Problem Statement and Goals
CVT Simulator

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Table 1: Revision History

Date	Developer(s)	Change
Sept 24	All	Initial draft
Apr 3	Cameron Dunn	Updated to Rev 1

1 Problem Statement

The problem statement is a high-level overview of the problem that our project is trying to solve. It specifies the problem in plain language and outlines the inputs, outputs, stakeholders, and environment.

1.1 Problem

The McMaster Baja engineering team is seeking to improve the tuning process for their Continuous Variable Transmission (CVT). The tuning of a CVT typically involves extensive real-world testing of physical components, which is time-consuming and prone to inconsistencies due to factors such as wear and weather. These conditions complicate the ability to fine-tune the CVT's torque transfer, which directly impacts vehicle acceleration and hill-climbing performance, both which are two of the team's main objectives in competition.

1.2 Inputs and Outputs

The inputs and outputs are the parameters and results that define the structure of the problem. The inputs provide a scope of what factors are being considered for the problem at hand. The outputs give the desired final form of the inputs after the problem has been solved.

1.2.1 Inputs

- CVT Parameters
  - Primary Flyweight Mass
  - Primary Spring Pretension
  - Primary Spring Rate
  - Primary Ramp Geometry
  - Secondary Torsional Spring Rate
  - Secondary Compression Spring Rate
  - Secondary Spring Rotational Pretension
  - Secondary Spring Linear Pretension
  - Secondary Helix Geometry
- Vehicle Weight
- Driver Weight
- Traction
- Angle of Incline
- Total Distance

1.2.2 Outputs

- Data that will be outputted from the simulation
  - Time
  - Car Velocity
  - Car Position
  - Shift Velocity
  - Shift Distance
  - Engine Angular Position
  - Secondary Angular Position
  - Engine RPM
- Graphs of the simulation output
- 3D Model of CVT Visualization
- Speedometer
- Tachometer
- Distance travelled visualization

1.3 Stakeholders

- McMaster Baja Racing Team
- Dr. Spencer Smith

1.4 Environment

The environment of the problem encompasses what hardware the application will be able to run on, as well as the software that the application will support and be developed in.

1.4.1 Hardware

- Device can be configured through the use of a personal computer or laptop.

1.4.2 Software

- The application will be supported on Mac, Windows and Linux operating systems.
- The application will be developed using Python and C#.

2 Goals

Develop a 3D model and simulation of the CVT system, which will include the driven pulley, driving pulley, belt, and engine, and will be implemented within a graphical user interface.

2.1 Mathematical Model

The mathematical model is the main component of the simulation and will be used to calculate the output of the CVT system based on the input parameters. This includes the calculation of the driving pulley's weights, ramps, and spring, as well as the driven pulley's helix and spring. From these, simulating the belt's interaction with both pulleys will allow us to output the CVT ratio, RPM, torque, and belt slippage. Finally, combining this with the engine's input will allow us to calculate the vehicle's acceleration, speed, and distance.

2.2 Graphical User Interface

The graphical user interface will allow users to input various parameters such as CVT specifications, vehicle and driver weight, traction, and angle of incline. Once complete, it will display a 3D model of the CVT system and the vehicle, as well as graphs of the simulation output.

2.3 Data Output and Visualization

After the simulation is complete, the application will display graphs of the simulation output and allow users to export simulation data.

2.4 Data Validation

Validation of the simulated data against real-world data is crucial to ensure accuracy. We will need to gather data from the McMaster Baja Racing Team to validate against, including speed, RPM and basic torque measurements.

3 Stretch Goals

The stretch goals of the project are the features that would improve the application, but they are not required and can be considered out of scope for the current implementation.

3.1 Simulating Heat

Heat can play an important role in the behaviour of the CVT system, especially in extreme configurations. Including basic heat simulation would allow users to understand which setups would lead to catastrophic results. Further, minimizing heat can also lead to an optimized performance.

This goal can be considered complete by including heat readings of various points on the 3D model, powered by the simulation of the heat generated by the CVT system.

3.2 Simulating Inertia of Non Rigid Components

Include complex simulation of the intertia of non-rigid components such as the belt and springs rather than treating them as rigid bodies.

3.3 Optimization Algorithm

Implement an optimization algorithm to find the optimal CVT parameters for a given set of conditions.

3.4 Advanced Data Validation

Depending on the available data, more advanced data validation techniques can be used to ensure the accuracy of the simulation. This includes validating belt slippage, advanced torque readings and acceleration data.

4 Challenge Level and Extras

The challenge level provides a rough estimate of the overall difficulty of the project. The extras are project specific additional deliverables that separate it from the standard capstone project requirements

4.1 Challenge Level

The challenge level for this capstone project is general.

4.2 Extras

The extras for this capstone project are:

- Usability Testing
- Validation Report

Appendix — Reflection

The purpose of reflection questions is to give you a chance to assess your own learning and that of your group as a whole, and to find ways to improve in the future. Reflection is an important part of the learning process. Reflection is also an essential component of a successful software development process.

Reflections are most interesting and useful when they're honest, even if the stories they tell are imperfect. You will be marked based on your depth of thought and analysis, and not based on the content of the reflections themselves. Thus, for full marks we encourage you to answer openly and honestly and to avoid simply writing "what you think the evaluator wants to hear."

Please answer the following questions. Some questions can be answered on the team level, but where appropriate, each team member should write their own response:

1. What went well while writing this deliverable?

   While writing this deliverable some of the things that went well included defining the problem, inputs, stakeholders, goals and environment. This was clear to us as we've encountered these issues firsthand and have a good understanding of the system.

2. What pain points did you experience during this deliverable, and how did you resolve them?

   During the writing of this deliverable, we ran into several pain points. The primary spots ended up being with the outputs, stretch goals and extras. It took more effort than we initially thought to determine what the outputs of our application were going to be. This is most likely due to the complexity of the system, along with the consideration of what data points would be valuable to our stakeholders. Stretch goals became more complex due to the math simulation's complexity. We realized certain aspects would be best approximated for our final product rather than risk getting bogged down in the details as we were unsure about the level of accuracy we'd be able to achieve. Finally, we had a hard time deciding on which extras to include in our project. We have went back and forth on which extras to include as part of our project, since we were unfamiliar with the options present.

   As well there were disagreements regarding the scope of the project and the level of detail that should be included in the development plan. Some team members had concerned about the level of difficultly of the project and if we would be able to complete it. On the other hand, other team members felt that we were capable of completing the project and needed to add more details for the deliverable. We resolved these issues by meeting as a team and doing a walkthrough of the entire project and its components. This helped the concerned team members understand the project better and made it feel more attainable. This walkthrough ended up serving as the basis for the development plan.

There were some disagreements within the team about the project's scope and the level of detail required in the development plan. While some members were concerned about the difficulty, others believe we were fully capable and needed to add more detail in our deliverables. We resolved these issues by holding a team meeting and conducting a full walkthrough of our system and its components. This helped clarify the project for those with concerns, as well as reinforce those who believed in the project. This walkthrough then ended up serving as the foundation for our development plan.

3. How did you and your team adjust the scope of your goals to ensure they are suitable for a Capstone project (not overly ambitious but also of appropriate complexity for a senior design project)?

   The scope of our project had to be adjusted a bit to ensure it was suitable for a capstone project. Originally, it was a bit overambitious as we had plans to implement an optimization algorithm to be used to find the optimal parameters for the CVT. However, upon flushing out the goals for this project, we realized optimization would be better suited as a stretch goal rather than one that is required for the completion of the project since it could be quite a difficult to achieve.