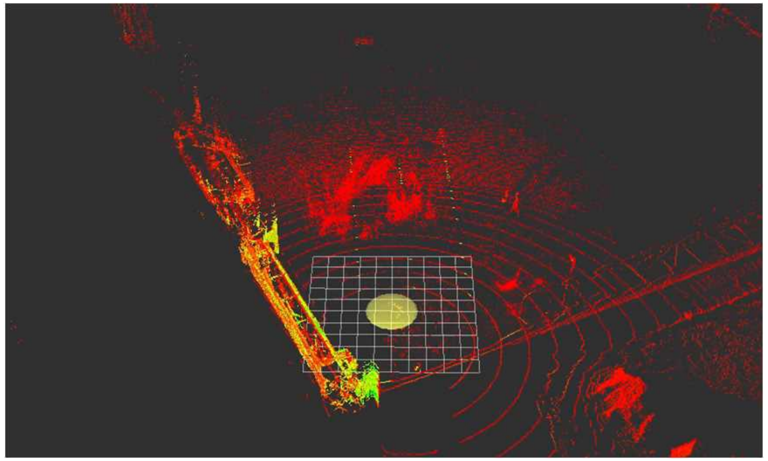
We conducted a factor study of modeling based on the NIED* rainfall test, and we were able to measure the phenomenon and the factors of malfunction peculiar to rainfall

LiDAR weakness condition

LiDAR (Doubts due to rain)

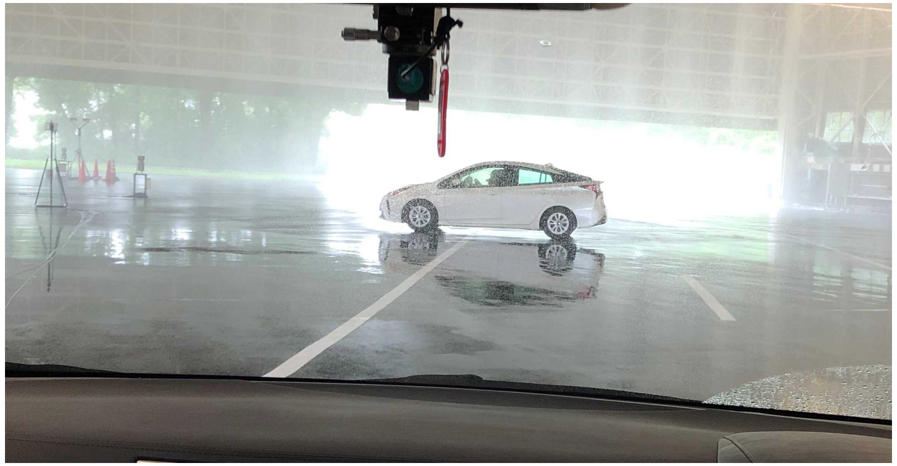


- Rainfall 20mm/h

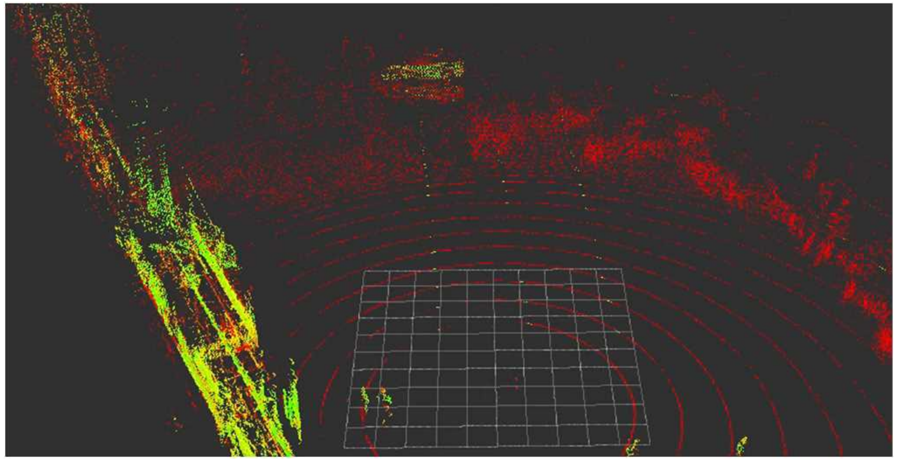


- Rainfall 180mm/h

LiDAR (Reflecting like a mirror)



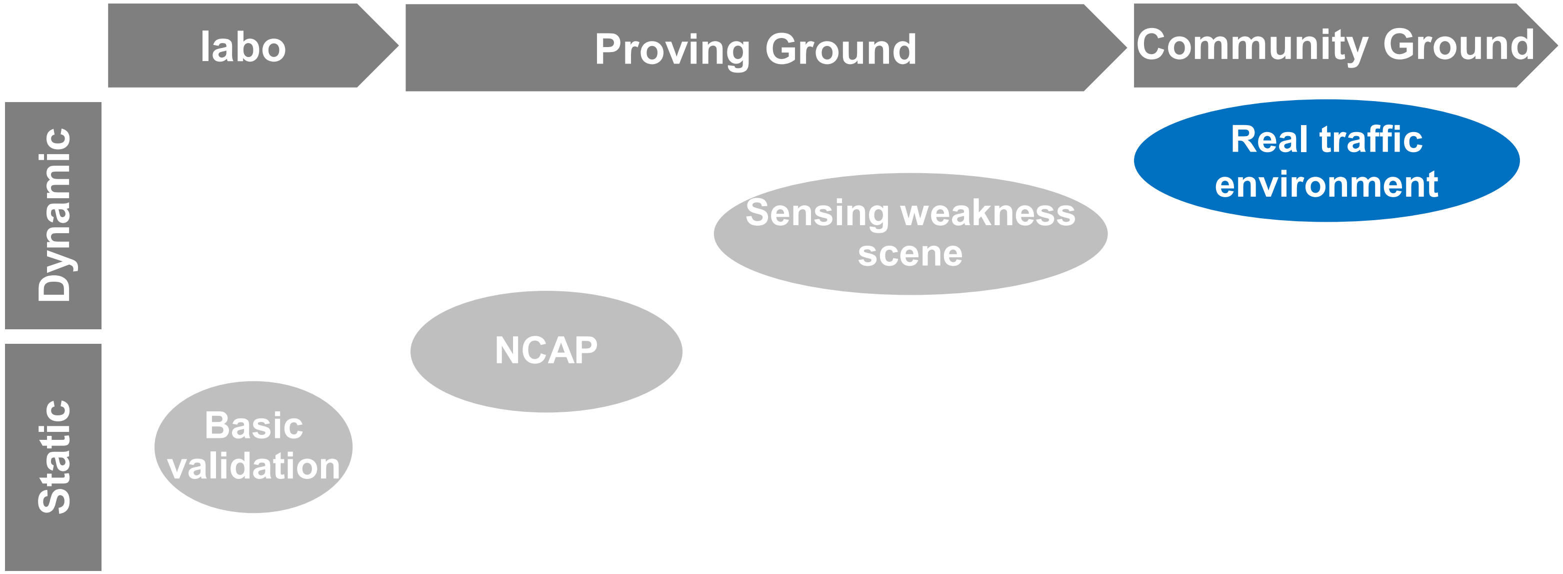
- Target vehicle in mirror on roadside



- LiDAR error percept vehicle in mirror

* : National Research Institute for Earth Science and Disaster Resilience
Source : Kanagawa Institute of technology, SOKEN, INC

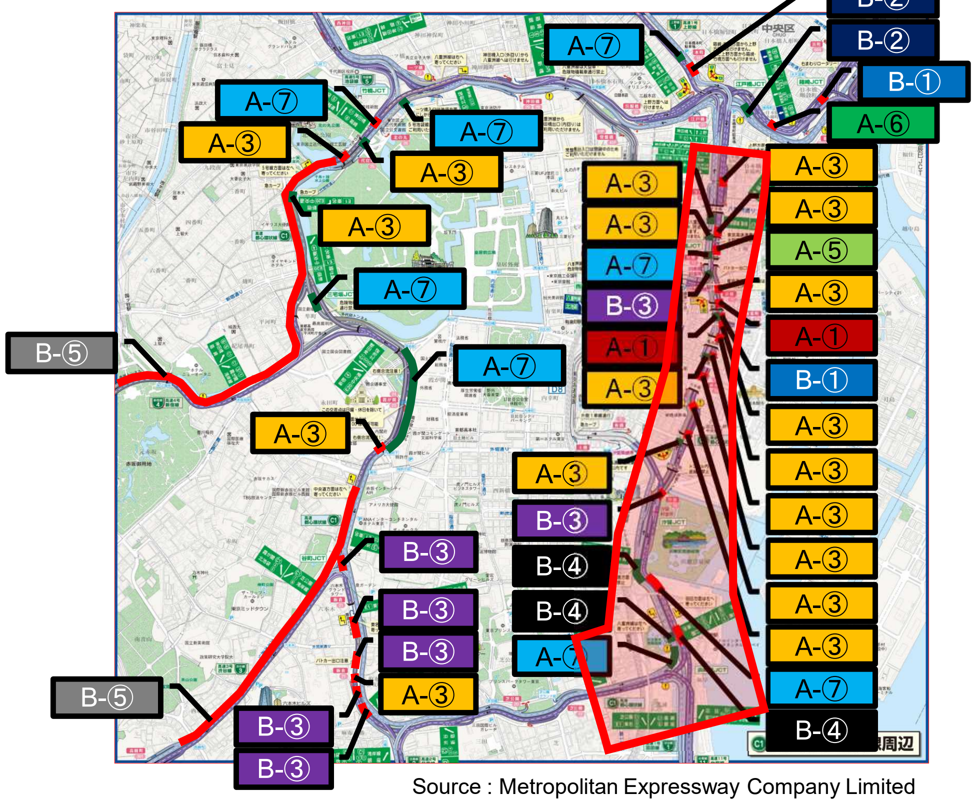
Virtual-PG / CG



Virtual-CG will be constructed by identifying factors such as Tokyo metro highway C1 and Odaiba White Line based on the interview run

Modeling based on interviews with Odaiba in Tokyo high C1

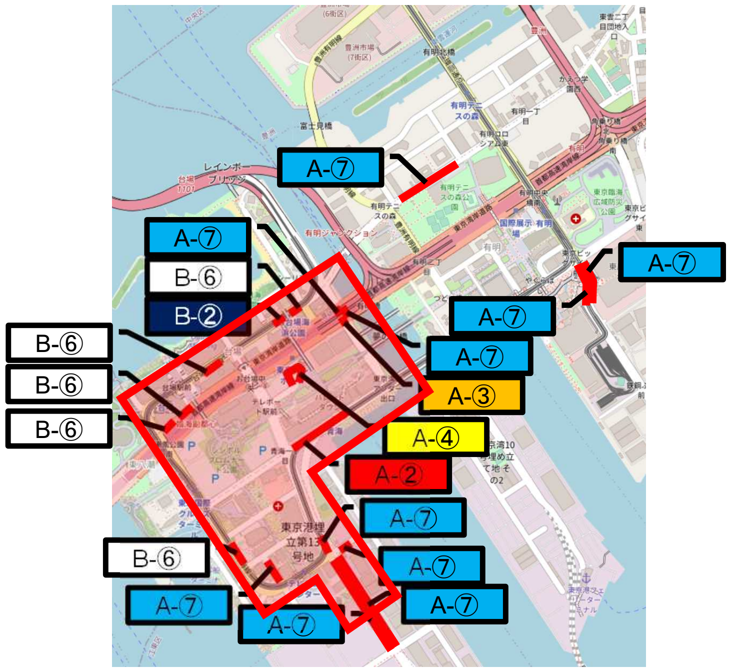
Tokyo high C1(clockwise, counterclockwise)



Source : Metropolitan Expressway Company Limited

No.	Cognitive Malfunctions		Difficulty Level
A-①	False-Negative	Shadow of noise barrier	Easy
A-②		Shadow of roadside trees	Difficult
A-③		Reflection	Normal
A-④		Road pattern	Normal
A-⑤		Wide white line	Easy
A-⑥		Road obstacles	Difficult
A-⑦		Blurred	Difficult
B-①	False-Positive	Shadow of noise barrier	Easy
B-②		Shadow of viaduct	Easy
B-③		Sunlight	Normal
B-④		Road pattern	Normal
B-⑤		curb	Easy
B-⑥		Road obstacles	(Easy)

Odaiba

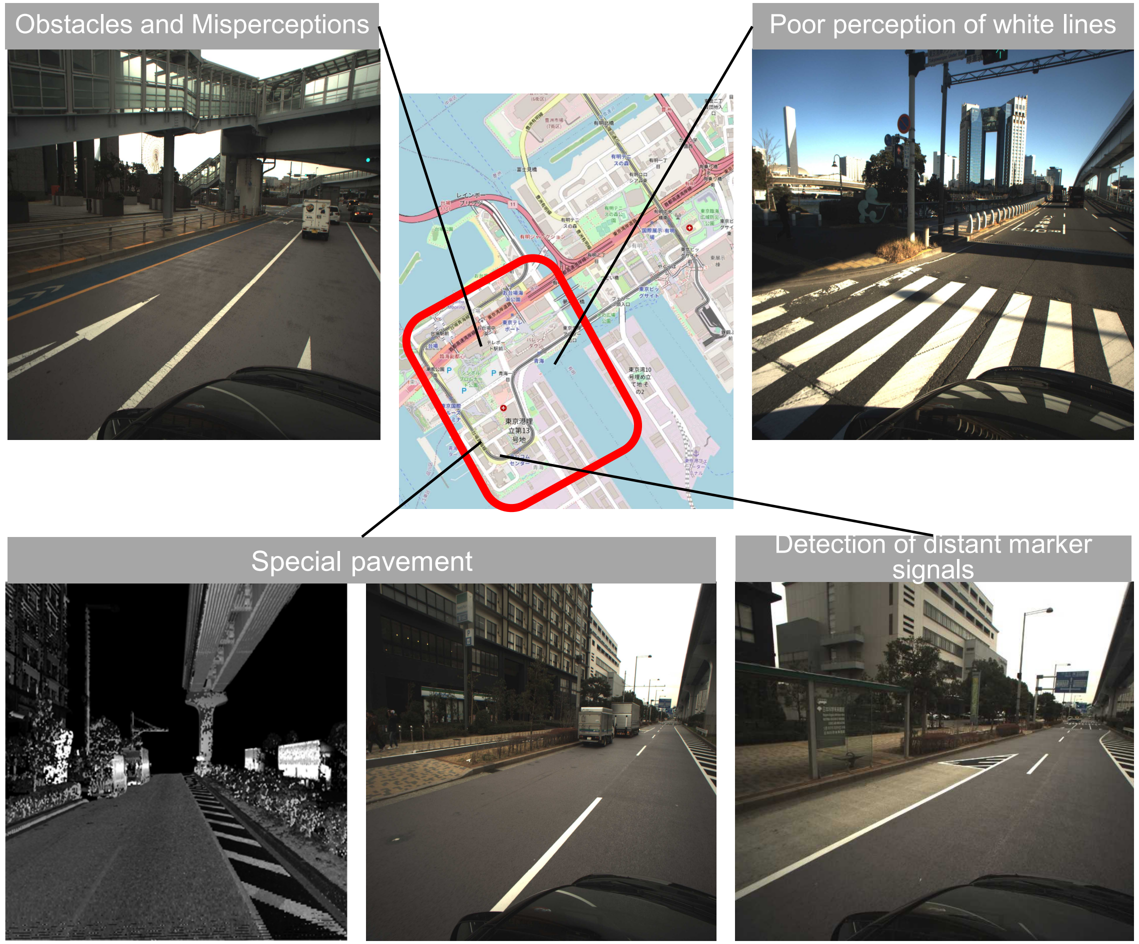


© OpenStreetMap contributors

Scheduled to confirm whether or not to use public roads (Odaiba, Metropolitan High C1) to obtain appropriate results in locations where the sensor is perceived as severe

Validation on public roads

Experiment schedule on public roads



Cooperation with Kanazawa University and Chubu University

Automatic driving vehicle at Kanazawa University

Camera image recognition at Kanazawa University and Chubu University (Semantic Segmentation)

Source: Kanazawa University, SIP Phase 2 Automatic Operation (Extension of Systems and Services) Measurement data "Research on Recognition Technologies Necessary for Automatic Operation Technologies (Levels 3 and 4)"

To the feedback of sensing weakness in the automatic operation demonstration project to the Virtual-CG and the results of cooperation within the SIP research project

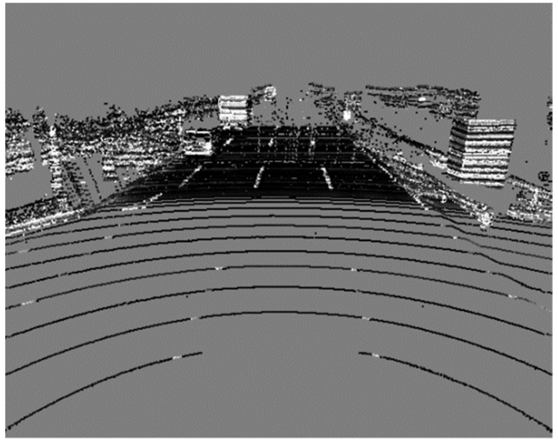
Pioneer

Collaboration with "Research on Recognition Technologies Necessary for Automatic Operation Technologies (Levels 3 and 4)"

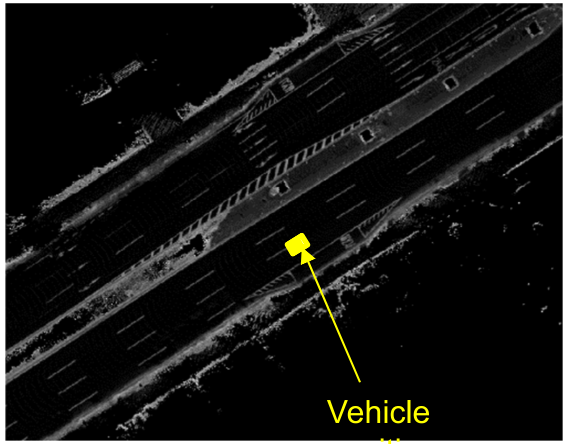
Normal asphalt (near Big Sight)

- Due to the difference in reflectivity between asphalt and white lines, white lines can be detected.

LiDAR point group



LiDAR ortho map

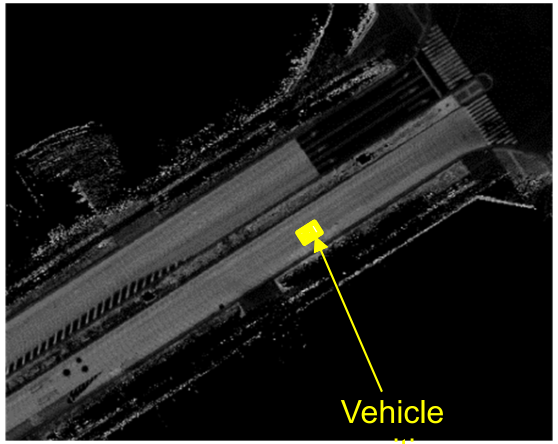


Thermal shielding paint (in front of telecom center)

- The reflectivity of asphalt and white lines is equal and white lines are difficult to detect.

LiDAR point group

LiDAR ortho map



Source : Kanazawa University, SIP Phase 2 Automatic Operation (Extension of Systems and Services) Measurement data "Research on Recognition Technologies Necessary for Automatic Operation Technologies (Levels 3 and 4)"

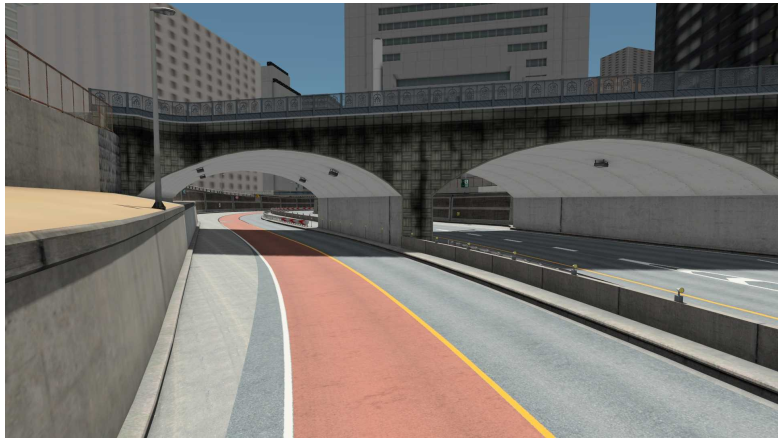
Measurement basis Tokyo metro highway & Odaiba area virtualization as Virtual-CG, for able to validate sensing weakness due by precise duplication

Virtual-CG construction

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

Tokyo metro highlway-C1 Kyobashi-JCT

Tokyo metro highlway-C1 Saikabashi-JCT



Tokyo metro highlway-C1 Shiodome-tunnel

Odaiba Ome area

Odaiba Telecom center

Odaiba Odaiba chuo

Source : MITSUBISHI PRECISION CO.,LTD.

For the sensing weakness validation in Real situation construction Odaiba Community Ground and contribute to AD safety assurance

Odaiba Virtual Community Ground

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

*The video is under development and may differ from the actual specifications.
Source： MITSUBISHI PRECISION CO.、LTD.

User review

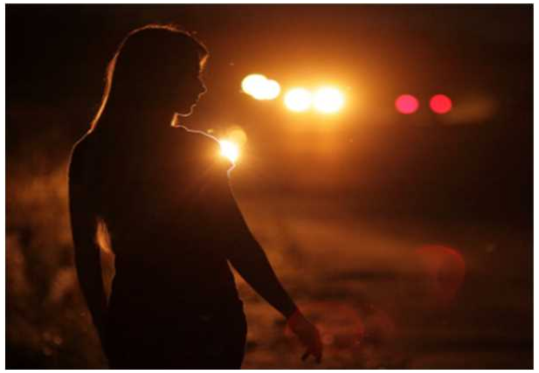
"Correctly precepting or not" is the Key to secure AD safety assurance liability

Perception validation cases

Target		Sensor perception: Exist	Sensor perception: Not
	Exist	Correct precepting	***Exist Objects but Missing perception***
	Non exist	***No Objects but False perception***	Object does not exist

Camera

Object not visible due to darkness & backlight



Flare or ghost could be percept as objects

Radar

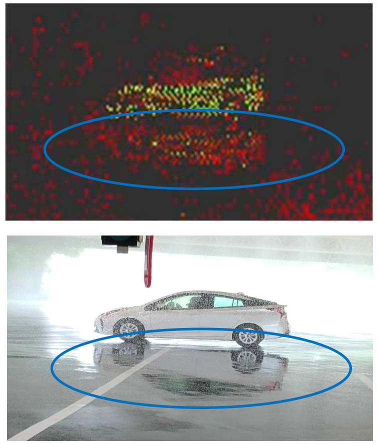
Multiple objects are not able to be segmented & percept as one object

Reflection of the gradient path leads to false perception of non-existent objects

LiDAR

Not able t percept due to wearing black leather.

False perception due by miller reflection

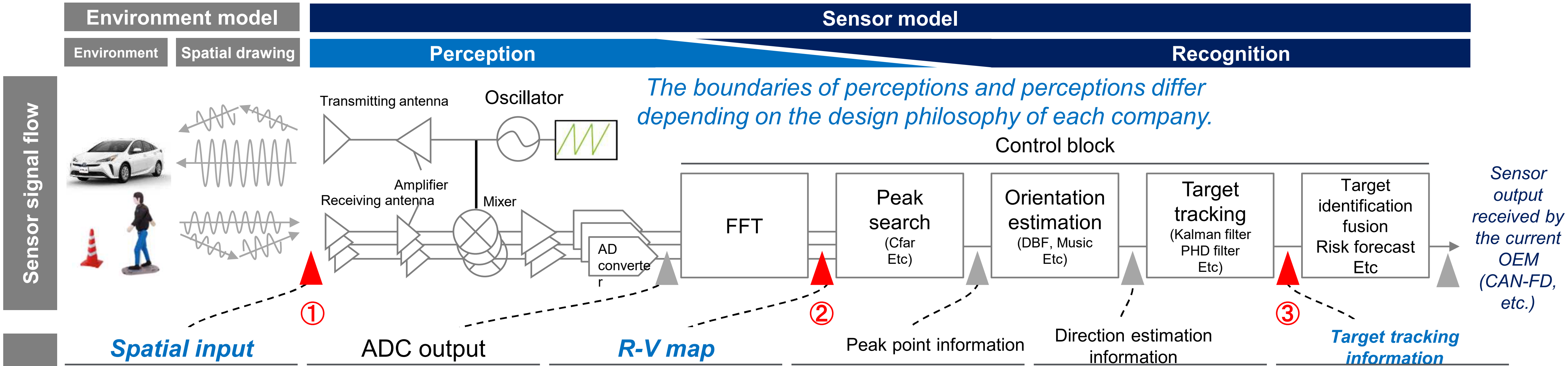


Source : MITSUBISHI PRECISION CO.、LTD.、 SOKEN,INC, Pioneer Smart Sensing Innovations Corporation

Standard I/F definitions are required because there are multiple I/Fs depending on internal control blocks in the sensor model. DIVP® proposes three I/F sections for safety validation

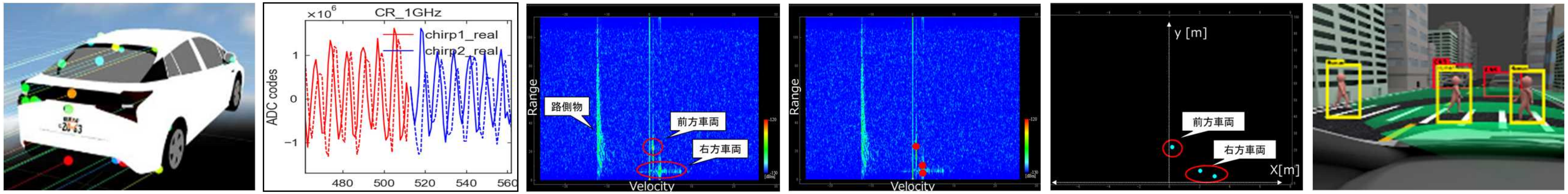
Radar I/Fs

Legend ▲: I/F ▲: DIVP® Proposed I/F



I/F output	***Spatial input***	ADC output	***R-V map***	Peak point information	Direction estimation information	***Target tracking information***
	■ Output of a spatial Ray tracing that reproduces the reflected waves from an object	■ The signal format is uniquely determined by the AD conversion output and modulation method of the received wave.	■ Include all radar physical phenomena ■ ***The cause of false detection/non-detection can be analyzed.***	■ Peak point distance, line-of-sight velocity, reception intensity, phase, etc. (The threshold values differ significantly depending on the policies of each company (emphasis on reduction of false detection or reduction of non-detection).	■ Distance, line-of-sight velocity ■ Azimuth (horizontal, vertical)	■ Information such as the position, orientation, and speed of the object ■ ***Tesla accident cause technology that tends to cause differences in sensor performance***

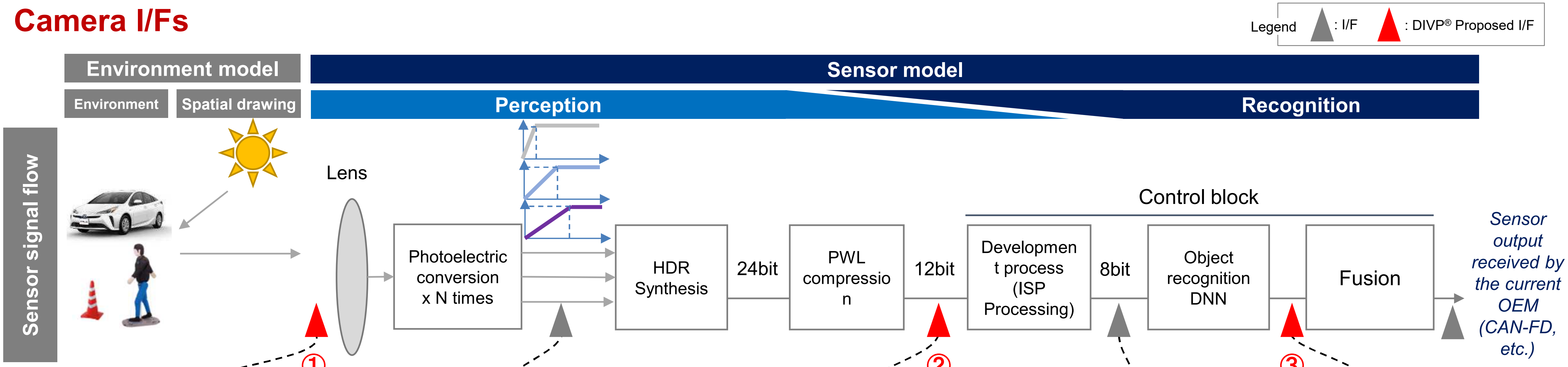
Example output



* Example of output is different from the reference example and actual output.
Source : SOKEN,INC

Standard I/F definitions are required because there are multiple I/Fs depending on internal control blocks in the sensor model. DIVP® proposes three I/F sections for safety validation

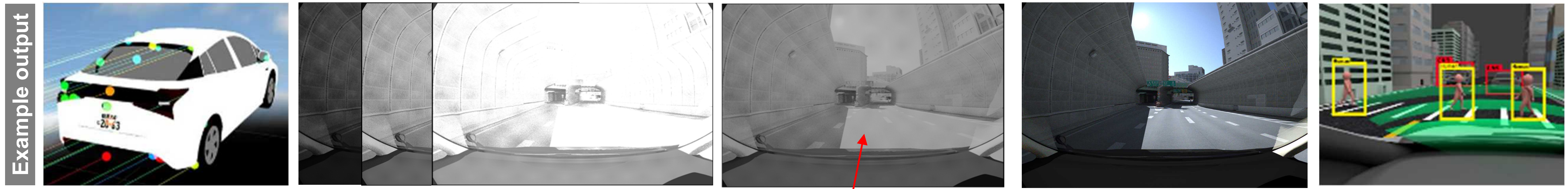
Camera I/Fs



I/F output

Spatial input ①	Multiple exposure output	RAW (Bayer array) image ②	Color image	Target recognition information ③
■ Output of the Ray tracing of the space reproducing the reflected light from the object	■ Taking multiple low-bit images with different exposure conditions ■ Combine into high-bit images by HDR synthesis	■ Images with a wide dynamic range and communication capability ■ ***It is possible to judge whether a large amount of information was perceived.***	■ Image with a color or a single color of 8 bits in the development process ■ Information may be lost due to processing methods.	■ Information such as the type, position, and size of the object

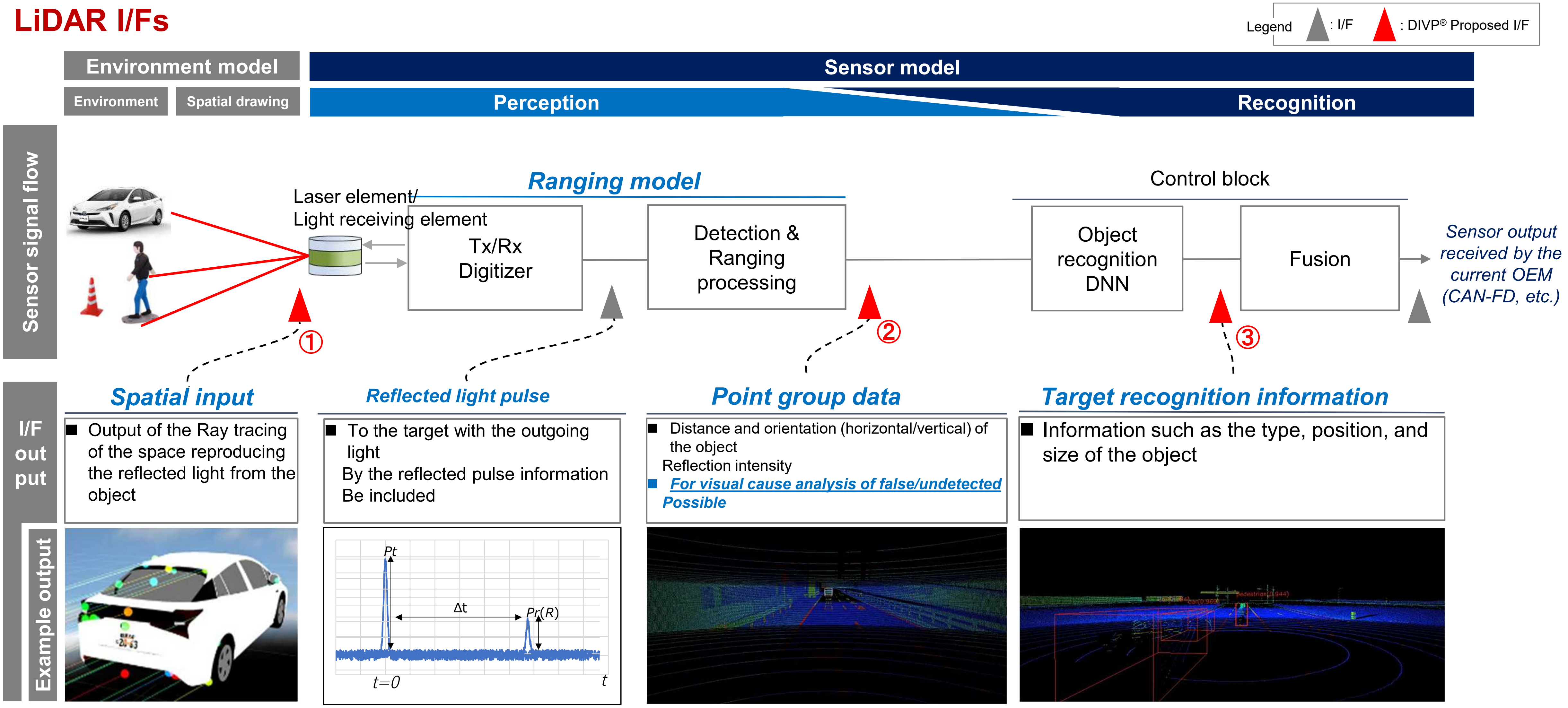
Example output



Color filter array (Bayer array)

* Example of output is different from the reference example and actual output.
Source : SOKEN,INC

Standard I/F definitions are required because there are multiple I/Fs depending on internal control blocks in the sensor model. DIVP® proposes three I/F sections for safety validation

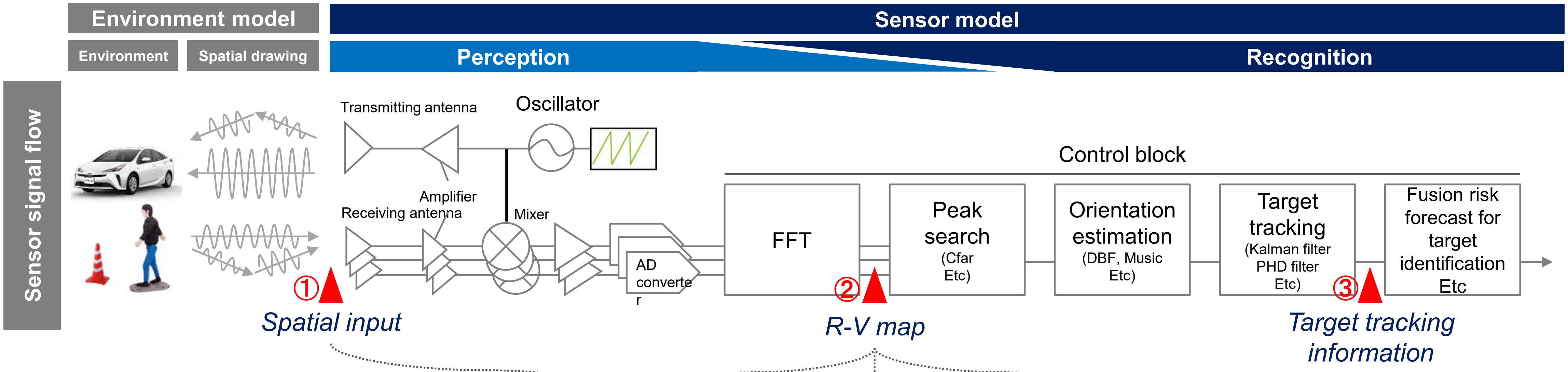


* Example of output is different from the reference example and actual output.

Source : SOKEN,INC

DIVP® will jointly study with OEM (JAMA) and sensor suppliers to standardize 3-I/F node positions & metrics for AD-safety validation

Advantage from Industrial stakeholders perspective



Expected value				
	Sensor supplier	■ ***Efficient development based on small module bases***	*In/Out Based Perception model validations and Performance Development*	*validation and performance development of the recognition module based on In/Out comparison*
	OEM	■ ***Proof of safety due to perception output***	*"Correctly perception?" To the optimization of vehicle ODD*	*Inputs for Fusion module development*

DIVP® would like promote jointly discussion even across the border between stakeholders, with using Simulation as a common language

Source : SOKEN,INC

DIVP® will conduct the user acceptance review with OEMs & Sensor suppliers on FY21, and targeting to launch the Trial version on FY22 April as a Start of Business

Social implementation schedule

	FY2020	FY2021	FY2022	FY23~
	Research	**POC and Completion of the Odaiba model**	**Start of social implementation**	

User Acceptance review

- November: OEM monitor validation
- June: Monitor validation by sensor manufacturer
  - *Key player's confidence*
  - *Support for the provision of sensor models*
- October: SIP coastal area demonstration demonstration
  - *Acquisition of pilot users*

Business

Established business working

Nihon Unisys, Ltd

SOLIZE

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

■ Expected users: Automotive OEM, Sensor manufacturers and public validation organizations

April: Start of business (target)

FY22: expansion

User review

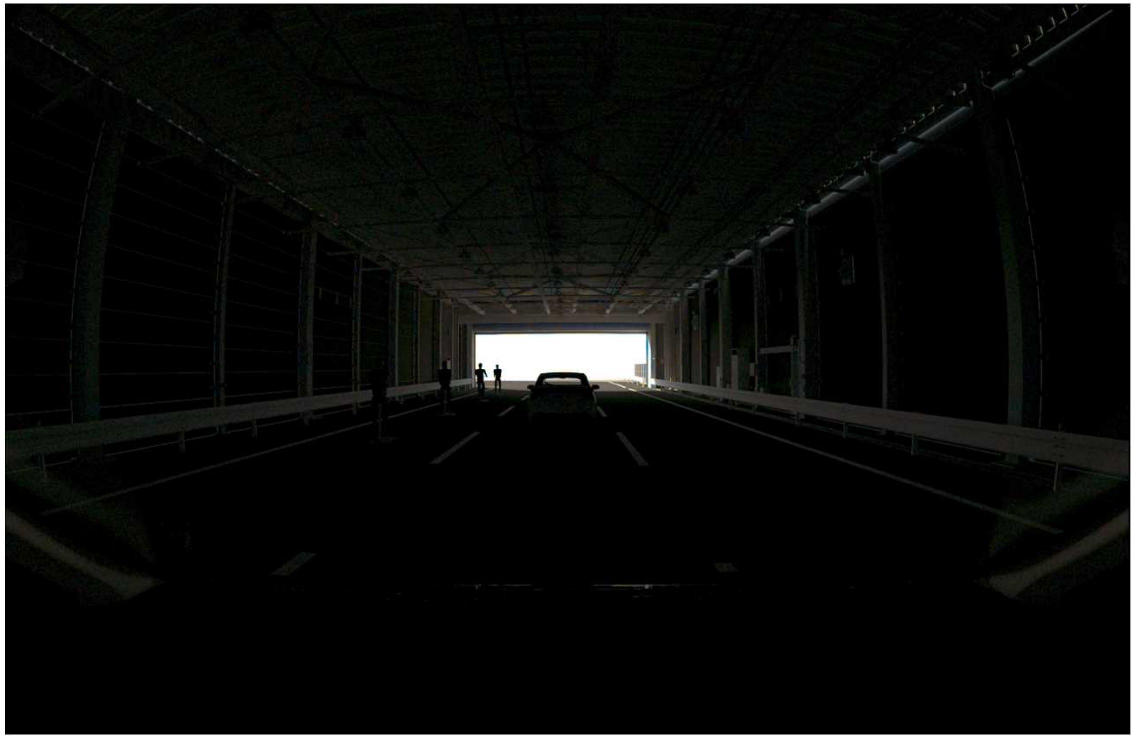
- Consortium members
- OEMs

Precise Environment & Space design model can validate the advantage of HDR Camera performance vs normal mode Camera

Example of Camera performance validation

- *Abled to simulated HDR Camera can percept objects even in really dark condition*

Normal (NML) Camera



High Dynamic Range (HDR) Camera

Source : Sony Semiconductor Solutions Corporation

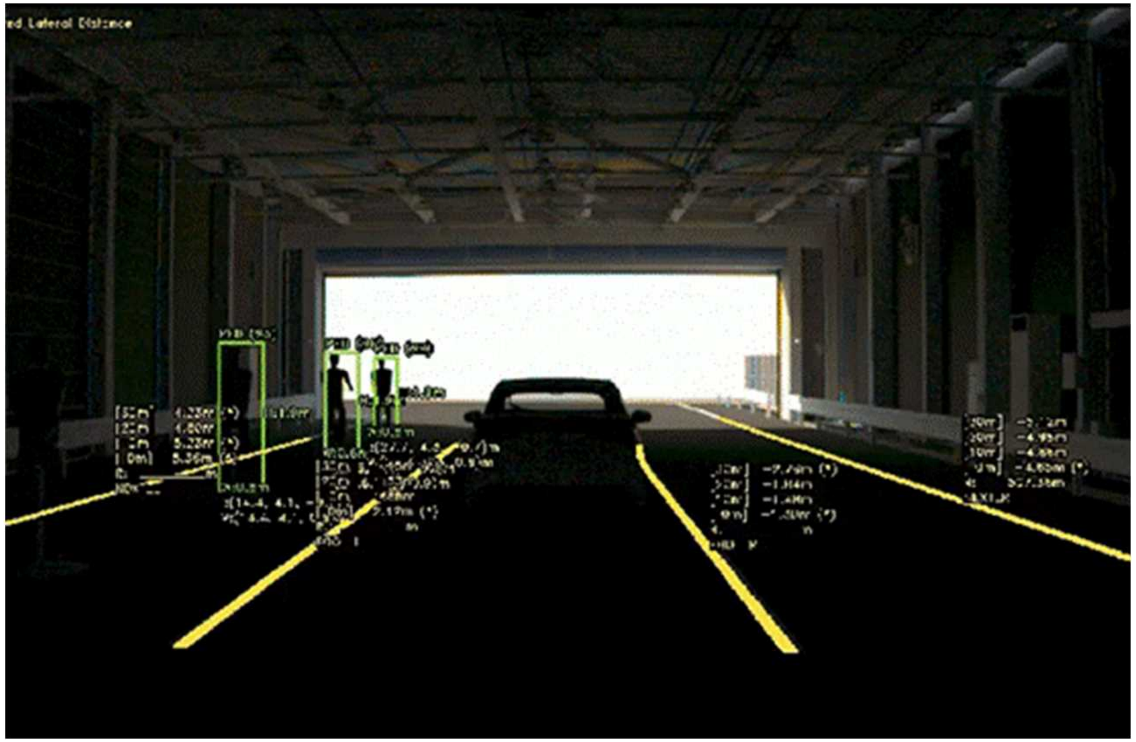
Precise Environment & Space design model can validate the advantage of HDR Camera performance vs normal mode Camera

Example of Camera performance validation

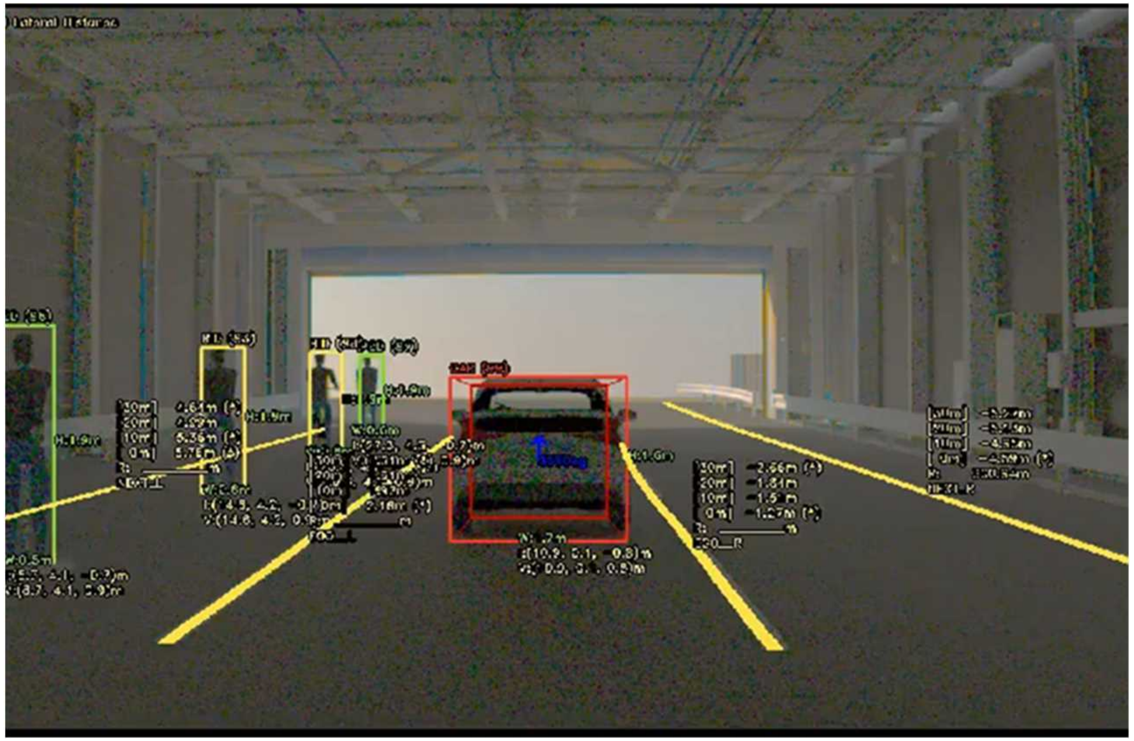
HITACHI
Inspire the Next

- *Abled to simulated HDR Camera can recognize objects even in really dark condition*

Normal (NML) mode



High Dynamic Range (HDR) mode



Source : Sony Semiconductor Solutions Corporation, Hitachi automotive systems

DIVP® simulation able to validate Rader resolution level

Example of Radar performance validation

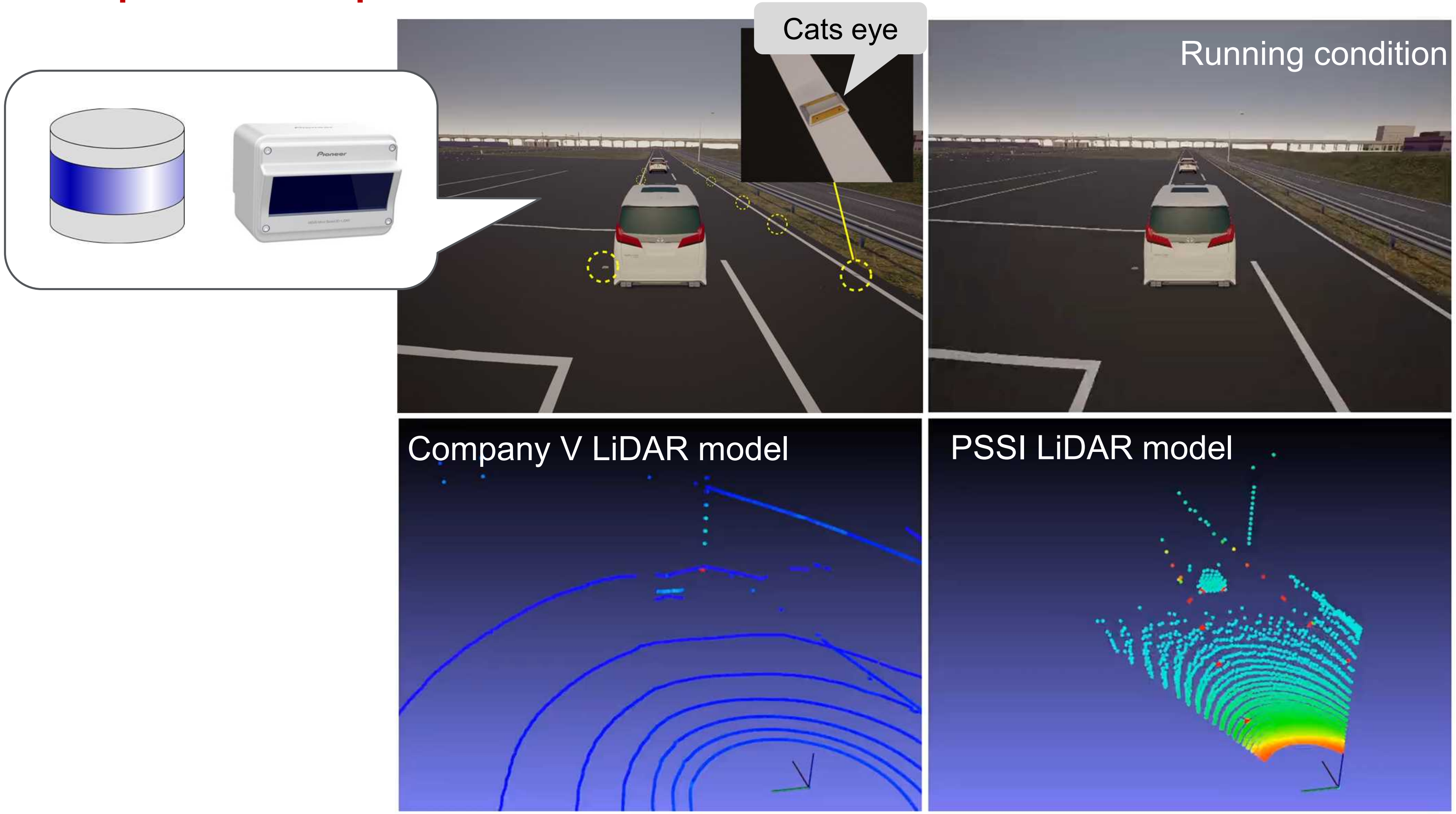
Low resolution

High resolution

Source : DENSO Corporation, Kanagawa Institute of Technology

DIVP® simulation able to duplicate high-density point cloud in closer range as PSSI LiDAR advantage

Example of LiDAR performance validation



*Pioneer SSI (PSSI): Pioneer Smart Sensing Innovations Corporation
Source : Pioneer Smart Sensing Innovations Corporation

Sensor supplier understand the value of Consistency & I/Fs could able to support their business, and expect the expansion of virtual-PG/CG for sensor validation

Self-validation of DIVP® Performance by each company

	Sony Semiconductor Solutions Corporation	DENSO	Pioneer	HITACHI Inspire the Next
Output value	■ Building of the environment for evaluating compatibility between in-house image sensor models and actual cameras ■ Camera perception model interface proposal for ASAM ■ By cooperating with the environmental model part which reproduces the precise driving environment, we were able to reproduce the consistency between the in-house image sensor model and the camera with high accuracy.	■ By standardizing the interface, simulators and models can be exchanged, and verification under various conditions becomes possible.	■ A simulator that verifies compatibility with the actual machine. ■ Design that allows replacement of the LiDAR model by IF standardization	■ Standardization of input/output interface facilitates the introduction of sensor models by each company. ■ Consistency with the real world
DIVP® potential for supporting business	■ It is effective in the occasion that the consistency of the model of developed sensors with actual ones are demonstrated.	■ In millimeter-wave radar product development, it is possible to discover potential defects and check trends due to parameter changes, which is expected to improve product development efficiency.	■ Tool for sensor development ■ Learning data generation tool for development of the recognition SW ■ True value data generation tool for recognition SW validation ■ Sensor promotion tool to OEM	■ Alternative to vehicle testing by realizing hazardous and difficult-to-reproduce tests. ■ An OEM operation assurance tool based on real-world consistency.
Next step & Further Expectations	■ Dealing with IR (near-infrared) bands ■ Verification of noise levels ■ Support for high-speed phenomena (bra, rolling shutter, flicker)	■ To construct a simulation that can accommodate a variety of environments	■ Expansion of sensing weakness conditions ■ Determination of LiDAR Perception Model Consistency Level from Object Recognition Perception and Improvement of Consistency toward it	■ Expansion of assets, including causes of malfunctions. ■ Early commercialization.

In actual vehicle experiments, personnel and time costs are very high.
DIVP® ensures high consistency and allows repeated data acquisition with few resources.

Comparison of resources in EURO-NCAP AEB control experiments

SOKEN RITSUMEIKAN

Real test conduction — Personnel × Time = 396h

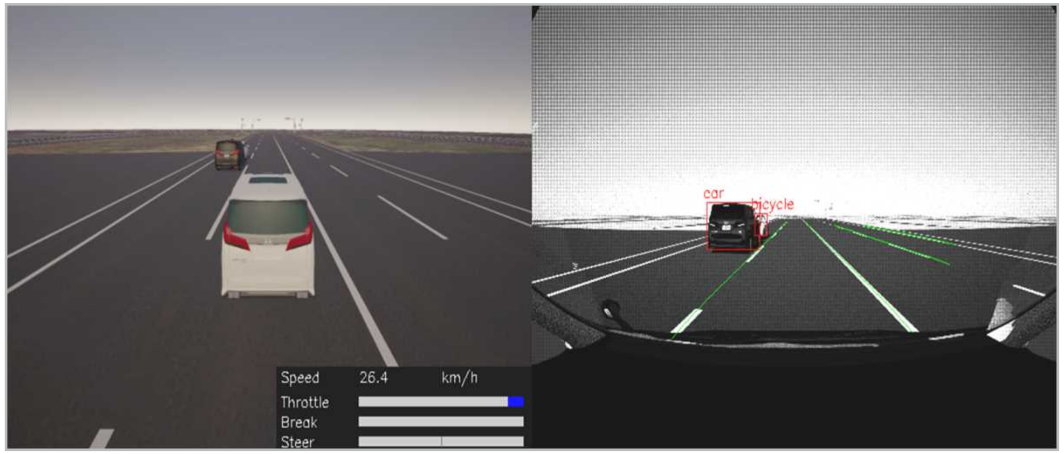
	Personnel	Time
Pre-operation check		24h
Vehicle transportation		24h
Preparation for experiment		9h
Experiment		24h (8h×3days)
Cleaning up after experiment		3h


4aSB device, Various sensor calibration
Brake disc wear, Tire wear

DIVP® Simulation — Personnel × Time = 15h

	Personnel	Time
Scenario development		3h
Experiment		12h

※No need to monitor during calculation



※Calculated based on data from NCAP AEB control experiment conducted in December 23~25, 2020
Source : SOKEN, Inc. Ritsumeikan University

DIVP® with standard, sensor-evaluable I/F allows for verification of sensor fusion. A platform capable of evaluating even fusion models and vehicle control methods.

AEB malfunction due to incorrect detection of fusion model and its improvement

RITSUMEIKAN

AEB malfunctions in response to black alfade on adjacent lane. Due to the position error of the millimeter-wave recognition model, it was judged that black alpha was present in the lane.

Improved fusion method to correct AEB malfunction. In addition, considering the actual amount of input delay, the AEB is designed so that it will not operate until the timing when a person cannot step in time.

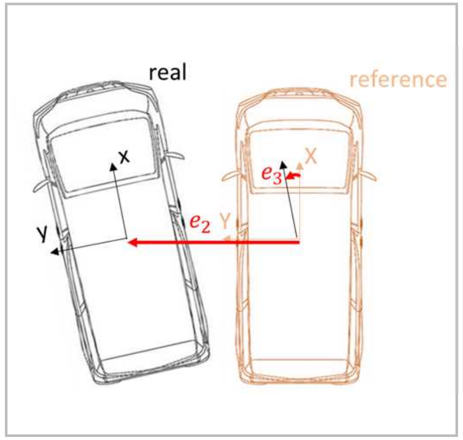
Source : Ritsumeikan University

DIVP® is a platform that can also develop sensor fusion models and control laws because it is a simulator that can evaluate each sensor and has a standard I/F.

Implementation of control laws for lane-keeping and speed-keeping

RITSUMEIKAN

Lane keep control



Define error system

$$\begin{bmatrix} e_1 \\ e_2 \\ e_3 \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_r - x \\ y_r - y \\ \theta_r - \theta \end{bmatrix}$$

Define error dynamics

※Assume $e_1 = 0, \frac{d}{dt} e_1 = 0$

$$\frac{d}{dt}\begin{bmatrix} e_2 \\ e_3 \end{bmatrix} = \begin{bmatrix} v \sin e_3 \\ w - w_r \end{bmatrix}$$

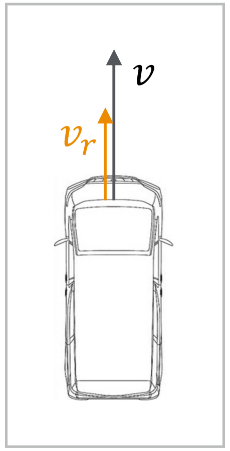
Design based on Lyapunov stability theory

$$V = \frac{1}{2} e_2^2 + \frac{1 - \cos e_3}{K_3}$$

Path Following Control

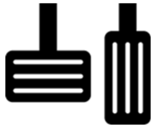
$$\omega = \omega_r - K_2 e_2 v - K_3 \sin e_3$$

Speed keep control



v : Current speed [m/s]

v_r : Target speed [m/s]



Speed Keep Control

$$u = K_f v + K_p (v_r - v) - K_d (\dot{v}_r - \dot{v})$$

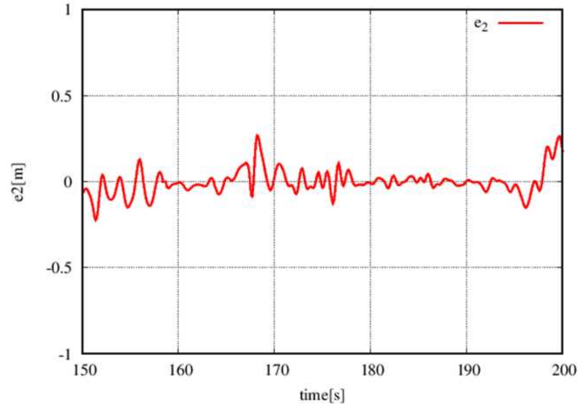
Making steady tuning of the parameters is necessary to achieve control with high accuracy.

Source : Ritsumeikan University

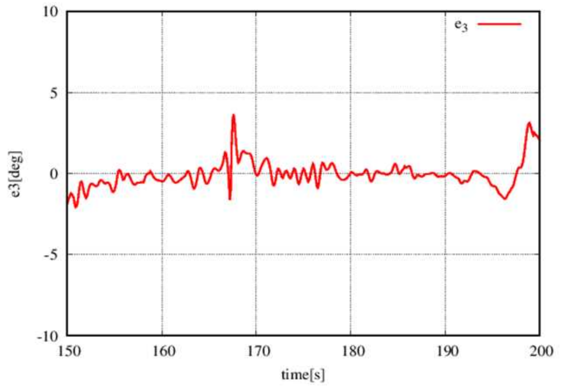
DIVP® reproduces the actual environment with high consistency, allowing the controller and sensor fusion design in practical conditions. It may contribute to minimizing the parameters tuning using actual vehicles.

Demonstration of the lane keep control on the C1 Metropolitan Expressway

Lateral error



Heading error



As a result of tuning parameters,
Travel with accuracy within 25 cm of lateral error and within 4 ° of heading error with respect to the center of the own lane

Source : Ritsumeikan University

User review

- Consortium members
- OEMs

OEM Monitor Validation was conducted to confirm the usefulness of the "environment-propagation-sensor model" output data with improved consistency

Implementation Overview

Nihon Unisys, Ltd

- Purpose
  Monitoring companies were invited to participate in the domestic OEM, and a monitoring validation was conducted to verify the effectiveness of the prototype version of the DIVP® simulator research product. The purpose of the project is to confirm the usefulness of the output data of the "environment, propagation, and sensor model" with improved consistency, and to provide feedback for future improvement of the simulation model. The project will be a stepping stone to commercialization.

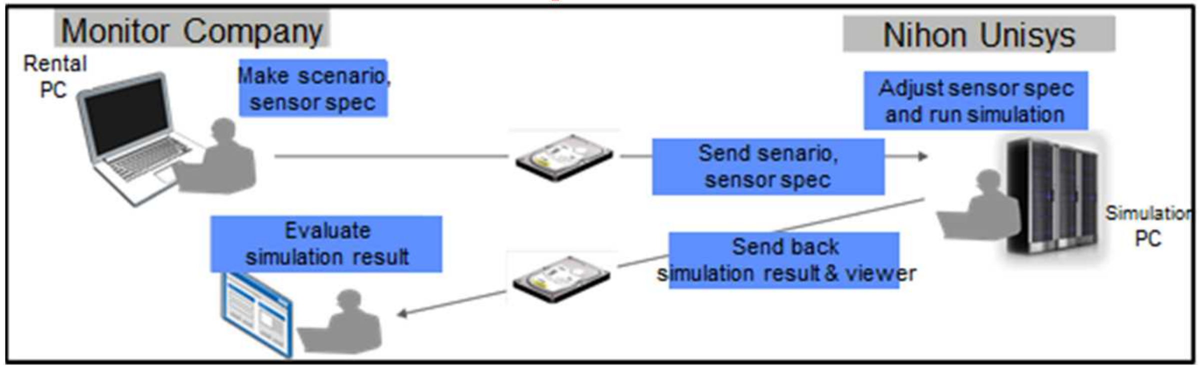
- For applications
  NEDO-HP recruited from October 9 to October 18 for "Monitoring and Verification of Effectiveness in the Simulation of Automatic Operation Performance of Output Data of 'Traffic Environment-Radio Propagation-Sensor Model' on the Second Phase of the Strategic Innovation Creation Program (SIP)/Development of Automatic Operation Evaluation Environment Method in Virtual Space.“

- Applications were received from 3-OEMs :
  Toyota Motor, Honda Motor, and Mazda Motor.

Since it is difficult to execute the simulation freely in a remote environment, a scenario is created by lending PC to each OEM and the sim was executed in Unisys,Ltd after sending

OEM Monitor Validation Implementation Overview

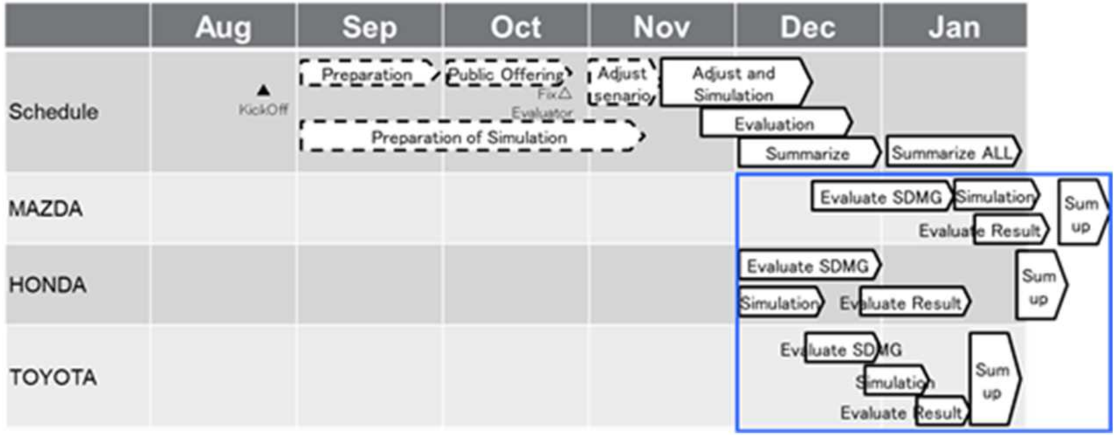
Nihon Unisys, Ltd



Prepare confidentiality agreements between each OEM and Japan Unisys (commissioned by NEDO).
9 DIVP® Consortiums prepared a written pledge to comply with the above agreement to OEM.

- **In the future, the simulation system is expected to be operated in the cloud environment.**
  However, because the system infrastructure has not been established this time, simulation scenarios are prepared on the PC (dedicated environment) on which the monitoring company has been lent.
  Scenarios created were received by Japan Unisys (commissioned by NEDO) and simulated in the simulation calculation environment prepared.
  The results are returned to the monitoring company for confirmation.

<Schedule/Results>



DIVP® has concretely grasped the expectations of each OEM as represented by the consistency. However, this time, the validation pattern remains rudimentary

Assessment summary for each OEM

Nihon Unisys, Ltd

Requested simulation scenario	■ (ADAS) 3 scenarios to be assumed to occur actually ①Right-handed pedestrian ②Convergence from a tandem parking line ③Forward pedestrian ■ (AD)5 scenarios to evaluate attenuation of LiDAR ①Standard ② light rain ③ heavy rain ④Pedestrian black leather clothing ⑤Surface of the heat shielding paint	■ Comparison of perceptions and perceptions of low and high beams in the standard scenario ■ Comparison of perceptions and perceptions of various parameter changes in the DIVP® standard scenario	
Validation	■ Camera and LiDAR have no sensation or tendency (difficult to make formal judgment). ■ Improvement is required for SDMGenerators and Viewers who are supposed to use the services.	■ Differences between low and high beams could not be evaluated ■ Lens distortion for camera and LiDAR No reproducibility from a sensory point of view, such as reproducibility. ■ Radar: Some parts do not match sensations	■ Qualitative consistency is confirmed. (Comparison with real phenomena is not yet) ■ Visualization is good
Remaining issues · Expectations for the future	■ Ensurance of consistency ■ Enriching assets ■ Support various phenomena ■ Practical use of I/F of intermediate output	■ Coverage of verification pattern	■ High-speed simulation ■ Improvement of SDMG and Viewer

- It have become clear that each OEM expects for ensuring consistency in simulations, expanding the scope of application based on the assumption of business use, and improving the operability of various applications.
- In particular, OEM is still searching for specific usage scenarios and possible validation methods. Lead as DIVP® is required to establish this.

In the valuation of accident scenario, we have got good reviews about camera and LiDAR. Verification of consistency and improvement for software usability are required.

Valuation pattern 1

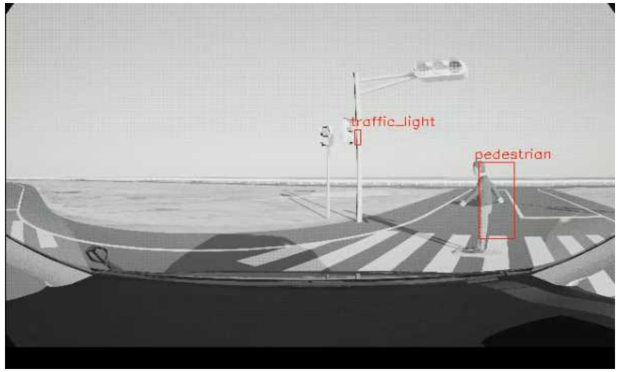
Nihon Unisys, Ltd

Valuation scenario

#	Overview	Conditions
①	■ Right-turn walk (Pedestrian pedestrian on the crosswalk ahead of the right-hand turn)	Fine at 3 p.m.
②	■ Parking departure (Sudden departure and convergence of vehicles from a tandem parking line)	As above
③	■ Pedestrian group (Pedestrian Groups on Forward Crossing Trails)	As above

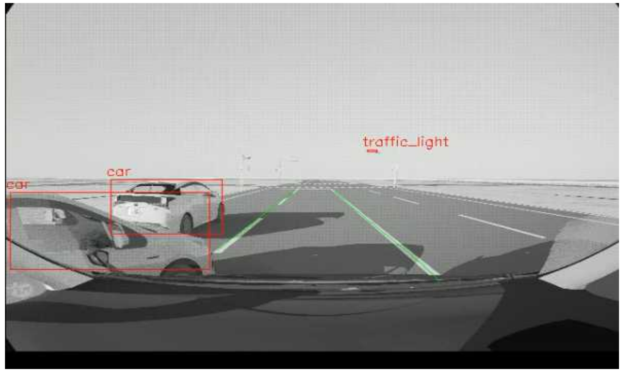
①(Camera)

Scenario time = 7 seconds, Calculation time = 45 min



②(Camera)

Scenario time = 5 seconds, Calculation time = 31 min



Validation results

- ■ OEM comments
  - ➢ Camera, LiDAR is sensory OK. (however, it is difficult to make a formal decision in situations where here are no data on consistency).
  - ➢ It would be good to be able to perform multi-object testing at low cost.
  - ➢ You want to create the vehicle trajectory by using other object standards (for example, at the center of the lane, at the same distance as other vehicles).
- ■ Summary
  - ➢ Although the camera and LiDAR were evaluated as sensory acceptable, it is necessary to show the grounds for consistency.
  - ➢ Radar cannot be evaluated by OEM alone and should be performed with the involvement of the sensor manufacturer.
  - ➢ We have received many requests for SDMGenerator and Viewer for business use, and we would like to reflect them in the DIVP® Development Plan.

Source : Nihon Unisys, Ltd

In the valuation of standard scenario with various parameters, we have got good reviews about tendency of LiDAR attenuation. Enriching assets and various phenomena is required.

Valuation pattern 2

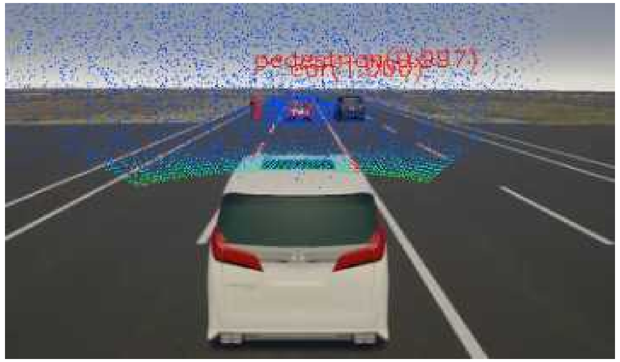
Nihon Unisys, Ltd

Valuation scenario

#	Overview	Conditions
①	■ The Basics	Cloud/12:00
②	■ Signal attenuation due to rain and fog	20 mm/h/12 o'clock in small rain
③	■ As above	Heavy rainfall 40mm/h/12:00
④	■ Malaise caused by black leather clothing	Cloud/12:00
⑤	■ Impaired white line perception on the road surface of the heat shielding coating	As above

②LiDAR

Scenario time = 10 seconds, Calculation time = 62 min



③LiDAR

Scenario time = 10 seconds, Calculation time = 61 min

Validation results

- ■ OEM comments
  - ➢ SDM Generator is intuitive and easy to use
  - ➢ The simulation results reproduced the trend of the attenuation of LiDAR due to rain.
- ■ Summary
  - ➢ There is a need for more assets (NCAP children, soundproof walls, motorcycles, etc.)
  - ➢ There is a need for enhanced response to LiDAR malfunctioning scenes (backlights, splashes, fog, and Lidar (the same wavelength beam) on opposite vehicles)

Source : Nihon Unisys, Ltd

Though most of requested valuation scenario were not executed in DIVP®, we have got good reviews about accuracy of camera & LiDAR.We must implement various condition & scenario

Valuation pattern 3

Nihon Unisys, Ltd

Valuation scenario

#	Overview	Conditions
①	■ Vehicle and people in front of the vehicle	Sun/17:00/low beam
②	■ As above	Sun/17:00/High Beam

①(Camera, Recognition Off)

Scenario time = 5.6 seconds, Calculation time = 52 min

②(Camera, Recognition Off)

Scenario time = 5.6 seconds, Calculation time = 52 min

Validation results

- OEM comments
  - Differences between low and high beams cannot be evaluated (not reflecting the light distribution characteristics of the headlights).
  - The SDMGenerator screen is simple and sensitive.
  - Camera: I felt that the lens distortion was beautifully reproduced and (to the extent not compared to actual data) well reproduced.
  - Radar: I can't say anything when compared with actual data, but I don't feel like I am output.
  - LiDAR is well shaped. I think it would be even better to reproduce the vehicle by adding the slope of the road surface.
- Summary
  - Many requests were received (recreation of unevenness on the road surface and vibration of the vehicle body, enhancement of assets, weather conditions such as rain, snow and fog, white line cassette, etc.)
  - Concordance was not mentioned. In addition, the perception was not evaluated in detail and was not evaluated qualitatively.
  - Most of the desired patterns could not be realized, including the low/high beam comparisons that were implemented, and the expectations were not adequately met.

Source : Nihon Unisys, Ltd

Perception and recognition performance are evaluated in the standard scenario with various parameters. We have got good reviews about sensor output tendency.

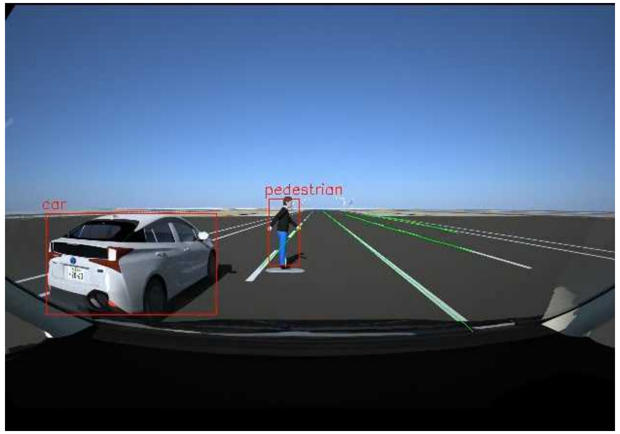
Nihon Unisys, Ltd

Valuation pattern 4

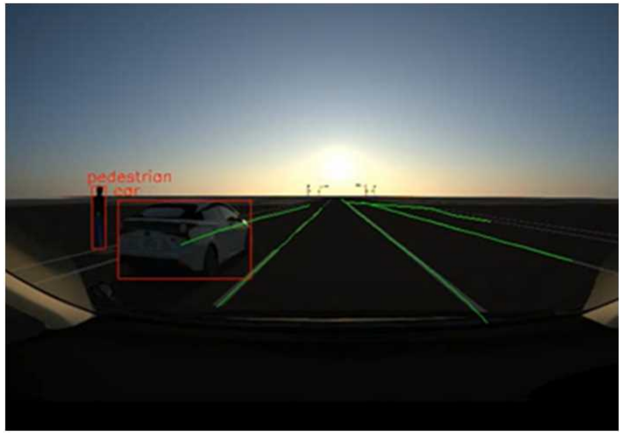
Valuation scenario

#	Overview	Conditions
①	■ NCAP pedestrian crossing (Stopped vehicle = black)	Fine/0:00/high beam
②	■ Same as above (Stopped vehicle = white)	Fine at 12 o'clock
③	■ Millimeter-wave malfunction	Fine at 12 o'clock
④	■ Camera/LiDAR weakness	Fine/0:00
⑤	■ As above	On sunset/dawn

②(Camera)



⑤(Camera)



Validation results

- ■ OEM comments
  - ➢ Camera, Radar, LiDAR shows good tendency. In particular, camera overflow by the sunlight is good.
  - ➢ Validation with real phenomena is required. We should evaluate consistency of DIVP® and judge the application of DIVP® for the simulation of serious scenario.
  - ➢ The usability of SDMGenerator is good.
- ■ Summary
  - ➢ We have got good reviews about every sensor simulation tendency, but we should show the evidence of the consistency.
  - ➢ The importance of intermediate interface output and the usage of it are agreed.
  - ➢ Implementation of the simulation in various scene is required.

Source : Nihon Unisys, Ltd

International Cooperation and promotions

DIVP® and VIVALDI(German consortium) launched joint project named VIVID from Nov-2020, Targeting to simulation-based AD safety assurance

VIVID project

Key objectives

- Simulation and test chains: Fidelity metrics
- Complementary methods from simple to realistic: SiL, HiL, ViL, FoT
- Multi-sensor platforms: Radar, lidar, camera
- Open interfaces: Scenario generation, sensor and environmental models, co-simulation
- Building a reference architecture => creating a knowledge base

Jointly study toward,,

- How safe is safe enough?
- How realistic is realistic enough?

Key contributors

: VIVALDI

TECHNISCHE UNIVERSITÄT ILMENAU
KIT Karlsruher Institut für Technologie
Hochschule Kempten University of Applied Sciences
TECHNISCHE UNIVERSITÄT DARMSTADT
Mercedes-Benz
Continental
AVL
IPG AUTOMOTIVE
Blickfeld LiDAR / scan your world
DLR

JAMA DIVP

Source : VIVALDI presentation

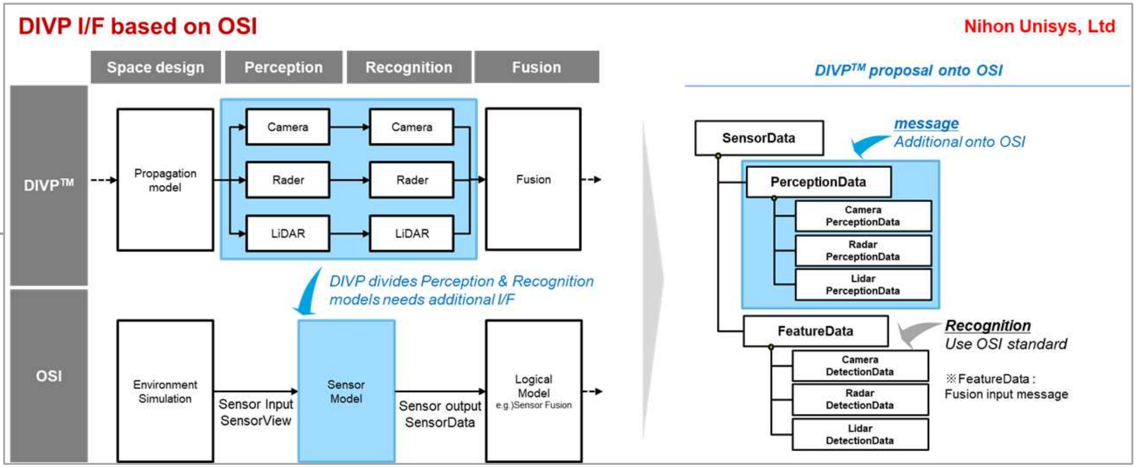
DIVP® key members have contributed to ASAM OpenX activity for I/Fs, Environmental assets structing, ontology technology etc. standardization

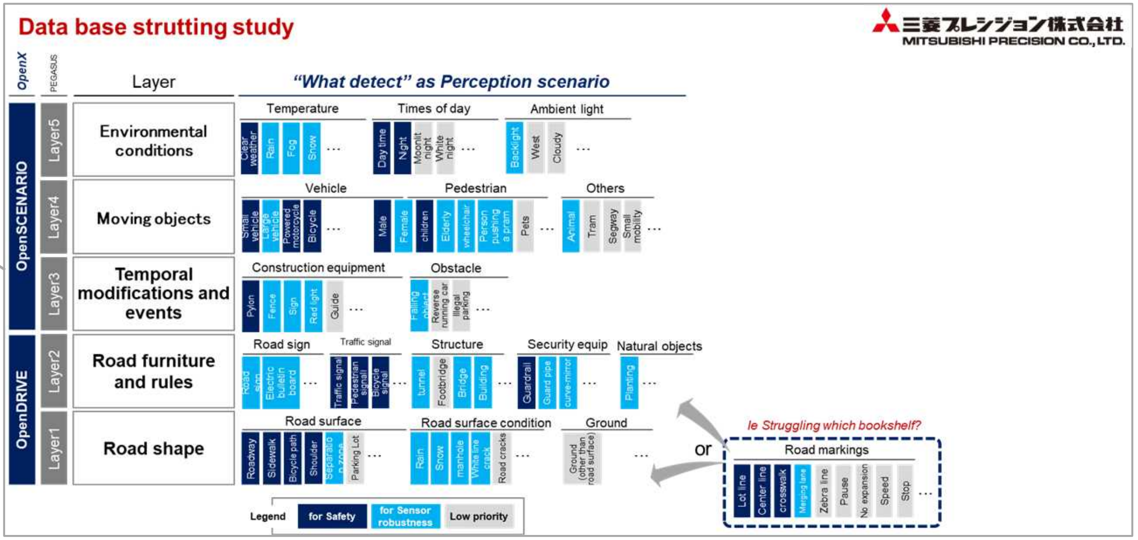
Standardization thru ASAM OpenX activity

OpenX	Contribution
■ OSI (OpenStandardI/F)	Nihon Unisys, Ltd
■ OpenSCENARIO / OpenDRIVE ■ OpenX ontology	三菱プレシジョン株式会社 MITSUBISHI PRECISION CO.,LTD. SOLIZE
■ OpenODD	神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

Proposal of perception output interface

Proposal of the structure of the traffic environment model





Accelerating promotion for expanding user awareness of DIVP® simulation

Promotion

Date	Presentation media	Presentation titles	Presenter
2020.10.20	SIP committee member visit	DIVP® Research outcome	Hideo Inoue
2020.11.10	SIP-adus Workshop 2020	Driving Intelligence Validation Platform	Hideo Inoue
2020.11.13	Workshop for virtual simulation on VIVID	Presentation	Hideo Inoue
2020.11.25	MotorFan illustrated Volume 171, (2021.1.28 published)	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	Hideo Inoue
2020.11.25	VIVID expert workshop, 4th Bilateral expert workshop on connected and automated driving Virtual meeting, German-Japan joint virtual validation methodology for intelligent driving systems	–VIVID Virtual validation –Technological progress	Hideo Inoue
2020.12.10	8th Automotive Functional Safety Conference	Presentation：SIP Phase2 AD: Development of AD validation environment improvement method in virtual space	Hideo Inoue
2021.02.17	6th Automotive Software Frontier 2021	Presentation：SIP Phase2 AD: Development of AD validation environment improvement method in virtual space	Koji Nagase
2021.03.23	[Automotive Technology Association] 14th Automobile Control and Model Division Committee	Presentation：SIP Phase2 AD: Development of AD validation environment improvement method in virtual space；About DIVP® Proj	Hideo Inoue

IPs

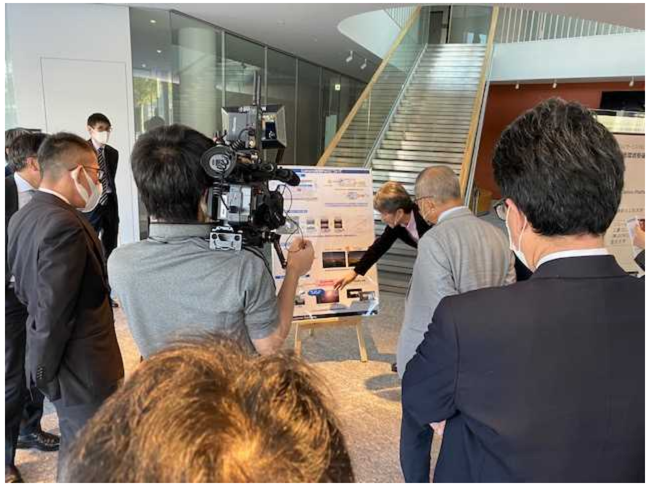
Filing date	Accession Number	Title of the patent, etc. in the application	Applicant
Preparing for filing	-	Driving simulator for validation of on-board cameras	Mitsubishi Precision Corporation School, Geotoku Gakuen
Preparing for filing	-	(Hypothetical) Camera Perception Model Consistency Verification Method	Sony Semiconductor Solutions Corporation

Reported outcome to SIP committee members

Oct-20th SIP committee member visit

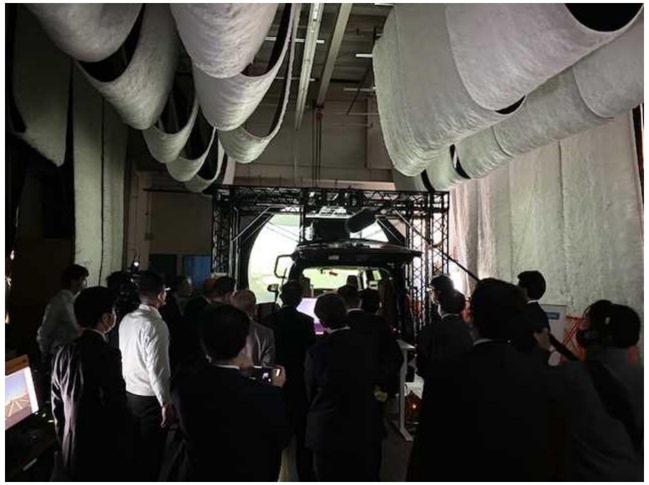
■ Outline

<u>Date and Time</u>: Tuesday, October 20, 2020
<u>Place</u>: Kanagawa Institute of Technology - Advanced Technology Research Institute
<u>Participants</u>: （General）Mr. Sudo,
（Commissioner）Mr. Kozuhata, Mr. Okazaki,
Mr. Shirai,Mr. Fujino, Mr. Kaminoyama, Mr. Kajiwara,
Mr. Igarashi, Mr. Kimishima, Mr. Takenaka, Mr. Hayashi and others
<u>Outline</u>: Visited the research base to deepen the understanding of experts and members of the validation WG.



■ Excerpts from comments from committee members

- ✓ As a second phase of SIP, the introduction of simulation technology for safety validation seems to be SIP, and we expect that it will be possible to develop uniquely in Japan.
- ✓ I would like to see the development that considers risks come to the fore and promote the building of consensus among the people toward the realization of AD.
- ✓ As a benchmark, please check what the United States and Germany are aiming for to promote self-driving, and make sure that the direction is correct.



END

Tokyo Odaiba FOT area → Virtual Community Ground