
## Team Members

**Mechanical Engineering:**

- Evan Dela Rosa, Gustavo Ramirez, Omar Joma, Kasy Batres Vasquez, Diego Ramos Lopez, Jonathan Chow

**Engineering Technology:**

- Daniel Zoueihid, Rene Contreras

**Electrical Engineering:**

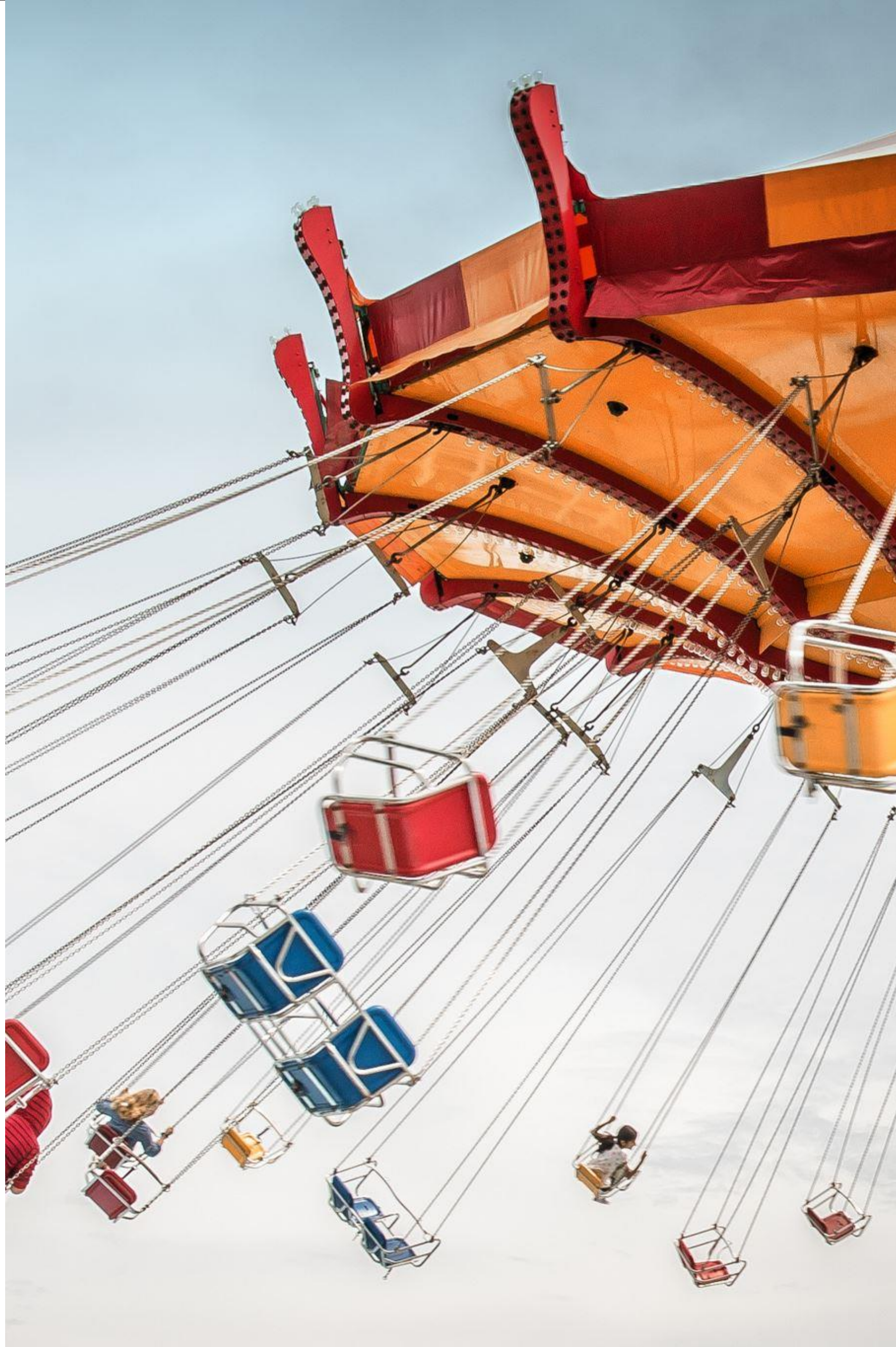
- Jonathan Galan, Kristian Anaya, Gabriel Corcio, Andy Tran, Erik Thomas

# TOPICS

- Background and Team Objectives
- Overview of Project
- Real-World Research
- Coaster Design
- Fabricating Model
- Vehicle
- Electrical System and Software
- Block Zones

# BACKGROUND:

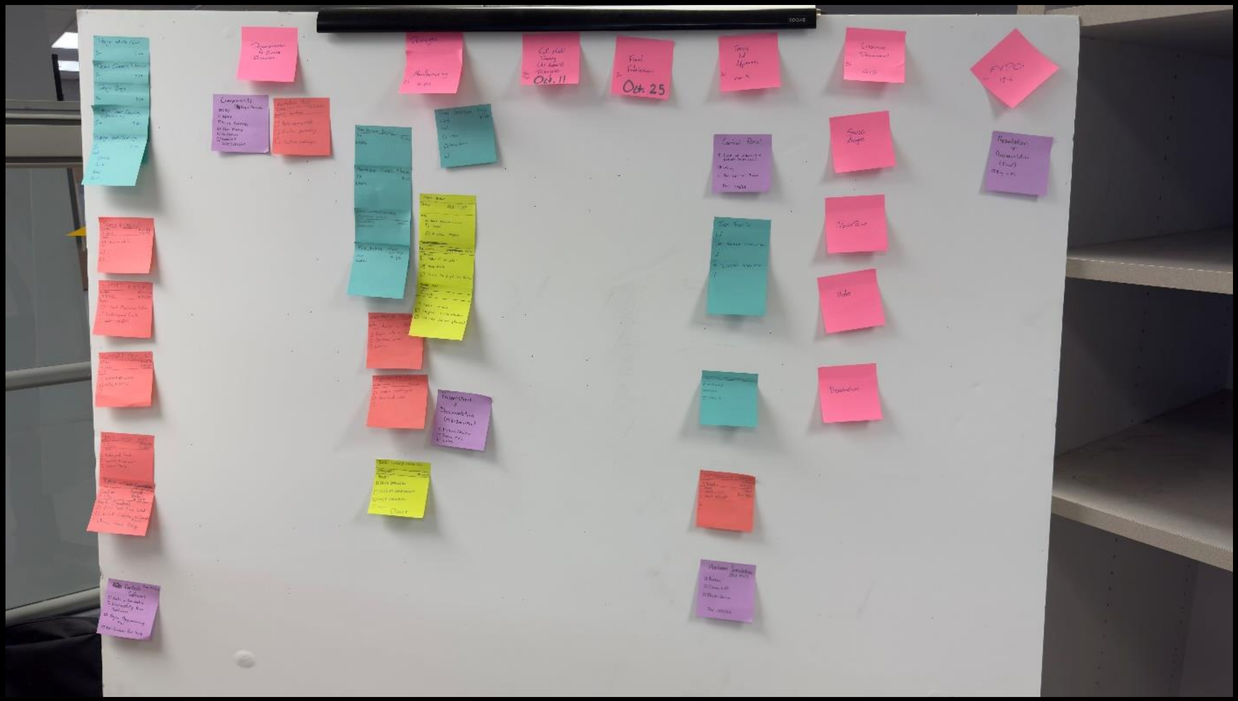
Our roller coaster project aims to blend engineering expertise with immersive storytelling to create a memorable and thrilling experience. Drawing inspiration from industry-leading theme park attractions, this model roller coaster is designed to showcase advanced automation, real-time control systems, and safety features. With a focus on precision and innovation, the project integrates a Programmable Logic Controller (PLC) for automation, sensors for accurate vehicle positioning, and ASTM-aligned safety mechanisms. Through this project, we push the limits of engineering in a scaled model, demonstrating our commitment to creating an engaging experience with every twist, turn, and loop!



# OBJECTIVE:

- Create a fully automated roller coaster model
- Include safety features, and incorporating thrill elements (loop, cobra roll).
- Develop all components in-house, including design, manufacture, and testing, using NoLimits2, OnShape, and Ladder Logic.

# PREPARATION



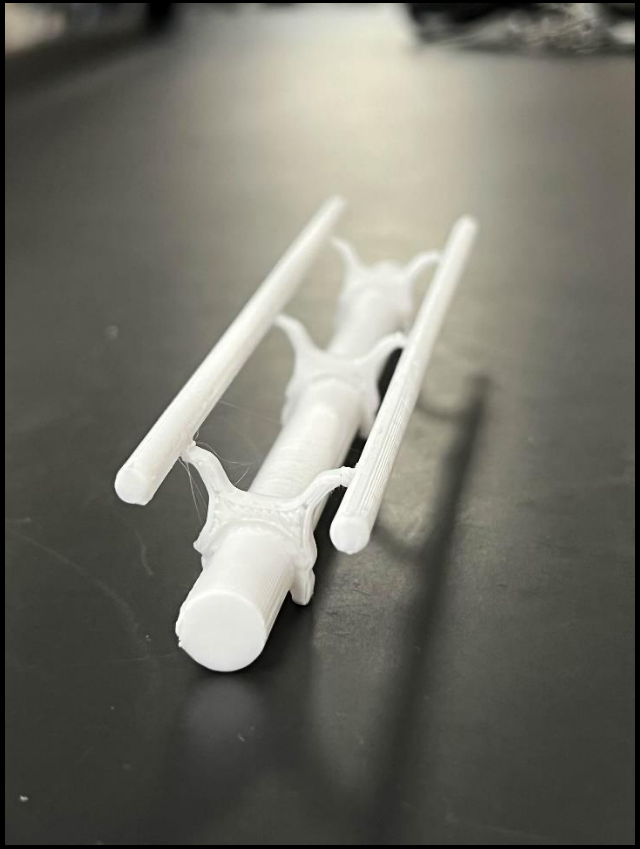
- Team members are to be divided into sub-divisions to focus on specific elements of the roller coaster
- Track
- Vehicle
- Specialty Features
- Control Systems
- Helps team stay organized and spread workload

# SYSTEM-LEVEL REQUIREMENTS:

| Criteria | Requirement | Results |
| --- | --- | --- |
| Braking System | Ability to halt vehicle | Met |
| PLC System | Ability to interact with specialty track features | Met |
| Structure | Ability to support the roller coaster and its applied forces | Met |
| Automation | Ability to perform multiple vehicles cycles without intervention | Met |
| Dimensions | Designed to fit on table and ability to be maneuvered out of the room | Met |

# MILESTONE 1:DESIGN AND PROTOTYPING

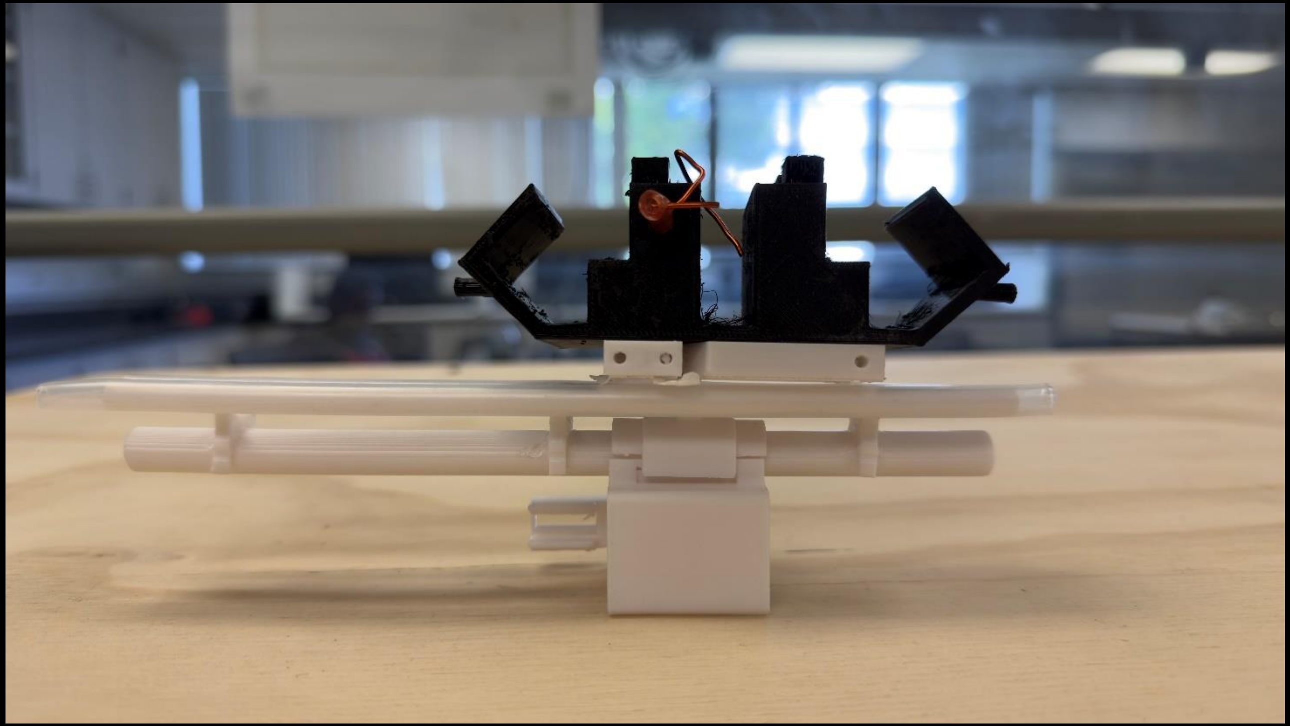
- Physical models and test equipment
- Close to producing 1st iteration of final product
- Designs ready to be sent for outsourcing of manufacturing



- First Test Print of Track

# MILESTONE 2:MODEL TESTING

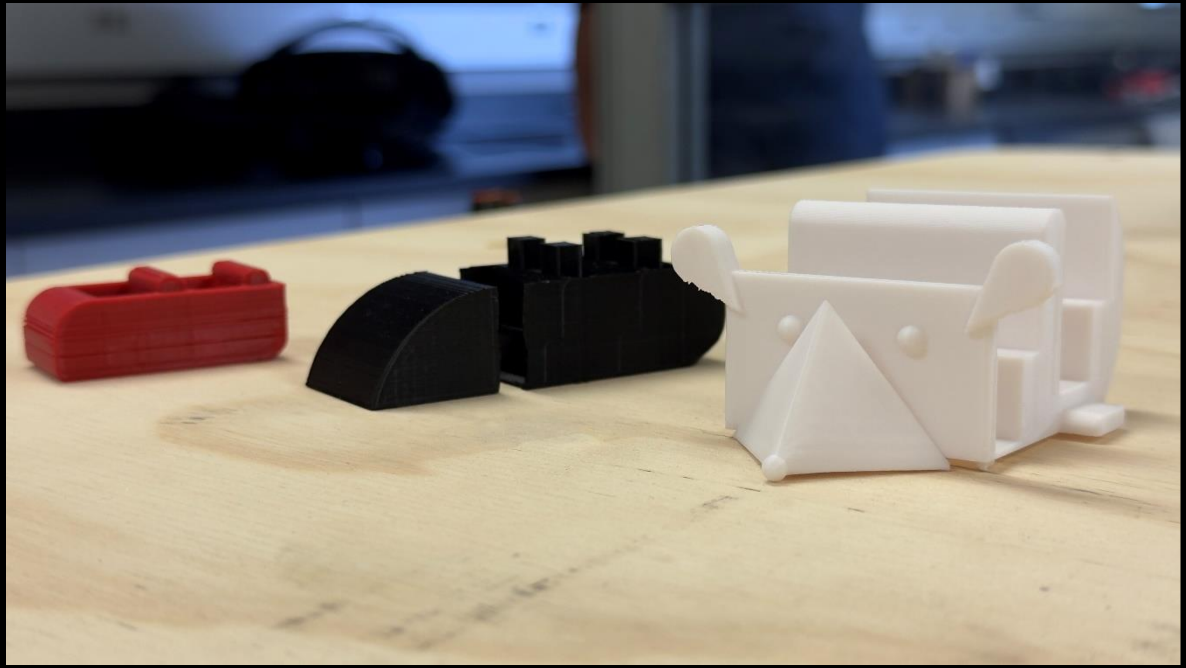
- Vehicle, track, control systems, specialty features established testing goals
- Assessments conducted to guarantee appropriate fit, interaction, and integration
- Specialty systems were all crucially tested
- Aimed to confirm model's overall functionality and component capability



- Fit Check of Multiple Roller Coaster Components

# MILESTONE 3:FINAL FABRICATION AND ADJUSTMENTS

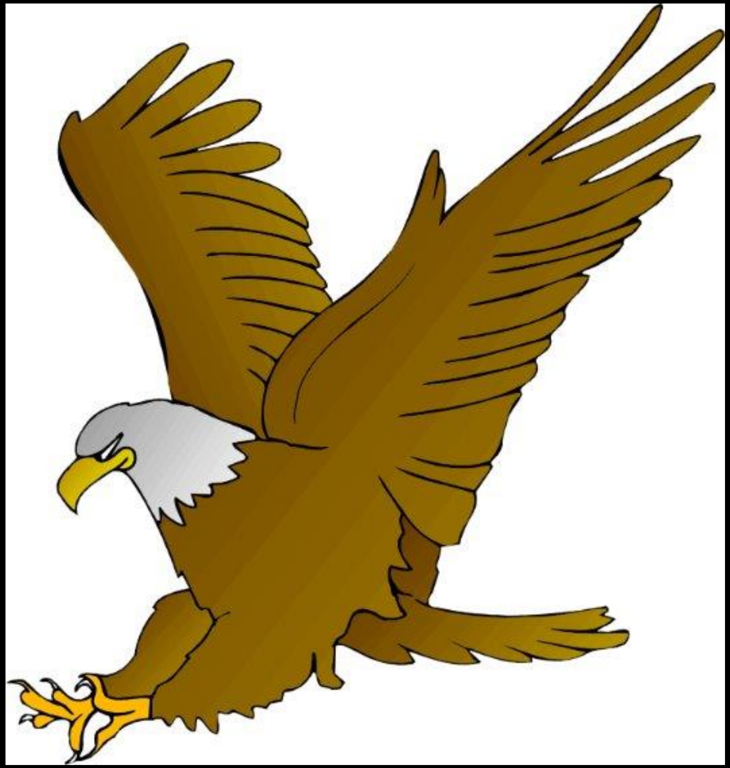
- Assembled materials and ideas from previous milestones
- Constructed track and other components using materials previously selected
- Each section would undergo adjustments to ensure peak functionality and integration
- Goal was to ensure all components meet design specifications and desired interactions
- Crucial for identifying and rectifying any discrepancies to confirm the project's success

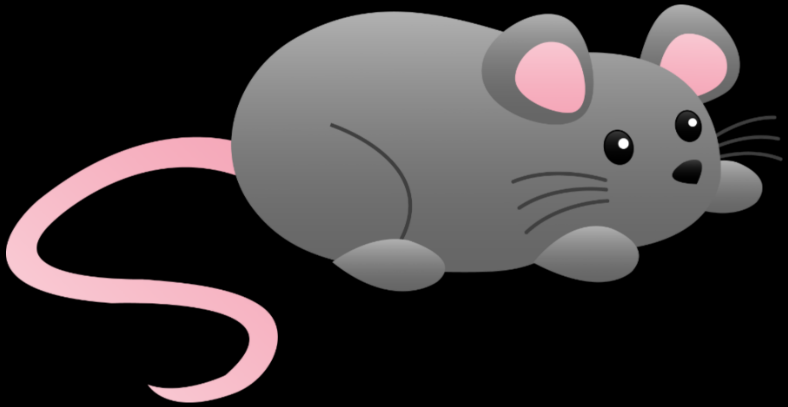


- Design Iterations of Passenger Vehicle

# OVERALL DESIGN APPROACH:

- Started with story behind the roller coaster
- What are our constraints?
    - Height, width, length?
- What design elements do we want incorporated?
    - Loop
    - Cobra roll
    - Corkscrew
    - Themed vehicle
- Reach envelope





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# TRACK & STRUCTURE

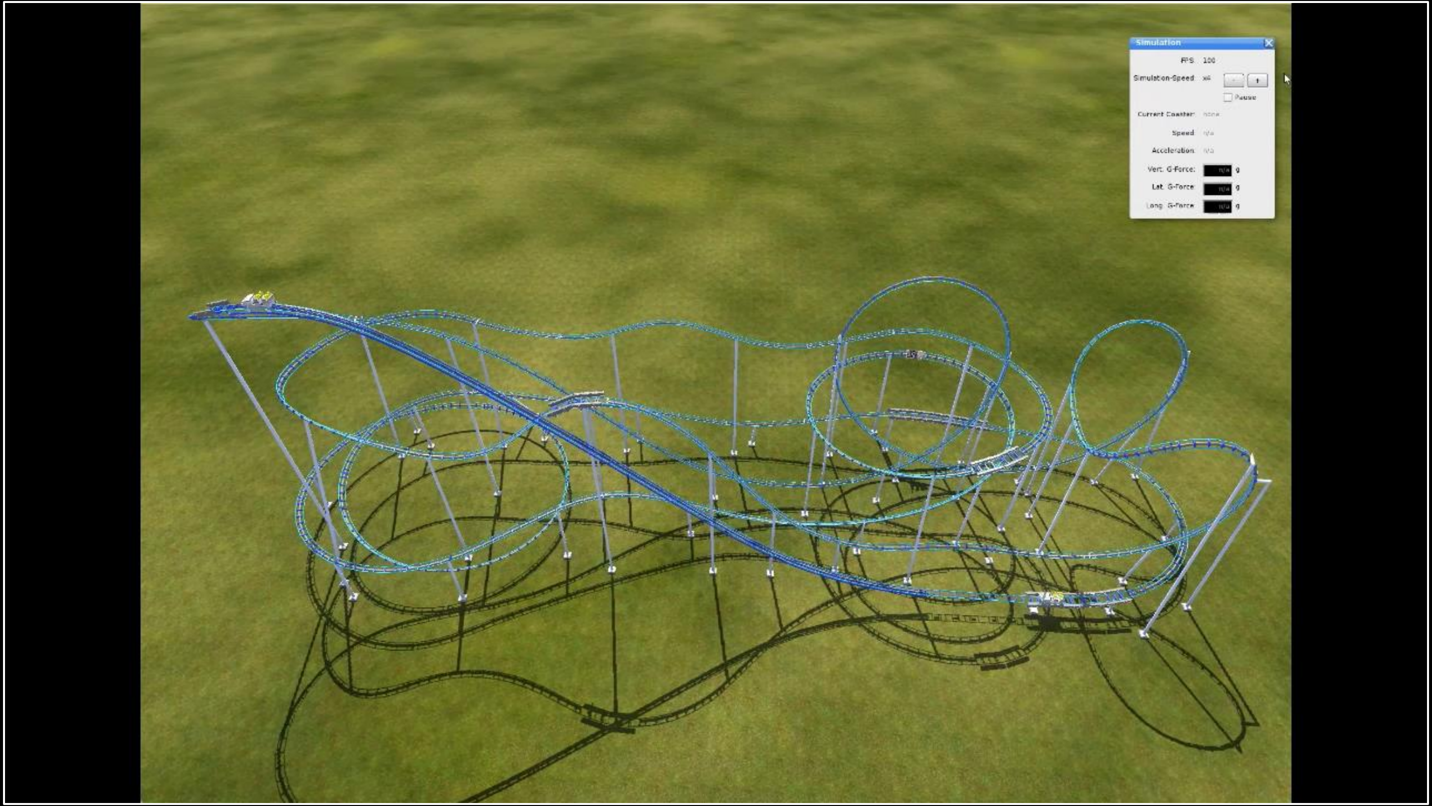
- **Designing a Roller Coaster**

- Availability of space.
- Type of roller coaster.
- Interference with other facilities or attractions
- Track layout, material
- Fun, exciting and safe coaster

# TRACK ELEMENT FEATURES

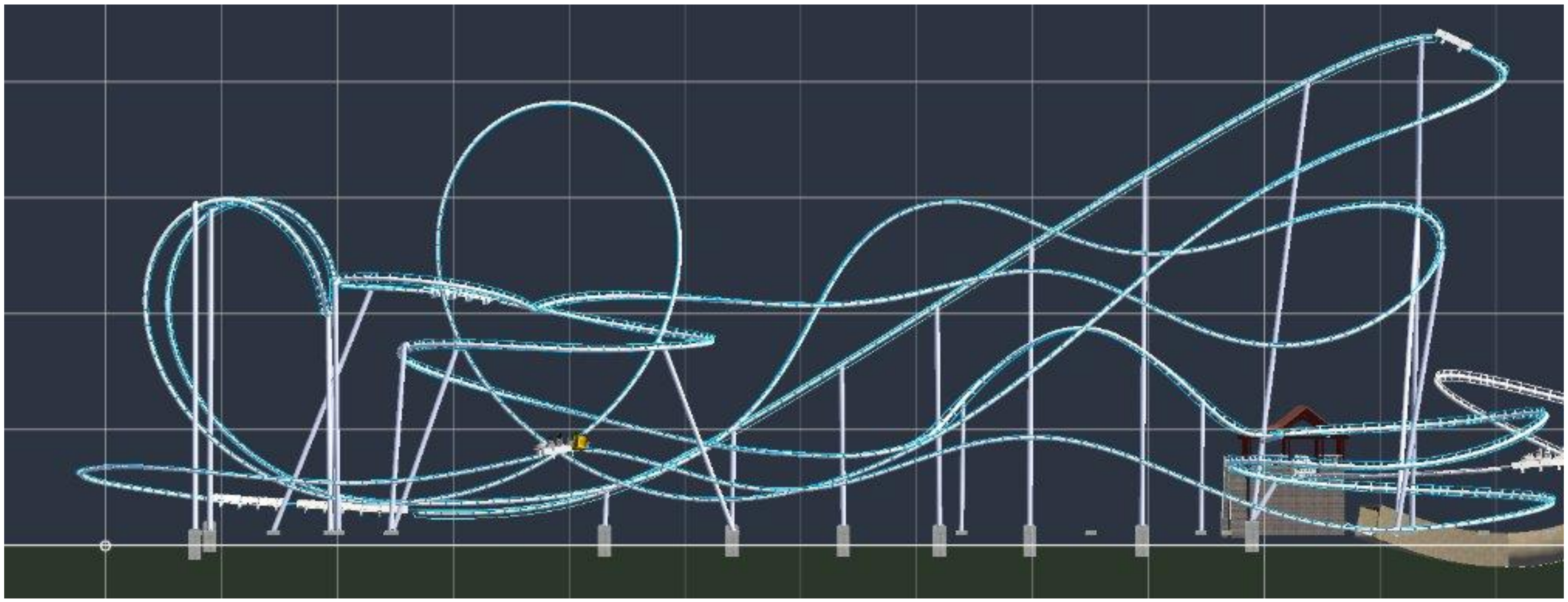
# NOLIMITS 2.0

- Simplifies the design process
- Built in:
  - Physics engine
  - Ride element equations
  - Block zone logic
  - Rendering and animation



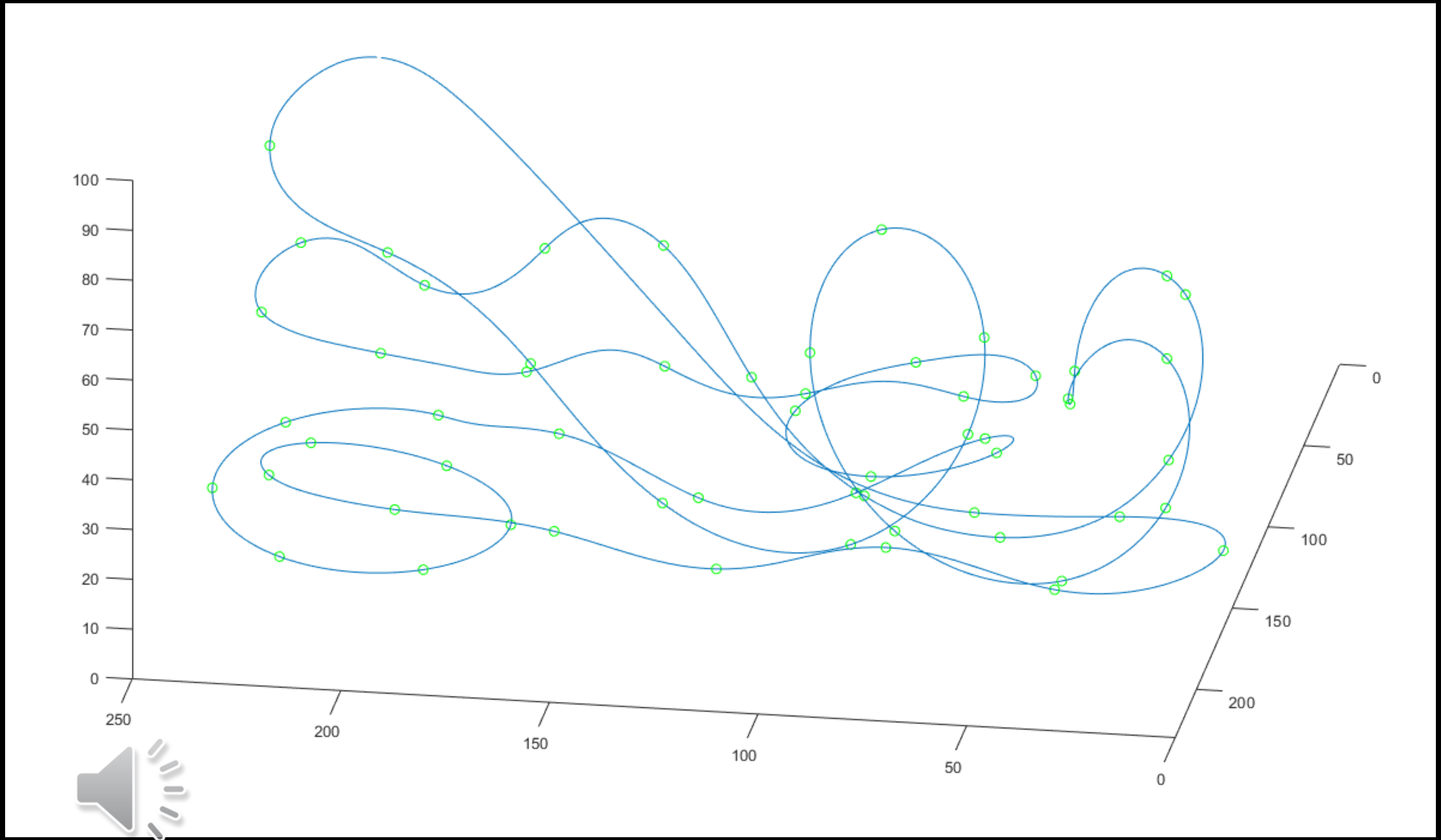
# INITIAL DESIGN

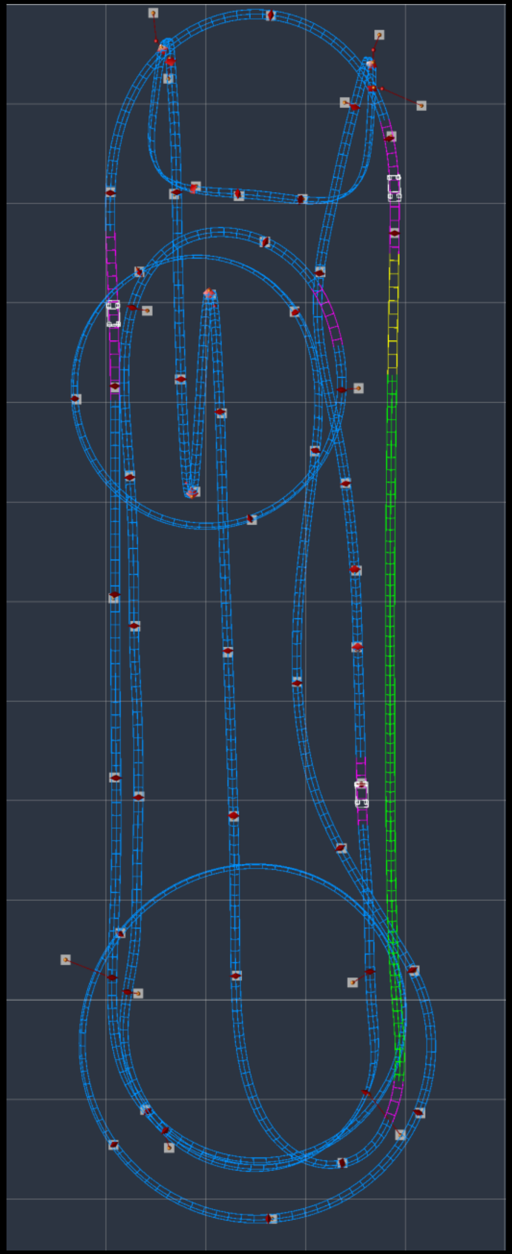
# INTERMEDIATE DESIGN



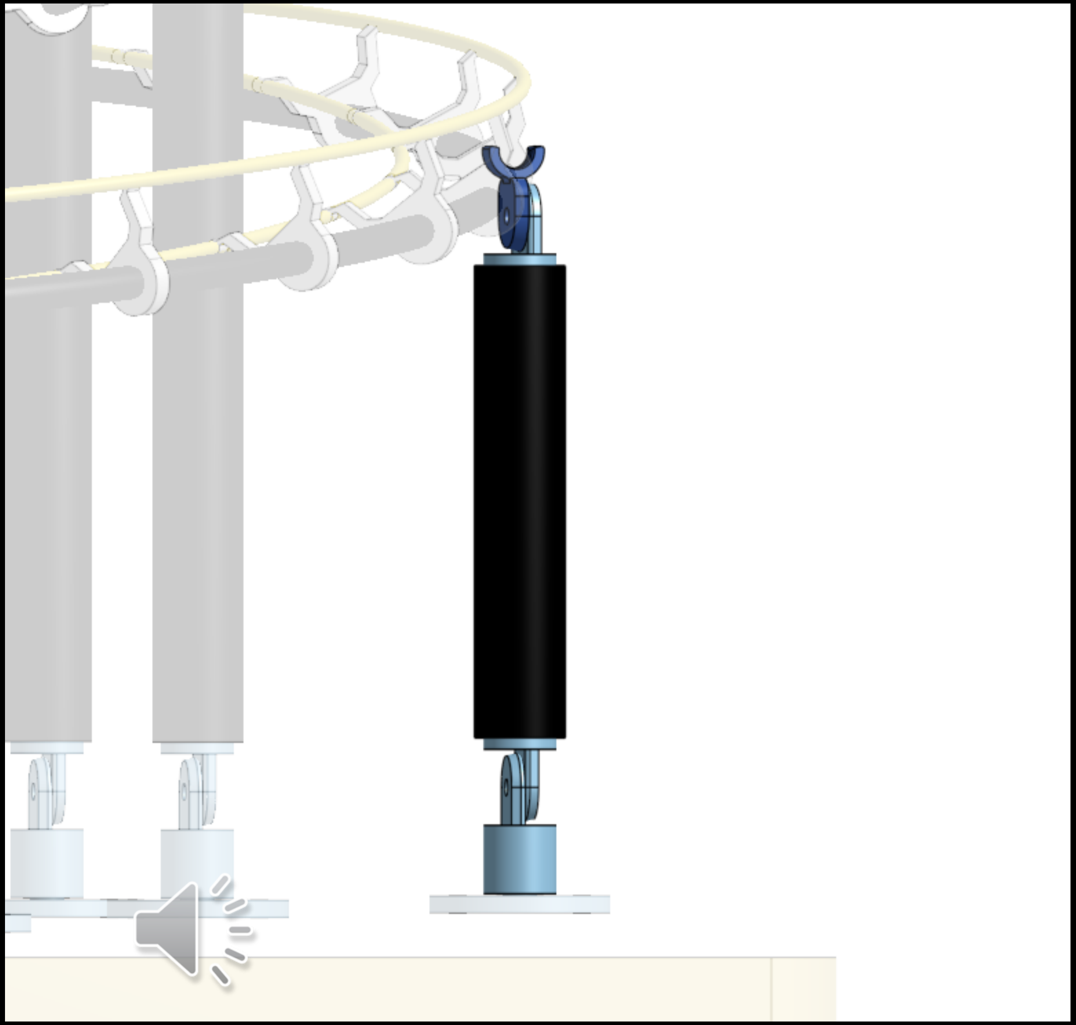
# FINAL TRACK DESIGN

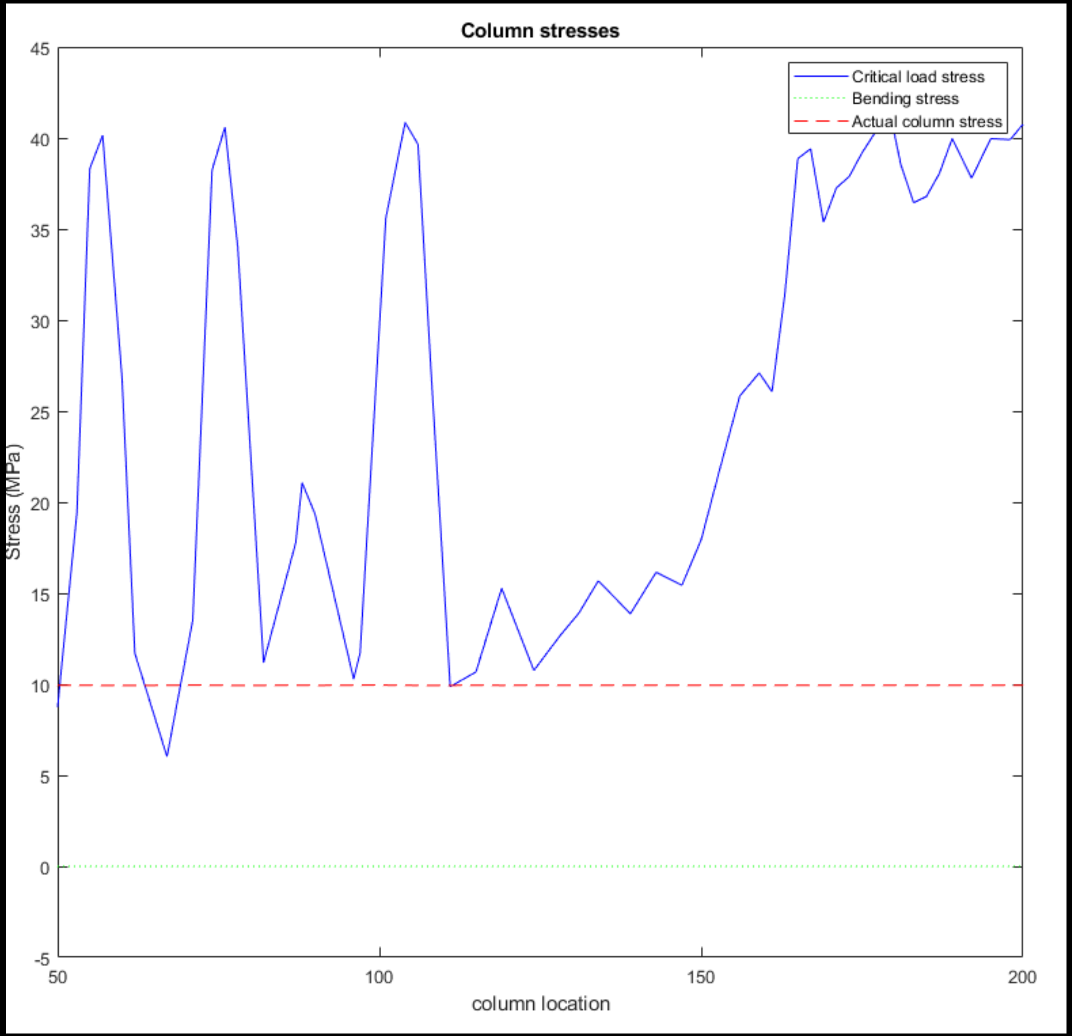
# SUPPORTS



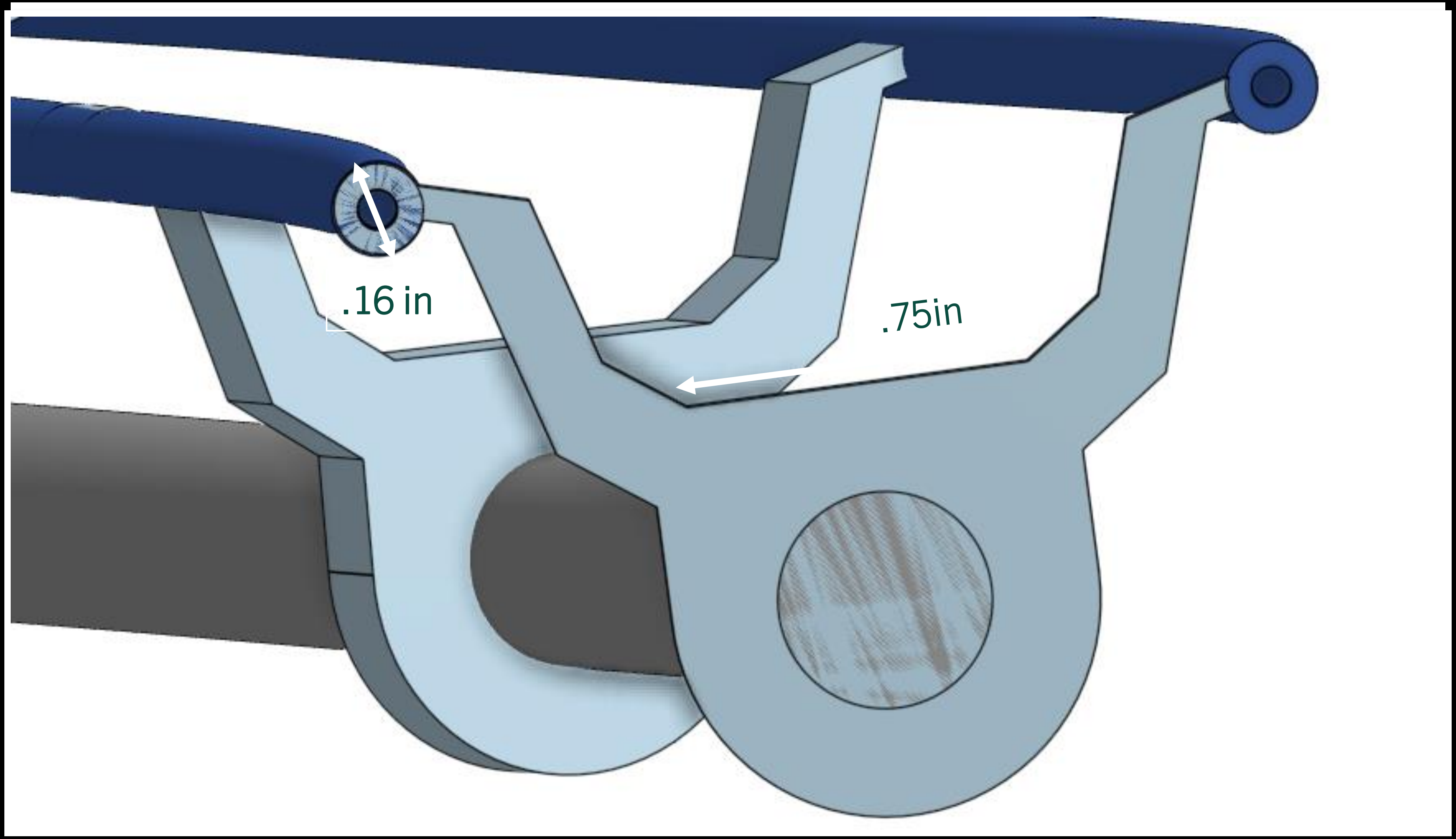
# SUPPORTS




Column stresses
Critical load stress
Bending stress
Actual column stress
Stress (MPa)
column location
45
40
35
30
25
20
15
10
5
0
-5
50
100
150
200

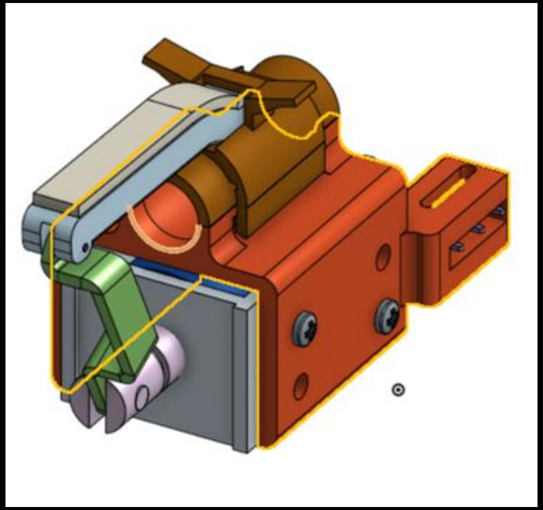
# ONSHAPE MODEL(FINAL)

# ONSHAPE MODEL(TRACK SPECS)



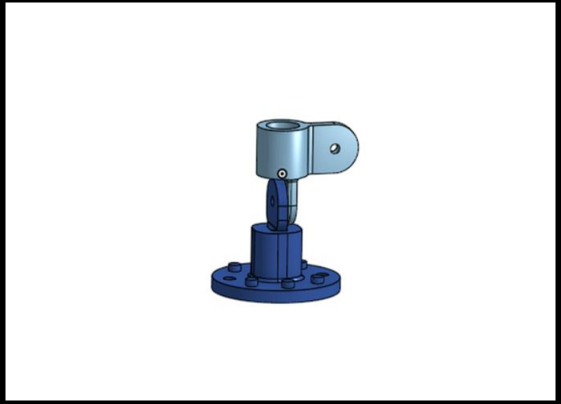
# TRACK PRINTS

- Bottom and top support couplings are essential to the track design/layout.
- These couplings hold the support columns in place to provide structural support for the track.
- Quantity needed= 58
- Printing process : export each part as stl.
- Slice plate using Bambu Lab slicer.



- The solenoid brackets are meant to slow down the incoming vehicle and halt it to a stop.

- Top support couplings



- Bottom support couplings

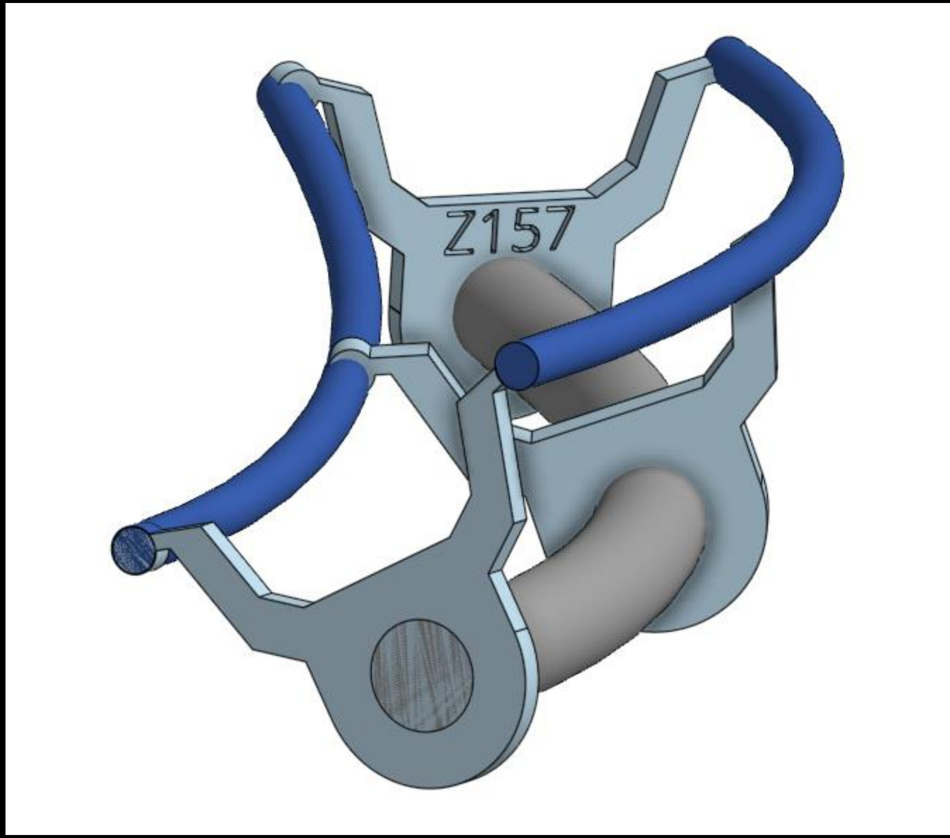
# BAMBU P1S AND P1P PRINTER

PS1 Bambu Printer

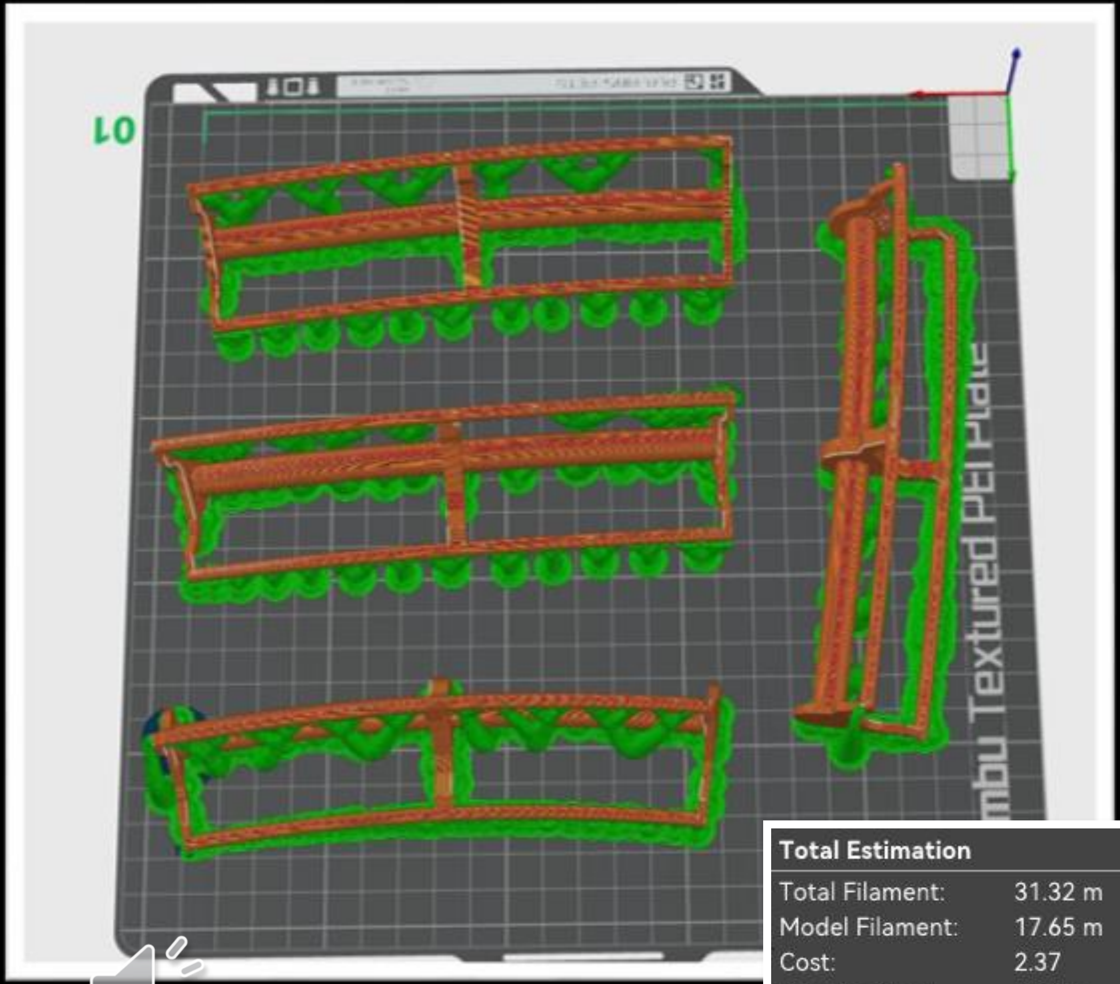
P1P Bambu Printer

# TRACK MANUFACTURING - PREPARATION

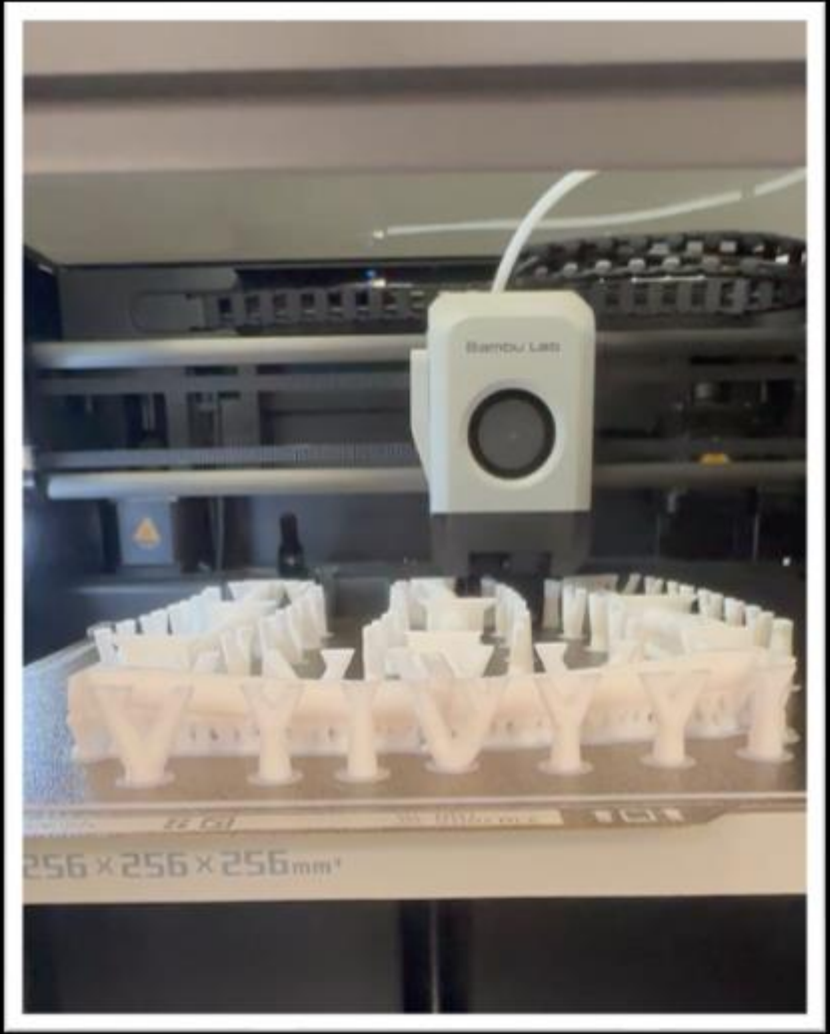
- Divided track into zones
- Cut each zone into convenient pieces for 3D printing
- Labeled each piece by zone and part number
- E.g. Z157
  - Zone 1
  - Part 57



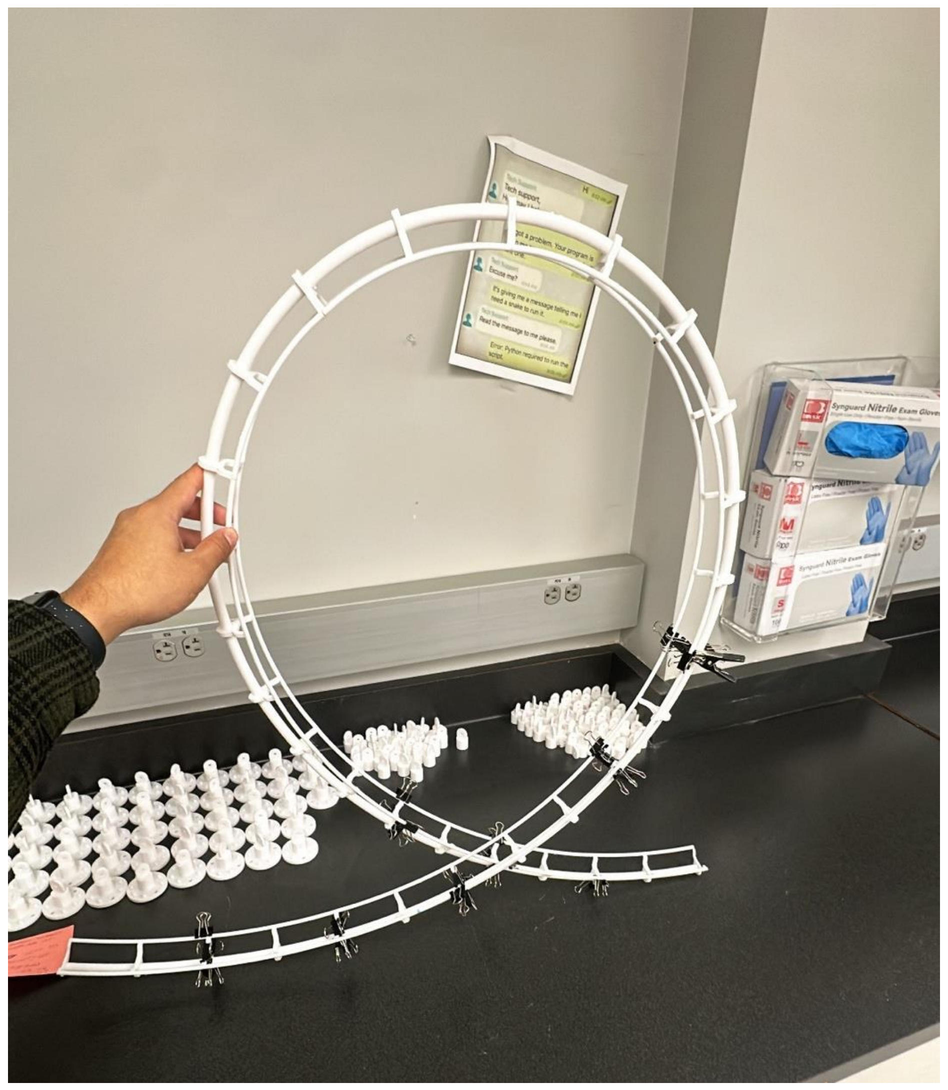
# TRACK MANUFACTURING - MANUFACTURE




| Total Estimation | | |
|---|---|---|
| Total Filament: | 31.32 m | 94.93 g |
| Model Filament: | 17.65 m | 53.48 g |
| Cost: | 2.37 | |
| Prepare time: | 5m45s | |
| Model printing time: | 5h16m | |
| Total time: | 5h22m | |



# TRACK MANUFACTURING - ASSEMBLY

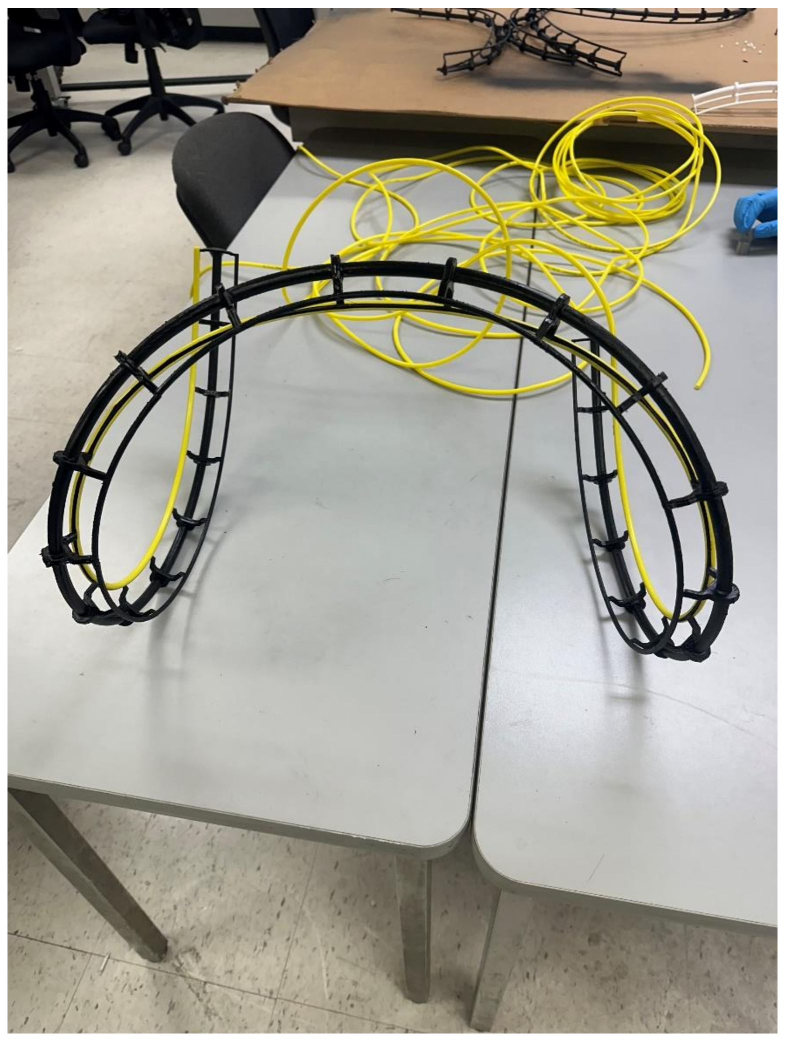


# TRACK MANUFACTURING - PAINTING

- Team decided to go w/ school colors.

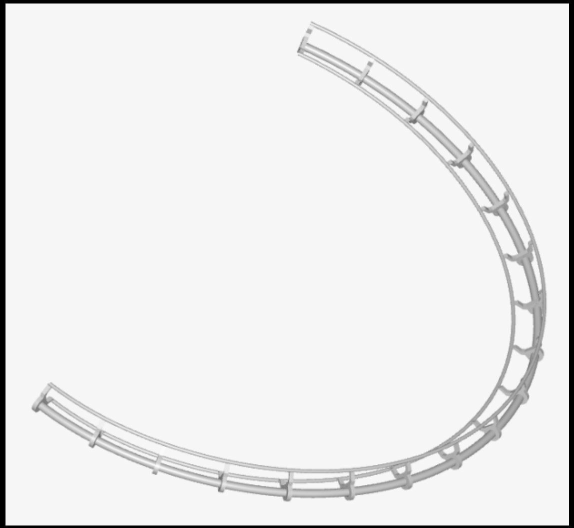
- Black
- Yellow (Rails)
- Grey

# TRACK MANUFACTURING - PAINTING

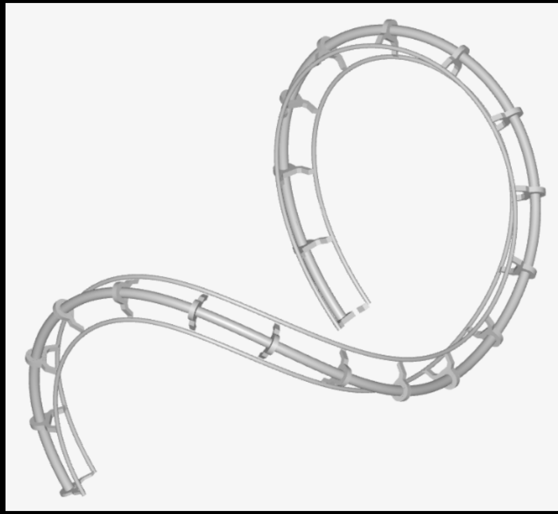


# FINITE ELEMENT ANALYSIS

- Stress is the ability of a material to withstand deformation when subjected to external loads.
- High stress is typically located on segments such as drops, inversions, helixes, and brake zones along the roller coaster tracks.
- Factors that create stress on track includes the weight of the vehicle and its speed.
- Stress analysis is critical in the design of track to ensure structural integrity and overall safety, abiding to ASTM standards.



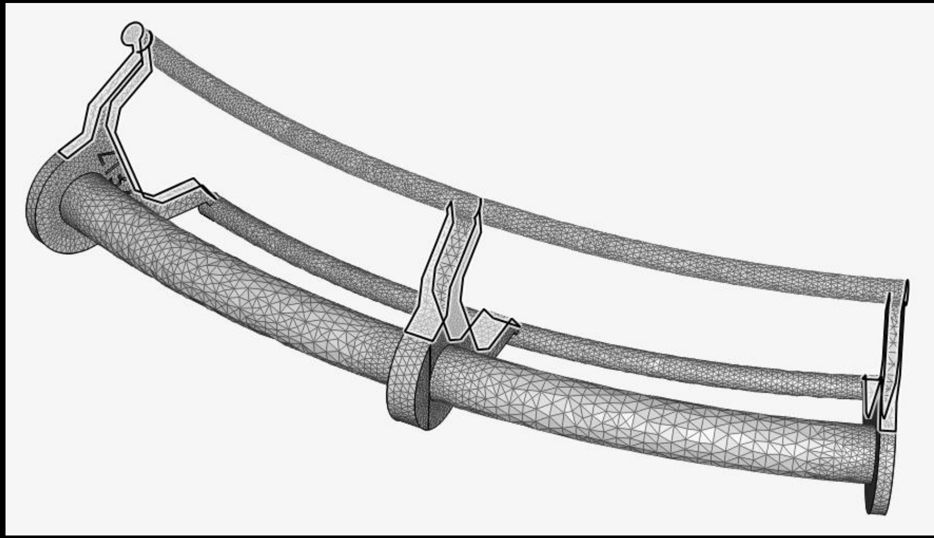
*Helix*



*Cobra Roll*

# FINITE ELEMENT ANALYSIS

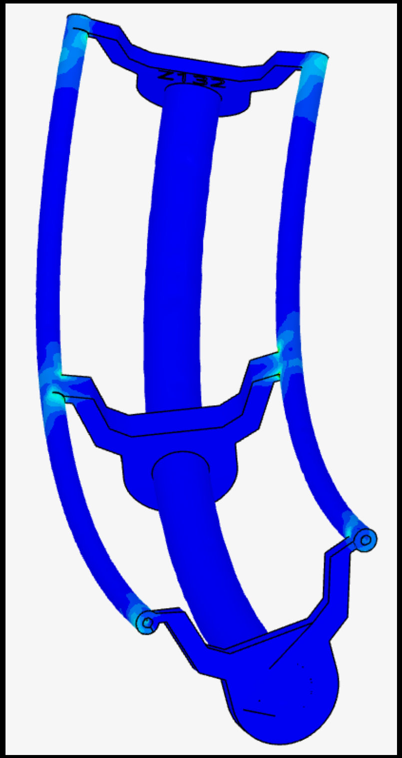
- SimScale is a cloud based CAE software that allows engineers to run various simulations, including thermodynamics, electromagnetics, vibrations, and CFD.
- FEA is a numerical method used to analyze and predict the behavior of materials under different physical conditions.
- After selecting material and boundary conditions, FEA breaks down large structure into small finite elements called mesh.
- FEA was used to perform stress analysis on cobra roll section where there is high centripetal force.



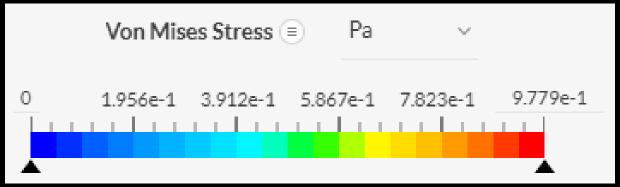
*Structural Mesh*

# FINITE ELEMENT ANALYSIS

- Post-process simulation shows most of stress is concentrated on track joints due to its thinness and lack of curvature.
- Since there is no critical values of stress even on tight inversions, it is theoretically safe to say the PLA material used can support the possible dynamic forces.
- Careful inspection of 3D printing ensuring there are no visible faults that jeopardizes structural integrity.

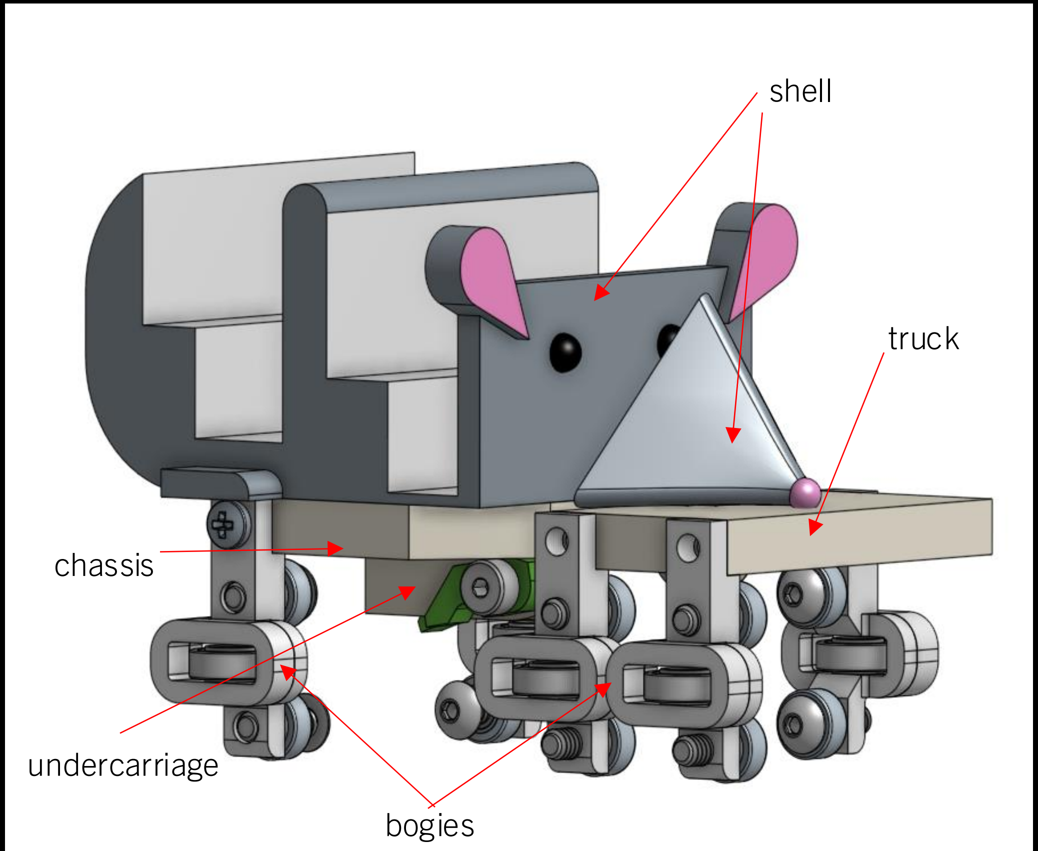


*Stress Distribution*



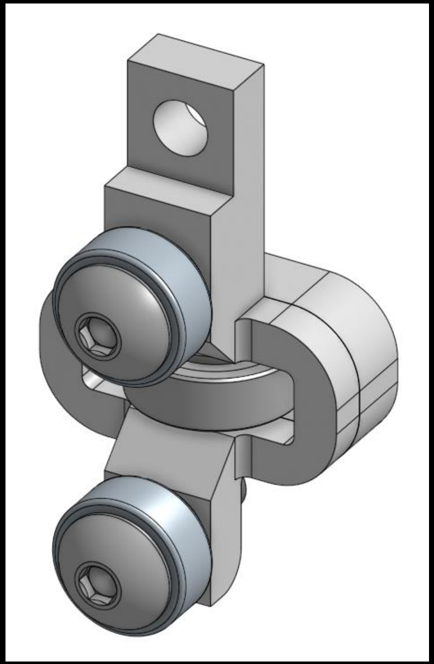
# VEHICLE

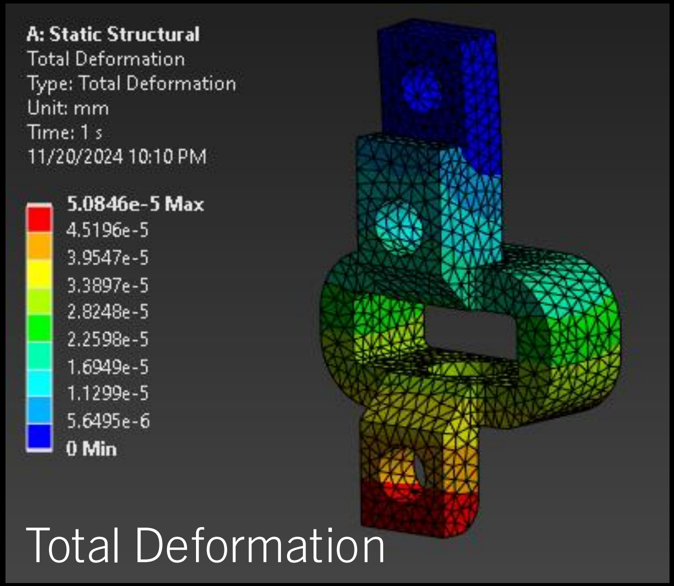

- One of the most essential parts of the coaster is the vehicle.
- The main components of the vehicle are the shell, bogies, chassis and truck, and undercarriage.
- Design process:
  - Use CAD software to design components
  - Fabricate using 3D printers and other components.
  - Run tests and analysis with other teams.



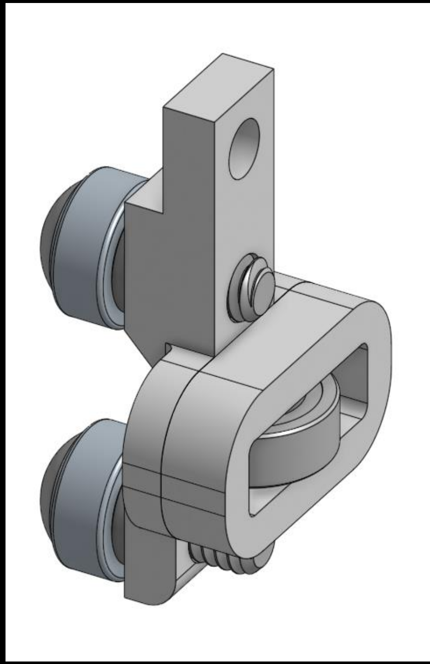
# VEHICLE: BOGIE

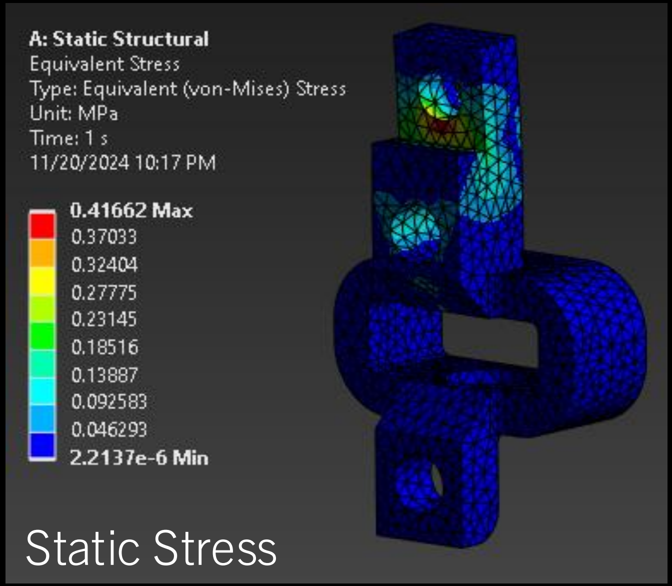
- The bogie itself uses bearings to simulate the load, up stop, and guide wheel.
- Having multiple bogies throughout our design ensures that our vehicle remains nominal and in contact with the track rails.
- In total there are 6 bogies on the vehicle, 2 on the chassis and 4 on the truck.
- Using the Ansys simulation software we can run test to get an idea on how our bogies will be affected by different loads.





Total Deformation

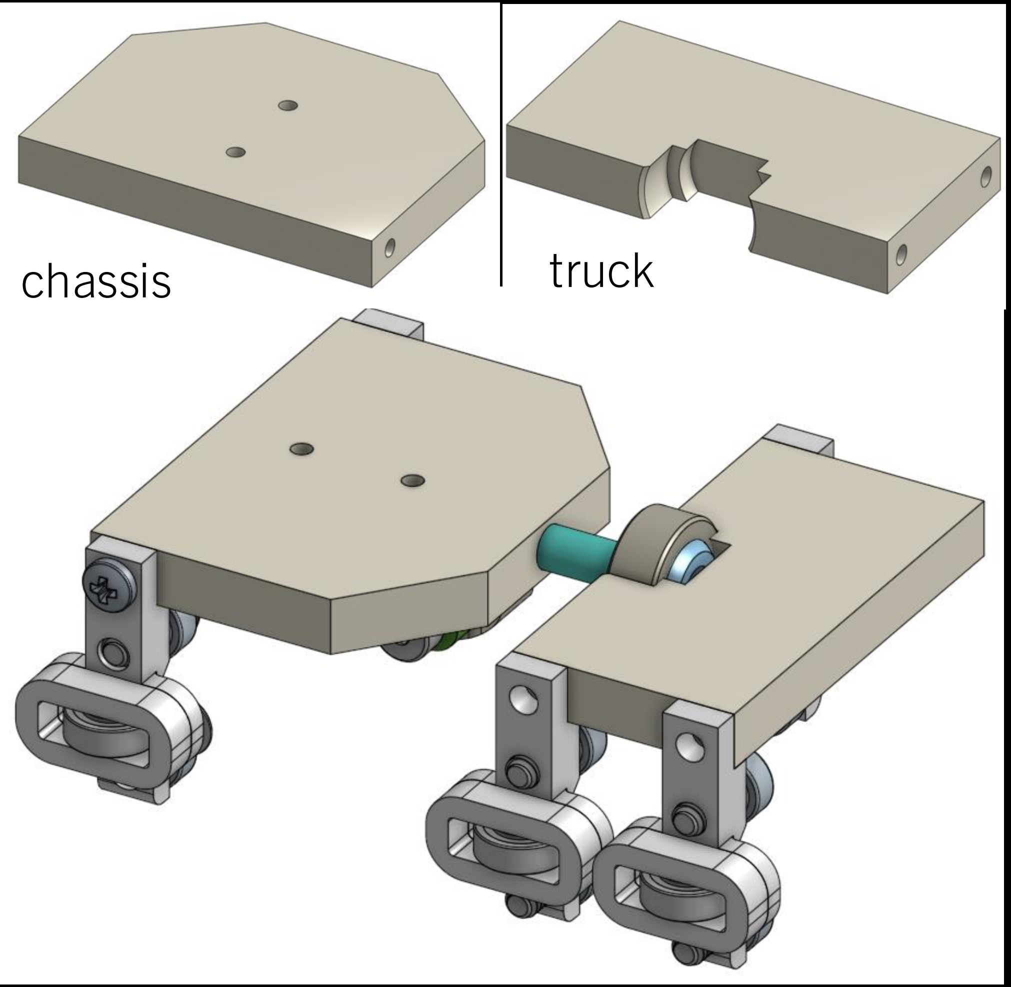




Static Stress

# VEHICLE: CHASSIS AND TRUCK

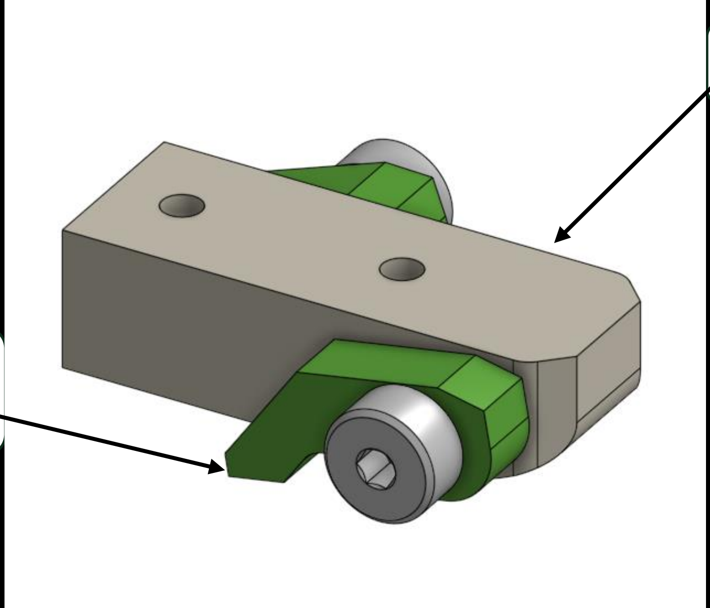
- Chassis:
  - Main function is to support shell and hold undercarriage.
  - Attached to truck via roll pin.
  - 2 bogies

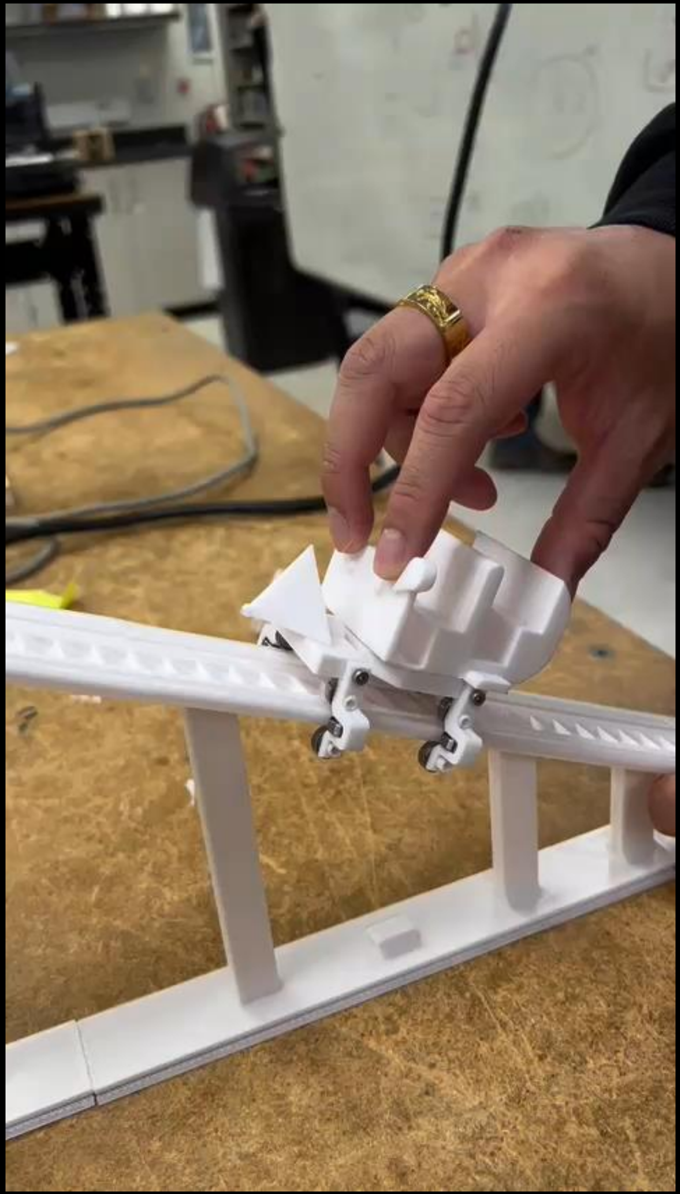



- Truck:
  - Main function is to guide chassis through tight turns.
  - Holds swivel joint which provides a maximum ball swivel of 34 degrees .
  - 4 bogies

# VEHICLE: UNDERCARRIAGE

- Main function of this part is to use special track features.
- Consists of magnets for sensors, antiroll back, chain dog/ antiroll back device, and undercarriage block for braking.



# SPECIALTY FEATURES

- They are made up of different components in which we will be focusing on the sensors, braking systems and lift hill.
- Sensors are strategically placed around the track to give real time data.
- Braking systems are to stop the train in different scenarios.
- Lift hill will often serve as a block zone but is the mechanical system that will lift the vehicle up the hill.

# LIFT HILL

## (CONCEPT)

- A lift hill is the section that uses mechanical system to elevate the train to its higher point creating potential energy which is then let go at the top exchanging it to kinetic energy as it descends.
- We have a ratchet system that prevents the train from sliding backwards in case of an emergency.
- Metal teeth on the lift hill engages with a ratchet under the train.

# BRAKES

(CONCEPT)

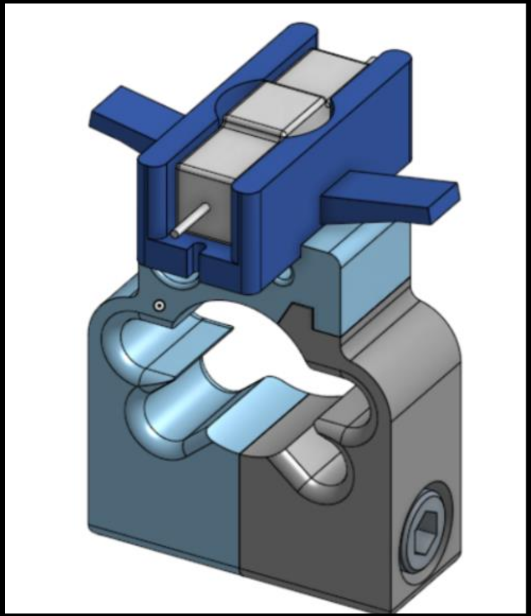
- Skid Brakes-Found on older coasters; long meatal skids applying friction against the underside of the train. They are positioned to contact the underside of the train when activated.
- The skids are raised or pressed upward against the train by a mechanical system. It is often powered by levers or other mechanisms.
- It is a simplistic mechanically straight forward and inexpensive design to implement.

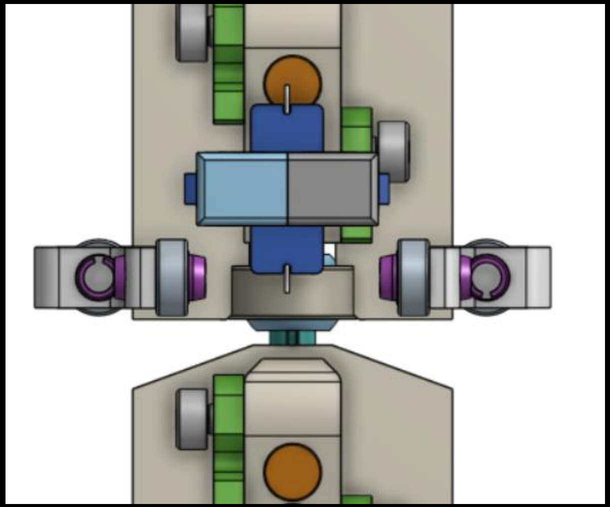
# SENSORS

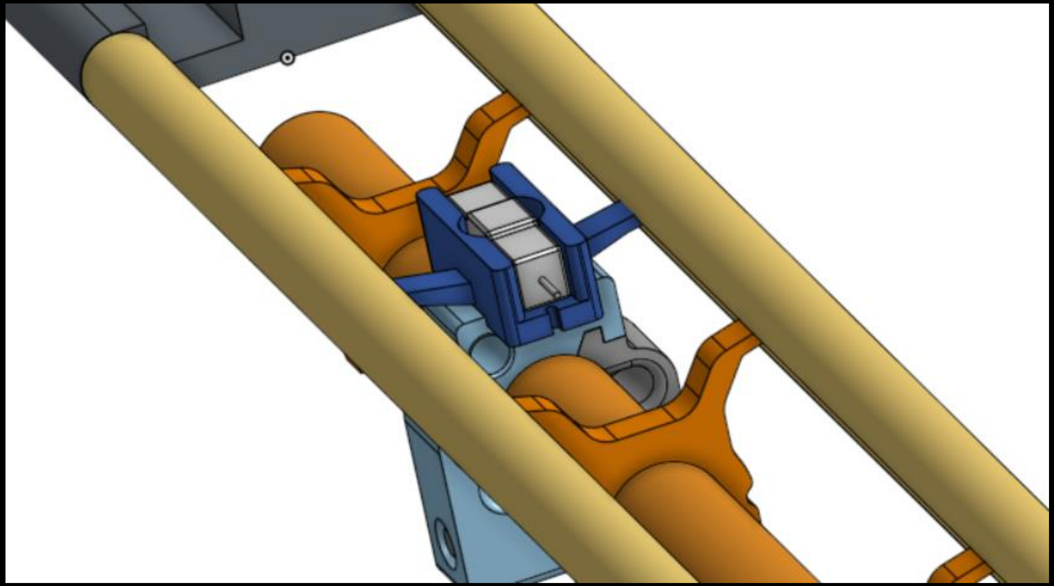
(CONCEPT)

- Roller coaster rely on variety of sensors to ensure safe and efficient operation.
- These sensors provide real time data to the  control system, monitoring train positions, speed, and mechanical functions.
- We will be using a Reed Switch sensor that operated based on the presence of a magnetic field.  It is used in applications like door sensors, proximity detections, and roller coasters.

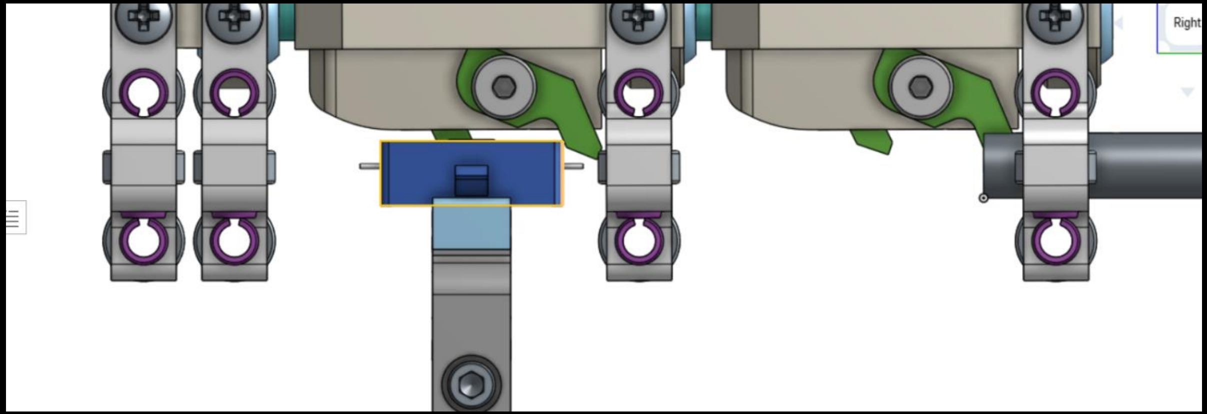
# SENSORS
## (DESIGN)

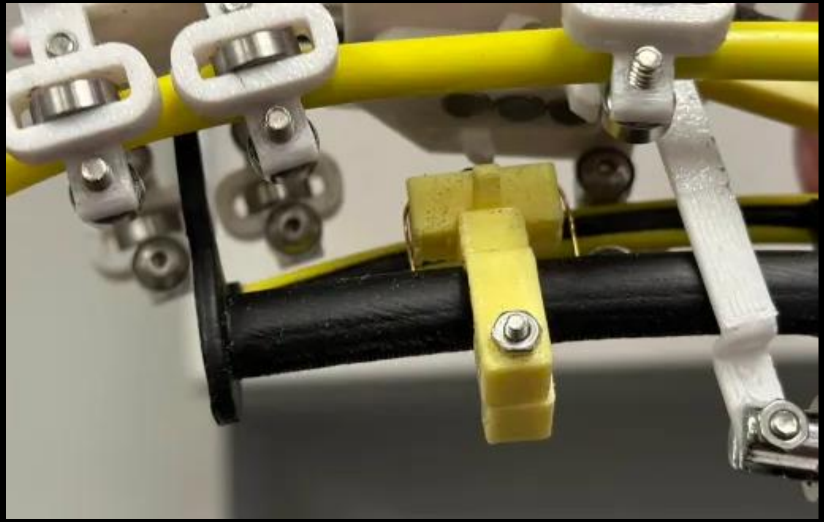






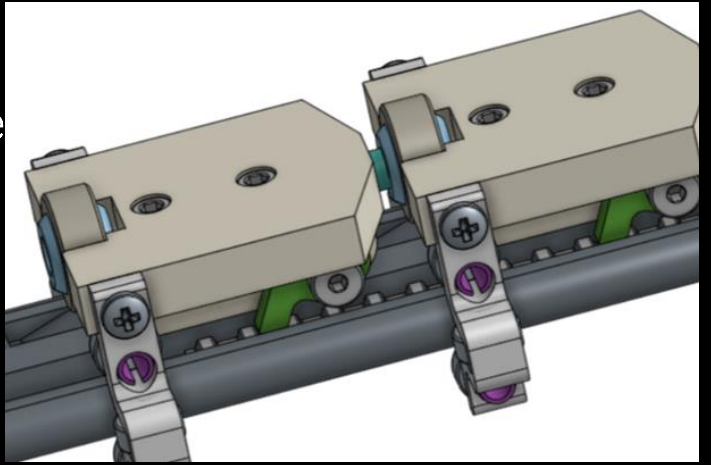
# SENSORS

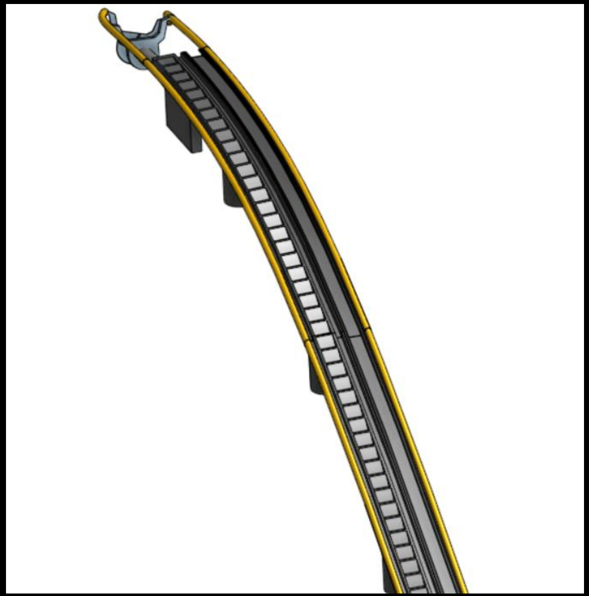


# LIFT HILL
## (DESIGN)

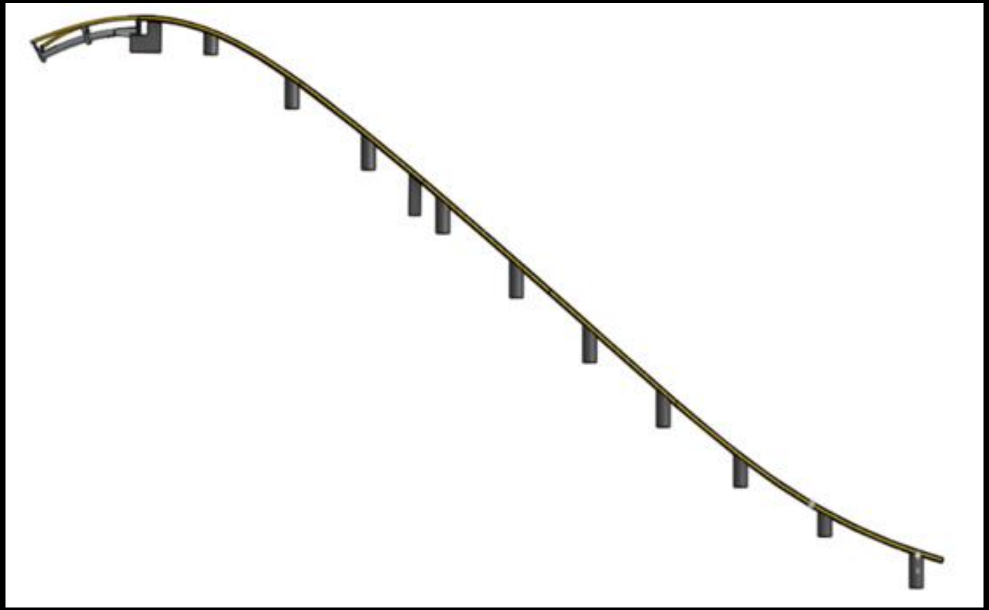
- Its components is made up of a timing belt along the lift hill track driven by a motor at the bottom. A sprocket wheel that pulls the belt continuously in a loop.
- The chain dog on the train that engages with the uphill to get pulled up the hill.







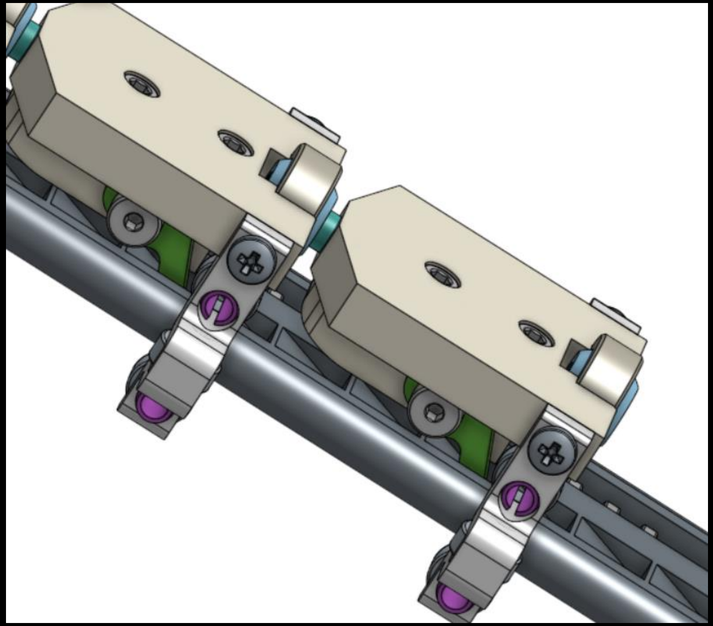




# LIFT HILL

## (DESIGN)

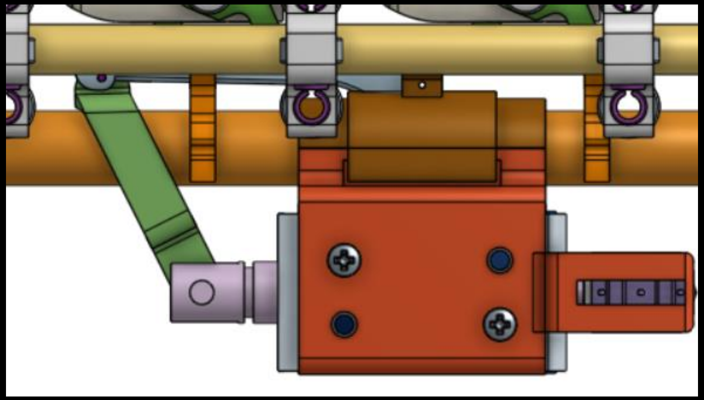
- An Anti rollback devices is also attached to the vehicle to prevent from the vehicle rolling back and prevent any hazardous events in case of a malfunction.

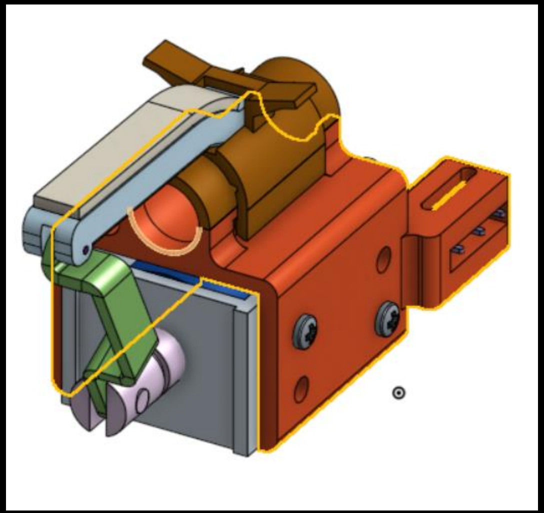


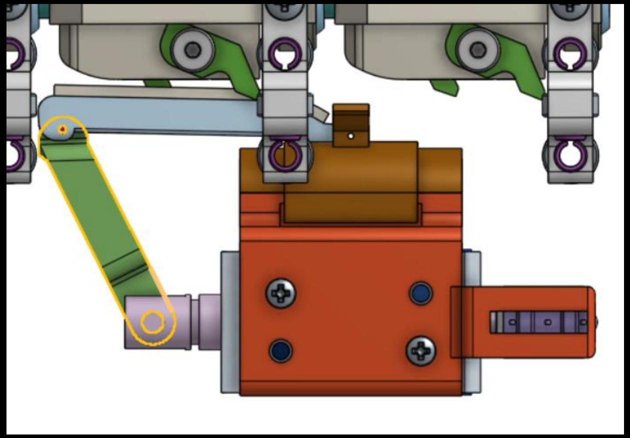
# BRAKES

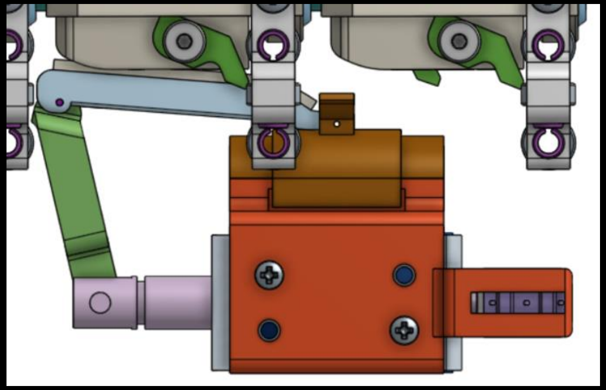
## (DESIGN)

- We have a skid plate made from 3d printer material that is sticked to a rubber piece to ease the braking of the vehicle.
- The lever is connected to a solenoid that is power by a 10-voltage source that is activated to bring down the skid plate as its rest state is up for safety.
- The braking system provides a constant braking force as it is always at the same position returned when not being in used.

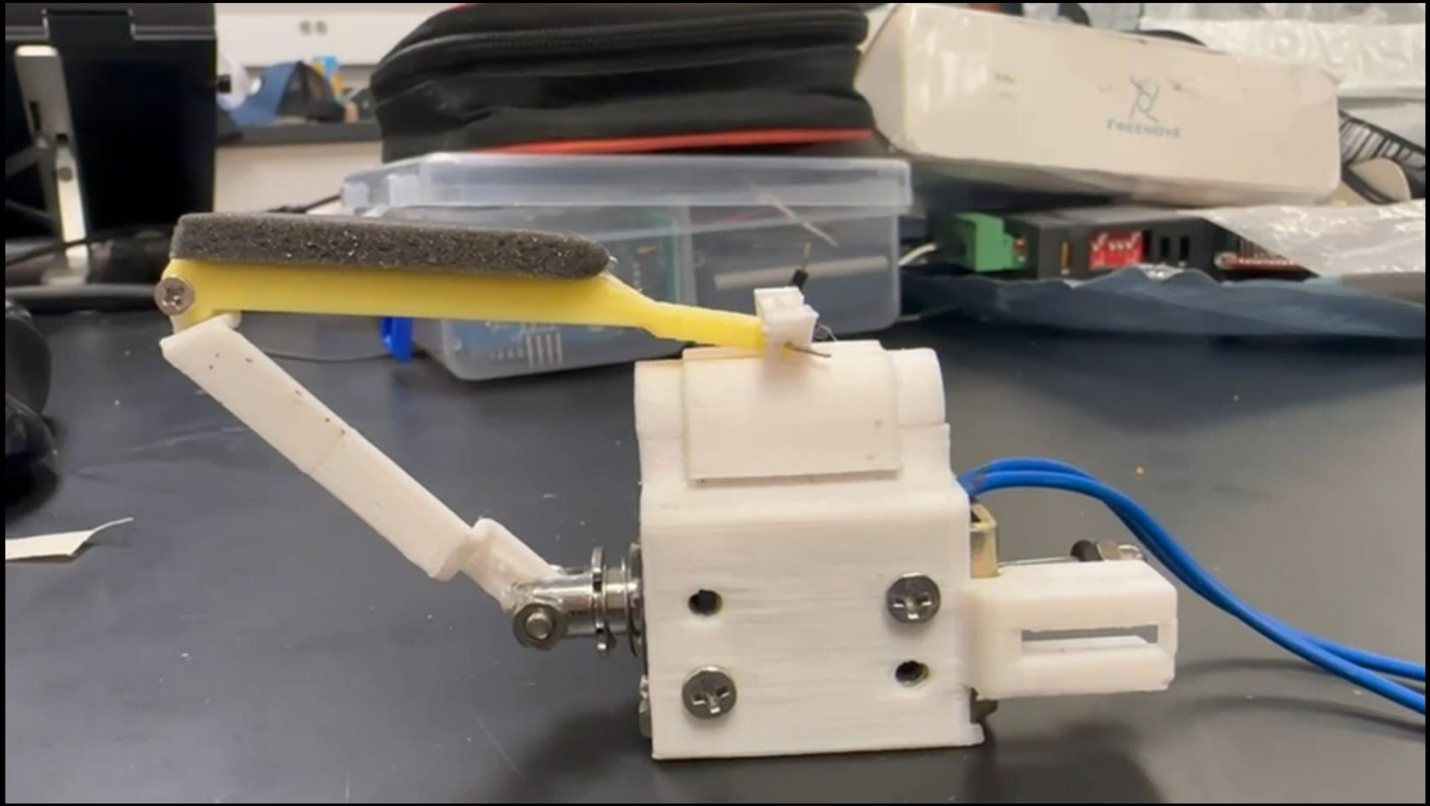






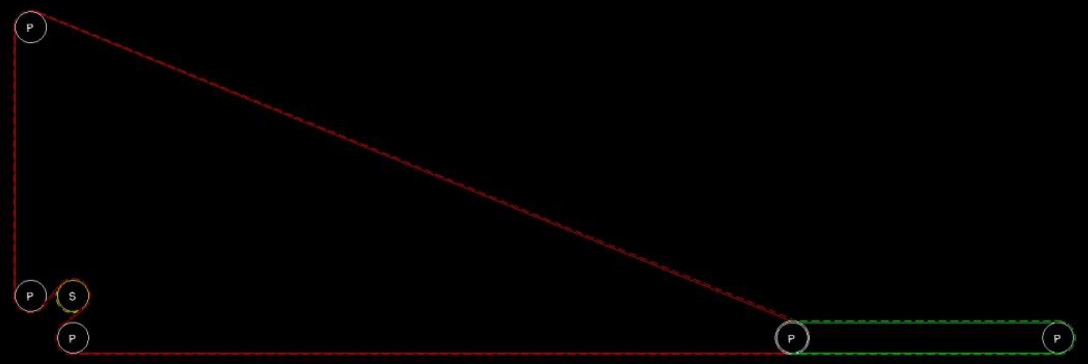


# BRAKES
## (DESIGN)

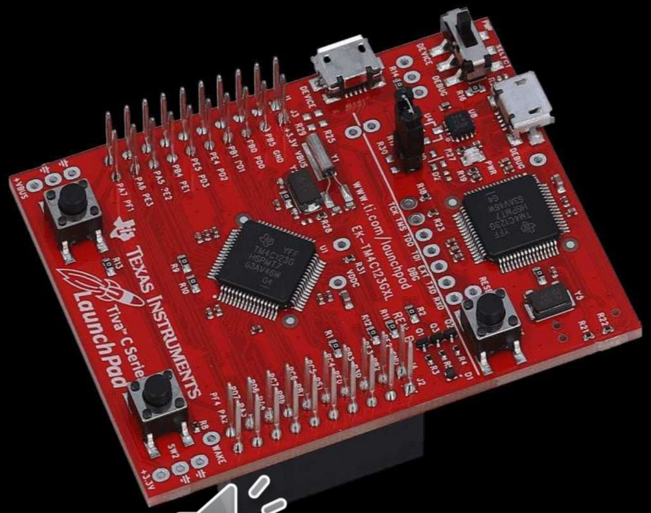


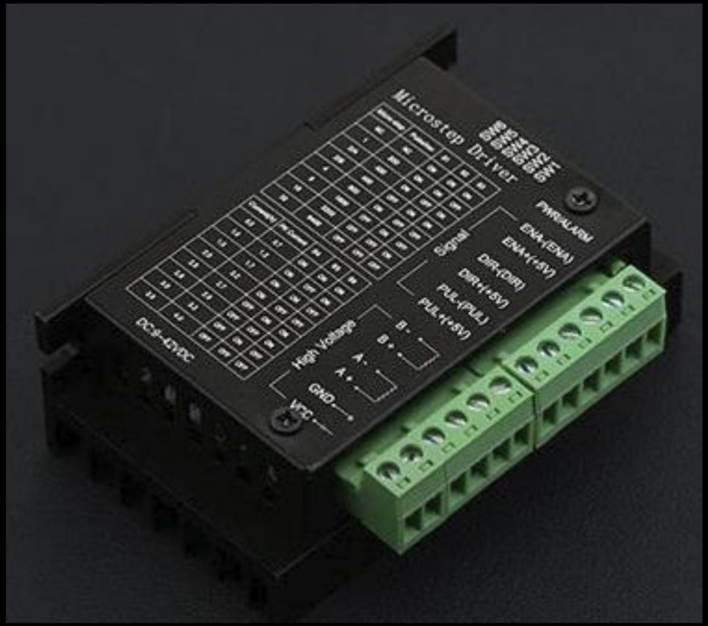
# LIFT FEATURES

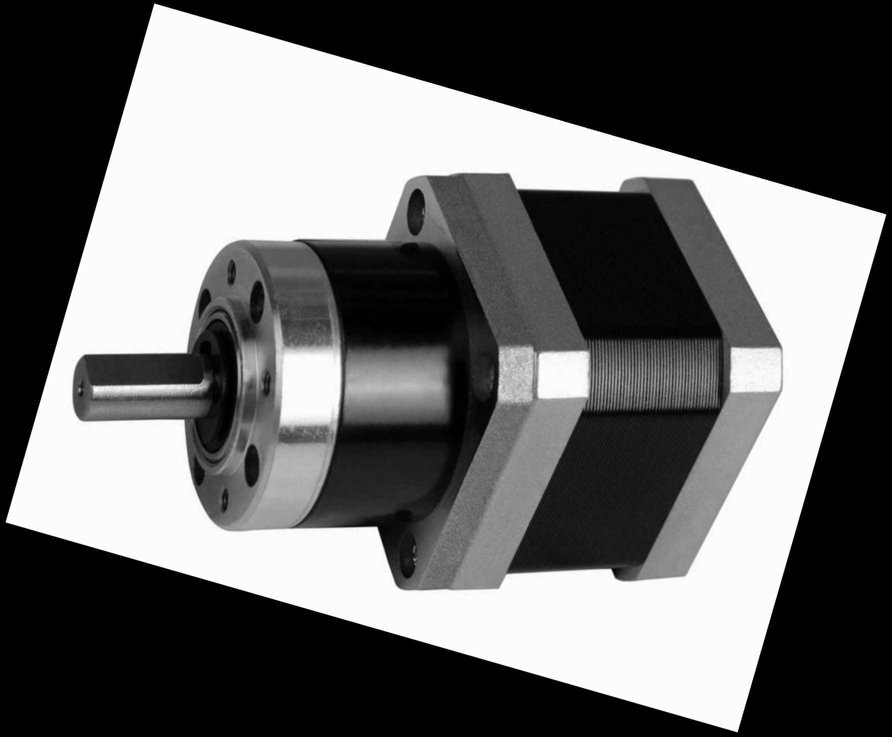
The lift pulley system



# INTERCONNECTION OF MECHANICAL AND ELECTRICAL SYSTEMS



# WHAT ARE BLOCK ZONES?

- A **block zone** is a section of a roller coaster's track that operates independently of other sections.
- Each block zone is controlled by sensors and signals to ensure only **one train occupies the block at a time**.
- This segmentation prevents collisions and allows the ride to run multiple trains simultaneously, enhancing overall capacity.
- Block zones also help keep the ride efficient and safe in case of emergencies, such as mechanical issues or power failures.

# PURPOSE OF BLOCK ZONES

**Safety**:

- The primary goal of block zones is to **prevent collisions** by ensuring no two vehicles are in the same block at the same time.
- If a vehicle stops unexpectedly, the system halts all vehicles in preceding blocks until the issue is resolved.

**Operational Efficiency**:

- Block zones allow more vehicles to operate on the track at once, improving ride capacity and minimizing wait times for guests.

**Emergency Control**:

- In case of malfunctions, block zones are crucial for **stopping vehicles at safe locations**, ensuring that passengers are never in harm's way.
- Emergency systems rely on block zones to isolate and control incidents efficiently.

# KEY COMPONENTS IN BLOCK ZONES

Sensors and Signals:

- Sensors monitor the location and speed of each vehicle within a block.
- They relay real-time data to the control panel to determine whether the next block is clear or occupied.

Brakes:

- Each block zone includes a set of brakes that can stop or slow down a train when necessary.
- These brakes ensure that a vehicle remains within its assigned block until the next block is clear.

Control System:

- A centralized control panel oversees the entire block system.
- It automates train movements, communicates with ride operators, and ensures no two trains enter the same block.

# BLOCK ZONES TRACK LAYOUT

## Station Block:

- Passengers board/exit vehicle safely
- Sensors ensure one vehicle is in the tran station at a time before the next train is dispatched

## Chain Lift Block:

- Controls the train climbing the lift hill.
- If the next block (Loop) is occupied, the vehicle waits safely at the base.

## Loop Block:

- Monitors the high-speed loop section.
- Sensors and brakes ensure proper vehicle spacing during intense maneuvers.

## Track Block:

- Covers the final part of the ride.
- Prepares the vehicle for a smooth and safe return to the station.

# DESIGN IMPACTS OF BLOCK ZONES

Increased Capacity

- Block zones make it possible for roller coasters to run multiple trains on the same track.

Smooth Operation:

- Trains are dispatched at carefully timed intervals to ensure a steady flow of operations, preventing bottlenecks or downtime.

Safety:

- Block zones create redundancies that reduce risks during malfunctions.

Experience:

Properly spaced trains ensure that passengers experience smooth transitions and avoid interruptions due to sudden stops

# WHAT IS A PLC?


- A Programmable Logic Controller (PLC) is a digital computer hardware device used (mostly used by industrial companies) to program machines and processes in real-time.
- It takes inputs from the instructions given to it, reads the information, and processes outputs.
- Some key components of a PLC include:

  - Input/Output Modules.

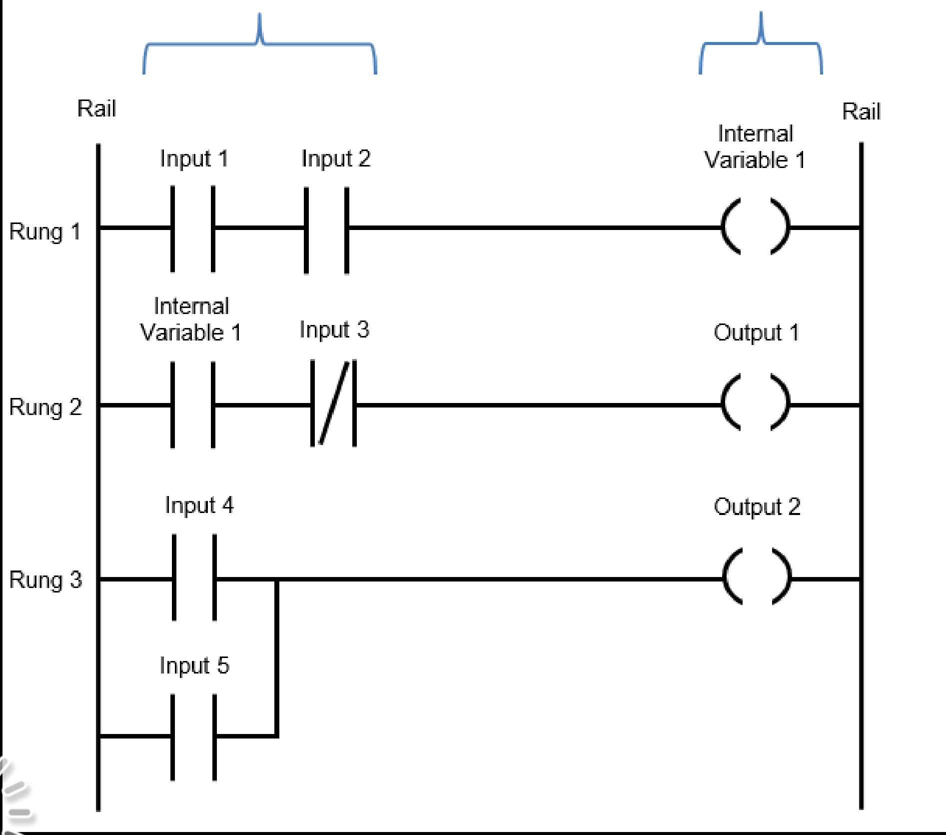
  - Power Supply.

  - CPU with Programmable Device.

# PLC USE IN THE REAL WORLD

- PLCs are widely used across various industries; however, their most common use is for automated services.
- Features such as real-time operation and durability allow PLCs to have a high range of variety in their potential tasks.
- Many companies may also modify their PLCs (e.g., changing the number of components) to ensure the task at hand is optimally processed.

# PLC LADDER LOGIC



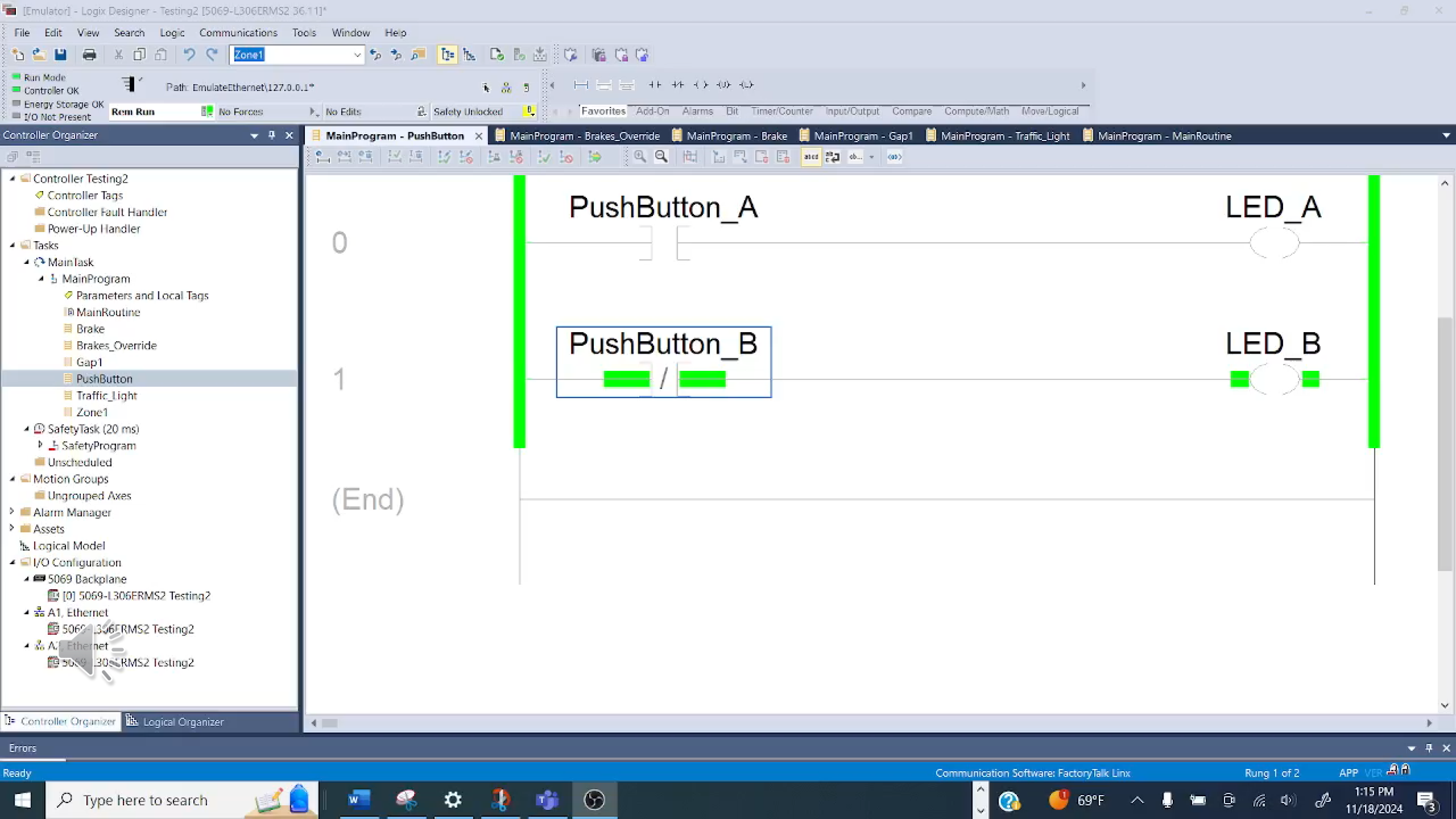

- Ladder logic (LD) is one of the languages used by PLCs to resemble electrical logic diagrams. These diagrams come in the shapes of horizontal "rungs," allowing them to create sophisticated input and output instructions.
- Each instruction is processed in order, from left to right, and top to bottom.
- Some components used in ladder logic programming---serving also as the foundation of the language itself---are:

  - Contacts (Normally Open/Closed).

  - Timers.

  - Coils (Outputs).

  - Counters.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Controller Tags
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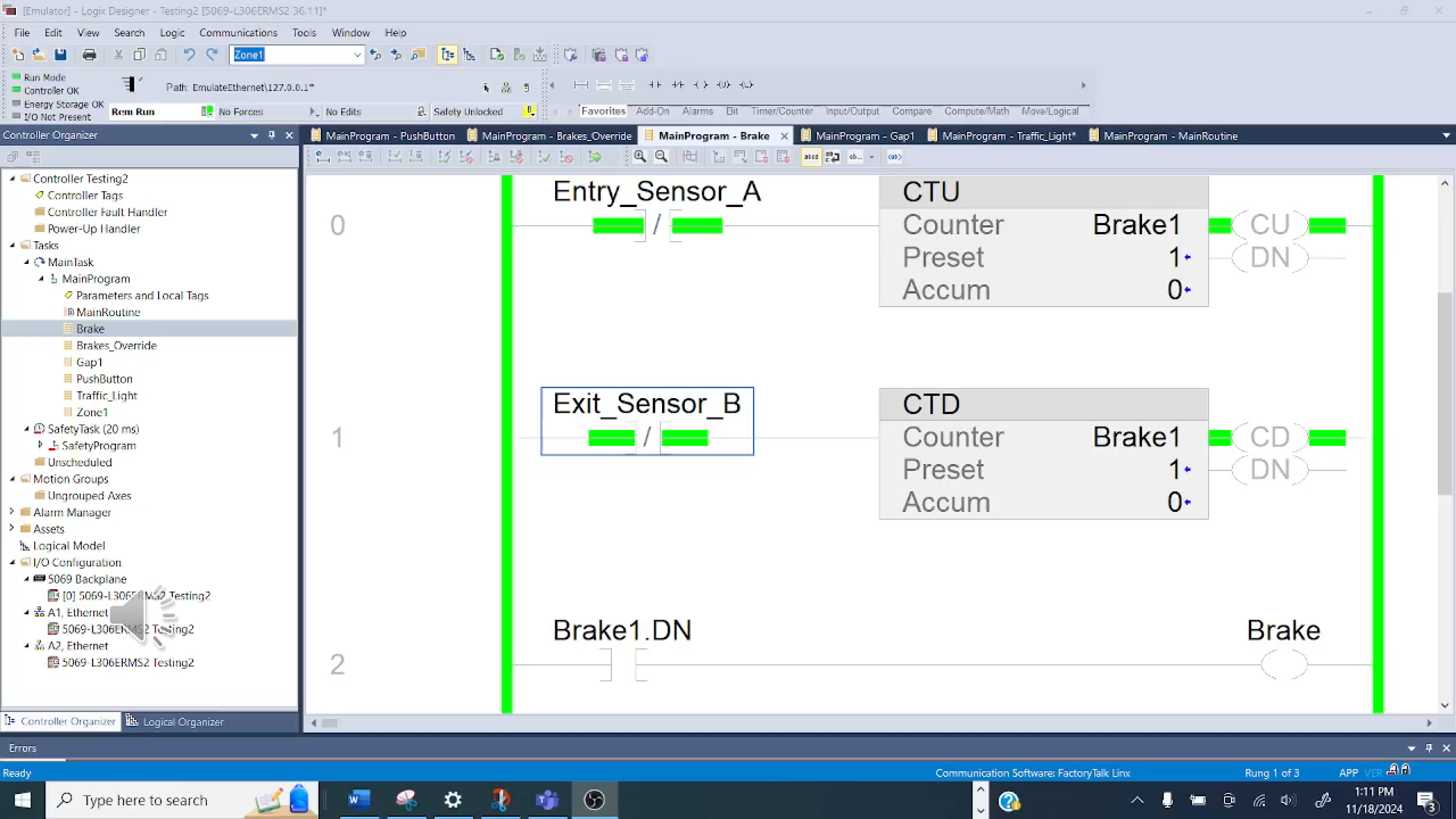
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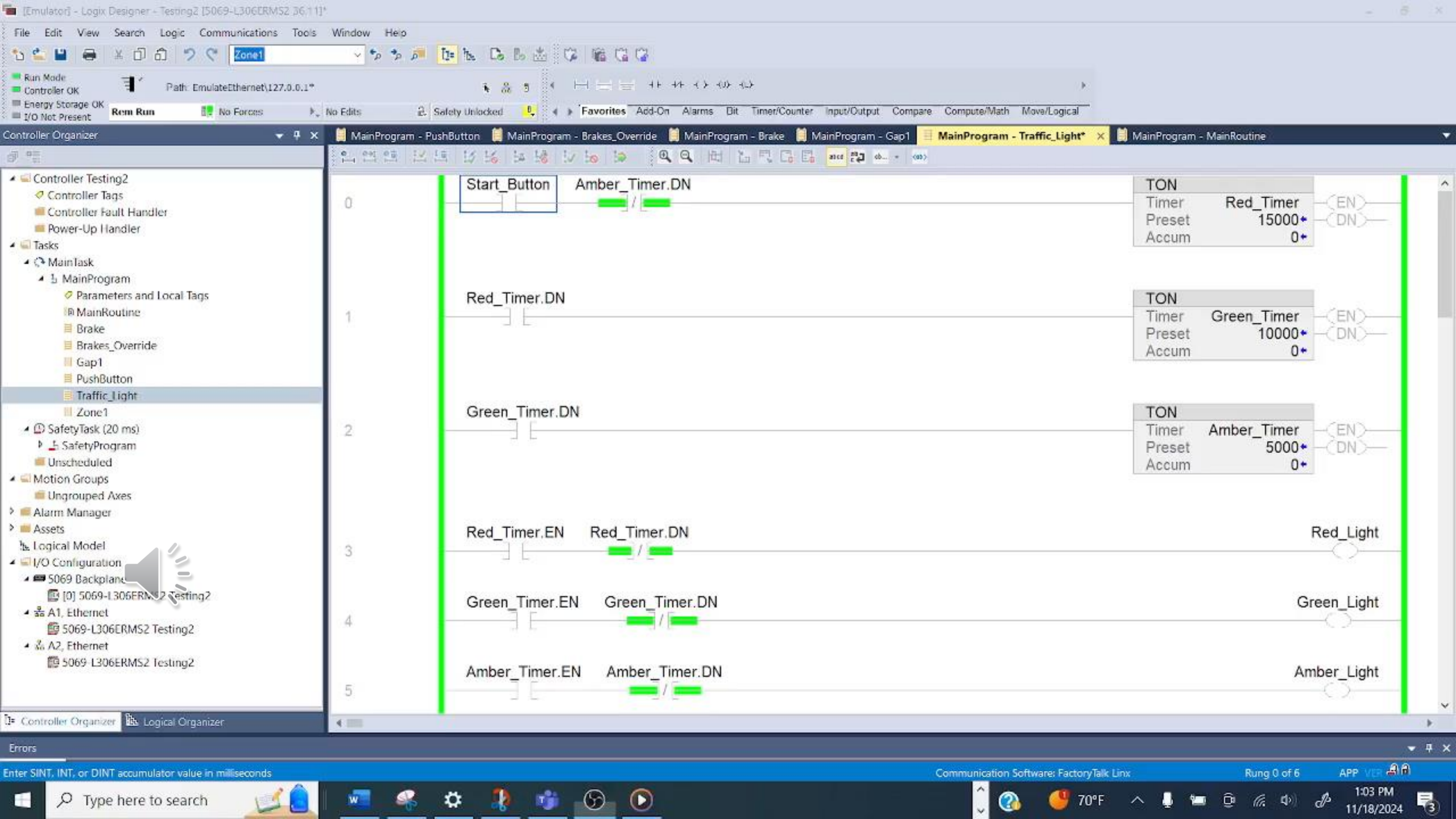
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Preset 10000
Accum 0
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Green_Timer.DN
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Timer Amber_Timer
Preset 5000
Accum 0
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3
Red_Timer.EN
Red_Timer.DN
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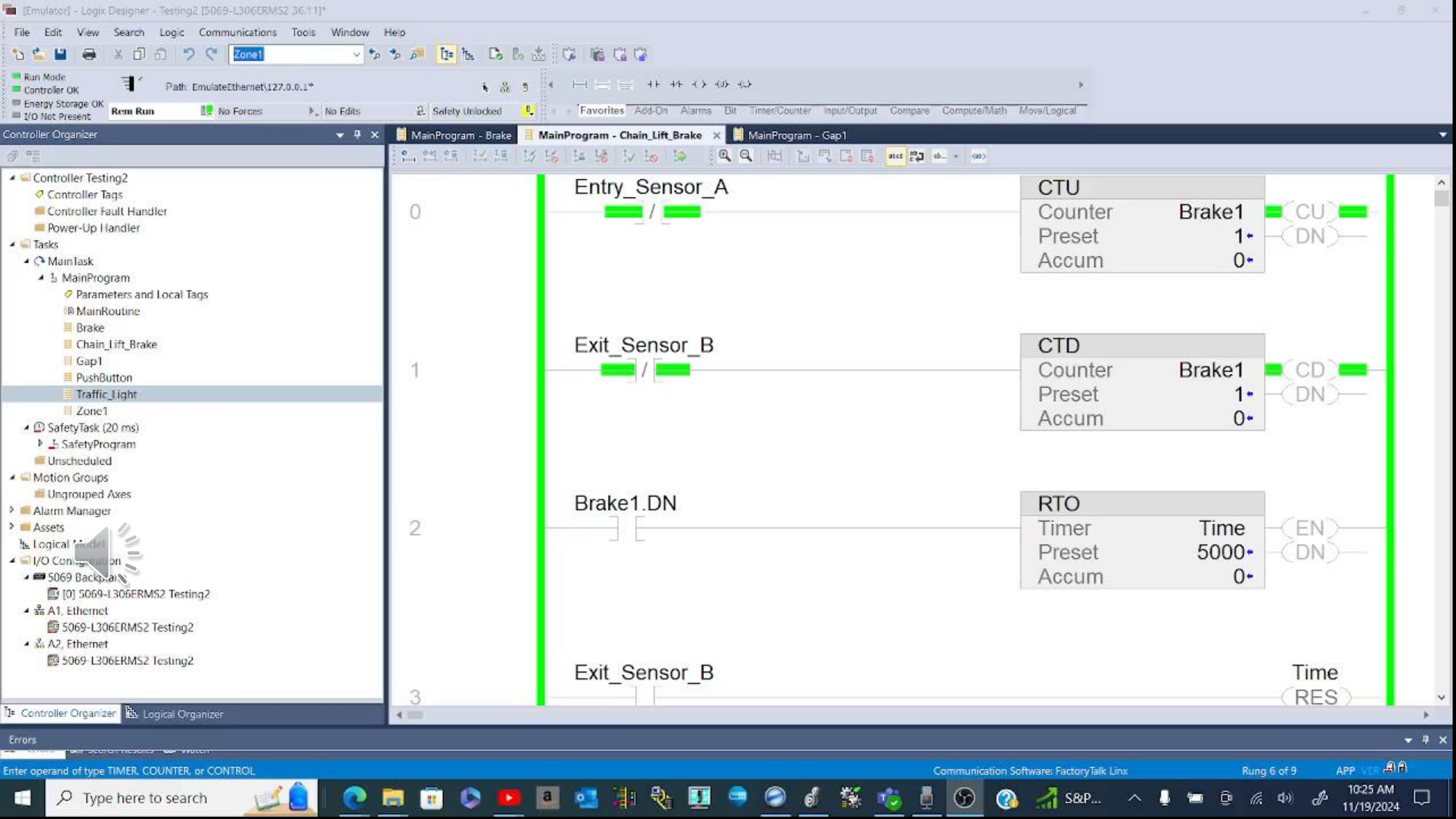
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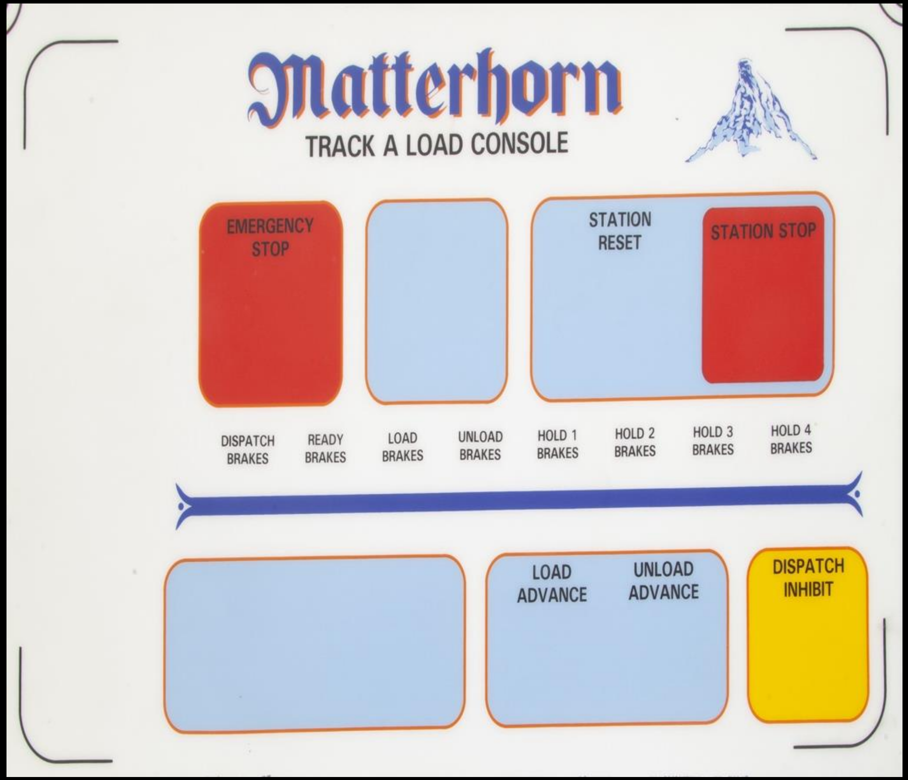
# CONTROL PANEL PURPOSE AND INTEGRATION

- Centralized interface for monitoring and controlling the rollercoaster's operation.
- Integrated with the track, and specialty features for seamless functionality.
- Displays and LEDs provide operators with real-time data about the ride's status, including vehicle positions and track conditions.
- Uses LEDs to indicate block zones, ensuring collision avoidance and operational efficiency.
- Interfaces with sensors, components, and PLC (Programmable Logic Controller) for seamless data exchange and control.

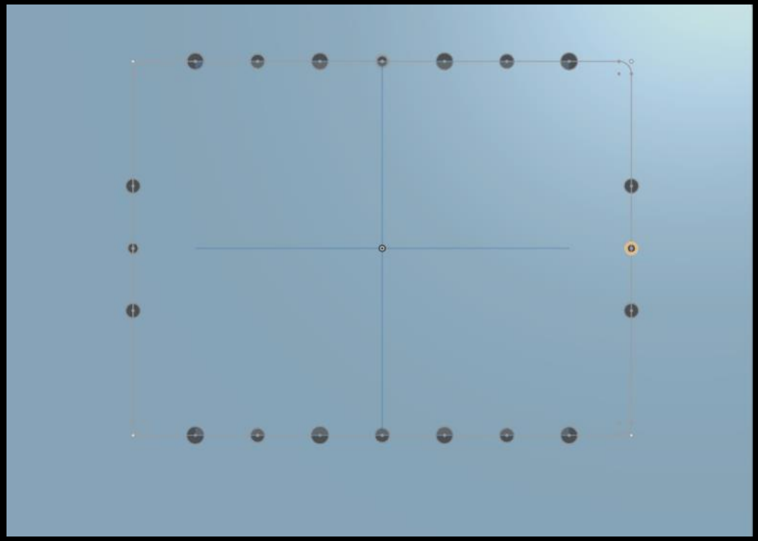
# CONTROL PANEL-COMPONENTS

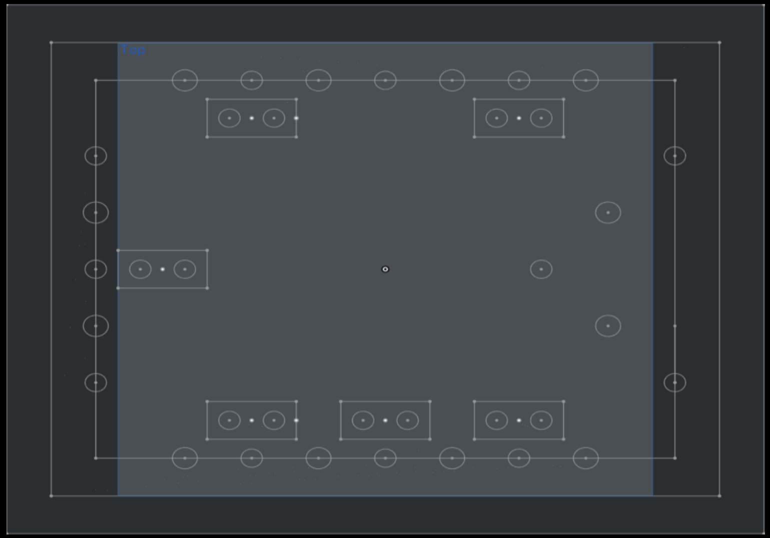
- Equipped with LEDs, push buttons, switches, and emergency stop buttons, the panel provides a user-friendly interface for controlling and monitoring rollercoaster operations.
- Integrated safety mechanisms like E-Stop buttons and real-time feedback through LEDs ensure safe operation and vehicle tracking across the track layout.
- Designed to work seamlessly with PLC systems, using Ladder Logic programming for automated control and real-world simulations inspired by professional systems like the Matterhorn console.



# CONTROL PANEL-DESIGN AND DEVELOPMENT

- Designed in Onshape to optimize layout, routing, and wire management.
- Finalized using measurements from hardware components to ensure precision fit.
- Referenced examples from existing rollercoaster control panels (e.g., Matterhorn) for best practices.



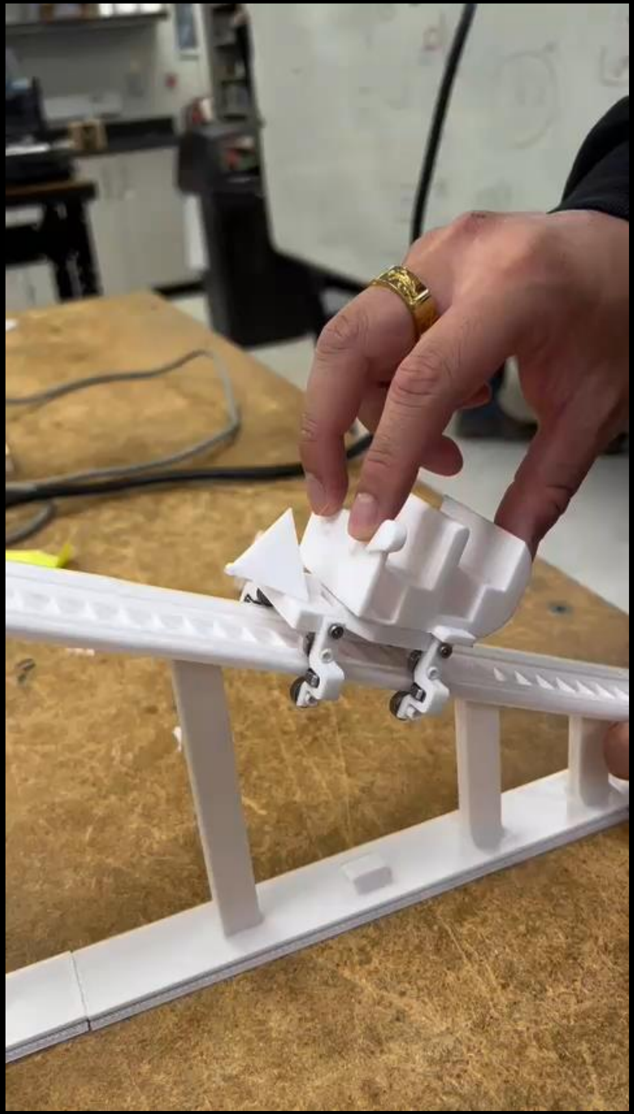


# CONTROL PANEL-FUNCTIONALITY

- Ladder Logic programming used to simulate real-time control of the coaster.
- Push buttons assigned to start/stop the chain lift and other operations.
- Sensors and LEDs map the vehicle’s journey across the track.
- Simulations conducted with the PLC to verify hardware-software interaction.

# RESULTS:

- PLC System handles all operations as intended
- Sensors successfully communicate with brakes
- Braking system effectively halts passenger vehicle
- Vehicle successfully contours to track's dynamics
- Vehicle bogies remain on track rails during twists, turns, and being rotated upside down
- Anti rollback features interact correctly and safely prevents vehicle from moving in an unintentional direction



# MAJOR CONCLUSIONS/FINDINGS:

Our roller coaster design approach focuses on a structured, multi-phase process to ensure precision, functionality, and safety. Starting with prototyping and manufacturing, we developed physical models and tested initial designs. In the full model testing, we assessed all components—including vehicle, track, and control systems—to verify fit, feature interaction, and integration. Finally, during assembly and adjustment, we combined all elements to ensure a seamless operation, refining each system to function cohesively as a fully operational ride experience.