

SE 3 Pokémon Challenge!

SPRING 2022 TERM PROJECT

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Changes since the previous update (5/7/22) are shown in red text.

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Introduction

The Engineering Design Process

The purpose of this term project is to allow students to use the engineering design process while building upon their prototyping and graphical communication skills through hand-sketching, CAD, and manufacturing techniques.

The following figure shows a generic design cycle for any engineering process. A reminder that this process is much less linear, often going from later steps in the cycle back to earlier steps as the engineer gathers more data about their project. Rigorous testing and multiple iterations are critical for producing a successful solution.

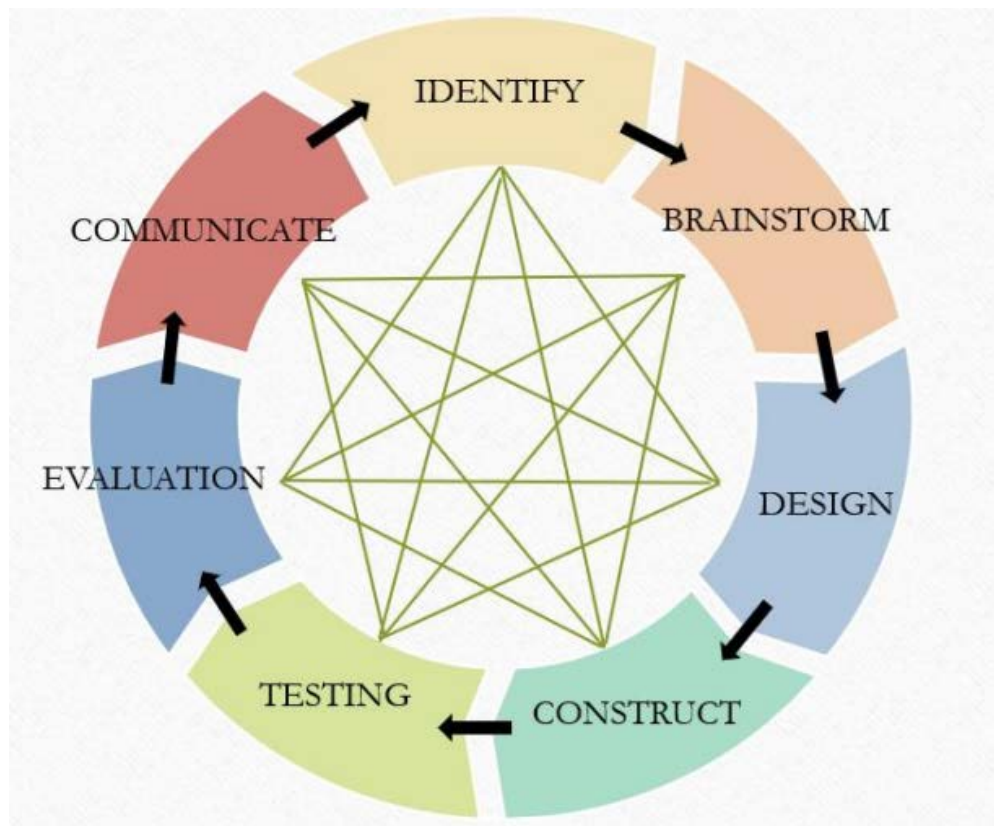


Figure 1: Iterative Engineering Design Process Diagram

This project also not only aims to reinforce concepts learned throughout this course but also teach practical communication, teamwork, and technical writing skills. The teaching team strives to make this a fun learning experience that allows students to explore engineering design in a low stakes environment.

Problem Statement

Prompt

Professor Oak (a colleague of Professor VDE) is interested in catching all the Pokémon in the Kanto region in order to help him fill his Pokédex and further his research. This project requires him to optimize the Pokémon catching method with a structure that can efficiently send a team into battle. The ideal design will be creative, aesthetically pleasing, fit within his grant budget, and be able to catch the rarest Pokémon.

Several teams of Pokémon trainers and engineers have been commissioned for this project and will compete against each other to create the best design. Your team of 3-4 students will develop a design proposal to submit to the Professor. The submission must include a working prototype, CAD drawings, and a poster presentation in addition to other state deliverables. All teams will present and demonstrate their prototypes at a final design competition at the end of the quarter.

Testing Set-Up

Overview

Each team will test their structure on the same set-up (Figure 2). All structures will start from rest and be deployed from the start zone using a pre-programmed arduino and servo motor.

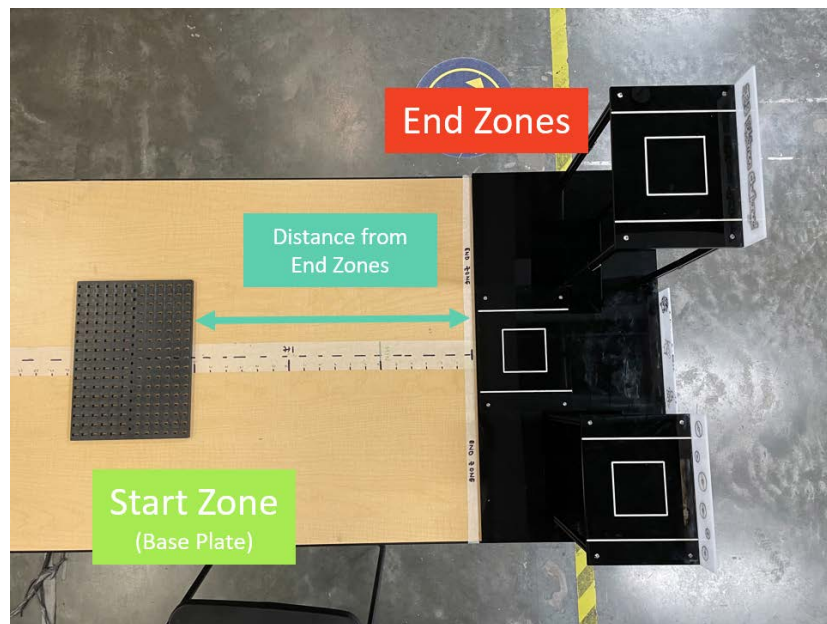


Figure 2a: Test Track (Top View)

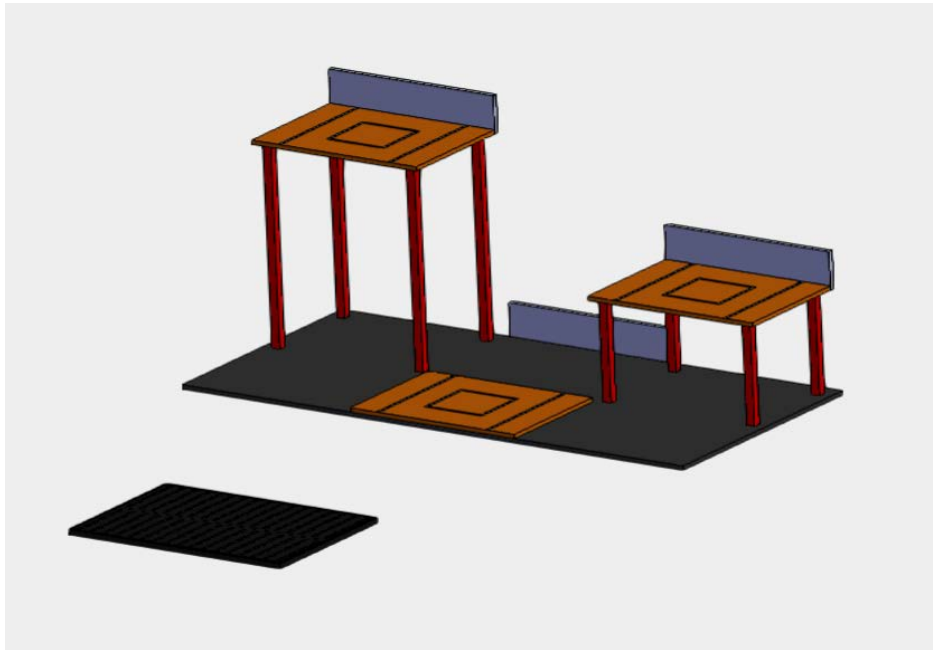


Figure 2b: Test Track CAD Model (Isometric View)

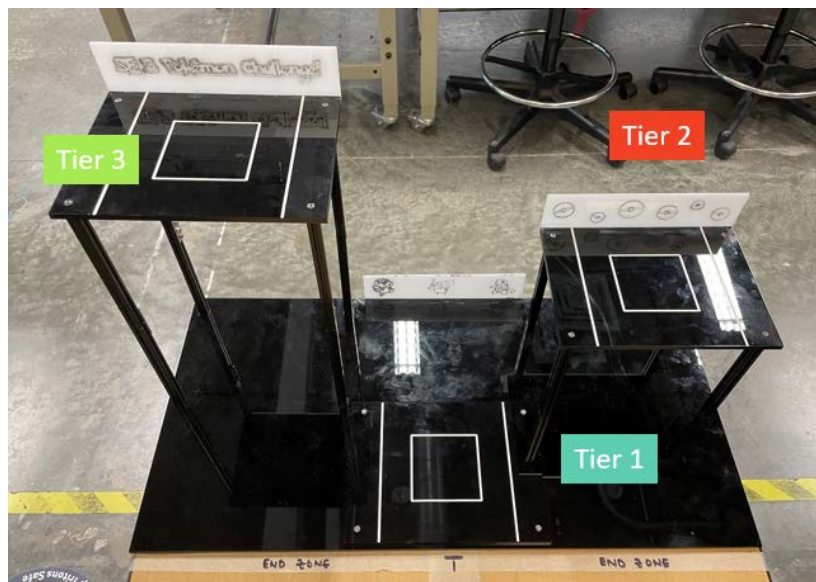


Figure 2c: End Zones and tier numbering convention

A CAD file of the set-up (and other critical components) will be provided. Please reference these files for the exact dimensions. The full set-up will be available in the Maker Studio and during labs for testing.

Objective

Each structure is required to move a Pokéball (Figure 3) from the start zone to one of the tiers in the end zone. The Pokéball has a mass of approximately 41 g and is 2" in diameter.



Figure 3: Pokéball

The rarest Pokémon can be found at the top (Tier 3) and the more common Pokémon can be found near the ground (Tiers 1 and 2). More points will be awarded for placing the Pokéball in a higher tier and closer to the inner zone

Start Zone

Base Plates will be provided to serve as the foundation for the structure (Figure 3) and will be fixed at the start zone.

Base Plates measure 258 mm x 186 mm (10.1"x7.3"), and have cutouts spaced at 15 mm apart for attaching other Fischertechnik parts. There are no extra Base Plates, so no replacements will be given if the Base Plate is lost.



Figure 3: Base Plate

End Zone

All three tiers in the End Zone measure 5.9" by 7.9" (see CAD assembly for full measurements) and have the same dimensions for each of the three zones. Zone A is considered the “most accurate” and will be worth more points than Zones B and C. (Likewise, Zone B is “more accurate” than Zone C).

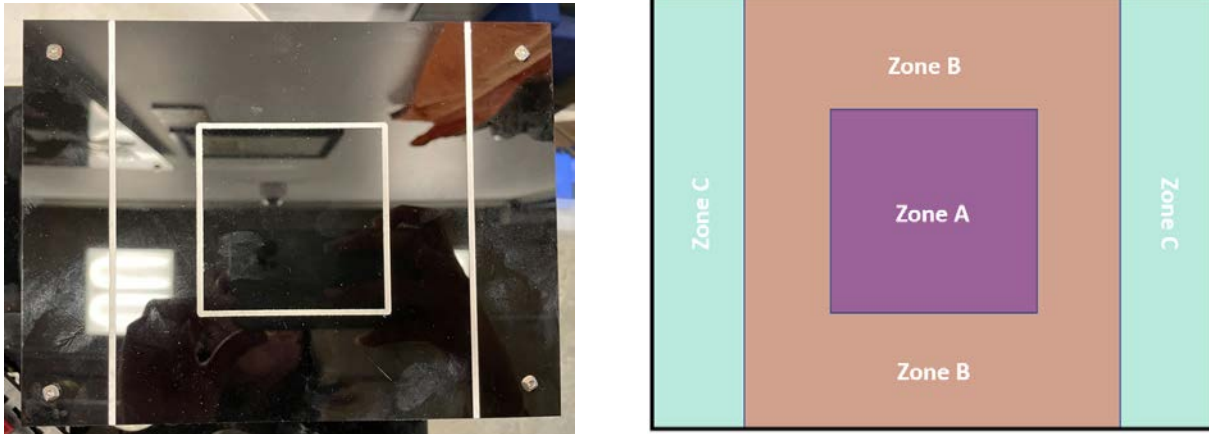


Figure 4: End Zone Tier close-up (left) and numbering convention (right) (all 3 tiers are identical)

Arduino + Servo Motor Input

An arduino is an open source microcontroller that is ideal for small-scale prototyping [1]. Each test track will have a pre-programmed arduino and servo motor (Figure 5a). The motor must be within the start zone (the arduino can also be in the start zone, but is not required to) and be able to be easily removed from the structure for multiple teams to use. The wires from the servo motor to the arduino can be extended so that your servo motor can move with your structure. Please notify the instructor team if you need this extension.

Upon turning on the arduino using the start button, the servo motor (Figure 5b) will rotate for a certain amount of time clockwise at a speed of 50 RPM. The potentiometer (Figure 5c) is capable of changing the duration of the motor’s runtime from 1-10s. Turning the potentiometer completely clockwise will run the motor for 1s and turning the potentiometer completely counterclockwise will run the motor for 10s. Turning the potentiometer to any angle in between will run the motor for the duration of time proportional to the angle swept between 1s and 10s (for example, turning the potentiometer to the midpoint between 1s and 10s will run the motor for 5.5s).

DO NOT re-wire the arduino or adjust anything aside from the potentiometer dial. Use the start button to run the arduino during testing. Ask a TA or Envision volunteer to help you

Each team will receive the same metal servo horn (Figure 5d) that they will use to interface their manufactured pieces with the servo motor. A CAD file of the servo motor and the servo horn will be provided for specs.

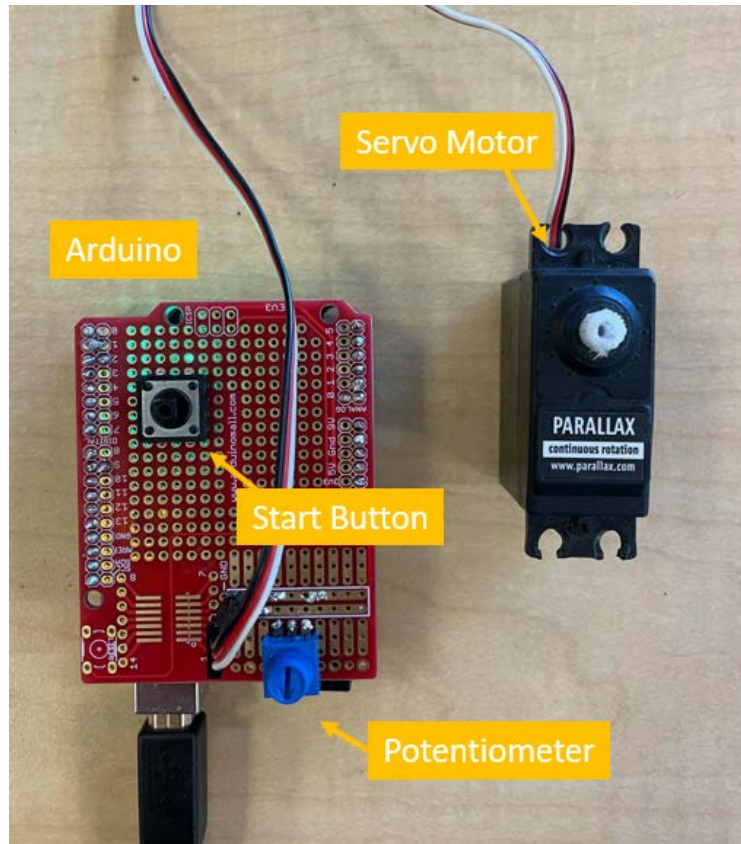


Figure 5a: Arduino and servo motor set up



Figure 5b: Servo motor with horn attached front view (left) and side view (right)

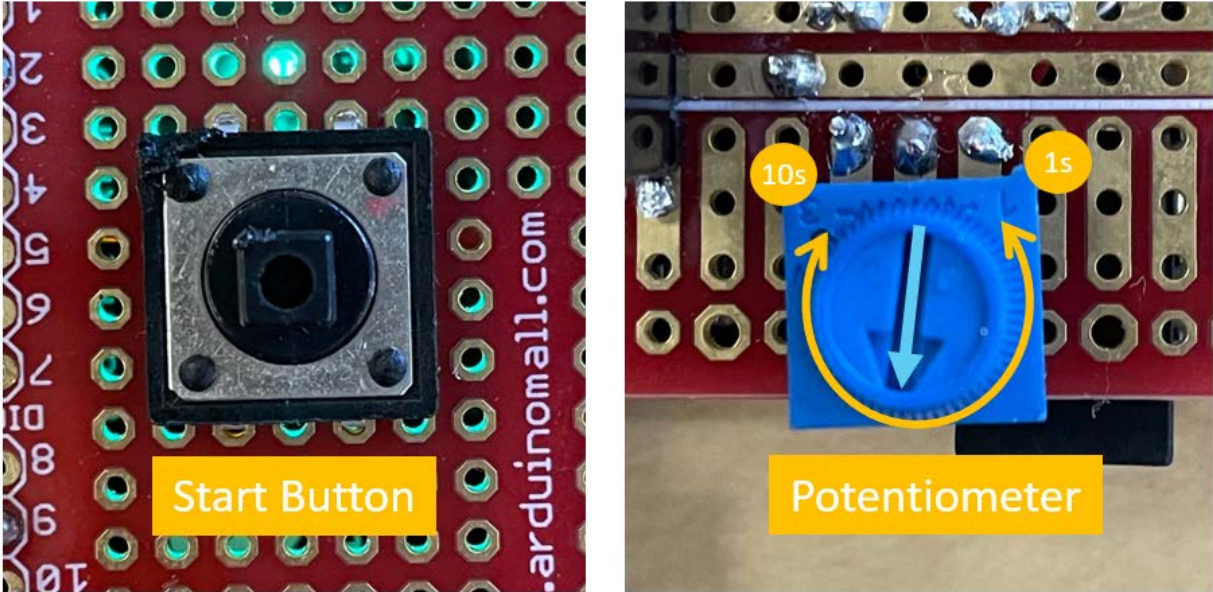


Figure 5c: Potentiometer + start button close-up



Figure 5d: Servo motor horn front view (left), side view (center), and back view (right)

Requirements

Each team must follow the criterion and requirements listed below. Teams will be subjected to a penalty and/or disqualification if the requirements are not met.

When in doubt, please ask the instruction team for clarifications on requirements. We reserve the right to make an executive judgment on what is allowed.

- Structure must fit within the start zone **BEFORE** being deployed. The start zone is 10.1"x7.3"x14" (ie, the structure fits within the footprint of the base plate and be no more than 14" tall *at the start*).
 - There are no boundaries for the structure **AFTER** the start trigger is deployed; **HOWEVER**, the Pokéball cannot touch the floor at **ANY** time
 - The structure **CAN** touch the floor and the End Zone after the start trigger
 - The End Zone (including the Tiers and the acrylic base) does *not* count as a part of the floor
 - The servo motor is considered to be part of the structure and must be within the start zone before the structure is triggered (the arduino + breadboard/wiring can stay outside the start zone and remain on the ground)
 - Nothing can be between the base plate and the floor
- The centerline of the start zone must align with the centerline of the End Zone (must be orthogonal); however, teams may choose to orient the base plate horizontally or vertically as well as adjust the distance from the End Zone
 - The minimum distance between the Start and End Zone is 6 in (measured from the front edge of the base plate to the front edge of the End Zone)
- All structures are energized by gravity, rubber bands, and/or the given arduino + servo motor. There are no additional energy sources permitted.
 - The structure must begin from rest
 - The arduino cannot be re-programmed, but teams may place the servo motor at any location on their structure (within the base plate) as long as it can be easily removed for the next team to use.
- No outside materials are allowed unless stated otherwise
 - **Exception:** outside materials (such as paint) are permitted for **decorative** purposes **ONLY**.
- Each structure must have a minimum of:

- **ONE** *unique* 3D printed part **PER TEAM MEMBER**
 - At least one piece must be at least 1"x1"x1"
 - Each teammate must be responsible for the CAD and manufacturing of one part
- **ONE** *unique* laser cut acrylic piece **PER TEAM MEMBER**
 - Each teammate must be responsible for the CAD and manufacturing of one part
- **ONE** type of connection
 - One of the previous required parts can count towards this requirement
- All required materials used must be an active part of the mechanisms involved **EXCEPT** for **ONE** of the *unique* laser cut acrylic pieces. Other decorative or unused pieces are NOT allowed to count towards the minimum requirements.
 - Decorative pieces are allowed *in addition* to the minimum requirements.

Connections

Connections are critical to joining two components together. Depending on the tolerances, manufacturing, and design of the connection, a part can be restricted or permitted to move in certain directions.

Examples of connections include (but are not limited to) snap-fit, threaded, and interlocking joints [2].

[Additional information on types of connections tbd, probably after tolerancing lecture]

Materials

Project materials are either **CONSUMABLE** or **RENTAL**. Consumable materials can be modified in any way, including cutting, trimming, and the addition of holes or other features.

Rental materials are not allowed to be modified. All rental materials need to be returned at the end of the quarter in the same condition that they were received.

Base Plates are considered rental materials.

Materials may be returned as long as they are in the same condition that they were bought in. If your rubber band breaks while testing, we will provide a replacement for free.

Reservations

Laser Cutter

Teams will be required to reserve a slot for access to the laser cutter during their lab times. Teams are permitted to reserve only 1 slot per week (either Tuesday or Thursday).

You are encouraged to also reserve the laser cutter through Envision during their open hours if you need additional time. If you choose a slot on a day with a design review, the instruction team will meet with you either before or after your reservation.

Please be prepared to laser cut with your file ready on a flash drive. This means that you will need to complete your drawings **IN AUTOCAD** AND export the .dwg file as an .xps. You can use the Envision computers to export to an .xps using the "Microsoft Print to XPS" printer and choosing "FSL ProLF 48x36" as the page size.

In AutoCAD, it is critical that you set your vector cut layer to red and your raster layer(s) to black otherwise the RetinaEngrave software will not be able to understand your settings.

3D Printers

On lab days where you do not have the laser cutter reserved, your team will have access to the 3D printers. However, you are only permitted to use the printer during your lab slot (ie, you cannot start a print that will not be finished before the end of lab). This is so that the afternoon labs have equal access to the printers as the morning labs. The code to access your funds on the 3D printers is **143482**.

Teams of three will designate one person to receive an additional \$10, for \$40 total per team.

If you need to do a long print, you will need to come to Envision during open hours and outside of SE 3 lab times.

You may estimate the time that your 3D print will take by downloading CURA (the software for the LulzBot printers). You can upload your part, adjust the settings, and have the software slice your .stl to give you a time estimate prior to printing.

Envision Tutorials

Please refer to the following videos for instructions on how to use the laser cutter and the 3D printers.

- [Laser Cutting Tutorial](#)
- [3D Printing Tutorial](#)

Consumable Materials

3D Printed Parts

Students will have access to the Maker Studio (SME 303) for all 3D printing. Every **team member** will receive \$10 of print balance at no cost (real or fictitious). \$1 of print balance is equivalent to 1 hour of printing.

The code to access your funds is **143482**. Enter the code on the 3D printer '\$' kiosk for an extra \$5 (added to your default \$5 for completing the training with Envision for a total of \$10).

Groups of 3 will receive an additional \$10 of print balance at no cost (so each **team** will have 40 hours of printing total).

Additional print funds can be requested from Colin Zyskowski (Envision Director) at a cost.

Although we are providing the CAD files of the Fischertechnik pieces, you are NOT permitted to 3D print them.

Acrylic

Each team will be provided a 12"x24" piece or larger of a random thickness of acrylic at no cost. Acrylic thicknesses vary from 3mm - 5.5mm. Additional pieces of acrylic can be purchased at a cost per square inch.

Teams may use scrap acrylic found in the Maker studio at no cost on a first-come first-serve basis. Only acrylic scraps may be used in the final prototype (no other materials).

All laser cut pieces must be made using AutoCAD. DO NOT IMPORT YOUR SOLIDWORKS SKETCHES INTO AUTOCAD

Screws, Nuts, and Washers

Phillips head 4-40 screws can be requested in lengths of 1/4", 1/2", 3/4", or 1". The screw size of 4-40 means the screw is a #4 (0.113" diameter) with 40 threads per inch. 4-40 screws fit in 1/8" (0.125") diameter holes. There are no limits or cost to the amount of screws, nuts, or washers that teams wish to use.

Rubber Bands

Rubber bands will be provided at a cost depending on the size of the band.

Aluminum Tubes

Each **team** will be provided with one aluminum tube with a diameter of 5/32", a wall thickness of 0.014", and a length of 18". Additional aluminum tubes can be purchased at a cost.

Spectra Fiber

Spectra Fiber is a specialty fishing line that comes in 65 lb. strength with a 0.0169" diameter. There is no limit or cost to the amount of fiber requested.

Rental Materials

Fischertechnik Parts

There is a large inventory of a variety of Fischertechnik parts that snap together, including the ability to attach to the Base Plate. Parts are limited to first come first serve, and the number of parts per team will be limited.

Stainless Steel Balls

Teams may purchase .75" stainless steel balls to use as weights. Each ball weighs approximately 28g.

All parts are available for viewing and purchase during select times and dates only (lab and OH).

Budget

All teams are limited to a budget of 1500 ₣ (Pokédollars). The budget will be tracked by the TA's; however, you are also responsible for recording what materials your team has purchased.

A summary of all the provided parts and their respective costs is summarized in the Materials List spreadsheet in Canvas.

Miscellaneous

Limitation Exceptions

If your team feels that any material maximum allowance (as listed above) is too limiting for your creativity, you may request an increase in the maximum allowed. Present your case to the instructor team and they will consider whether to grant your team an exception to the material limits.

Outside materials (such as paint) are permitted for **decorative** purposes **ONLY**.

Adhesives

NO GLUE OR TAPE OF ANY KIND IS ALLOWED TO BE USED.

EXCEPTION: If your 3D printed/laser cut part breaks and you do not have the time or money to manufacture a new one, you may glue it back together.

Lost or Damaged Rental Materials

The trust we afford you to take care of rented materials and return them undamaged at the end of the quarter is taken very seriously. If your team has damaged or lost any of the rented materials, consequences could include penalties to your final Performance Index, disqualification from the competition, and/or penalties to your grade.

Competition

The term project will culminate in a Final Competition (during the Final Exam slot) where each team will demonstrate their final prototype and present their poster at a design fair.

Extra credit will be awarded to the top individual teams with the highest PI and to the top conference with the highest average PI.

Conferences

Each lab section will compete as a conference under the leadership of the TA's:

Team	Lab Section(s)	TA
<p style="text-align: center;">VALOR</p> 	9am and 11am	Andres
<p style="text-align: center;">MYSTIC</p> 	1pm	Anna
<p style="text-align: center;">INSTINCT</p> 	3pm	Ezra

Performance Index

Scoring

Prior to testing, the structure will be reviewed to ensure that it meets all the requirements. Teams are subject to a penalty or DQ if they do not meet the requirements.

The top 10 individual teams will receive extra credit on their term project grade (10% for 1st place, 9% for second place, etc). The winning Conference (average of all the PIs) will get an extra 3% on their term project grades.

The Pokéball must be at rest before scoring. For example: if a Pokéball initially lands in Zone A but rolls into Zone C and stops there, teams will earn points for Zone C. Teams will receive a **score out of 10** for accuracy, height, and distance:

Accuracy (Zone A, B, or C)

Each tier has identical Zones: A, B, and C (see Figure 4), with Zone A being the most “accurate” (and the most points). If the Pokéball is in between Zones, points will be awarded for the outermost Zone.

Zone	Points (did NOT hit the backboard)	Points (hit the backboard)
A	10	5
B	6.7	3.35
C	3.3	1.65

Height (Tier 1, 2, or 3)

Teams will earn more points for landing in a higher Tier (see Figure 2c).

Tier	Points
1	3.3
2	6.7
3	10

Distance

Points will be earned for the distance between the Start and End Zones (measured from the front edge of the base plate to the front edge of the End Zone).

The minimum distance is 6 in (0 points) and the maximum distance is 48 in (10 points). Teams are permitted to start further away than 48in, but will not receive additional points (not necessary to be that far away to catch Pokémon!).

Equation 1 will be used to calculate the score for Distance:

$$D_n = (10pts) \frac{d - 6in}{42in} \quad [1]$$

where,

D = points earned

d = distance from the target (inches)

Precision

All teams will deploy their structure in multiple rounds to test precision and consistency. You may not change the design of your structure in between competition rounds, but you can move your structure closer/further from the End Zone.

Aesthetic, Creativity, & Design

Teams will be scored on a scale of 0-10 by the instructor team during their Poster presentation for aesthetic, creativity, design, and quality of presentation. This will contribute to a scale factor that will be multiplied by the PI.

Performance Index Equation

The final rankings will be determined from every team's Performance Index (PI). The highest PI possible is 110 (dimensionless, ignore units). The PI will be calculated using Equation 2:

$$PI = \left(1 + \frac{A}{100}\right) \left(\frac{1}{k} \sum_{n=1}^k R_n - .015C\right) \quad [2]$$

where,

A = aesthetic, creativity, & design score

$R_n = 3T_n + 5Z_n + 2D_n$ = Catch Rate for round n [3]

k = number of rounds = 3

T_n = height (tier) score for round n

Z_n = accuracy (zone) score for round n

D_n = distance score for round n

C = cost in Pokédollars

If a team does not land in a Zone/Tier (ex: landing on the base of the End Zone or the floor), the Catch Rate for that round will be 0.

Disqualification

Teams may be disqualified for any of the following reasons (or from an executive decision from the Instructor Team):

- Did not meet all the requirements
- Did not have a working mechanism
 - **Note:** does not need to be an accurate or efficient mechanism. You can completely miss the target but still not get DQ'd as long as it's clear that your structure moves in some capacity and that your team put in effort
- Damaged rental materials (including the arduino + servo)

Deliverables

[Details for Final Deliverables will be released later in the quarter]

Team & Conference Design Reviews

Engineering Notebook

Additional entries to your engineering notebook are due 9am the morning of each design review in addition to any physical deliverables. The requirements for the upcoming team design review will be released about a week before and can include completed CAD files, drawings/hand sketches, manufactured parts, a working prototype, etc.

See the timeline for a schedule of when the design reviews are. Additional deadlines may be assigned in between design reviews to check your progress. Please refer to the Canvas module for a comprehensive list of deliverables.

Poster

All teams will create a poster to present their design during the Final Competition.

Drawing Files

Please see the “Term Project Drawing Standards SP22” file in Canvas for a comprehensive list of requirements. *This is just an overview!!*

Phase 1: Solidworks

A complete, updated Solidworks Assembly will be due at the end of the quarter in addition to the drawing files of each component. Each team will develop drawings for the following categories:

- Build Schematic
- Sub-assemblies
- Placements
- Custom Parts

Phase 2: AutoCAD

Teams will be required to submit AutoCAD drawings of the plan and elevation views of their structure within the scenery of the test set-up. Each individual AutoCAD drawing must include:

- 3 images from the internet that are pulled in as blocks (such as people, trees, etc.)
- 1 complex item that is traced from an internet image
- 1 complex item that is drawn by hand
- Screen video recordings of ALL of these are required so the teaching team can see that these instructions were followed for each student

Phase 3: Title Sheet

Teams will be required to create a title sheet in AutoCAD on **sheet size A** and include the following:

- SE 3 course number and term project title “SE 3 Pokémon Challenge Term Project”
- Team Number (optional: Team Name/Company Name/Logo)
- Conference Name
- Date
- A single isometric view of the Assembly (a Solidworks image file imported into AutoCAD)
- The title “Final Drawings for the XXX Assembly”, where XXX is the name of your project
- List of team member names

Timeline

[SUBJECT TO CHANGE, please use this as a ROUGH outline as this does not include all required deliverables. Required deliverables will be detailed during lab, on Canvas, and in the Engineering Notebook/Team Design Review requirements.]

Week 4

Tuesday	Thursday
<ul style="list-style-type: none"> ● Form teams and assign roles ● Individual hand sketches 	<ul style="list-style-type: none"> ● Team Hand Sketch ● Determine sub-assemblies and designate responsibilities ● Develop materials and parts list ● Create project plan/schedule

Week 5

Tuesday	Thursday
<p>Team Design Review 1</p> <ul style="list-style-type: none"> ● All hand sketches and project plan due ● First review session with TAs ● Start CADing parts and sub-assemblies 	<ul style="list-style-type: none"> ● Materials experiment lab activity ● Time to work on project <ul style="list-style-type: none"> ○ Refine model & finalize details/connections in CAD model

Week 6

Tuesday	Thursday
<ul style="list-style-type: none"> ● Materials experiment lab ● Time to work on Solidworks 	<p>Team Design Review 2</p> <ul style="list-style-type: none"> ● Show completed individual parts in Solidworks ● Begin sub-assemblies

Week 7

Tuesday	Thursday
<p>Team Design Review 3</p> <ul style="list-style-type: none"> ● Present full assembly in Solidworks ● Material store opens ● Start manufacturing ● Tolerancing Lab Activity 	<p>Conference Design Review 1</p> <ul style="list-style-type: none"> ● Peer review with other teams ● Time to work on project

Week 8

Tuesday	Thursday
<p>Team Design Review 4</p> <ul style="list-style-type: none"> ● Show completed 3D printed and laser cut parts ● Begin assembling prototype, complete manufacturing ● Material limits removed 	<p>Testing Round 1</p> <ul style="list-style-type: none"> ● Demonstrate complete, working prototype ● Work on Phase 1 SolidWorks drawings

Week 9

Tuesday	Thursday
<p>Team Design Review 5</p> <ul style="list-style-type: none"> ● Iterate and improve on design after previous week of testing 	<p>Testing Round 2</p> <ul style="list-style-type: none"> ● Phase 1 Drawings completed ● Demonstrate new and improved complete, working prototype ● Work on Phase 2 AutoCAD drawings

Week 10

Tuesday	Thursday	Friday
Working Day	Final Team Design Review <ul style="list-style-type: none">• Check in with TAs ahead of Final Competition• Work on final construction drawings and poster• Phase 2 Drawings completed	Poster DUE 11:59pm <ul style="list-style-type: none">• Submit for printing

FINAL EXAM

Final Competition and Poster Fair!

Phase 3 drawings due **Sunday 6/5 11:59PM** along with complete drawing set

References

[1] <https://www.arduino.cc/reference/en/libraries/servo/>

[2] <https://markforged.com/resources/blog/joinery-onyx>