MathWorks
AUTOMOTIVE
CONFERENCE 2024
Korea

Calibration in a Virtual Environment using Simulink Design Optimization

Sangmin Park,Hyundai motors Group

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Contents

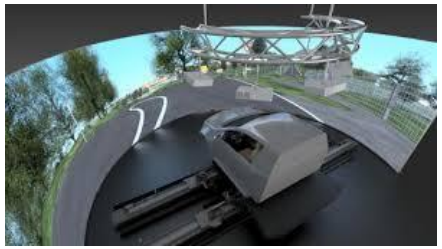
- Introduction of the Team/Task
- Definition of Virtual Calibration
- Model Parameter Optimization
- Use Case
- Conclusion

본 문서는 현대자동차·기아의 정보자산으로 관련 법령에 의해 보호받습니다.

Profile

20years Chassis Engineer in HMC R&D Center

- Platform Development Team (2005~
  - Suspension & Steering Design
- Vehicle Performance Development Team
  - Advanced Vehicle R&H Development
- High Performance Development Team
  - i30 N MDPS & ESC Test
- Dynamics Functional Concept (~)
  - Brake Control Simulation & Driving simulator



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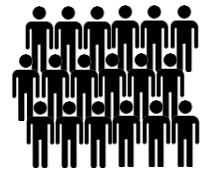
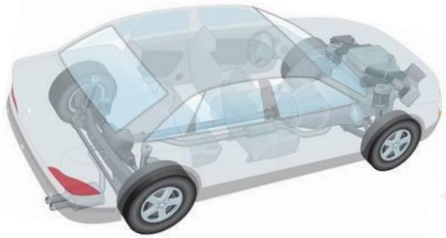
Automotive Industry trend: Increasing complexity

Today

⇧Vehicle Complexity =

⇧ Number of parameters + ⇧Engineers + ⇧ Prototype Vehicles





Past

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Virtual Vehicle

Virtual vehicle refers to the virtualization of the vehicle product development lifecycles, typically using a system-level simulation of the vehicle behavior.

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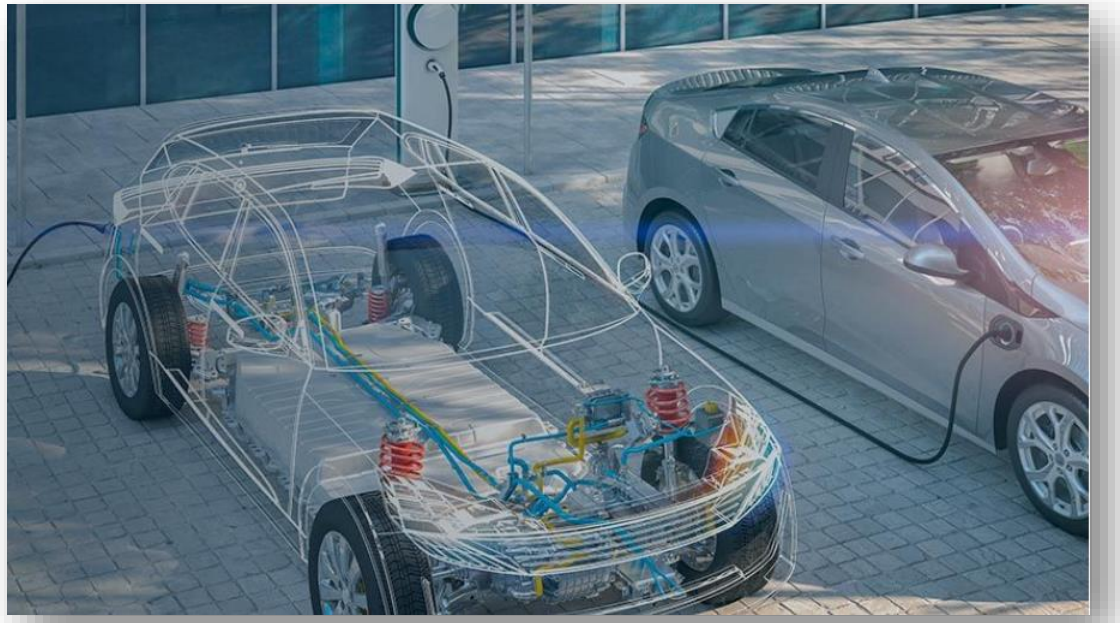
Virtual Vehicle

Virtual vehicle refers to the virtualization of the vehicle product development lifecycles, typically using a system-level simulation of the vehicle behavior.

In order to develop a virtual vehicle, you must

- Create vehicle model
- Integrate embedded software
- Define test scenarios
- Simulate and analyze



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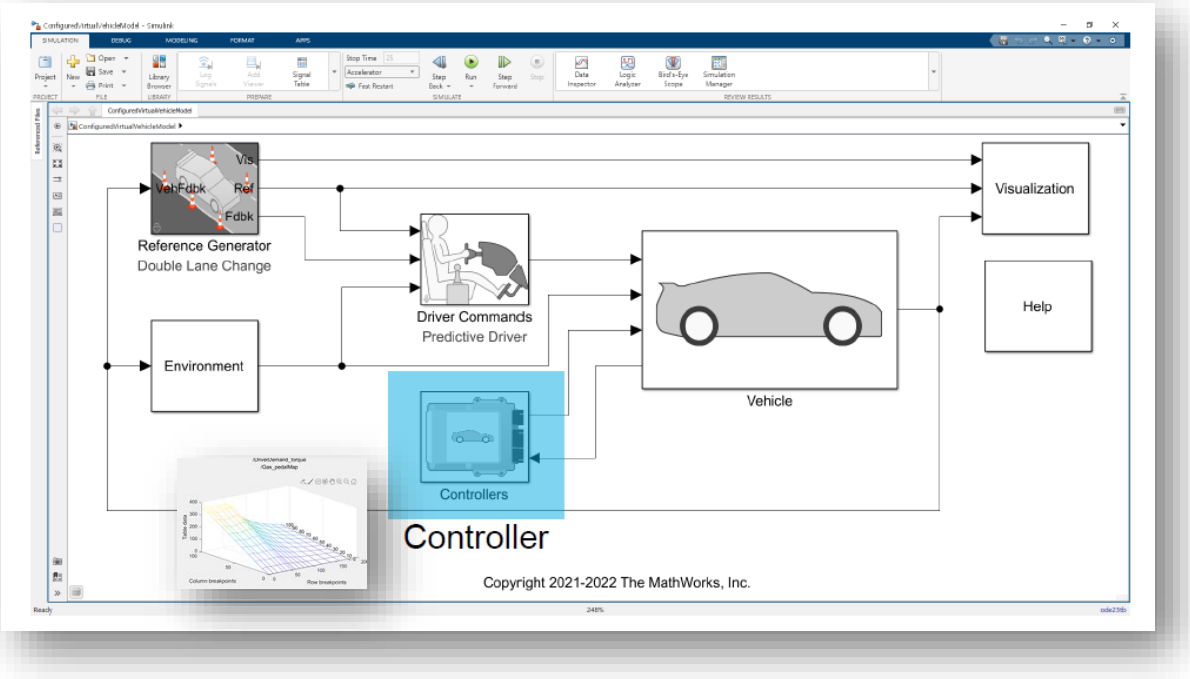
Concept of Virtual Calibration

- Process of optimizing control system parameters in a Virtual Environment
- Deriving performance without physical tests
- Time and Cost efficiency, repeatable test



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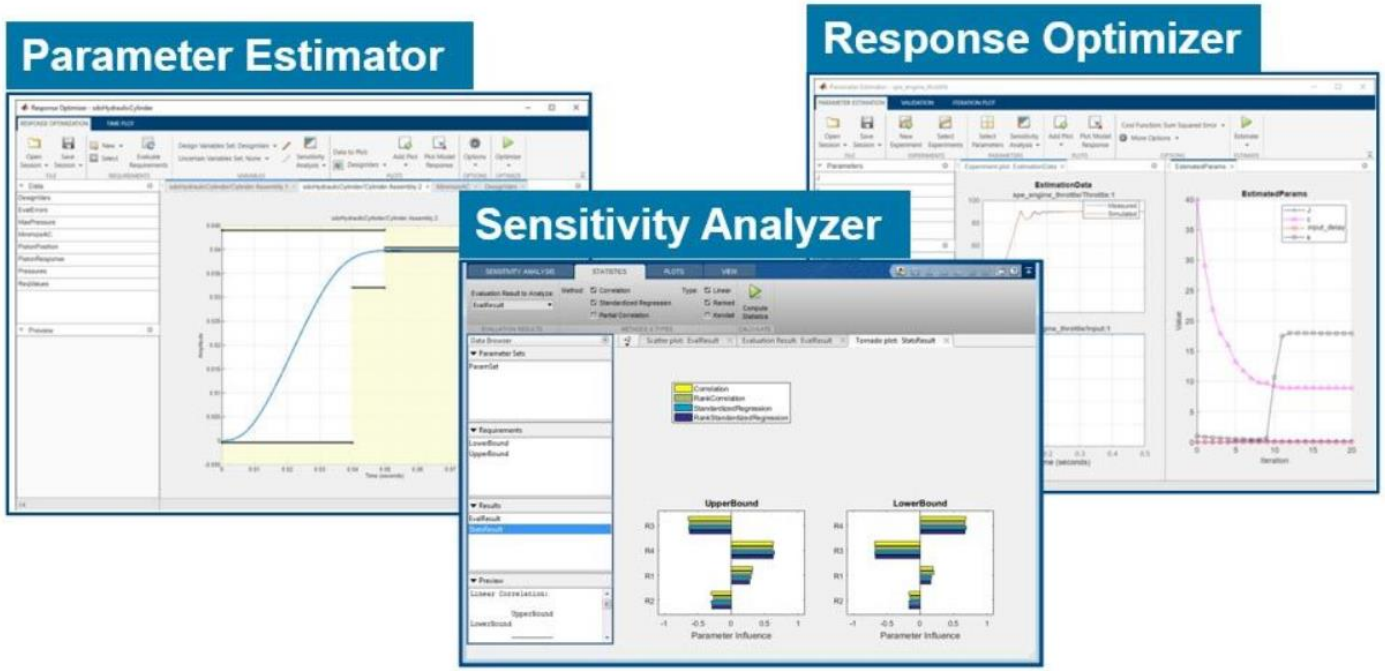
Model Parameter Calibration in Simulink

Simulink Design Optimization

Analyze model sensitivity and tune model parameters

Simulink Design Optimization provides functions, interactive tools and blocks for analyzing and tuning model parameters.

- Design Optimization Apps
- Parameter Estimation
- Response Optimization
- Sensitivity Analysis
- Optimization Solvers



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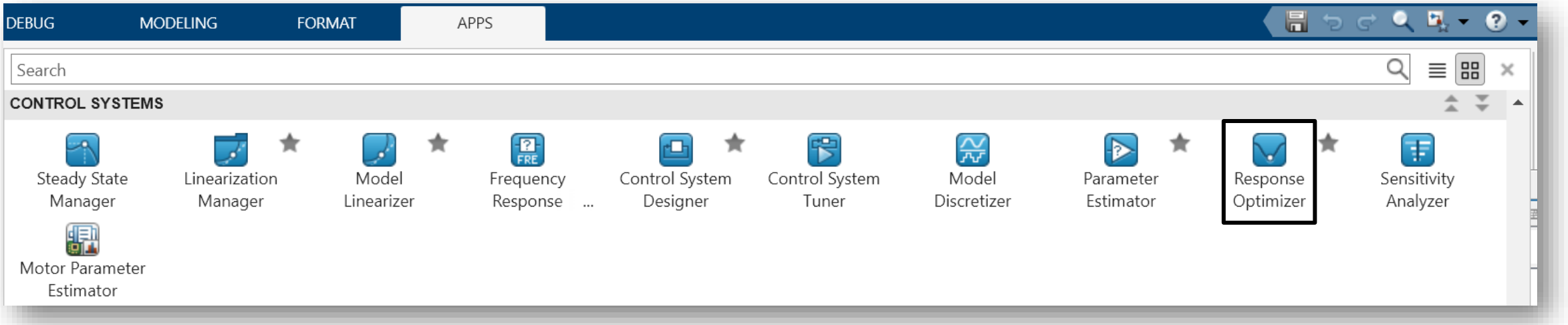
Overview of Response Optimizer



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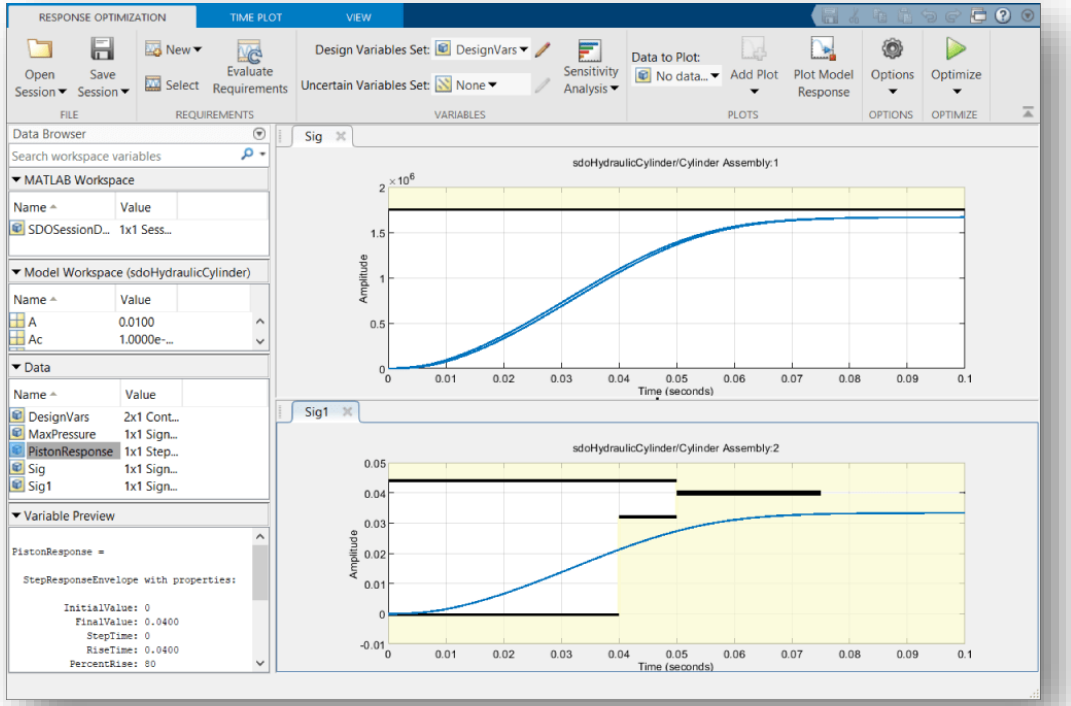
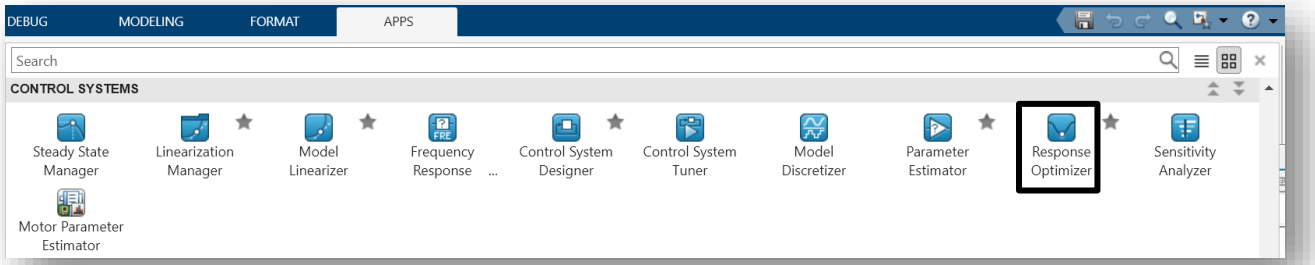
Overview of Response Optimizer

- A tool for optimizing based on Simulink models
- Setting performance goals and Constraints
- Parameter Optimization and Real-time feedback
- Application in PID controllers, ESC,ABS





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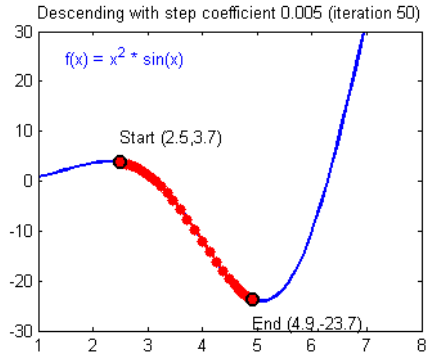
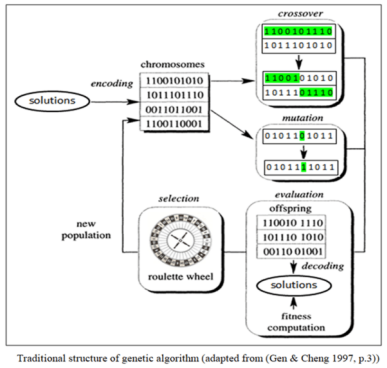
Optimization Algorithms

- Gradient Descent

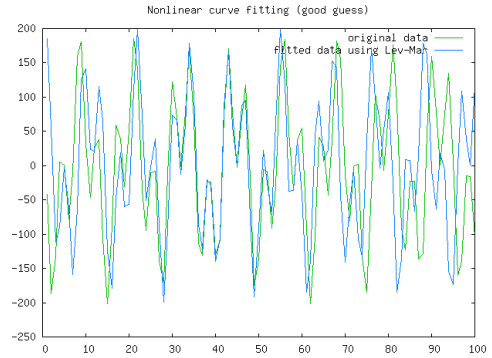


- Genetic Algorithm

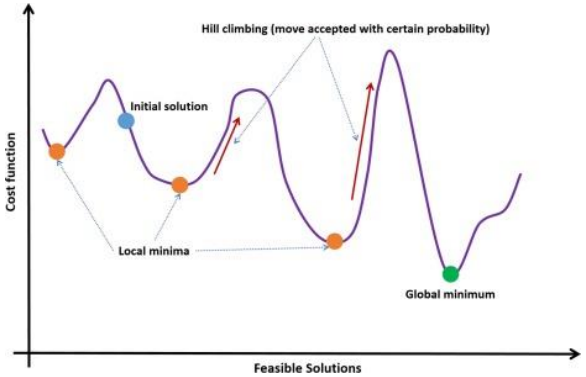


Traditional structure of genetic algorithm (adapted from (Gen & Cheng 1997, p.3))

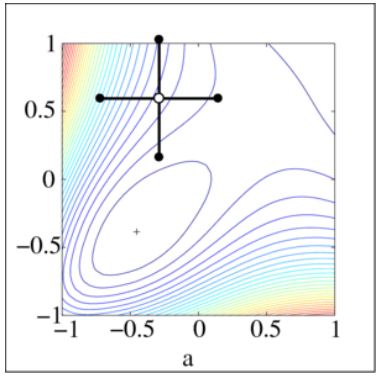
- Levenberg-Marquardt Algorithm



- Simulated Annealing



- Pattern Search



ⓐ Gradient descent : https://hackernoon.com/life-is-gradient-descent-880c60ac1be8
ⓑ Simulated Annealing : https://www.sciencedirect.com/topics/social-sciences/simulated-annealing
ⓒ Genetic Algorithm : https://learnwithpanda.com/2020/09/20/what-is-genetic-algorithm
ⓓ Pattern Search : https://en.wikipedia.org/wiki/Pattern_search_(optimization)
ⓔ Levenberg-Marquardt Algorithm : https://en.wikipedia.org/wiki/Levenberg%E2%80%93Marquardt_algorithm

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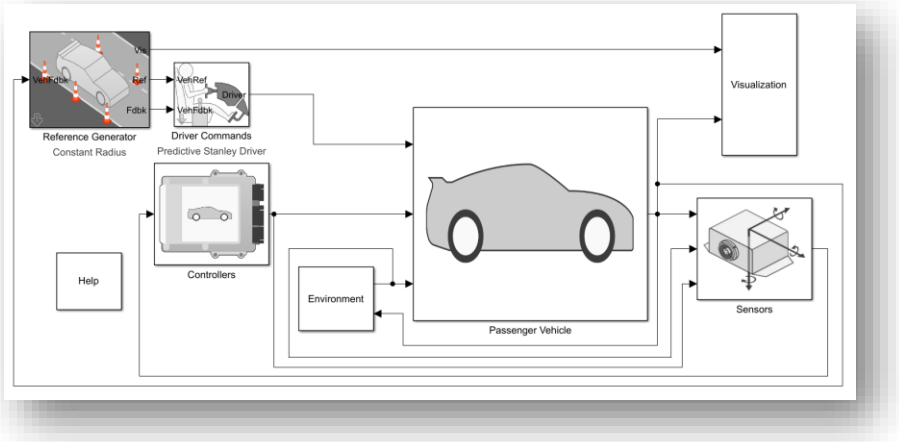
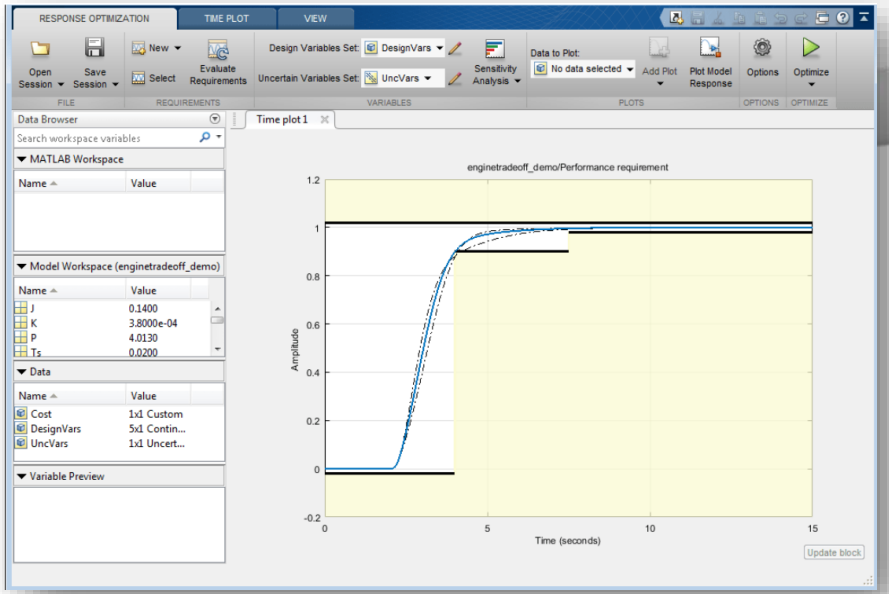
Optimization Process

- Build Simulink Model
- Set performance goals and constraints
- Select parameter optimization and run optimization
- Review and validate results





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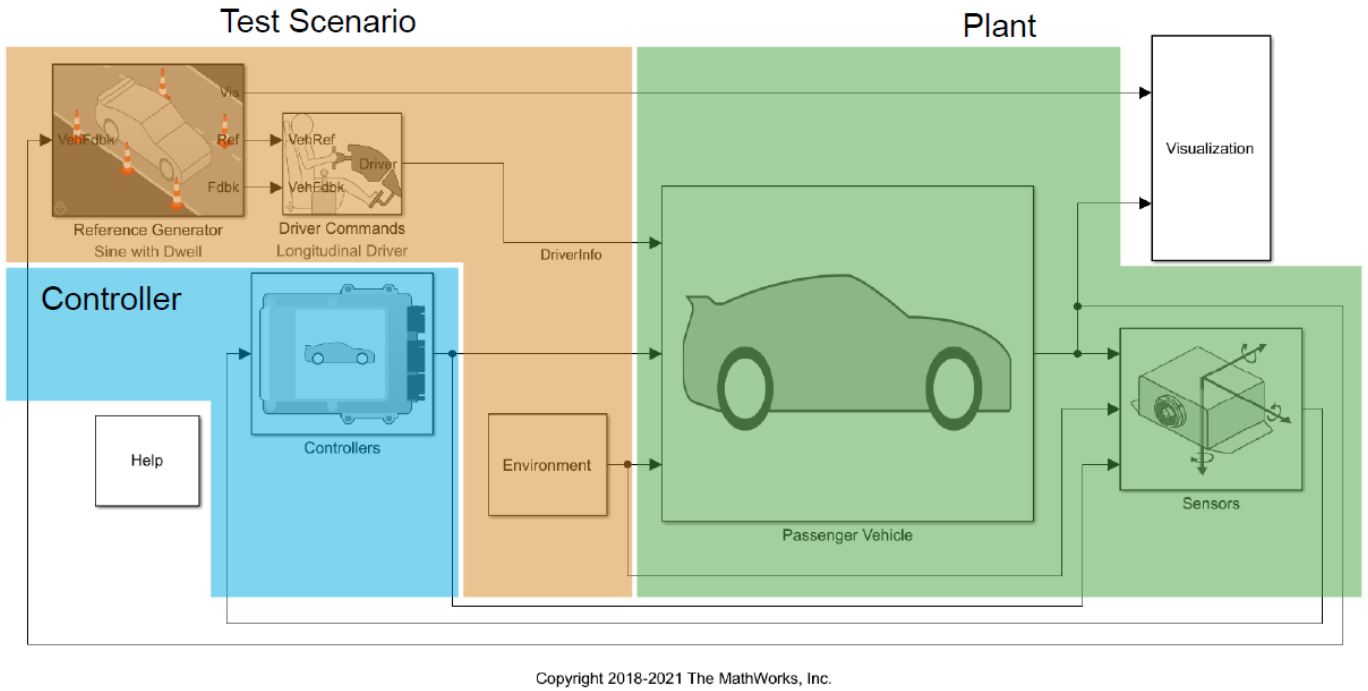
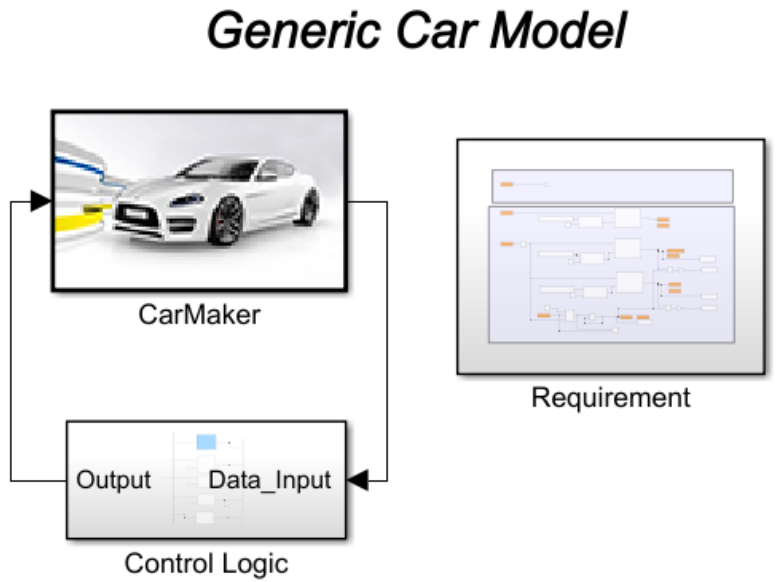
MIL - Simulation Environment Setup

- Build Vehicle Dynamics and Integrated Control Models in Carmaker4Simulink
- Implement ABS,ESC and xECU controllers





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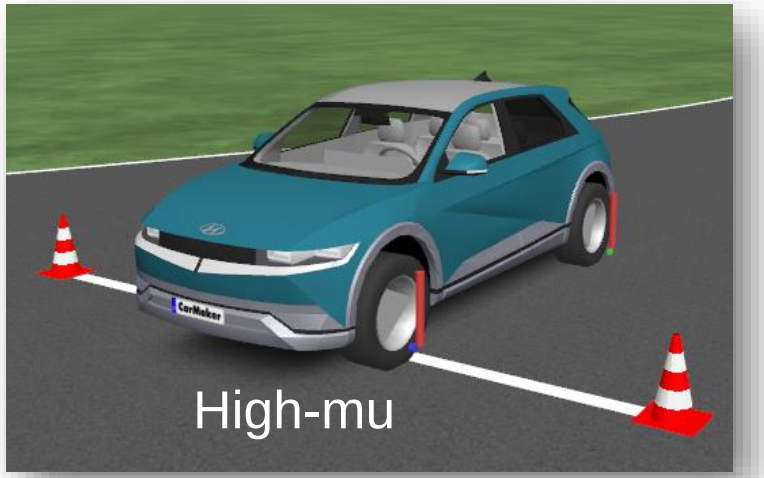
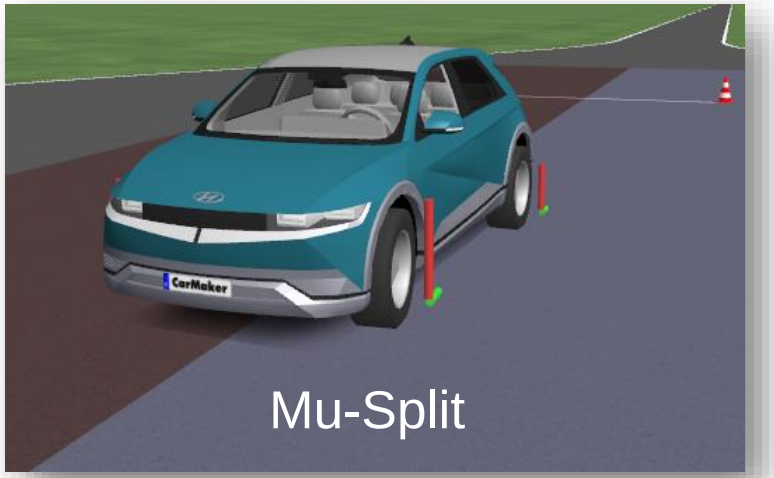
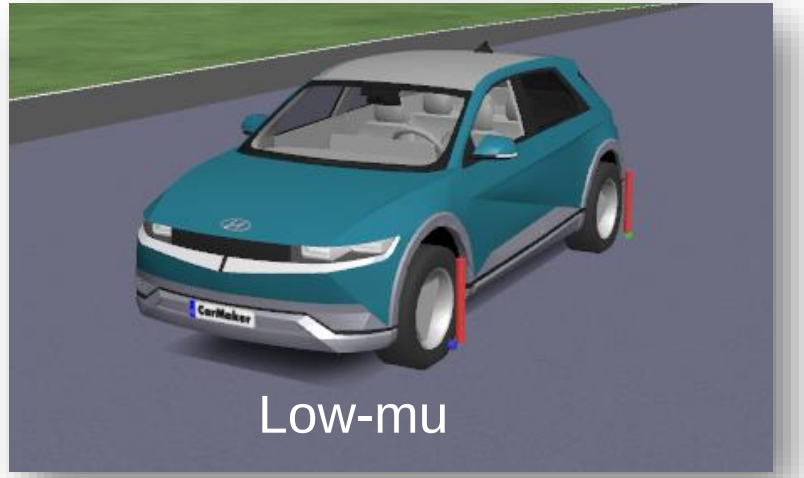
Optimization in Various Driving Conditions

- Optimize for different road conditions (Dry,Wet,icy)
- High /low-speed driving ,sudden Acceleration/Braking
- Cornering ,uphill/downhill driving







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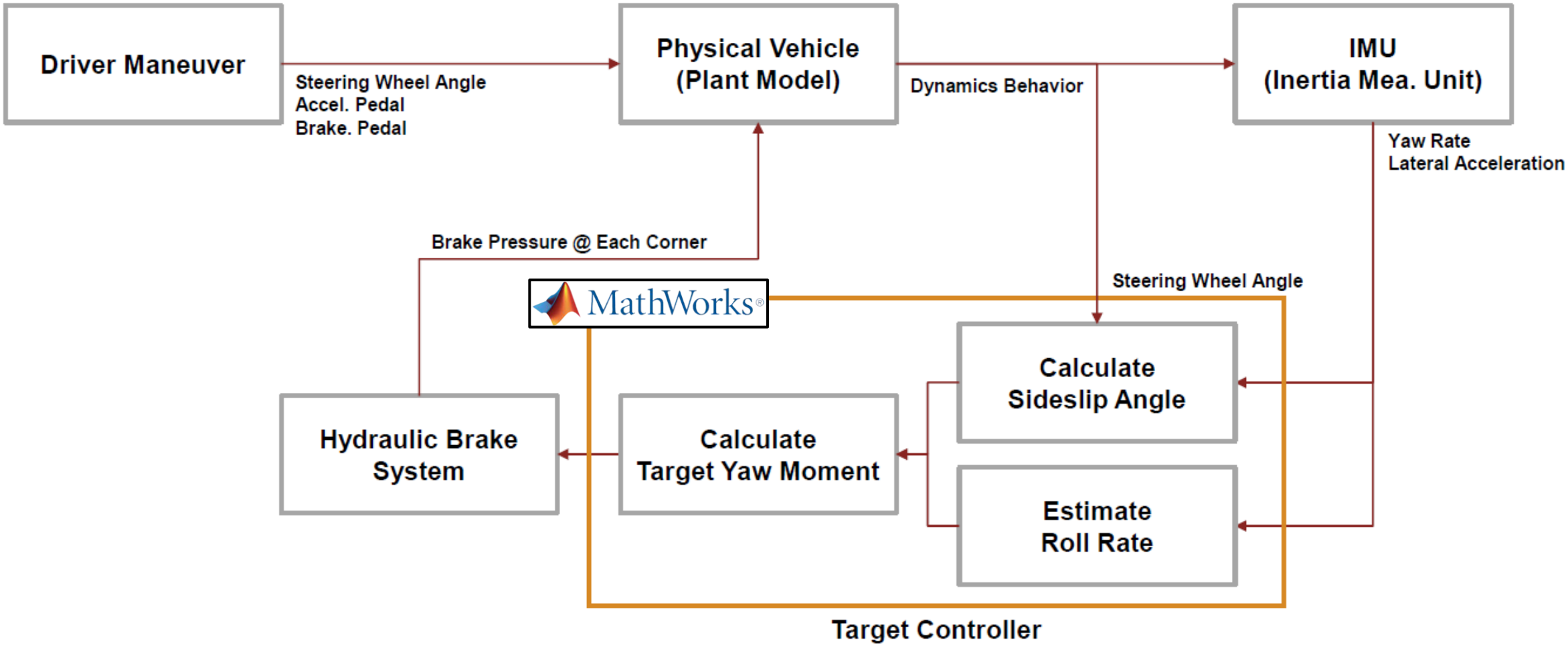
Chassis Controls System (ESC) -General



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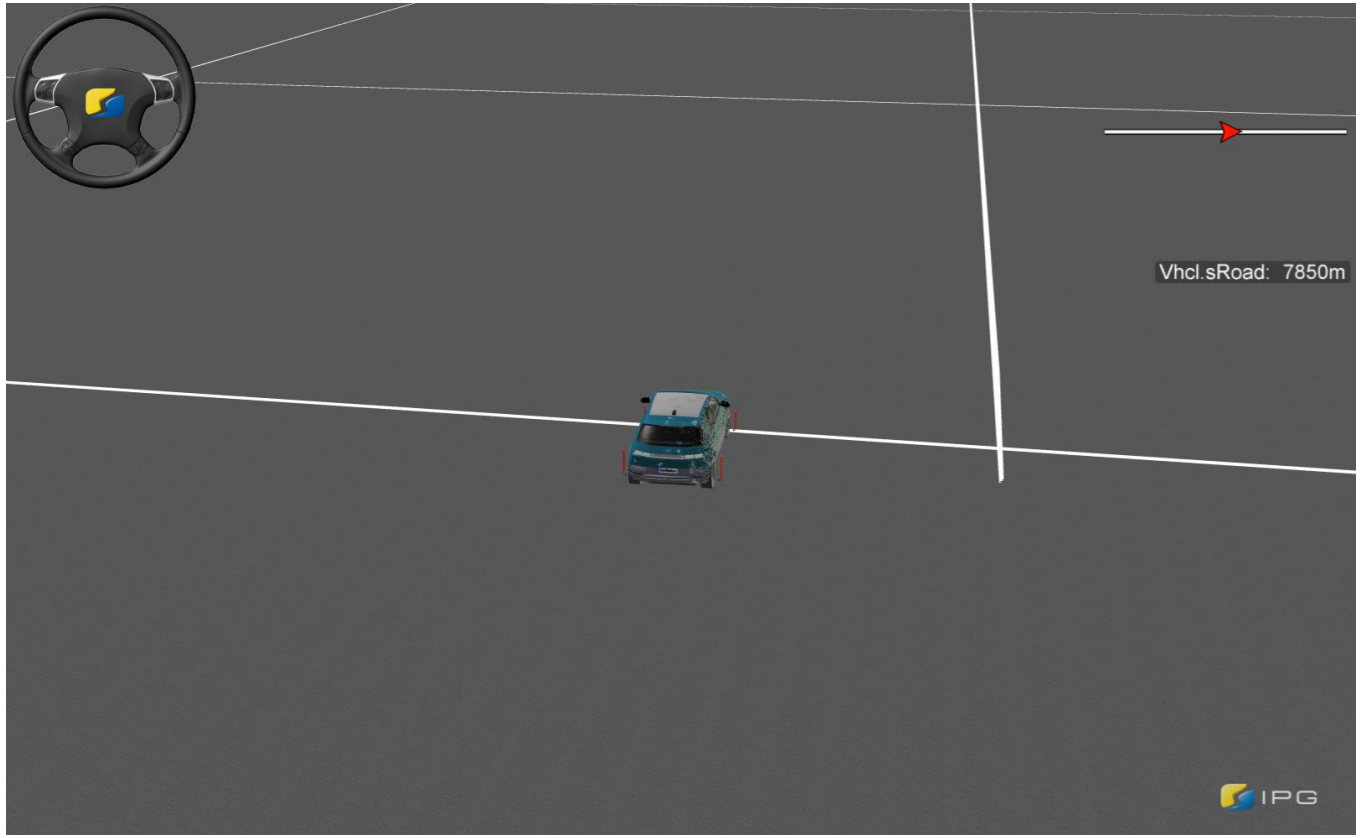
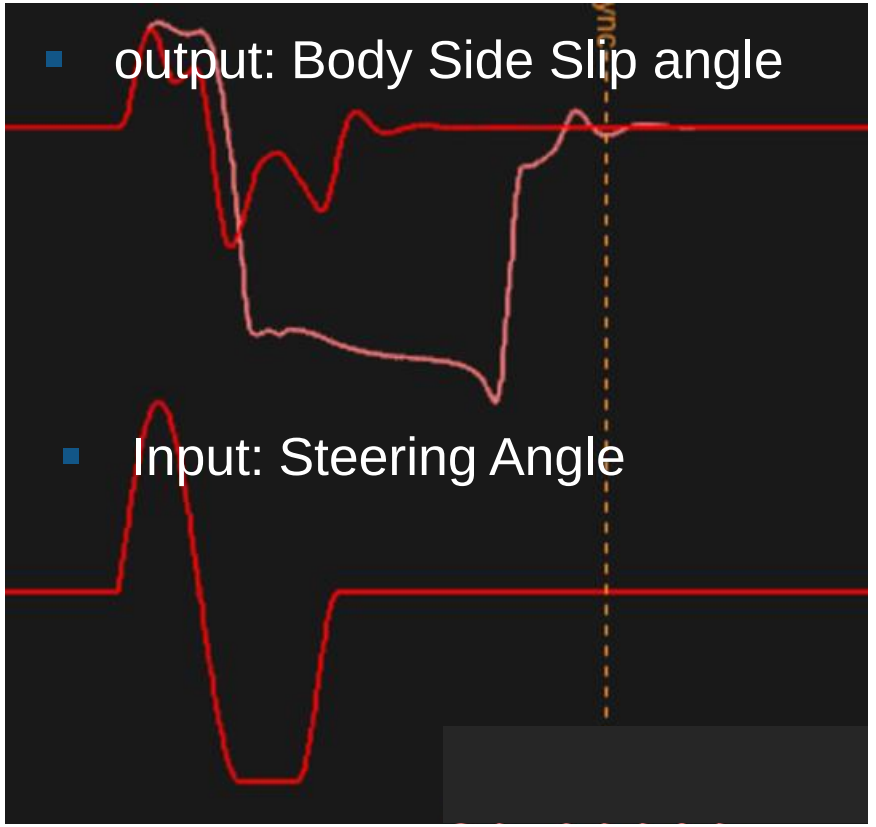
Use Case #1. ESC On/Off

- SinewithDwell Simulation





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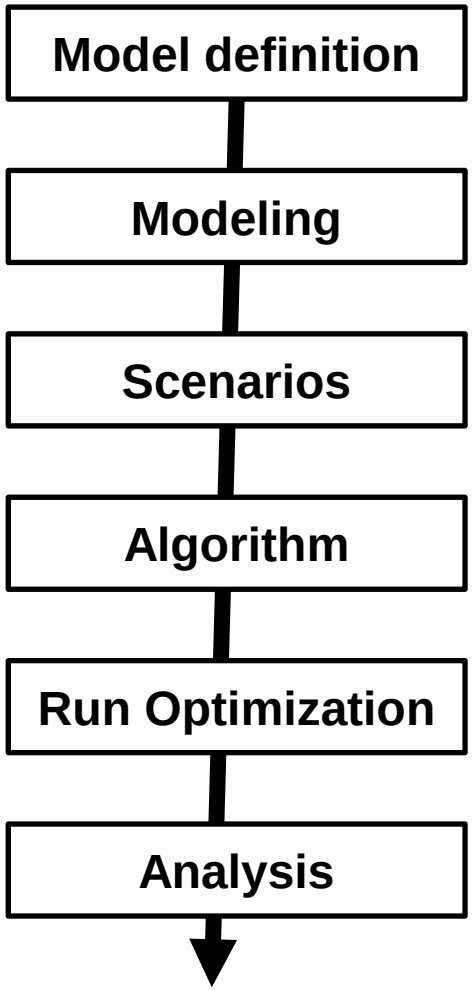
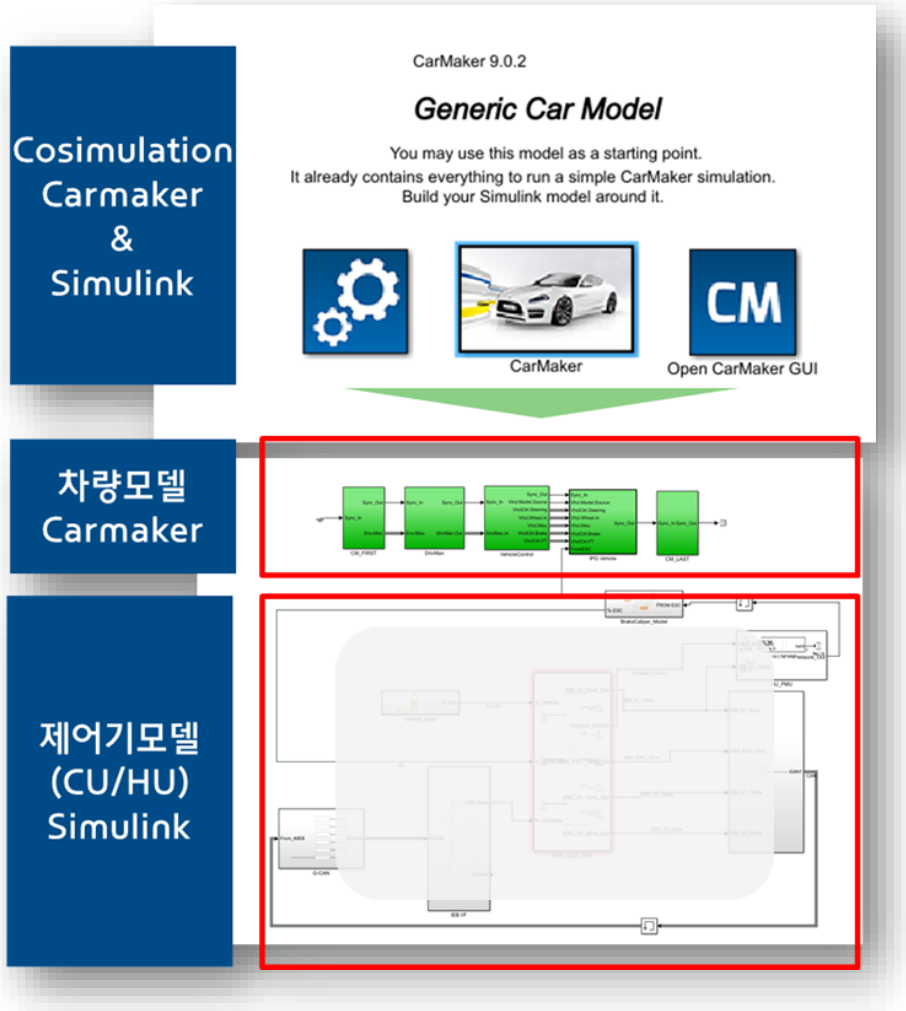
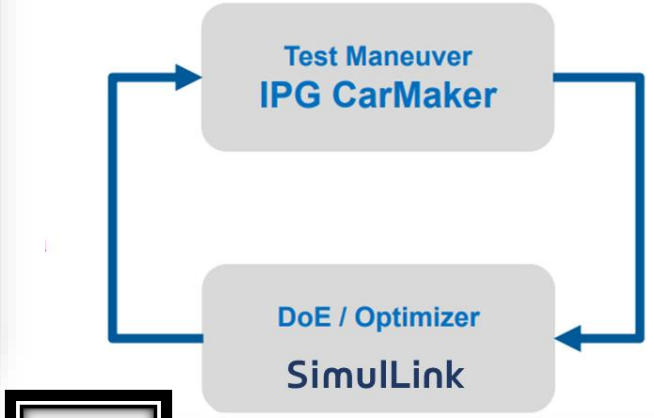
Simulation Environment and Work-Flow

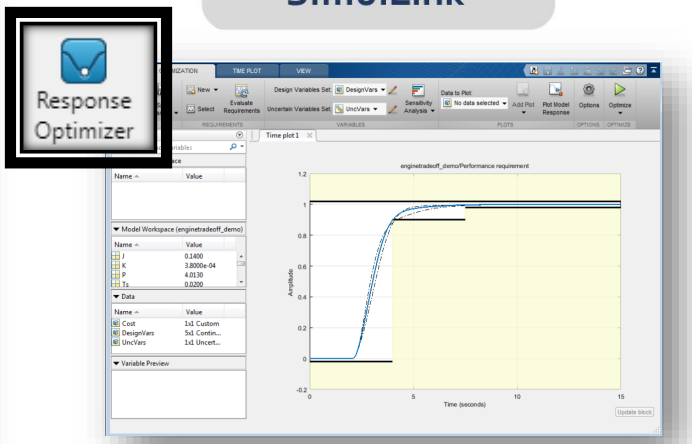
- Optimization Work-flow



- Co-simulation (IPG CarMaker & Simulink)







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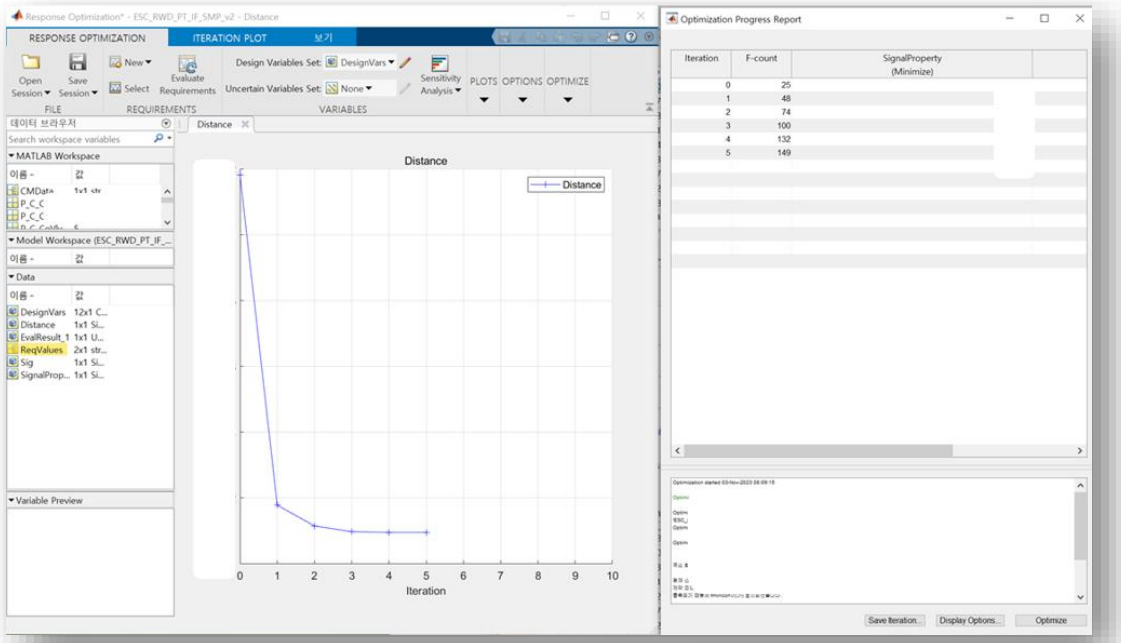
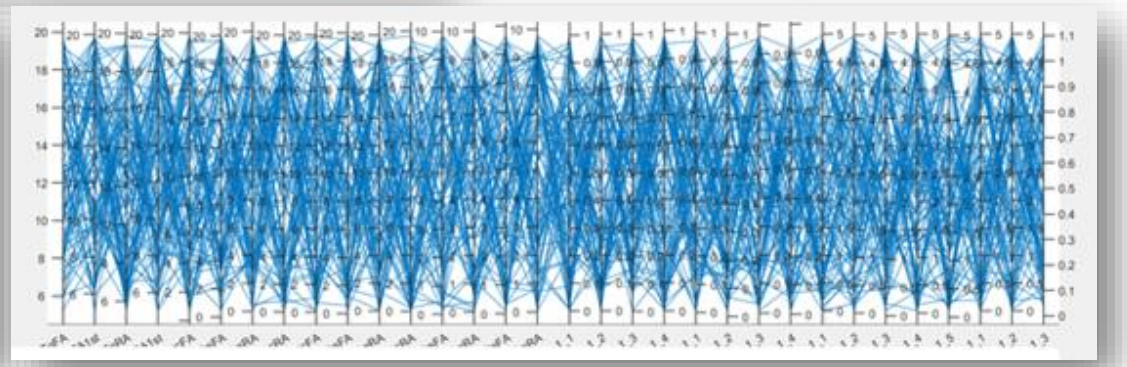
Optimization Calibration of ABS Braking

- Work-Flow



- Requirements
  - Minimal Braking Distance
  - Yaw Rate *.0 deg/s ↓
- Result : 2.5%reduced (1.084 ↓)
- Solving Time : 26min



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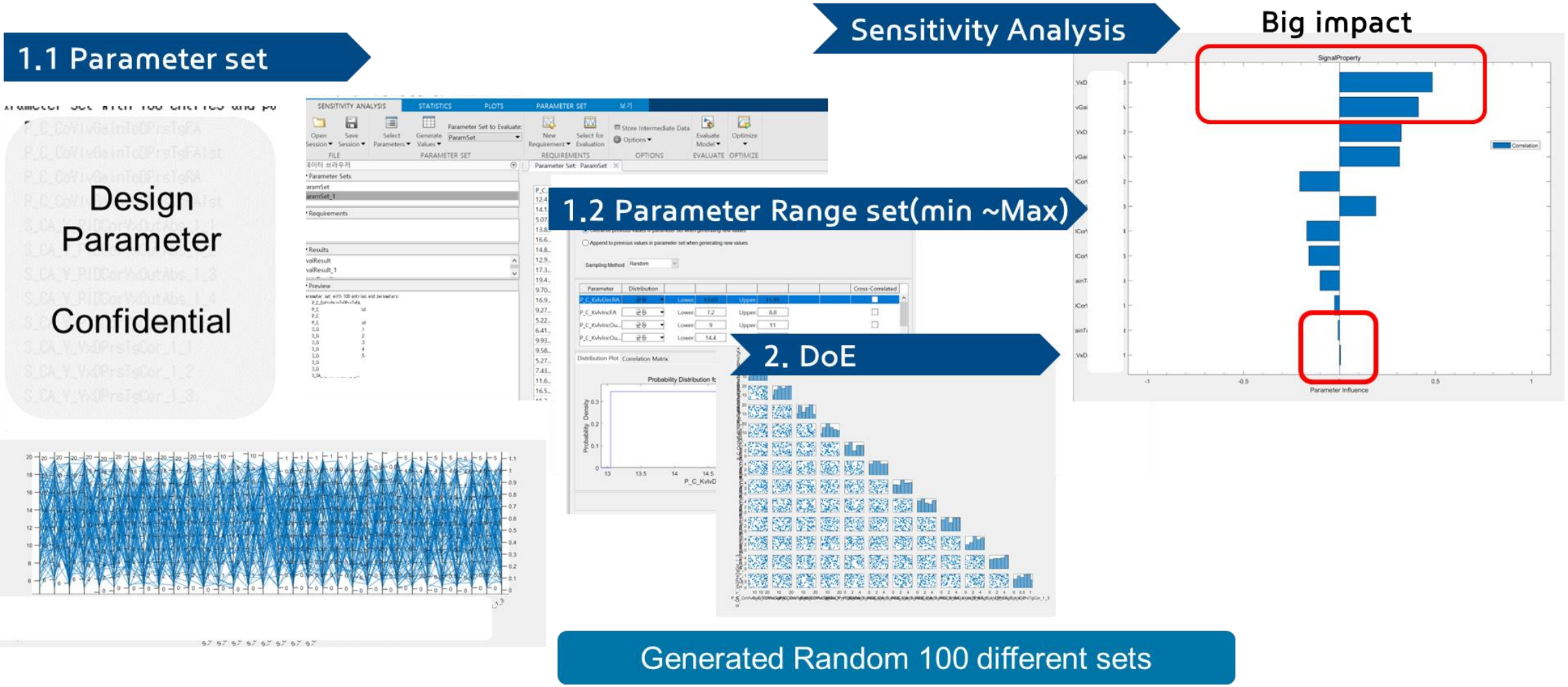
Study Sensitivity Analysis of Parameters

- Work-Flow



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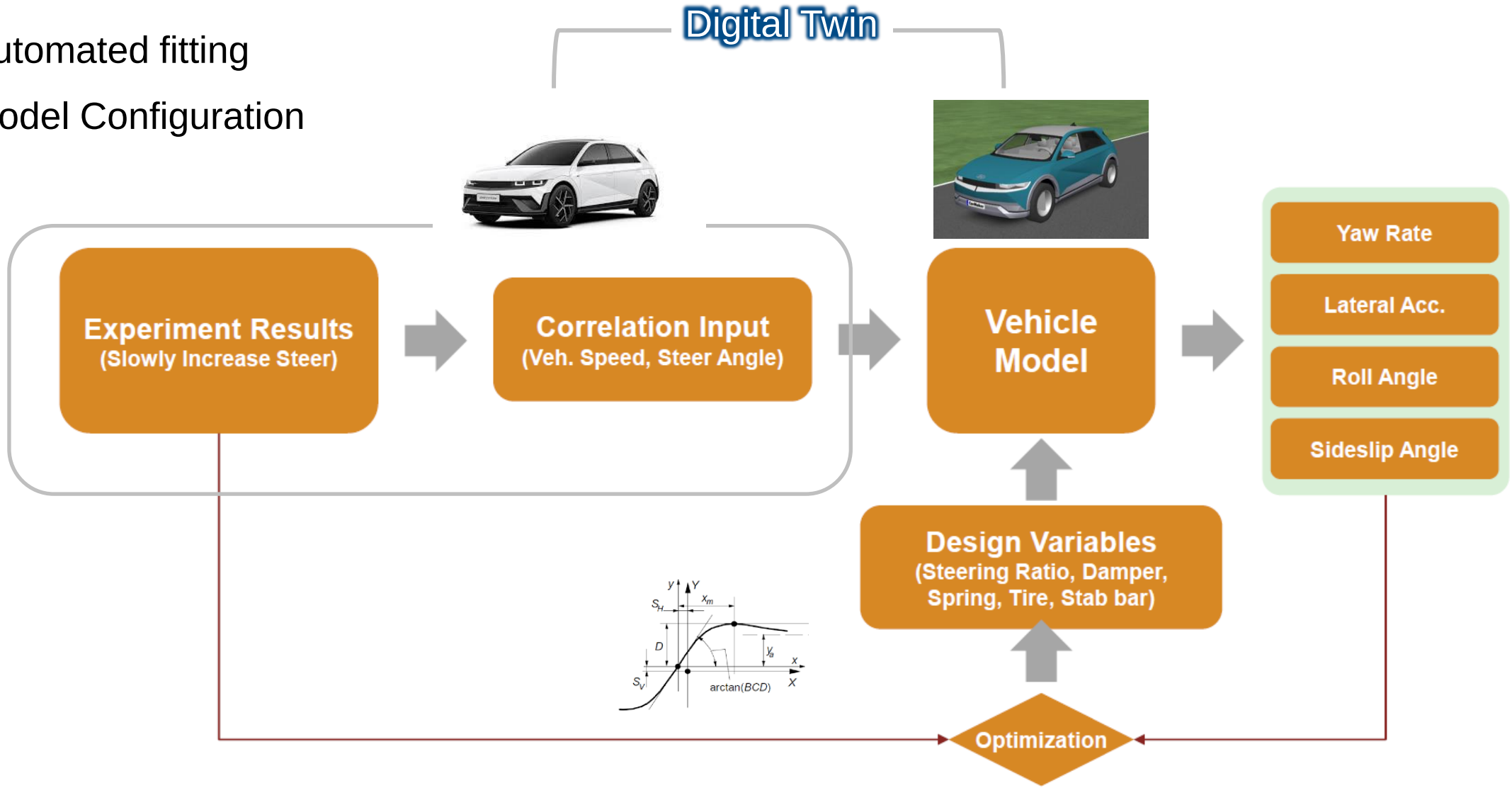
Use Case #2 Vehicle Model Correlation using Simulink Design Optimization

- Automated fitting
- Model Configuration



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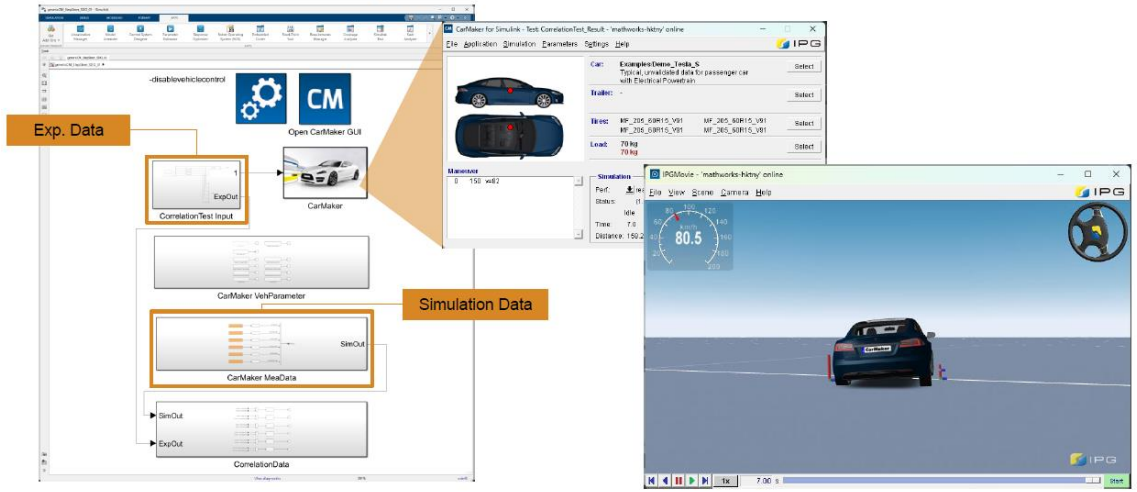
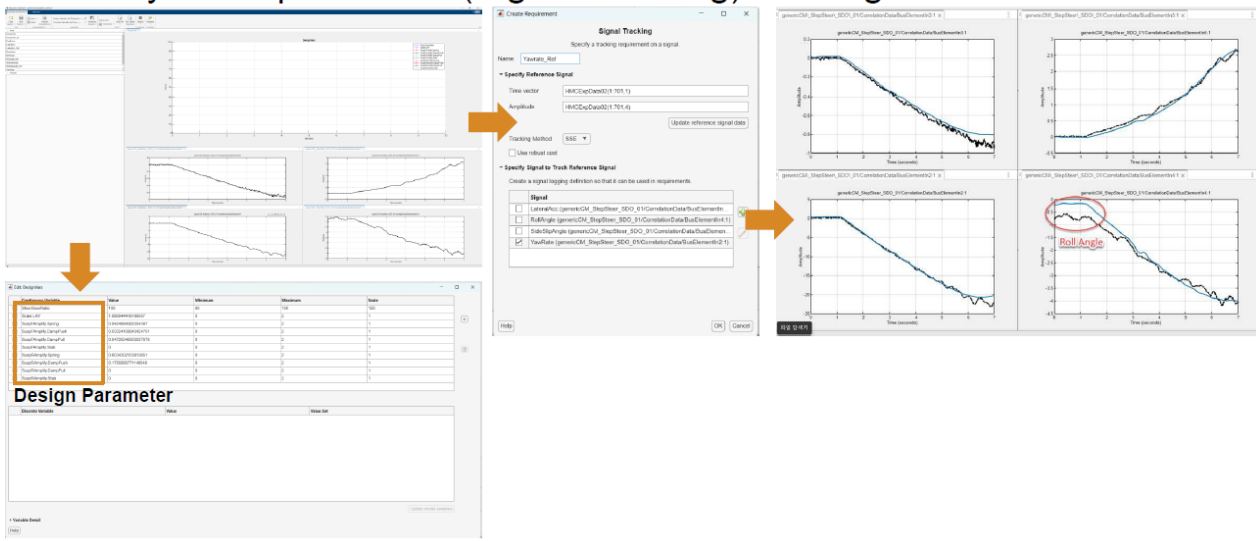
Use Case #2 Vehicle Model Correlation using Simulink Design Optimization

- Simulink Model Configuration
- IPG CarMaker Configuration – Reference
  - Model Correlation Test Run – SIS (Slowly Increase Steer) with Constant Speed (80kph)
  - Vehicle Parameter Configuration
- Response Optimizer App in Simulink Design Optimization

▪ Simulink Model Configuration



▪ Summary of Requirements (Signal Tracking) & Design Variables



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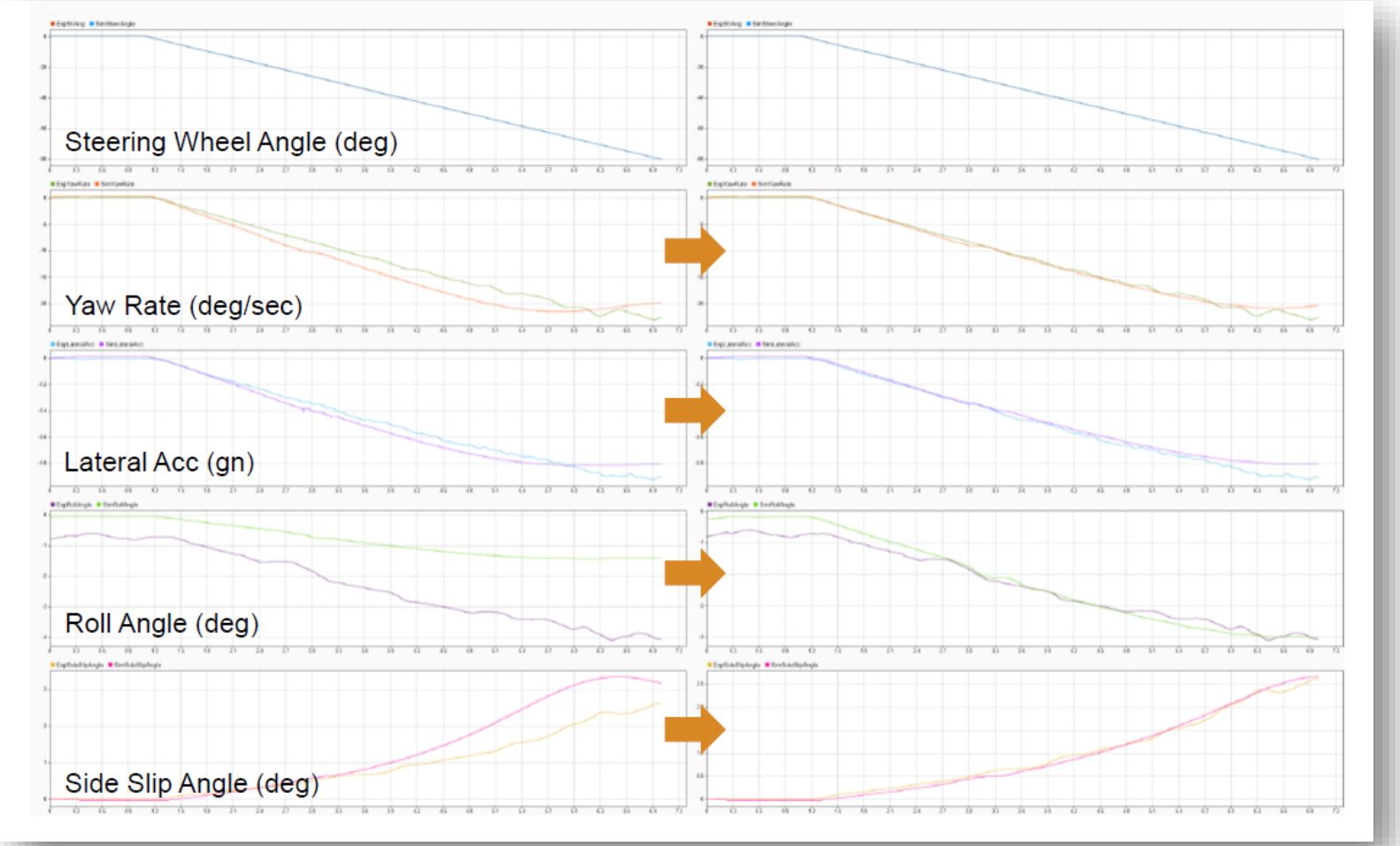
Use Case #2 Vehicle Model Correlation using Simulink Design Optimization

- Optimized Results (247 iterations using fmincon)



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Conclusion

- Efficient Optimization through Virtual Calibration
- Time and cost savings, reduced risks in real-world testing
- Applicability in autonomous driving, electric vehicle control Systems

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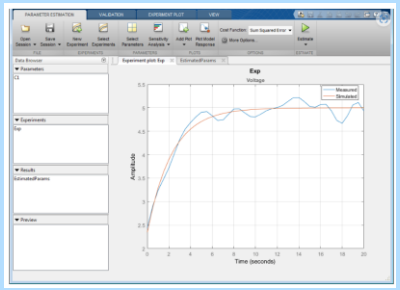
Plan

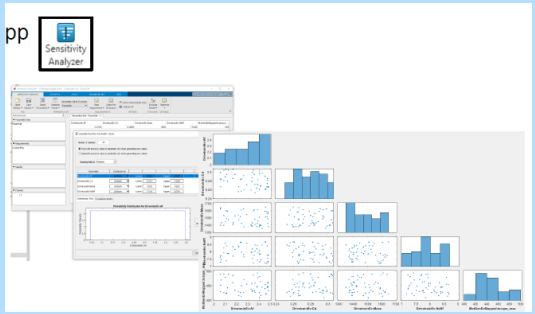
- Requirements Toolbox & Simulink Test & Report Generation

Phase1. Parameter Optimization Methodology

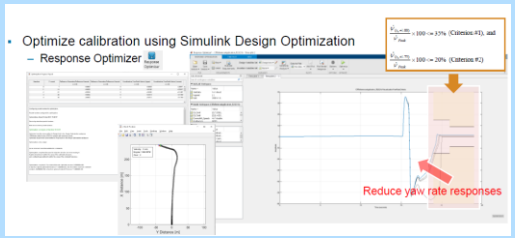
Model automation fitting



Parameter study

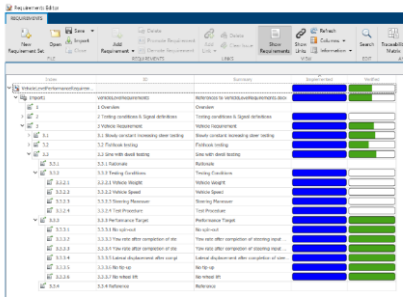


Parameter Opitimization



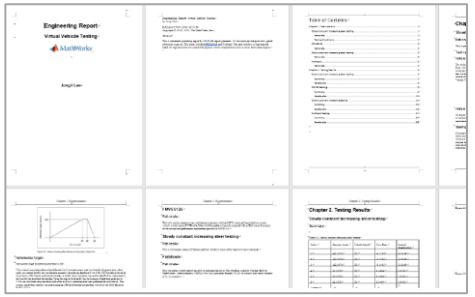
Phase2. Plan (Requirement box & Report Generating)

Requirements

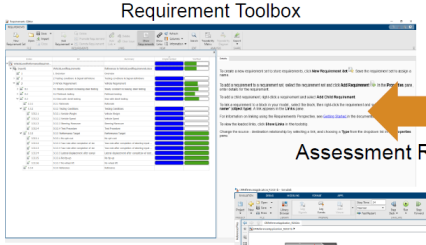


Post Process

Engineering Report

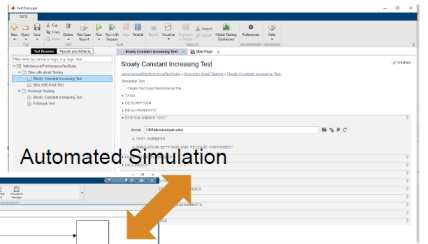


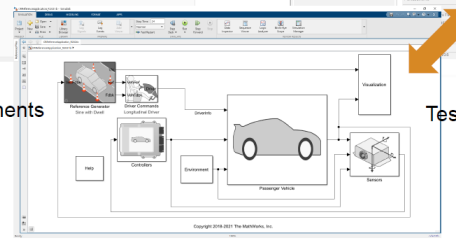
Requirement Toolbox



Assessment Results

Automated Simulation





Requirements

Test Cases

본 문서는 현대자동차·기아의 정보자산으로 관련 법령에 의해 보호받습니다.

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