BATTERY-TRUCK PLANT MODEL

STUDENTS: JUSTIN JANG, LIN CAI, ISABELLE COTA, MINCHU SINGRAIAH PRAKASH, ARJUN VAISH

Problem Statement

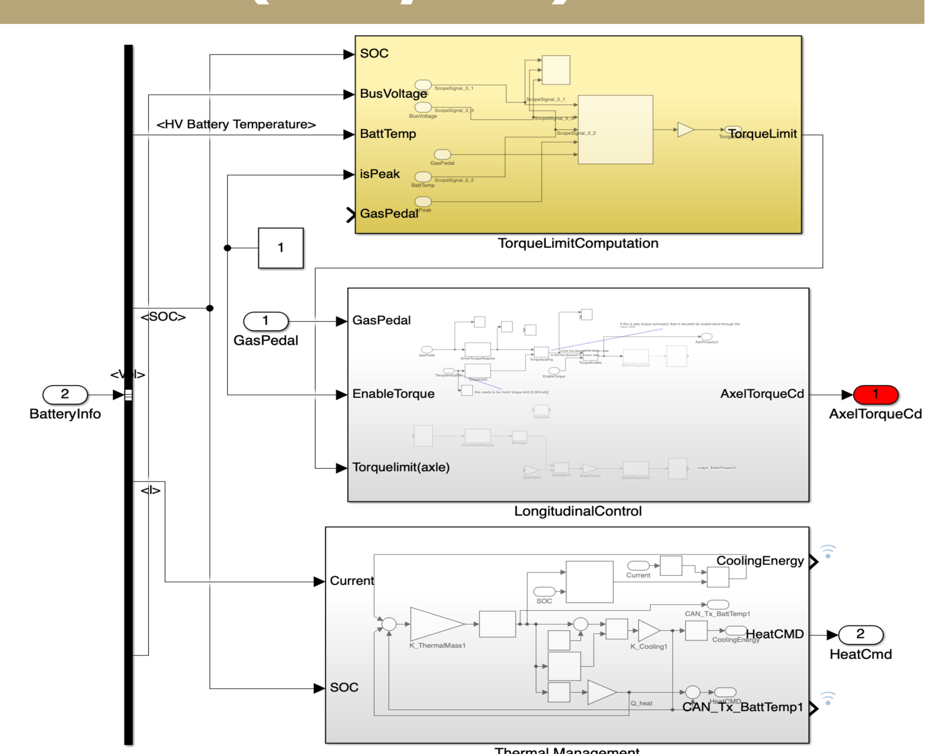
- The UW E-Truck project is converting a Class 7 Peterbilt 337 to a fully battery-electric vehicle, requiring coordination across complex electrical, mechanical, and control subsystems.
- The project currently lacks a unified, high-fidelity plant model to evaluate subsystem interactions, control strategies, and vehicle performance before physical testing.
- A comprehensive MATLAB/Simulink electric truck plant model is needed to enable model-based design, CAN (Controller Area Network) data validation, and scalable development for future teams.

Objectives

- Develop a unified MATLAB/Simulink plant model of the battery-electric [1] truck
- Integrate powertrain, high-voltage battery, thermal management, vehicle dynamics, and supervisory control subsystems
- Support closed-loop simulation of vehicle operation under varied drive cycles and conditions
- Enable performance analysis including energy consumption, acceleration, braking, and range
- Use logged CAN data to calibrate, confirm, and refine model accuracy
- Ensure modular design, clear interfaces, and maintainability for future project teams
- Fully document model assumptions, parameters, architectures, and validation results

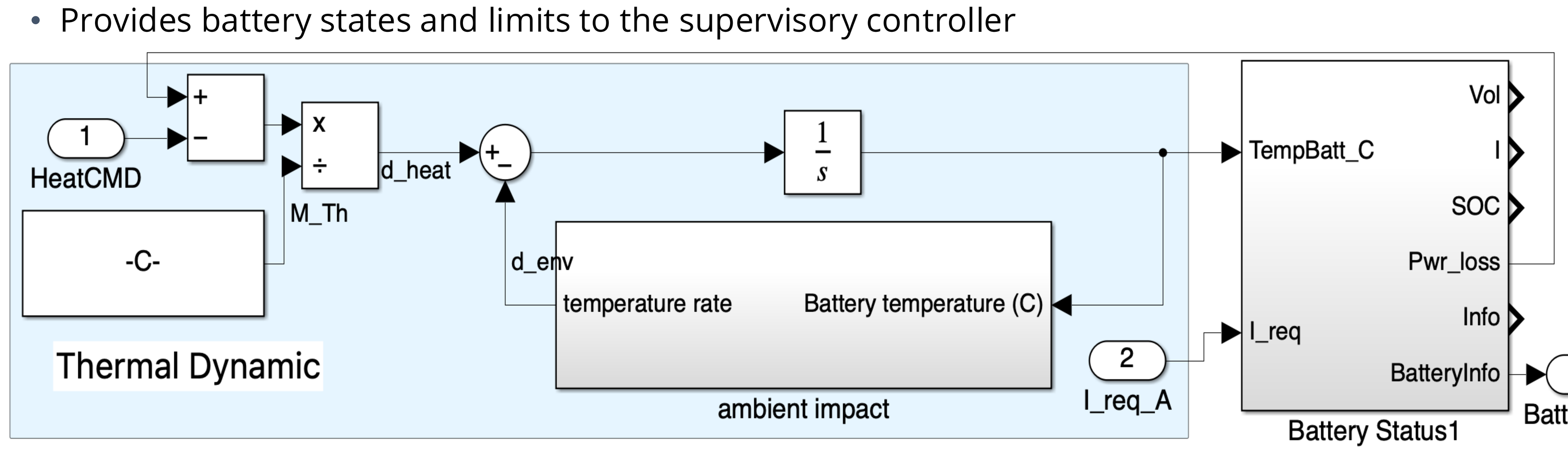
Controller Unit (Subsystem)

- The main goal of this controller is to take in driver demand and vehicle feedback.
- Output is torque command that decides how much power the electric motor should deliver



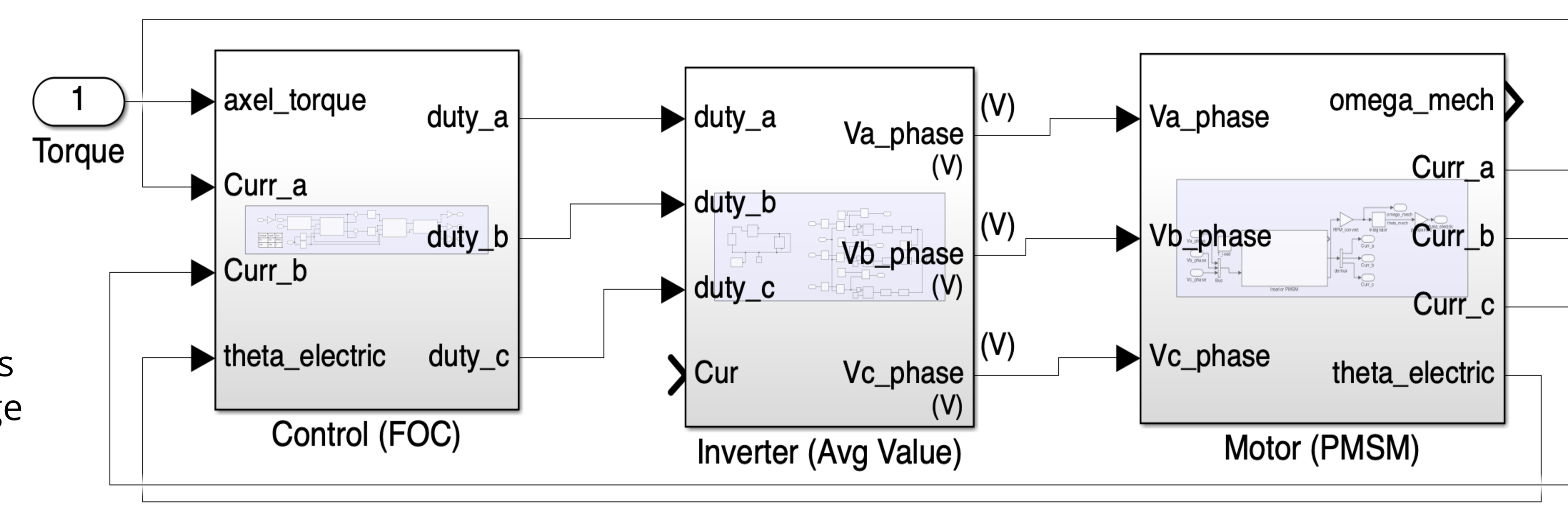
High-Voltage Battery (Subsystem)

- Modeled using a simplified equivalent-circuit representation in Simscape Electrical
- Represents dominant electrical behavior with open-circuit voltage and internal resistance
- Computes SoC (State of Charge), terminal voltage, current, power output, and internal losses
- Provides battery states and limits to the supervisory controller



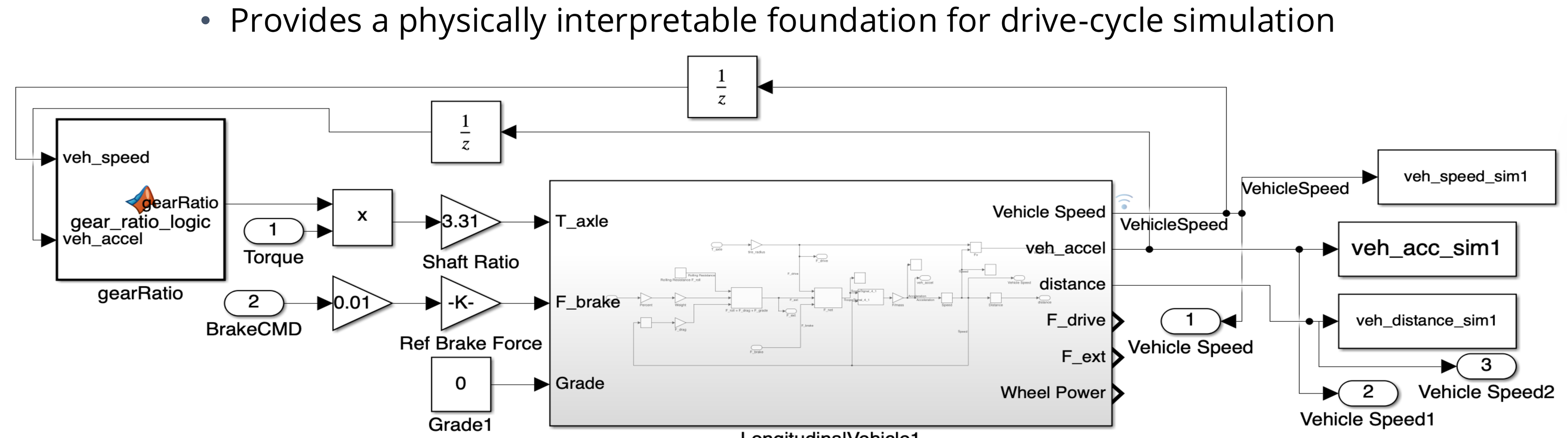
Powertrain (Subsystem)

- Uses field-oriented control (FOC) with PI (Proportional-Integral) controllers to regulate torque and speed
- Average-value inverter converts DC bus voltage into three-phase motor voltages
- PMSM (Permanent Magnet Synchronous Motor) model converts electrical inputs into mechanical torque and rotor speed
- Outputs axle torque and motor speed to the vehicle dynamics subsystem



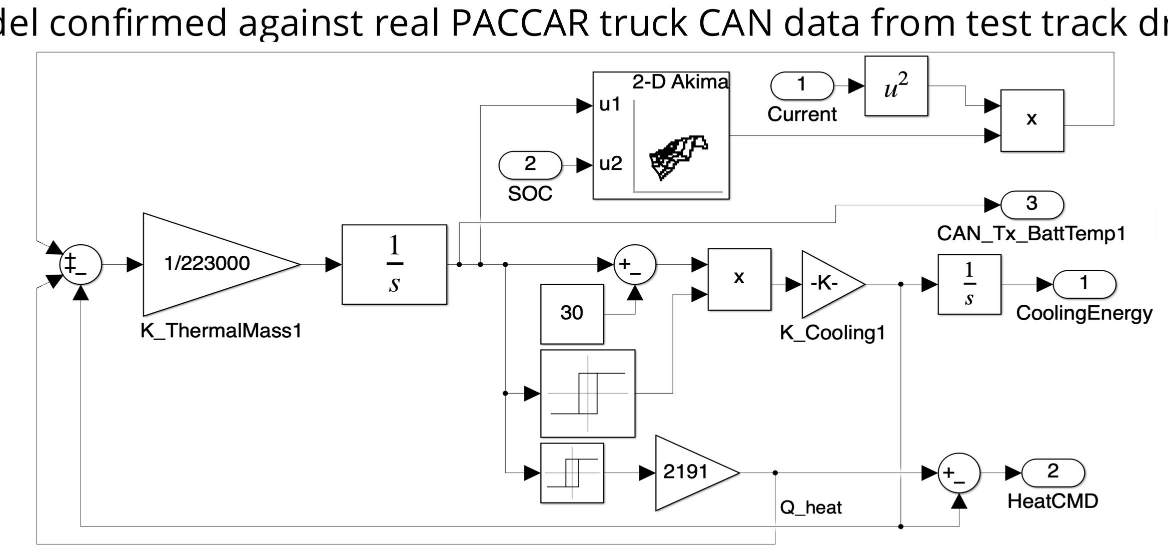
Longitudinal Dynamics (Subsystem)

- Converts axle torque into tractive force using effective tire radius
- Models resisting forces including rolling resistance, aerodynamic drag, and road grade
- Computes net force, vehicle acceleration, speed, and distance traveled
- Calculates wheel power for performance and energy analysis
- Provides a physically interpretable foundation for drive-cycle simulation

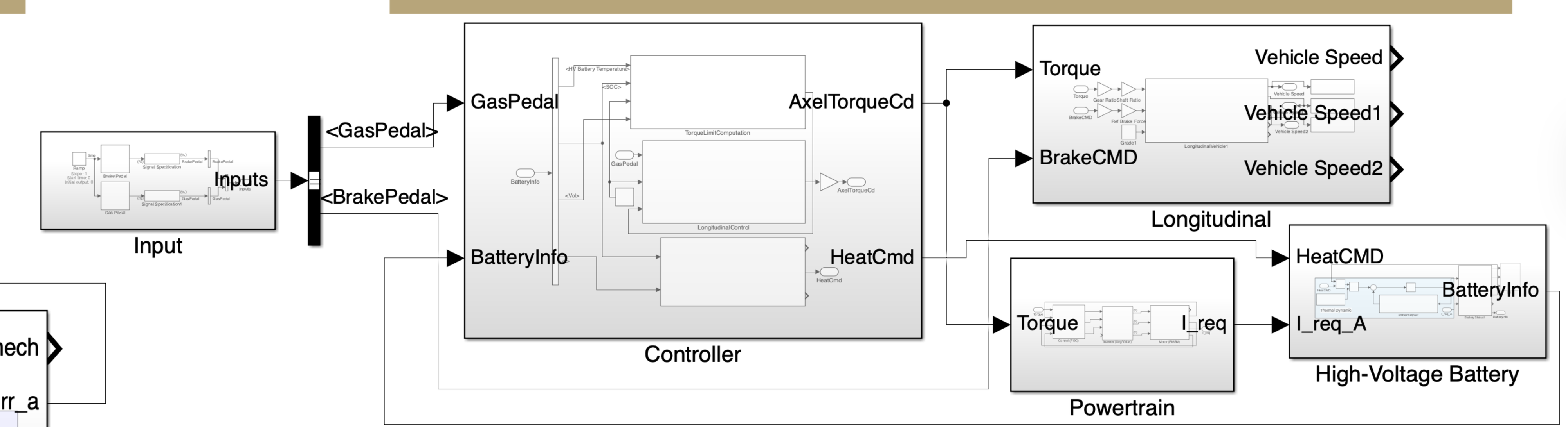


Thermal Control (Subsystem)

- Simulink model simulates battery pack temperature dynamics using I²R heat generation from load current and state of charge
- Thermal mass set to 223,000 J/K based on CATL (battery) [2] pack specifications
- Liquid cooling activates at T ≥ 30°C and resistive heating film activates at T ≤ 12°C
- Model confirmed against real PACCAR truck CAN data from test track drive cycles

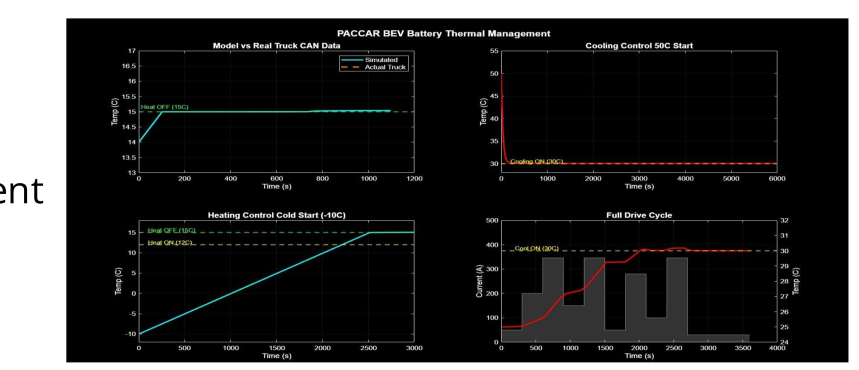


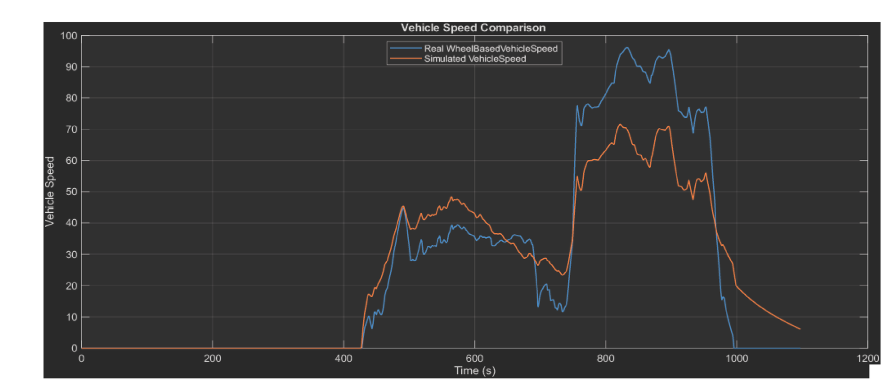
Final Product Model



Testing Results

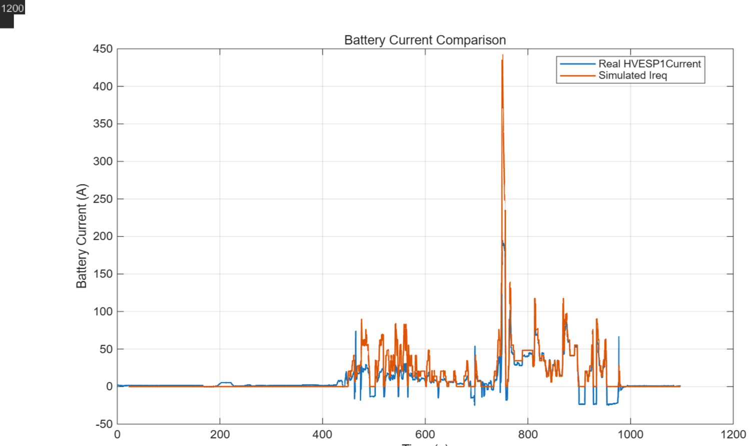
Thermal management

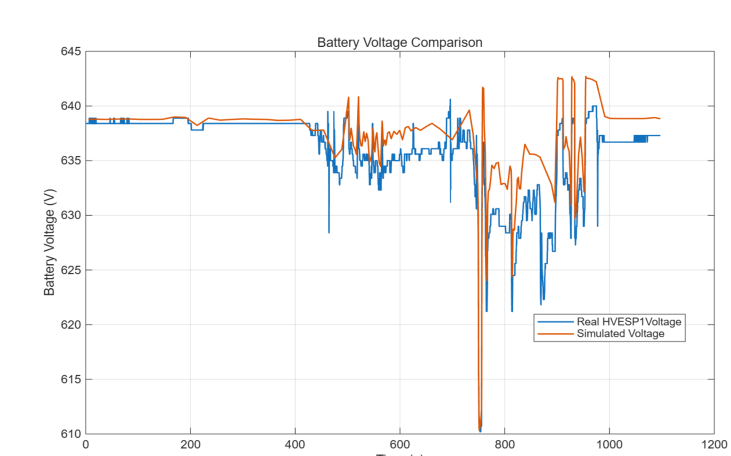




Speed Response Output

Test Current Output





Test Voltage Output

Future Work, References

- Expand CAN-based calibration across multiple drive cycles, payloads, and environmental conditions.
- Automate parameter identification using logged data (e.g., resistance, inertia, drag coefficients).
- Quantify error bounds and confidence intervals for key outputs (speed, SOC, torque)

[1]
mathworks, "Simscape-Battery-Electric-Vehicle-Model/BEV at R2025b · mathworks/Simscape-Battery-Electric-Vehicle-Model," *GitHub*, 2025. https://github.com/mathworks/Simscape-Battery-Electric-Vehicle-Model/tree/R2025b/BEV (accessed May 12, 2026).
[2]
CATL,"CATL," *www.catl.com*.https://www.catlcom /en/

ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

ADVISERS: YUDONG LIN (INDUSTRY MENTOR), JING YU (FACULTY MENTOR)

SPONSOR: PACCAR INC.