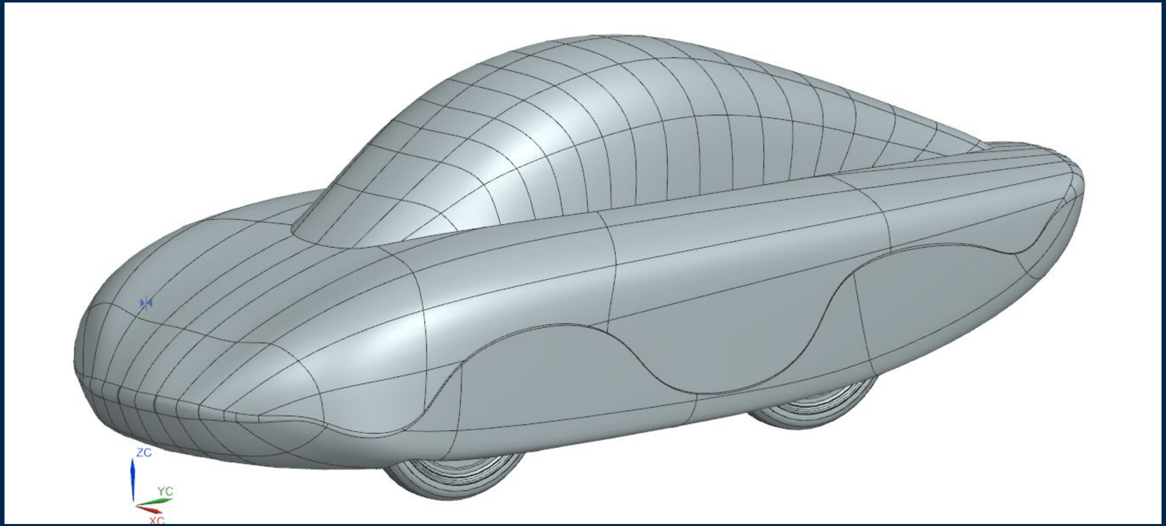
AUTO 566 Group 11
Supermileage
Midterm Presentation

Savannah Belton
Austin Leiphart
Skylar Lennon
Ryan O'Malley
Vijay Balasekaran



Project Scope and Plan

Develop Simulink models for U-M Supermileage's new EV, "Cedar", including:

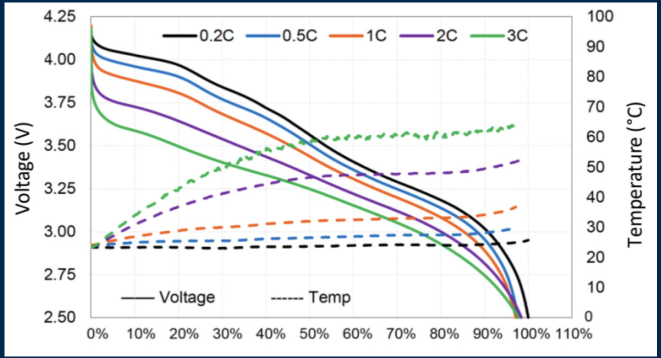
- Vehicle
- Race Strategy
- Battery
- Inverter
- Motor
- Transmission

All to help UMich win the 2026 Shell Eco-Marathon competition

Literature Review - Battery Model

Battery Model:
Bayesian Estimation of Model Parameters of Equivalent Circuit Model for Detecting Degradation Parts of Lithium-Ion Battery [1]

- Supermileage needed to improve its battery modeling capabilities to accurately capture open circuit voltage and SOC in their onboard BMS.
- Accurate capture terminal voltage by implementing an OCV-R-RC battery model with parameter estimation, experimental OCV-SOC data, and numerical methods.
- RC pair in equivalent circuit model captures the diffusion effects of lithium-ions in the cell during dynamic current profiles.



Terminal Voltage vs SOC for Amprius SA10 Cells [2]

A. EQUIVALENT CIRCUIT MODEL

The internal state estimation method used in this study was based on an equivalent circuit model, which is a simplified model of an actual battery with electrical elements (i.e., resistors and capacitors) representing the battery characteristics to reduce computational intensity compared to the electrochemical model.

The general equivalent circuit model used for state estimation considers both the dropped voltage (V_n) and OCV, which is the voltage when the battery terminals are open (V_{ocv}). The equivalent circuit model used in this study is shown in Fig. 1. The equation of state is defined as follows:

$$V_0(t) = -R_0 I_{obs}(t), \tag{1}$$

$$V_n(t) = \frac{C_n R_n}{C_n R_n + \Delta t}\left\{V_n(t-\Delta t) - \frac{\Delta t}{C_n} I_{obs}(t)\right\}, \tag{2}$$

$$V_{est}(t) = V_{ocv}(t) + V_0(t) + \sum_{n=1}^{N\_RC} V_n(t), \tag{3}$$

where n is the number of orders of the RC parallel branch, t is the time, Δt is the sampling time, $V_{est}(t)$ is the current estimated terminal voltage at the present time, $V_0(t)$ is the voltage of ohmic resistance at the present time, $I_{obs}(t)$ is the observed terminal current at the present time, and N_RC is the total number of parallel RC branches. The voltage $V_n(t)$ for each parallel branch is derived with unknown parameters, including the resistor R_n, capacitor C_n, and past voltage $V_n(t-\Delta t)$, and known parameters, such as the current $I_{obs}(t)$ and sampling time Δt. Moreover, $V_{ocv}(t)$ is regarded as a known parameter since it was assumed that it can be obtained from conventional methods [20], [21]. This study aimed to derive the model parameters of third-order circuits because they can represent the impedance at various time scales, which changes owing to degradation.

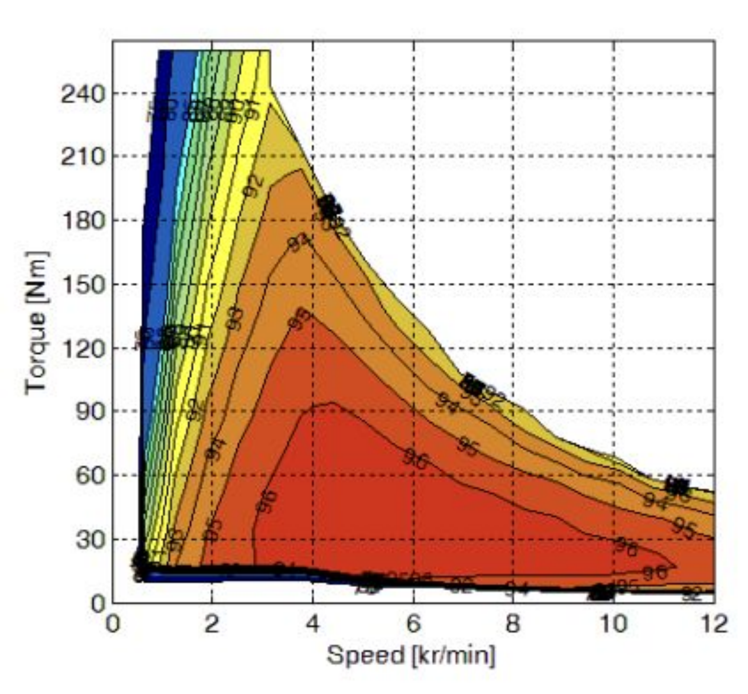
Battery ECM [1]

Literature Review - Motor Model

Motor Model:

Efficiency Maps of Electrical Machines [3]

- How to generate efficiency models for various types of motors
    - Fitting datasheet parameters to various motor models from literature review
    - BLDC / Brushless motors
- Understanding motor efficiency as a polynomial function of torque and speed
- Understand how race strat effects where operating points land on efficiency contour



Torque-Speed-Efficiency Contour [3]

Literature Review - Race Strategy

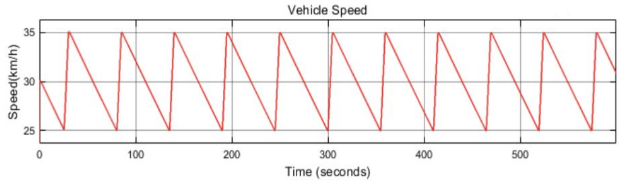
Race Strategy Model:

A Pulse-and-Glide-driven Adaptive Cruise Control System for Electric Vehicle [4]

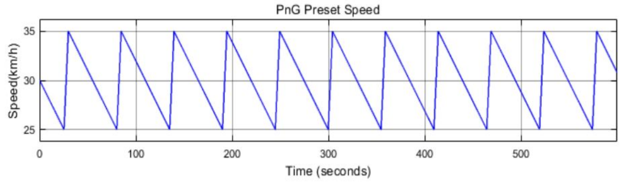
- Drive mode switching strategy (PnG vs CC)
- Investigating various algorithms for efficiency optimization given competition and vehicle constraints.
- Developing track and drive strategy models of various levels of complexity.

TABLE II. SWITCHING STRATEGY

Distance	Vp>Vset	Vp≤Vset
$d<d_{des}$	ACC	ACC
$d_{des}\leq d<d_{logic1}$	CC or PnG	ACC
$d_{logic1}\leq d<d_{logic2}$	CC or PnG	Buffer
$d\geq d_{max}$ or $d\geq d_{logic2}$	CC or PnG	CC or PnG



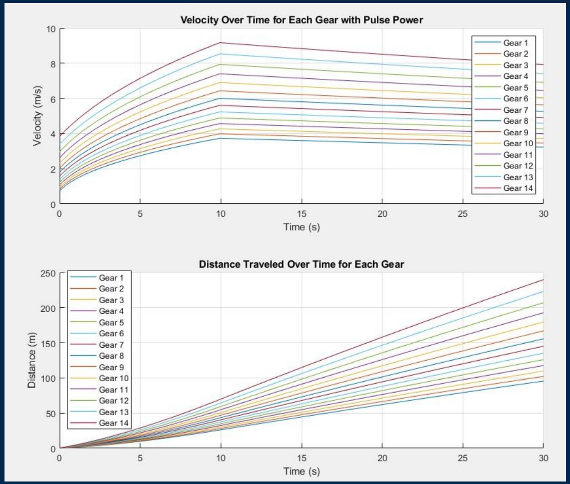
(a) Vehicle speed

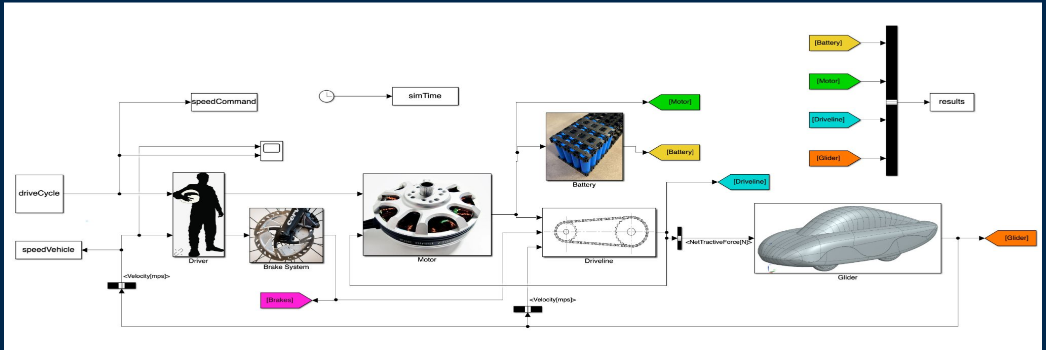


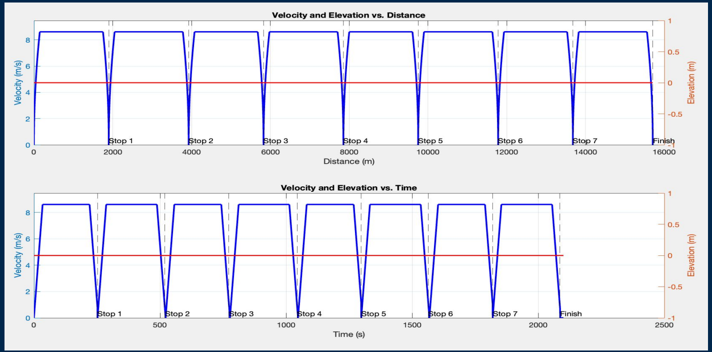
Switching Strategy & PnG Drive Strategy [4]

Initial Models & Preliminary Results

- Initial vehicle model
- Initial Battery, Inverter, Motor, Transmission Models
- Simple race strat for dev







Questions?

References

[1] Amprius Battery Cell Data

[2] Bayesian Estimation of Model Parameters of Equivalent Circuit Model for Detecting Degradation Parts of Lithium-Ion Battery

[3] Efficiency Maps of Electrical Machines

[4] A Pulse-and-Glide-driven Adaptive Cruise Control System for Electric Vehicle