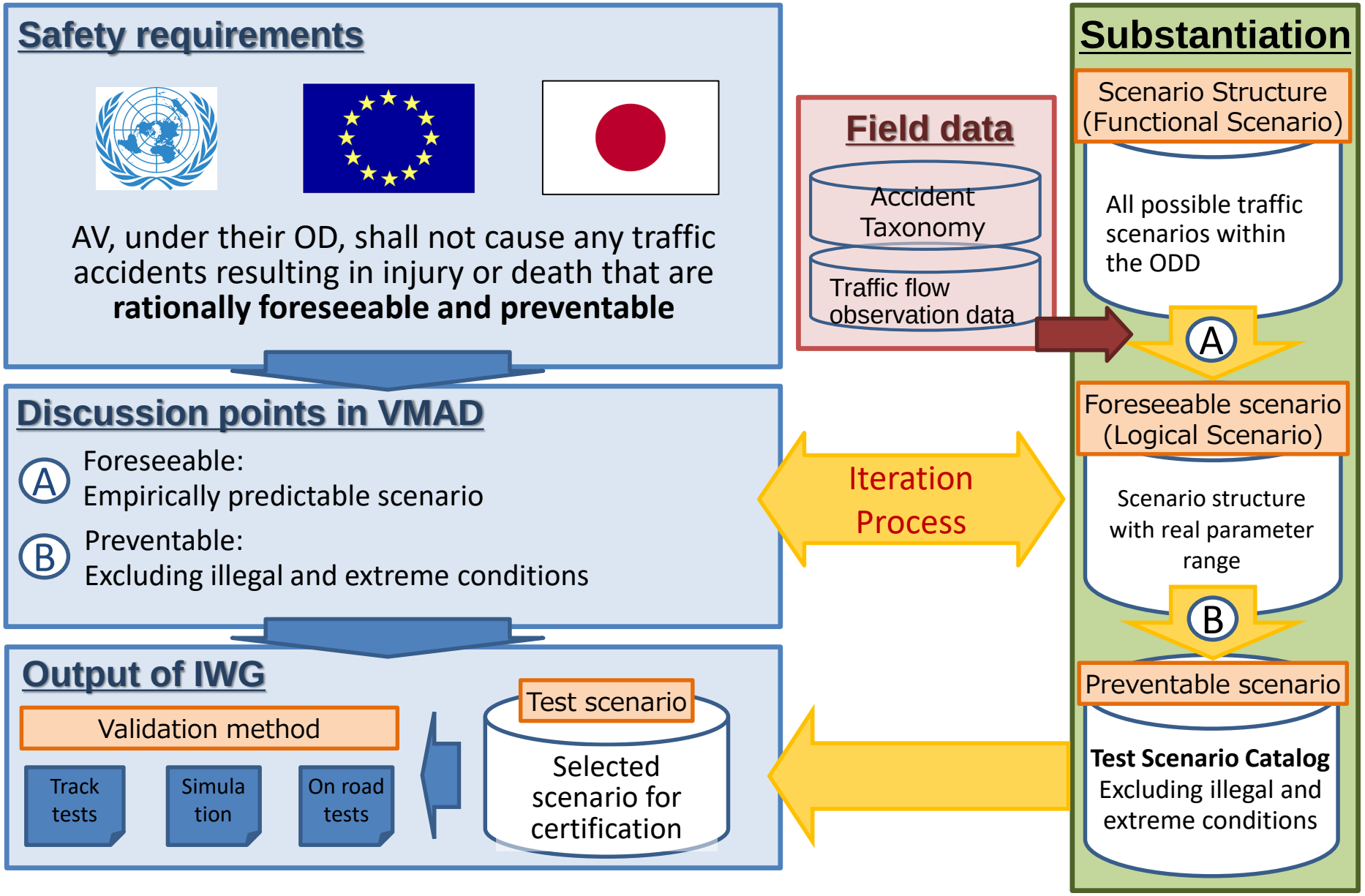
19.06.12, HEADSTART Expert Network Workshop
Eindhoven, The Netherlands

AD Safety Assurance Methodology

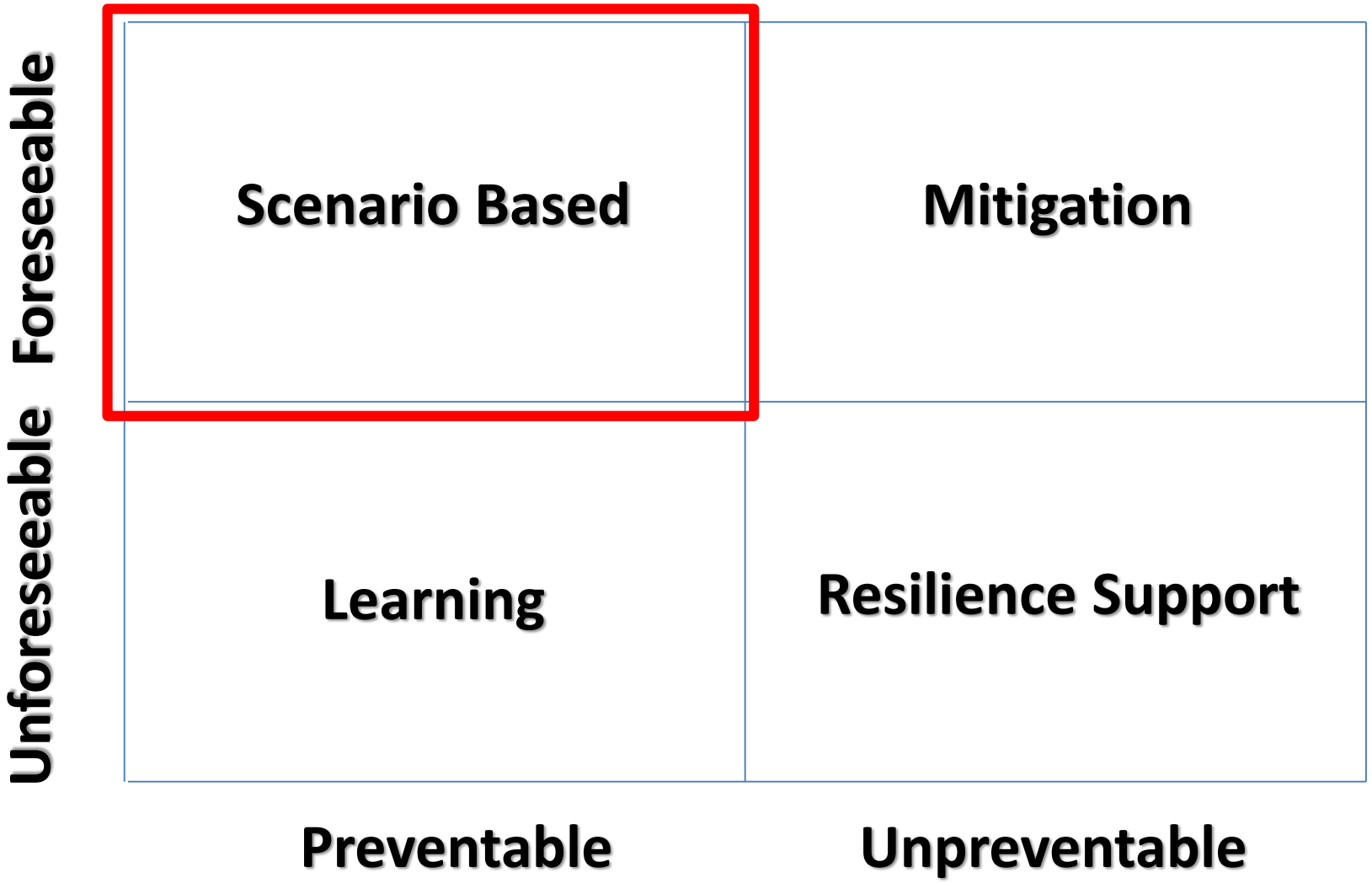
JAMA AD safety Assurance WG, chair
Toyota Motor Corporation
Satoshi Taniguchi

JARI AD safety standardization group, manager
Jacobo Antona-Makoshi PhD.

Certification Test Scenario Derivation Process



Comprehensive approach to safety



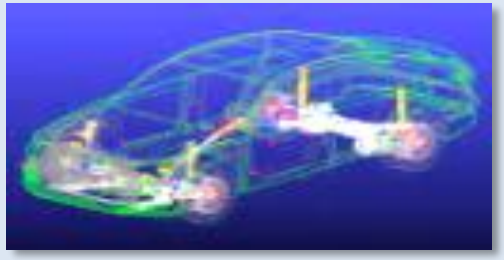
Scenario based approach

Scenario Structure

- Perception
  - Perception limitation

- Judgement
  - Traffic Disturbance

- Control
  - Vehicle Disturbance

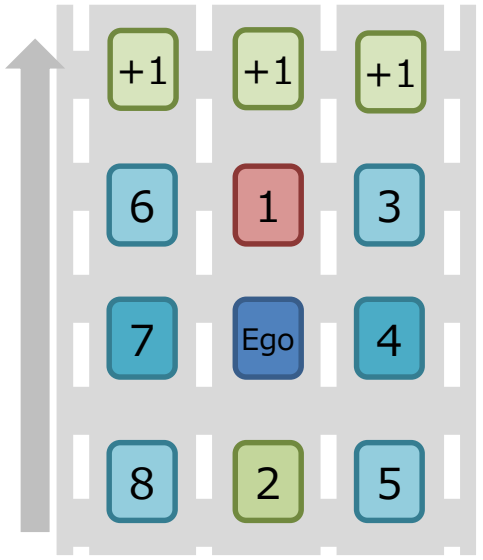


Safety testing driven by three scenario categories related to the physics of the AD system

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	Free Driving Following	Lane changing Overtaking
	Merge zone	Being Merged	Merging
	Departure zone	---	Departing
	Ramp	Free Driving Following	Lane changing Overtaking

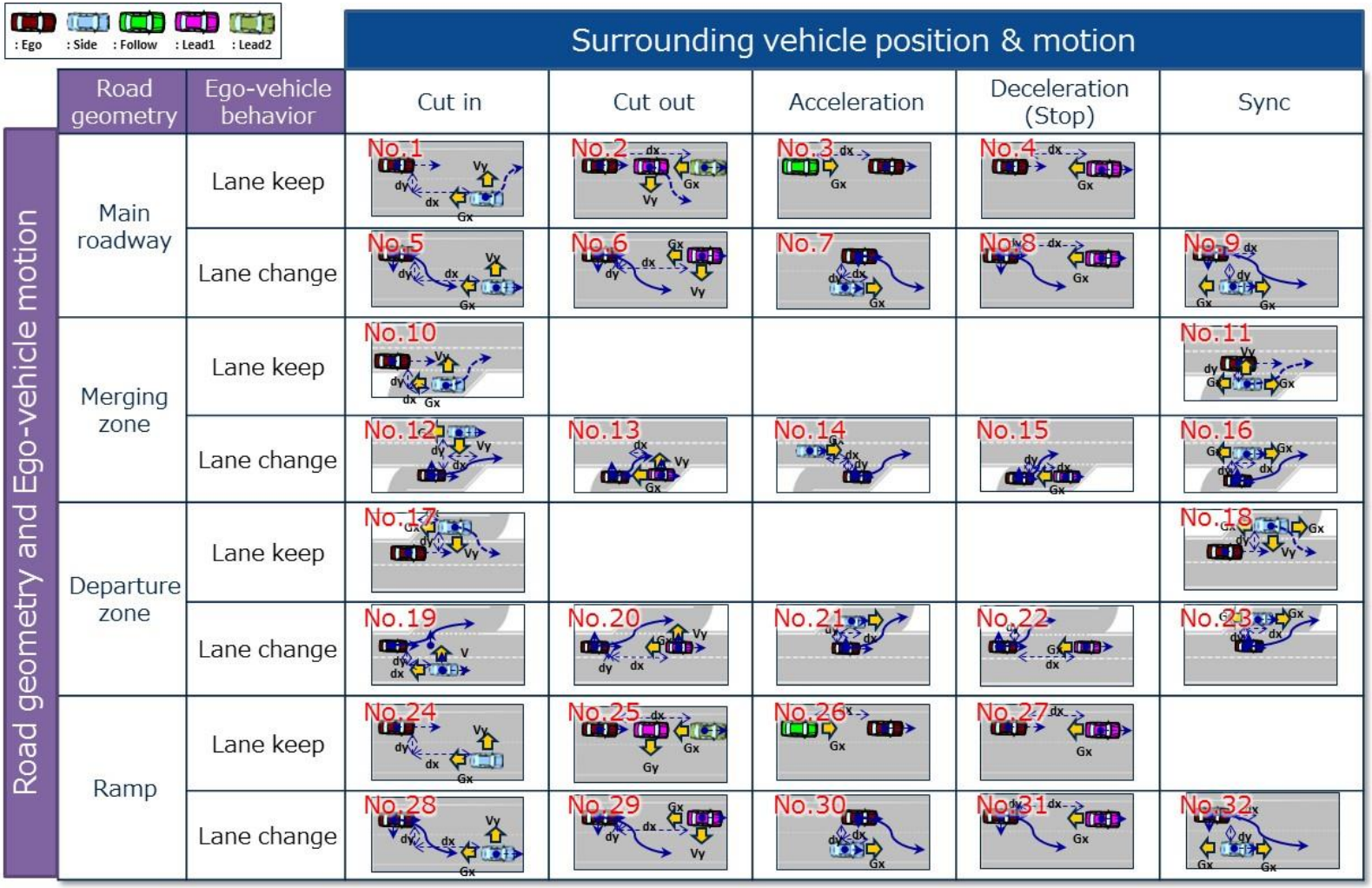


Veh. loc.	Cut in	Cut out	Acc.	Dec.	Sync
1		✓		✓	
2			✓		
3	✓			✓	
4	✓				✓
Ego					
5	✓		✓		
6	✓			✓	
7	✓				✓
8	✓		✓		

✓ May affect AD judgement

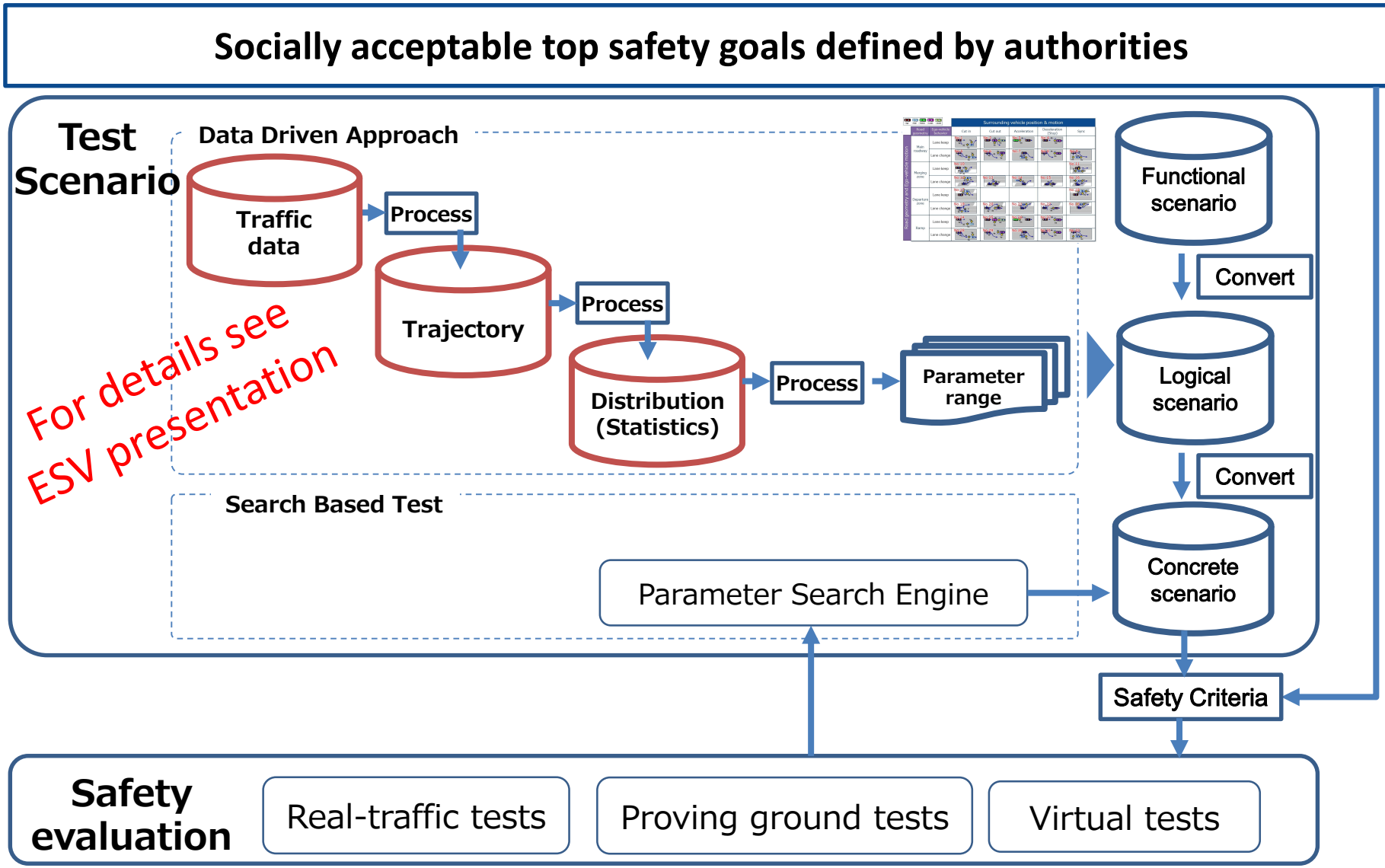
Scenario Structure based on road geometry, ego-vehicle behavior, and surrounding vehicles location and motion

Traffic disturbance scenario structure



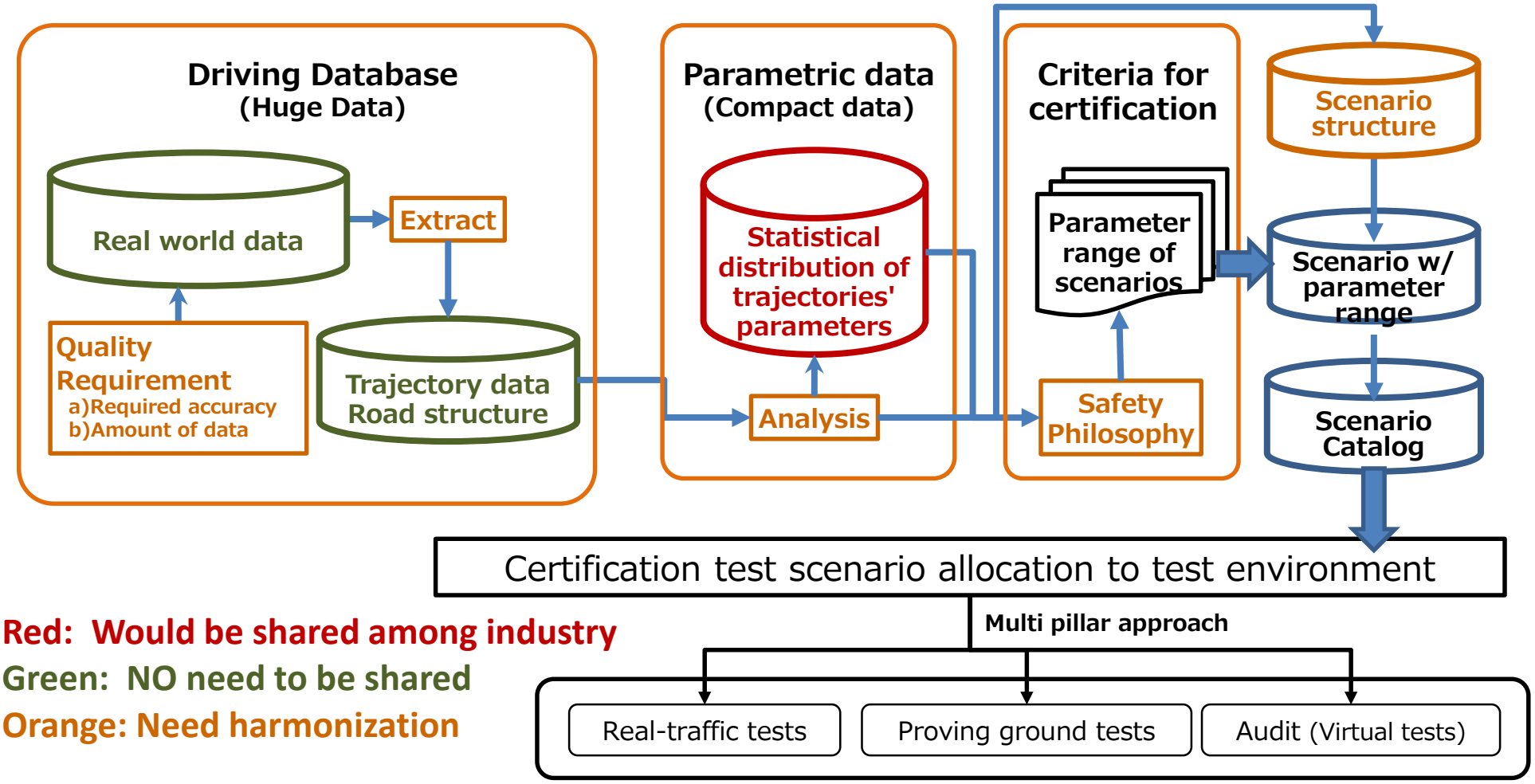
32 well organized functional scenarios out from the proposed structure

AV safety assurance engineering approach



Summary

We are defining a draft methodology that may be used in the homologation process. We are willing to share the draft to jointly develop and harmonize the related activities at the global level.



Red: Would be shared among industry

Green: NO need to be shared

Orange: Need harmonization

19.06.11, 26th ESV conference, Eindhoven, The Netherlands

Development of a Safety Assurance Process for Automated Vehicles in Japan

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N Uchida
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S Taniguchi (Toyota Motor)
K Ozawa (Honda R&D)
E Kitahara (Nissan Motor)

JARI
JAPAN AUTOMOBILE RESEARCH INSTITUTE

JAMA

Aim of this presentation

To report on an AD system safety assurance engineering process developed in Japan.

(SAE Level 3+ in motorways)

Global trend for AV social acceptance

GUIDELINES ON THE EXEMPTION PROCEDURE FOR THE EU APPROVAL OF AUTOMATED VEHICLES

Informal document **WP.29-177-19**
177th WP.29, 12-15 March 2019
Agenda items 2.3 and 17

Framework document on automated/autonomous vehicles

Safety requirements (pg.4)

When in the automated driving mode, the vehicle shall not cause any traffic accidents that are rationally foreseeable and preventable

Safety vision (pg.1)

Automated vehicles 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

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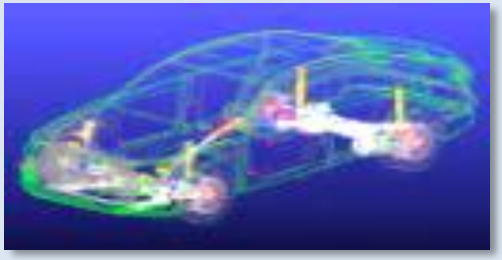

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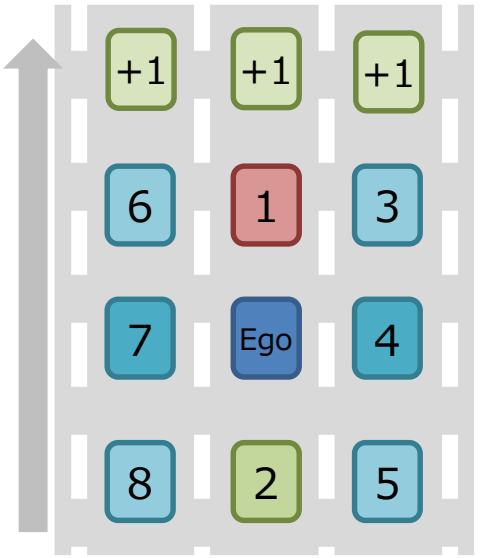

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1		✓		✓	
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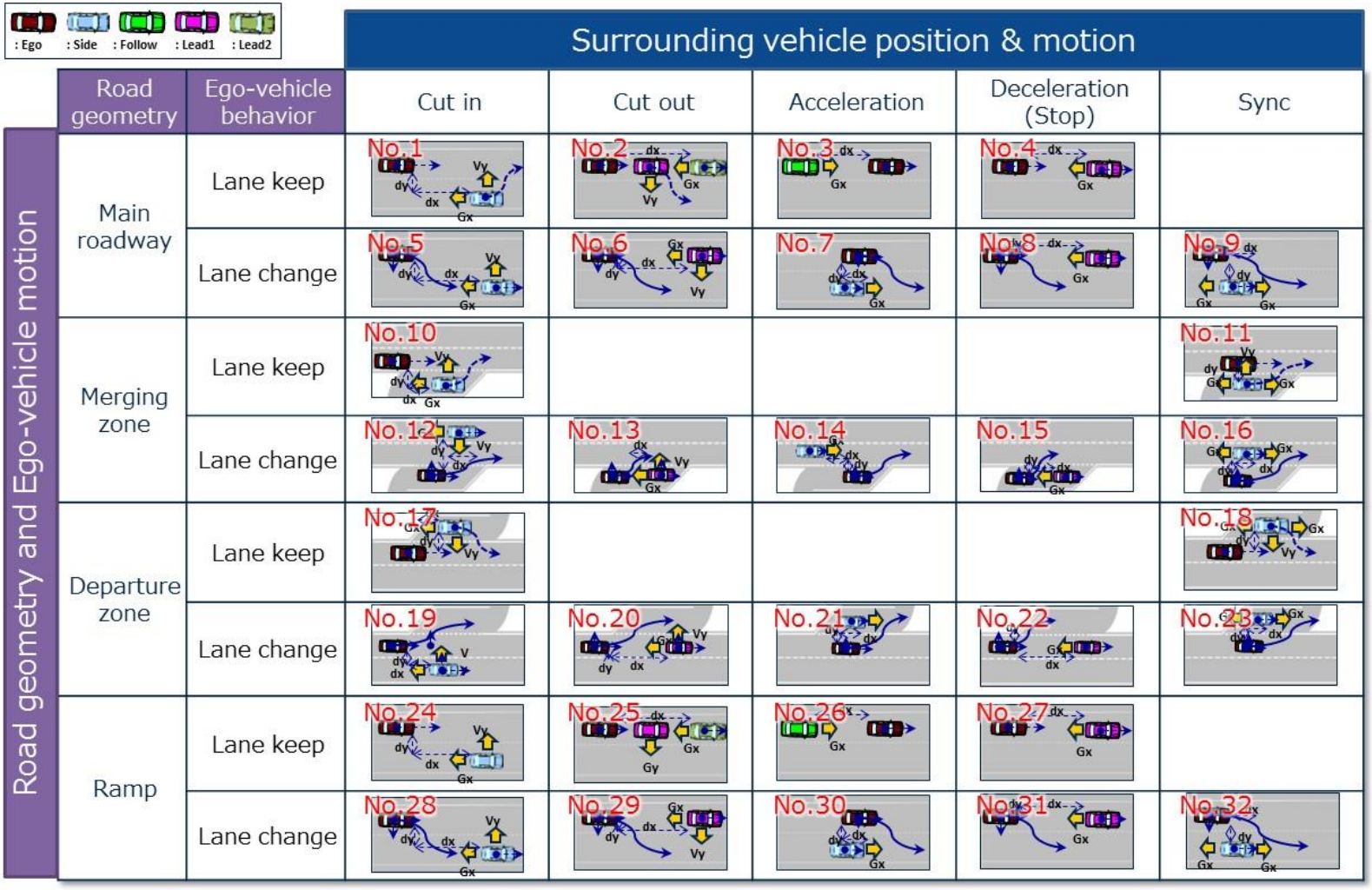


32 well organized functional scenarios out from the proposed structure

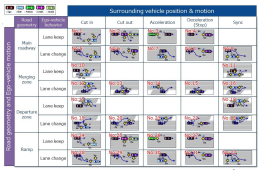
AV safety assurance engineering approach

Socially acceptable top safety goals defined by authorities

Test Scenario

Data Driven Approach

Traffic data → Process → Trajectory → Process → Distribution (Statistics) → Process → Parameter range



Functional scenario → Convert → Logical scenario → Convert → Concrete scenario

Search Based Test

Parameter Search Engine → Concrete scenario

Safety Criteria

Safety evaluation

Real-traffic tests | Proving ground tests | Virtual tests

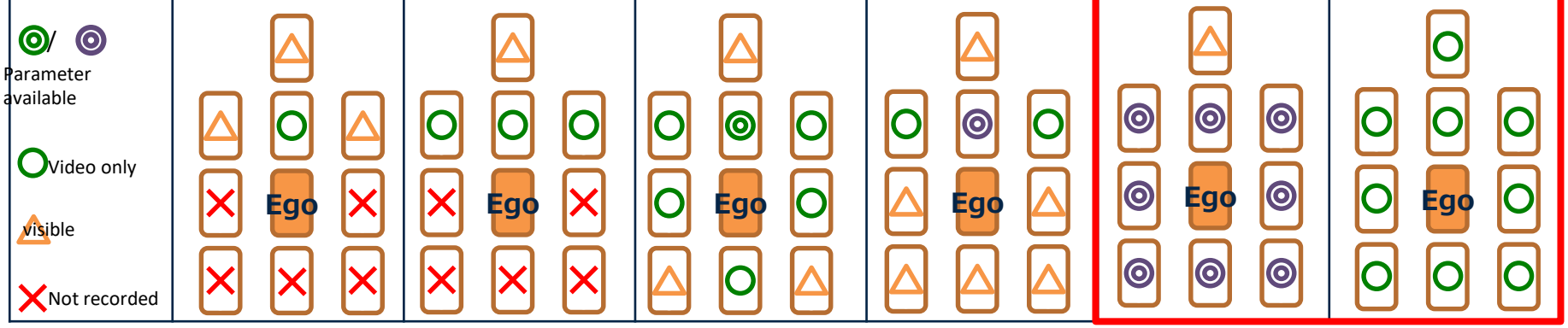
JARI JAPAN AUTOMOBILE RESEARCH INSTITUTE

JAMA

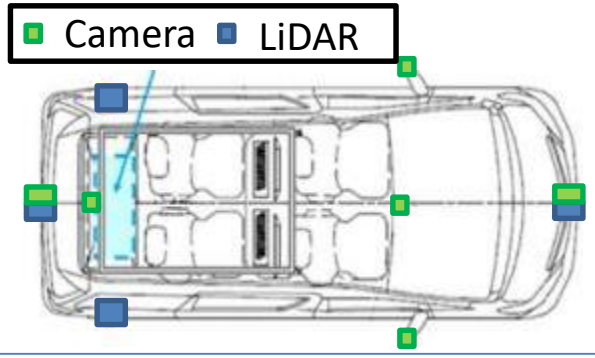
Traffic data acquisition

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						



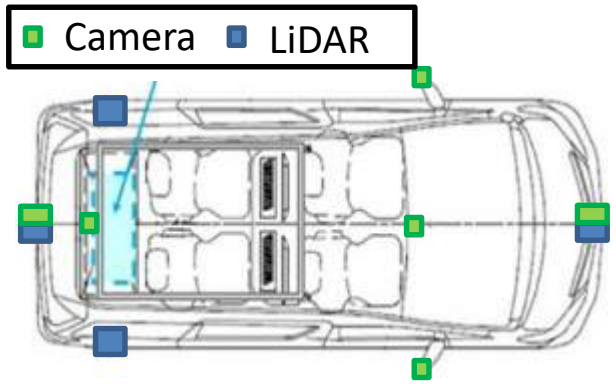
Instrumented vehicles

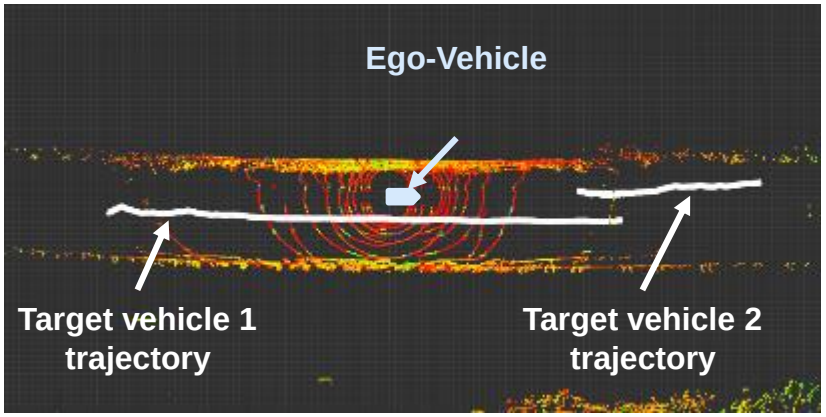


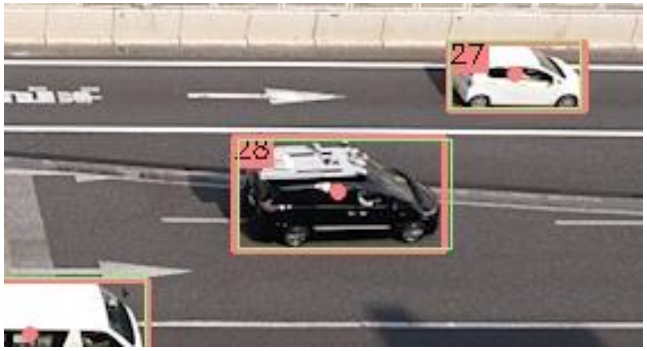
Fixed cameras

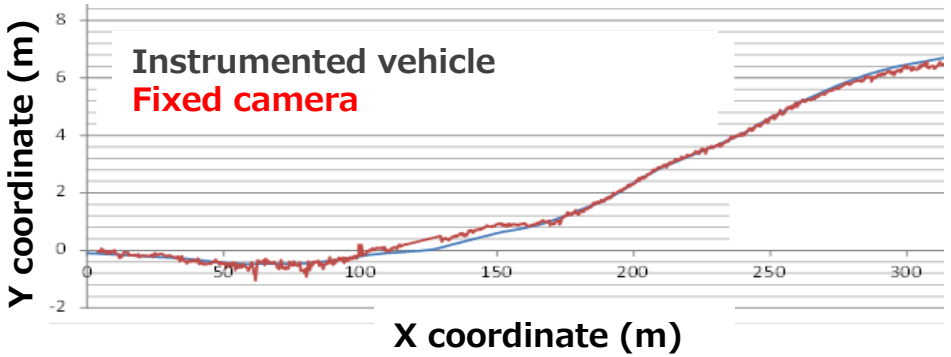
Ongoing third-party data acquisition with both instrumented vehicles and fixed cameras over motorways

Trajectory data extraction



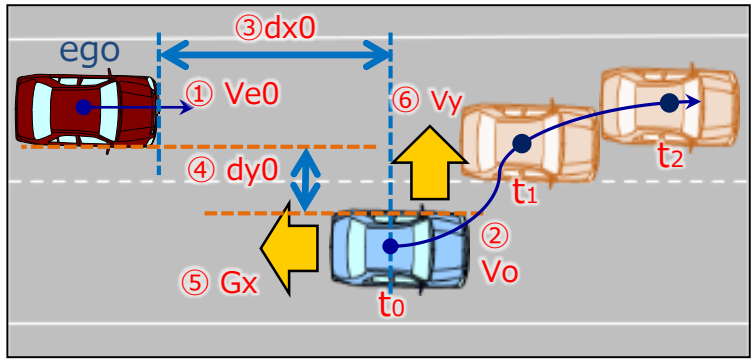


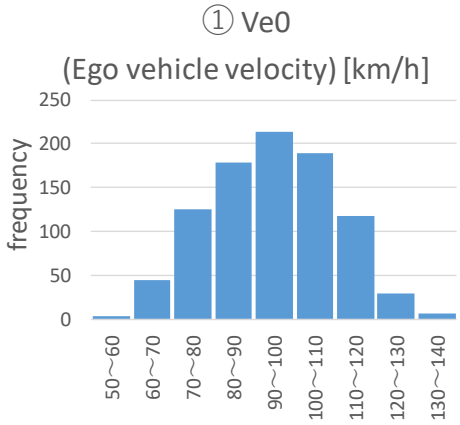


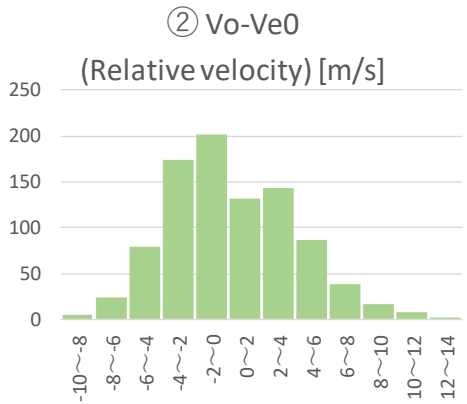


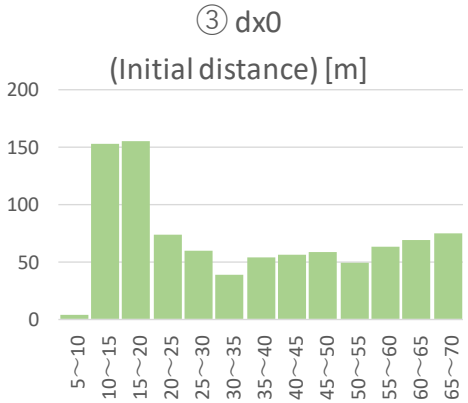
Vehicle trajectory extraction from both instrumented vehicles and fixed cameras, including data accuracy verification

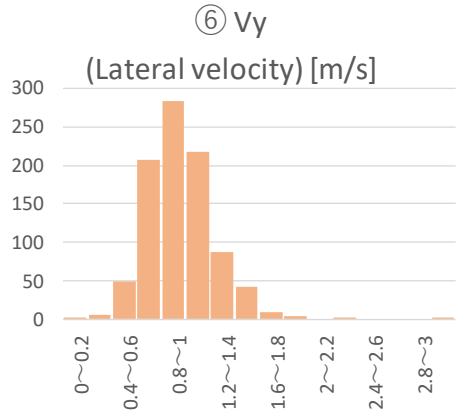
Parameter distribution extraction (cut-in)







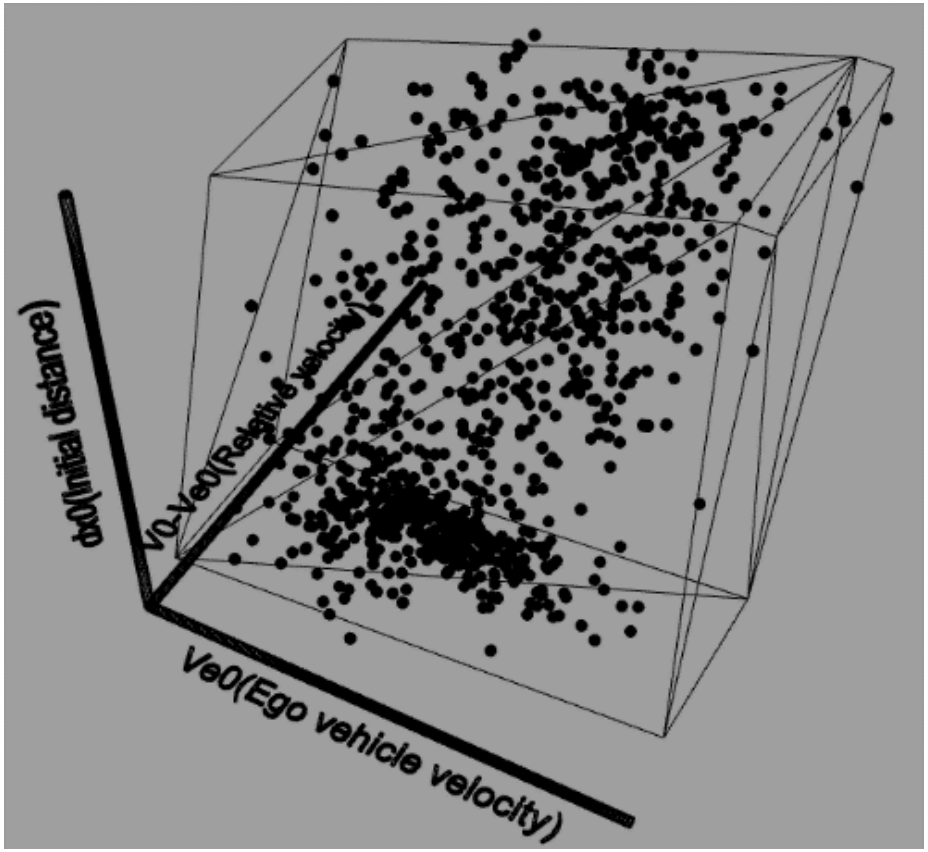




Consensus based rules to detect scenarios, and to define and measure parameters from the vehicle trajectory data

Generation of concrete scenarios (cut-in)

3-D cloud of correlated parameters

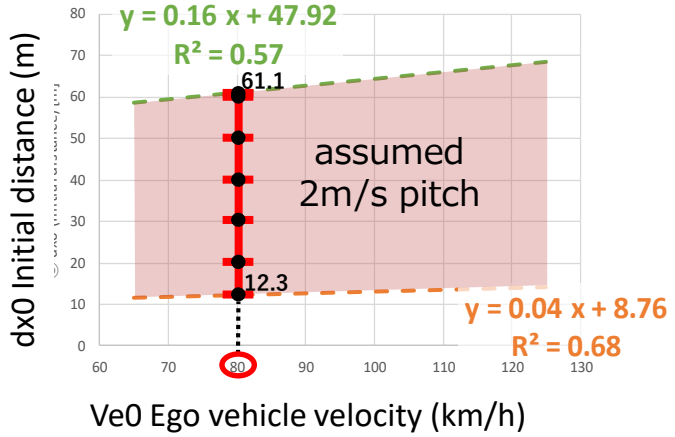


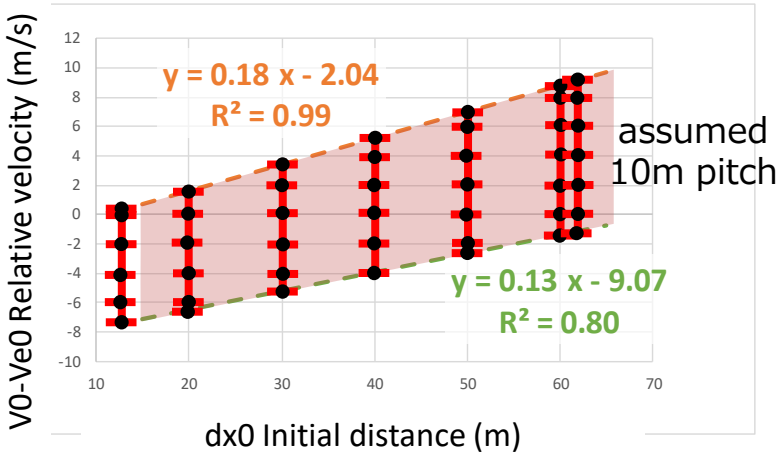
Generation of concrete scenarios consider parameter correlations

Generation of concrete scenarios (cut-in)

Parameter	Unit	Value
①Ve0(Ego vehicle velocity)	km/h	80
②V0-Ve0(Relative velocity)	**m/s**	**see table**
③dx0(Initial distance)	**m**	**see table**
⑥Vy(Lateral velocity)	m/s	1.45

		③dx0 (Initial distance) [m]						
		12.3	20	30	40	50	60	61.1
②V0-Ve0 (Relative velocity) [m/s]	Min	-7.49	-6.50	-5.21	-3.93	-2.64	-1.35	-1.21
	Max	0.19	1.58	3.39	5.21	7.02	8.83	9.03

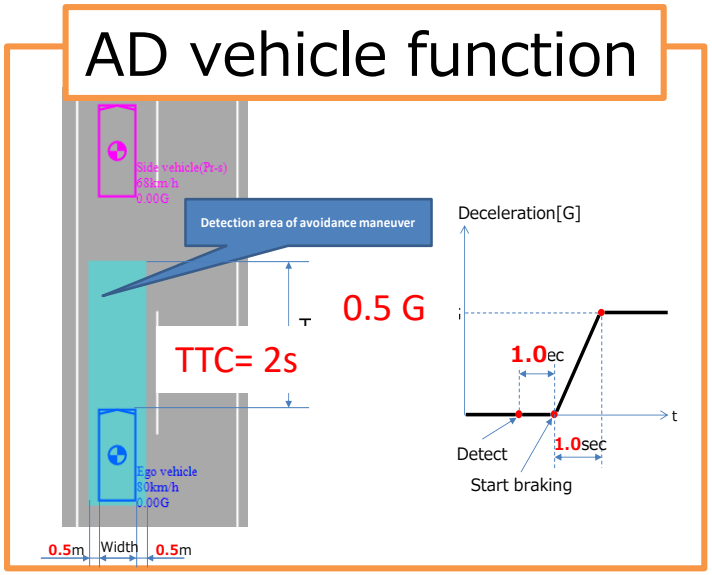




For pre-set initial ego-vehicle velocity of 80 km/h and lateral velocity of 1.45 m/s, initial distances of 12.3 to 61.1m and their correlating relative velocity values need to be considered

Case study: 'moderate' performance system

'moderate' performance (0.5g)



Simulation results

Ve0=80km/h, Vy=1.45m/s

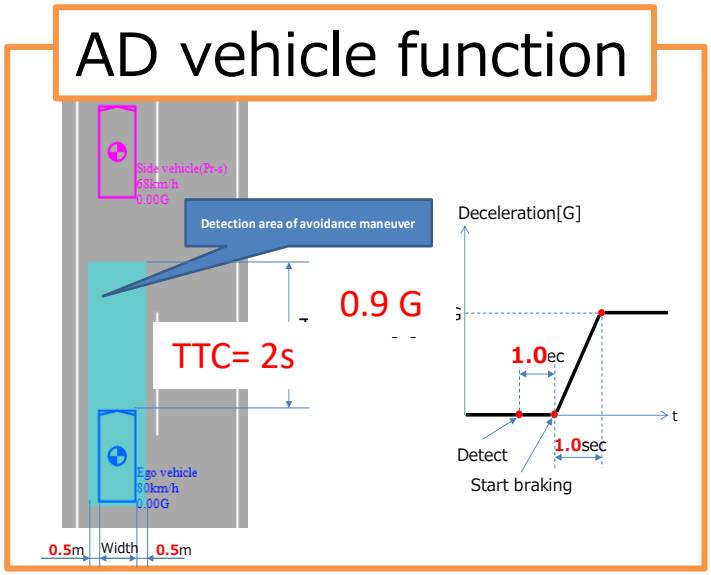
②V0-Ve0 (Relative velocity) [m/s]	③dx0 (Initial distance) [m] 12.3	20	30	40	50	60	61.1
						✘ 8.83	✘ 9.03
					✘ 7.02	✘ 8	✘ 8
				✔ 5.21	✘ 6	✘ 6	✘ 6
			✔ 3.39	✔ 4	✔ 4	✔ 4	✔ 4
	✔ 0.19	✔ 1.58	✔ 2	✔ 2	✔ 2	✔ 2	✔ 2
	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0
	✔ -2	✔ -2	✔ -2	✔ -2	✔ -2	✔ -1.35	✔ -1.21
	✔ -4	✔ -4	✔ -4	✔ -3.93	✔ -2.64		
	✔ -6	✔ -6	✔ -5.21				
	✔ -7.49	✔ -6.50					

✔ : Success (non-crash), ✘ : Fail (Crash)

Within the generated concrete scenarios, some cases could not prevent a crash based on the applied 'moderate' performance system

Case study: 'improved' performance system

'improved' performance (0.9g)



Simulation results

Ve0=80km/h, Vy=1.45m/s

②V0-Ve0 (Relative velocity) [m/s] \ ③dx0 (Initial distance) [m]	12.3	20	30	40	50	60	61.1
						✔ 8.83	✔ 9.03
					✔ 7.02	✔ 8	✔ 8
				✔ 5.21	✔ 6	✔ 6	✔ 6
			✔ 3.39	✔ 4	✔ 4	✔ 4	✔ 4
	✔ 0.19	✔ 1.58	✔ 2	✔ 2	✔ 2	✔ 2	✔ 2
	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0
	✔ -2	✔ -2	✔ -2	✔ -2	✔ -2	✔ -1.35	✔ -1.21
	✔ -4	✔ -4	✔ -4	✔ -3.93	✔ -2.64		
	✔ -6	✔ -6	✔ -5.21				
	✔ -7.49	✔ -6.50					

✔ : Success (non-crash), ✘ : Fail (Crash)

All crashes in the generated concrete scenarios were prevented by improving the system's performance.

Case study: Results visualization (cut-in)

initial distance = 60 m
relative velocity = 8.83 m/s
moderate performance (0.5g)

★Collision

initial distance = 60 m
relative velocity = 8.83 m/s
improved performance (0.9g)

No Collision

This case study illustrates how the developed methodology can discriminate between non-safe and safe systems.

Summary

- JAMA and JARI, under the auspice of METI, are collecting data and developing engineering methodologies and processes for specific AD safety assurance purposes.

- We are **willing to collaborate** internationally to harmonize the activities that will lead to a safer and global AD society.

Thank you!