CACTI's Mission:

Our objective is to create a **mobile robotic ball** to enhance the **quality of life** of the cheetahs at the **Houston Zoo** by stimulating their **natural chase behavior**.

Team Members:

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Electronics, Programming, CAD

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Documentation, Electronics, Mechanical Design

From Previous ENGI 120 Group:

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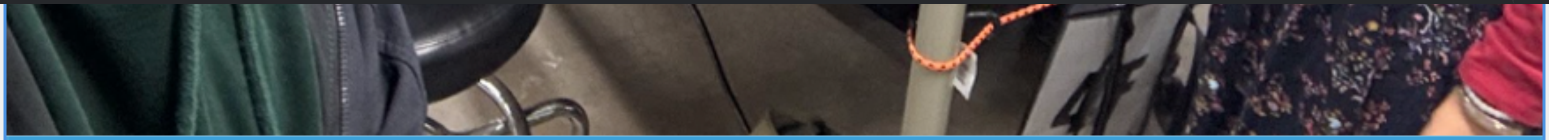
CAD, Mechanical Design

Clay Goldsmith, Anika Gupta, Tyra Helper, Ian Schechter, and Cassidy Chhay (left to right)

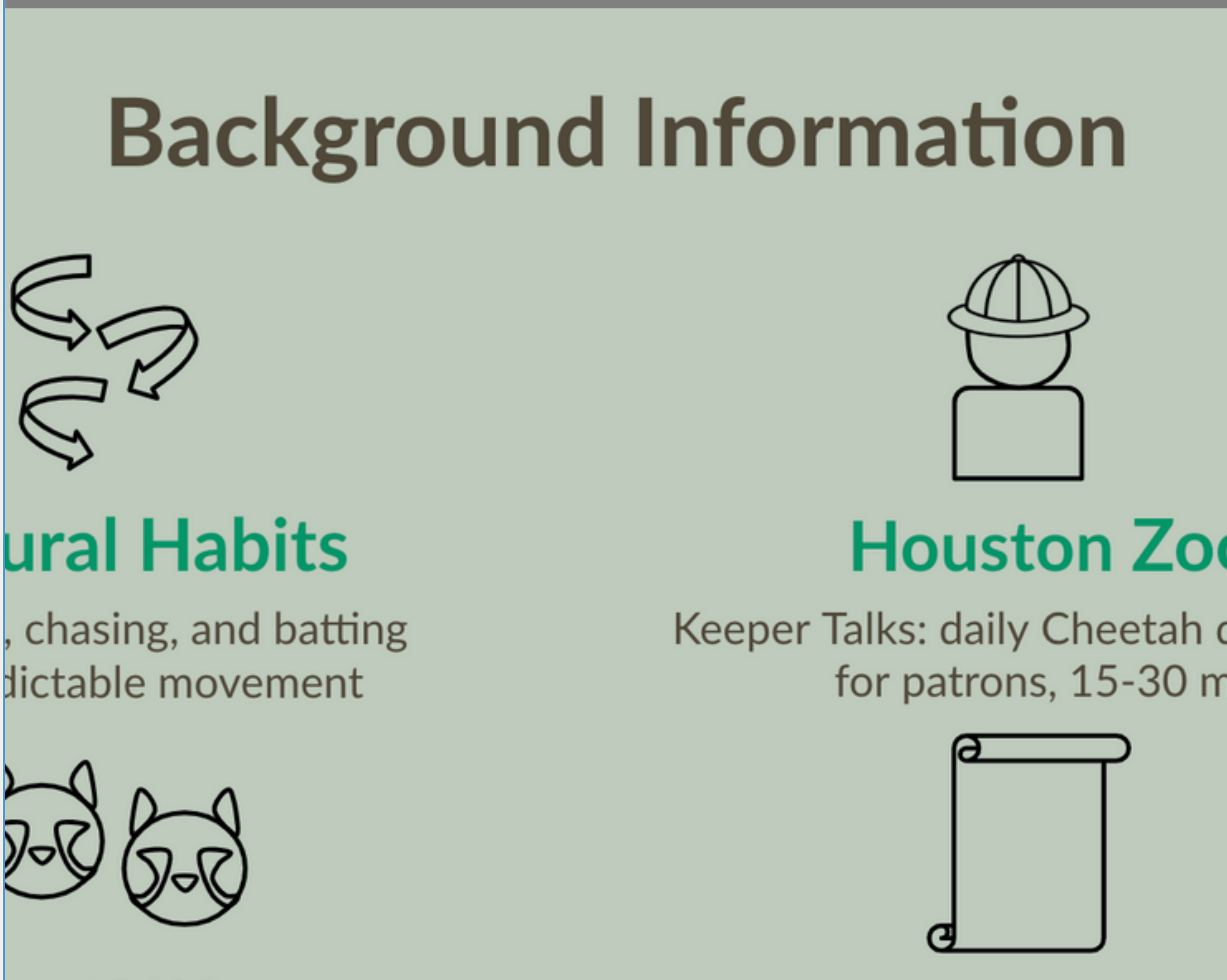


Problem Context and Background

Dinari (1/2 of The Boys)

To keep the cheetahs active and engaged, zookeepers provide them with daily enrichment activities that encourage mental stimulation through natural behaviors. Dash and Dinari (aka The Boys) are particularly curious about new enrichment items and events, but their interest tends to fade more quickly than in some other species. Although the cheetah brothers receive a complete diet at the Houston Zoo and do not need to hunt or run for food, zoo staff aim to encourage more movement and interaction with objects that promote hunting-like behavior for guests to observe. To achieve this, the goal is to design and develop a durable, self-propelled ball specifically for the cheetahs. This ball should stimulate their instinct to chase and interact while meeting the zoo's safety and practical requirements.

The device should be able to stimulate the cheetah's natural habits, such as watching, chasing, and batting, and replicate unpredictable movements. Although the two cheetahs have different personalities, they have the same preference for activities. The device should follow minimal AZA (Association of Zoos and Aquariums) laws applicable to enrichment toys and will be used during the Zoo's Keeper Talks, a daily discussion for patrons that lasts for about 15-30 minutes.



preferences enrichment toys

Figure 1: Current ball used by the Zoo

Existing Solutions:

- Zipline Lure
- Stationary, rigid, plastic toys (Ball Toy)
- Hand Lure

The existing solutions for moving cheetah toys all require a large open space and proximity between the keepers and the cheetahs. However, the keepers cannot safely be near them, and the cheetahs cannot be let outside of their enclosure.

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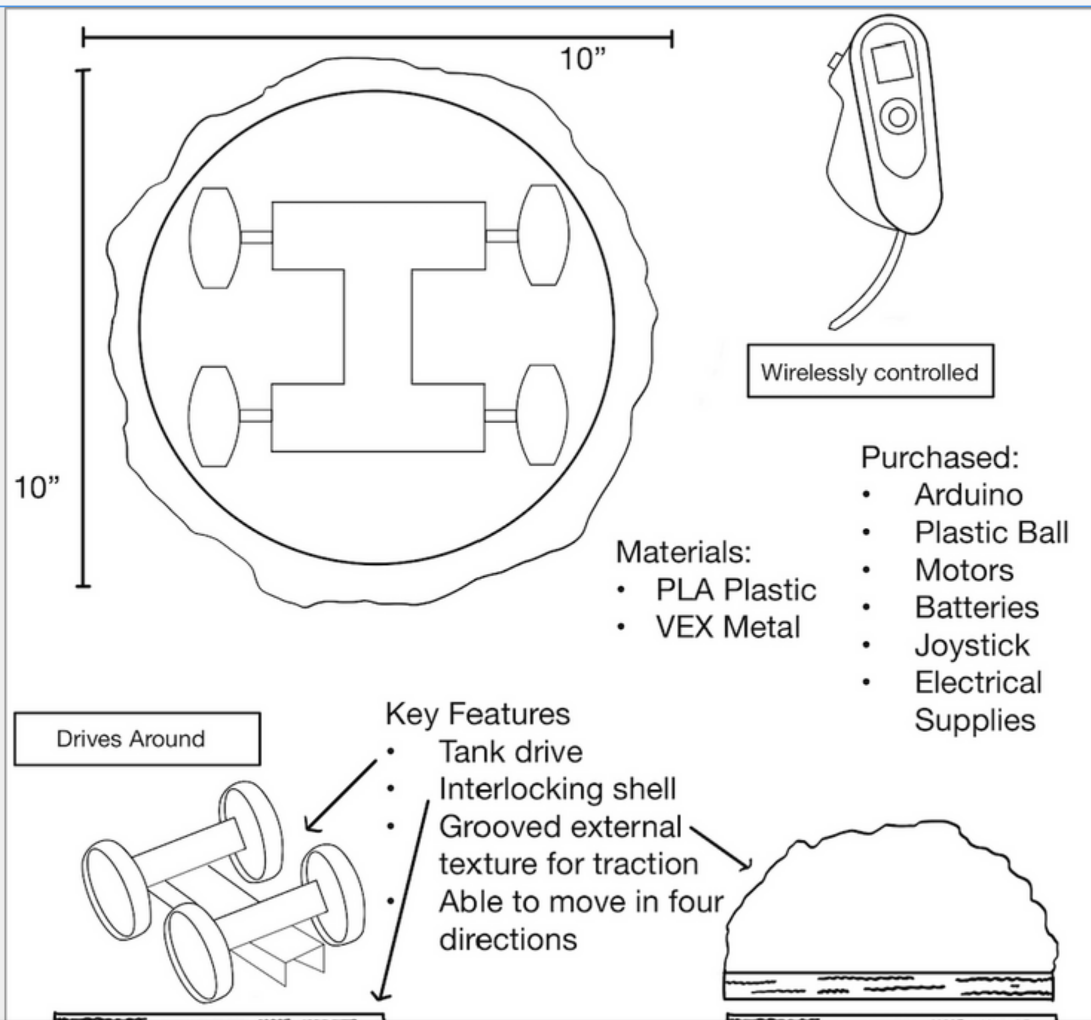
Last Semester Solution:
Design features a wirelessly controlled, rechargeable, and resilient ball intended as an enrichment toy for cheetahs. Key design choices include a wireless single-hand joystick controller, a four-wheel drive mechanism, internal electronics powered by an Arduino, and a shell with nubs for enhanced traction, secured with a simple interlock mechanism.

Issues:

- Shell was too weak
- Electronics were too bulky
- Sizing compatibility issue with the shell and the drive

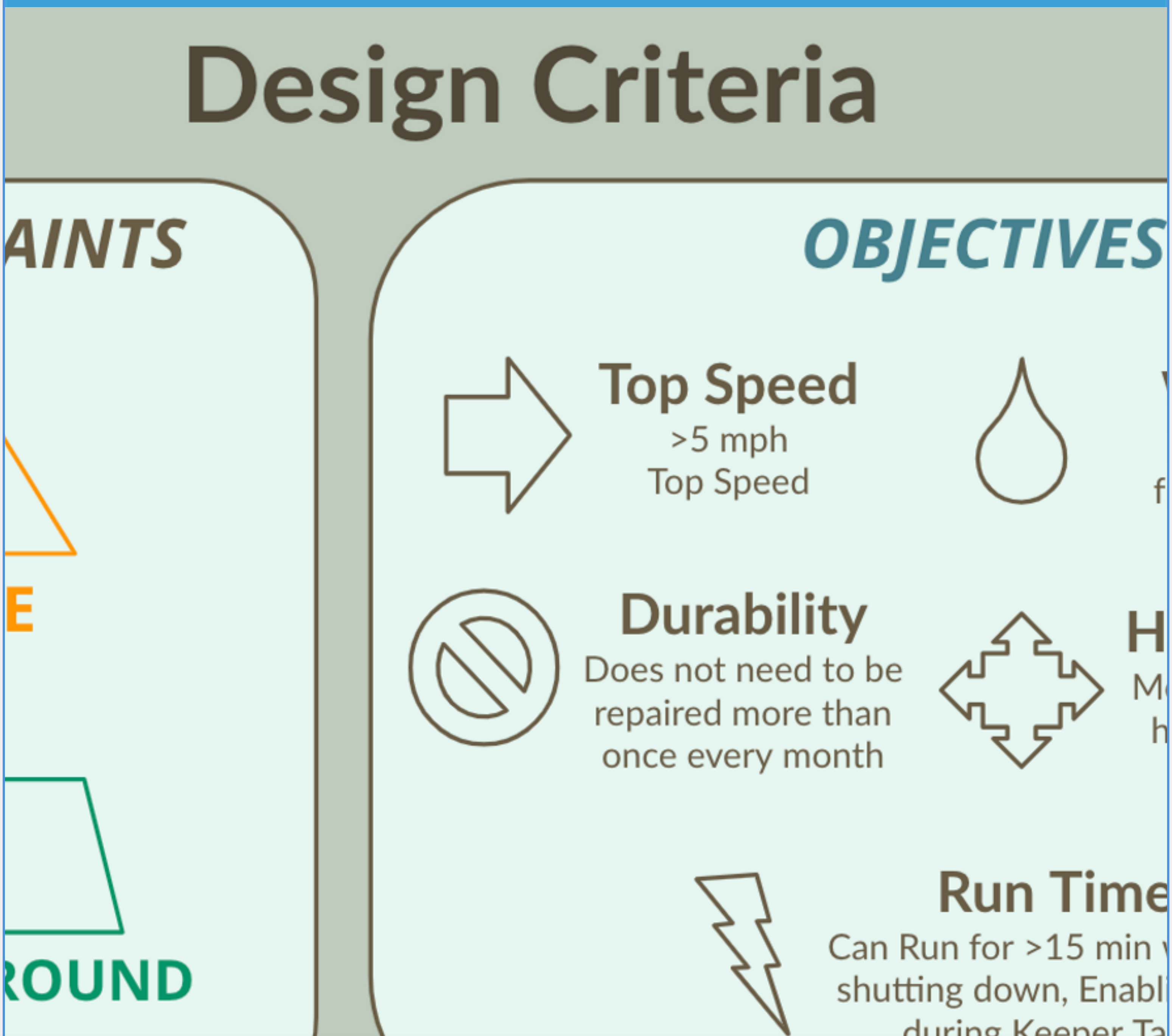


Prototype Drawing

Fasteners:

- Necessary adhering methods for electrical components and wheels
- Interlocking mechanism

Design Criteria and Brainstorming



Constraints:

- **Safety:** Design must not harm the cheetahs
- **Mobility:** Device must be able to move around and engage the cheetahs

Objectives:

- **Top Speed:** Must be able to move more than 5 miles per hour to enrich the cheetahs, as they do not need to hunt, and it is only meant to encourage more movement
- **Waterproof:** The cheetah enclosure has a body of water, so if the device falls in accidentally, it shouldn't damage the electronics
- **Durability:** Used in their exhibit, and the mechanisms should not need repairs more than once a month for ease of the zookeepers
- **Handling Terrain:** The device should handle the different terrains within the enclosures and be able to move up and down the hills and valleys in the exhibit
- **Run Time:** The device is meant to be used during Keeper talks, which last at least 15 minutes

Shell Design

Increased Size

Print Orientation

Electrical System

Motor Control Board

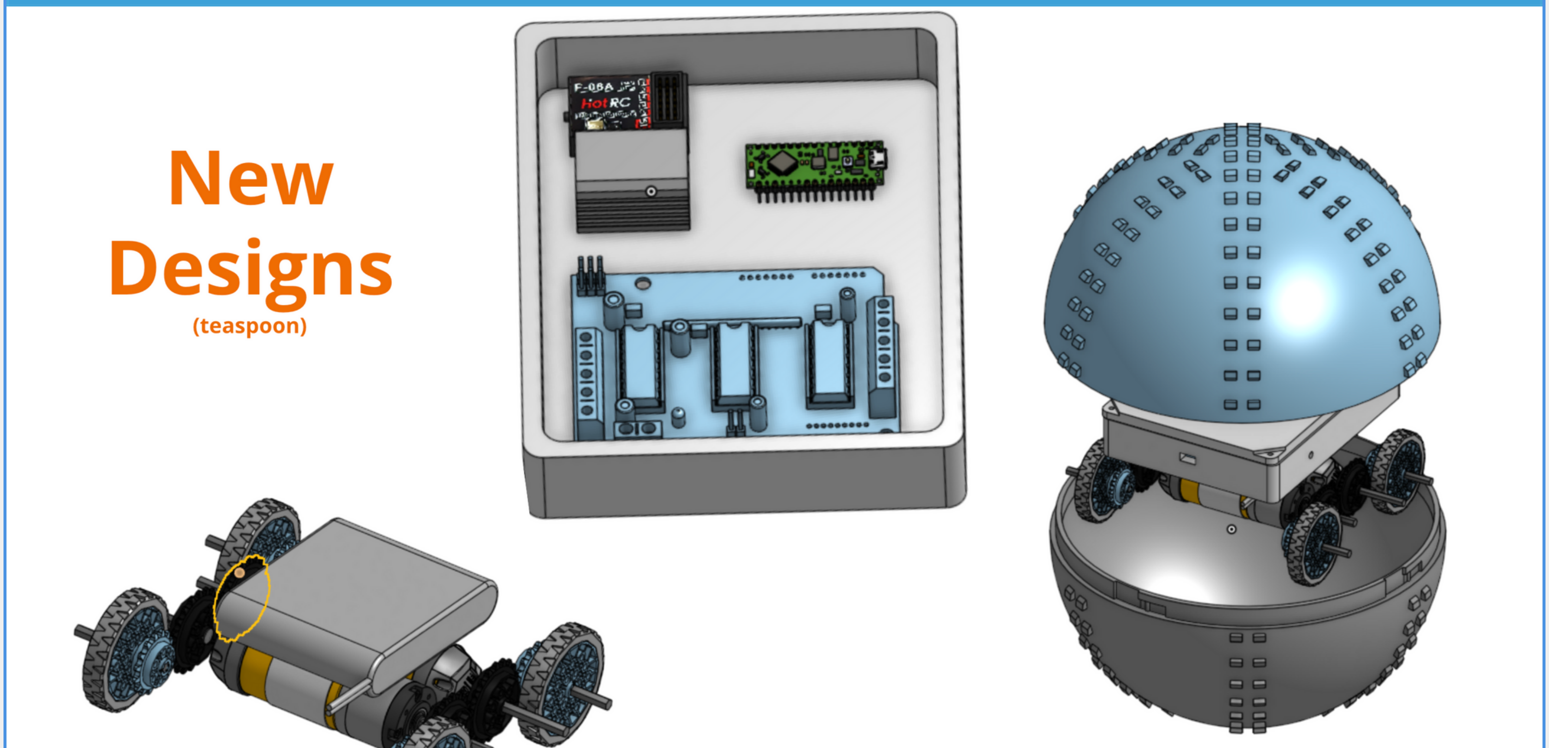
PWM output

Brainstorming Improvements:
Instead of developing an entirely new solution, we built upon the previous semester's prototype, which, despite not functioning perfectly, provided a solid foundation for improvements. We focused our brainstorming on refining and enhancing key components of the design, informed by our background research, rather than starting from scratch.

We did one round of brainstorming and split it into four different categories:

- Shell interlock
- Materials
- Electrical System
- Drive Mechanism

First Iteration



New Design CADs: driving mechanism, electronics, and shell design (from left to right)

Proposed Solution & Changes
The core of our design remains largely unchanged. The device will be a wirelessly controlled, rechargeable, and durable enrichment ball for cheetahs, designed to stimulate natural behaviors and track location data for zookeepers. Key features include a wireless single-hand joystick controller, a four-wheel drive system, Arduino-powered internal electronics, and a textured shell with nubs for enhanced traction, secured by a simple interlock mechanism. To refine last semester's prototype, we've upgraded the motors and electronics. As a result, the shell will increase in size to accommodate these improvements to the electronics and driving mechanisms.

Substantial Iterations
With new electronic components, we've streamlined the system, reducing the bulk above the driving mechanism. This should resolve previous size compatibility issues between the shell and driver.

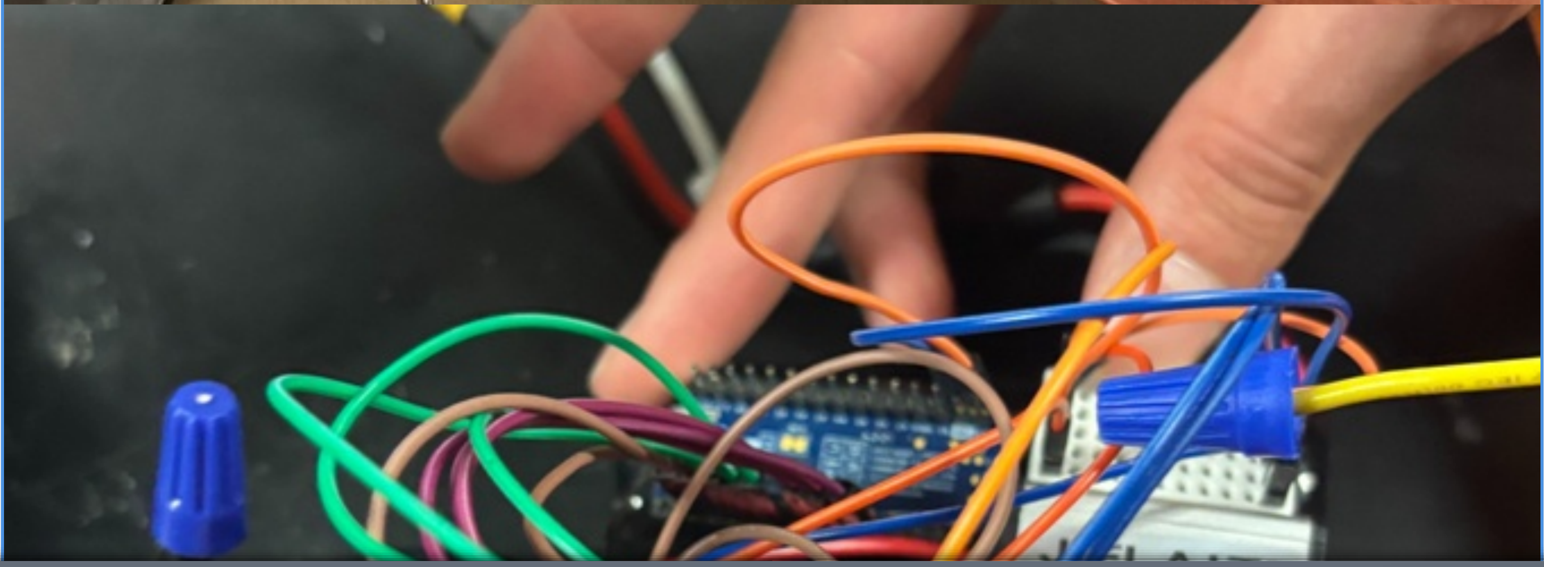
We iterated through several generations of 3D-printed shells using different materials and interlocking methods. While the drive mechanism's structure remained consistent, its components became more precise and specialized. Starting with paper and laser-cut wood prototypes, we progressed to a 3D-printed drive frame featuring prefabricated holes for motor mounting and a bearing through-hole.

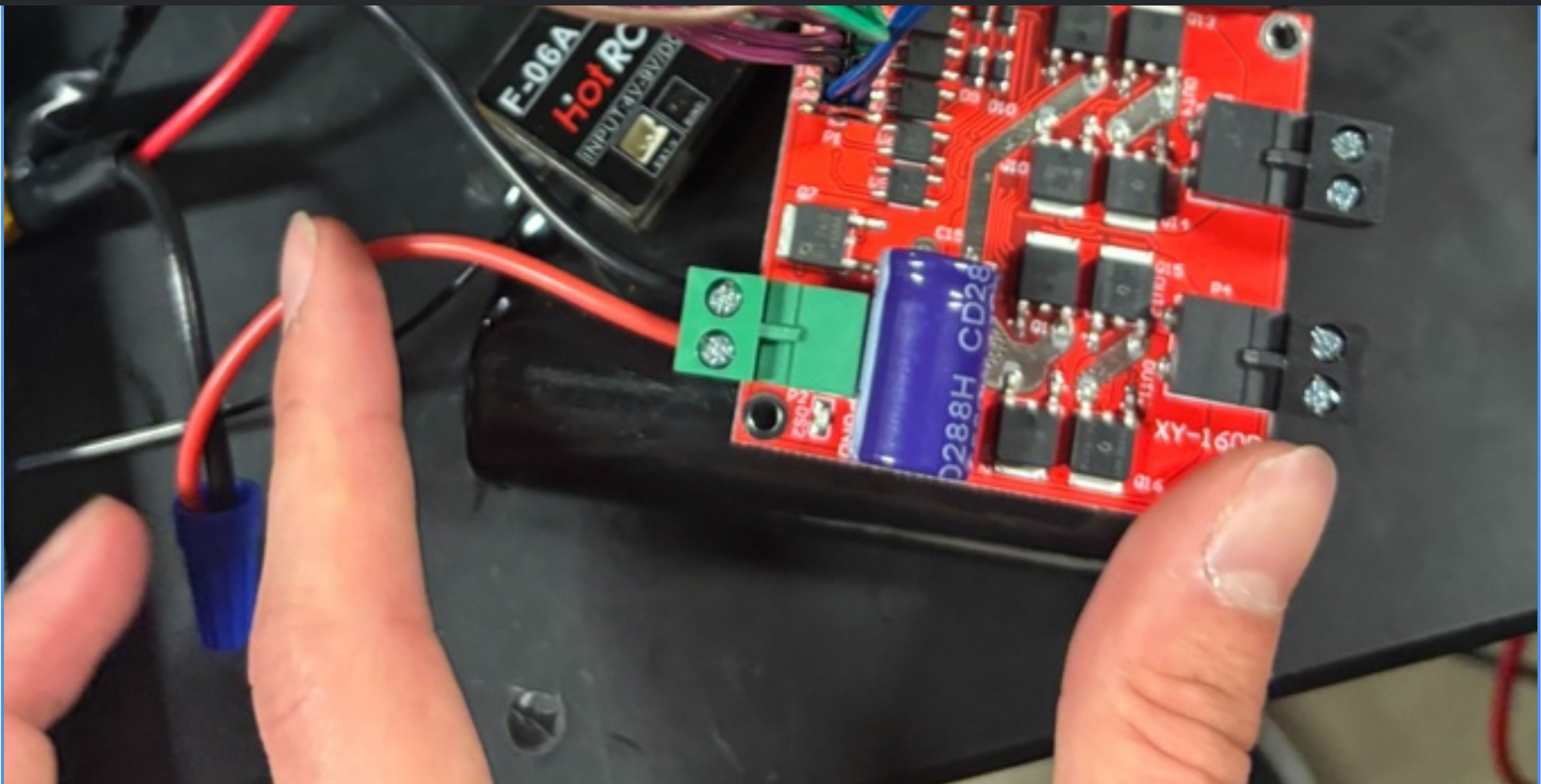
Initially, we tested small resin shells but discarded resin due to manufacturing difficulty. TPU offered better collision resistance, so we printed larger versions, though they proved too flexible. This led us to test ABS shells, which locked poorly but were durable in drop tests. We improved their interlocking by using screws on both halves. After consulting with our client, ABS was selected as the preferred material, and we are now printing a 13" shell in ABS.

We evaluated other manufacturing methods like CNC machining and injection molding but chose to continue 3D printing for its convenience and low cost. With access to larger printers, we plan to further explore TPU shells at scale

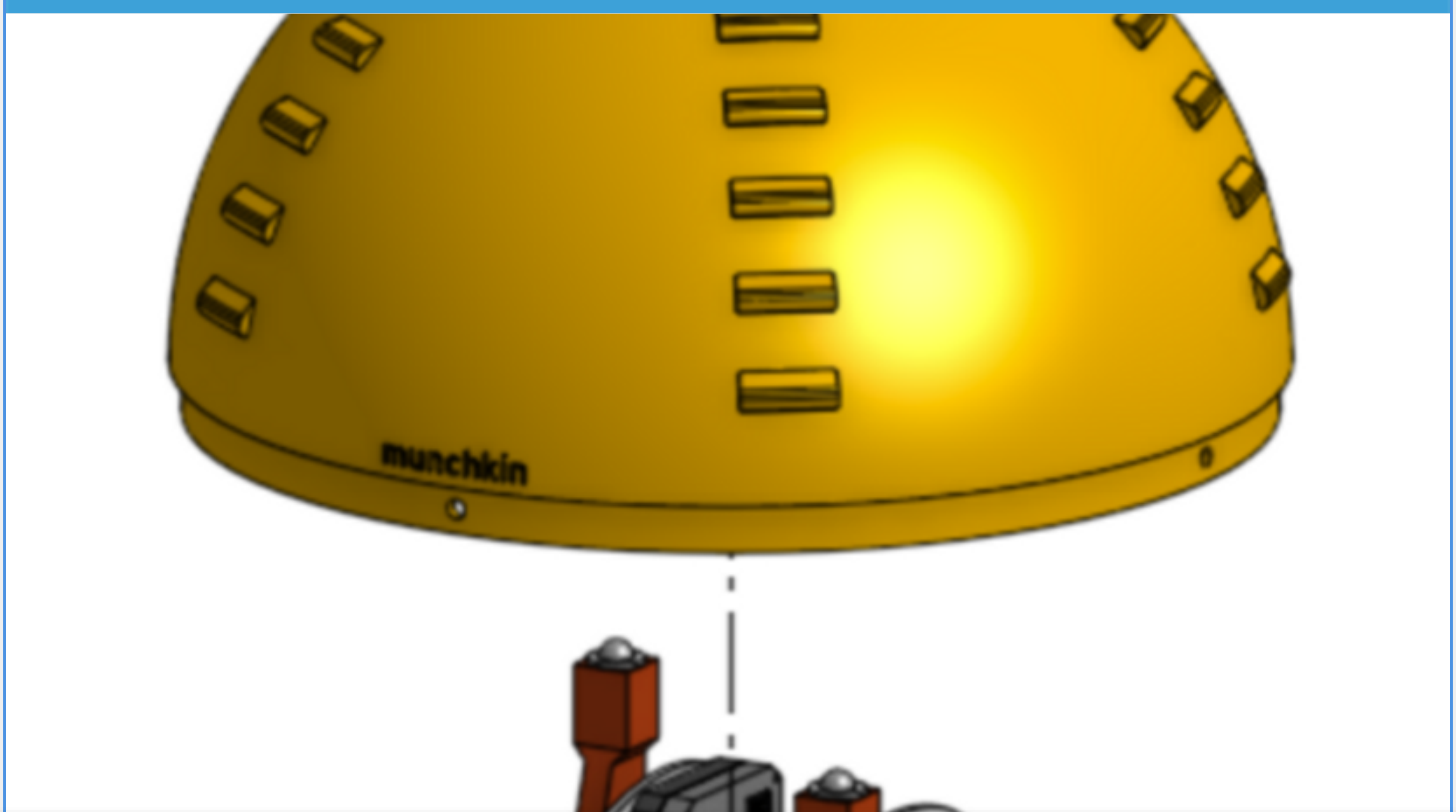
Using the water jet to create the frame for the driving mechanism

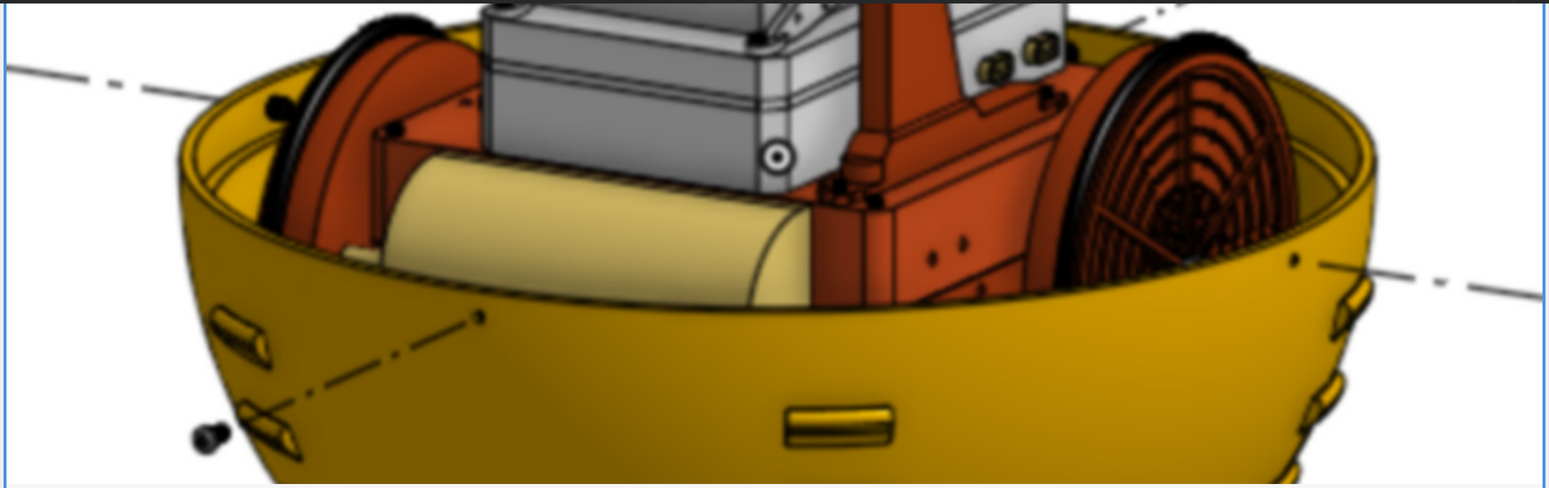
All the shell iterations lined up



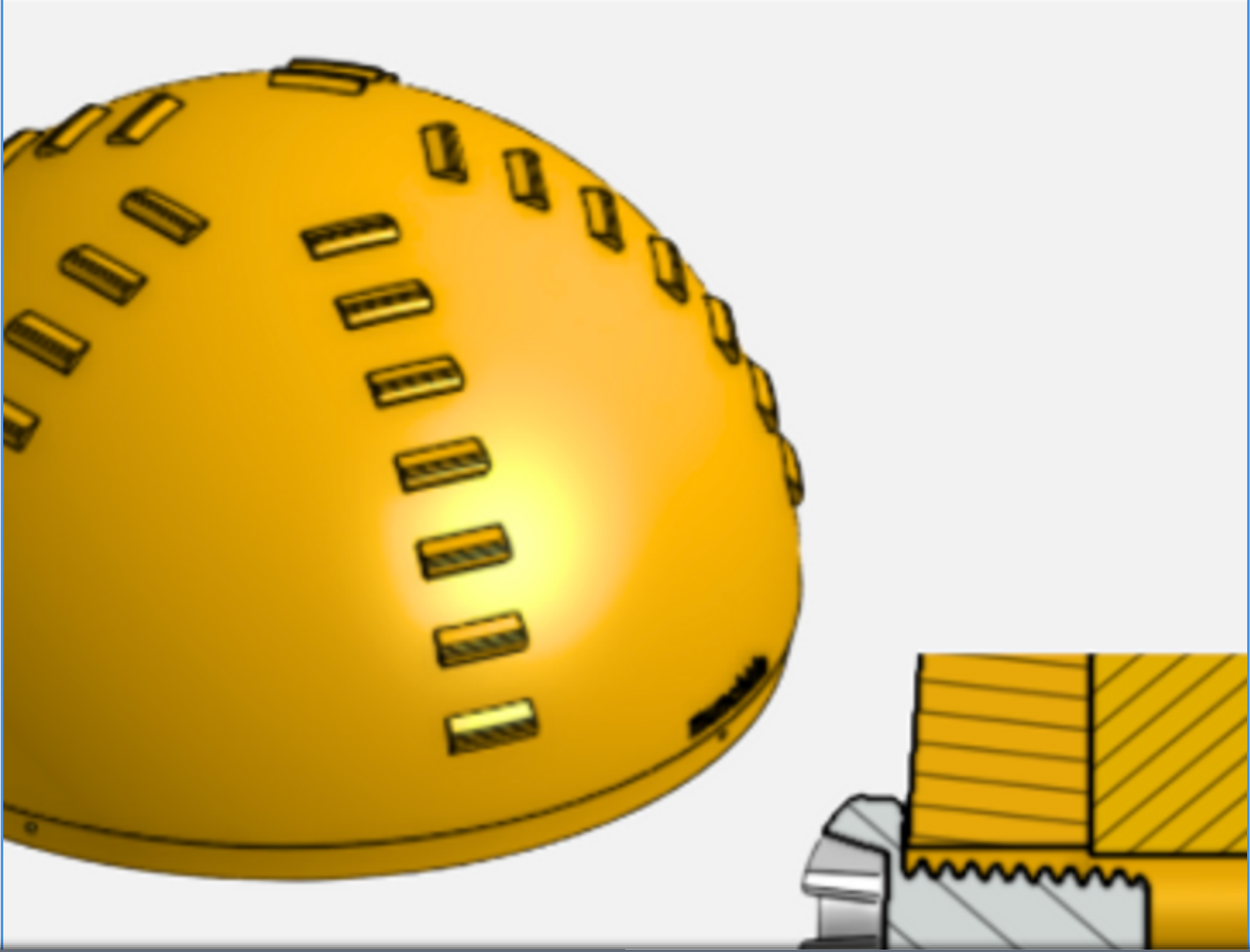


Final Design





Shell Design
The shell is 3D printed from durable ASA plastic and features an interlocking and screw mechanism for secure assembly. Ridges along the surface provide added grip on uneven terrain, while contact rollers at the top offer two additional points of stability. The internal diameter of the shell measures 10 inches.

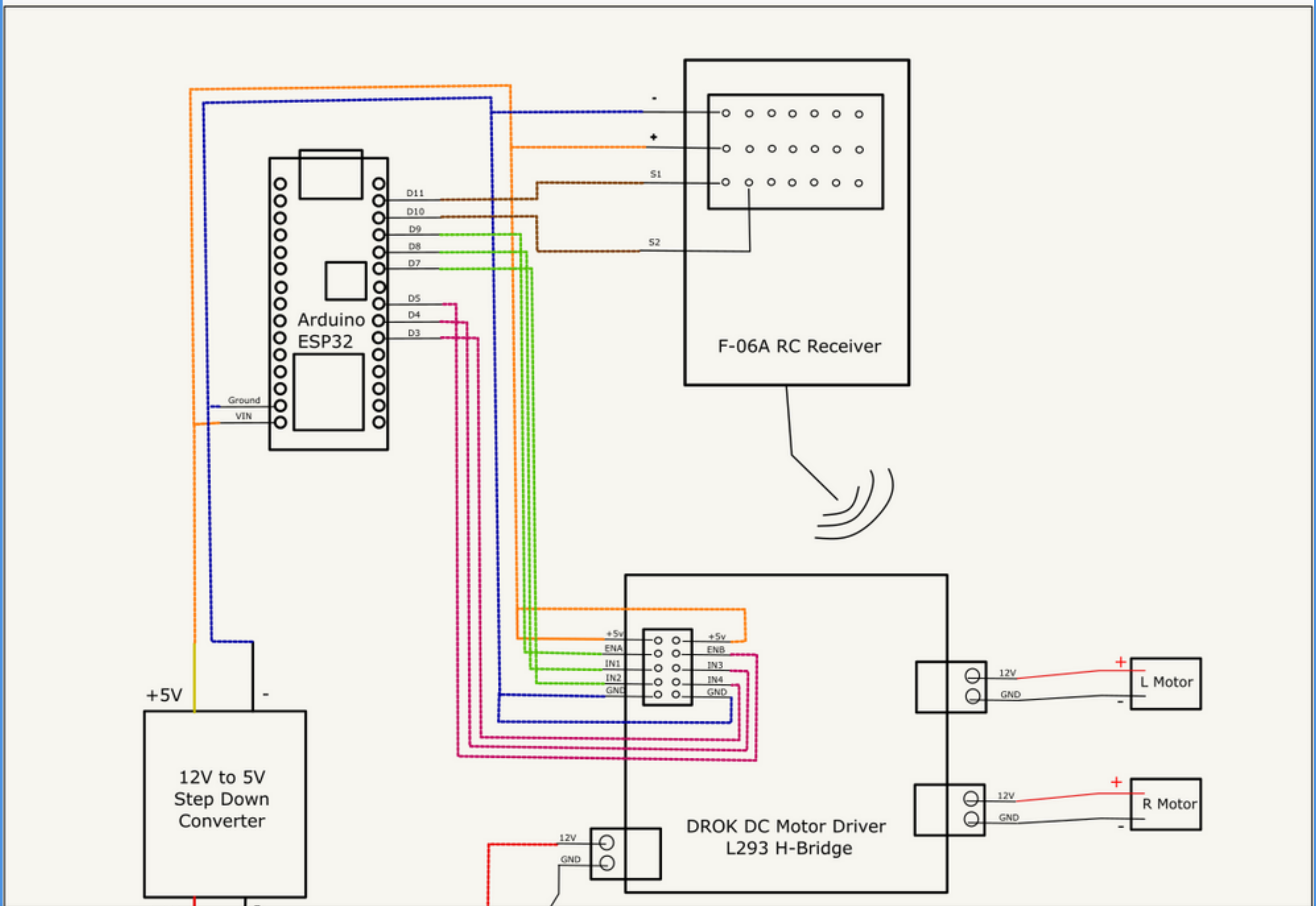


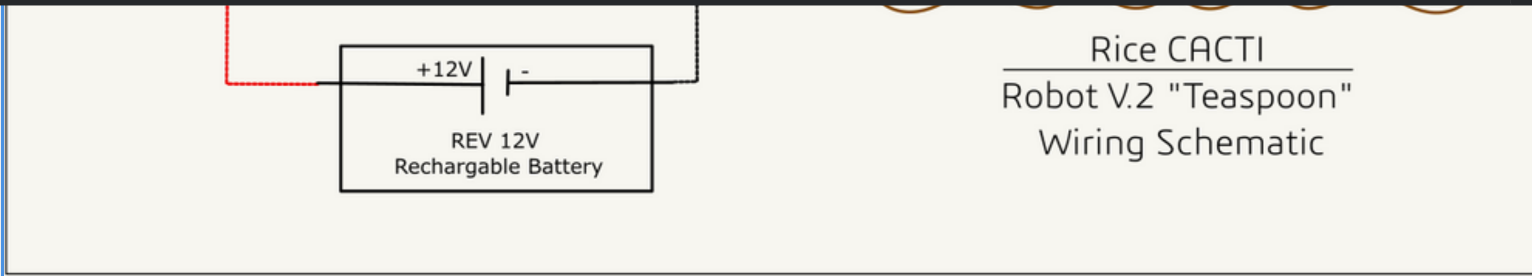
Electronics

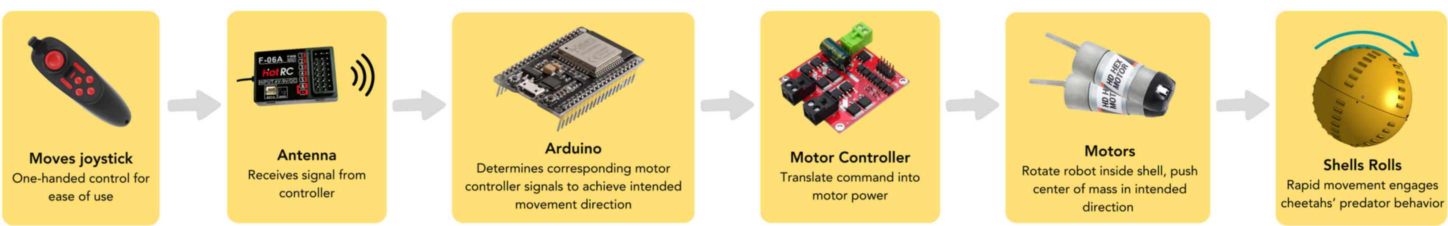
A 12V REV FTC battery powers the motors and entire electronic system, but since not all components can handle 12V, a step-down converter reduces it to 5V for sensitive parts. Only the motors and resistor remain on the high-voltage circuit.

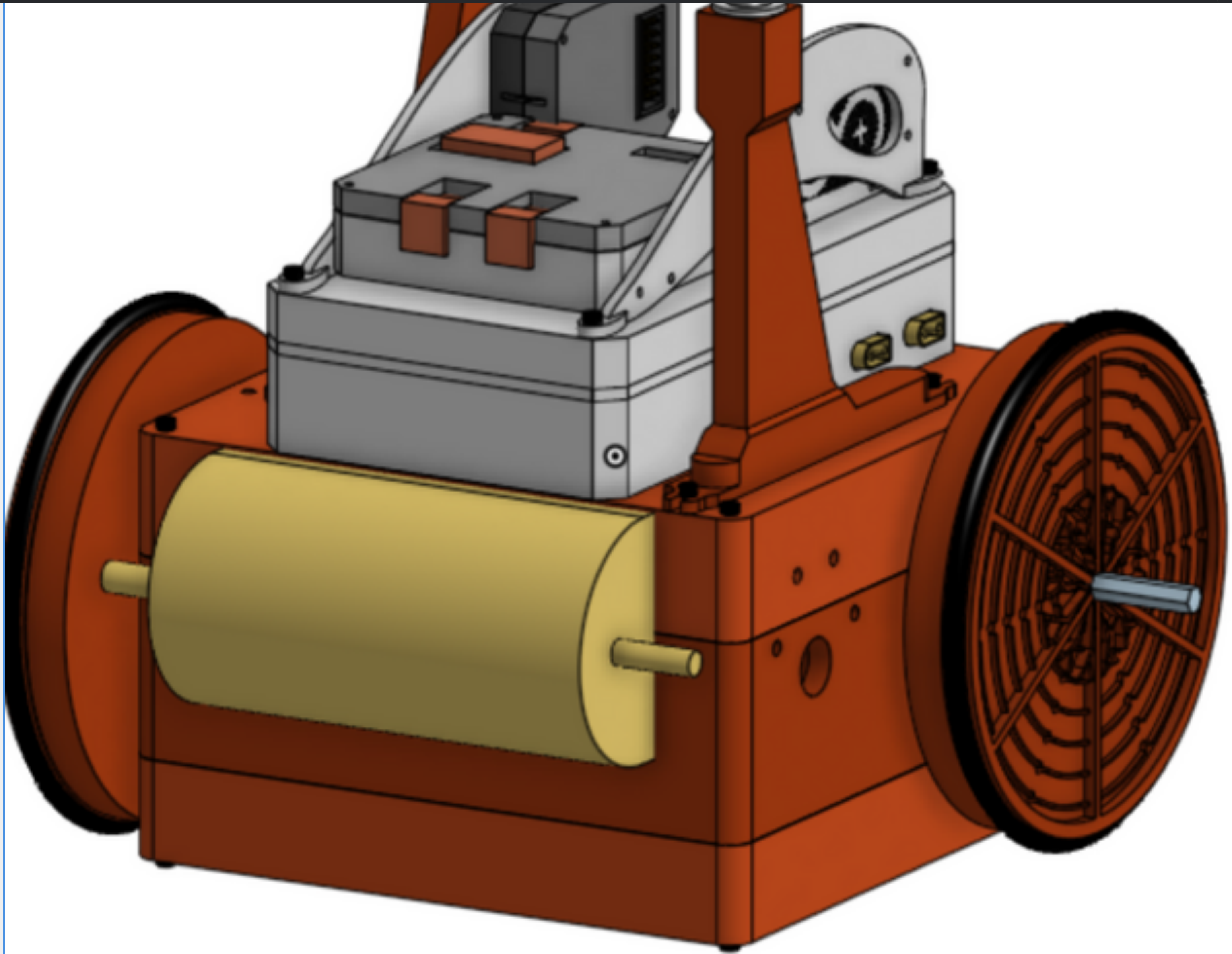
Key components include the Arduino, H-Bridge (L293D), and RC Receiver. The receiver collects forward/backward commands from the controller and sends them to the Arduino, which translates them into H-Bridge commands. The H-Bridge then controls motor direction, power, and throttle.

A 1-ohm, 200W resistor limits motor current to 12A, sufficient for full performance while safely dissipating up to 144W.
We also CADed and 3D printed a protective electronics box (excluding the receiver), with openings for battery and motor wiring.




+12V
-
REV 12V
Rechargable Battery
Rice CACTI
Robot V.2 "Teaspoon"
Wiring Schematic

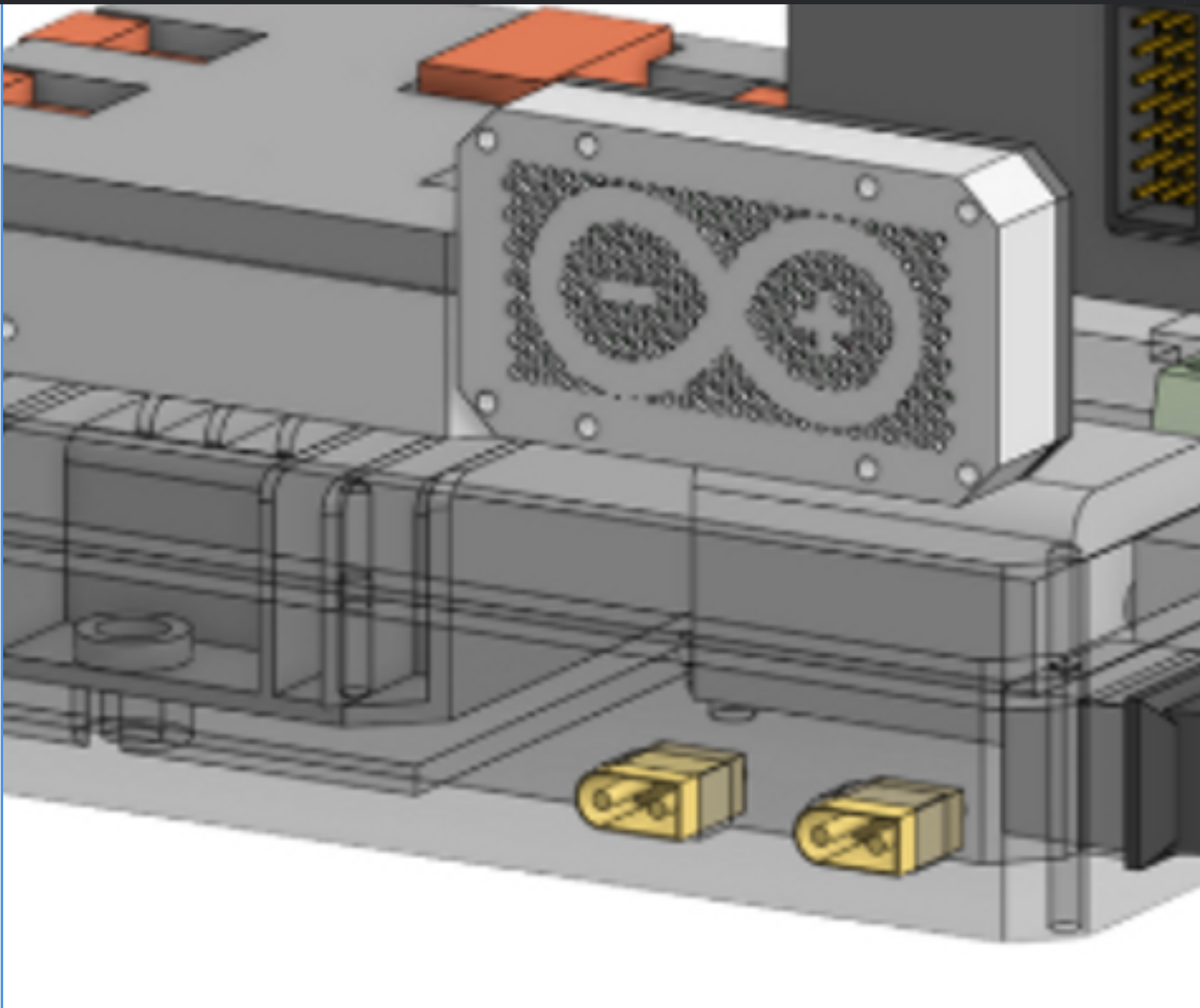

Moves joystick
One-handed control for ease of use
Antenna
Receives signal from controller
Arduino
Determines corresponding motor controller signals to achieve intended movement direction
Motor Controller
Translate command into motor power
Motors
Rotate robot inside shell, push center of mass in intended direction
Shells Rolls
Rapid movement engages cheetahs' predator behavior



Drive Mechanism
The system is powered by a 12V rechargeable REV battery, which offers a simple three-step process for powering or charging and provides approximately two hours of runtime. Its placement also helps lower the robot's center of mass for better stability.

The drive mechanism uses 12V motors connected to 4.5 x 0.3-inch 3D-printed TPU wheels for improved traction. It supports forward, backward, and turning movements, with unpredictable motion patterns designed to engage the cheetahs. All electronics— including the power distribution system, Arduino, MCU, and antenna—are housed in a protective enclosure that allows for easy access and shields components from impact.

The device is controlled using a one-handed RC boat controller, which wirelessly sends movement signals to the internal electronics. With a range of over 50 feet, it allows full control of the device from anywhere within the cheetah enclosure.



Cheetah Enrichment Toy for Houston Zoo

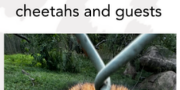
RICE | OEDK Oshman Engineering Design Kitchen

CACTI: Anika Gupta[1], Cassidy Chhay[2], Clay Goldsmith[3], Tyra Helper[1], Ian Schechter[1]

Mechanical Engineering,[1] Cognitive Sciences,[2] Astrophysics[3] | *cactirice@gmail.com*

Cheetah Enrichment Background

- In the wild, cheetahs hunt to be fulfilled, but they can't do this in enclosures at the Houston Zoo
- Goal is to mimic prey, allowing cheetahs to chase, survey, exhibit natural behaviors
- Designed for 15-min "Keeper Talks" to engage cheetahs and guests



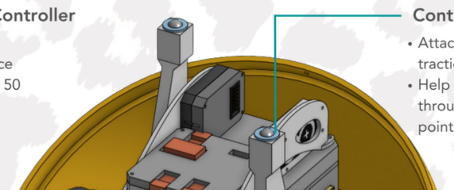
Problem Statement

Our objective is to

Enrichment Ball (TIM) - Final Design and Evaluation

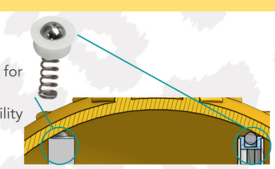
RC Boat One-Handed Controller

- Sends signals to the internal electronics to move the device
- Connects to robot from over 50 ft away, allowing it to travel within the enclosure



Contact Rollers

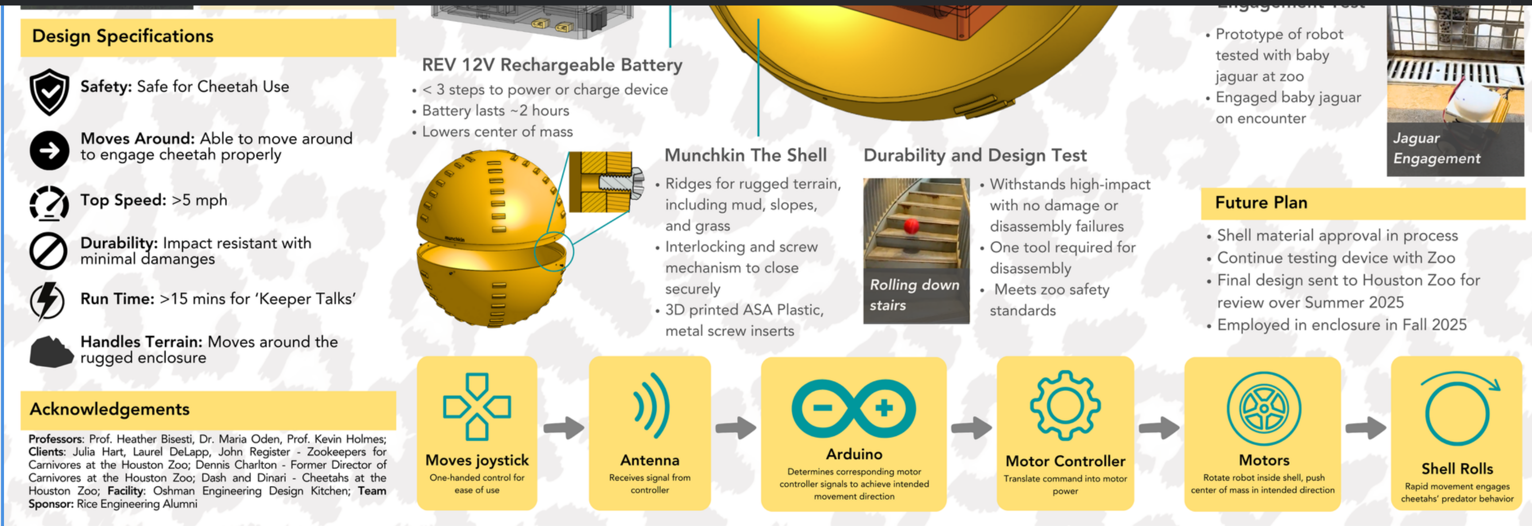
- Attached to spring for traction on shell
- Help maintain stability through two extra points of contact



Electronics Housing

Drive Mechanism

- 12V Power Motors attached to 4.5



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Testing and Future Iteration

The device has undergone multiple rounds of testing, including drop tests and mobility trials, to evaluate durability, traction, and electronic performance. After testing the full device in the enclosure, we found it had difficulty moving across the terrain because of the muddy soil and tall grass. To address this, one key future iteration involves adding more weight to increase stability, as well as potentially refining the shell design to improve traction. These insights are guiding continued improvements to stability, controller responsiveness, and material choices to better suit the cheetah environment.

Future Involvement

We are maintaining ongoing communication with the Houston Zoo as we continue to refine the device. The final handoff is planned for the end of the semester, with the goal of having the toy approved and ready for the cheetahs to use this summer.