

2023 EMEA VI-GRADE ZERO PROTOTYPES SUMMIT



Model Base Development of Powertrain Noise Using an NVH Simulator



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1. Importance of Powertrain NV Performance in Automobiles

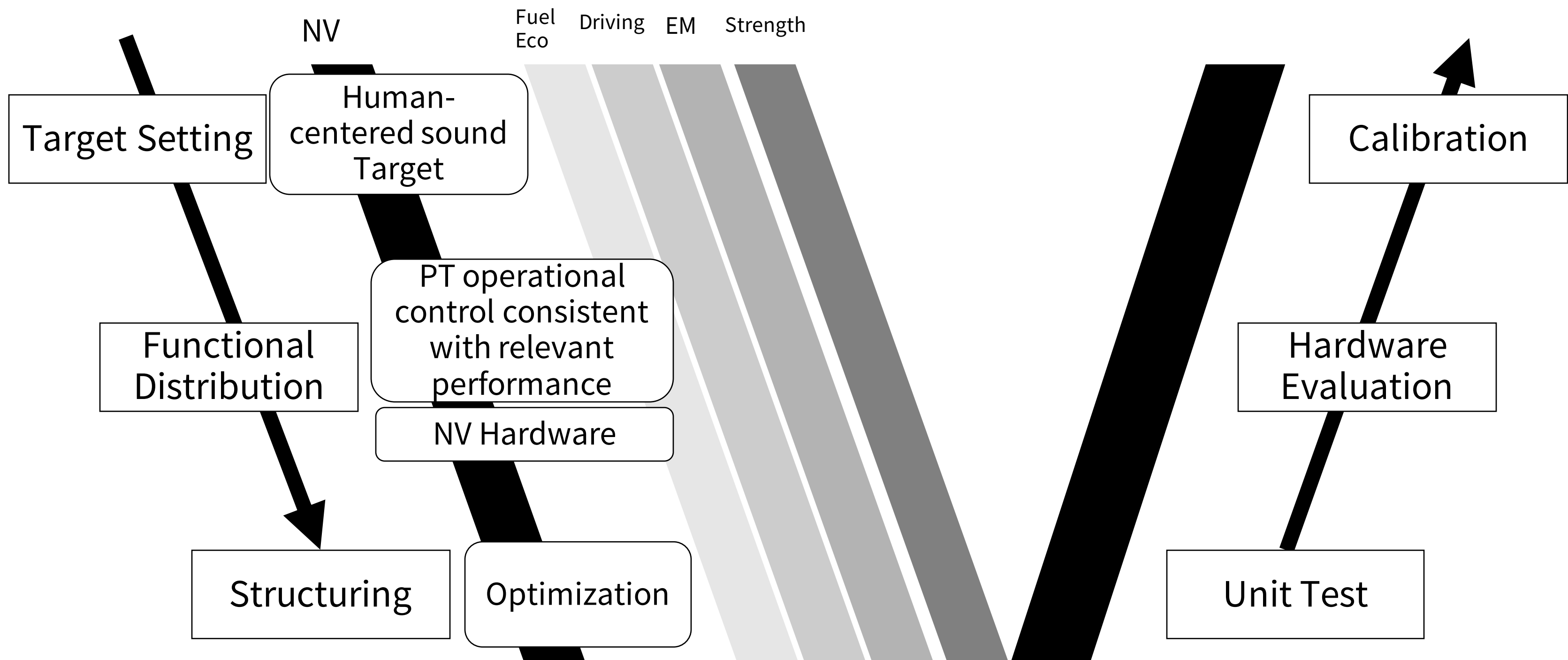
CORPORATE VISION

We love cars and want people to enjoy fulfilling lives through cars.
We envision cars existing sustainably with the earth and society,
and we will continue to tackle challenges with creative ideas.

1. Brighten people's lives through car ownership.
2. Offer cars that are sustainable with the earth and society to more people.
3. Embrace challenges and seek to master the Doh ("Way" or "Path") of creativity.

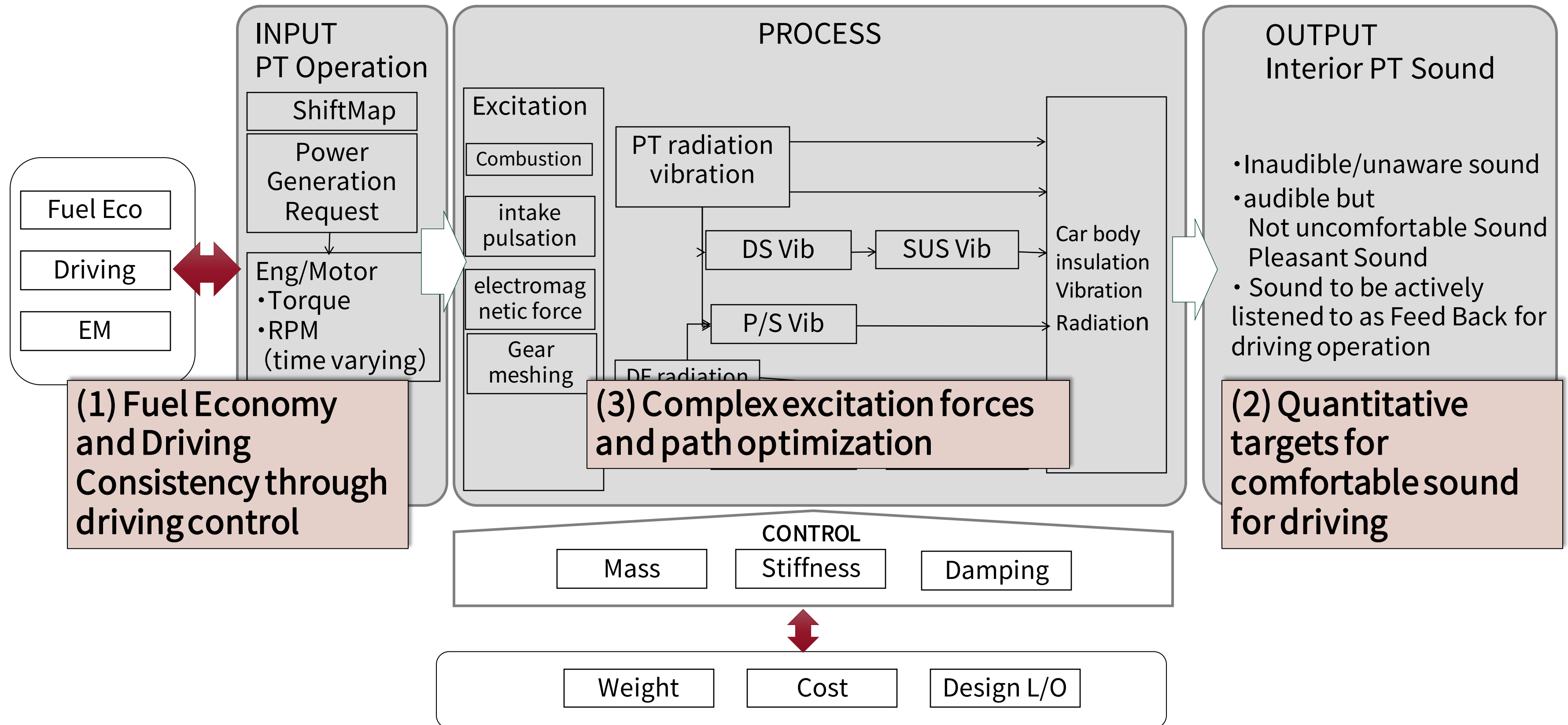
2. Powertrain NV Development Challenges

■ How it should be



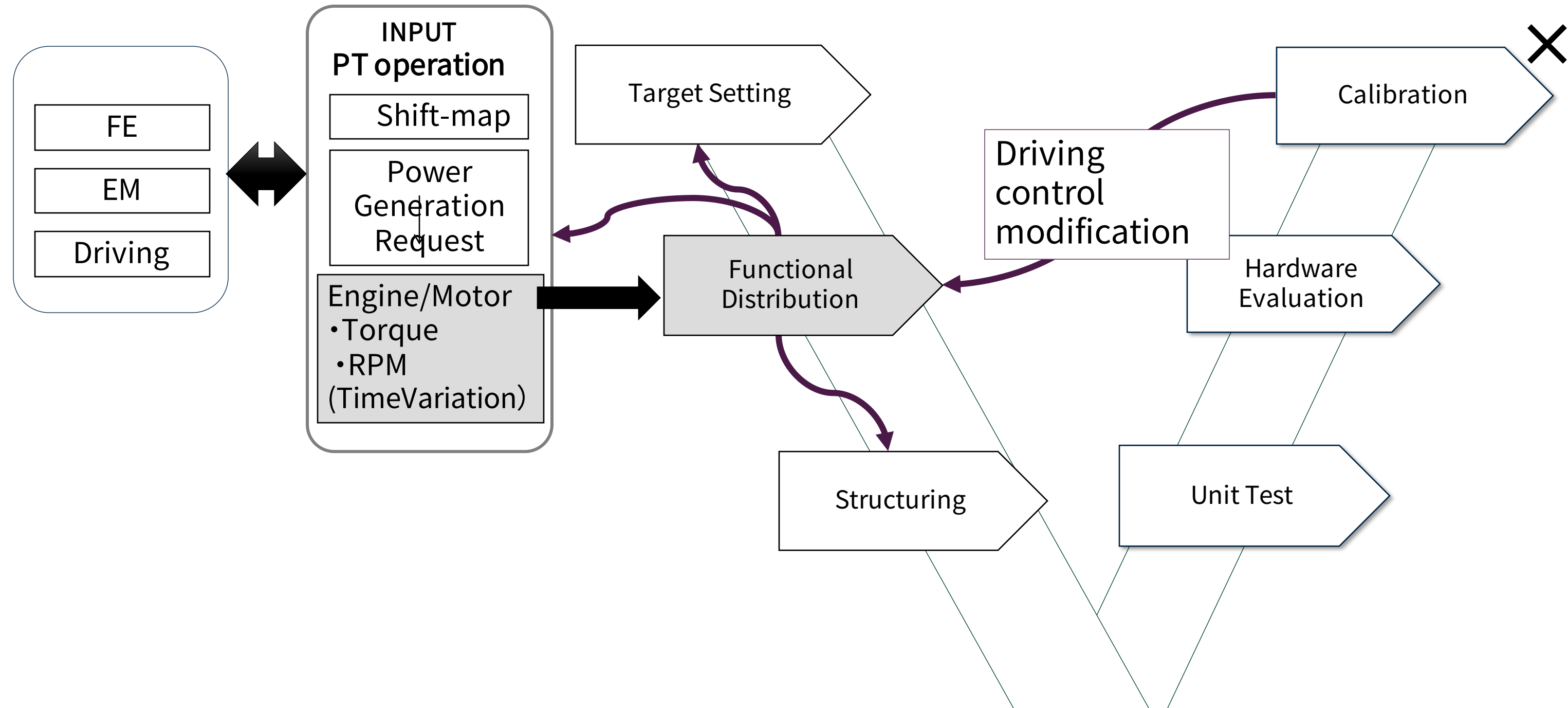
It is important to built in relevant performance and quality in the functional allocation in the early stages of development.

■ Difficulties in developing powertrain NV



■ Challenge: Fuel Economy, Driving and NV Consistency

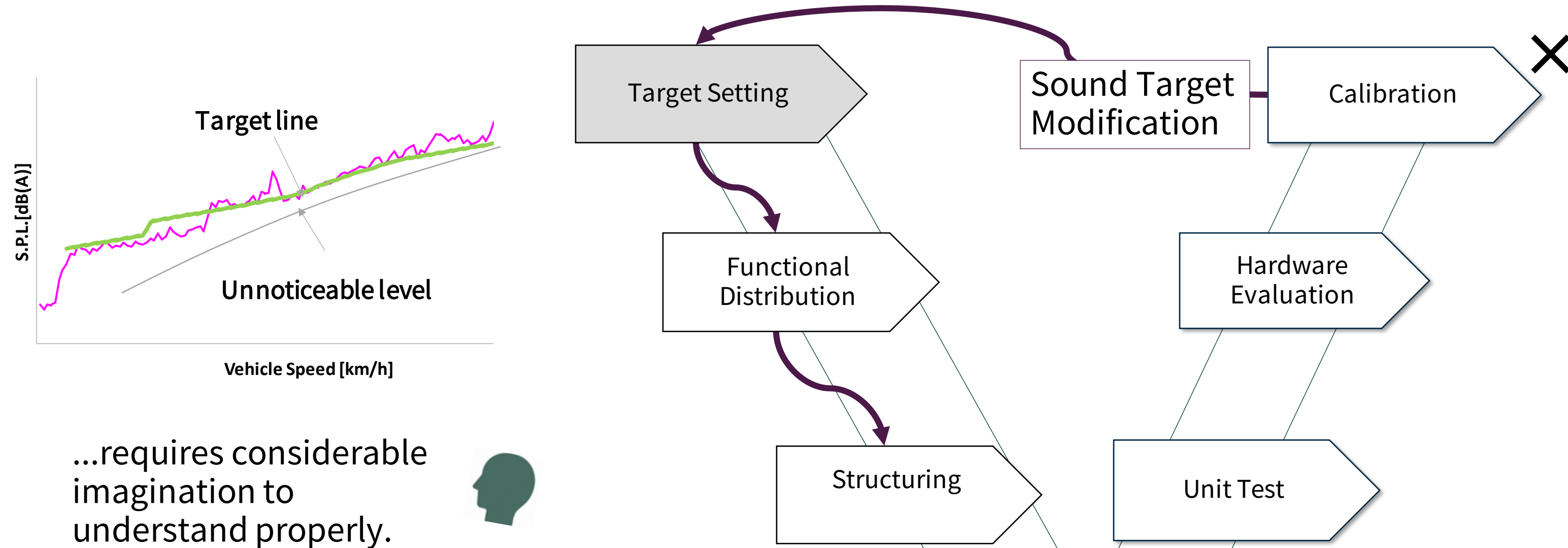
NV excitatory force varies greatly depending on how the engine/motor is operated



PT operational control changes NV excitation, and redoing function allocation and countermeasure structures will result in major rework.

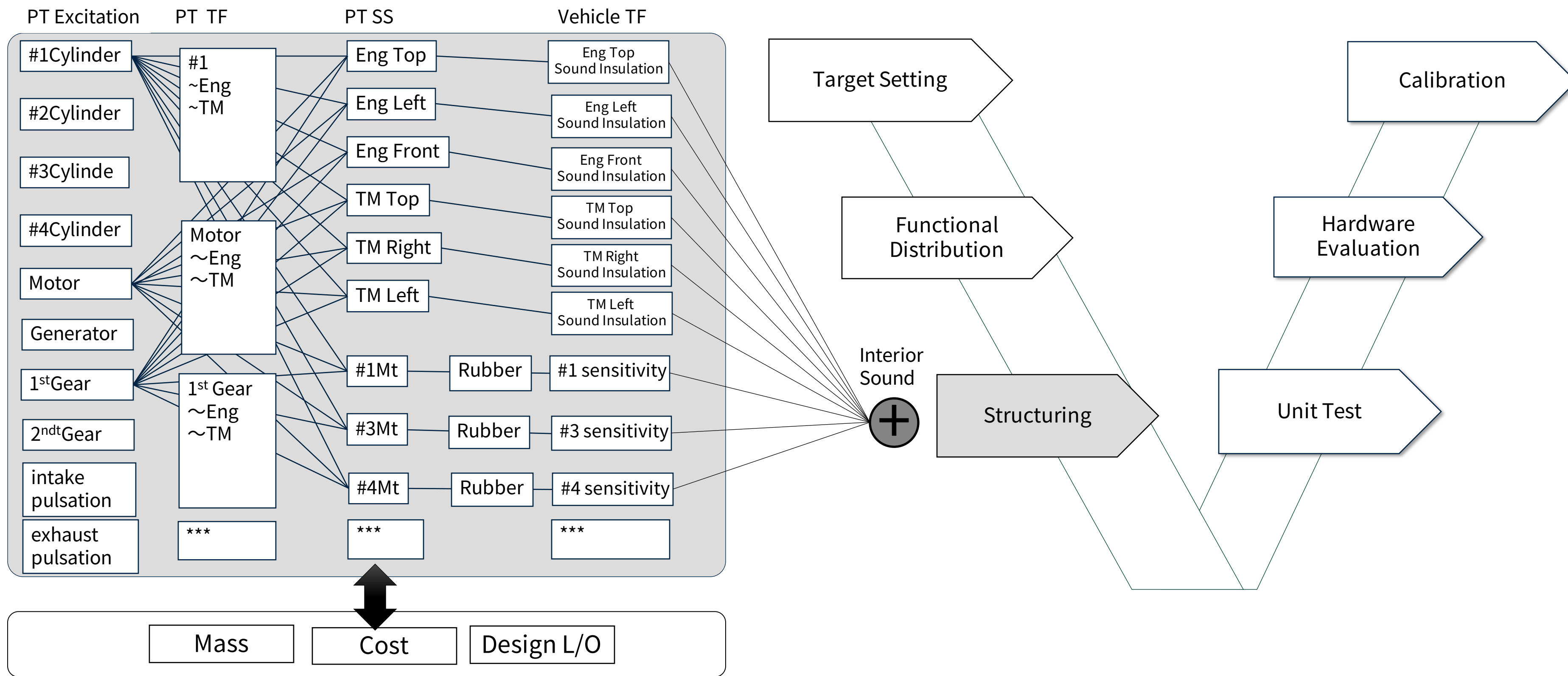
■ Challenge: Quantitative targets for audible sounds according to operation

Targets for engine and EV sound are complex and vary depending on driving conditions. Although there are basic quantitative targets, there are accuracy issues related to differences in sound quality, and it is difficult to reach a consensus among stakeholders with numerical data.



If the sound target changes, there will be major rework, such as redoing the countermeasure structure.

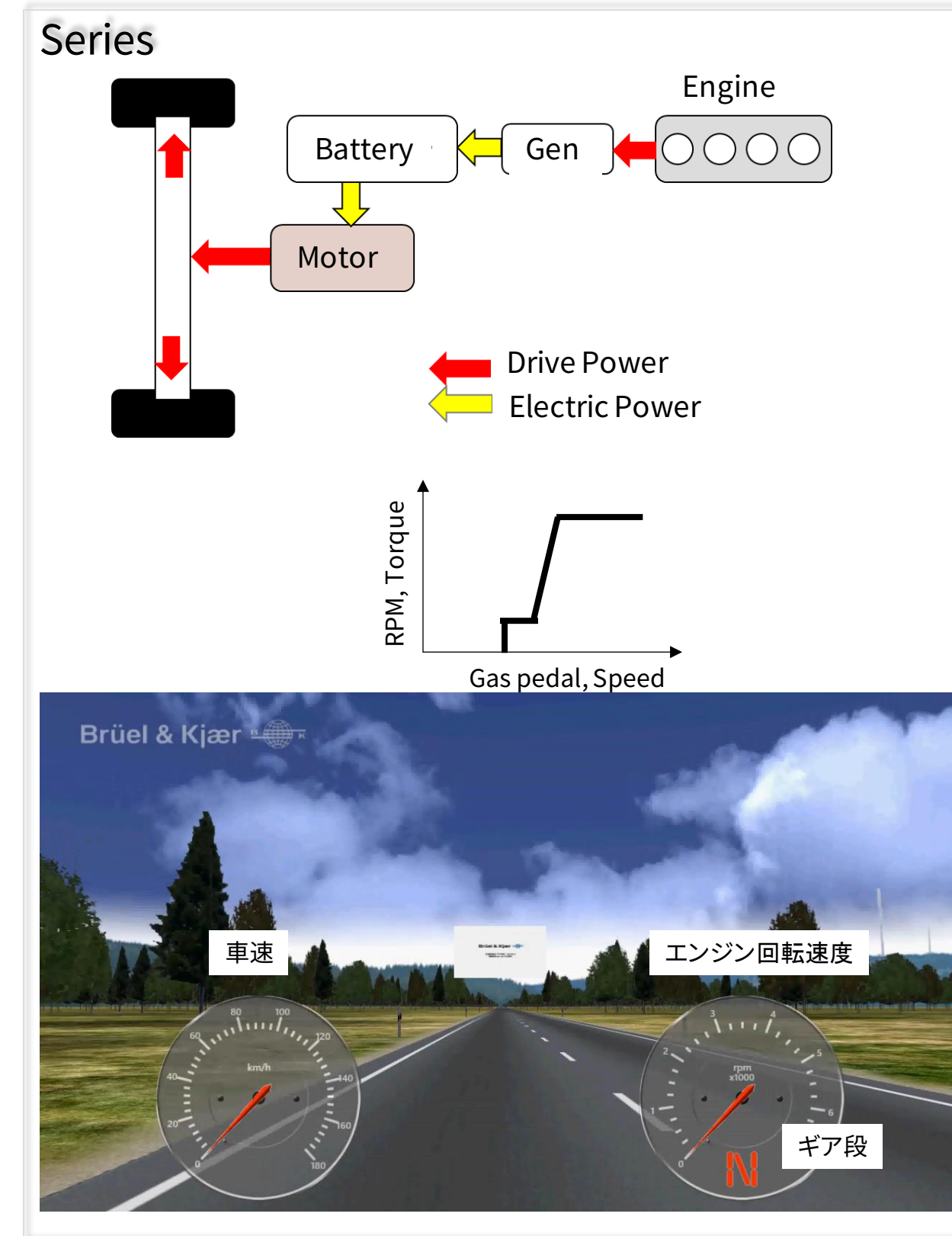
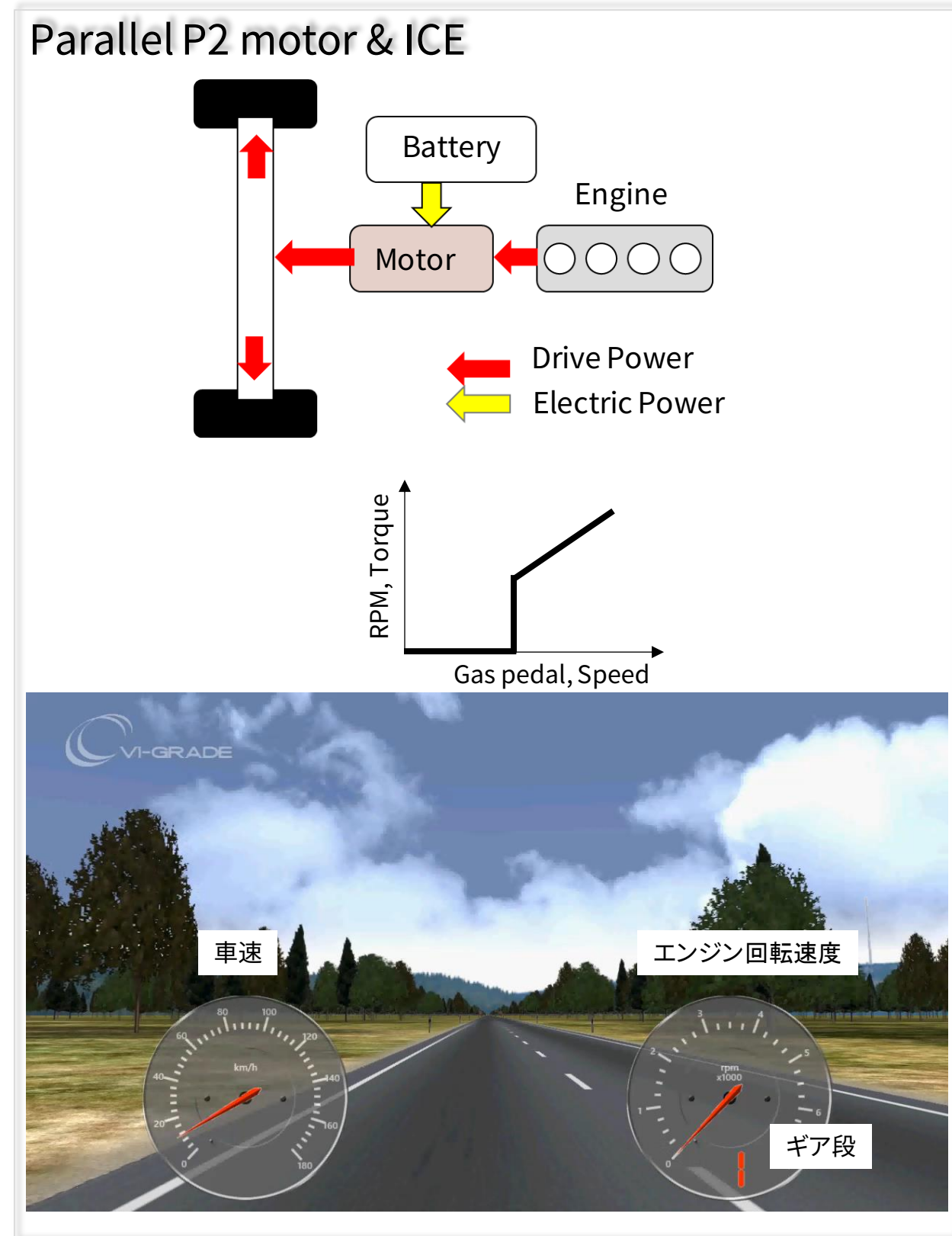
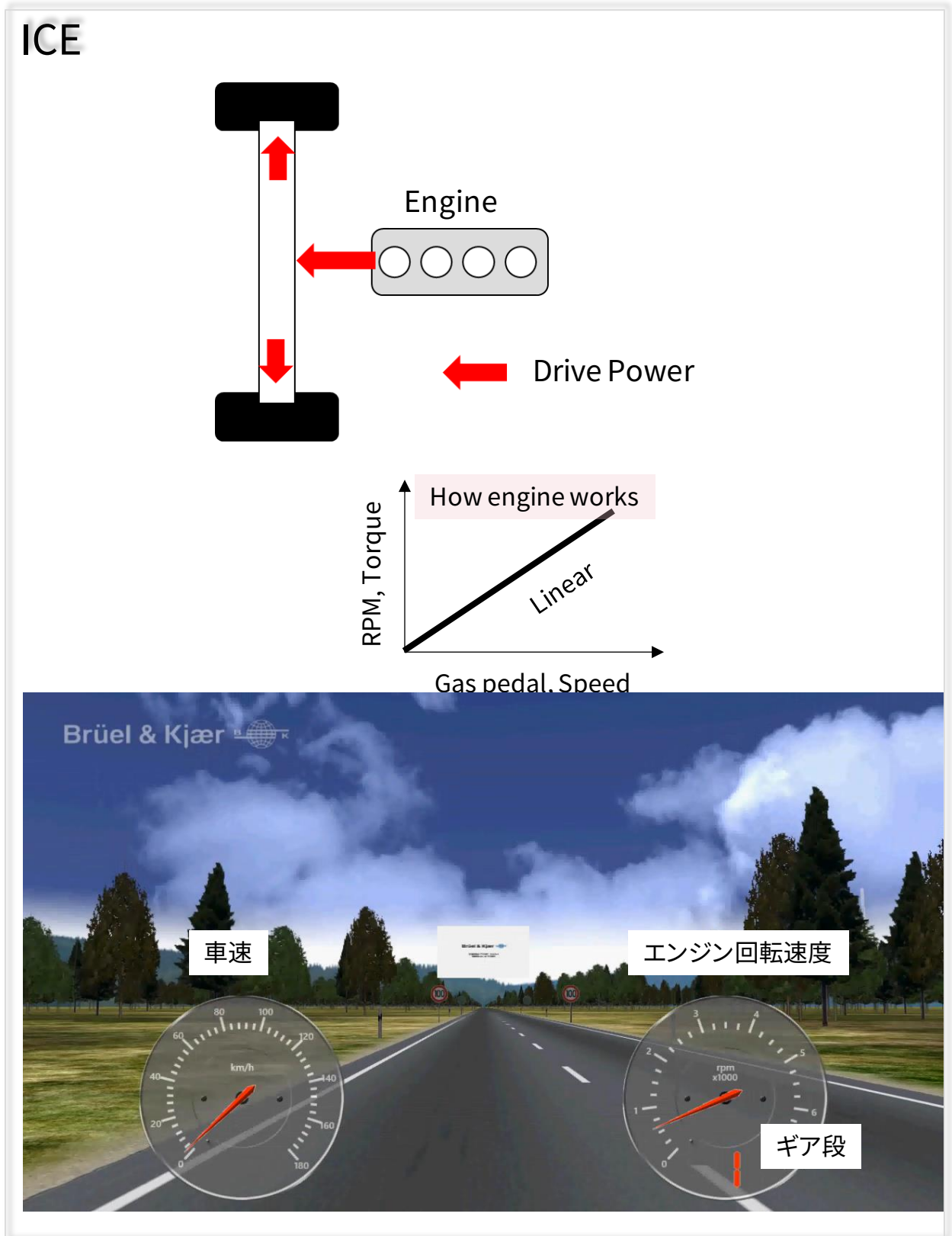
■Challenge: Enormous excitation force and path optimization



Visualization of "where is the most efficient way to improve the numerous excitation and paths" is necessary.

■ Risk to sound from increased complexity of PT usage

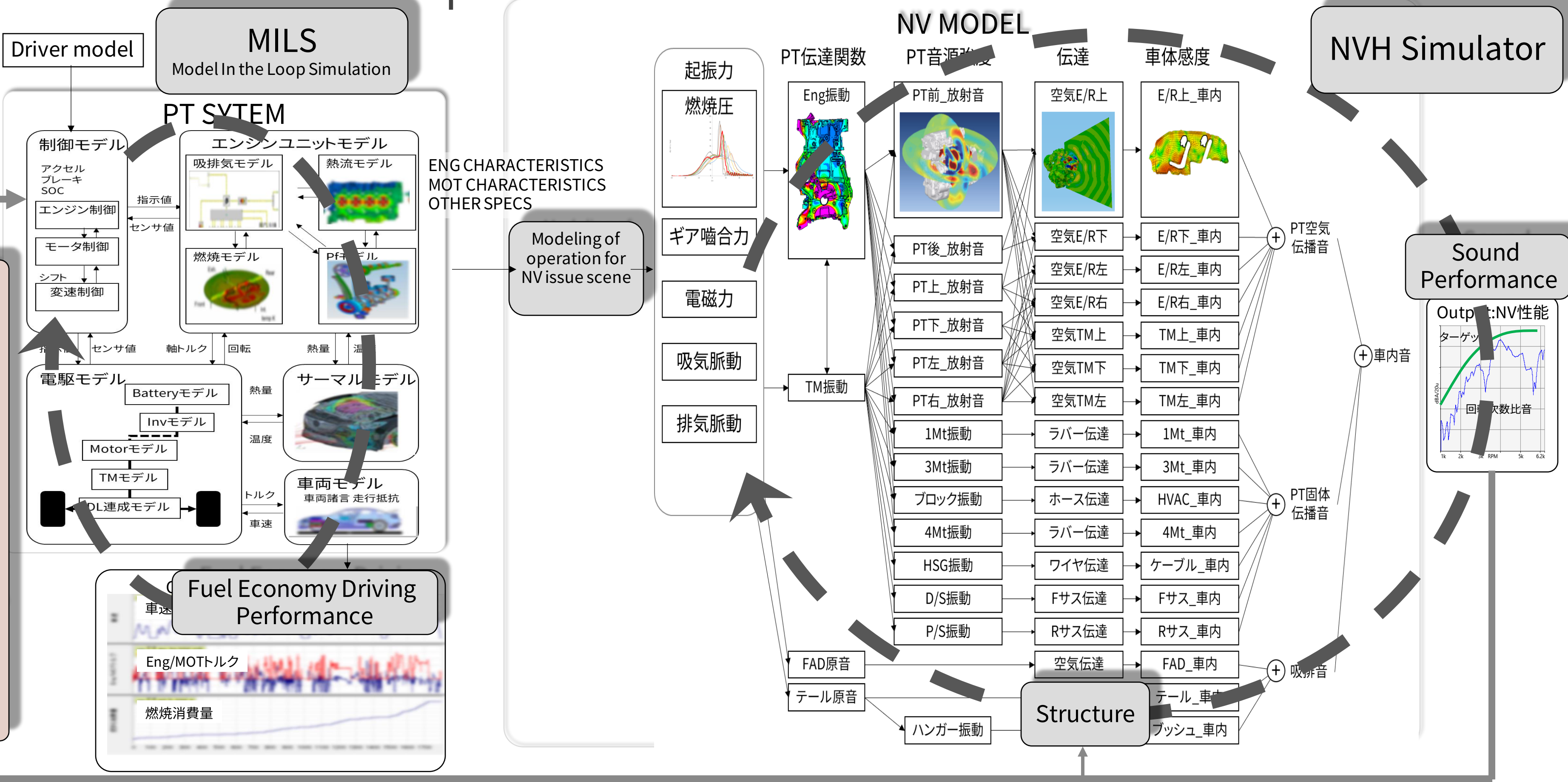
Acceleration with increasing gas pedal from launch with 3 virtual cars
(PT noise is exaggerated).



A risk is that NV requirements for better control of RPM and torque will increase and become increasingly difficult to match with fuel-efficient driving.

3. Model Based Development ★ *参考文献;マツダの目指すモデルベース開発、藤川、マツダ技報 No.31(2013)

Reflecting NV requirements = rework



Evolution of Model-Based Development

Free Drive Operation

*参考文献;SKYACTIV の MBD 検証環境
について、臼田、マツダ技報 No.31(2013)

High-Speed
MILS*

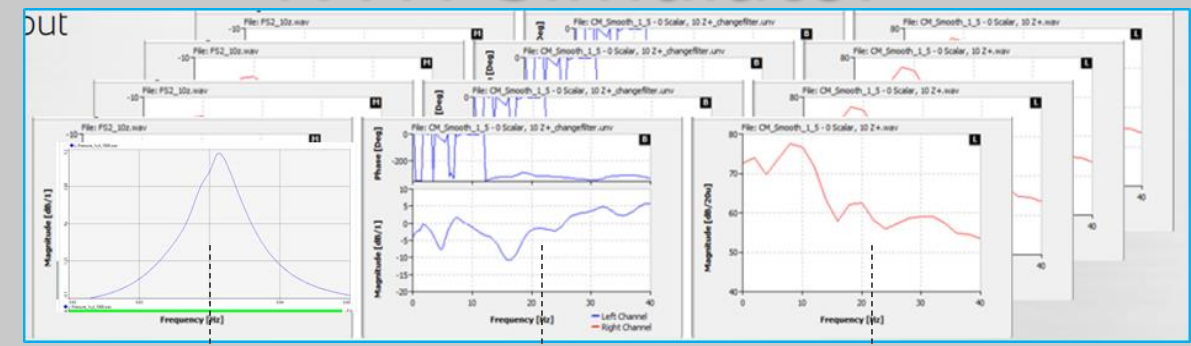
Control
Model

ENG → MOT → Gear → Vehicle

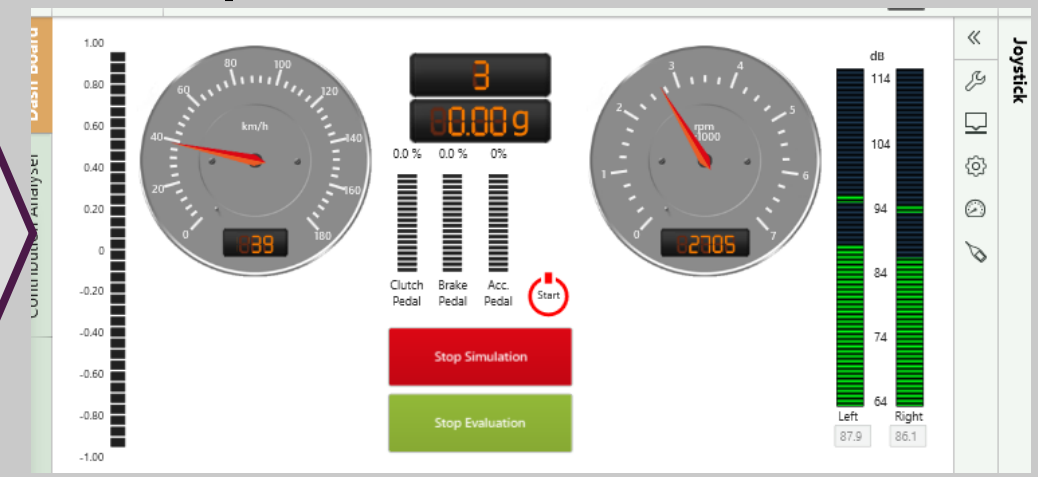


Real Time
UDP
Communication

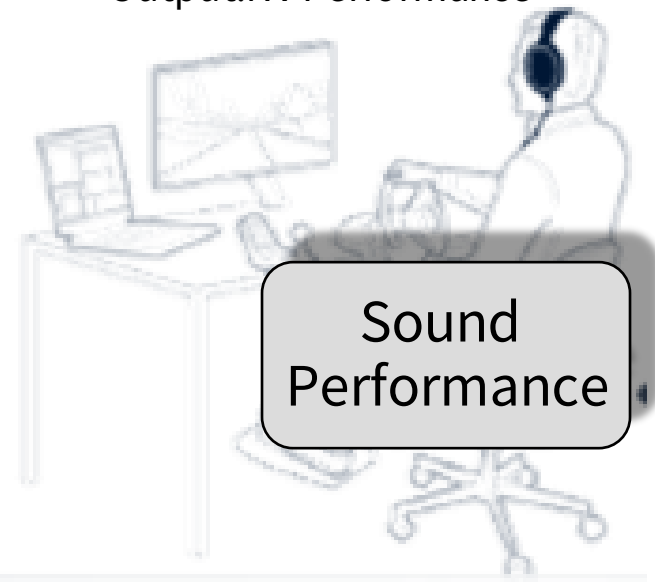
NVH Simulator



Excitation → PT TF → Vehicle TF



Output:NV Performance



Sound
Performance

Output:FuelEco,Driving,Emission

Vehicle Speed
Eng/MOT Torque
Fuel consumption

Fuel Economy
Driving
Performance

Reflection of
control model

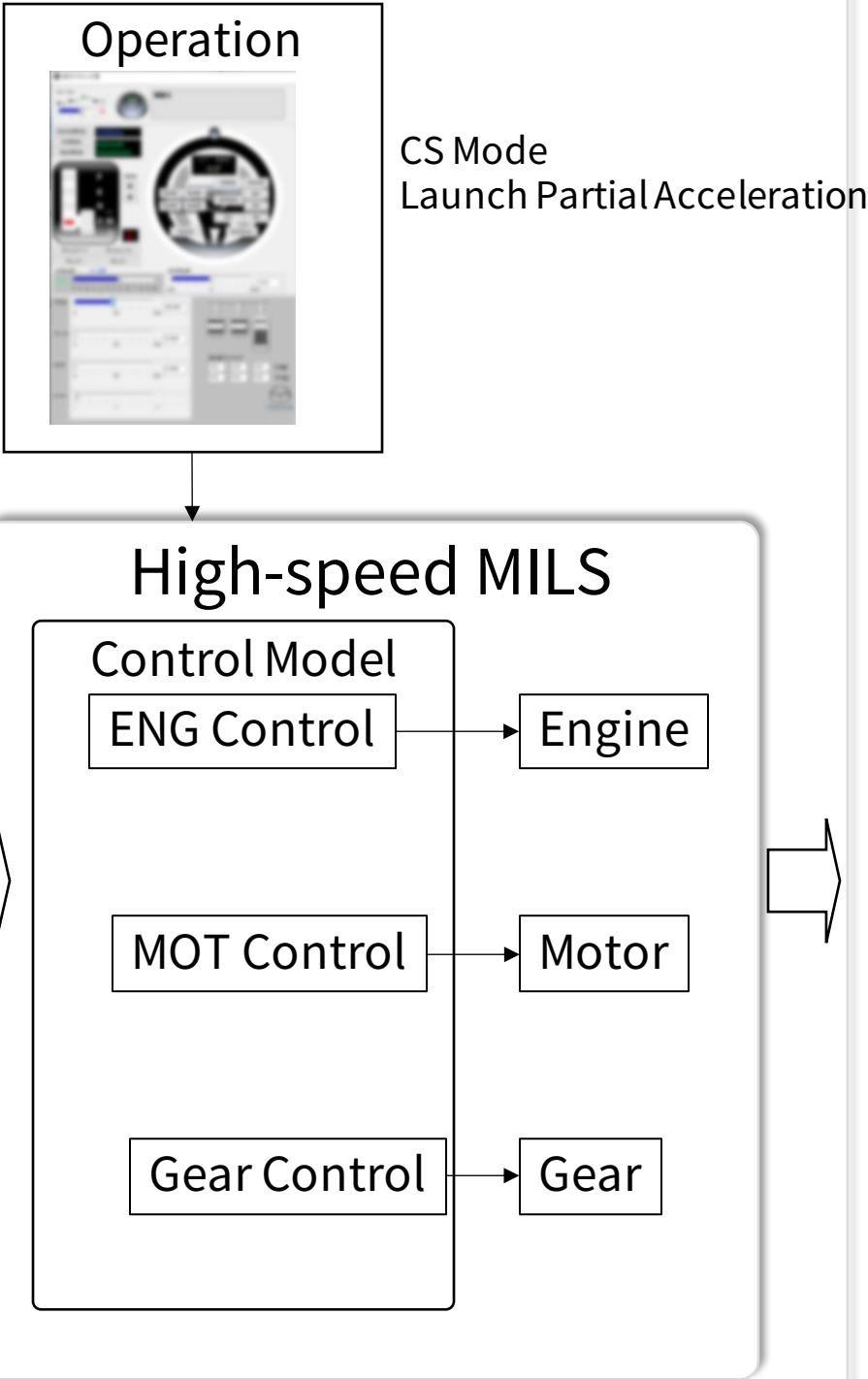
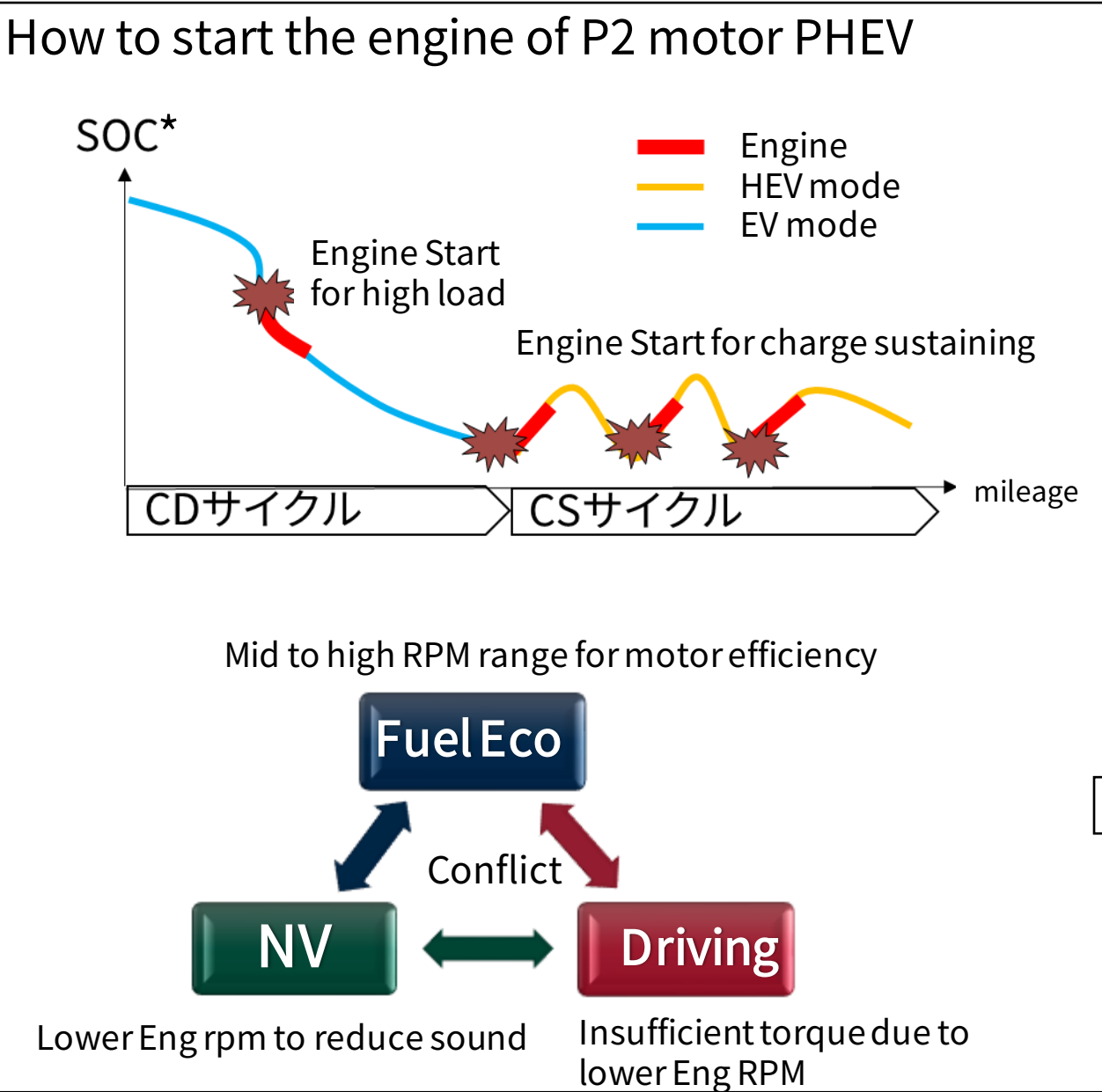
System integration will enable early calibration and verification of control models that achieve both NV and fuel-efficient driving.

*Model In the Loop Simulation

4. Application Examples

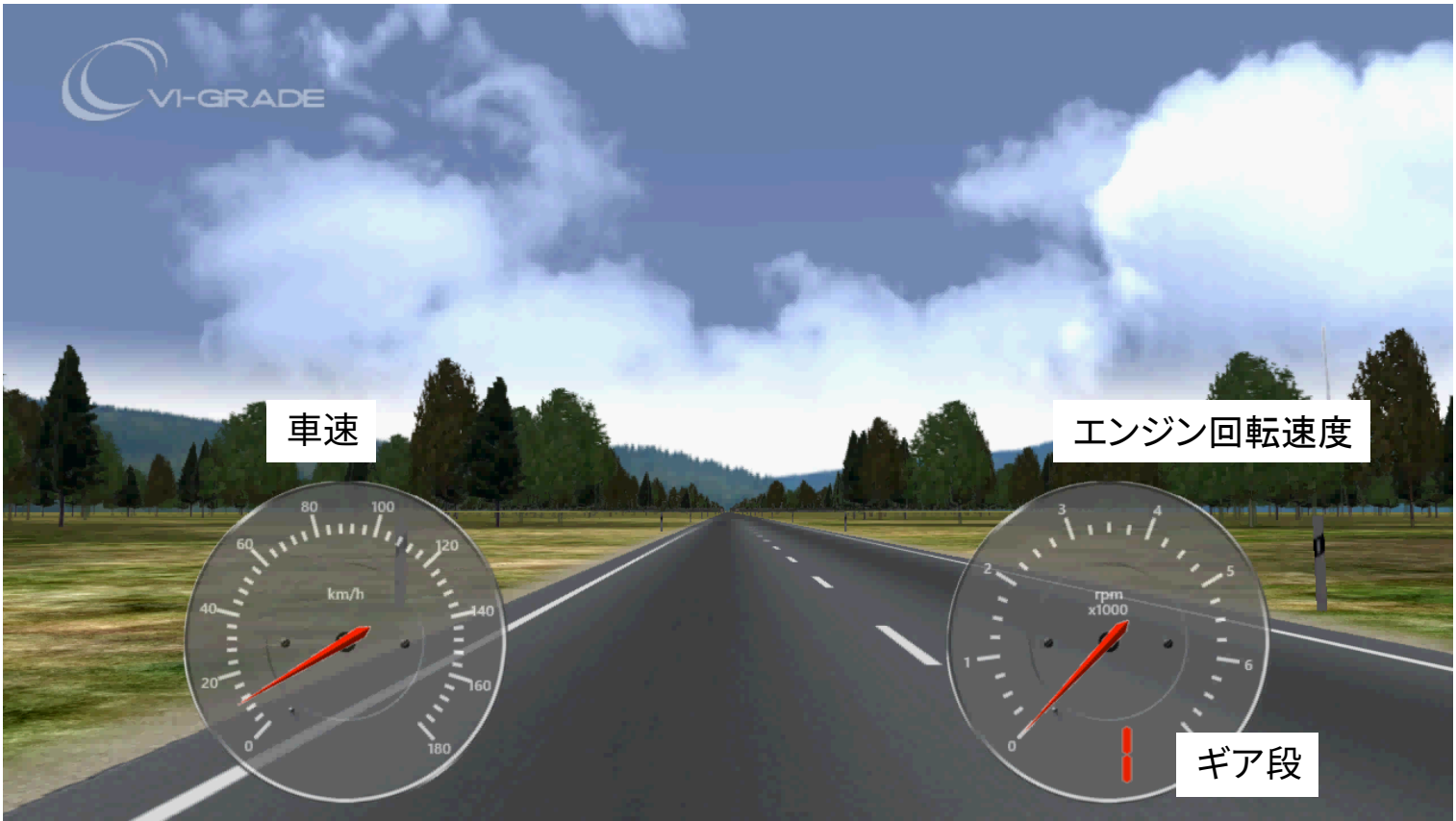
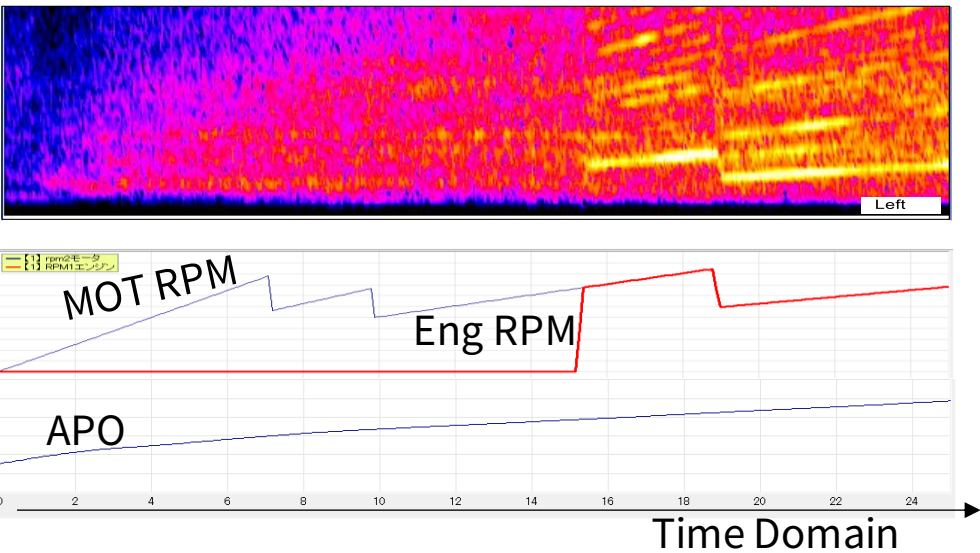
(1) EV to ENG switching sound in parallel P2 motor and engine

Extract sound issues in the left Side

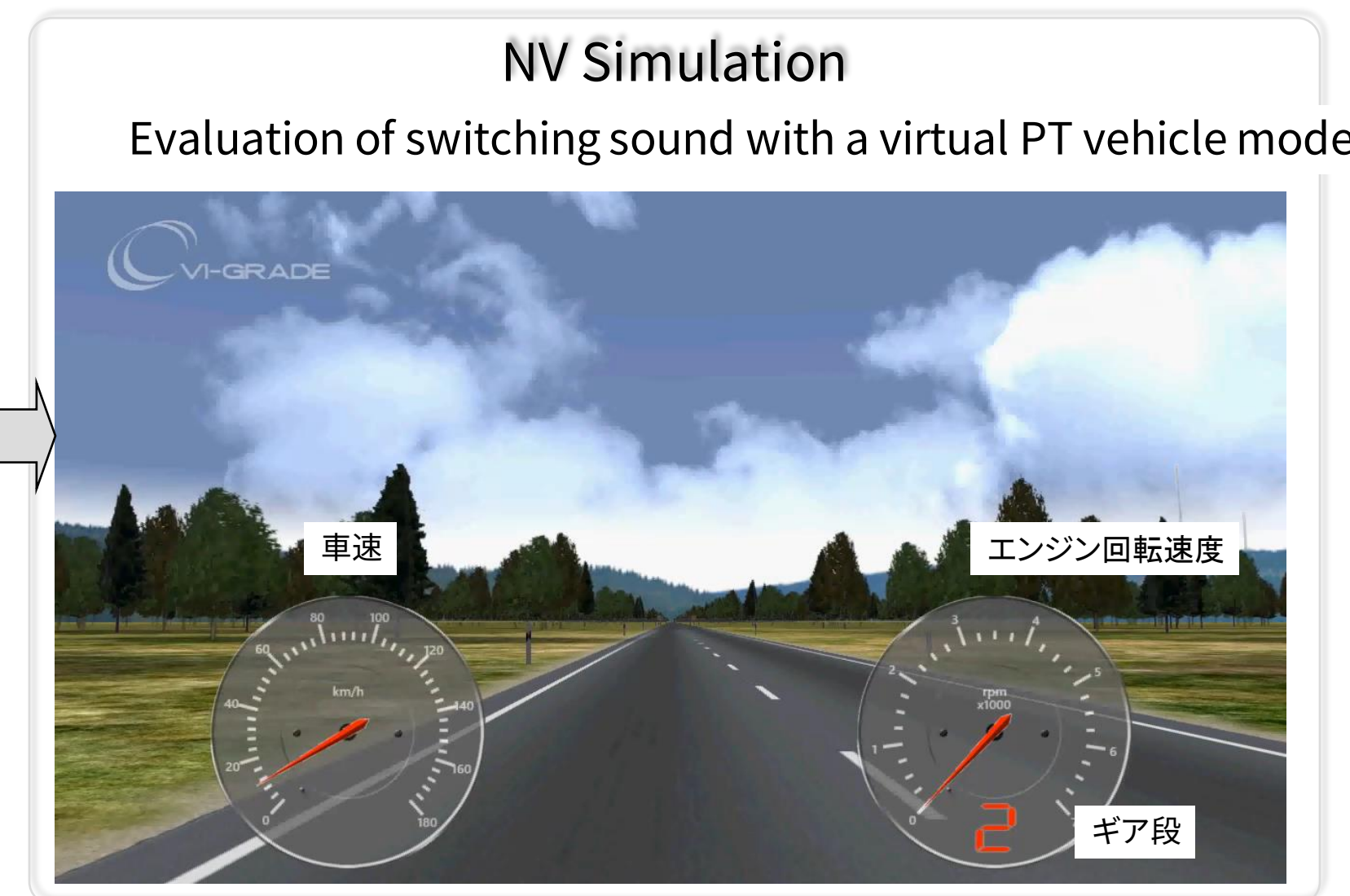
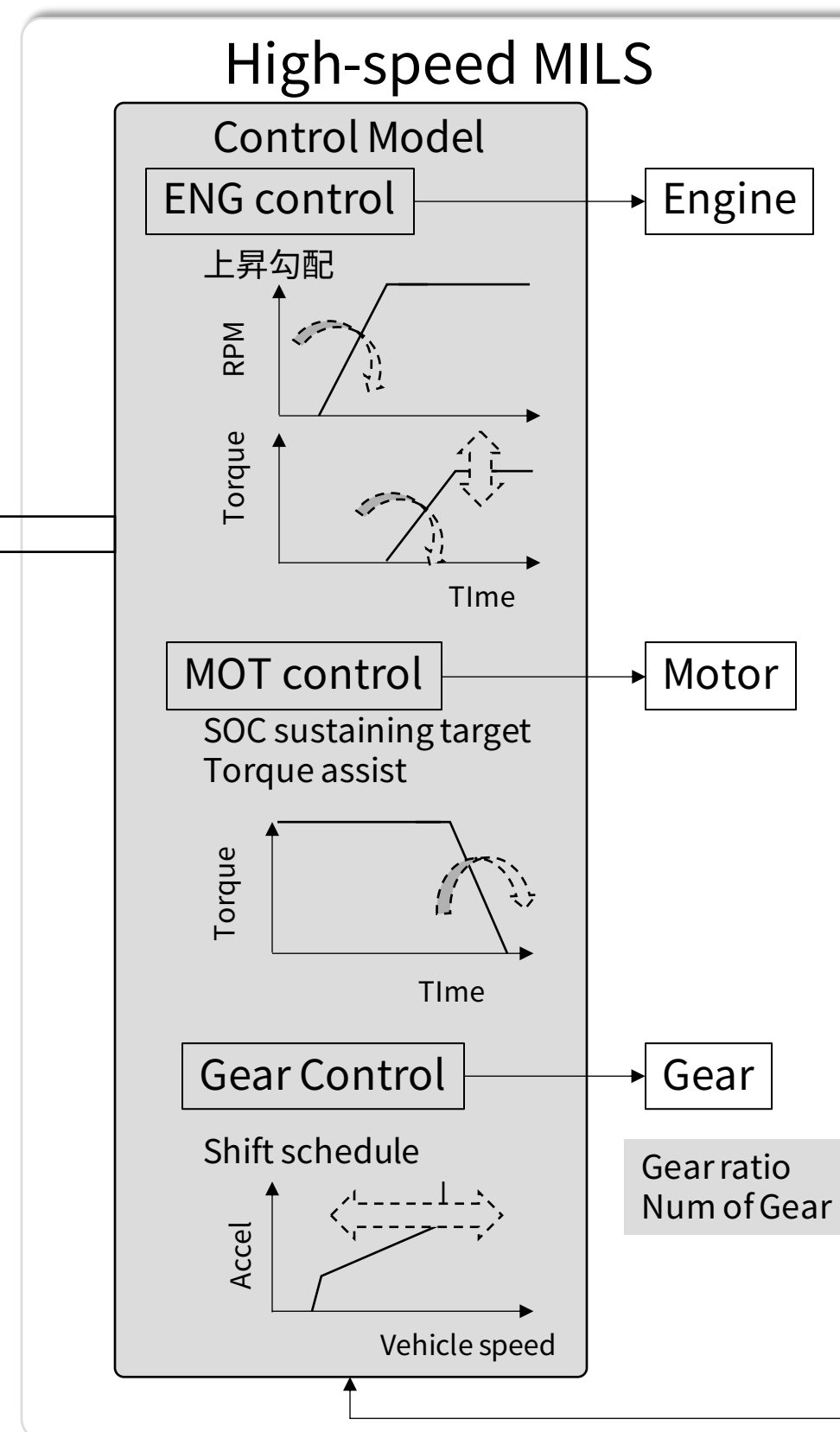
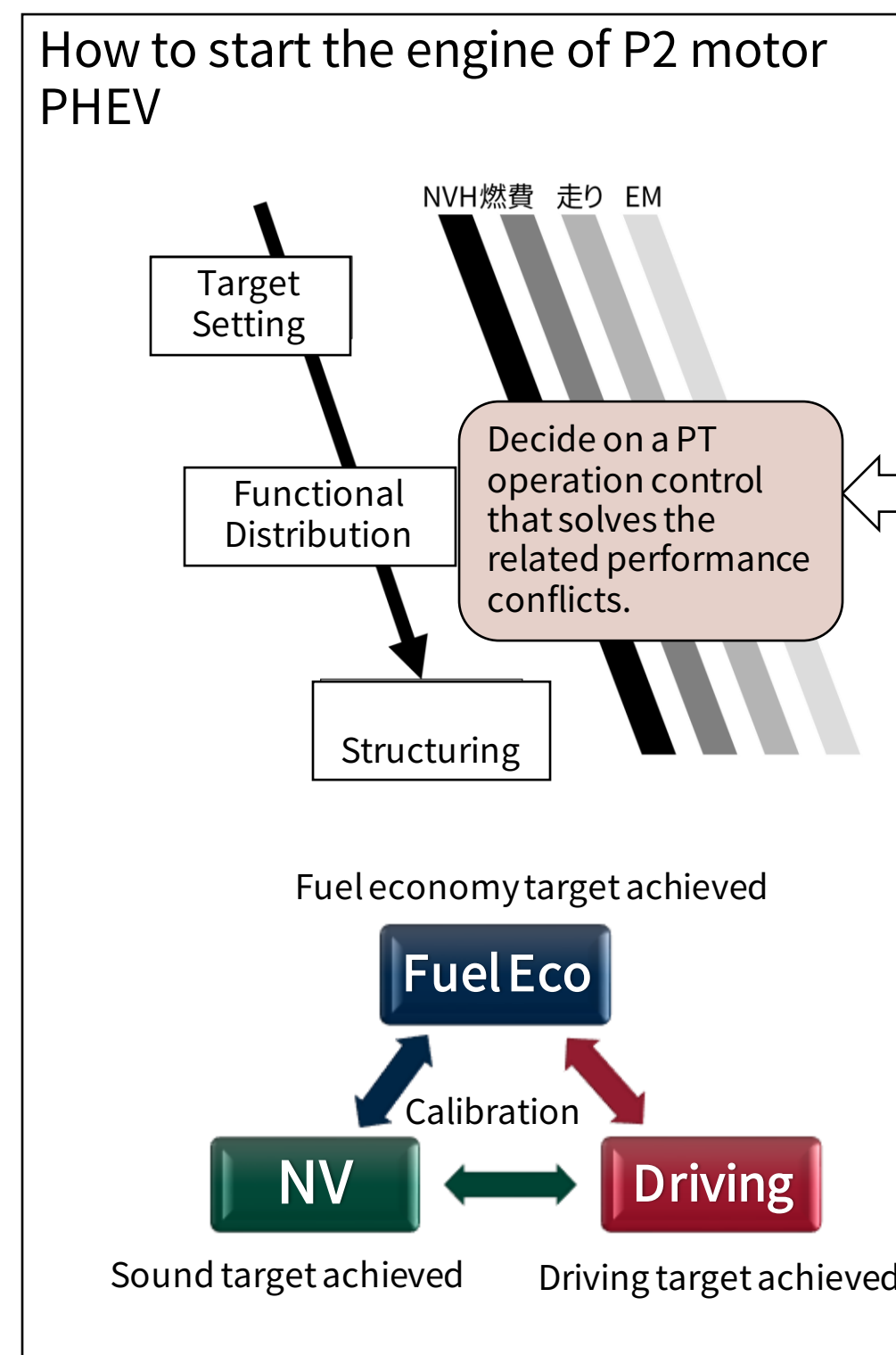


NVH Simulator

Evaluation of switching sound with a virtual PT vehicle model



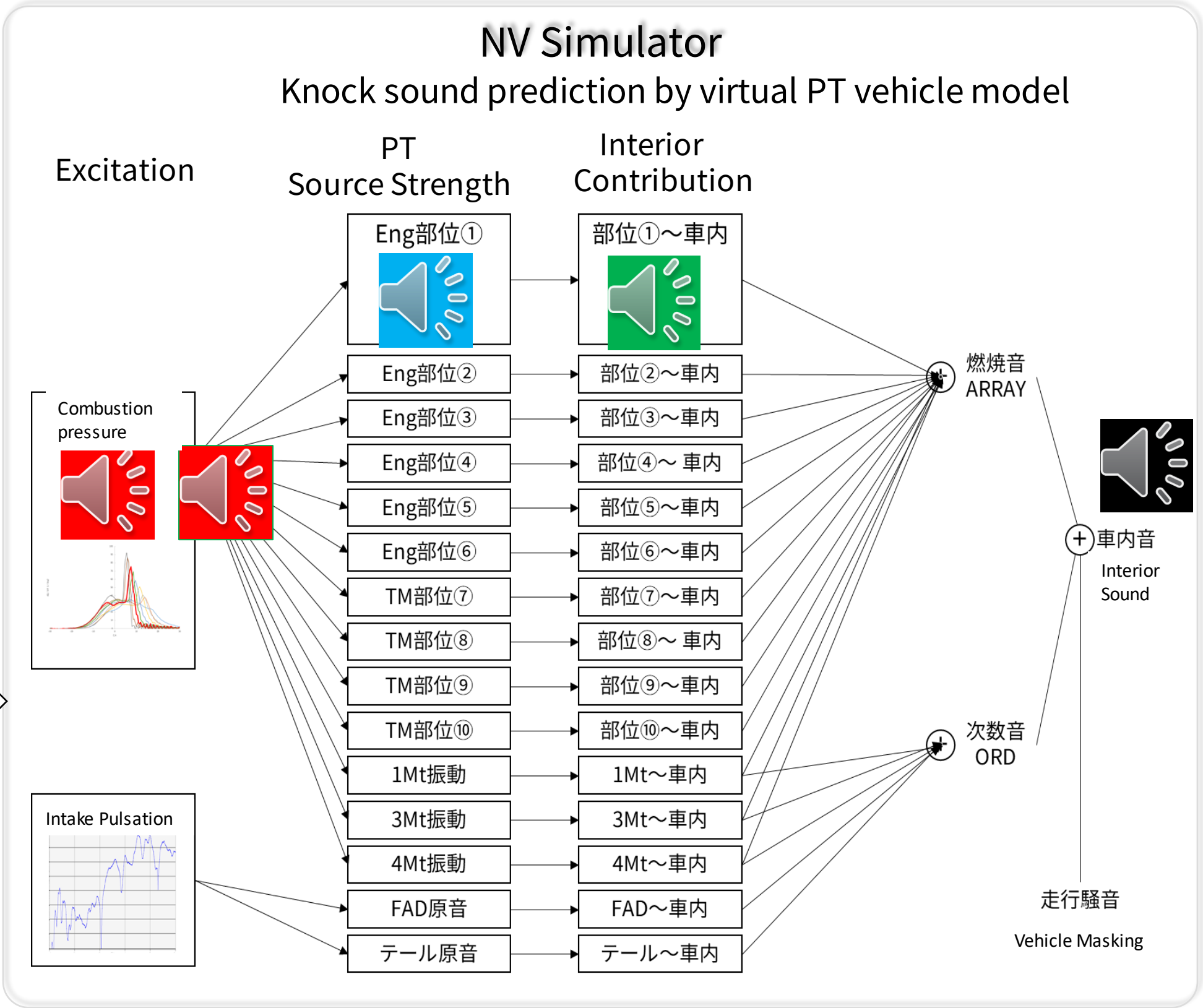
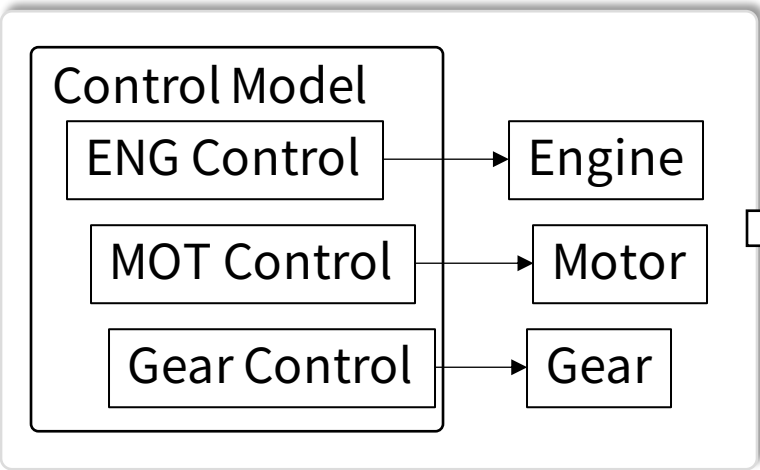
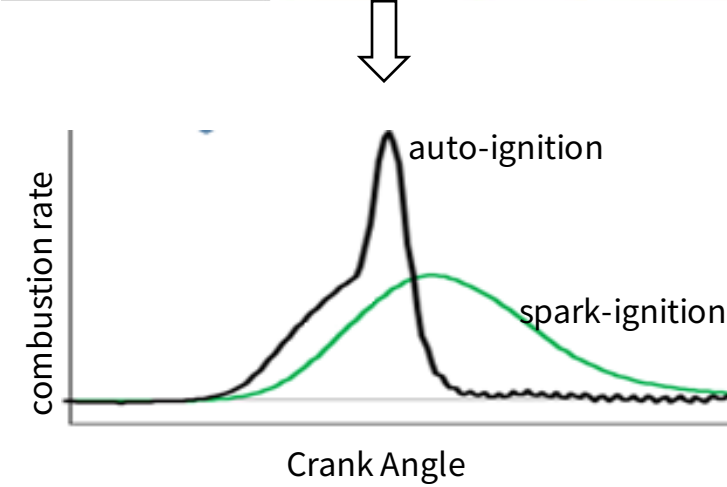
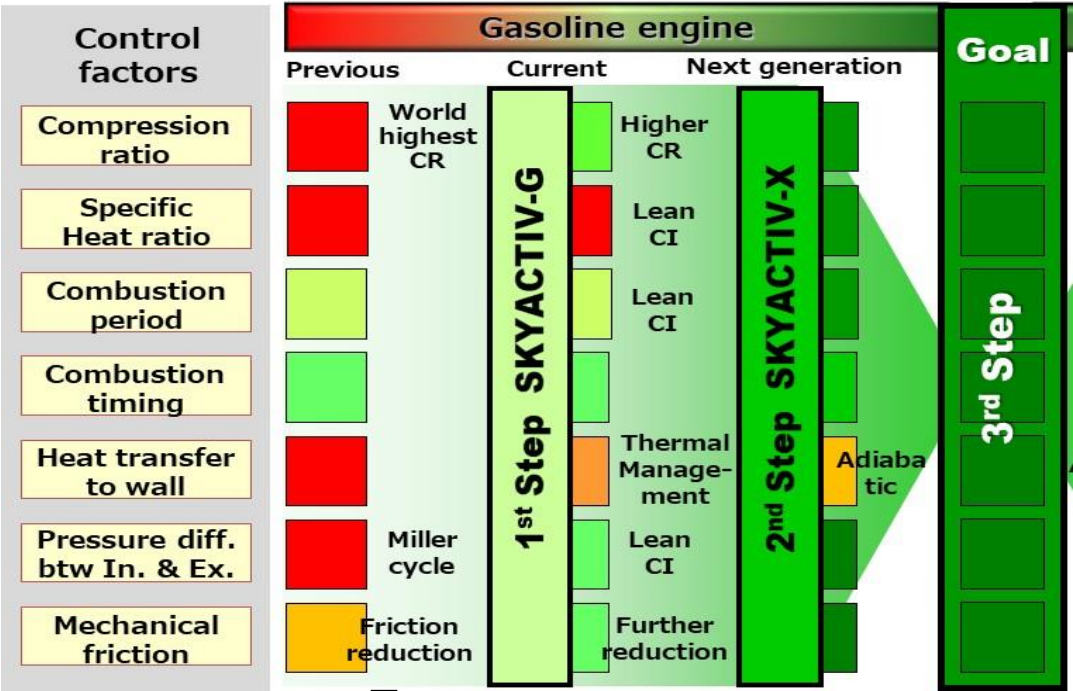
Calibration verification on left Side



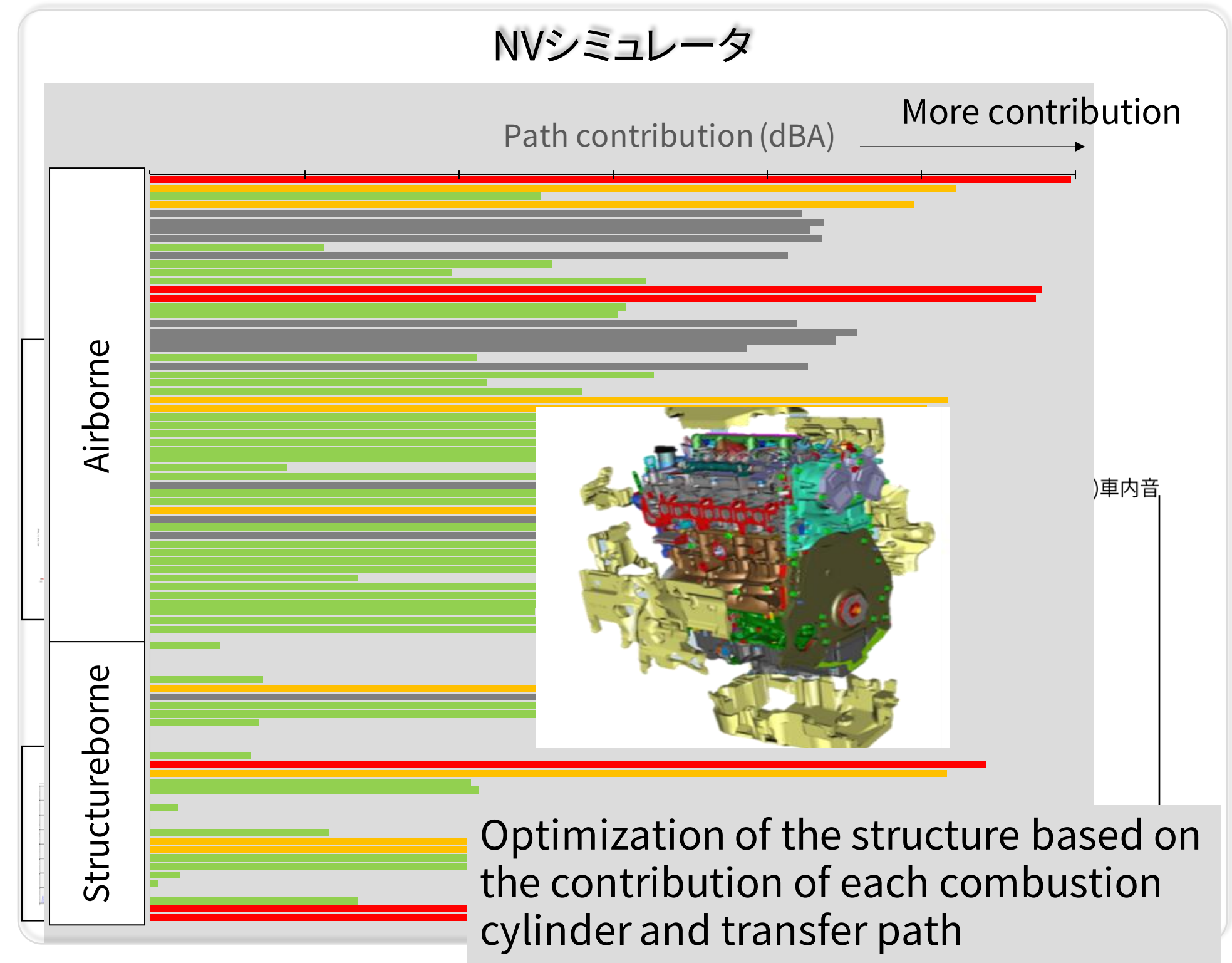
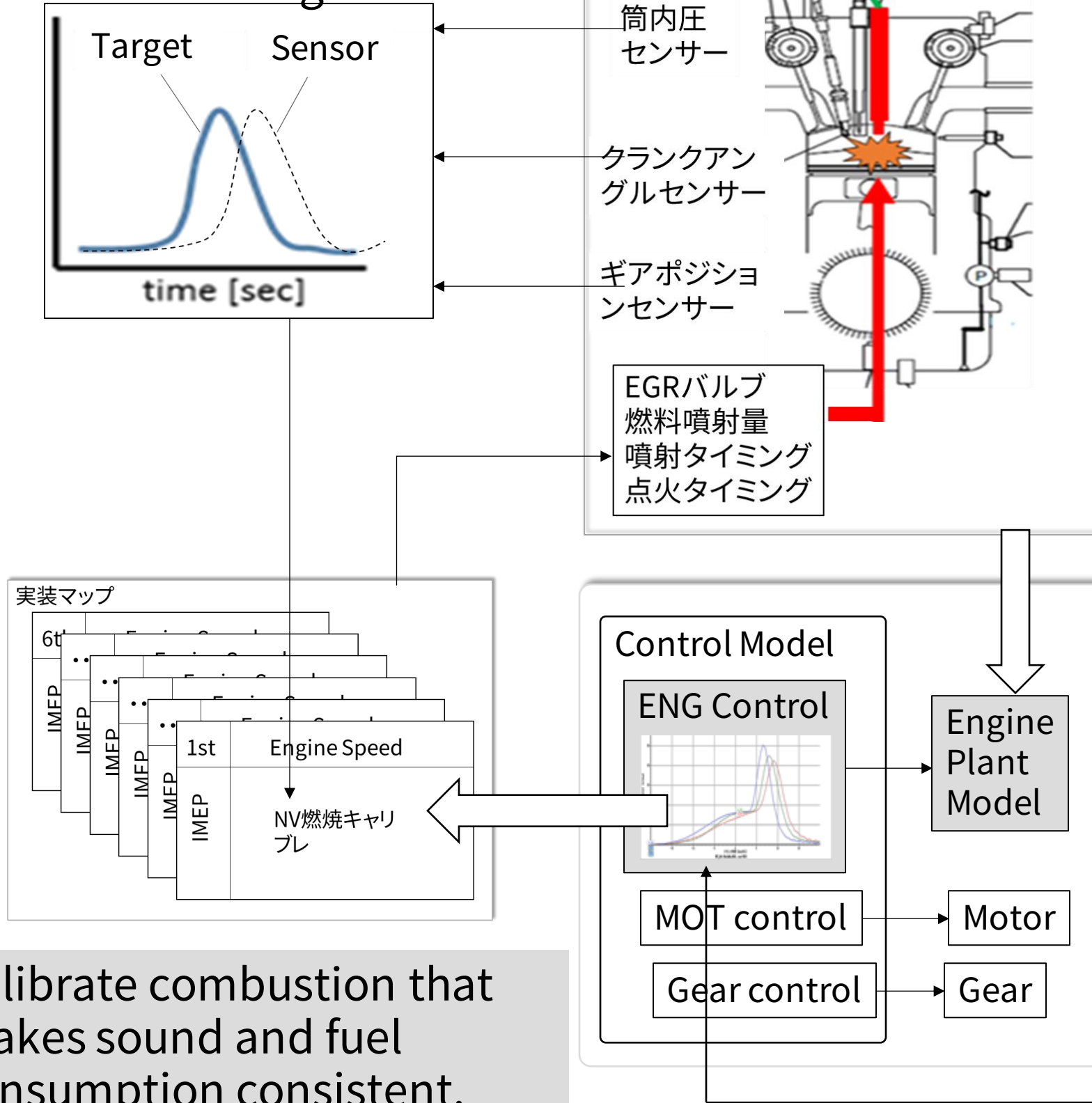
Enabling calibration verification on the left side

(2) Combustion knocking sound

Understanding sound issues on the left side



Improvement of control strategies *

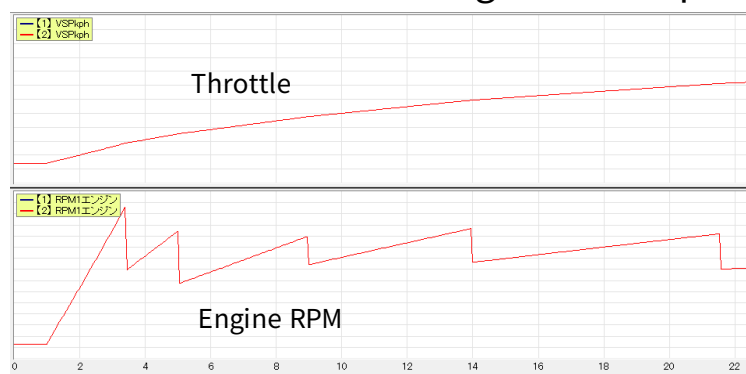


Calibration verification on left Side

Operation

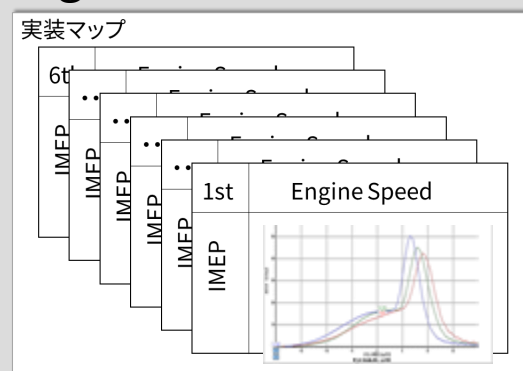


Gentle acceleration driving from a stop



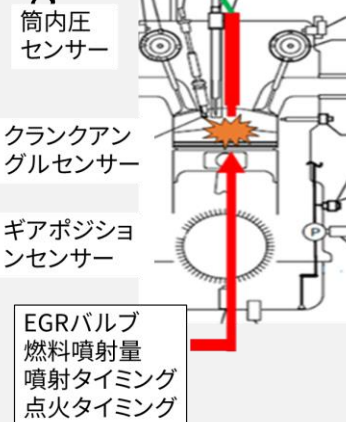
Control Model

Engine Control



Plant Model

Engine



Motor Control

Torque assist

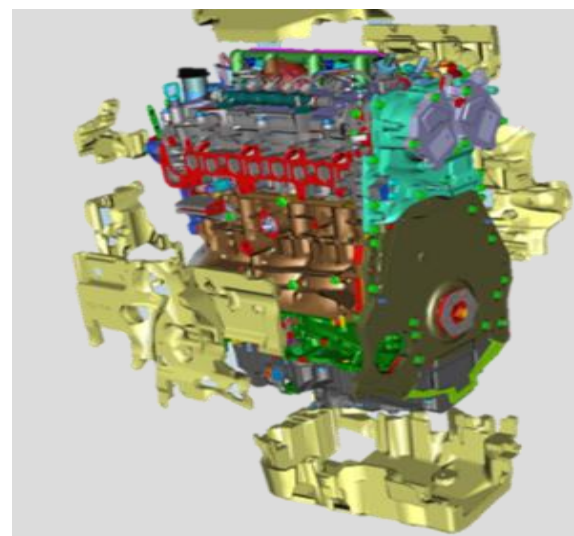
Motor

Gear Control

Shift map

Gear

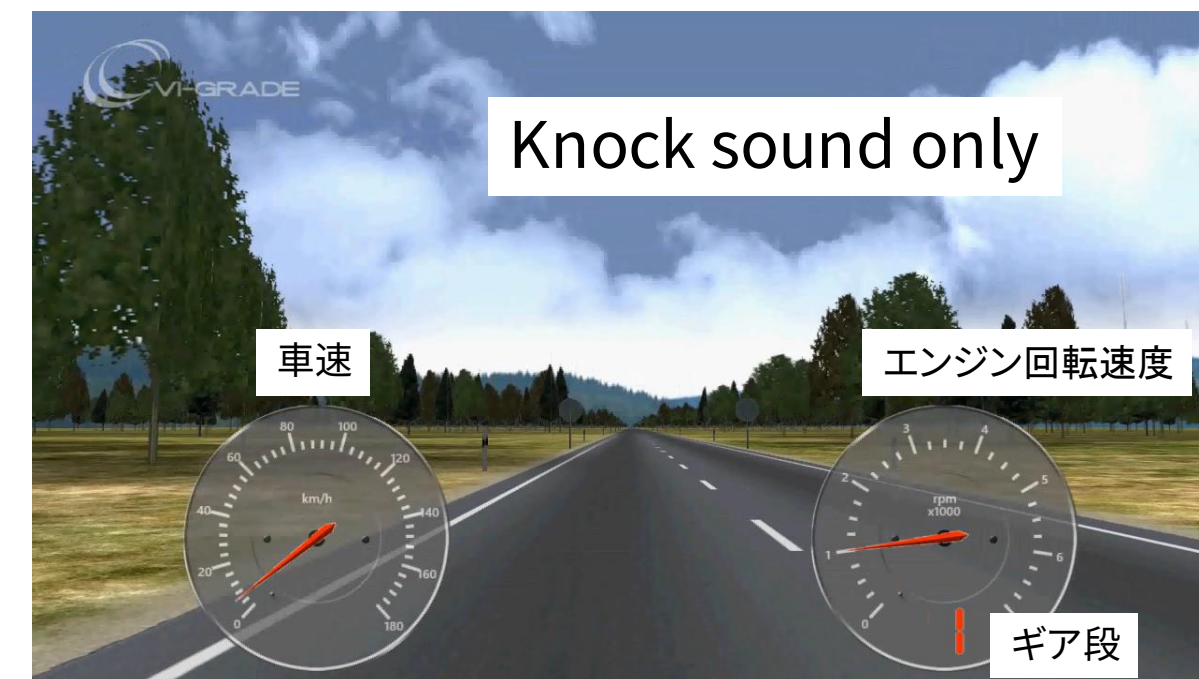
TF model



NVH Simulator

Knock sound prediction by virtual PT vehicle model

Knock sound only



Knock sound & all other



Combustion calibrations, which have traditionally been performed on the right side using actual vehicles, are now being performed on the left side.

Conclusion

- ① Model-based development of powertrain noise has been further advanced by integrating the control/NVH model, which has been built conventionally, with the NVH simulator.
- ② Through collaborative model-based development, all parties involved in Powertrain/vehicle/design are able to optimize engine/motor usage and transmission structure from a whole-vehicle perspective.
- ③ By achieving a high level of compatibility between NVH and fuel economy, Mazda provides excellent environmental performance toward carbon neutrality and a powertrain NVH with high dynamic quality that makes the lives of people who touch Mazda sparkle.



