Towards global AD Safety Assurance

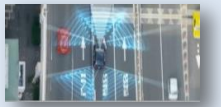
JAMA AD safety assurance WG
Satoshi Taniguchi

1. Need for innovative AD safety assurance methodologies
2. Current global efforts by Japanese industry and safety principles
3. Proposed safety validation methods by Japanese safety experts
4. Need for harmonization and consistency for all automation levels and all operational domains

Need for innovative safety assurance methodologies

AD system challenges

Perception disturbances



- Weather
  - Rain

  - Fog

- Road
  - Deteriorated Lane marks

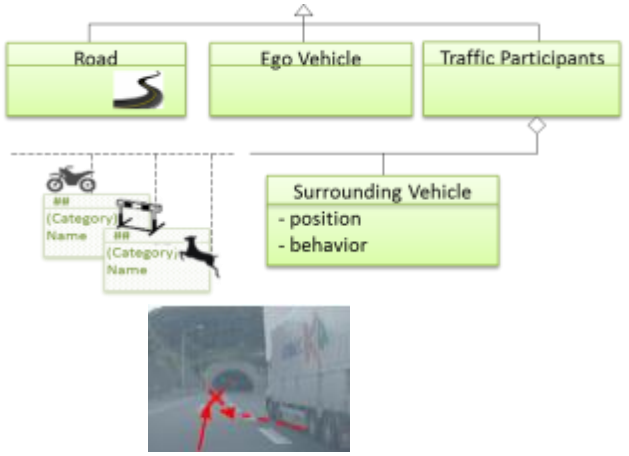
  - Roadworks

- Road Users
  - Traffic Marshals

  - Emergency Vehicles

Traffic Disturbances

- Sudden Invasion



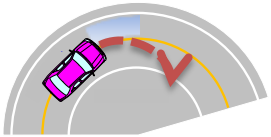
- Blind spots
  - Road related

  - Vehicle related

Vehicle Disturbances

- Tire Input
  - Pothole

  - Pronounced curves

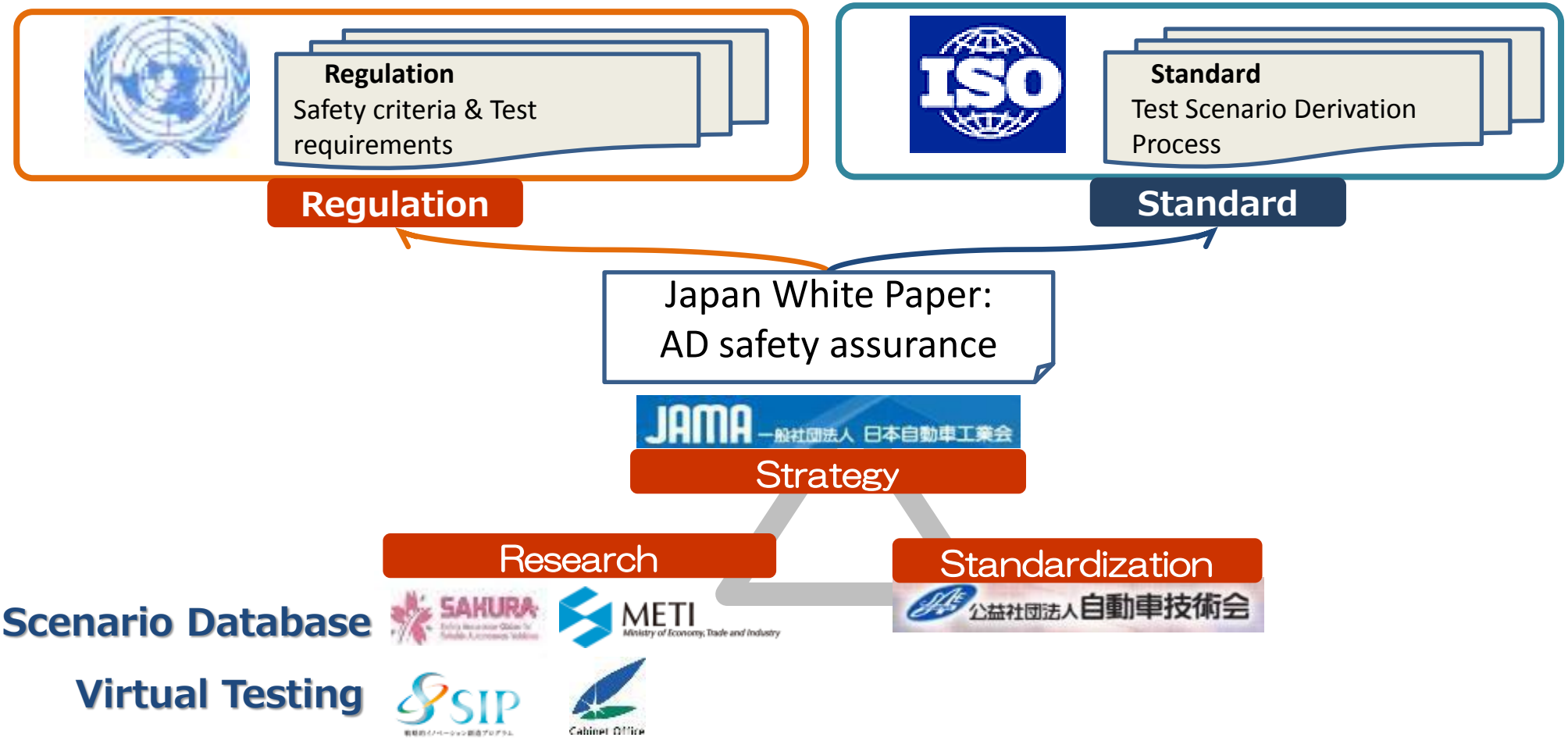


- Body Input
  - Side Wind

Ensuring and proving AD safety is a major industry challenge and traditional safety approaches based on long driving distances and limited physical tests are insufficient. **Innovative safety assurance methodologies are needed.**

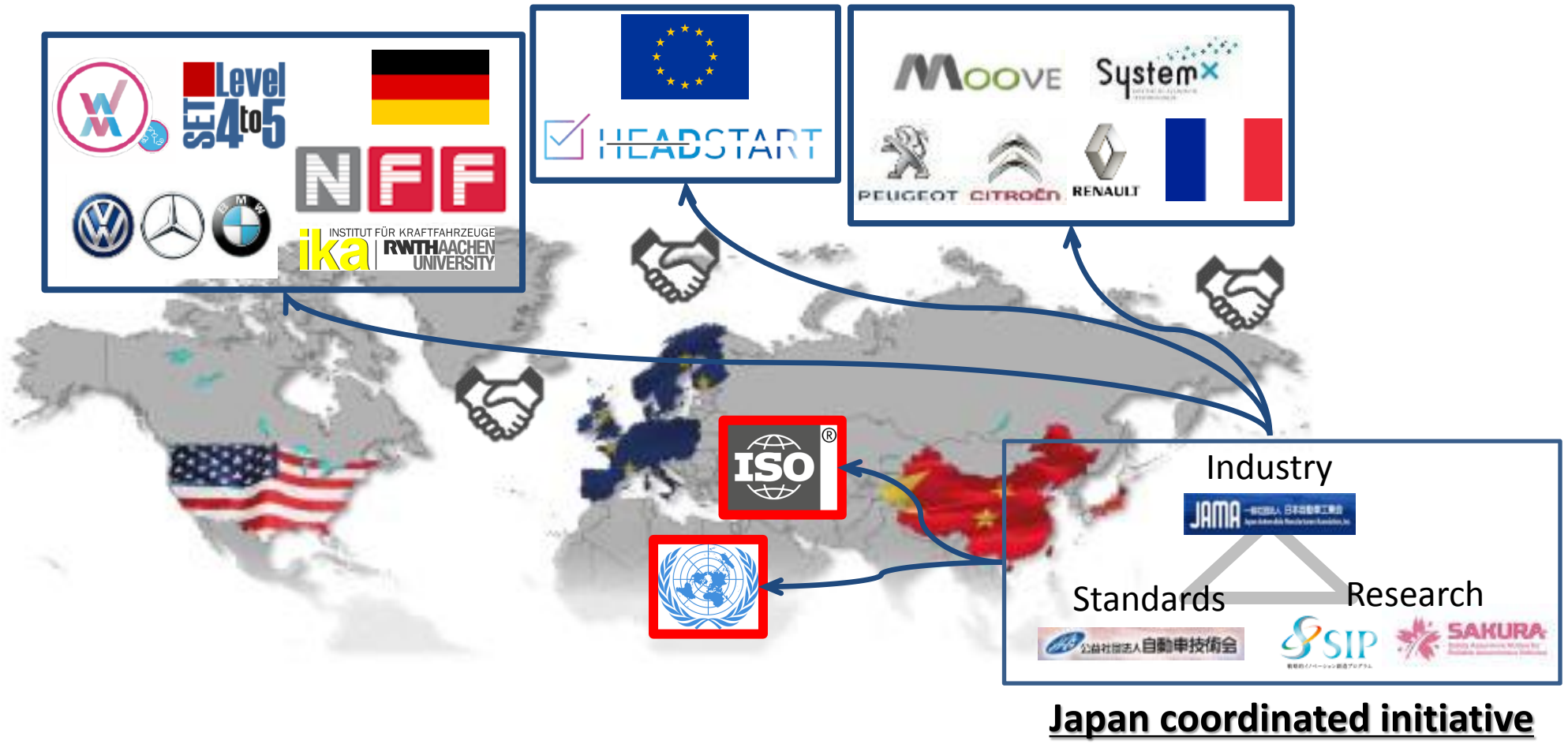
1. Need for innovative AD safety assurance methodologies
2. Current global efforts by Japanese industry and safety principles
3. Proposed safety validation methods by Japanese safety experts
4. Need for harmonization and consistency for all automation levels and all operational domains

Japan coordinated efforts for global regulations and standardization



Japanese industry and authorities are closely working to develop safety validation methodologies, tools, processes and databases that support the development of national and international regulations and standards.

Global collaborative research efforts by the Japanese industry



Japan coordinated initiative

We are deploying a global collaborative research plan involving a number of key collaborators to develop consensus driven approaches

Safety Assurance Standard Landscape

2 Safety Process (ISO/SC32/WG8; SOTIF)

Project Lead

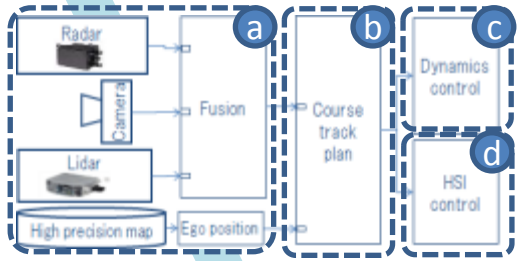
1 Safety Validation(ISO/SC33/WG9)

Project Lead

ODD/DDT

SAKURA

Test Scenario for safety validation

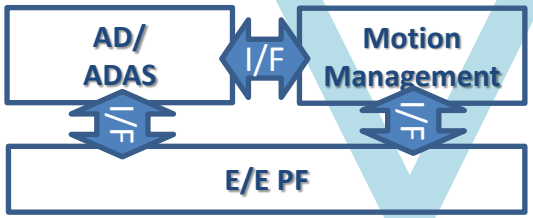


a. Reception limitation
b. Traffic disturbance
c. Vehicle disturbance
d. Driver misuse

3 ISO/SC31/WG9(Sensor IF)

Project Lead

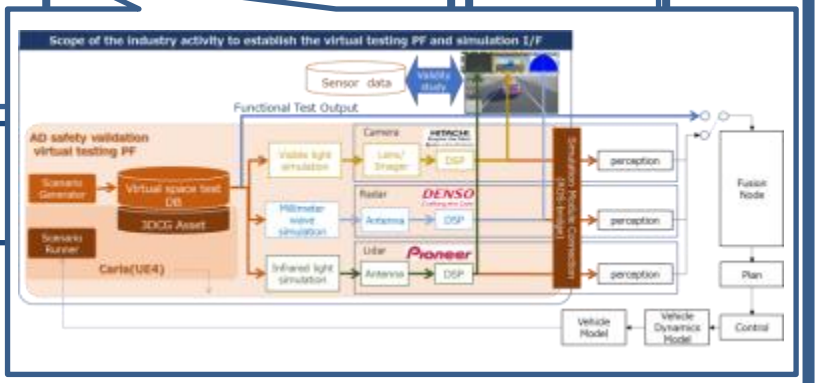
Standard Architecture IF for efficient Supply chain



4 Virtual Testing Simulation IF(ISO/SC33/WG11)

Project Lead

	Virtual Testing	PG test	Public road test
a. Perception malfunction	SIP		
b. Traffic disturbance			
c. Vehicle disturbance			



Safety assurance standards are being developed actively

Global authority driven 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	l. 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.

Safety principles and corresponding engineering framework

ADS, under their ODD, shall not cause any traffic accidents resulting in injury or death that are rationally foreseeable and preventable

Preliminary proposed by NHTSA and predominantly adopted by UN VMAD

Safety Principle

Key safety elements

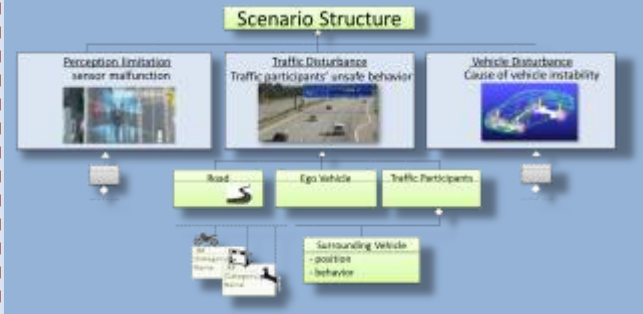
Safety by Design

Safety Documentation

-ISO21447 SOTIF
-ISO26262 Functional Safety
…

Safety by V&V

Validation method



Testing Environment

SAKURA

SIP

A comprehensive safety assurance methodology and corresponding virtual testing environment are the key.

1. Need for innovative AD safety assurance methodologies
2. Current global efforts by Japanese industry and safety principles
3. Proposed safety validation methods by Japanese safety experts
4. Need for harmonization and consistency for all automation levels and all operational domains

Ongoing discussion scheme in Japan for UN proposals

Safety requirement

UN EU JP

AV, under their OD, shall not cause any traffic accidents resulting in injury or death that are rationally foreseeable and preventable

Discussion points in VMAD

(A) Foreseeable: empirically predictable scenario w.r.t observed field data

(B) Preventable: No illegal and No extreme conditions

Output of IWG

Validation method

Considered validation methods

Track tests | Simulation | On road tests

Test scenario

Selected scenario for certification

Iteration Process

Field data

Accident taxonomy

Traffic monitoring data

Substantiation

Scenario Structure (Functional Scenario)

All possible traffic scenario in the ODD

(A)

Foreseeable scenario (Logical Scenario)

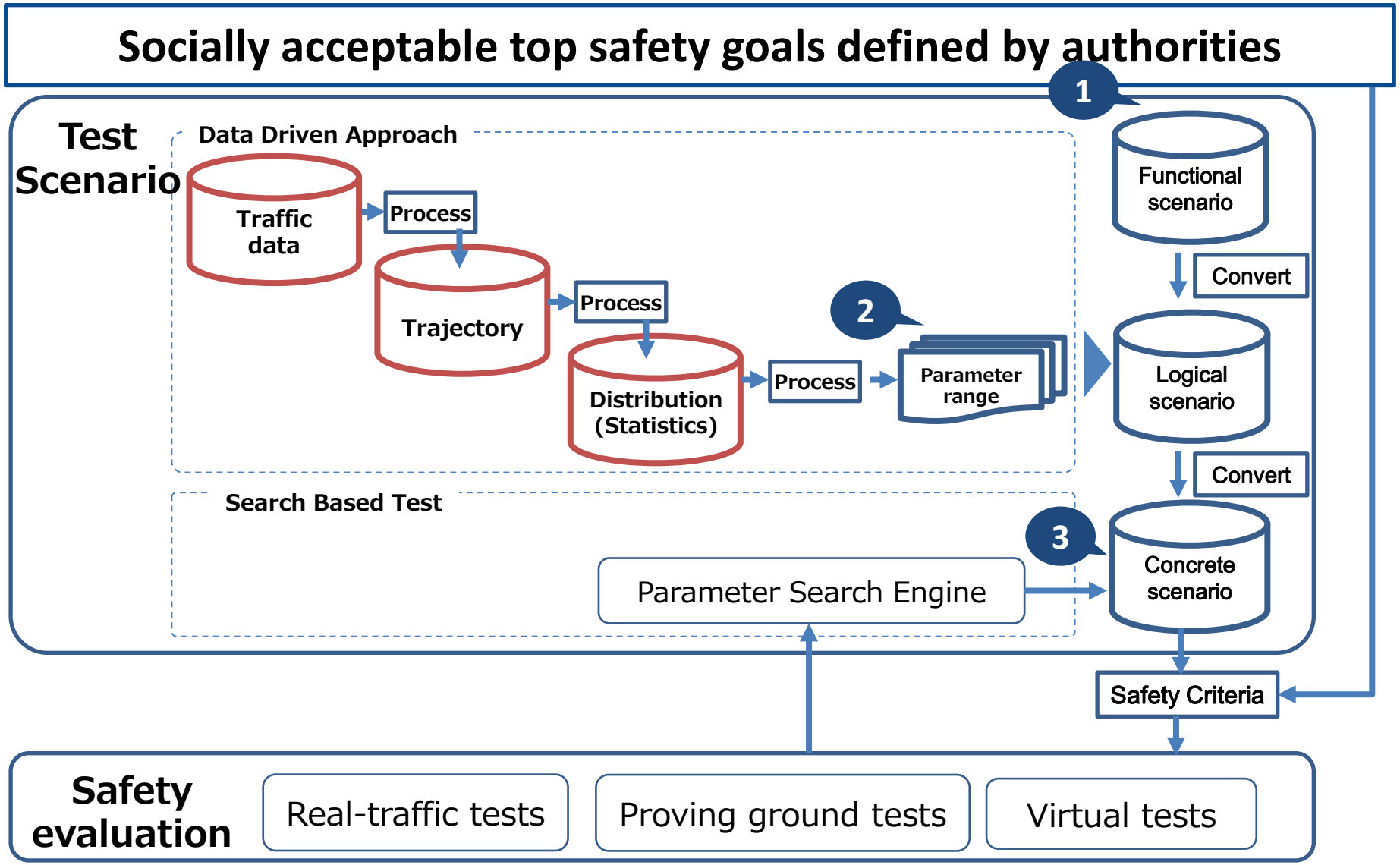
Scenario structure with realistic parameter range

(B)

Preventable scenario

Test Scenario Catalogue (No illegal and No extreme conditions)

Development of traffic disturbance scenarios



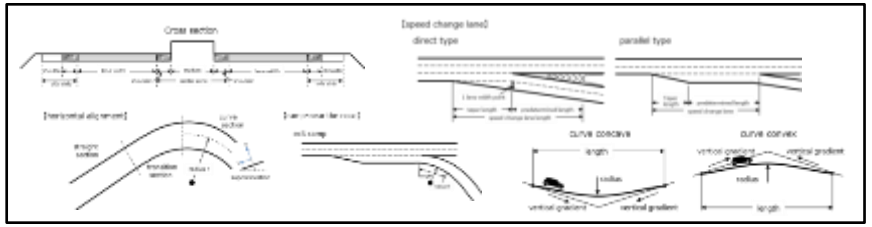
Key items: ① scenario structure, ② parameter ranges, ③ acceptance criteria.

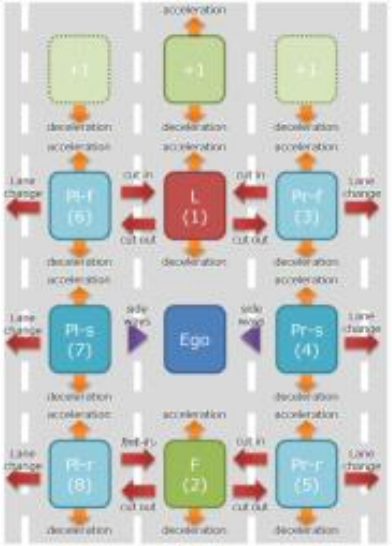
Traffic disturbance scenario structure

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

		Ego-vehicle behavior	
		Lane keep	Lane change
Road geometry	Main roadway	Free Driving Following	Lane change Overtaking
	Merge	Merging in front	Merge
	Departure	---	Branch
	Ramp	Following Free Driving	Lane change Overtaking

Road Structure Ordinance





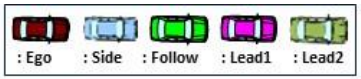
8+1 locations

Surrounding vehicle locations and motions

Surrounding vehicle location	Cut in	Cut out	Accel.	Decel.	Sync
1. Lead		○		○	
2. Follow			○		
3. Parallel	○			○	
4. Parallel	○				○
EGO vehicle					
5. Parallel	○		○		
6. Parallel	○			○	
7. Parallel	○				○
8. Parallel	○		○		

Scenarios developed by systematic analysis and classification of different combinations of road geometry, ego-vehicle behaviour, and surrounding vehicles locations and motion

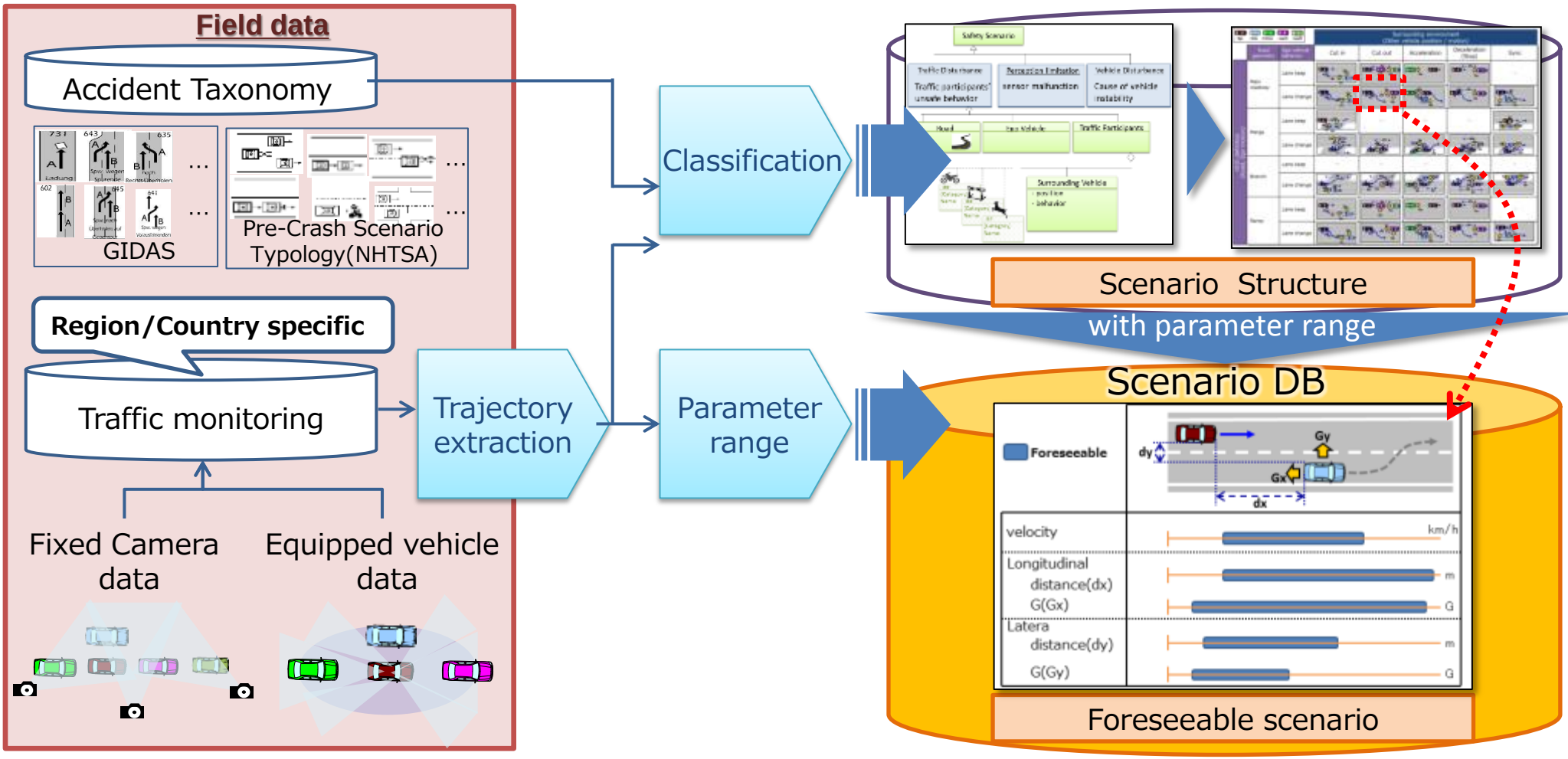
Traffic disturbance scenario structure



Road geometry and Ego-vehicle motion	Road geometry	Ego-vehicle behavior	Surrounding vehicle position & motion: Cut in	Cut out	Acceleration	Deceleration (Stop)	Sync
	Main roadway	Lane keep	No.1	No.2	No.3	No.4	
		Lane change	No.5	No.6	No.7	No.8	No.9
	Merging zone	Lane keep	No.10				No.11
		Lane change	No.12	No.13	No.14	No.15	No.16
	Departure zone	Lane keep	No.17				No.18
		Lane change	No.19	No.20	No.21	No.22	No.23
	Ramp	Lane keep	No.24	No.25	No.26	No.27	
		Lane change	No.28	No.29	No.30	No.31	No.32

32 well organized functional scenarios out from the proposed structure

Scenario completeness verification and parameter ranges



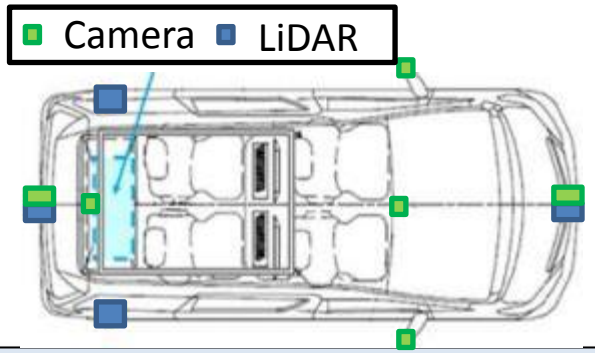
Accident data and traffic monitoring data applied to evaluate the completeness of the scenario structure and to define parameter ranges for each scenario

Traffic data collection in Japan

Ongoing

Data Source	TUAT Driving Recorder (~2018~)	JAMA Driving Recorder (2008)	Driving Database (2017)	On road Recognition Database (2017)	Instrumented Vehicles (2018~)	Fixed Camera (2018~)
Parameter available Video only visible Not recorded	Ego	Ego	Ego	Ego	Ego	Ego

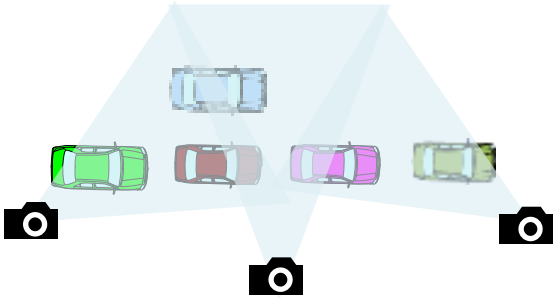
Instrumented vehicles

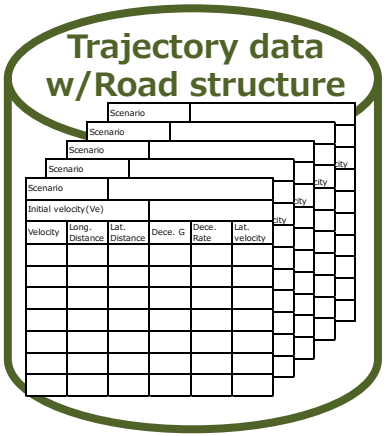


Fixed cameras

Ongoing data acquisition by third party institutions using instrumented vehicles and fixed cameras over safety critical sectors in motorways

Traffic data accuracy evaluation





Fixed camera

Video data output

Reference

High precision GPS Car

Object detection library

Detection & Tracking → Trajectory generation

Fixed camera value (x, y)

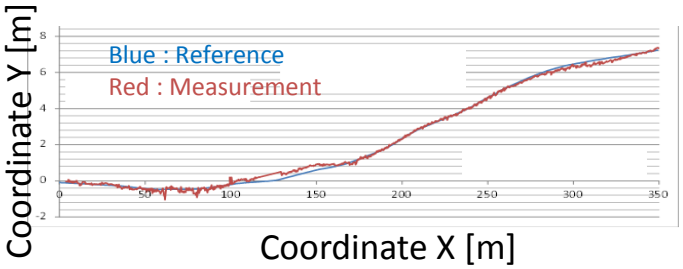
Coordination convert → Precision comparison

Reference value (x, y)

Data processing

Accuracy verification

Fixed camera and reference data (X-Y)

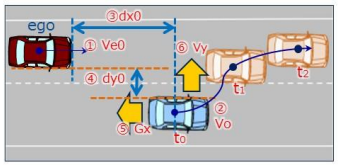


Verification of the accuracy of the collected traffic data, extraction of the vehicle trajectories and classification according to the scenario structure.

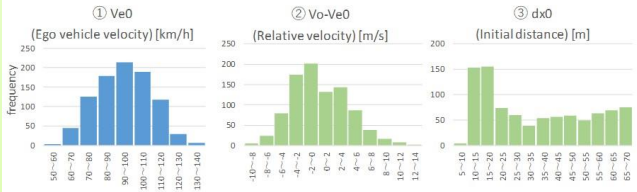
Derivation process of foreseeable scenarios

Driving data processing

Traffic data → Extract → Trajectory + road structure data



Scenario dependent parameter definition and automatic extraction

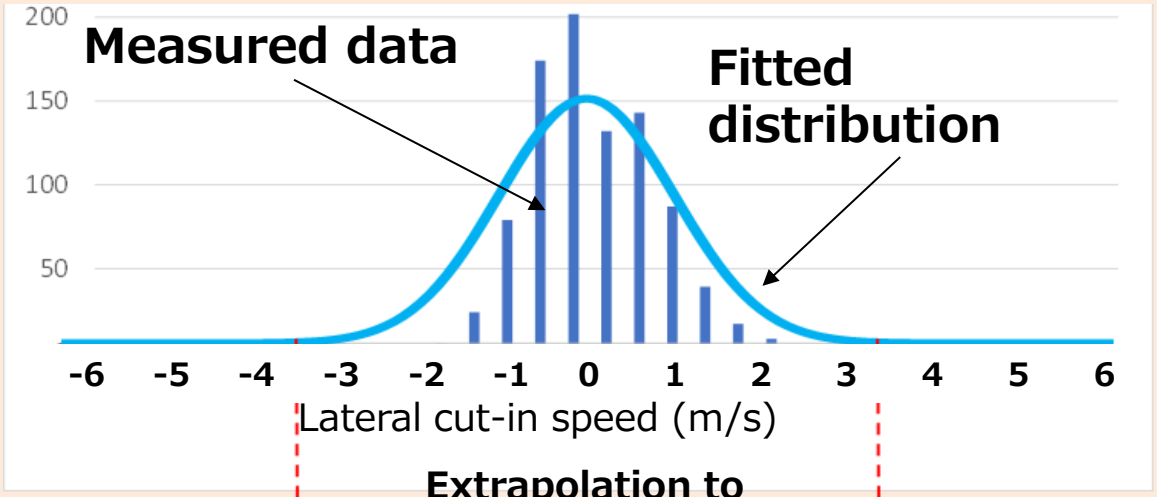


Analysis and parameter selection

Statistical distribution of trajectory parameters → Parameter Selection

Analysis

Scenario structure → Foreseeable → Scenario DB

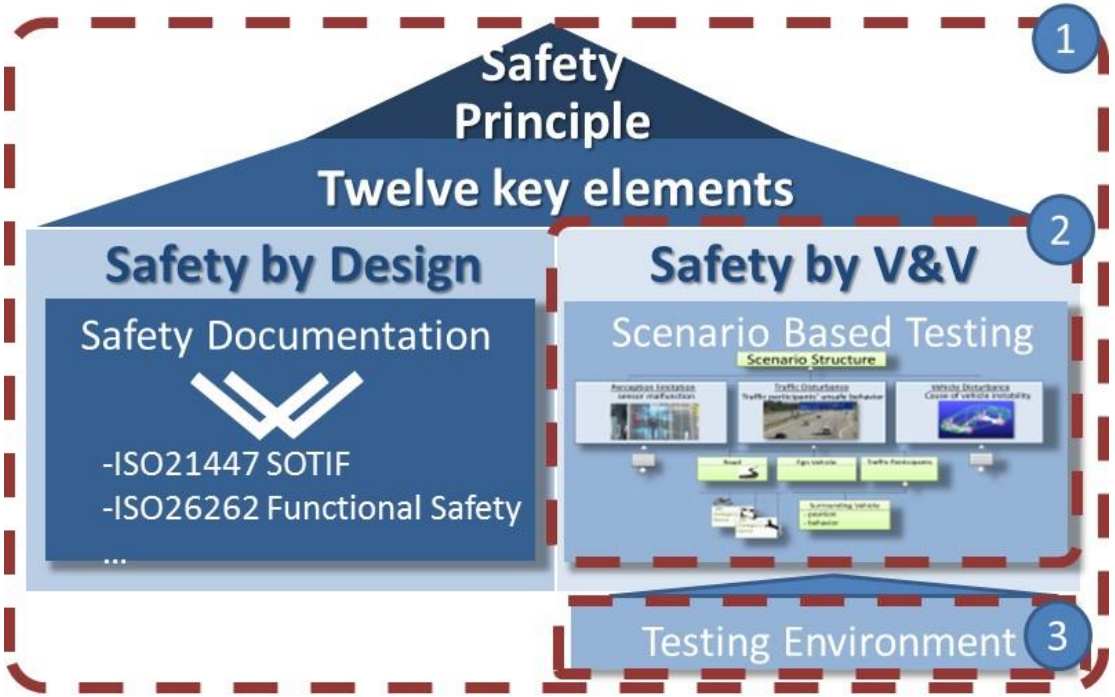


Consensus based rules to process and analyze real-world data, as well as to define corresponding foreseeable parameter ranges

1. Need for innovative AD safety assurance methodologies
2. Current global efforts by Japanese industry and safety principles
3. Proposed safety validation methods by Japanese safety experts
4. Need for harmonization and consistency for all automation levels and all operational domains

Summary

- ✓ The Japanese industry and authorities are closely working to develop safety validation methodologies, tools, processes and databases to support the development of national and international regulations and standards.
- ✓ We are deploying a global collaborative research plan involving a number of key collaborators to develop consensus driven approaches, and we are willing to expand these collaborations.



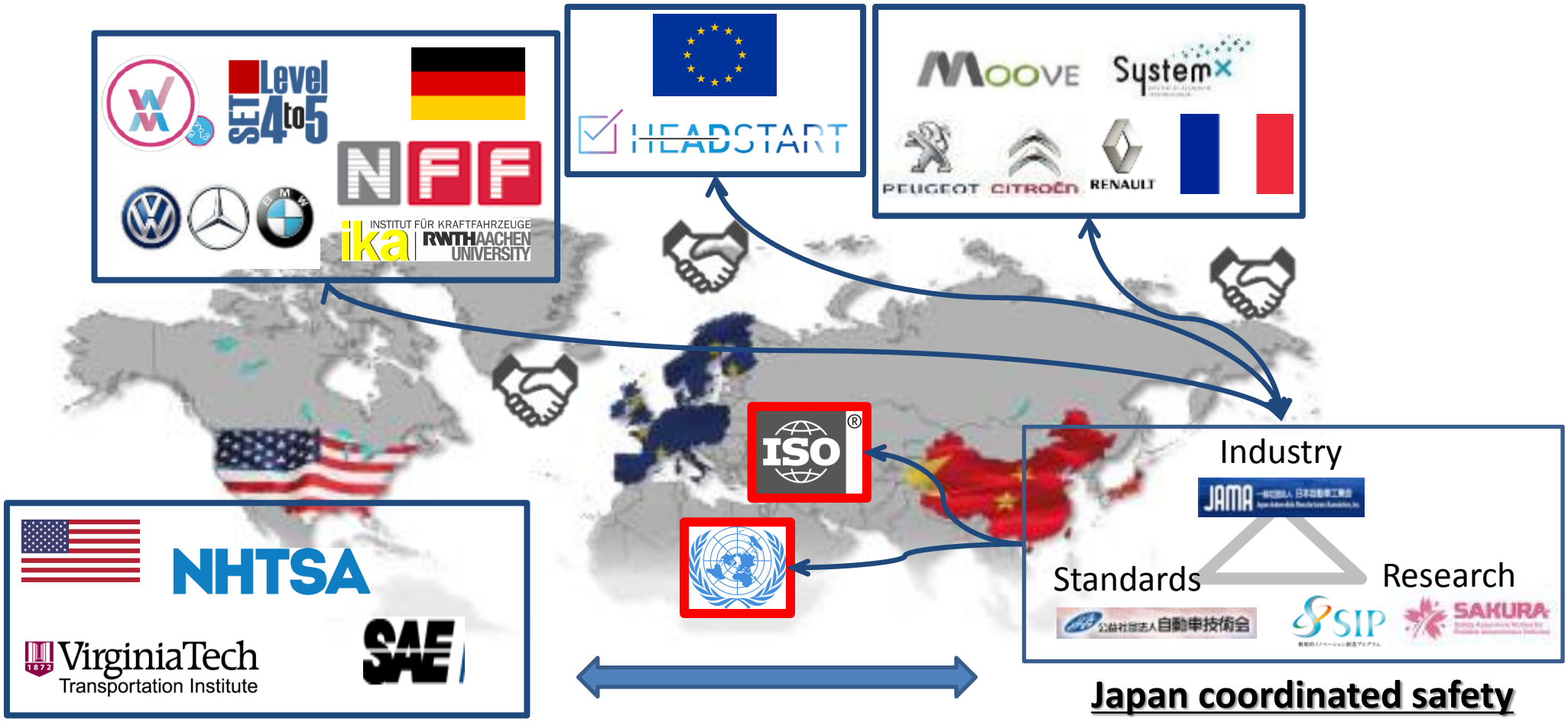
Main collaborative topics:

1. Safety Argumentation
2. Scenario Structure/Databaase
3. Tool/Simulation

Coordinated proposals

- UN/GRVA/VMAD
- ISO/TC22/SC33/WG9
- Others?

Global collaborative research effort by the Japanese industry



Japan coordinated safety assurance initiatives

12nd -14th/Nov at Tokyo

Thank you!

satoshi_taniguchi_ad@mail.toyota.co.jp

SIP

Cabinet Office