

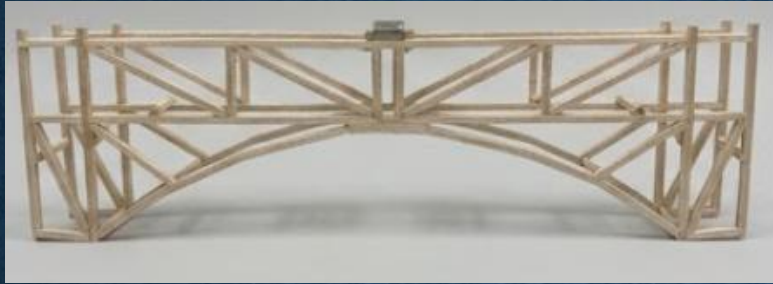
MECHANICAL ENGINEERING PORTFOLIO

William Millard

University of Alberta | Varsity Athlete



BALSA WOOD BRIDGE



Project Scope:

A design challenge for a balsa wood bridge with mass less than 150g, maximizing load to mass ratio.

Design Decisions:

Used **parametric CAD** optimization of a Howe Truss design with integrated diagonal bracing to **minimize material** usage and reinforce high-stress joints.



Key Results:

Achieved a final load of 100 kg on a final mass of 149.9g, yielding a structural **efficiency of 667x**.

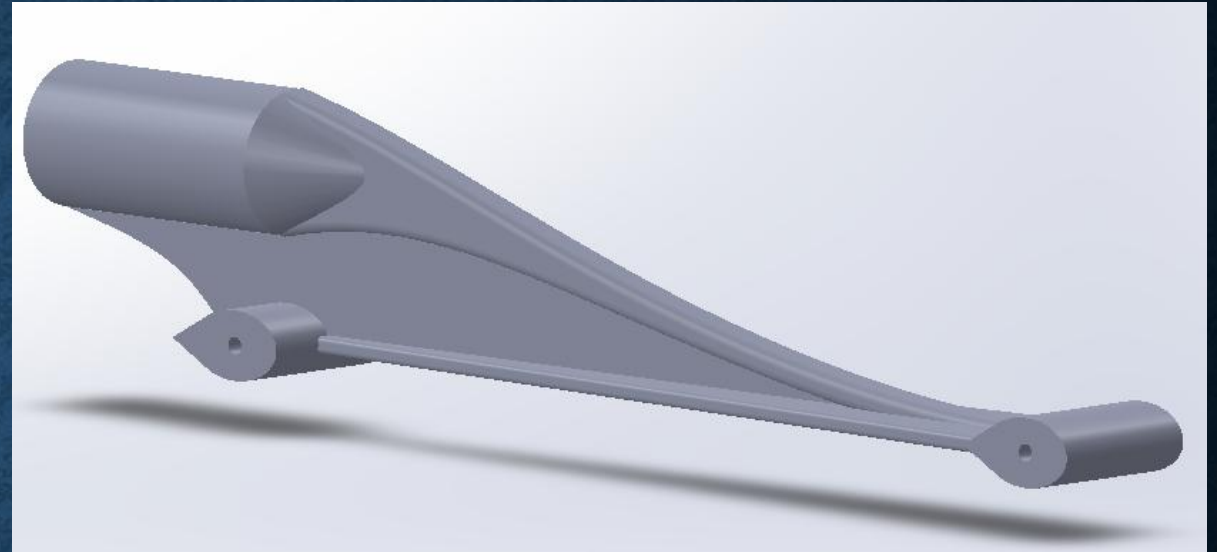
CO₂ POWERED CAR

Project Scope:

Design a drag racer powered by a CO₂ canister to race over a 30m track.

Design Decisions:

Engineered the body to focus on aerodynamics. Developed a CAD model and used **CFD analysis** to iteratively reduce drag. Integrated a contoured undercarriage for ground effect reductions and stabilization



Key Results:

Won first place in design challenge tournament while breaking the **previous record by 0.5x**. The Integrated ground effect provided **noticeable friction reduction**, allowing the wheels to reduce contact and friction.

ELECTRIC GO-KART DESIGN

Project Scope:

Co-designed an electric go-kart under a compressed timeline, fabricating the **suspension** and **custom steering system**.

Design Decisions:

- **Integrated Differential:** Engineered a **standard differential** into the drive/steering assembly to reduce scrubbing and aid in cornering on off road tracks.
- **Impact Suspension:** Fabricated a robust rear suspension to absorb high-impact loads and protect the electric drivetrain



Key Results:

- **Placement:** Placed highly in the off-road category, validating the mechanical subsystems under real race conditions.
- **Mechanical Reliability:** Zero failures across the steering linkage or suspension throughout the entire dynamic event.

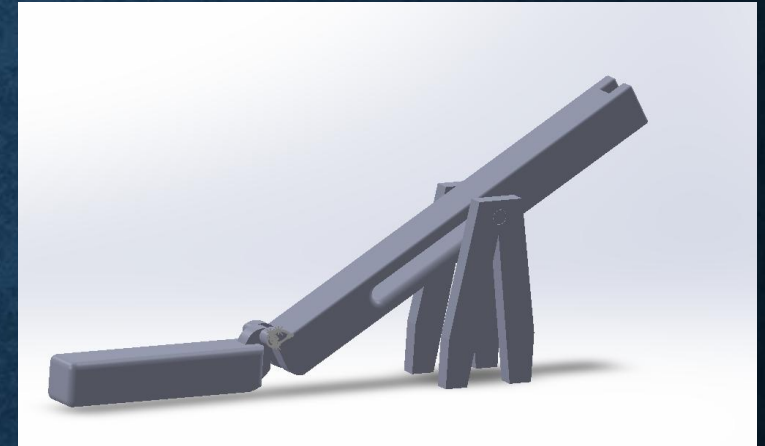
KINEMATIC LIFTER: SHIFTING FULCRUM OPTIMIZATION

Project Scope:

First-year design project to lift a 250g mass using a strictly power-limited motor. While most teams used complex gearboxes, I developed a geometric solution.

Design Decisions:

- **Shifting Fulcrum Geometry:** Engineered a lever with a dynamic pivot point, providing **maximum mechanical advantage** at the start of the lift when torque demand is highest.
- **Kinematic Advantage:** Calculated linkage lengths on paper and verified through field testing to ensure the motor never reached stall torque.



Key Results:

- **Maximum Efficiency Score:** Achieved a perfect performance score by bypassing inefficient gear-reduction systems.
- **Elegant Constraint Resolution:** Overcame an underpowered actuator using geometric design rather than brute-force gear ratios.

BLUETOOTH SPEAKER

Project Scope:

Design and manufacture a custom PCB to integrate a Bluetooth 5.0 receiver with a 3W audio amplifier.

Key Results:

- **Functional Hardware:** Successfully converted a breadboard prototype into a permanent, soldered PCB.
- **Manufacturing Insight:** Realized the importance of width tolerances in subtractive manufacturing.
- **Reliability:** Validated the board through continuous high-fidelity audio playback.

Design Decisions:

- **Prototyping:** Validated circuit logic on a breadboard before translating the hand-drawn schematic to a physical layout.
- **Chemical Etching:** Fabricated the board using a **Ferric Chloride** subtractive process.
- **Troubleshooting:** Managed over-etching issues by performing precision solder-bridge repairs to restore circuit continuity.
- **Integration:** Integrated voltage regulation to provide a stable 3.3 V supply, eliminating signal noise during Bluetooth transmission.

CORONOGRAPH PYTHON SIMULATION

Project Scope:

Developed a Python simulation to model the optical performance of a coronagraph, using Fourier Optics to suppress starlight and reveal orbiting exoplanets.

```
#Purpose: interpolates for amplitude and phase
#Inputs: im (2D array) => the grayscale image
#Outputs: IMa (2D array) => amplitude
#         IMp (2D array) => phase in radians
#Activity: None
def dft2(im):
    IM = np.fft.rfft2(im)
    IMa = np.abs(IM)
    IMp = np.angle(IM)
    return (IMa, IMp)

#Purpose: Reconstructs image from DFT amplitude and
#Inputs: IMa (2D array) => amplitude
#        Imp (2D array) => phase
#Outputs: im (2D array) => the reconstructed image
#activity: none
def idft2(IMa, IMp):
    IM = IMa * (np.cos(IMp) + 1j * np.sin(IMp))
    im = np.fft.irfft2(IM)
    im[im < 0] = 0
    im[im > 1] = 1
    return im
```

Computational Methods:

- **Frequency Domain Analysis:** Applied `numpy.fft` to simulate light propagation between a telescope's aperture and focal planes.
- **Signal Reconstruction:** Reconstructed optical images from phase and amplitude components using complex number manipulation and Euler's Formula.
- **Data Scaling:** Implemented clipping and normalization logic to map simulation results to physical detector bounds of $[0, 1]$

