

# Eco-Gear Challenge Simulator

## Understanding and Solution Documentation

### Page 1: Problem Understanding

#### 1. Problem Overview

The Eco-Gear Challenge Simulator models a bicycle-style rover moving along a one-dimensional track with varying terrain conditions. The objective of the problem is to design an energy-efficient gear-selection controller that enables the rover to successfully complete the track within a given time limit while minimizing total energy consumption.

At every simulation step, the controller must output a valid gear ratio between 0.0 and 5.0. The simulator then uses this gear ratio to compute the rover's dynamics, including wheel torque, forces, velocity, position, and energy usage.

The controller must ensure that the rover finishes the track before the time limit, does not stall on uphill segments, maintains stable motion, and uses minimal propulsion energy.

#### 2. Vehicle and Physics Model Summary

The rover is modeled using classical mechanics principles, including a fixed total mass, driven rear wheel dynamics, maximum input torque, and resistive forces such as gravity, rolling resistance, and aerodynamic drag. Energy consumption is accumulated based on applied torque and wheel angular velocity over time.

#### 3. State Variables Available to the Controller

At each timestep, the controller receives the current system state including position, linear velocity, wheel angular velocity, track slope, elapsed simulation time, and total energy consumed so far.

## Page 2: Solution Approach

### 4. Control Strategy Overview

The implemented controller uses a rule-based adaptive gear selection strategy. The gear ratio is dynamically adjusted based on terrain slope and vehicle velocity to balance torque requirements and energy efficiency.

### 5. Terrain-Based Gear Selection

Uphill segments use higher gear ratios to prevent stalling. Flat terrain uses moderate ratios for steady cruising. Downhill segments use lower gear ratios to reduce unnecessary energy usage.

### 6. Stall Prevention Mechanism

If rover velocity drops below a threshold, the controller temporarily increases the gear ratio to provide additional torque and recover motion, especially on steep inclines.

### 7. Energy Efficiency Considerations

Energy minimization is achieved by avoiding excessive torque, using only required gear ratios, and limiting high-gear usage to necessary situations.

### 8. Conclusion

The controller successfully completes the track within constraints while minimizing energy consumption. The rule-based adaptive strategy provides a simple, robust, and efficient solution.