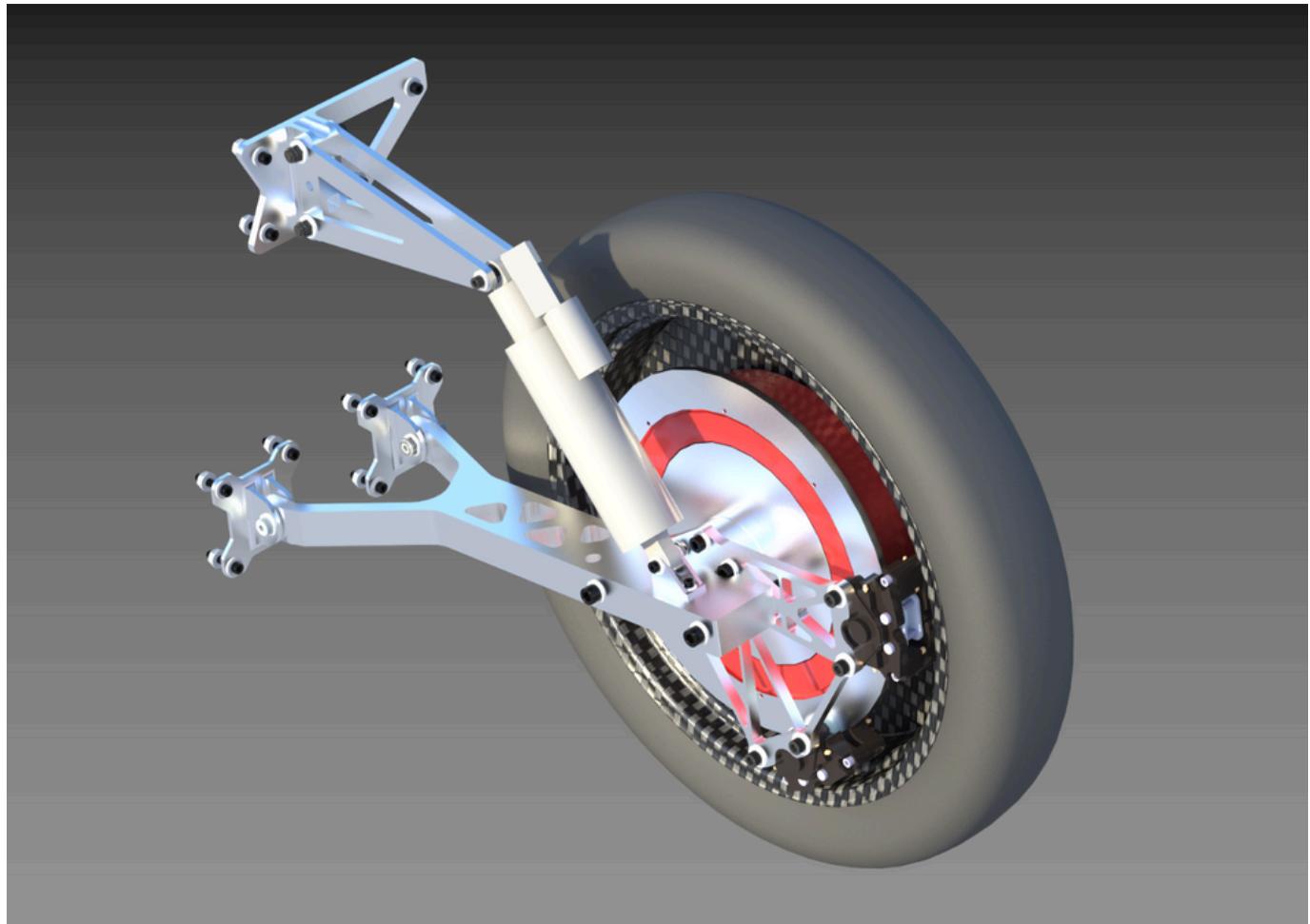


Engineering Portfolio

Pallab Layak

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Quick Overview

Graduating Senior in Mechanical Engineering at the University of Illinois at Urbana-Champaign (UIUC). Student advisor and former lead mechanical engineer for the **Illini Solar Car Team**. **Tutor for Mechanical Engineering** courses at UIUC. Research assistant from this semester in **non-Newtonian Fluid Mechanics and Rheology research lab**.



About Me

Hi, I'm Pallab!

I am passionate about analytical and practical problem-solving for contemporary problems. I enjoy collaborating with people from various walks of life, learning and growing together.

I would love to apply my Mechanical Engineering knowledge to the renewable energy sector, automotive industry, medical fields, and cutting-edge research in fields including (but not limited to) robotics and electric vehicles. Using my knowledge and experiences to make the world a better place is my life's ultimate goal.



In my free time, I love solving Rubik's Cubes and other 3D puzzles. In fact, I got my first Rubik's Cube as a Christmas gift in first grade. I taught myself how to solve it almost 15 years ago and today I can solve one in less than 10 seconds (click [here](#) to watch!). Now, I own a collection of 20+ Rubik's cubes and puzzles and hope to design my own 3D puzzle one day.



Please take a look at some exciting engineering projects I've had the opportunity to work on and feel free to reach out to me about anything!

AUTOFEEDER IMPROVEMENT - SENIOR CAPSTONE

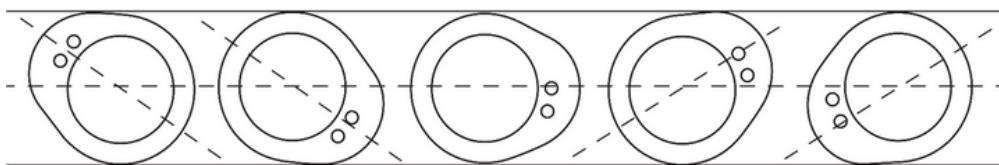


What?

- Created improvements for autofeeder system that palletizes cam lobes for camshaft manufacturing.
- Goals:
 - <3.75s cycle time
 - 99% uptime
 - <5 minute tooling changeover for different cam profiles.

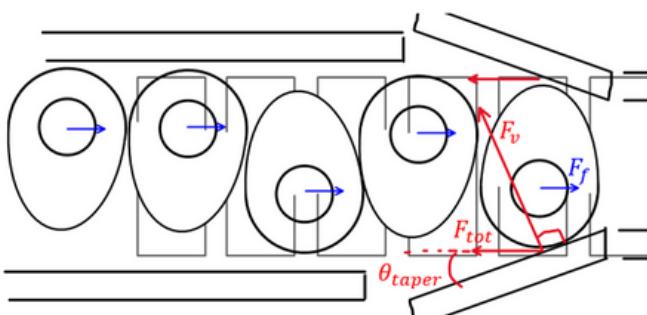
How?

- Created high-fidelity prototype for offsite testing and rapid prototyping in **Creo**.
- Designed **sheet metal** vibration fixture to funnel lobes into narrowing conveyor section.
- Performed **dynamic load analysis** and **fatigue analysis** on fixture using **hand-calcs** and **FEA**.
- Implemented a **roller-bearing gripper** to passively orient lobes.

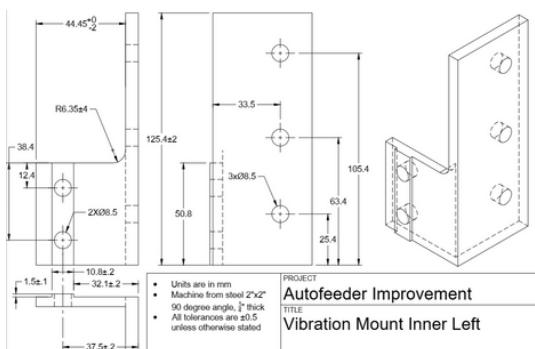
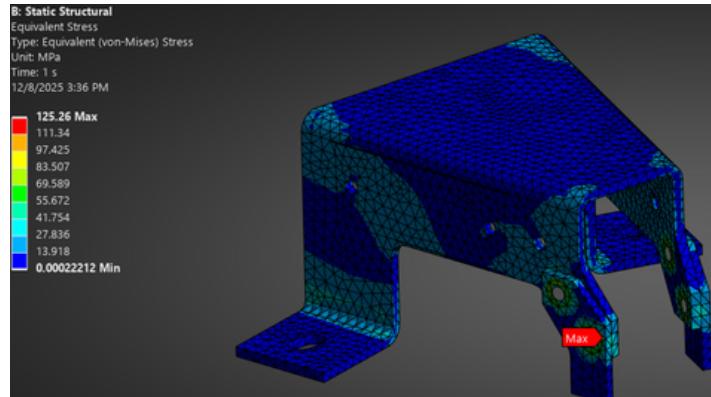


Minimizing angular variability with narrow walls

Calculation Sneak Peak



Force diagram for jamming of narrowing conveyor section



Engineering drawing for fixture mounting bracket

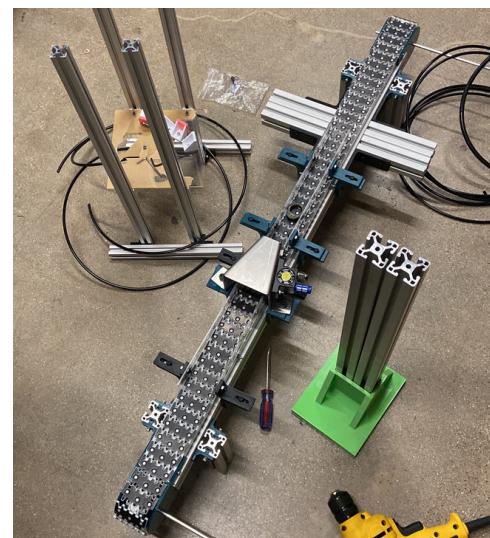


Brackets I machined on a manual mill

Further details upon request! :)

Results

- By decreasing angular variability of lobes, **failure rate was reduced to 0 in 1000 lobes**.
- Cycle time **reduced by 0.5s**.
- No tooling changeover required.
- Won 1st place in ~40 groups for best prototype :)



High-fidelity prototype setup



COMPOSITE CHASSIS ANALYSIS AND OPTIMIZATION - ILLINI SOLAR CAR

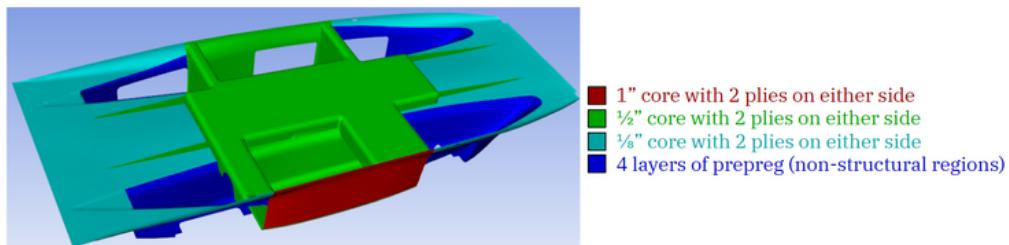


What?

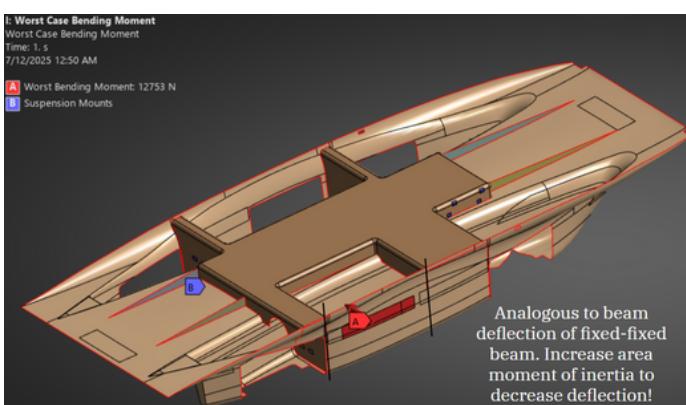
- Analyzed composite chassis to satisfy load cases based on competition regulations.
- Ensure safety of driver in the event of an impact.
- Created 5 custom load cases to satisfy.
- Optimized composite layup plan to minimize overall weight of chassis and aero-shell.

How?

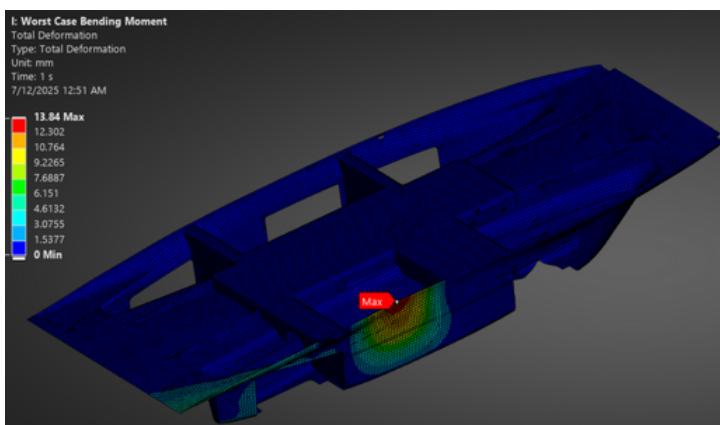
- Utilized ANSYS Composite PrepPost (ACP) to assign material properties and composite stackups.
- Used beam-bending equations to estimate maximum deformation and required stiffness.
- Set up load cases in ANSYS Static Structural and observed deformation and stress distribution.
- Iterated until optimal results were obtained.



Thickness plot for shell and chassis



Example of ANSYS Static Structural setup



Deformation results for a load case

Results

- Weight of composite chassis reduced by 30% from previous generation.
- Overall weight of ~ 50 kg.
- Deformation < 25 mm and no yielding (satisfied regulations).
- Topology optimization will be used to further reduce weight.
- Physical panel testing will be used to validate analysis.
- Learn more from [this report](#).

Calculation Sneak Peak

Regulation:

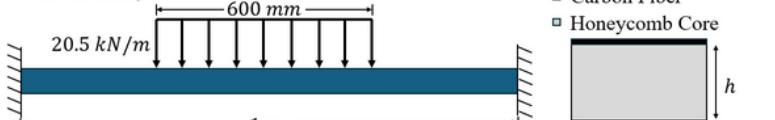
Drive occupant cell cannot deform more than 25 mm under 5G side loading.

We know:

$$\text{Deflection } (\delta) \propto \frac{1}{EI}, \text{ Bending Stress } (\sigma) \propto \frac{1}{I}$$

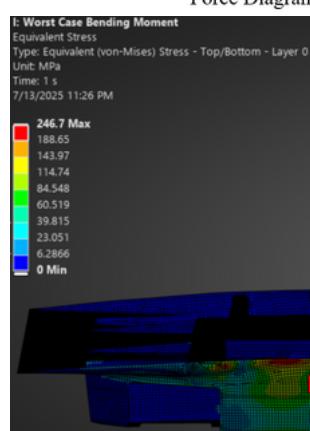
Increasing E would require adding layers of carbon fiber.

Aim to maximize I by using thicker core (since honeycomb core is lighter than carbon fiber).



Force Diagram

Composite Cross Section



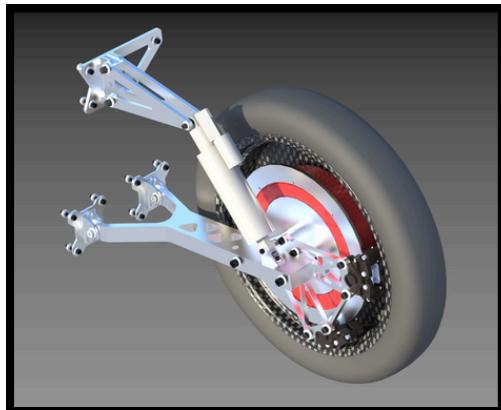
Stress results for a load case

REAR SUSPENSION REDESIGN - ILLINI SOLAR CAR



What?

- Redesign trailing arm rear suspension for Solar Vehicle.
- Primarily focused on lower trailing arm mounts but contributed to all component designs.
- Optimize weight** with minimum FoS = 1.25 (based on fatigue calculations from S-N Curve)
- Previous design had minimum safety factor = 4.50.



How?

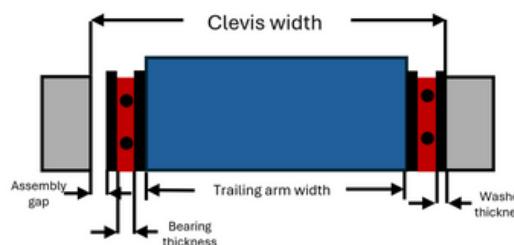
- Designed in **NX**.
- Used **free-body diagrams** to calculate reaction forces on each component.
- Performed **Finite Element Analysis** and **topology optimization** in **ANSYS**.
- Performed **lug analysis** at clevis.
- Researched into **bolt preload** for analysis.
- Performed **worst case tolerance stackup analysis** for **thrust bearing, clevis and trailing arm** in assembly ensuring clearance.

Results

- Designed on tight timeline- less than **1 month**.
- Weight of design was reduced by **40%**.
- Minimum safety factor = 1.28.**

Calculation Sneak Peak

Clevis width = Assembly gap + 2 (Bearing thickness) + 4 (Washer thickness) + Trailing arm width



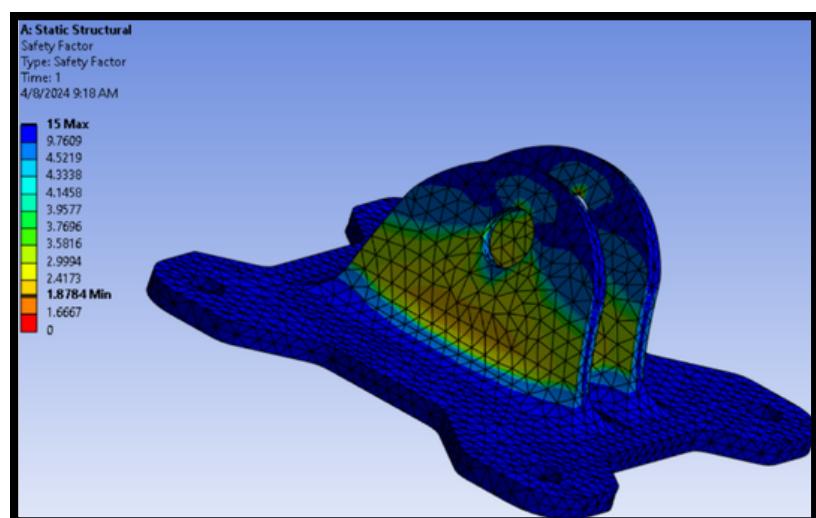
Worst Case Stackups:

Maximum Clevis Width = 0.80825 in

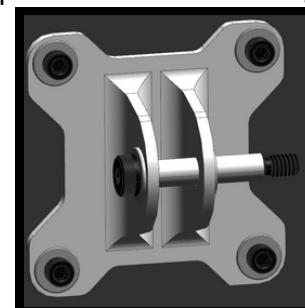
Minimum Clevis Width = 0.77445 in

Clevis Width = 0.791 ± 0.017 in

ANSYS FEA



Optimized Final Design



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COMPOSITE PLUG DESIGN AND MANUFACTURING - ILLINI SOLAR CAR



What?

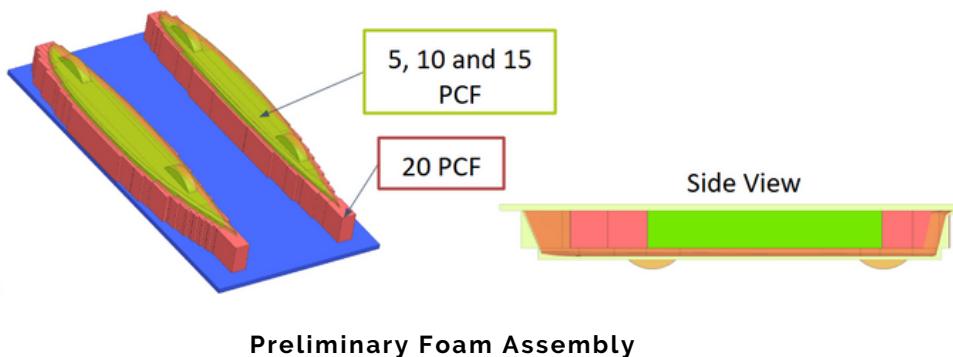
- Designed a preliminary **6.5ft x 16ft** HDPU foam mold assembly for composite aeroshell.
- Created procedure for reference geometry transfer between mold and final part.
- Carbon fiber layup** on male plug to create female mold.

How?

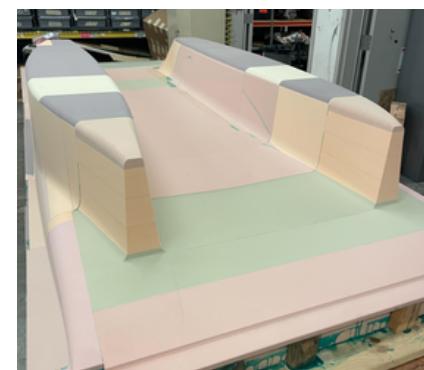
- Designed foam mold assembly in **NX**. Minimized cuts required by tracking with spreadsheets and slides.
- Created foam molds using **planers**, a **track saw** and elaborate gluing setups.
- Outsourced mold manufacturing with **5-axis CNC**.
- Post-processed mold** for layup.
- Machined **100+** inserts for reference geometry transfer on **manual lathe**.

Results

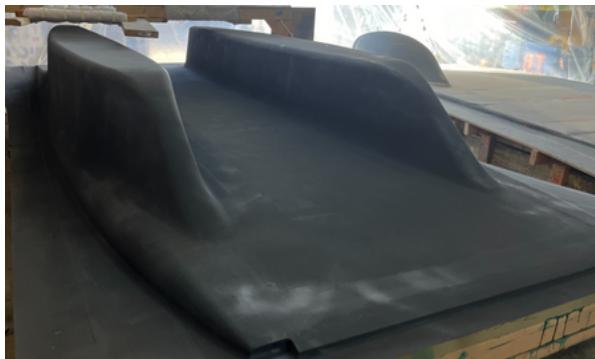
- Created using existing resources - **no additional materials purchased**.
- Reference geometry successfully transferred from male to female mold.
- Mold layup completed successfully.



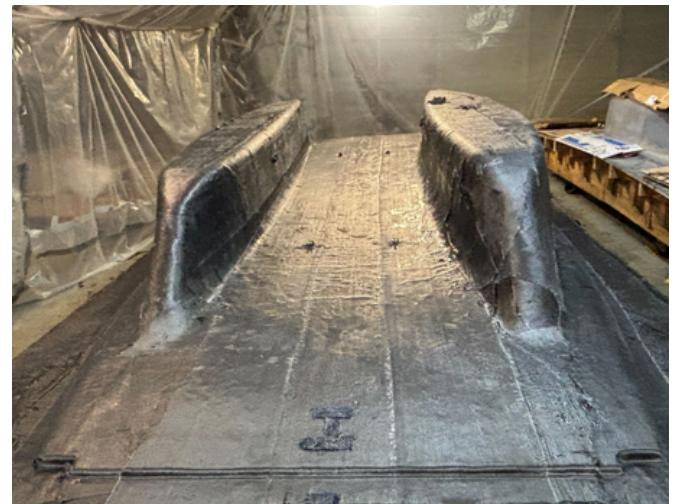
Preliminary Foam Assembly



Final Machined Plug



Plug Prepped for Layup



Layup Complete!



Inserts Machined for Hole Transfer

PALLAB LAYAK

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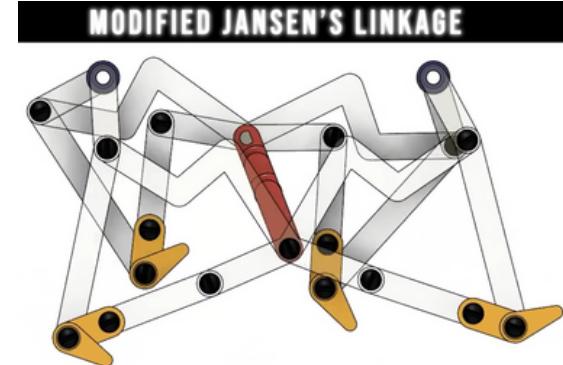
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STRIDER - INCLINED WALKER ROBOT

-Click [here](#) to watch!



What?

- **Design, prototype and assemble** a walker robot that can climb up a 30 degree incline on grassy/muddy terrain.
- Minimum required speed of 4 m/min.
- Given a motor and a battery pack.

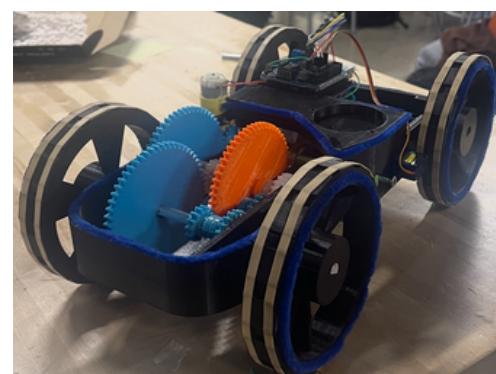
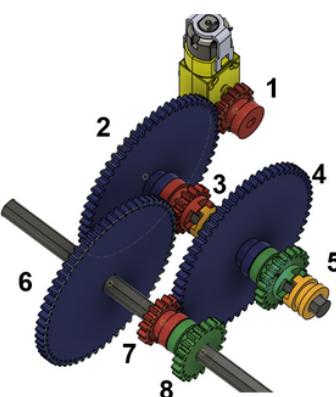
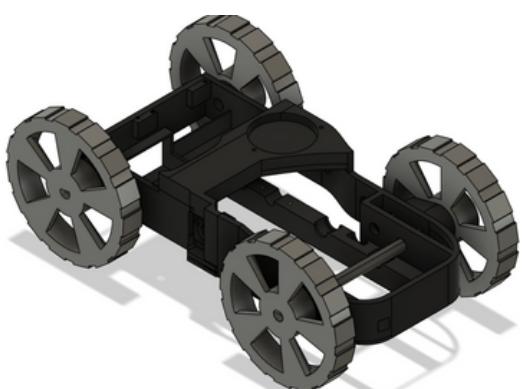
How?

- Performed **PVA analysis** to create **linkage** system.
- **Bevel gears** used to transmit rotation from motor to linkage.
- Linkage **laser cut** from Delrin to minimize friction.
- Performed gait analysis and **CG analysis** to verify design.

Results

- 18 m/min speed achieved.
- 2nd fastest robot in the class.
- Designed for 3d printing for **rapid prototyping** and iteration.
- Hand calculations allowed for **optimizing gear ratio** to maximize speed.

LIGHT RUNNER - MANUAL TRANSMISSION RC CAR



What?

- Create a car that is controlled by an IR remote that can:
- Lift **2 kg** up a **20 degree** incline.
 - Drive at **1 m/s** average speed.
 - **Shifts gears** with only **one servo**.
 - Can shift between low, high and reverse gear smoothly.
 - Costs less than **\$15** to make.

How?

- Performed **gear ratio calculations** based on motor power and rpm to create **drivetrain**. $P = T\omega$
- Performed **bending stress analysis** on gear teeth,
- **Barrel cam** for converting rotational to translational for shifting.
- Machined metal D-shafts.
- Used **Arduino Uno, l298n motor driver**, and **IR sensor** to control the car.

Results

- Car was able to:
- Lift **4.6 kg** up a **20 degree** incline.
 - Drive at **1.05 m/s** average speed.
 - **Shifts gears** with only **one servo**.

PALLAB LAYAK

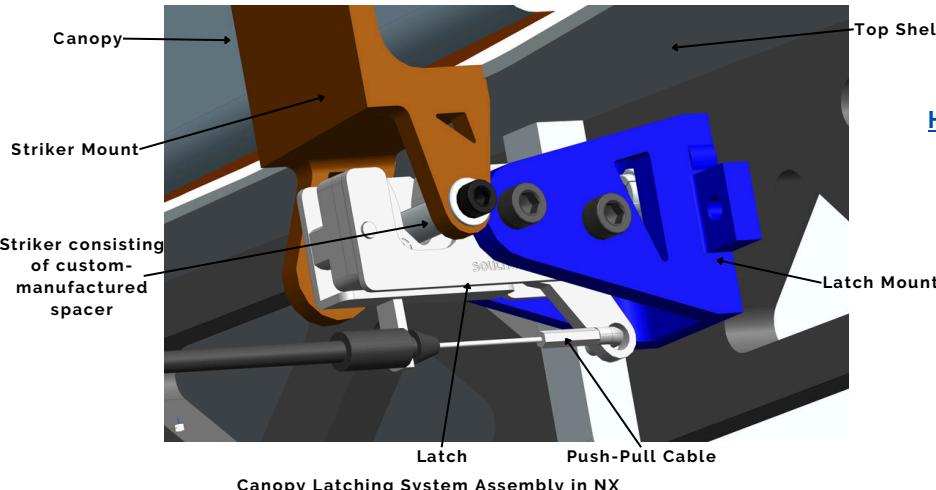
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LATCHING SYSTEM - ILLINI SOLAR CAR



What?

- **Design** a latching system to secure:
 - Top shell to bottom shell.
 - Canopy to top shell.
 - **Minimize costs** by using resources that we already had.
 - Incorporate buttons as the "user-interface" with the latching system.
- Human-centered design** was used to do so.

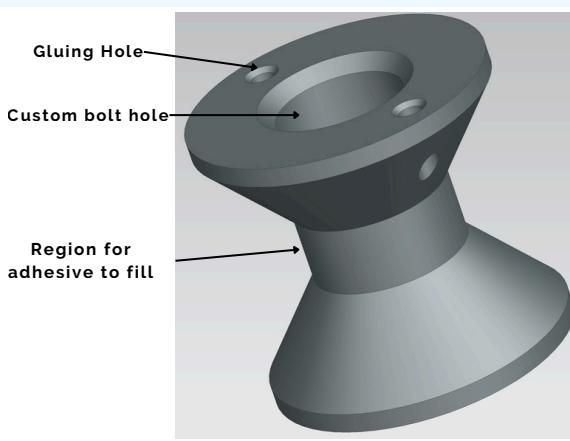
How?

- **3-D printed** latch and striker mounts.
- Striker mount was glued onto the canopy. Latch mount was slotted and bolted into triangular chassis cutouts.
- Used **rapid prototyping** to test fit.
- **Push-pull cables** were used and customized along with **mechanical buttons** to activate the latch.
- Striker consisted of a bolt and custom-made spacer I manufactured on the **lathe**.
- Top shell latch system was made in a similar manner.

Results

- Completed within 4 days.
- Latch systems successfully survived the entire race.
- **\$0** cost because the project was designed to use existing resources.

INSERTS FOR CARBON FIBER - ILLINI SOLAR CAR



What?

- **Design** and **manufacture** custom diameter inserts to bolt components through carbon fiber.
- Ensure that the inserts can be glued.

How?

- **Design** in NX and made engineering drawings using **GD&T**.
- Manufactured in-house using the **manual lathe** and **mill**.
- Created a setup to test whether the inserts withstand their required load cases.



Inserts manufactured

Results

- Manufactured more than 30 custom inserts.

PALLAB LAYAK

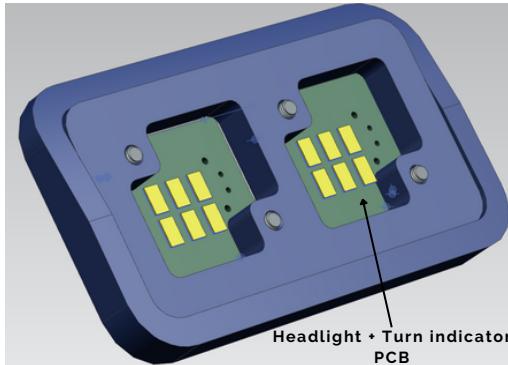
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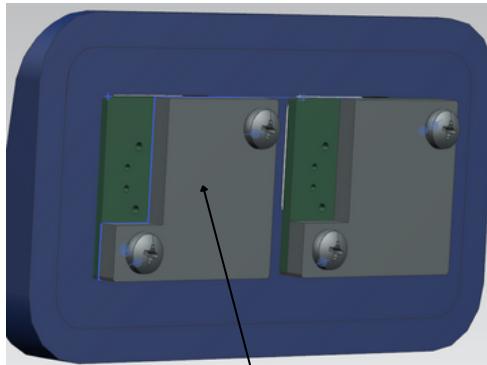
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HEADLIGHTS - ILLINI SOLAR CAR



Headlight + Turn indicator PCB



Aluminum Heat Sink with hole for PCB connectors



Lights shining bright while driving in the night!

What?

- **Design, manufacture and assemble** a system to incorporate the headlights and front turn indicator into 3rd generation solar vehicle.
- Maintain safe temperatures by attaching a heat sink to the PCB.

How?

- Designed on **NX**, importing PCB components from **KiCAD**.
- **3D-printed** holder for headlight.
- **Waterjet** Aluminum heat sinks to prevent overheating.
- Performed **heat transfer hand calculations** to determine thickness and area of heat sink required.
- Headlight cover **SLA printed** polished, and sprayed for clear finish.

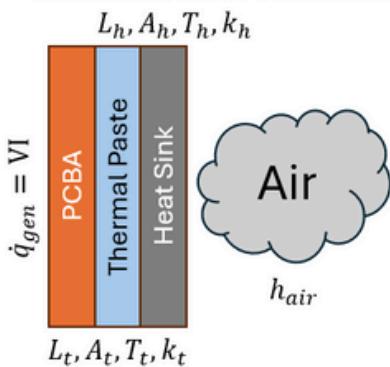
Results

- Headlight system successfully incorporated satisfying all rules and regulations.
- Heat sink dissipates sufficient heat.

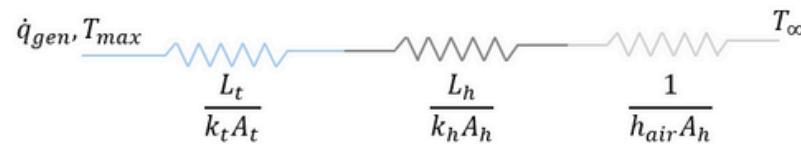
Calculation Sneak Peak

Goal:

Estimate heat-sink thickness ensuring temperature of PCBA doesn't exceed T_{max}



Resistor diagram for 1D SS heat flow:



(Assuming cross-sectional area of heat sink \approx surface area)

$$T_{max} - T_\infty = VI \left(\frac{L_t}{k_t A_t} + \frac{L_h}{k_h A_h} + \frac{1}{h_{air} A_h} \right)$$

Solve for L_h to determine required thickness!

RESEARCH - EMBEDDED 3D PRINTING

What?

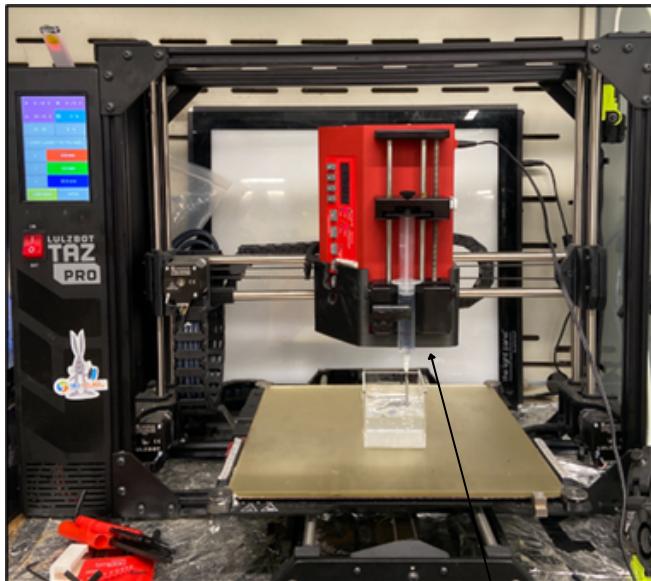
- Design structures to show the capabilities of **embedded 3-D printing**- printing a fluid within another fluid.
- Incorporating an **automatic** extrusion systems to provide accurate results.
- Conducted numerous experiments to determine rheological properties.

How?

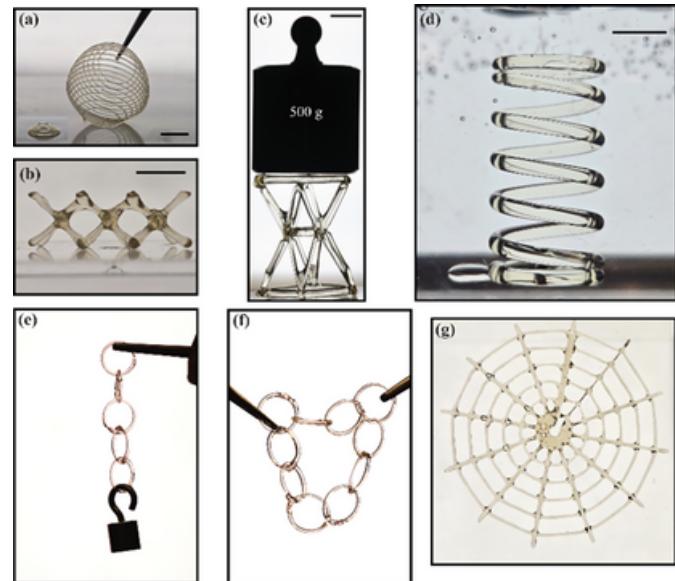
- Used **Python** and researched 3-D printer G-Code to create 9 shapes.
- **3-D printed** custom housing for extrusion pump.
- Automated printing using **Arduino Nano** to connect printer output to pump input.

Results

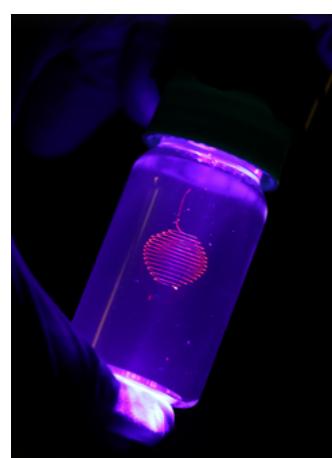
- Structures depicting the "wireframe" printing ability of embedded 3-D printing.
- **100+ hours** of printer monitoring saved by automating the printing.
- Currently **co-authoring** a paper on the rheology of hagfish slime.
- Writing another paper this summer focused on **embedded 3-D printing**.



Custom attachment for pump to printer



Numerous structures printed via embedded 3-D printing. Toolpath G-Code generated using Python Scripts



Embedded 3D printed spiral using UV ink