# CVT-SIMULATOR

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ENGINEERING
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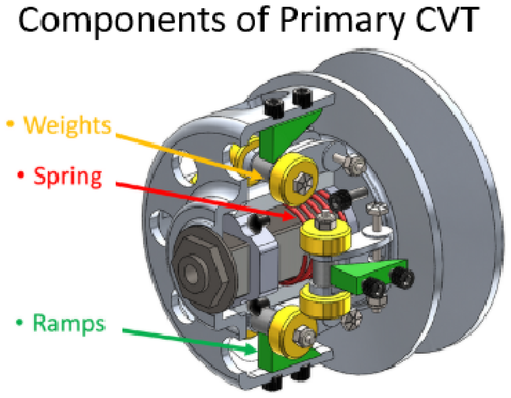
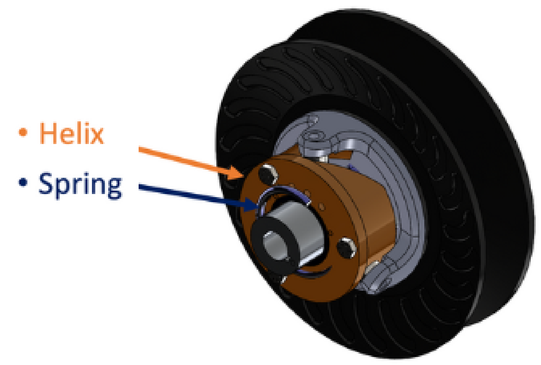
## Project Motivation

- **Primary Stakeholder:** McMaster Baja Racing Team
- **Key Component:** Continuous Variable Transmission (CVT) – responsible for maximizing power transfer from the engine.
- **Importance:** The CVT is crucial for performance in key competition events such as hill climb, acceleration, and the endurance race.
- **Current Issue:**
  - The mechanical CVT is complex, with ~10 tuneable parameters.
  - Last year, CVT tuning took over 8 weekends, even with formalized testing tools.
  - Despite optimization, there is still untapped performance potential.
- **Challenges:**
  - Some metrics of the CVT's performance are not fully understood.
  - Limited drive time each season hampers optimization.
  - Manual tuning is resource-intensive and costly.
  - Expensive manufacturing techniques for CVT components add to costs.

Components of Primary CVT




Components of Secondary CVT




## Our Solution

- Developed a comprehensive powertrain model for the Baja vehicle.
- Modeled resistive forces, engine, and CVT system.
- Enables rapid assessment of component changes and their impact.
- Provides a cost-effective way to test and iterate designs.

## Key Features

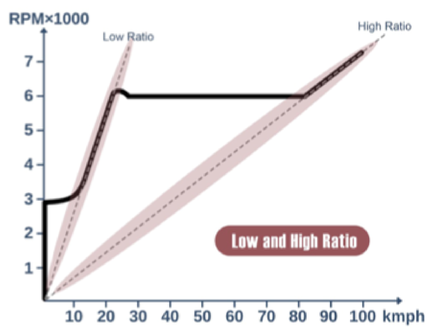
- Successfully simulates the McMaster Baja Team's CVT using mathematical models.
- Computes primary and secondary clamping forces based on CVT parameters.
- Calculates acceleration, velocity, and distance of the car.
- Allows users to adjust CVT tuning parameters as well as other inputs.
- Provides an interface for users to play and the simulation
- Displays graphs of the simulation results
- Exporting of the simulation data.

$$= v_{\text{shift}} \frac{dv_{\text{shift}}}{dd_{\text{shift}}} = \frac{F_{\text{prim\_clamp}}(d_{\text{shift}}, \omega_{\text{eng}}) - F_{\text{sec\_clamp}}(d_{\text{shift}}, T_{\text{eng}}, R_{\text{cvt}})}{m_{\text{sheaves}}}$$

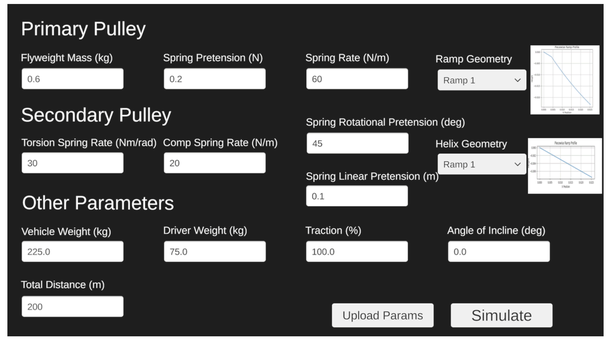
*Shifting Acceleration ODE*

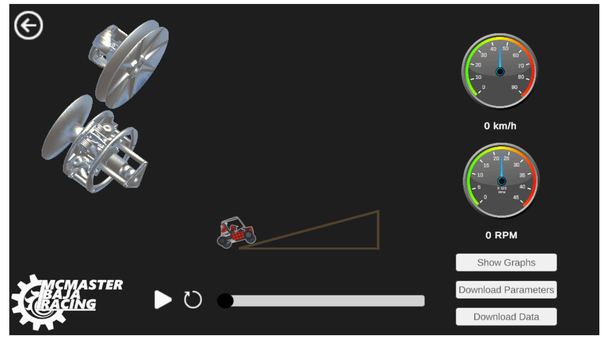
$$\frac{dv_{\text{car}}}{dt} = \frac{\frac{R_{\text{CVT}} R_{\text{gearbox}}}{r_{\text{wheel}}} \tau_{\text{engine}}\left(\frac{v_{\text{car}} R_{\text{CVT}} R_{\text{gearbox}}}{r_{\text{wheel}}}\right)}{m_v + m_d} - g \sin\theta_{\text{inc}} - \frac{\rho C_D A}{2(m_v + m_d)} v_{\text{car}}^2$$

*Car Acceleration ODE*

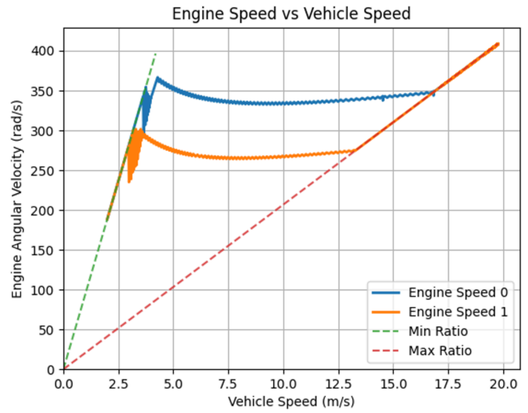



## Product

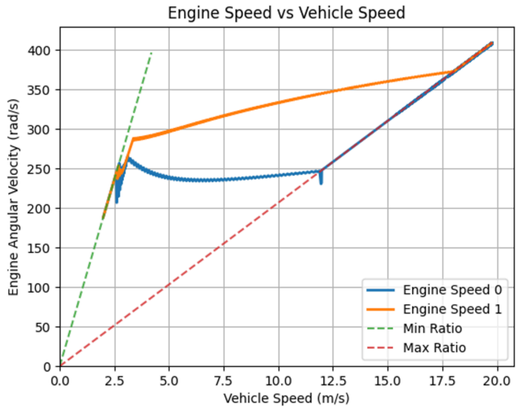



## Trend Analysis



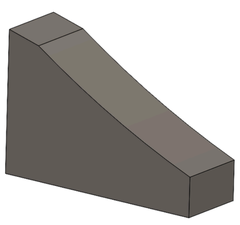

- Increased weight lowers peak engine speed.
- Heavier configurations slow CVT ratio engagement.
- "Engine Speed 1" shows a flatter curve due to increased load.
- Simulation reflects added inertia delaying speed transitions.




- Spring rate variations influence CVT response.
- Stiffer springs cause an earlier upshift.
- Higher initial engine speeds and quicker ratio adjustment.
- Simulation accurately reflects spring rate effects.

## Results

The software has already been instrumental in guiding the design of new ramps, streamlining the development process and contributing to more efficient, data-informed design decisions.



| # Pos. | # Car No. | School / Team Name | Status | # Time | # Points |
|---|---|---|---|---|---|
| 1 | 66 | Case Western Reserve Univ CWRU Motorsports | OK | 3.863 | 70 |
| 2 | 69 | Univ of Michigan - Ann Arbor Michigan Baja Racing | OK | 3.916 | 68.86890244 |
| 3 | 27 | Ecole de Technologie Superieure Baja ÉTS | OK | 3.919 | 68.80487805 |
| 4 | 36 | California Polytechnic State Univ-SLO Cal Poly Racing | OK | 3.989 | 67.31097561 |
| 5 | 73 | Cornell Univ Cornell Baja Racing | OK | 4.033 | 66.37195122 |
| 6 | 72 | Rochester Institute of Technology RIOT RACING | OK | 4.117 | 64.57926829 |
| 7 | 76 | Univ of Maryland - Baltimore County UMBC Racing | OK | 4.187 | 63.08536585 |
| 8 | 65 | Johns Hopkins Univ Blue Jay Racing | OK | 4.199 | 62.82926829 |
| 9 | 16 | ITESM - Campus Guadalajara Mad Rams | OK | 4.254 | 61.6554878 |
| 10 | 64 | McMaster Univ McMaster Baja Racing | OK | 4.285 | 60.99390244 |
| 11 | 34 | Univ of Calif - Los Angeles Bruin Racing Baja | OK | 4.297 | 60.73780488 |
| 12 | 25 | Utah State University USU Baja | OK | 4.36 | 59.39329268 |
| 13 | 75 | The Ohio State University Baja Buckeyes | OK | 4.372 | 59.13719512 |
| 14 | 32 | Oregon Inst of Tech Oregon Tech Racing | OK | 4.413 | 58.26219512 |
| 15 | 43 | San Diego State Univ Aztec Baja Racing | OK | 4.422 | 58.07012195 |
| 16 | 22 | Oregon State Univ Beaver Racing | OK | 4.434 | 57.81402439 |
| 17 | 55 | Universite de Sherbrooke Universite de Sherbrooke | OK | 4.441 | 57.66463415 |
| 18 | 18 | California State Poly Univ - Pomona Bronco Racing | OK | 4.448 | 57.5152439 |
| 19 | 35 | Harding Univ Bison Baja | OK | 4.489 | 56.6402439 |
| 20 | 12 | Univ of Missouri - Kansas City Roo Racing | OK | 4.56 | 55.125 |
| 21 | 64 | McMaster Univ McMaster Baja Racing | OK | 4.56 | 55.125 |