Realizing Shift Performance Evaluation through Transmission-iLS

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Contents

Background and Purpose

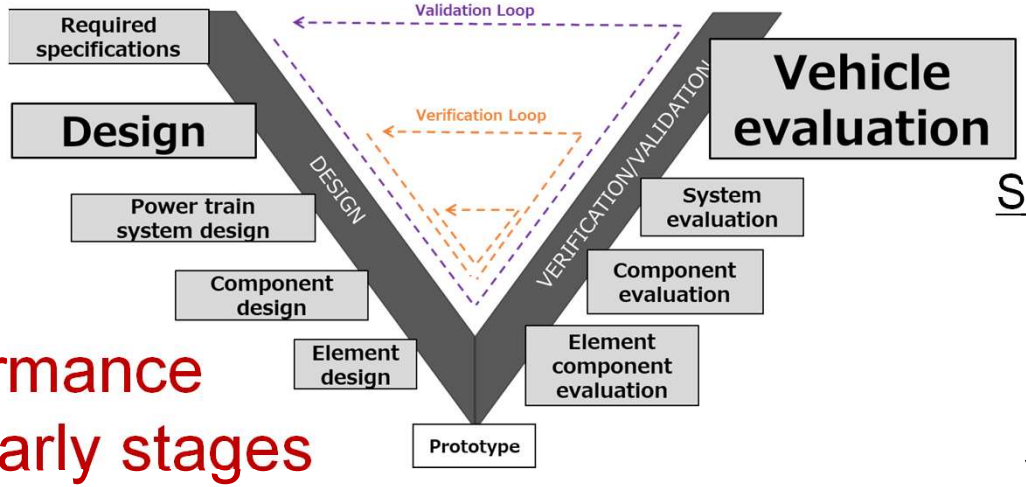
・In recent years, there has been an increasing demand for environmental performance.
In response, we have chosen a multi-pathway strategy
・This strategy requires the development of multiple vehicles at the same time.

Various customer needs / competition / regulations / infrastructure / energy circumstances.

It is necessary to enhance the design level in the early stages to make the period of developments shorter.

The vision for the development of transmission shifting performance.

V-model development



Verification of performance is important in the early stages without actual vehicles

Shifting performance evaluation

- Performance confirmation in the later stages
- An actual vehicle is required for the evaluation.

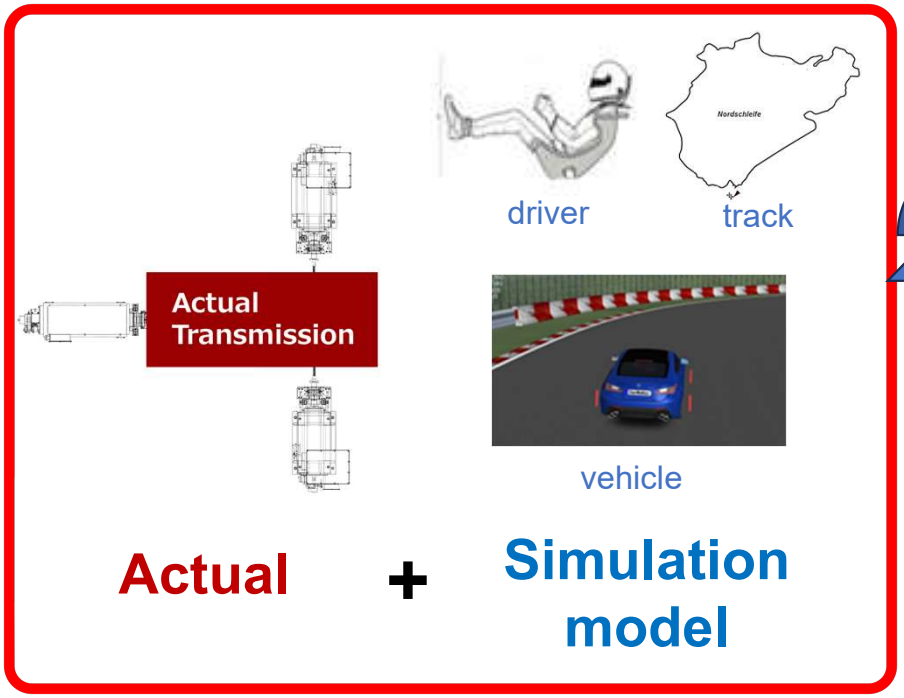
NG If issues are identified at this stage

- **Limited flexibility in countermeasures**
- **In the case of fundamental countermeasures, there is a significant rework.**

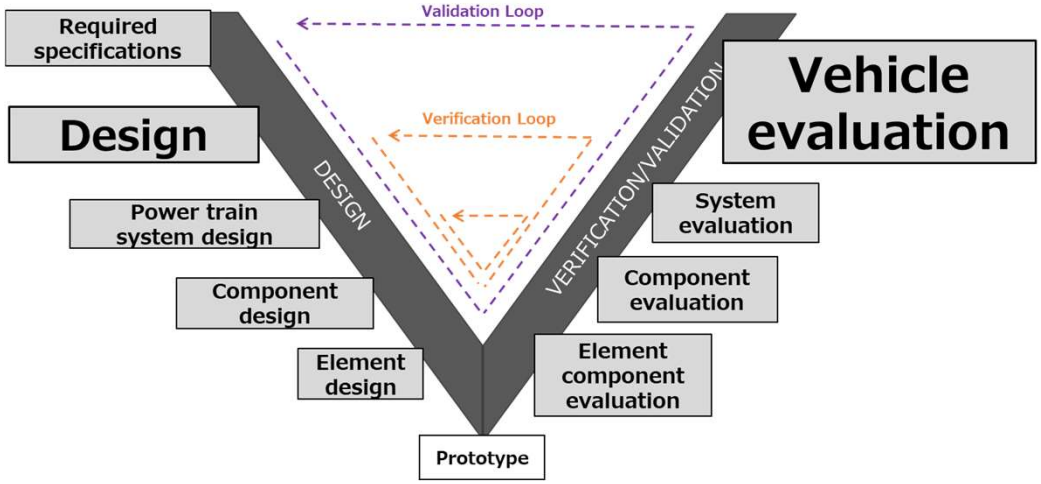
Target: Front-loading the shift performance development

To achieve front-loading

Transmisson-iLS



V-model development

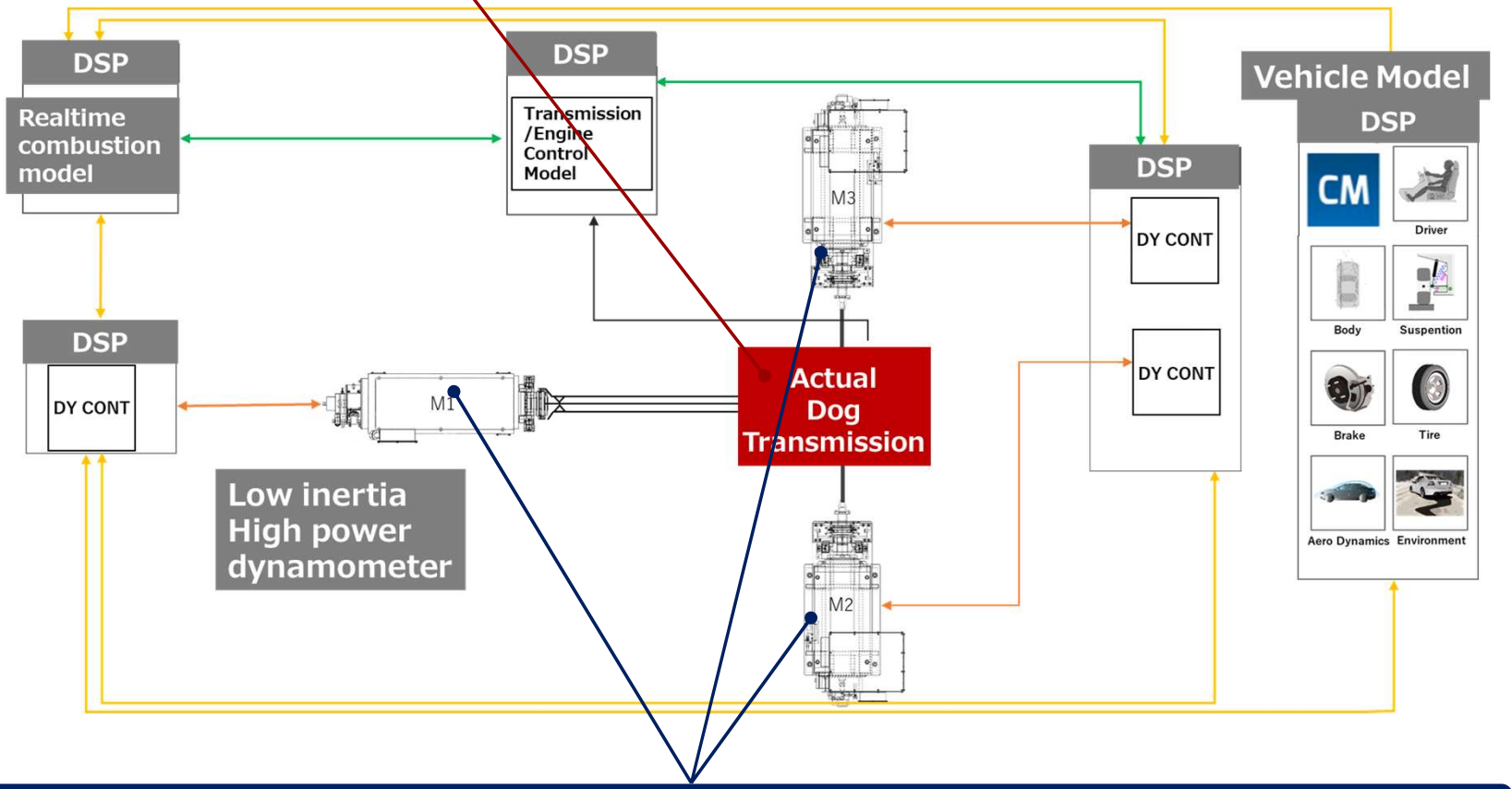


We challenged ourselves to evaluate shifting performance without vehicles and engines.

We had started the development of Transmission-iLS

Overview of Transmission-iLS Test Bed

The transmission is an actual object.



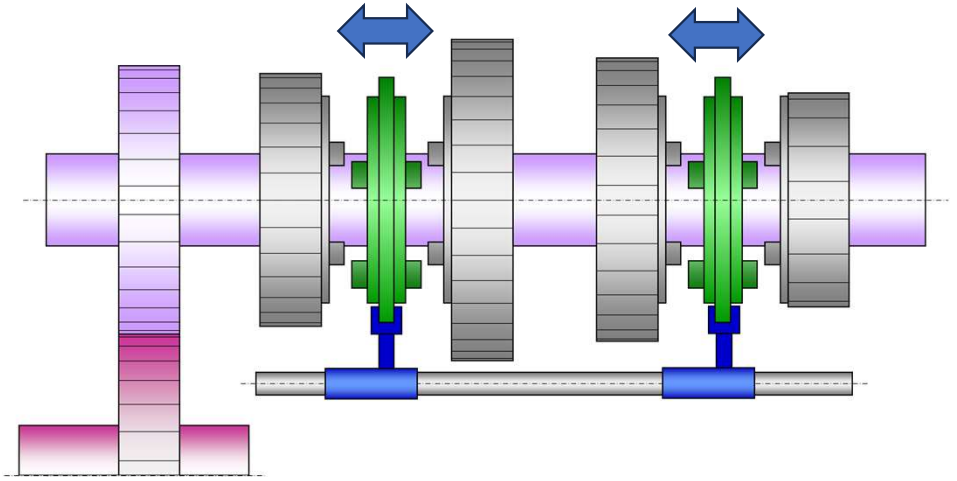
The engine and the tires were replaced with the dynamometers

Contents

The transmission used in this case

●Starting with a simple dog transmission structure.

Shifting by sliding the dog teeth



Goal:
Fast, reliable,
and durable shifts

Fig. Overview of the dog transmission

The dog transmission was chosen to try the transmission-iLS

To evaluate actual vehicle shifting performance by the transmission-iLS

- Simulating engine transition torque during shifting.
- Simulating vehicle transition behavior during shifting, which is related to the changes of the rotational speed of the transmission output shaft.

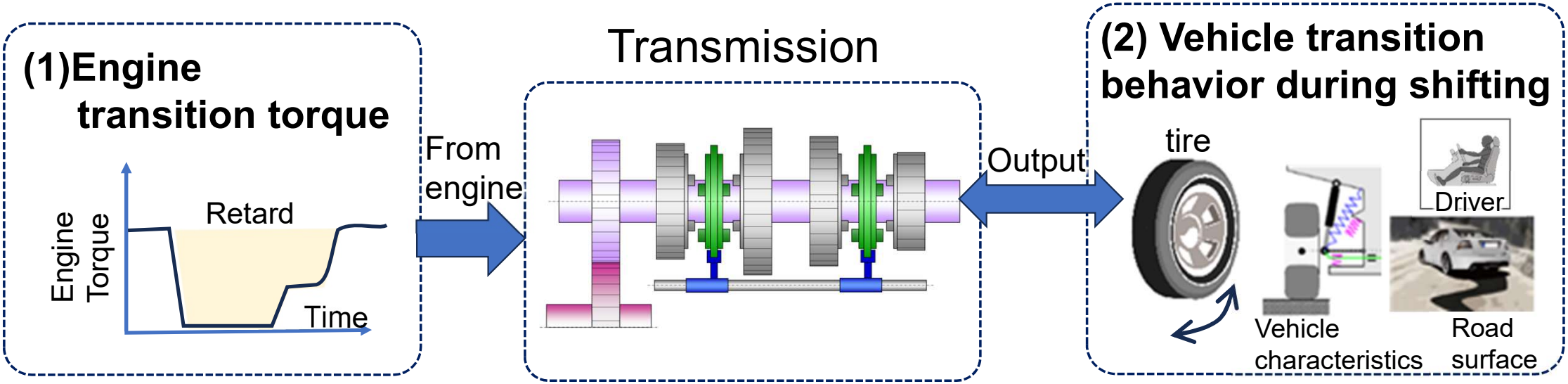
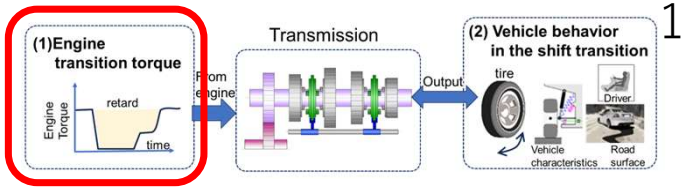


Fig. Requirements to evaluate actual vehicle shifting performance

Simulating transition behavior for both the engine and the vehicle is necessary.

Simulating engine transition torque



- 3D engine model accelerated calculation speed by 40x to achieve real-time performance
- Newly developed dynamometer that increases torque by 60% without additional inertia.

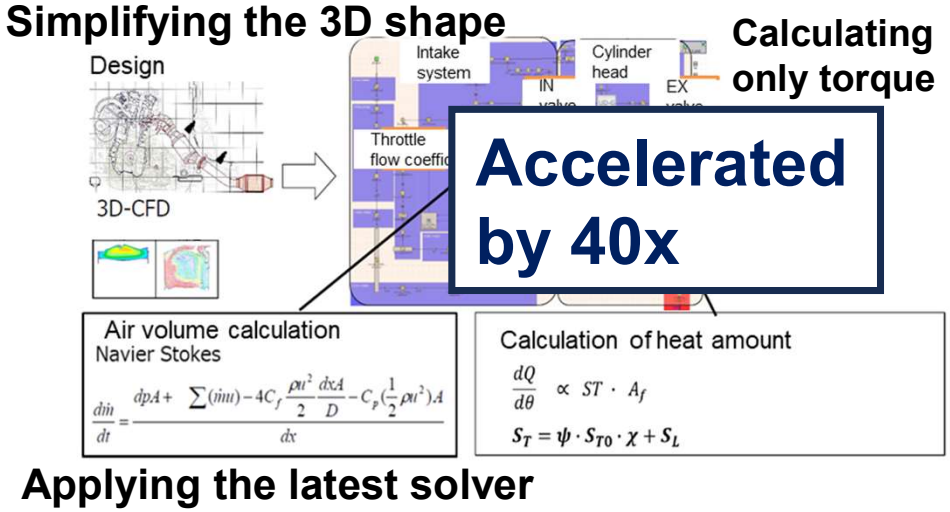


Fig. Real-time 3D engine model

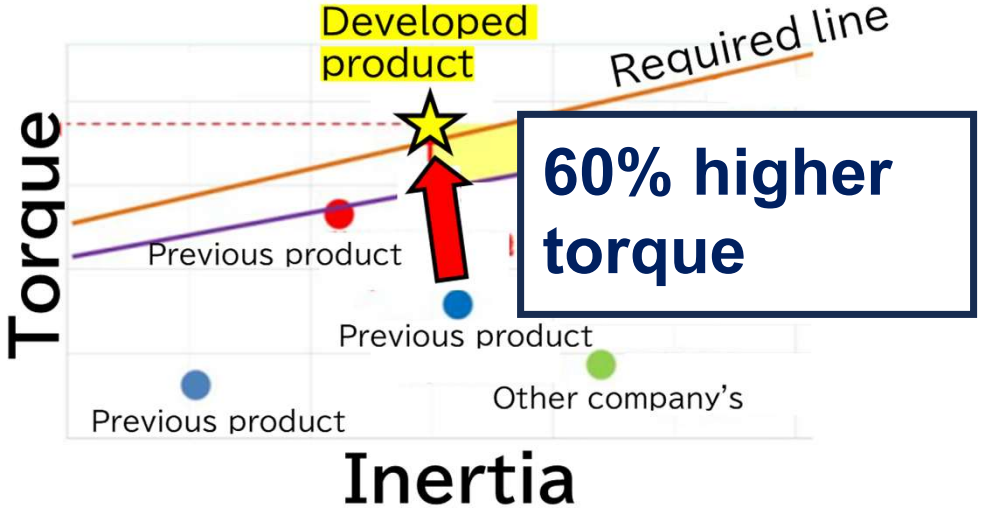
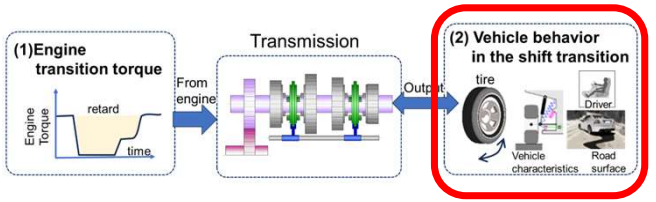


Fig. Performance of the developed dynamometer

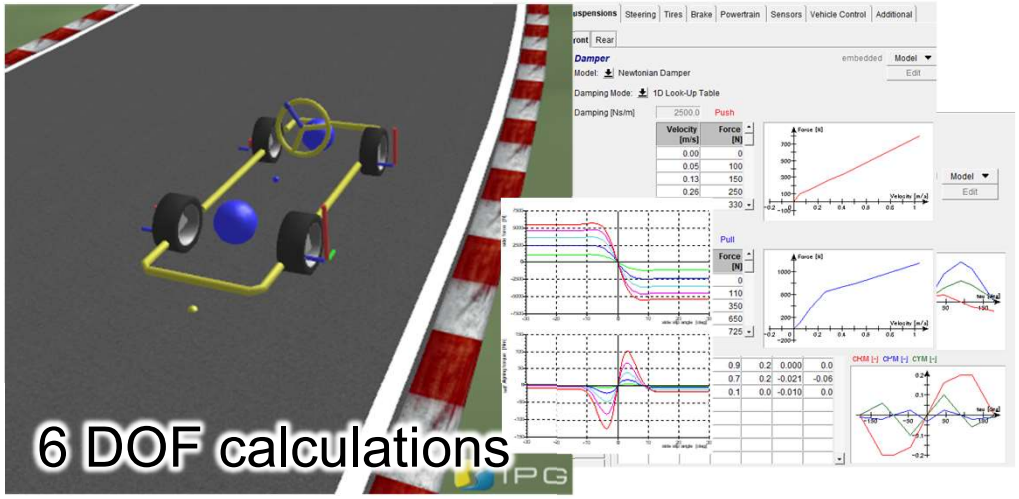
New real-time model and dynamometer for the engine was developed

Simulating vehicle transition behavior

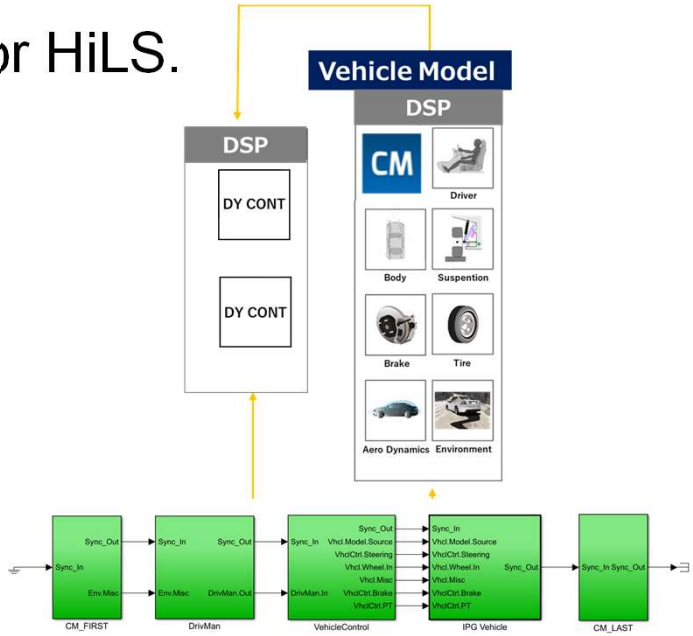


- Simulating the vehicle behavior in the shift transition requires 6 DOF calculations of translations and rotations.
- The flexibility of model modifications is important for HiLS.

DOF : degrees of freedom



Vehicle behavior in the shift transition



Model modifications are easy

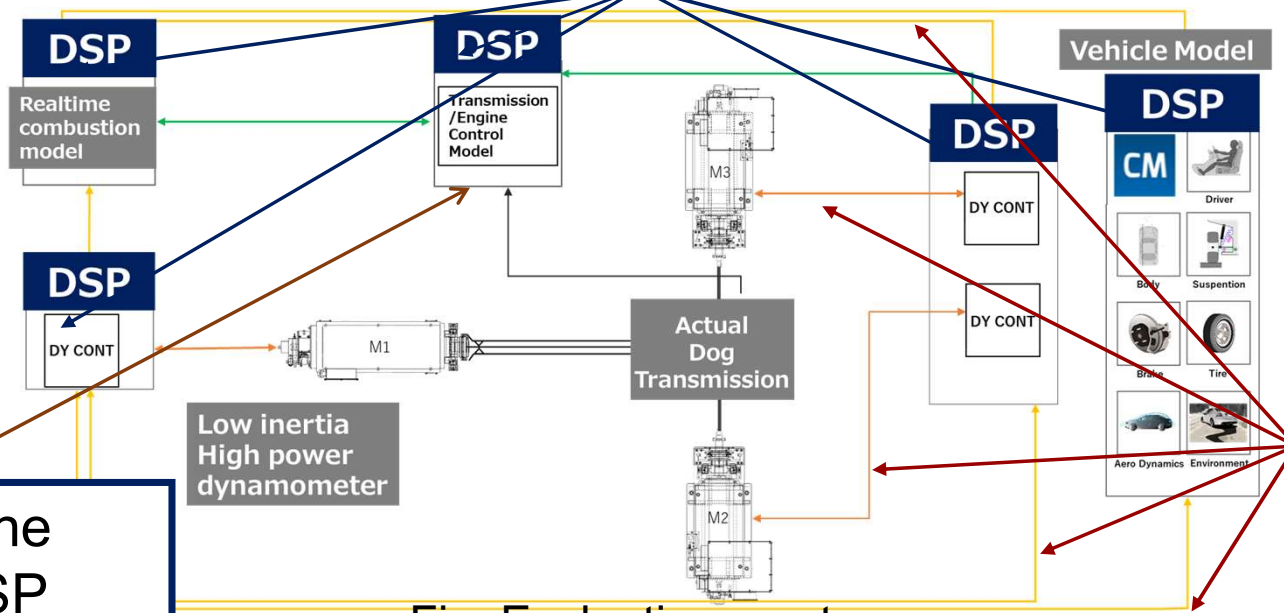
CarMaker was adopted due to calculations capability and flexibility to modify the model

Evaluation system

- In the early stages of development, there is no ECU to control the prototype units like engines and transmissions, So it is simulated using DSP.
- Distributed calculations across multiple DSPs, implemented high-speed communication network and minimized idle time to nearly zero.

Increasing DSP units from 1 to 5

DSP:Digital Signal Proseccor



Simulating the ECUs by DSP

High-speed communication network

Fig. Evaluation system

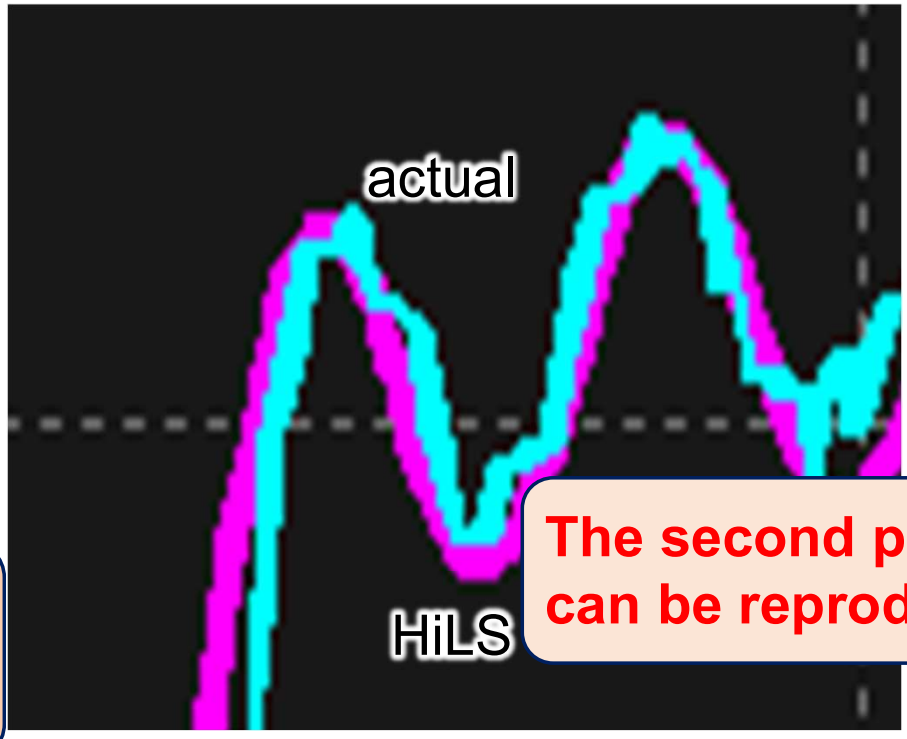
This system enables the transition behavior for the engine and the vehicle to be simulated.

Validation

●Comparing actual vehicle and transmission-iLS in case of tip-in throttle.

The second peak, which is important for driver feeling was not reproduced

Fig. Previous HiLS



The second peak can be reproduced.

Fig. Current HiLS

The actual vehicle shifting performance can be reproduced with this transmission-iLS.

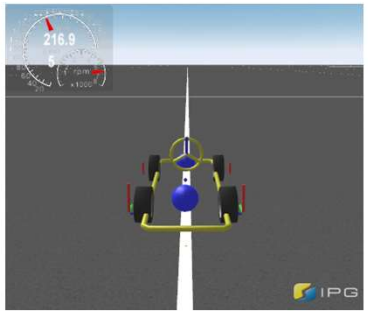
Contents

Flow of shifting performance development:

1. Calibration for upshifting on flat roads.
2. Calibration for downshifting on flat roads.
3. Calibration for shifting under combined conditions (Circuit driving).

1. Calibration for upshifting on flat roads.

Acceleration on flat roads



Engine model

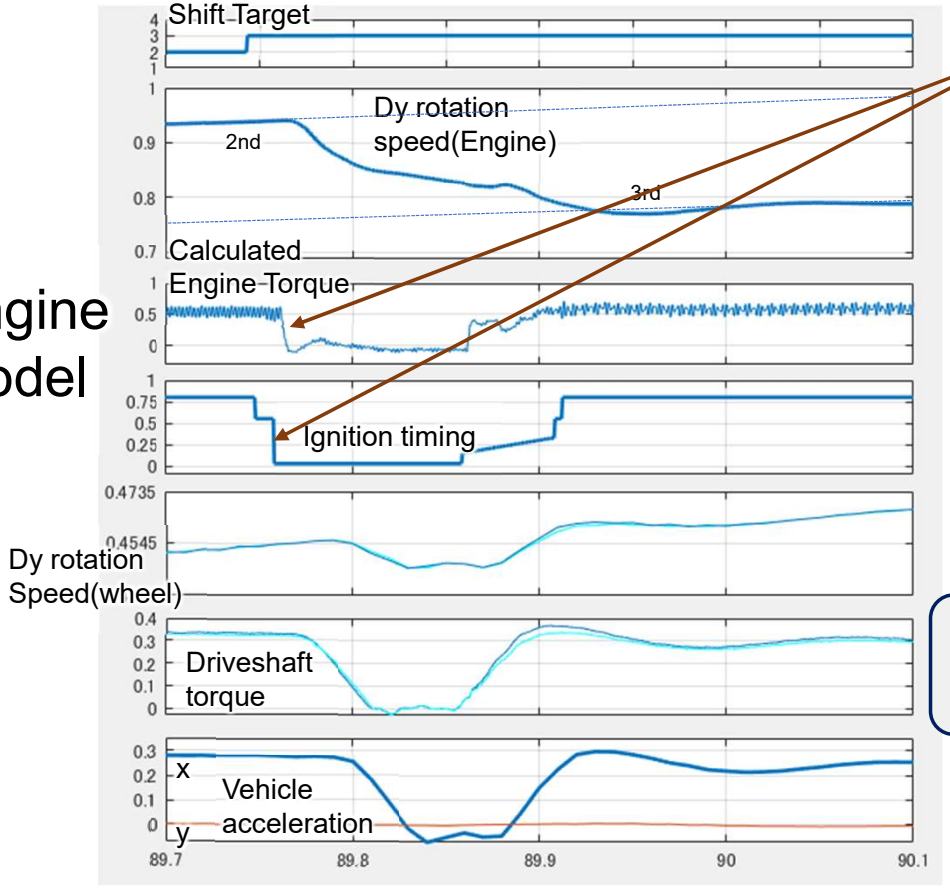


Fig. 2-3 upshift waveforms

After deciding to shift

Engine torque reduction

Engine speed decreases

The dog gear engages

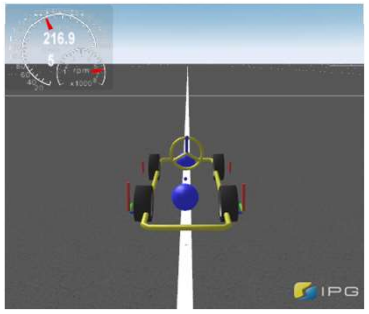
Engine speed decreases

Engine torque recovers

Driveshafts twist

1. Calibration for upshifting on flat roads.

Acceleration on flat roads



Engine speed

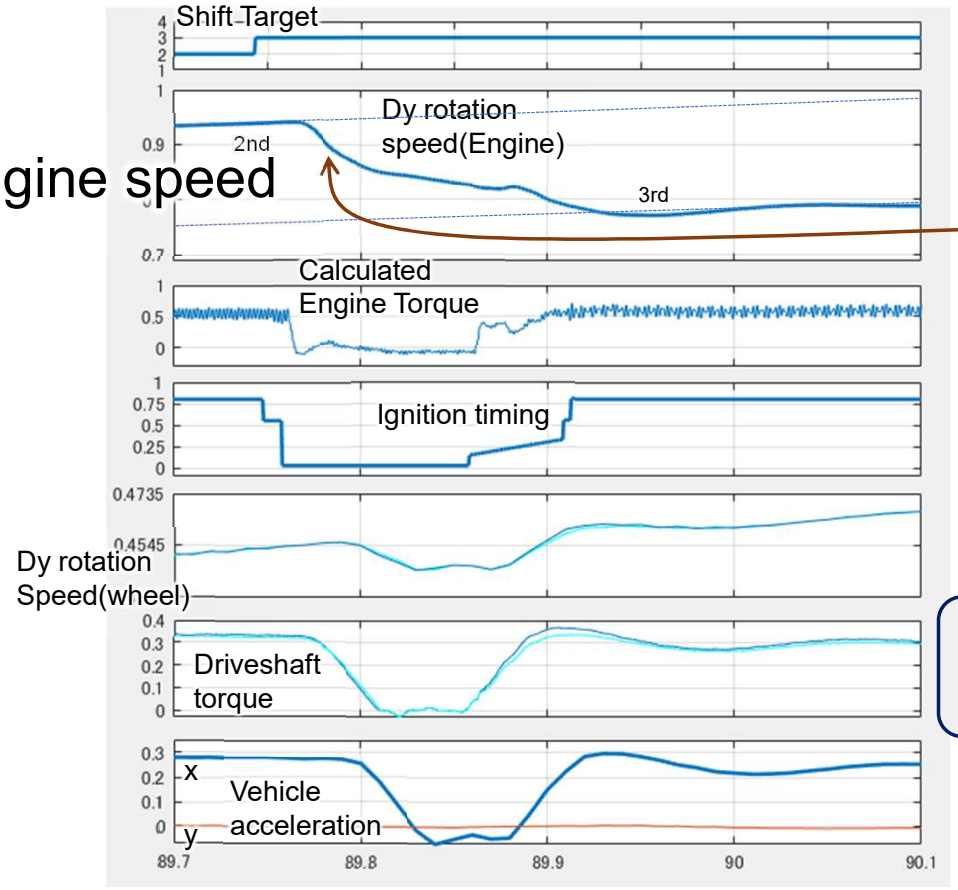
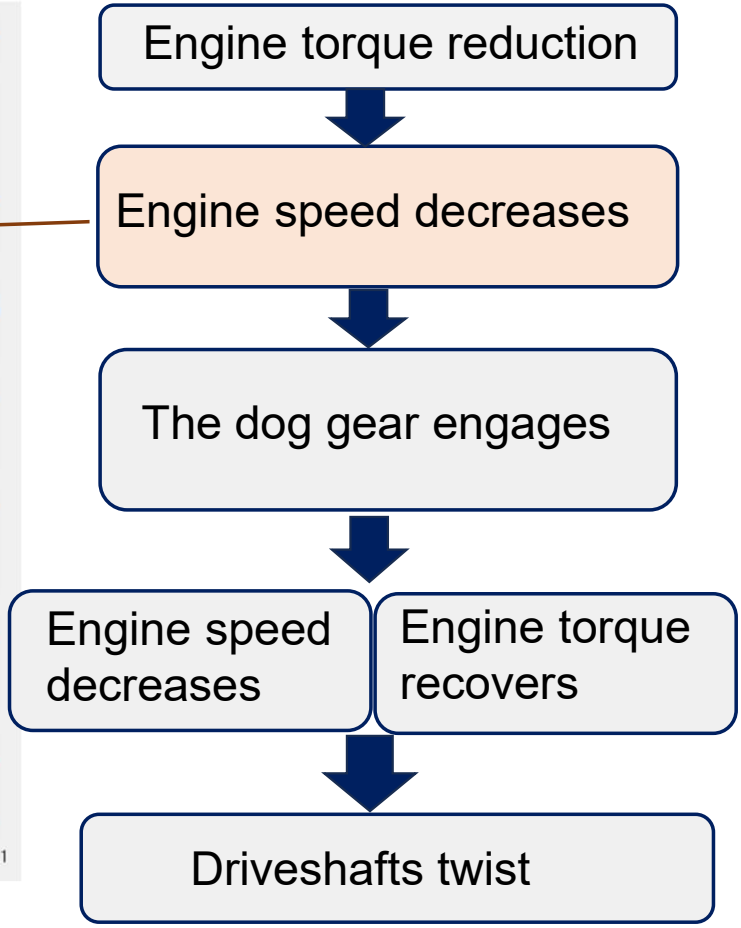
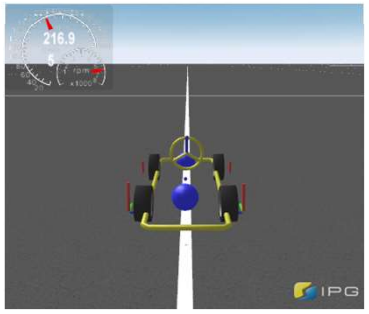


Fig. 2-3 upshift waveforms

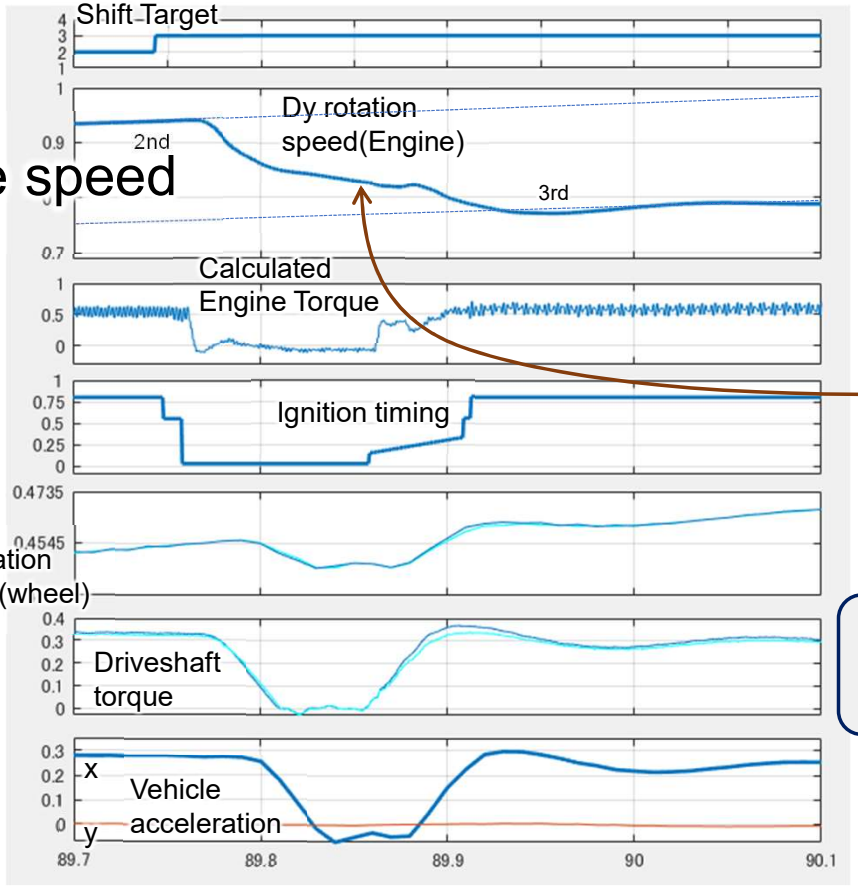


1. Calibration for upshifting on flat roads.

Acceleration on flat roads



Engine speed



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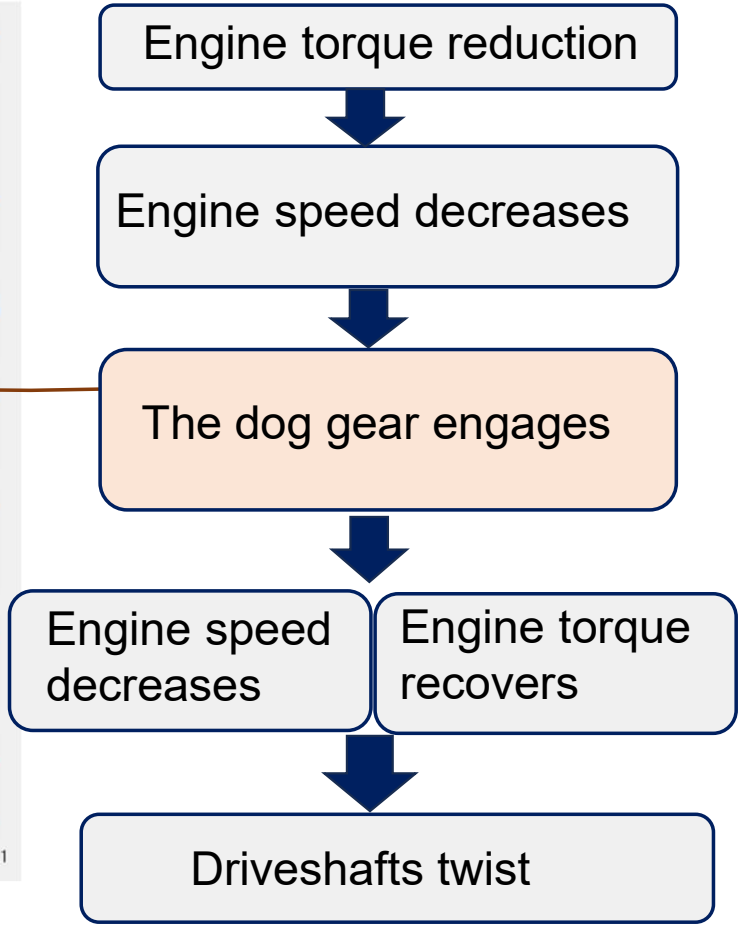
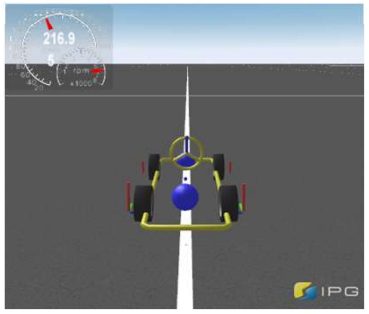


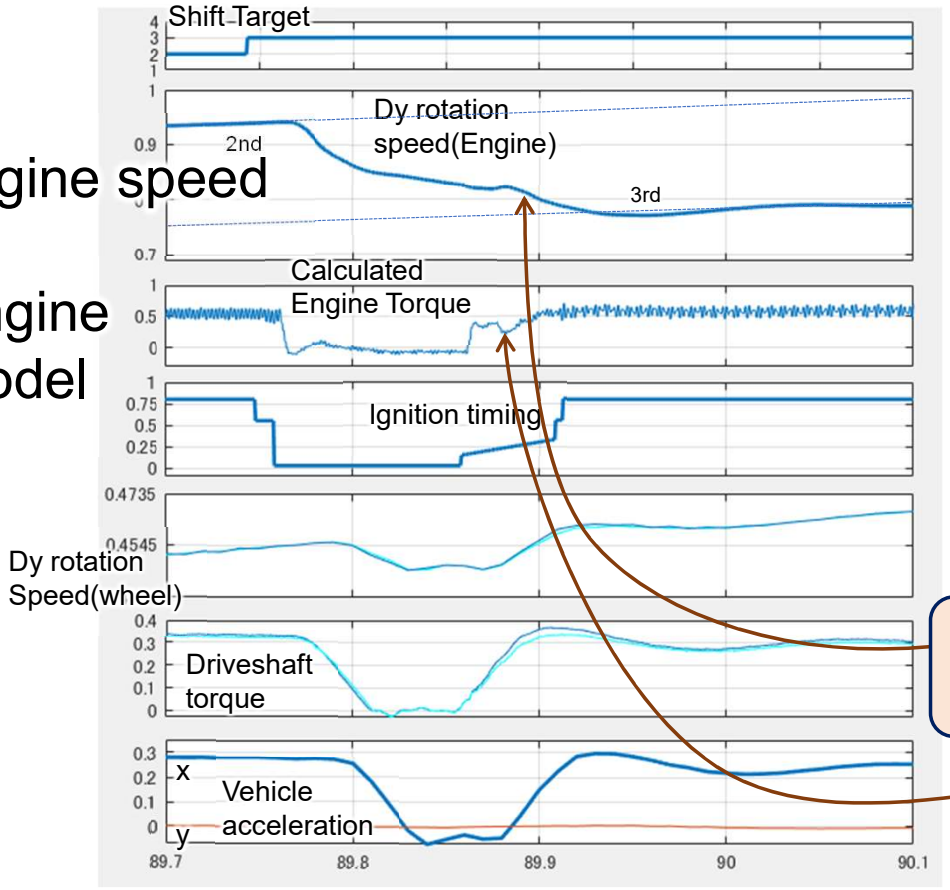
1. Calibration for upshifting on flat roads.

Acceleration on flat roads



Engine speed

Engine model



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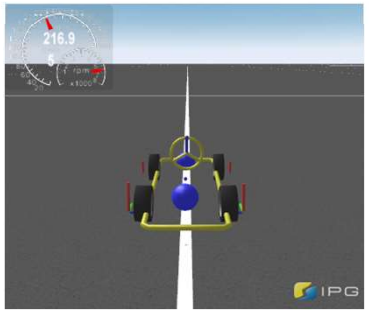
Acceleration on flat roads



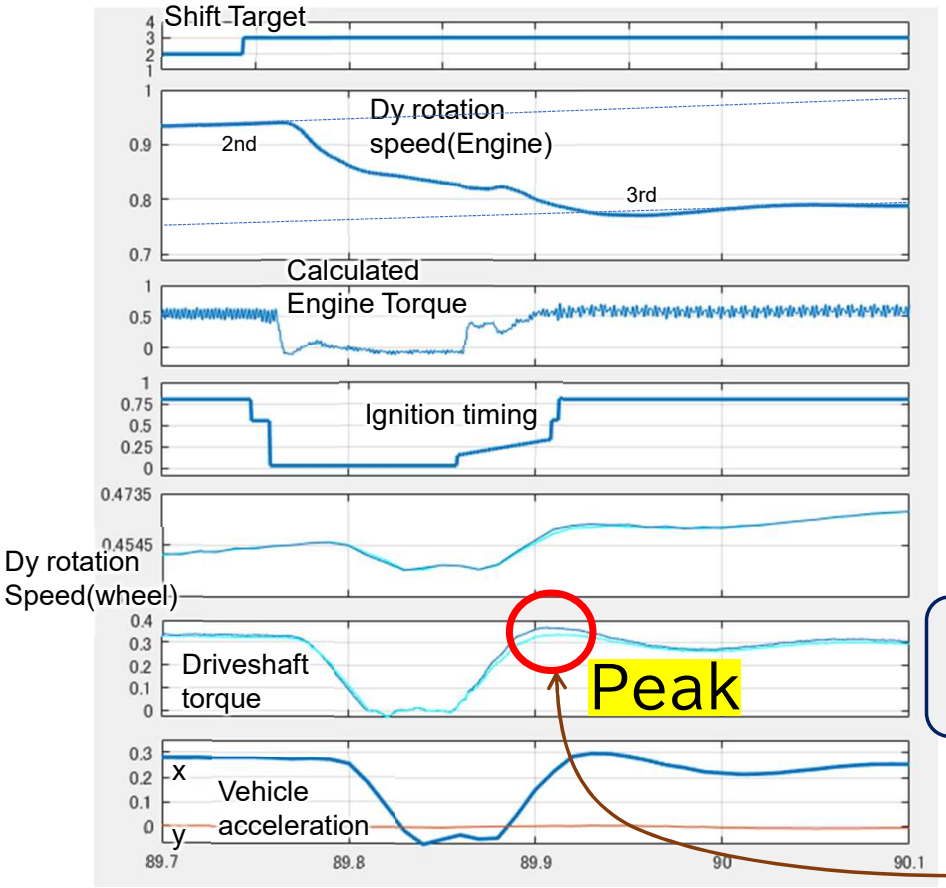
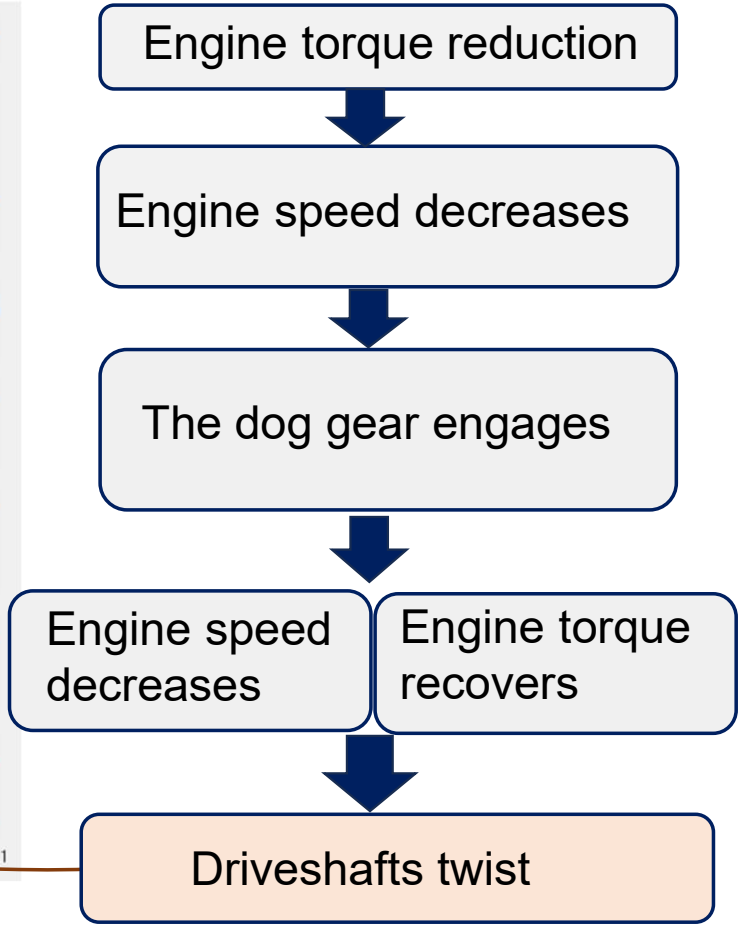
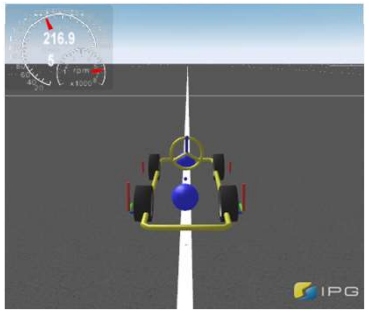


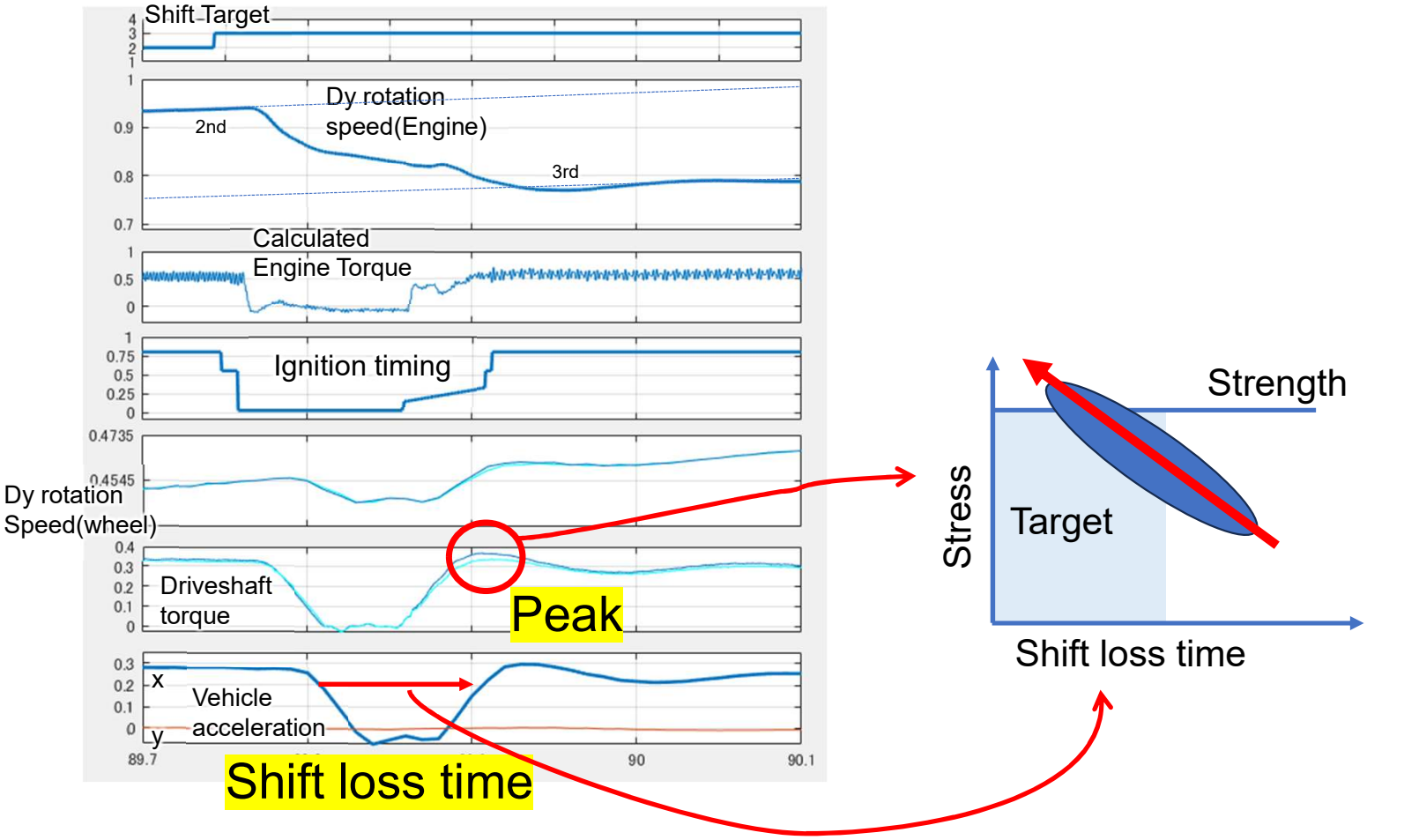
Fig. 2-3 upshift waveforms



How upshift performance optimized?

Acceleration on flat roads





Aiming for the fastest shifting within the strength limits

1. Calibration for upshifting on flat roads.

- In this case, the recovery timing of engine ignition retard was adjusted in the transmission-iLS.

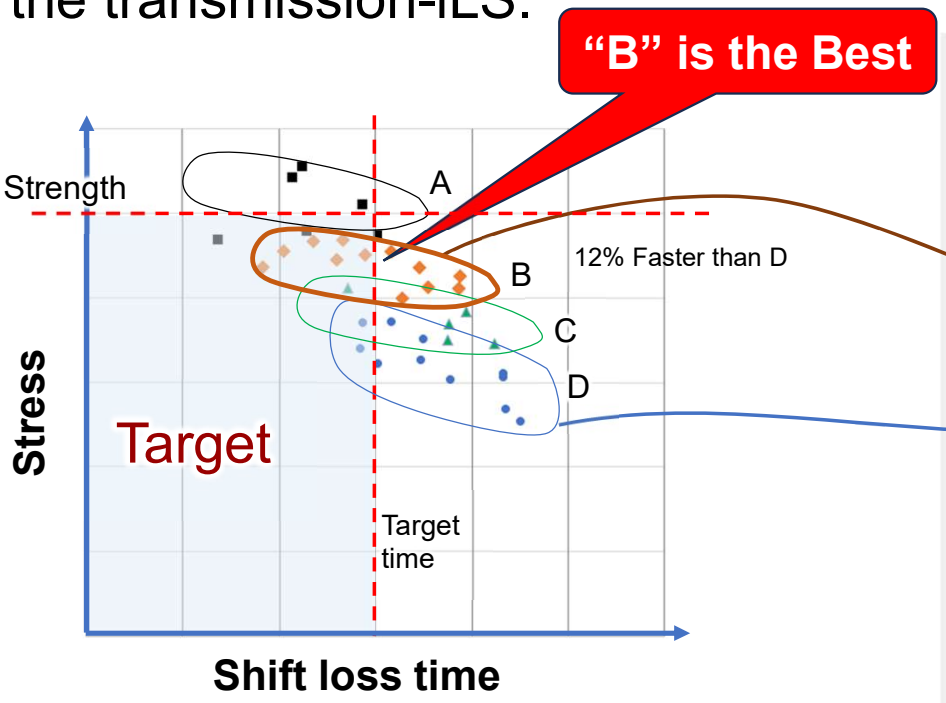


Fig. Gear shift performance for each coefficient value

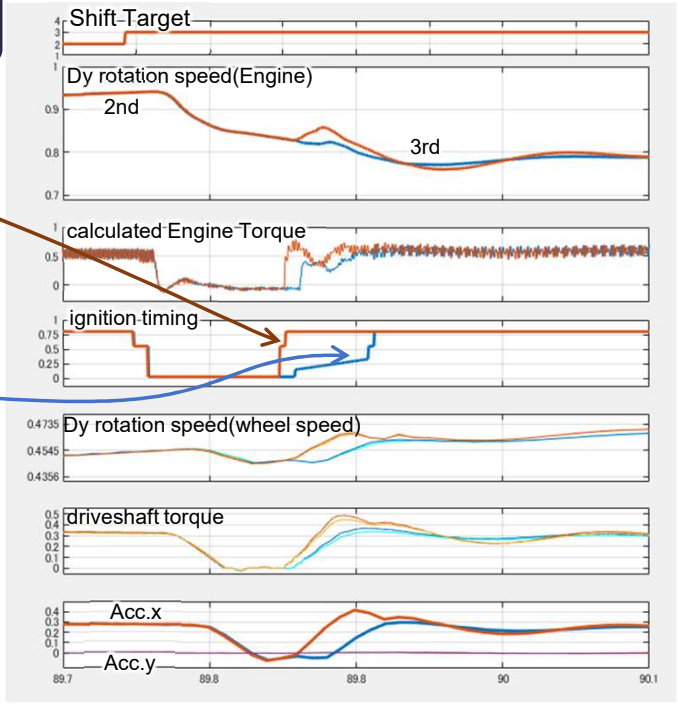
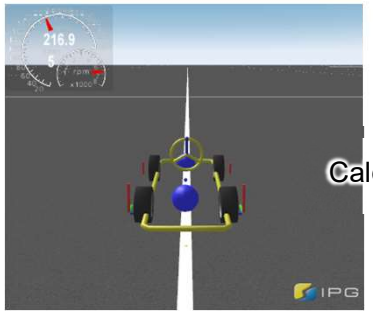


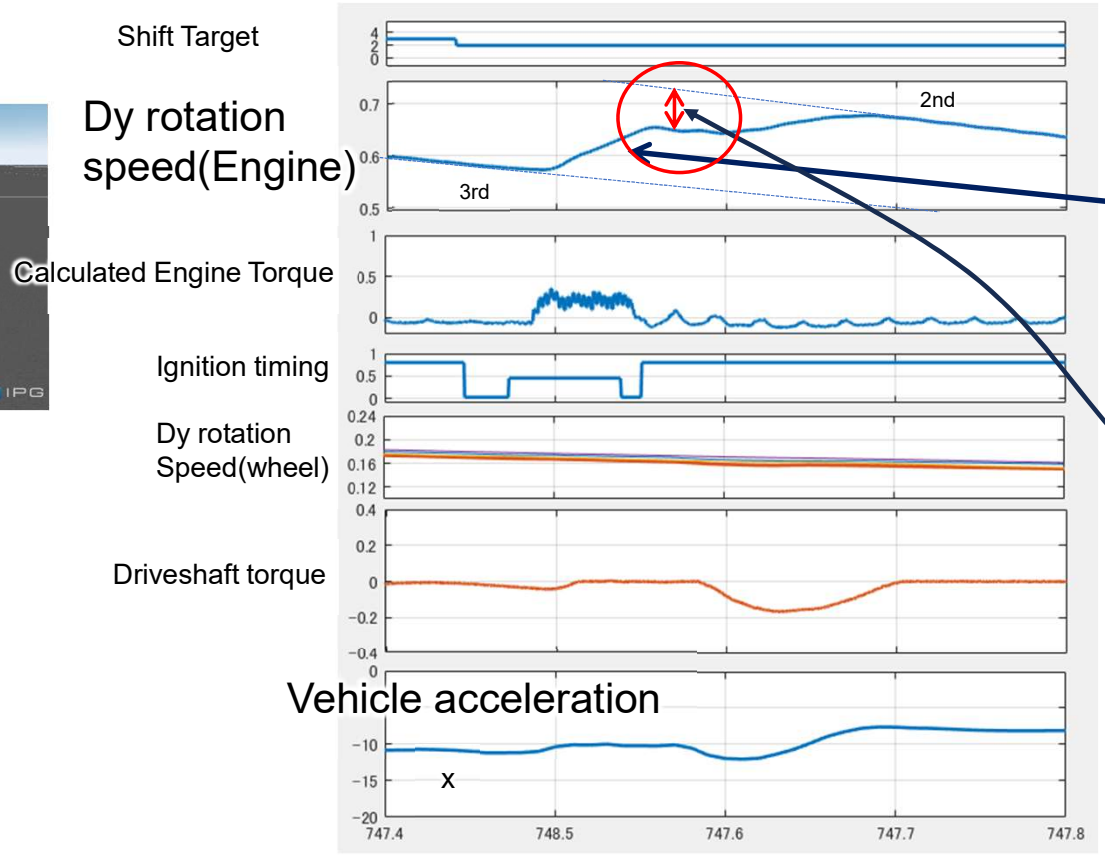
Fig. 2-3upshift waveforms with coefficient B and D

Calibration value optimized to minimize shift loss time under the strength limits

2. Calibration for downshifting on flat roads

Deceleration on flat roads





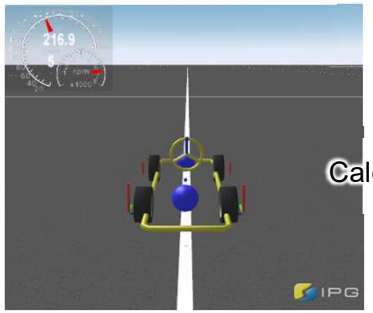
Increasing engine speed by blipping control in the downshift.

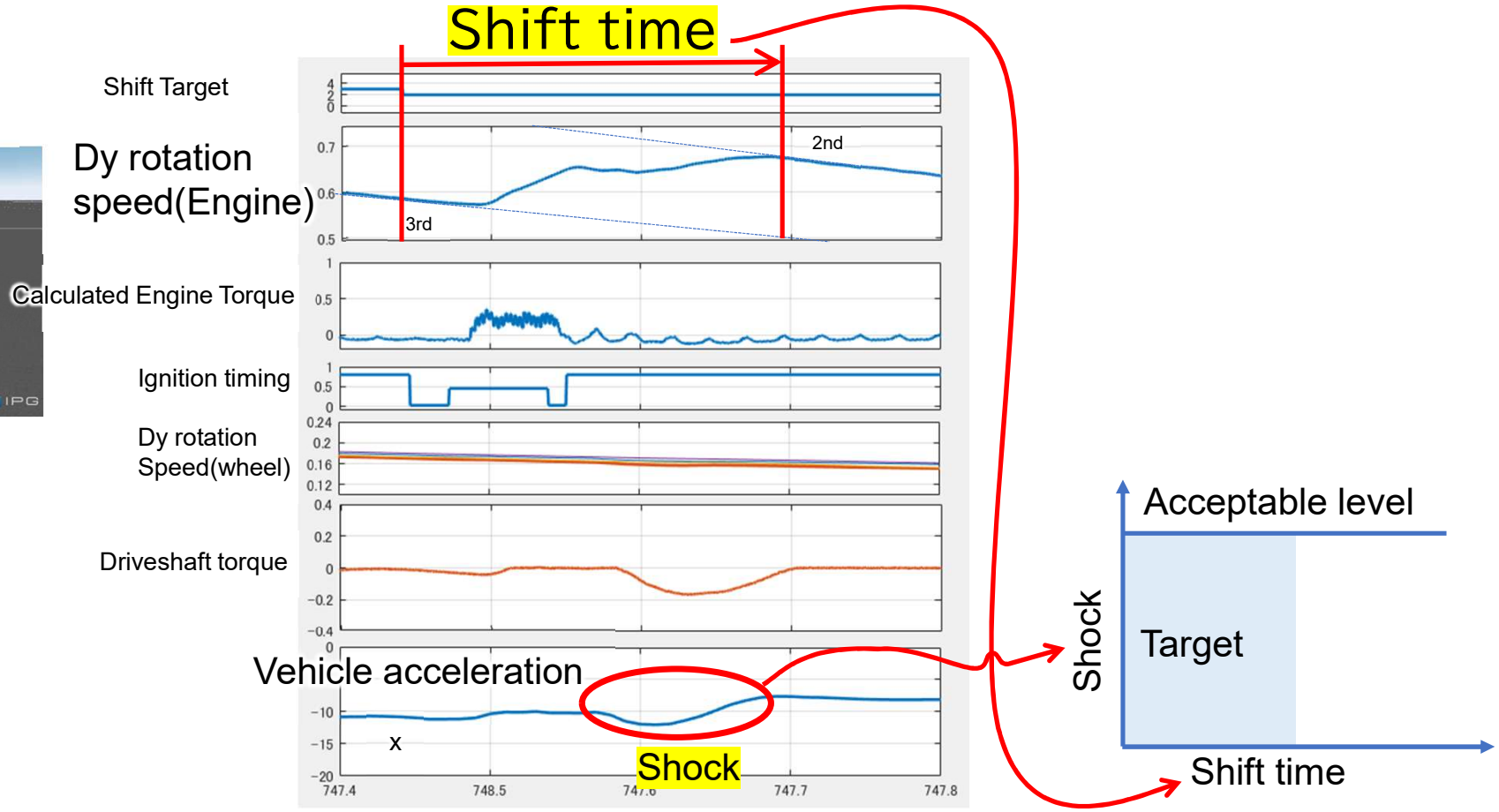
In dog transmissions, gears can not be engaged at the timing when the engine speed reaches to the synchronous speed, so it needs to have the difference before the engagement.

Fig. 3-2 downshift waveforms

2. Calibration for downshifting on flat roads

Deceleration on flat roads





The blipping control was adjusted to minimize shift time under the acceptable shock level

Flow of shifting performance development:

1. Calibration for upshifting on flat roads.
2. Calibration for downshifting on flat roads.
3. Calibration for shifting under combined conditions (**Circuit driving at Nürburgring**).

Circuit driving simulation using Transmission-iLS

- In past developments, there were various issues with prototype vehicle during circuit driving at Nürburgring, even after completing calibration on flat roads.
- To break through this situation, we challenged ourselves to simulate circuit driving using Transmission-iLS.

Previous development

Prototype

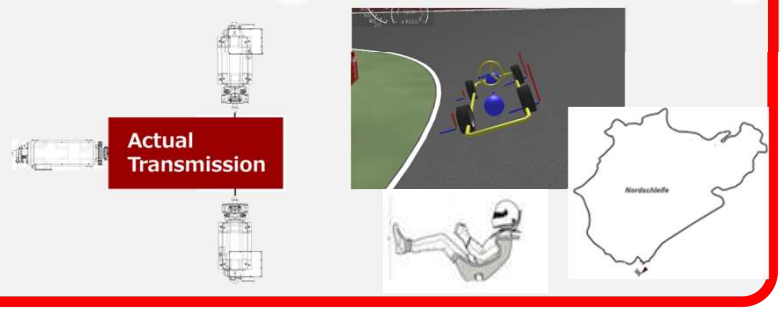
Calibration on flat roads

Circuit

Front-loading

Development we challenged

Simulating circuit driving



Transmission-iLS

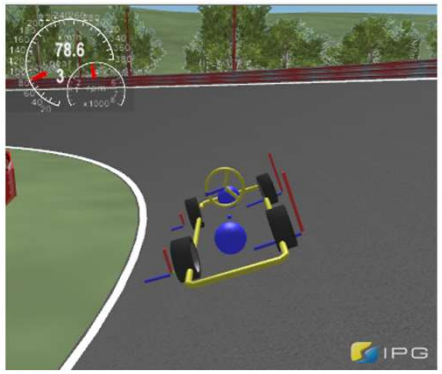
Prototype

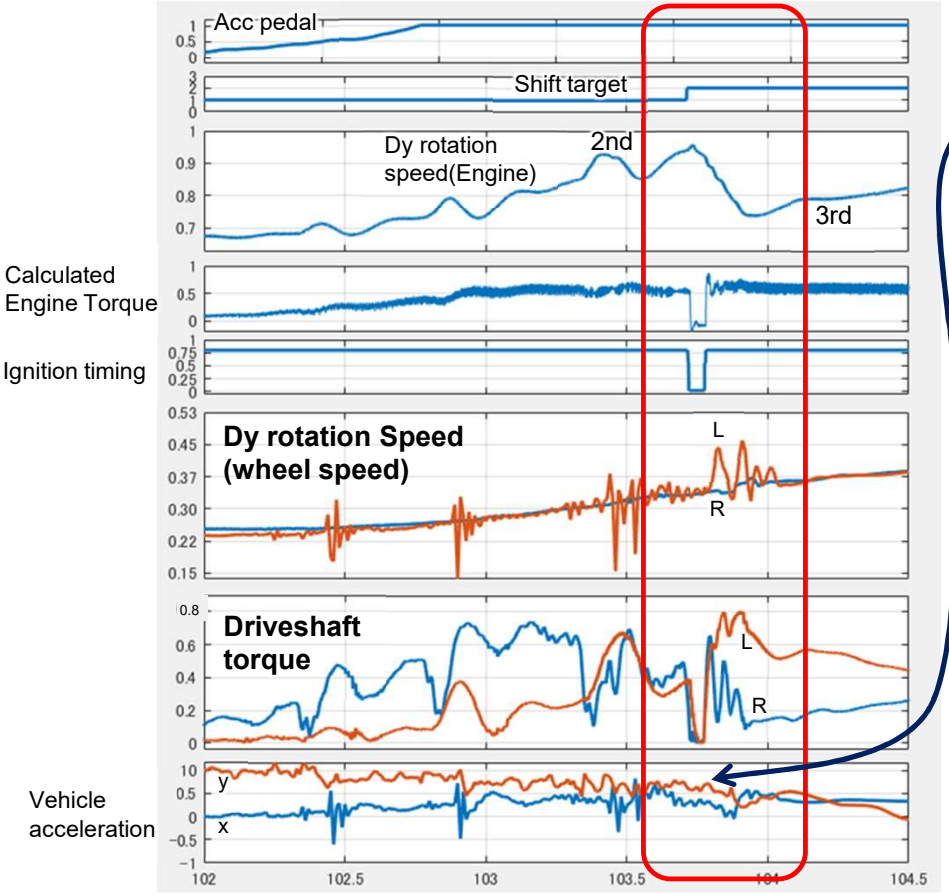
Circuit

Circuit driving simulation results (Large twist in drive shaft).

- In the past developments, the driveshaft broke in the corners with uneven road surfaces. We checked if this issue would occur on the vehicle we were developing.

Uneven road surfaces





cornering

Slip due to uneven road surfaces

Upshift

Driveshafts are twisted

Fig Upshift waveforms simulated during the uneven road surface

Circuit driving simulation results (Large twist in drive shaft).

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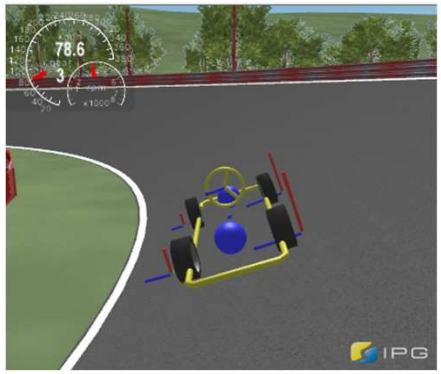
uneven road surfaces



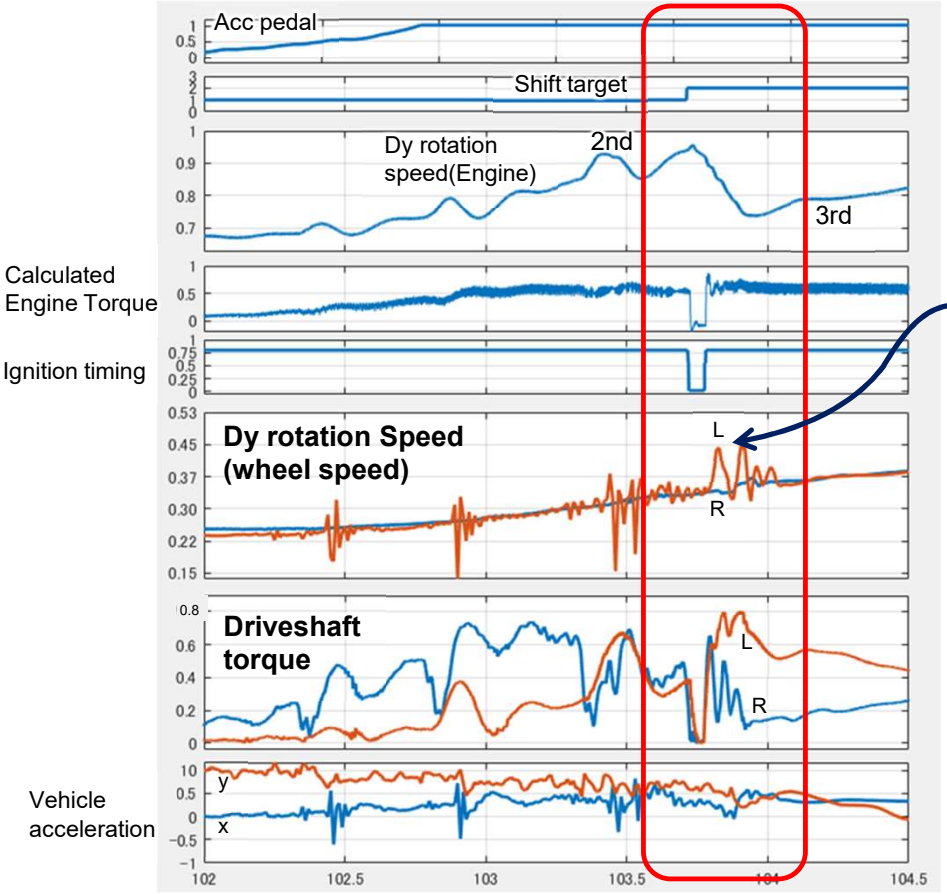


Fig Upshift waveforms driving on the uneven road surface

cornering

↓

Slip due to uneven road surfaces

Upshift

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Circuit driving simulation results (Large twist in drive shaft).

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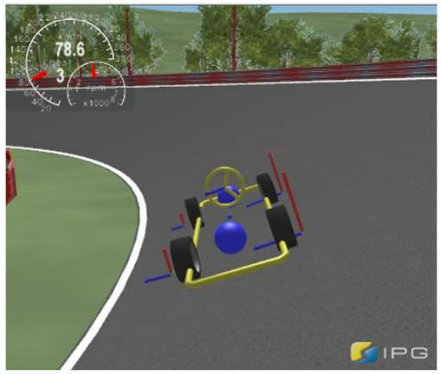
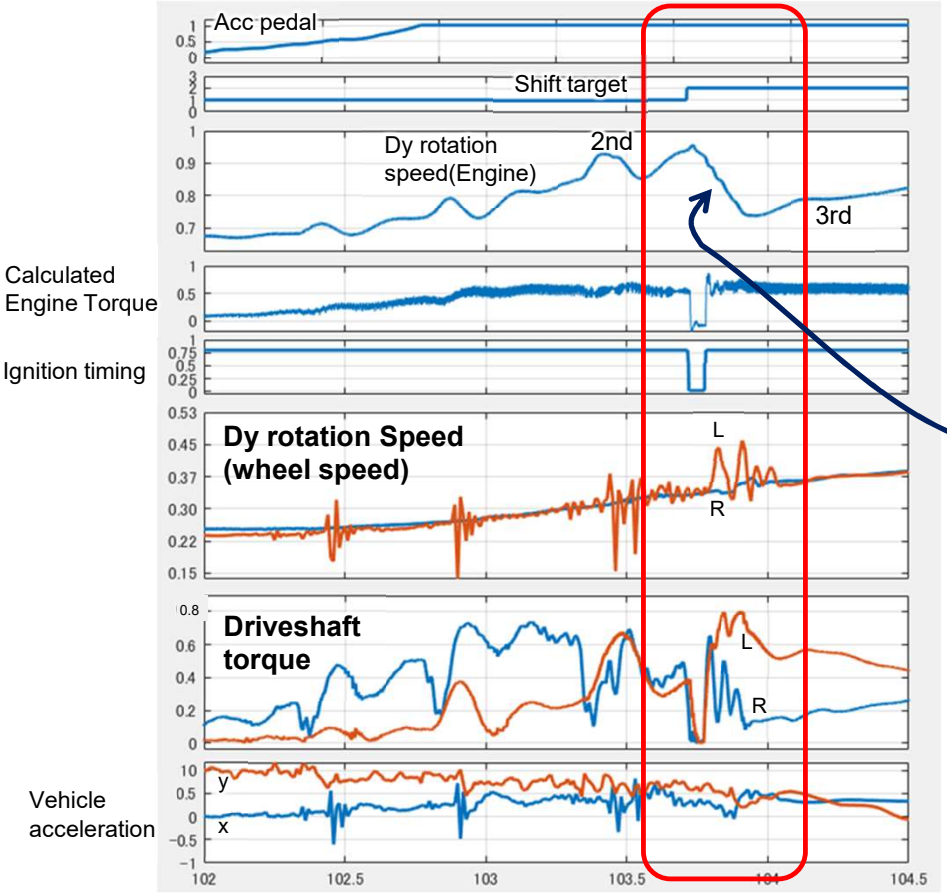
uneven road surfaces





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cornering

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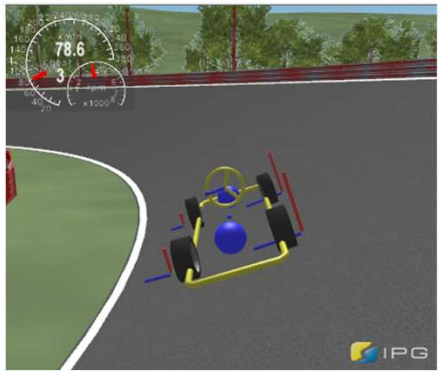
uneven road surfaces



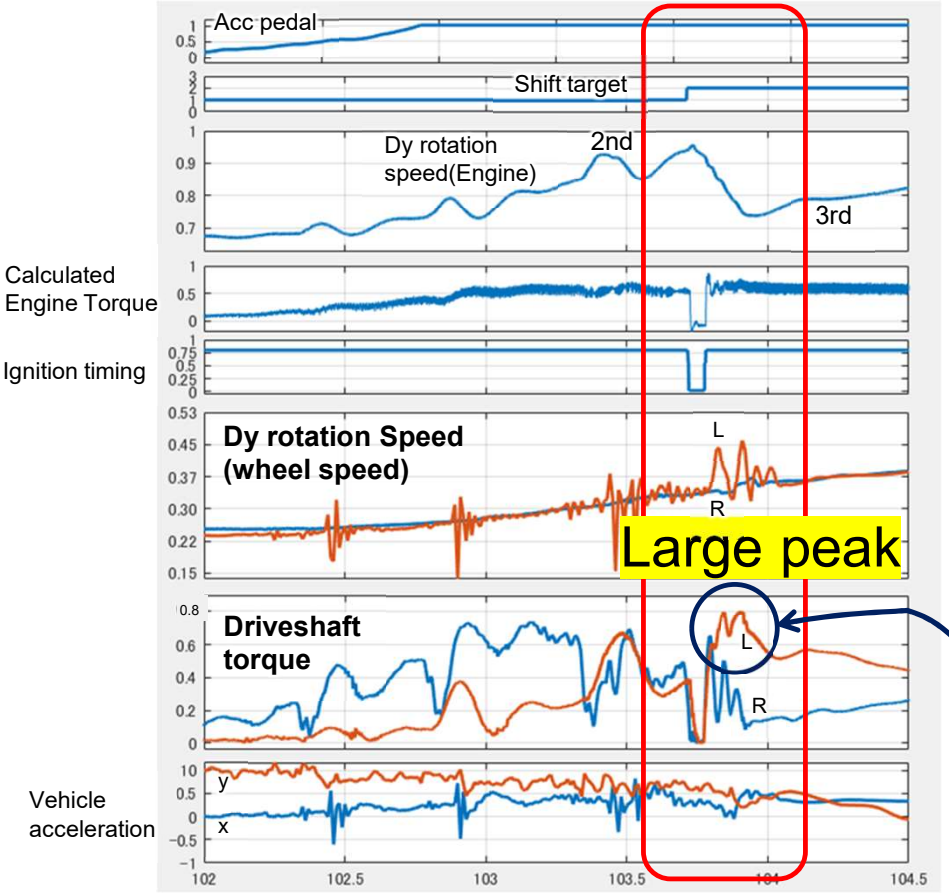


Fig Upshift waveforms driving on the uneven road surface

cornering

↓

Slip due to uneven road surfaces

Upshift

↓

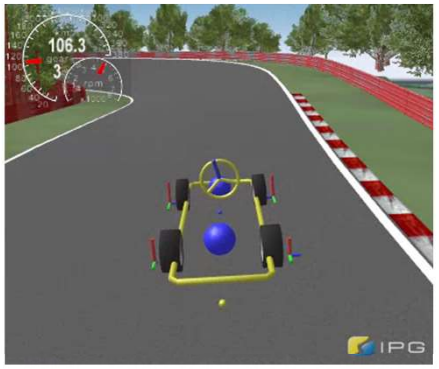
Driveshafts are twisted

We confirmed that the twist must be reduced by reproducing in transmission-iLS

Circuit driving simulation results (Downshift failure).

- In the dog transmissions, there are cases of downshift failures during rapid deceleration.
- Identified the corners where this issue could occur

Rapid deceleration



Downhill cornering

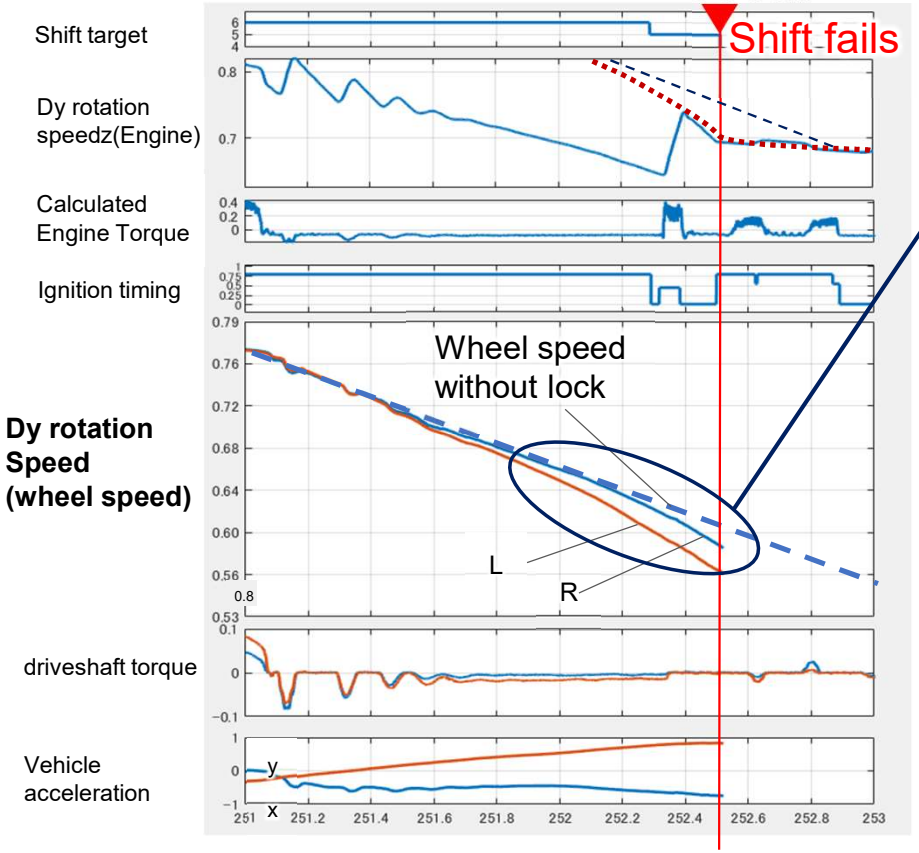


Fig Downshift failure waveforms during the downhill corner

The tire is about to lock

The target gear's synchronized rotational speed decreases

Rotation synchronization fails due to blipping

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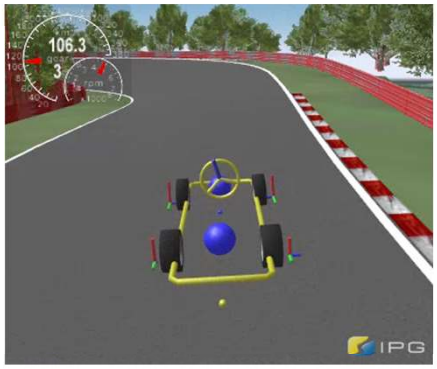
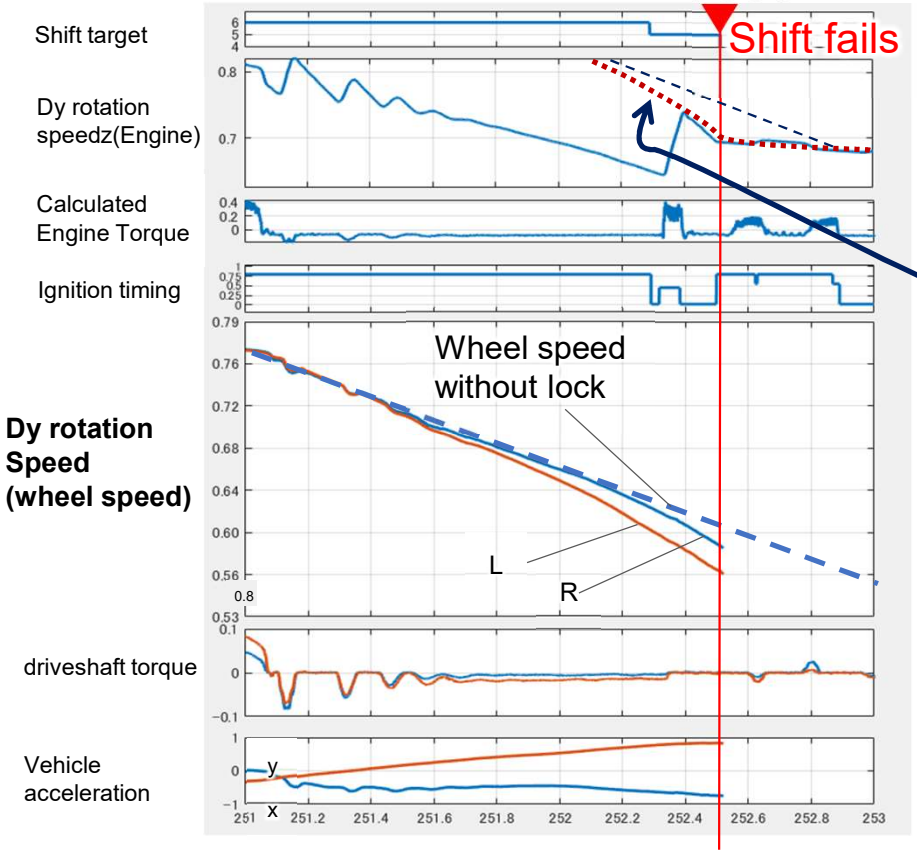
Rapid deceleration



Downhill cornering



The tire is about to lock

The target gear's synchronized rotational speed decreases

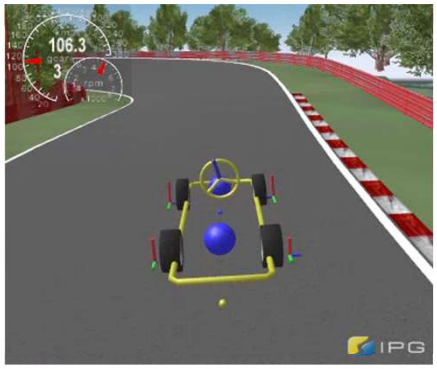
Rotation synchronization fails due to blipping

Fig Downshift failure waveforms during the rapid deceleration

Circuit driving simulation results (Downshift failure).

- In the dog transmissions, there are cases of downshift failures during rapid deceleration.
- Identified the corners where this issue could occur

Rapid deceleration



Downhill cornering

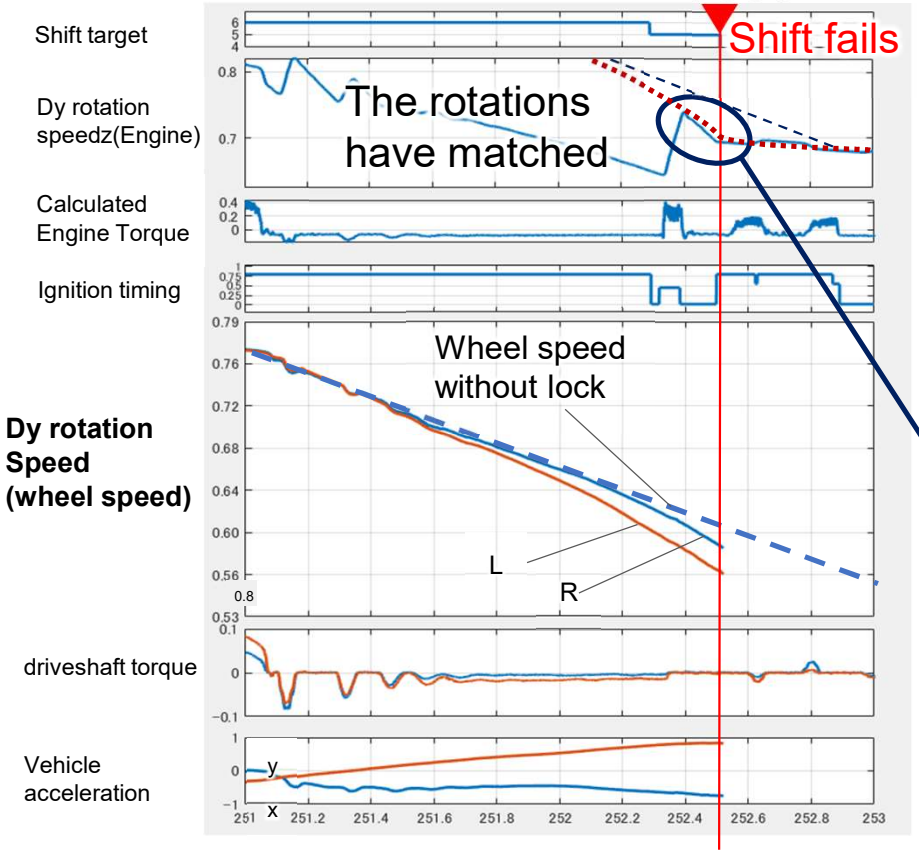


Fig Downshift failure waveforms during the rapid deceleration

The tire is about to lock

The target gear's synchronized rotational speed decreases

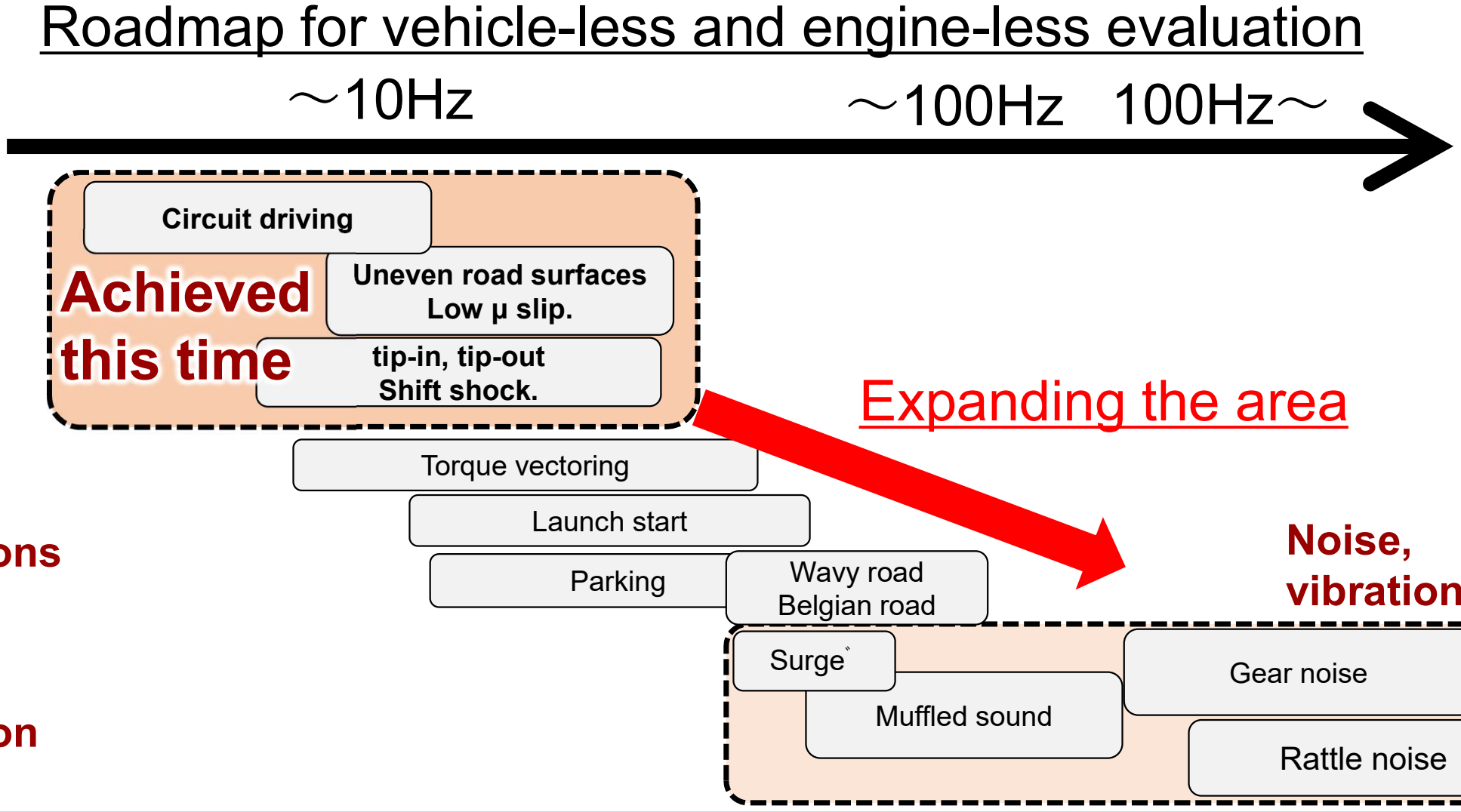
Rotation synchronization fails due to blipping

Problem with Dog's mechanism

This time, the blipping was adjusted to match the tire lock-up

Contents

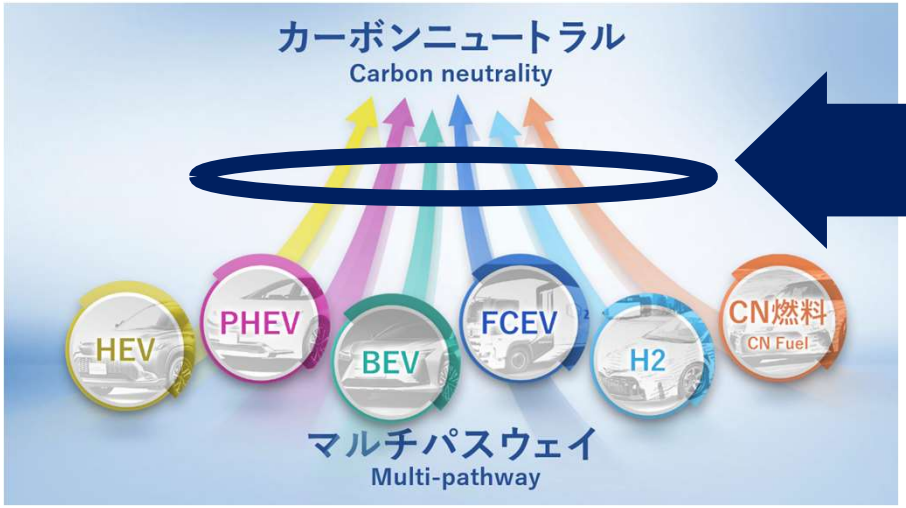
Roadmap for vehicle-less and engine-less evaluation



As the next goal, we will work on simulating the actual behaviors of the functions, noises and vibrations.

Conclusion

- Transmission-iLS had been developed mainly by CarMaker.
- It has been found to be effective in improving the initial completeness of development.
- It is expected to reduce the development period by approximately 20%.
- We have acquired a tool for multi-pathway strategy.
- Moving forward, we will challenge ourselves to achieve our ultimate goal of front-loading all phenomena.



Transmission-iLS