2020.07.28 AVS symposium. Safety Assurance Session.

Automated Driving Safety Assurance in Japan

Satoshi Taniguchi

Toyota Motor Corporation
JAMA/SIP AD Safety Assurance Lead

AD safety requirements

Safety requirements

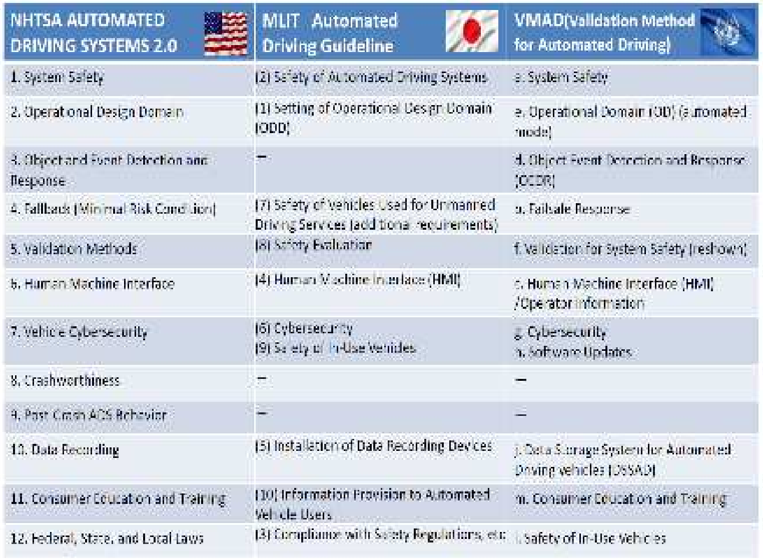
Guidelines on the exemption procedure for the EU approval of Automated Vehicles

Safety requirements: When in the AD mode, the vehicle shall not cause any traffic accidents that are rationally foreseeable and preventable

WP29: Framework document on automated vehicles

Safety vision: AV shall not cause any non-tolerable risk, meaning that, under their operational domain, shall not cause any traffic accidents resulting in injury or death that are reasonably foreseeable and preventable

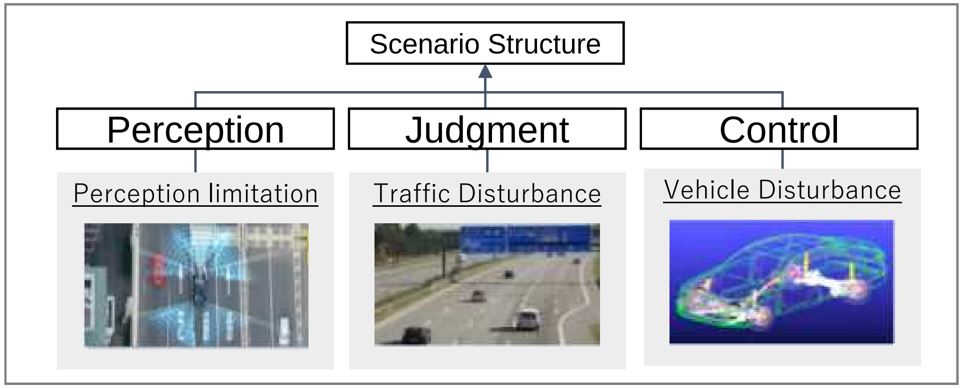
Key safety elements



NHTSA AUTOMATED DRIVING SYSTEMS 2.0	MLIT Automated Driving Guideline	VMAD(Validation Method for Automated Driving)
1. System Safety	(2) Safety of Automated Driving Systems	a. System Safety
2. Operational Design Domain	(1) Setting of Operational Design Domain (ODD)	e. Operational Domain (OD) (automated mode)
3. Object and Event Detection and Response	–	d. Object Event Detection and Response (OEDR)
4. Fallback (Minimal Risk Condition)	(7) Safety of Vehicles Used for Unmanned Driving Services (additional requirements)	b. Failsafe Response
5. Validation Methods	(8) Safety Evaluation	f. Validation for System Safety (reshown)
6. Human Machine Interface	(4) Human Machine Interface (HMI)	c. Human Machine Interface (HMI) /Operator information
7. Vehicle Cybersecurity	(6) Cybersecurity (9) Safety of In-Use Vehicles	g. Cybersecurity h. Software Updates
8. Crashworthiness	–	–
9. Post Crash ADS Behavior	–	–
10. Data Recording	(5) Installation of Data Recording Devices	j. Data Storage System for Automated Driving vehicles (DSSAD)
11. Consumer Education and Training	(10) Information Provision to Automated Vehicle Users	m. Consumer Education and Training
12. Federal, State, and Local Laws	(3) Compliance with Safety Regulations, etc.	i. Safety of In-Use Vehicles

Industry challenge: To develop state-of-the-art engineering products that are fully compatible with these safety requirements and elements.

Standardization and Regulatory context


Scenario Structure
Perception
Judgment
Control
Perception limitation
Traffic Disturbance
Vehicle Disturbance

Regulations for level 3 systems on highways

Regulation
Safety criteria & Test requirements

Regulation

ISO34502 Engineering framework and scenario based approach

Standard
Test Scenario Derivation Process

Standard

OpenDRIVE, OpenSCENARIO, …

Technical Standard
Specification of driving maneuvers and test scenarios.

Technical Standard

Japan White Paper on AD safety assurance

STRATEGY
RESEARCH
STANDARDIZATION

Supporting government research projects

SAKURA
Safety Assurance KUdos for Reliable Autonomous Vehicles

METI
Ministry of Economy, Trade and Industry

SAKURA Objectives

- *Standardized engineering process*
- *Scenario based safety assurance methodology*
- *Scenario database*

DIVP

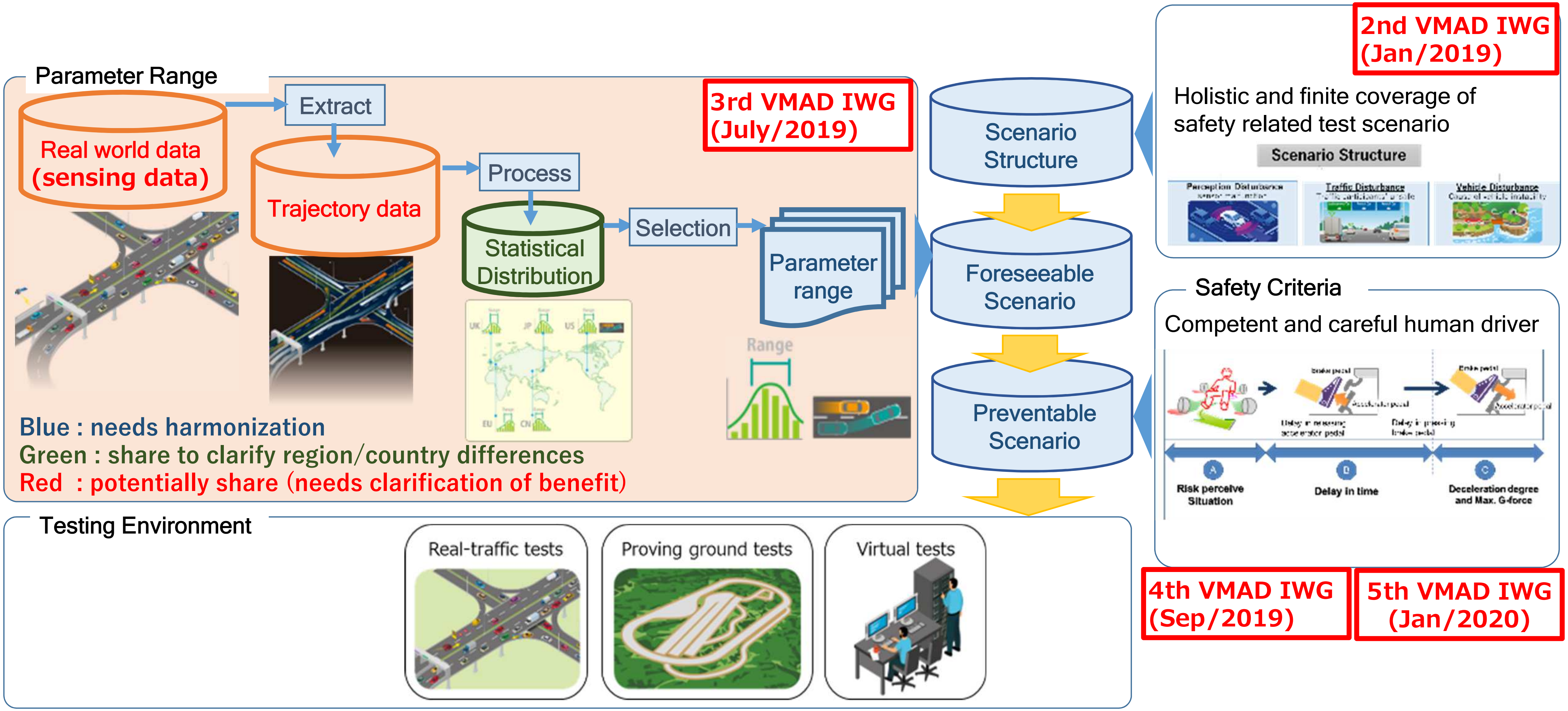
SIP

Cabinet Office

DIVP™ Objectives

- *Open Standard Interface*
- *Reference platform with reasonable verification level*
- *Environment & Sensor paired models based approach*

Japan Proposal to ISO and VMAD



2nd VMAD IWG (Jan/2019)

Holistic and finite coverage of safety related test scenario

Scenario Structure

Perception Disturbance
Traffic Disturbance
Vehicle Disturbance

Parameter Range

3rd VMAD IWG (July/2019)

Real world data
(sensing data)

Extract

Trajectory data

Process

Statistical Distribution

Selection

Parameter range

UK
JP
US
EU
CN
Range

Blue : needs harmonization

Green : share to clarify region/country differences

Red : potentially share (needs clarification of benefit)

Scenario Structure

Foreseeable Scenario

Preventable Scenario

Safety Criteria

Competent and careful human driver

Brake pedal
Accelerator pedal
Delay in releasing accelerator pedal
Delay in pressing brake pedal
A
Risk perceive Situation
B
Delay in time
C
Deceleration degree and Max. G-force

4th VMAD IWG (Sep/2019)

5th VMAD IWG (Jan/2020)

Testing Environment

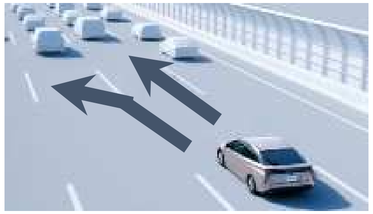
Real-traffic tests

Proving ground tests

Virtual tests

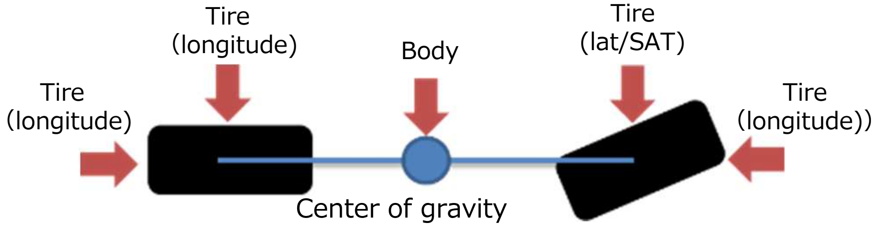
Japan ISO proposal: Scenario Strucutre

Road geometry ✖ Ego-vehicle behavior ✖ Surrounding vehicles location ✖ Surrounding vehicles motion



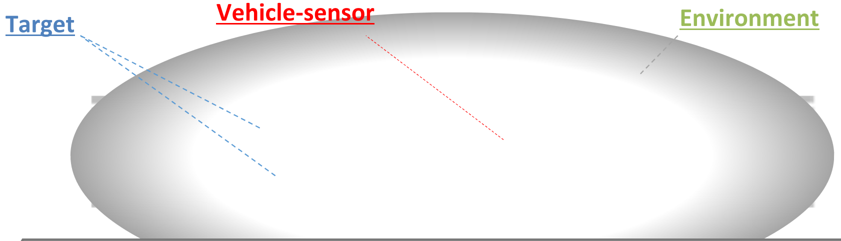
Traffic Disturbance Scenario
(Judgment)

Body input ✖ Tire input


Tire
(longitude)
Tire
(longitude)
Body
Tire
(lat/SAT)
Tire
(longitude))
Center of gravity

Vehicle Stability Scenario
(Control)

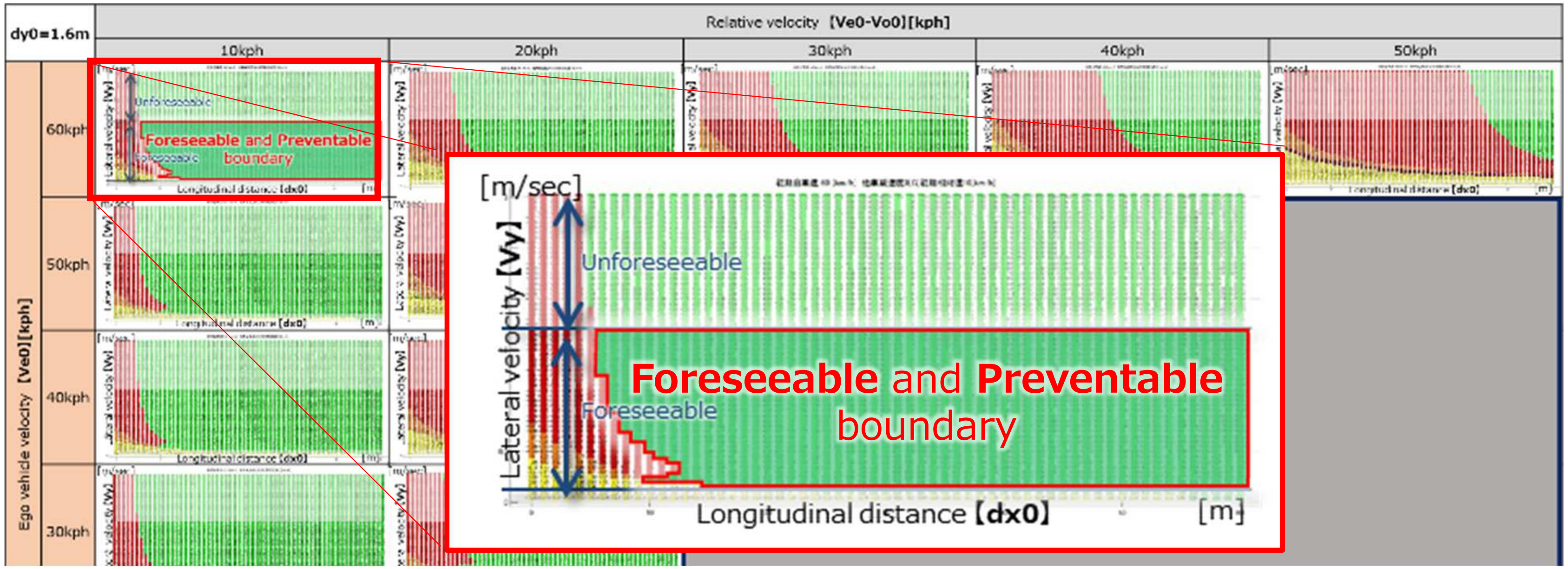
Vehicle-sensor ✖ Environment ✖ Target

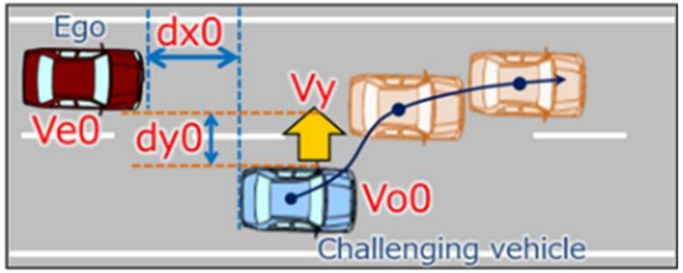

Target
Vehicle-sensor
Environment

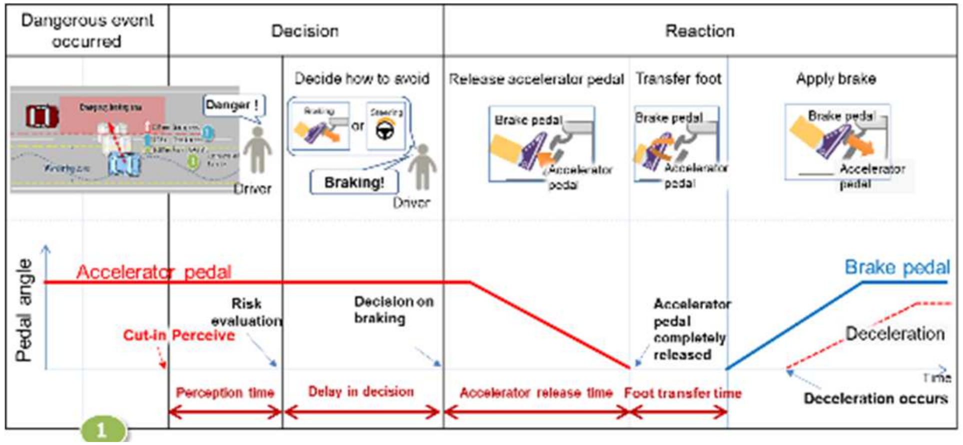
Perception Disturbance Scenario
(Perception)

Japan VMAD proposal: ALKS criteria

Informal document **GRVA-06-02-Rev.4**
6th GRVA, 3 – 4 March 2020

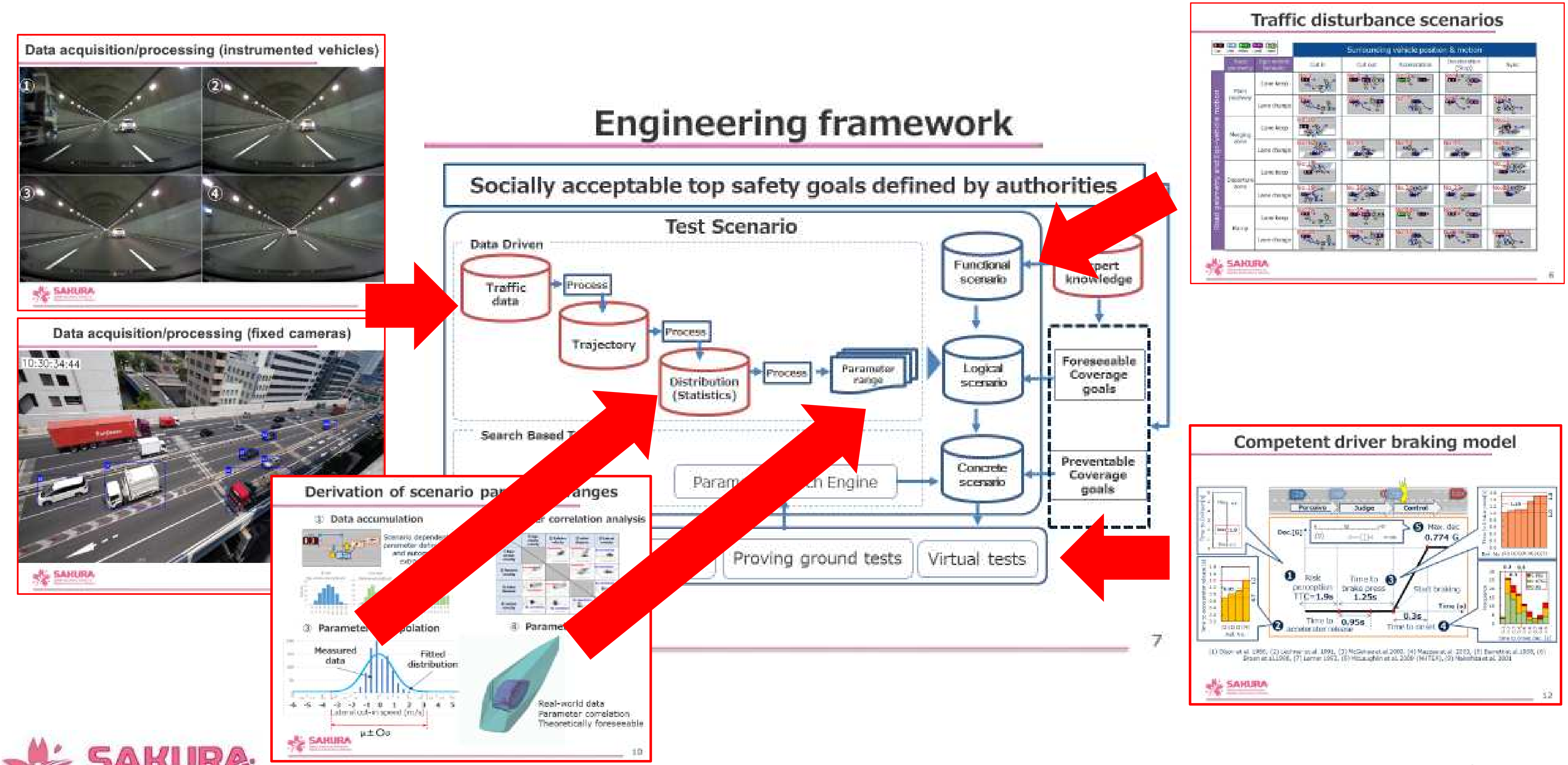



Ego
dx0
Ve0
dy0
Vy
Vo0
Challenging vehicle


Dangerous event occurred
Decision
Reaction
Decide how to avoid
Release accelerator pedal
Transfer foot
Apply brake
Danger !
Driver
or
Braking!
Driver
Brake pedal
Accelerator pedal
Brake pedal
Accelerator pedal
Brake pedal
Accelerator pedal
Pedal angle
Accelerator pedal
Brake pedal
Risk evaluation
Cut-in Perceive
Decision on braking
Accelerator pedal completely released
Deceleration
Time
Perception time
Delay in decision
Accelerator release time
Foot transfer time
Deceleration occurs
1

Competent & careful human driver reference model for ALKS emergency situations

SAKURA Engineering framework research



Data acquisition/processing (instrumented vehicles)

①
②
③
④

Data acquisition/processing (fixed cameras)

10:30:34:44

Engineering framework

Socially acceptable top safety goals defined by authorities

Test Scenario

Data Driven
Traffic data
Process
Trajectory
Process
Distribution (Statistics)
Process
Parameter range
Search Based T
Param
n Engine
Functional scenario
Logical scenario
Concrete scenario
pert knowledge
Foreseeable Coverage goals
Preventable Coverage goals
Proving ground tests
Virtual tests
7

Traffic disturbance scenarios

Surrounding vehicle position & motion
Cut in
Cut out
Acceleration
Deceleration
Sync
Lane keep
Lane change
Merging zone
Departure zone
Ramp
6

Derivation of scenario pa anges

① Data accumulation
r correlation analysis
Scenario depende parameter dat and autom extr
③ Paramete polation
Measured data
Fitted distribution
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5
Lateral cut-in speed (m/s)
μ± Oσ
③ Parame
Real-world data
Parameter correlation
Theoretically foreseeable
10

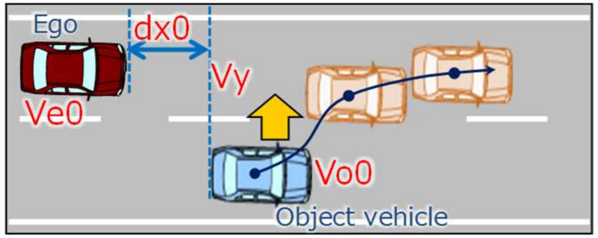
Competent driver braking model

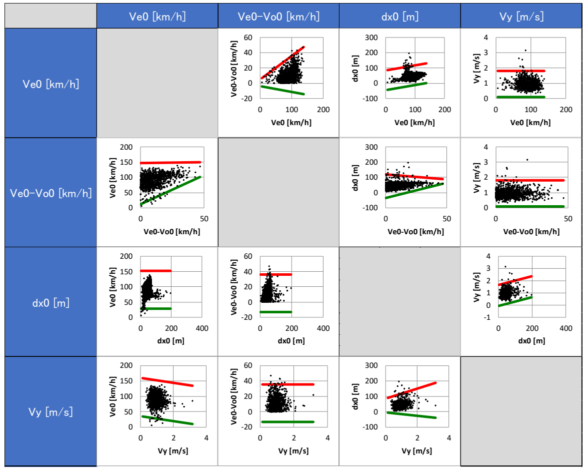
Perceive
Judge
Control
Dec.[G]
❶ Risk perception TTC=1.9s
Time to brake press 1.25s
❸
Start braking
❺ Max. dec 0.774 G
Time (s)
0.3s
❷ Time to accelerator release 0.95s
Time to onset ❹
12

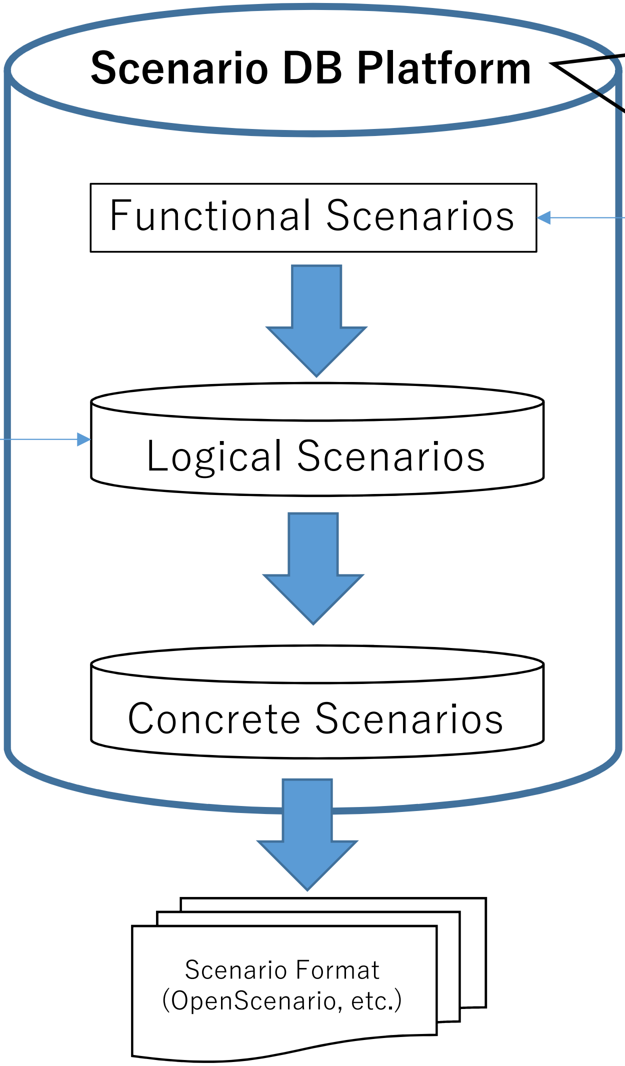
SAKURA scenario database

Parameter range of Scenario

ex) Cut-in


Ego
dx0
Vy
Ve0
Vo0
Object vehicle





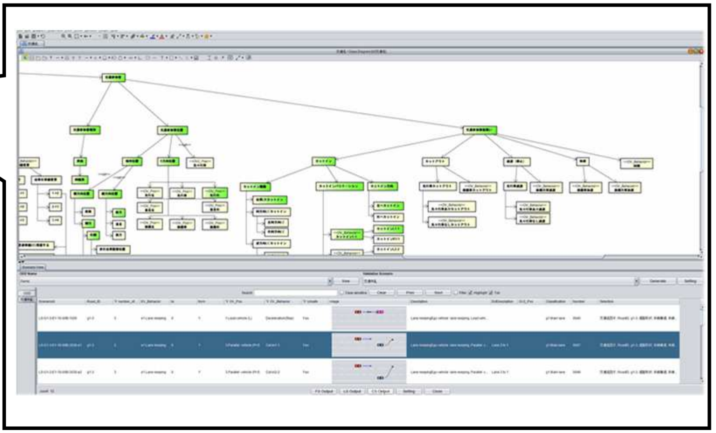
Scenario DB Platform

Functional Scenarios

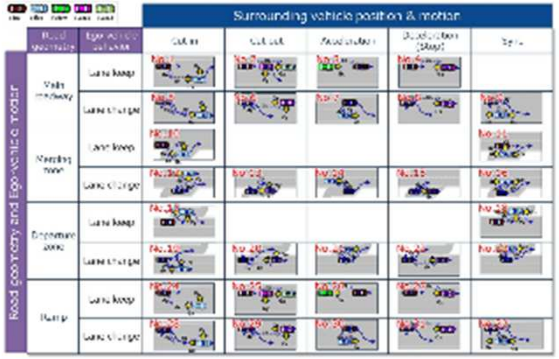
Logical Scenarios

Concrete Scenarios

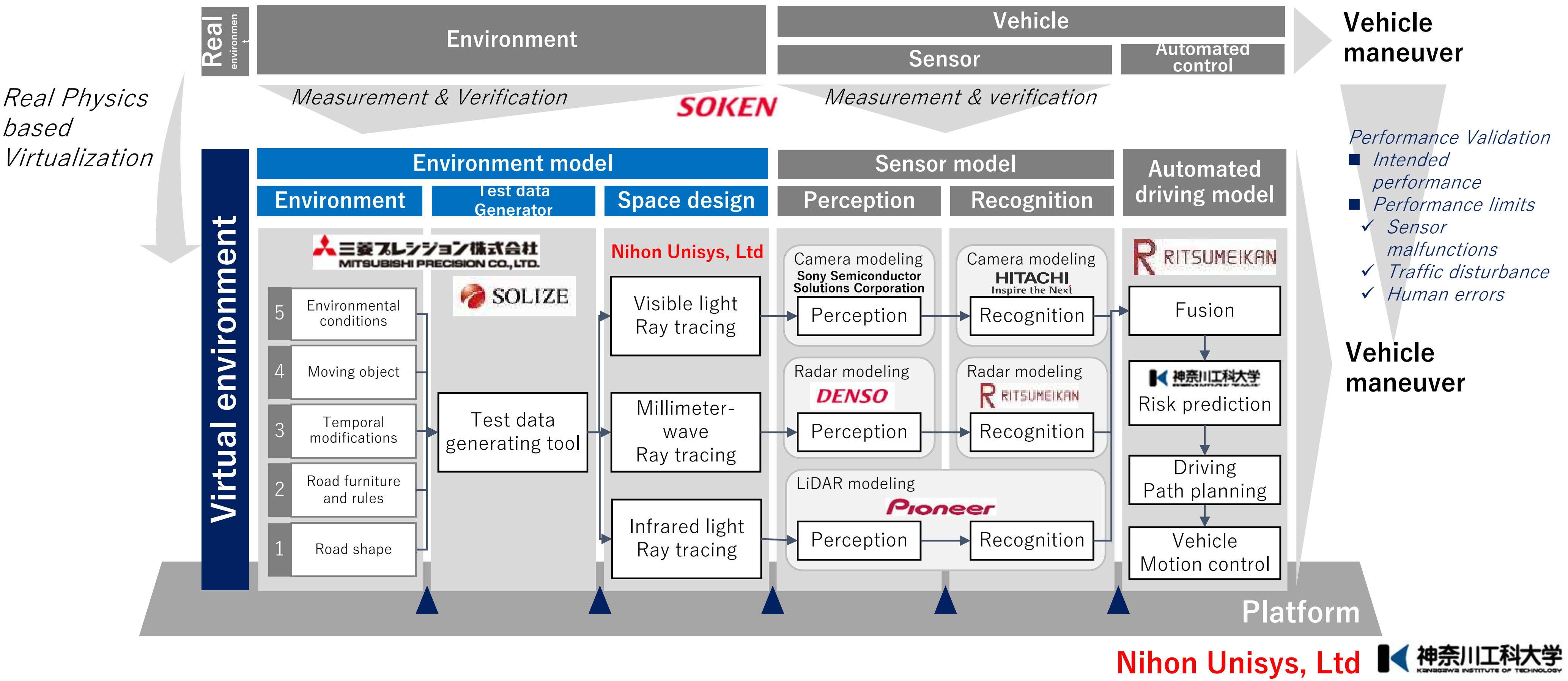
Scenario Format
(OpenScenario, etc.)



Highway scenarios


Surrounding vehicle position & motion
Road geometry and Ego-vehicle motion
Cut in
Cut out
Lane keep
Lane change
Ramp

DIVP^{TM} project design



Real Physics based Virtualization

Real environment

Environment

Vehicle

Sensor

Automated control

Measurement & Verification

SOKEN

Measurement & verification

Vehicle maneuver

Virtual environment

Environment model

Environment

Test data Generator

Space design

Sensor model

Perception

Recognition

Automated driving model

MITSUBISHI PRECISION CO., LTD.

5 Environmental conditions

4 Moving object

3 Temporal modifications

2 Road furniture and rules

1 Road shape

SOLIZE

Test data generating tool

Nihon Unisys, Ltd

Visible light Ray tracing

Millimeter-wave Ray tracing

Infrared light Ray tracing

Camera modeling

Sony Semiconductor Solutions Corporation

Perception

Camera modeling

HITACHI Inspire the Next

Recognition

Radar modeling

DENSO

Perception

Radar modeling

RITSUMEIKAN

Recognition

LiDAR modeling

Pioneer

Perception

Recognition

RITSUMEIKAN

Fusion

神奈川工科大学

Risk prediction

Driving Path planning

Vehicle Motion control

Performance Validation

- *Intended performance*
- *Performance limits*
  - ✓ *Sensor malfunctions*
  - ✓ *Traffic disturbance*
  - ✓ *Human errors*

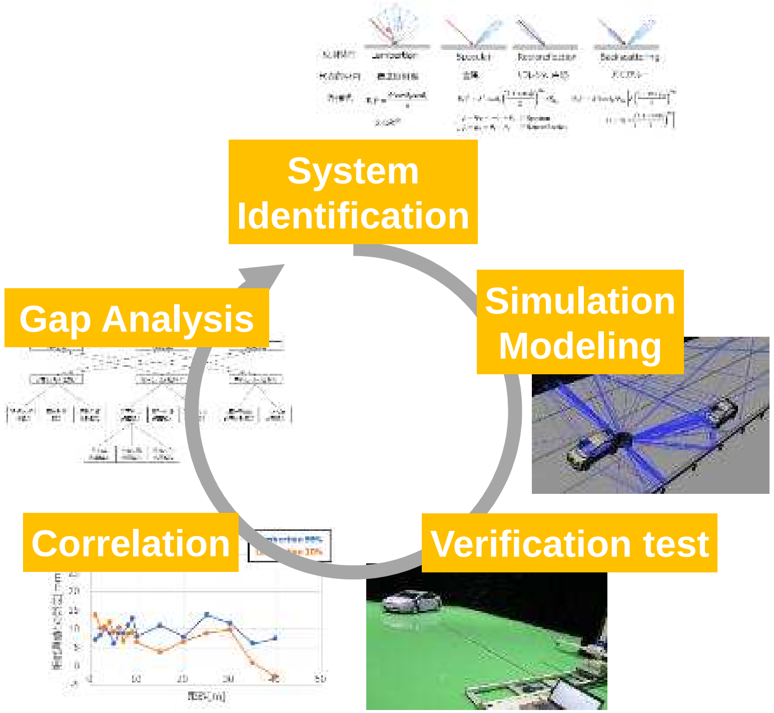
Vehicle maneuver

Platform

Nihon Unisys, Ltd 神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY

DIVP$^{\mathrm{TM}}$ physical model framework

Real physics based approach



System Identification

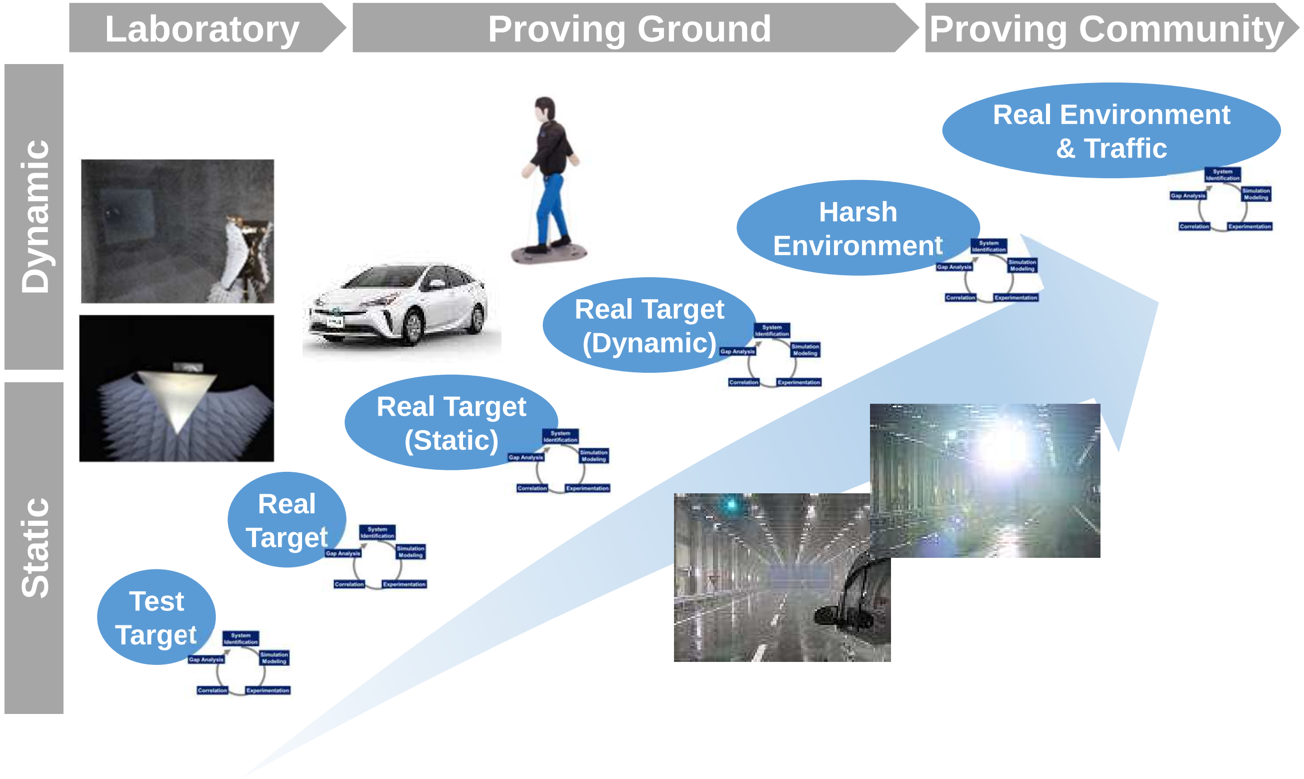
Simulation Modeling

Verification test

Correlation

Gap Analysis

Enhancement roadmap



Laboratory

Proving Ground

Proving Community

Dynamic

Static

Test Target

Real Target

Real Target (Static)

Real Target (Dynamic)

Harsh Environment

Real Environment & Traffic

DIVP^{TM} focus on perception challenges

Difficult for Sensor detection

Black jacket

Group moving objects

Card board

Wet surface

Affects for light / millimeter wave propagation

Night

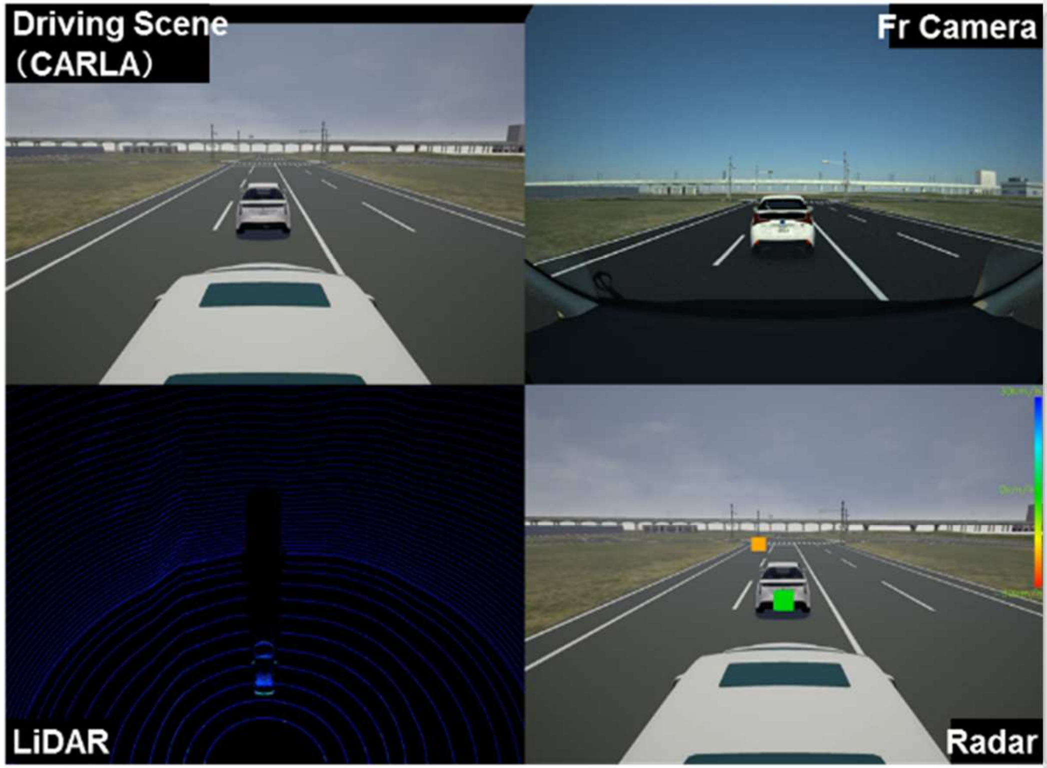
Millimeter wave Multi-path

Rain

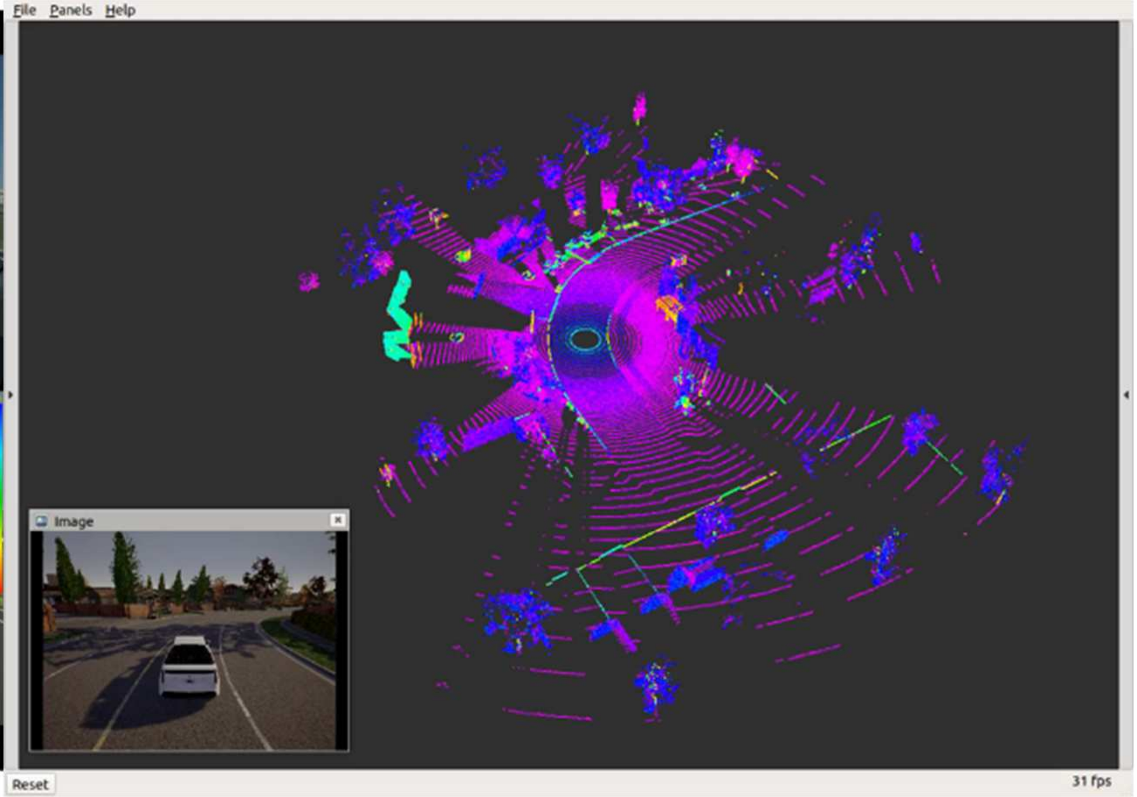
Sun light, Backlit

Sensor integration and output precision verification

- 3-sensor output


Driving Scene
(CARLA)
Fr Camera
LiDAR
Radar

- LiDAR output


File
Panels
Help
Image
Reset
31 fps

Summary

Safety Principle

Audit Pillar

Safety by Design

Documentation structure in accordance with
-ISO21447 SOTIF
-ISO26262 Functional Safety, etc

Testing Pillar

Safety by V&V

Scenario Structure

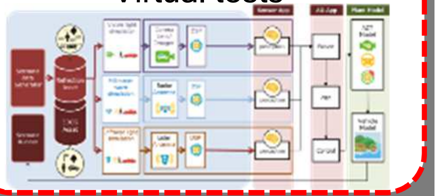
Scenario base approach
- ISO TC22/SC33/WG9

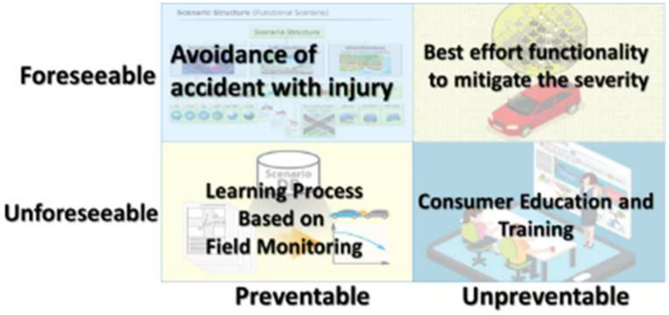
Testing Environment

Real-traffic tests

Proving ground tests

Virtual tests





	Preventable	Unpreventable
Foreseeable	Avoidance of accident with injury	Best effort functionality to mitigate the severity
Unforeseeable	Learning Process Based on Field Monitoring	Consumer Education and Training

Willing to collaborate with research, industry, standardization and regulatory institutions, towards joint efforts to ensure a safe automated driving global society

Thank you!

satoshi_taniguchi_ad@mail.toyota.co.jp