Cheetah Enrichment Toy Documentation

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Oshman Engineering Design Kitchen

RICE ALUMNI
REA

Table of Contents:

1. Background

In the Intro to Engineering Design course, August 2024 - December 2024, we focused on the engineering design process, researching, documentation, and brainstorming. The Background section of this document covers most of this preliminary information that we gathered before starting the prototyping process.

1.1 The Team

We are Team CACTI, an undergraduate engineering team from Rice University working to build a cheetah enrichment toy for the Houston Zoo. Dennis Charlton pitched the idea to us in fall of 2024. In the spring, we continued this project through the Engineering Design Studio class, where we gained another member and were able to make much more progress on the project.

Our team has five members. From left to right in the image below:

Clayton Goldsmith (Astrophysics, Martel College '27) Electrical System and Code Lead; **Tyra Helper** (Mechanical Engineering, Sid Richardson College '28) Drive Mechanism Lead; **Cassidy Chhay** (Cognitive Sciences, Martel College '25) Documentation and Team Organization Lead; **Anika Gupta** (Mechanical Engineering, Martel College '28) CAD and Shell Manufacturing Lead; **Ian Schechter** (Mechanical Engineering, Sid Richardson College '28) Communication and Integrated System Lead.

1.2 Research

Initial Problem:

Due to changes in Houston Zoo Policy, the two cheetahs, Dash and Dinari, are unable to leave their enclosure for enrichment purposes. Dash and Dinari are easily engaged by enrichment toys and activities, but their interest fades more rapidly than that of other species. While the cheetah brothers do not need to run or hunt, zoo staff are interested in finding ways to stimulate them and promote hunting behavior for patrons to observe during Keeper Talks.

Interview and Outside Research Notes:

We set out to design a durable, remote-controlled enrichment ball for cheetahs that stimulates their natural hunting, chasing and surveying behaviors. Existing enrichment fails to hold the cheetahs' attention for long, thus our goal is to sustain interest and promote physical activity in a small enclosure. The device must comply with safety and regulations, and has the potential to be used with other animals.

Dash is active and loves motion (e.g. looking at cars), while Dinari has eye problems and is calmer. Cheetahs exhibit behaviors such as zigzag chasing, pouncing, and chewing, though they don't typically lift or carry objects. Their teeth, which range from 2 to 4 inches long, are sharp but prone to breaking. They stand about 3 feet tall on all fours and reach up to 6 feet when standing. Their paws are roughly the size of a human hand. They are about as physically destructive as a typical dog.

To avoid choking risks, the ball shell needed to be between 6" and 2 ft diameter, to be safe to bat and avoid choking risk. The ball should be heavy enough for stability but light enough to move and bat safely. The material should be hard, non-porous plastic to be safe and easy to clean, with no rubber or breakable components, and no holes or tight spaces that could trap teeth.

For our initial design, we decided that the enrichment ball needed to be remote-controlled with a range of at least 50 feet, though optional randomized autonomous movement could help maintain the cheetahs' interest when keepers aren't present. It should reach speeds of around 10 miles per hour, with variable speed control for flexibility during use. The ball must be capable of navigating grassy terrain, climbing slopes, and exiting water, requiring sufficient traction and ideally the ability to float or otherwise avoid getting stuck in the exhibit's pool. Additionally, the shell should be weatherproof (sun, rain, wind), and /or be able to protect the electronics from slobber, water, and rough play.

The internal components of the enrichment ball should be completely inaccessible to the cheetahs to ensure their safety. However, the ball should be openable—such as through a screw panel or similar mechanism—to allow for maintenance, repairs, and access to internal electronics. A rechargeable battery is required, with an easily accessible charging port to ensure smooth operation and daily use.

The cheetah exhibit spans approximately 50 feet from front to back and is enclosed with mesh fencing. It contains a mix of grass, slopes, rocks, logs, trees, and a pool that is drained during the winter months. When not in use, the ball will be stored indoors. The exhibit is fully exposed to weather. A flat area near the front is ideal for keeper demonstrations, while the backyard space includes more sloped terrain that the ball must be able to traverse.

To ensure safety, the ball should not reach speeds that could cause injury to the cheetahs or damage the enclosure upon impact. Excessive weight could also pose a hazard or make interaction difficult for the animals. While autonomous movement may help stimulate the cheetahs, it introduces risks such as getting stuck or startling the animals if not carefully designed. The ball must be constructed to prevent tooth damage—avoiding trap points, weak spots, or porous materials that could be chewed through. Additionally, loose or breakable parts must be avoided to eliminate choking and ingestion risks. The device should withstand various weather conditions. It must also be easily disinfectable after use.

We drew inspiration from similar products such as the Sphero Ball or a hamster-in-a-ball design, which both involve an internal drive mechanism within a rolling shell. The "Cheetah Lure," is the most effective existing option, a wench and pulley system that drags prey-like objects across a field, simulating a chase.

1.3 Problem Statement

Before moving on to brainstorming, we designed a problem statement to define the purpose of our project.

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.

To clarify our problem statement, our main objective was to create a remote controlled ball that would move around the cheetah exhibit at the Houston Zoo, giving them something to chase and hunt within the exhibit. This will help enrich the cheetahs and improve their physical and psychological health.

1.4 Design Criteria

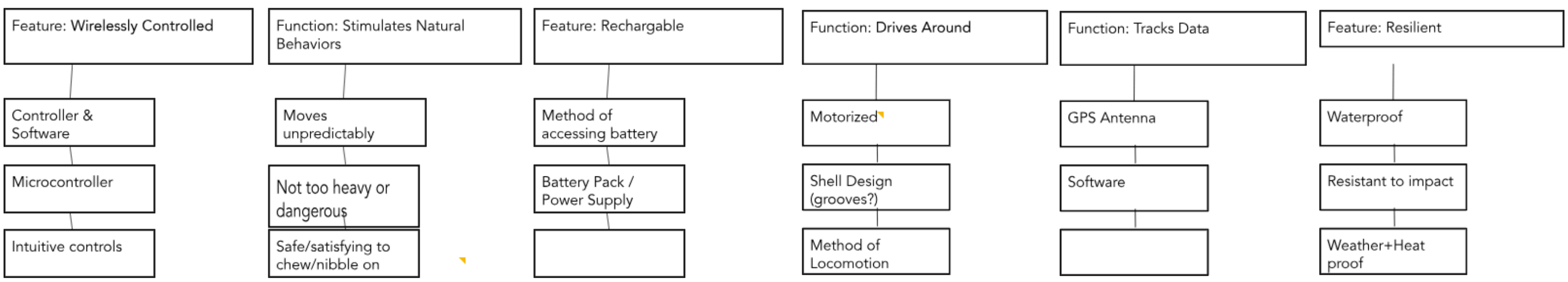
Design criteria are the specific requirements or guidelines that a design solution must meet to be considered successful and effective. Ours are divided into two categories: Constraints and Objectives. Constraints are project requirements, while objectives are goals to be achieved.

Design Criteria Chart		
Goal	*Measure*	*Reasoning*
Constraints		
Safety	Must be safe for cheetah use	Must be approved by the Zoo and not endanger the cheetahs
Mobility	Able to move around the enclosure	To engage cheetah properly
Objectives		
Top Speed	5 mph	Given the size of the enclosure and the fact that the cheetahs do not need to reach their top speeds, the ball must still move fast enough to effectively engage them. A top speed of 5 mph allows the ball to mimic the quick, unpredictable movements of prey, encouraging natural chasing and stalking behaviors in a safe and stimulating way.
Durability	Impact resistant	Be able to handle impact from terrain and cheetah
Run Time	>15 mins	'Keeper Talks' are about 15 minutes long, so the toy will need to last at least that long to be effective
Handles Terrain	Moves around the rugged enclosure	Be able to move around the front of the enclosure that has long grass, rocks, etc.

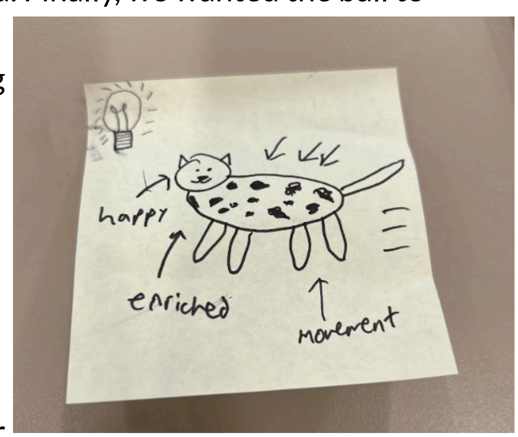
1.5 Choosing The Final Design

We spent a long time in the design process during the fall semester. Since we started this process in an introductory class, we filled out engineering design tables given to us by our professor. Our tables are linked here, and the video playlist detailing the engineering design process we followed is linked here.

Our brainstorming is summed up in the table below.

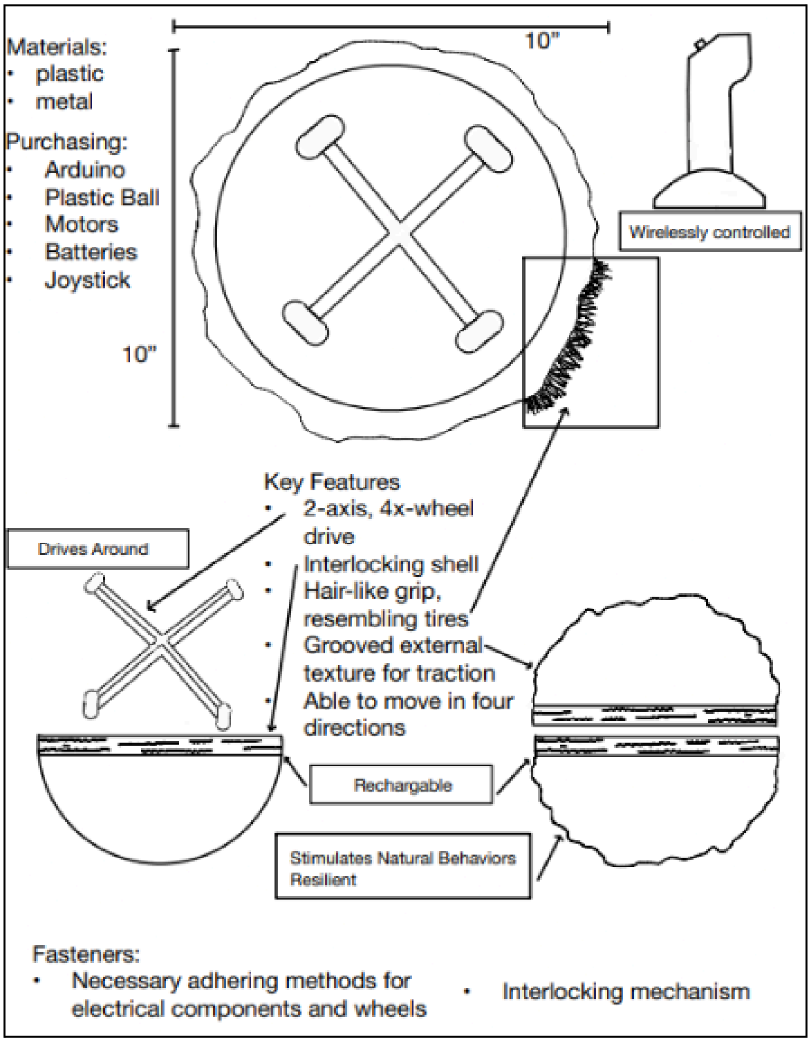


We wanted to make a wirelessly controlled mobile ball that was capable of traversing the cheetahs' enclosure. In order for it to be wirelessly controlled, it would need a controller that could connect to some hardware and be programmed to run from outside the ball. We would need a suitable microcontroller for this. Additionally, we wanted to have the controller be intuitive for the keepers. The next feature is rechargeability, which is important because we didn't want the zoo to have to change out batteries or worry about repeated disassembly. In order to fulfill this criterion, we would need a method of accessing the battery and a battery that can be recharged. Finally, we wanted the ball to be resilient, withstanding cheetah play and the environment. Ideally, it would last a year without needing repair so that it wouldn't use up zoo resources and time. As the enclosure is outdoors the ball would need to withstand Houston's weather conditions. Cheetahs aren't very violent, so we were comfortable with making or buying an existing ball that would withstand batting, chewing, and rolling.



We wanted the ball to stimulate natural behaviors, as our main goal is to help improve the cheetahs' health. Cheetahs enjoy watching and chasing unpredictable movement. To engage the cheetahs, we wanted our ball to move dynamically, make it lightweight enough that they could bat it around, and interesting for them to chew and rub on. In order for the ball to drive, we wanted it to be motorized in some way and have a shell design that can handle the environment. The robot would need enough force to push the ball forward in tall grass and mud, and having a high-traction outer surface would help with that.

Using various brainstorming and scoring methods including a Pugh Screening Matrix, we generated many designs and then settled on one. Our winning design had a one handed joystick for control, a 2 axis four wheel drive base design, tire type grooves on the outside of the ball, and an interlocking shell mechanism. The design is shown in the diagram to the left. This solution scored the highest due to many factors. The drive mechanism was one of the lightest options due to fewer motors and a smaller frame than other designs. We were unsure of whether or not this design would be possible to build, but the actual drive mechanism was something we could change during the prototyping process. The robot would be rechargeable and move in four directions, allowing flexible movement and intuitive control. A strong interlocking mechanism would ensure that the product was durable, resilient to cheetah use, and was easy to use. Also, the interlocking mechanism was something we could 3D model and then print at the OEDK, rather than having something more complex that we had to manufacture externally. The outer grooved surfaces fulfilled our goal of having an interesting texture traction on the outside of the ball. We chose the controller to be a single handed joystick, as that allowed for flexibility and ease of use for the keepers.



Based on this design, we planned out a prototyping process and began prototyping. Our final design ended up radically different from this initial draft, but we made many important design decisions during this stage of the design process that are fundamental to our final design.

1.6 Prototyping Process

Due to issues in early prototyping of the two axis four wheel drive mechanism, we pivoted to a tank drive design for the internal robot. This robot proved able to pivot and

1.7 Testing

Testing was done based on the Design Criteria Chart. Click this link to see testing video footage. These are the following tests our team performed, and the results:

Test		**Description**	**Success/ Failure**	**Notes**
Shell Durability Test	Drop Test	Shell dropped down stairs (two locations)	Success	Interlocking mechanism kept shell together, no visible cracking or damage
	Movement and High Impact Test	Interlocking mechanism kicked (high impact) on grass	Success	Interlocking mechanism kept shell together, no visible cracking or damage
Engagement Test	Preliminary Engagement Test	Just robot movement, baby jaguar behind fence, moved robot to see if animal was engaged	Success	Movement attracted the jaguar from a distance away
	Cheetah Shell Interest Test	Just shell (no robot) in enclosure, zookeepers put meat on the shell to attract cheetah initial interest.	Success	Cheetah engaged, smelling and rubbing against the shell
Mobility Test	Robot Movement	Does the robot move	Success	The robot moves, matching the controls features of

				the remote (up → forward, down → back, left, right, etc)
	Smooth Flat Terrain Tests	Integrated device moves on smooth flat terrain (concrete) - multiple tests	Success	Initial testing showed that the ball moved, after testing on different terrains, added weights aided in control of the robot and movement
	Short Grass	Integrated device moves on short grass (miltiple test)	Success	Initial testing showed that the ball moved, after testing on different terrains, added weights aided in control of the robot and movement
	Enclosure (long grass, mud, etc.)	Integrated device moves in enclosure (long grass, mud, etc.)	Failure	The device wasn't able to move in the enclosure. It was just wiggling around. We determined it was a weight issue, and added more weights. Previous test were redone with this addition (successful). Further enclosure testing is needed.
Ease of Use (Dis)Assembly Test		Assmebly and disassembly of the the shell interlocking and screw mechanism	Success	Requires 1 tool, not complicated
Signal Processing Test		Confirmation that the controls of the remote compute	Success	It works!

Weatherproof	UV Resistant	Success	The material of the shell is UV resistant!
Waterproof	Paper towels were placed into the shell interior, assembled together, and put into a body of water	Failure	When opened, the paper towels were wet, indicating the interlocking mechanism isn’t water tight. The zoo told us that this isn’t a top priority, as they can drain the water feature in the enclosure.

2. Technical Systems

2.1 Overall Design Explanation

This section is meant to show how to use and repair the cheetah ball. This isn't entirely comprehensive but is intended as a summary of our current product.

At its core, our design functions as a remote-controlled car housed inside a ball—when the car moves, it propels the ball forward. The ball consists of three subsystems: Drive Mechanism, Electrical System, and the Shell.

This section will breakdown how each subsystem works, the code, and CAD files.

The final design, all put together, looks like this:

2.2 Drive Mechanism:

The ball is driven by a mechanism composed of two 12V motors. Each one powers a wheel, arranged so that they are on opposite corners of the mechanism. One wheel on either side of the ball is powered and one is unpowered, meaning the internal robot can roll forwards, backwards and turn as normal. To prevent the internal robot from teetering or flipping inside the ball, two bearings are pressed against the top of the ball on the corners without powered wheels. These act as suspension. The motors are secured with a 3D-printed ABS plastic box that has three layers. The top and middle sections sandwich the motors and have holes that the motors bolt into. The bottom section holds the battery and additional weights to increase the torque of the system.

2.3 Electronics System:

The ball is controlled by a system of electronics detailed **here**.

The main flow is as follows:

1. Signal from the controller is received by RC boat controller that sends out PWM (pulse width modulation) signals to the Arduino Nano Microcontroller.
2. The Arduino interprets these signals and sends further PWM + digital signals to the motor driver.
3. The motor driver controls the flow of power to the motors in the correct direction and speed, making the drive mechanism move.

A REV 12V battery powers the device, providing the current needed to run the motors. However, 12V will overload the arduino and the receiver, so we use a step-down converter to reduce the current flowing to both of them to 5V.

The resistor (the large block on the back of the system) reduces the current going through the motor driver to prevent destructive levels of inrush capacitance from the 1000mF capacitor on the motor driver. This does come with the downside of potentially heating up if run for too long, but did not get warm during our 2 hour continuous test run.

The electronics are connected via a series of custom casings to minimize wiring distance and protect the components.

While we considered implementing something like a PCB to consolidate everything onto 1 board, the wiring system was entirely composed of a small number of large prefabricated boards and so we decided connecting them together in a 3D enclosure like this was a more space-efficient solution. This does come with the downside of potentially increased fragility. It remains to be seen how big of an issue that is; ideally, our electronics should be protected from impact by a shock-absorbing mechanical system but the capabilities of our current design are limited in that regard due to our need to maintain constant pressure against the shell to prevent flipping + increase the traction on the shell.

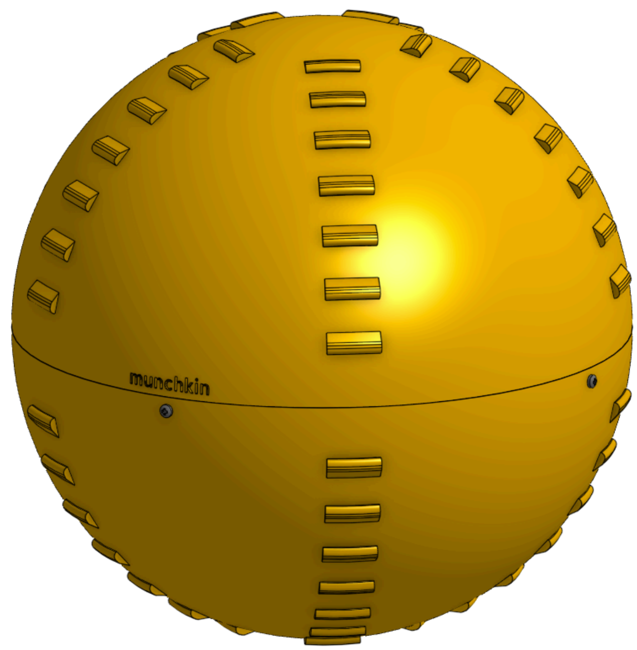
2.4 Code:

A link to the code that runs the entire system can be found **here**.

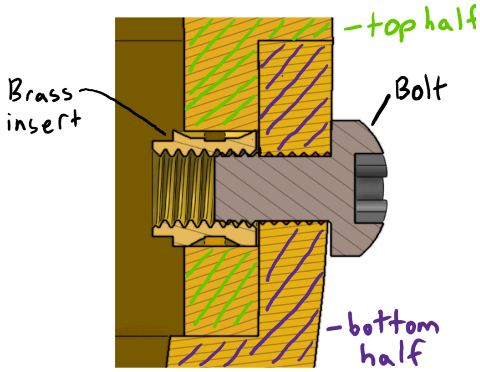
This code operates with three simple steps:

1. Read the PWM signal from the RC antenna. This gives it two different numbers, one indicating left/right direction and the other indicating forward/backwards.
2. Take the larger number as the ‘winning’ direction and the winning speed.
    a. If both numbers are under a certain limit(meaning that the joystick is near the center) then set direction to stationary.
3. Translate that speed and direction into the correct output signals to the XY-160D H-Bridge motor controller.

2.5 Shell:



Having a robot sitting in front of the cheetahs is obviously unsafe, so the shell encloses and protects the entirety of the electronics and drive mechanism. It is modeled after the plastic balls that the cheetahs typically use and made from ASA plastic. When the robot drives, it moves inside of the shell and will push it around. The shell is able to split into hemispherical halves to allow for maintenance, cleaning, and charging. Additionally, the shell can be used as a toy for the cheetahs without the robot inside.

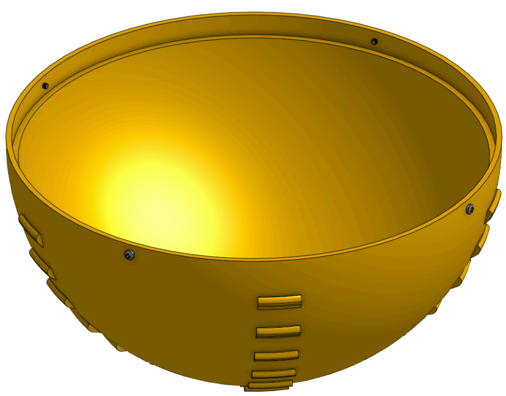


The shell is made of two halves, with two lips that overlap each other to seal. The full sphere has a 10 inch inner diameter and a thickness of 0.25 inches. There are four holes placed symmetrically around the ball, which go through both halves of the shell. The top half, which has the inner lip, has a slightly bigger hole, with a threaded insert set soldered in. The bottom half, with the outer lip, has a hole big enough to fit M3x7.5mm Screw Head bolts in it. To secure the ball, the outer lip holes and the inner brass inserts are aligned, and four of the screw head bolts are screwed in. To take it apart, each bolt is unscrewed and the two halves of the ball can be pulled apart with some effort. There are ridges on the outside of the shell which serve to provide some traction in grass and hopefully interest the cheetahs due to the interesting texture. The name of the shell, Munchkin, is engraved into the side of the top half.

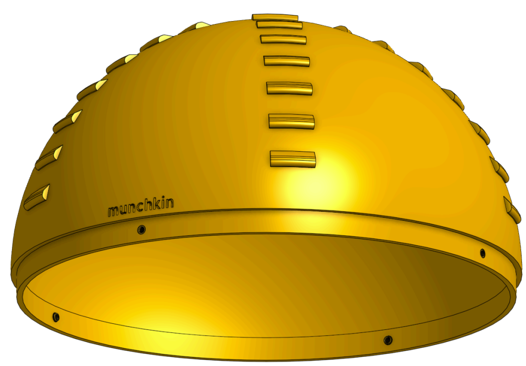
ASA is a durable plastic that is made to handle outdoor use. It has withstood all of our testing. For more information on this plastic, refer to the Material Safety Data Sheets in the Safety section. The shell halves are manufactured using the Original Prusa XL 3D printers in the OEDK, with each half being printed separately and taking about two days to print. The threaded inserts are inset using a soldering iron. If replacements are needed, we are able to manufacture more shells in the OEDK, but any 3D printer with a print bed size greater than about 12in x 12in that can use ASA plastic filament rolls will be able to print the shell.

We have done extensive testing on the shell and fabricating over ten prototypes, so we are confident that this final design will be durable and interesting to the cheetahs. We have thrown it down stairs, hit it with various tools, kicked it around, and dropped it on the floor repeatedly. When screwed in, it will not break apart, and the shell material itself can withstand a lot of force. The shell can withstand slobber or sprays of water, but it is not fully waterproof.

Bottom Half



Top Half



2.6 CAD Files

A link to all the CAD (computer aided design) files that we have used to 3D model this design can be accessed here.

We designed and modeled all of the parts we ended up putting together to make this ball using a free software called Onshape. The CAD files we've provided here are just an easy way to look at all the internal components in the ball and how they assemble. It may make it a bit easier to understand how the ball looks and works without looking at a physical prototype, and you can also see everything inside the ball without ever taking it apart. The CAD folders are organized by our design blocks - drive mechanism, electronics, and shell. Clicking any of the tabs in the bottom will take you to the respective design block's folder. In the folder, you can view part studios, which will show the steps we went through to design each part you see in the final product. There will also be assemblies, which combine individual parts to simulate what a final product would look like all together. We have included exploded views of these assemblies as well. When you click the link, you will be free to go through any of the parts, move them around, and see the different steps that went towards our final design. Additionally, if the zoo ever needs to reprint any of the parts and is unable to contact a CACTI team member, you can download the file straight from the CAD folders and print it using a public 3D-printer, such as the ones in the Ion Prototyping Lab. To make all of this a bit easier to understand, we have included a video to help you navigate the CAD files.

Video Link: CACTI CAD Explanation

3. Assembly

3.1 Parts List

Below is a list of each part we used in our final prototype and some information about it. Each one is also assigned a number and name that can be referenced in the bill of materials and the CAD. If any of the parts are broken or missing, the parts list and CAD can be referenced to replace it. For the cost of each of these parts, refer to the Bill of Materials below.

Part #	Part Name	Use	Where to buy or manufacture	Quantity
1	Shell Top Half	Encloses the inner components	Manufactured using ASA plastic and 3D printer at the OEDK. Link to buy ASA plastic rolls: Polymaker ASA Plastic Filament - Amazon Takes ~2 days and one roll per half. CAD files can be found above.	1
2	Shell Bottom Half	Encloses the inner components	Manufactured using ASA plastic and 3D printer at the OEDK. Link to buy ASA plastic rolls: ASA Plastic Filament - Amazon Takes ~2 days and one roll per half. CAD files can be found above.	1
3	M3x7.5mm Phillips Round Head Bolts	Hold the two halves of the shell together	Link to buy:	4
4	M3 x 4mm L x 5mm OD Brass Insert Nuts	Acts as a nut inset into the 3D print to hold the shell together	Link to buy: UXCELL Inserts - Amazon	4
5	Drive Mechanism Top	Top part of the main robot	Manufactured using ABS plastic and 3D printer at the OEDK. Link to buy ABS plastic rolls: ABS Plastic Filament - Amazon Takes <1 day and <1 roll. CAD files can be found above.	1
6	Drive	Middle part of	Manufactured using ABS plastic and 3D printer at	1

	Mechanism Middle	the main robot, holds motors	the OEDK. Link to buy ABS plastic rolls: ABS Plastic Filament - Amazon Takes <1 day and <1 roll. CAD files can be found above.	
7	Drive Mechanism Bottom	Bottom of the main robot, holds battery	Manufactured using ABS plastic and 3D printer at the OEDK. Link to buy ABS plastic rolls: ABS Plastic Filament - Amazon Takes <1 day and <1 roll. CAD files can be found above.	1
8	REV HD Hex 40:1 12V Motor	Move the robot	Link to buy: REV Robotics HD Hex 40:1 Motor	2
9	REV 12V Battery	Powers the robot	Link to buy: REV Robotics 12V Slim Battery	1
10	Wheel	Move the robot	Manufactured using PLA plastic and 3D printer at OEDK. Link to buy PLA plastic rolls: Takes <1 day and <1 roll. CAD files can be found above.	2
11	Tires	Provide traction on the inside of the ball	Taken off of a pulley motor combination. Link to buy: Geared Motor with Pulley	2
12	Ears	Hold bearing balls to provide support on the top of the robot	Manufactured using ABS plastic and 3D printer at the OEDK. Link to buy ABS plastic rolls: Takes <1 day and <1 roll. CAD files can be found above.	2
13	Ball Bearings	Roll against top of the ball to provide support	Link to buy: Stainless Steel Transfer Bearing Balls - Amazon	2
14	Springs	Underneath ball bearings to bear impacts	Link to buy: Spring Assorted Pack - Home Depot	2
15	M3x60mm Allen Key Bolts	Connect sections of drive mechanism and electronics box together	Link to buy: M2 Socket Cap Assortment Kit - Amazon	12

16	M3x10mm Allen Key Bolts	Connect ears to drive mechanism	Link to buy: M2 Socket Cap Assortment Kit - Amazon	4
17	M2x10mm Pan Head Phillips Screws	Secure motors to drive mechanism	Link to buy: M2 Phillips Pan-Head Assortment Kit - Amazon	8
18	Single Hand Joystick Controller	Controls the robot wirelessly via radio signal	Link to buy: DS 600 RC Transmitter and Receiver for RC Boat - Amazon (this includes part #19)	1
19	PWM Radio Signal Receiver for Boat Controller	Receives the radio signal sent by the controller and sends a signal to the arduino	Included in the amazon link for part #18	1

4. Operation & Maintenance

4.1 User Manual:

To use our product, follow the steps below.

1. First, turn on the robot. This can be done by flipping the on switch on the back of the robot. If the robot turns on correctly, a rainbow light will flash from the electronics section and then a green light will show.
2. Turn on the controller. To do this, press the ON button in the center. The controller will make a beeping noise and then display some numbers on the screen.
3. If you'd like to ensure that the robot and controller are fully functional before using them, you can place the robot on the ground and see if it drives around properly without the ball.
4. Next, place the robot in the half of the ball with Munchkin engraved on the side.
5. Find the arrows on the top and bottom half of the shell and align them. Then, press the shell halves together and make sure there are no gaps.
6. Screw the shell together using M3x7.5mm Phillips pan head bolts (a link for these is in the Parts List, but we will give them to you with the product and you may be able to find more around the OEDK or another makerspace). Use a screwdriver or a drill to drive the bolts into the brass inserts, and tighten them by hand.
7. Your ball is ready to use! Place the ball on the ground and move the joystick on the controller to move it around.
8. Once you are done using the ball, unscrew the shell and take it apart.
9. Turn off the robot and controller. Make sure to turn the robot off first, as the robot can act up when the controller signal is turned off first.
10. The robot can be charged using the REV battery charger, and the controller can be charged using a USB-C charger. Both have a battery life of about 2-4 hours, so it isn't always necessary to charge them if the ball was used for a short period of time.

A video displaying all of these steps can be found here.

4.2 Troubleshooting & Repairs

For any issues with the ball, if you are unsure how to approach it and this guide is not helpful, you can always contact us, at our email address or phone numbers above. We will usually pick up calls and respond to texts if needed, and we check our email regularly. We are able to repair and remake most parts of the product very easily and quickly at the OEDK. Below are some potential problems you may encounter and how to address them.

Drive mechanism - Some issues you may encounter with the drive mechanism and their solutions:

1. The bearing balls or springs have fallen off.
    a. If this is the case, you can attempt to re-attach them by soldering the spring to the bottom of the bearing ball and then soldering the other end of the spring to the Ears.
    b. Otherwise, you can contact us and we can easily provide new parts and repair them.
2. Part of the drive mechanism is broken.
    a. If any of the printed parts are broken, they can be reprinted by finding the part in the CAD files and then printing it on any 3D printer with a big enough print bed. Then, you can reference the CAD to reattach them or contact us.
3. The motors are not working properly or the robot is not driving properly.
    a. To check if the motors are broken, wiggle the wheels around and see if the motor seems to be moving inside. If the shaft comes off or the motor feels like it is moving around inside the robot, you may have to order a new motor and replace it.
    b. If the robot is not driving properly, you can take it out of the shell, place it on a flat surface, and attempt to drive it there. Then, you'll be able to see if the motors are having an issue or if any signals are not being received.
    c. If there are issues with the signal being received, then we recommend contacting us, as electronics can be very finicky to repair.
    d. If there are issues with the motors moving, you may have to order a new motor and replace it.
    e. After a lot of use, the wheels may get worn down and the motor shaft will spin inside the wheel rather than spinning the wheel. In this case, you will have to reprint the wheels and replace them.
4. The tires are falling off or not gaining traction on the inside of the shell.
    a. If the tires feel smooth and not rubbery, they may be worn down and will need to be replaced.
    b. If the tires are falling off of the wheels, you can superglue or hot glue them back to the wheels.

Shell - Some issues you may encounter with the shell:

1. If the shell does not slide together.
    a. In this case, check for anything in the way of the shell closing.
    b. The shell may be broken somewhere or worn out so much that it doesn't close. In this case, you may have to replace one of the halves.
2. The bolts do not go into the inserts.

a. Sometimes, the inserts may start spinning with the bolt rather than staying in place and acting as a nut. You can check if this is happening by trying to move or poke the screw inserts with a screwdriver. If this is happening, it is best to remove the insert with a pair of pliers and reinstall them.
b. The bolts may be the wrong size. Refer to the Parts List if the bolts are lost or the wrong size.

Electronics -Some issues you may encounter with the electronics:

1. Any part is broken or falling off.
   a. Refer to the CAD files or Parts List to replace the part. You can also reprint any of the plastic printed parts if they break.
   b. If any of the parts or wires seem loose, you can hot glue them back to any of the surfaces on the robot.
2. The electronics aren't working.
   a. You can check the color of the light when it is turned on. If it is not green, there is a short somewhere in the circuit or not enough power going. If this is the case, turn the robot off immediately and contact us.
   b. Check for any unplugged wires, and if any are unplugged, check the wiring diagram in the electronics section to fix it.
   c. Check that the battery is plugged in and charged.
   d. Check that the controller is charged.
3. The robot is moving without any instruction.
   a. Turn it off and turn on the controller first. If this issue persists, contact us.

Controller - The controller has alternative modes of operation designed for alternative boat motor setups it can sometimes switch to which can result in unpredictable and uncooperative signals and movement. To fix this, try:

1. Power the controller off and on again
2. Press the 'OK' button on the back to ensure the setting for continuous broadcast is toggled off
3. Recalibrate the controller by pressing down on the side trim arrows until the long beeping sound occurs for each.
4. Turn the controller off, then hold down the '3' button and turn it on again. This will change its mode and may need to be done multiple times before it will operate correctly.

If all is setup correctly, the robot should move properly and the controller screen should look like this:

[IMAGE HERE]

In terms of repairs, most of the parts can be 3D printed and all parts that are ordered are linked above if they need to be replaced. We are working on putting together an assembly and repair guide for how to create the ball from scratch, but at this time, we recommend consulting the CAD to see where certain parts go and how they are attached. Additionally, we are always open to contact.

4.3 Safety

Safety was a large concern of ours in creating the cheetah enrichment toy. The toy is slow enough and weighs little enough to not damage the cheetahs or the enclosure with its movement. Additionally, the shell is made of hard ASA plastic, made for outdoor use, with a thickness of 0.25 inches. The shell completely seals off the inner mechanism, so there should be no danger of the cheetahs accessing the electronics or drive mechanism. Additionally, the shell itself should have no pieces that can break off or catch cheetah teeth in them. To provide the most peace of mind while the zoo is using our product, we've put together a list of some safety precautions to take when using the shell.

- Before using the shell, we advise that you review the safety data sheets provided here. Each part and material used in the robot has its own specifications and dangers, and we recommend reviewing those for any official approval.
    - ASA Plastic (used for the shell)
    - ABS Plastic (used for robot parts)
    - PLA Plastic (used for robot parts)
    - Hot Glue
    - Battery
    - Tires (not the exact material - tires are made from pulley belt, this is the closest)
    - Solder
- Make sure no water enters the shell. Before use, the pool should be drained and it should not be rainy outside, as the shell is not waterproof enough to withstand those conditions. If the shell is submerged in water or rained on hard enough, the electronics will take on water and may short circuit. Additionally, for the safety of the cheetahs, if this does occur, **remove the ball from the exhibit immediately**. The ball should withstand cheetah slobber, urine, and mud.
- To ensure there is no mold growth within the shell, wipe down the shell interior and drive mechanism with a wipe after use. It is best to leave the shell open when not in use, so that nothing will grow inside. Any of the plastic components can be

disinfected or replaced, however, do not put any liquids or cleaners on the electronics.

- Anytime before the shell is being used or after it has been used, inspect the outside for any peeling plastic or chips in the shell. The plastic is very durable and we have not noticed any imperfections that could be bitten off by a cheetah, but for the safety of the cheetahs, we recommend doing a quick check of the shell as 3D printed plastics can come undone.
- If the controller is turned off before the robot is, the robot may start making erratic movements as it is misinterpreting and attempting to respond to a lack of signal. To avoid any unexpected movements of the robot, be sure to **turn off the robot using the switch before turning off the controller**.

At any point, if something about the ball seems off or dangerous, please remove it from the exhibit and contact us. We have done our best to make a product that can safely be used with the cheetahs, but in the end, we are college students, not professionals. The safety and health of Dash and Dinari are our highest priorities in this project, and we hope that our product can contribute to those aspects of their lives.

5. Project Wrap-Up

5.1 Next Steps

In terms of next steps for us as a team, we have decided to come to a stopping point on this project. As undergraduate students, we are all eager to use the knowledge we have gained during this project for new projects and in our future endeavors. As of May 2025, we will be handing the ball off to Julia Hart at the zoo to be tested with the cheetahs and potentially worked on further.

While we did not have the time or resources to fully realize our vision for this project, we do have a lot of ideas on how everything we did could be improved. We as a team have compiled a list of everything we wanted to do with this ball and did not get the chance to, in the event that future engineers will apply them to this project. Below are some ideas on things to improve:

- Improving the ability of the robot to put torque on the shell. The robot seems to move around inside the shell without pushing the shell down, and this is something we'd like to improve upon.

6. Other

6.1 Bill of Materials

Below is a spreadsheet with the bill of materials for our final prototype. It includes all the parts and materials detailed in the Parts List with their cost and quantity. It has the total cost of the ball added up at the bottom.

Bill Of Materials for Final Prototype

6.2 Digication Portfolio

https://rice.digication.com/tyra-helper/edes-200/published

6.3 Poster

CACTI Poster Final.pdf

6.4 Acknowledgements:

Professors: *Prof. Heather Bisesti, Dr. Maria Oden, Prof. Kevin Holmes;* **Clients:** *Julia Hart, Laurel DeLapp, John Register - Zookeepers for Carnivores at the Houston Zoo; Dennis Charlton - Former Director of Carnivores at the Houston Zoo; Dash and Dinari - Cheetahs at the Houston Zoo;* **Facility:** *Oshman Engineering Design Kitchen*

6.5 Google Drive

Below is a link to our Google Drive for this project, where you will find all the documents linked above, and more. You can see our reports, presentations, images and videos from the zoo or testing, and any other work that we have done throughout the last two semesters.

Cheetah