ME 218b Winter 2022: Duelling Reverse Skee-Ball
Shooting Kinetic Energy Elements By Autonomously Launching Layups

Project Preview on February 24 from 1-7 pm.
Grading Period begins February 24, and runs through 11:59 pm on March 1.
Project Presentation on March 3 starting at 7:00 pm.

Goal:

The goal of this project is to provide you with an opportunity to apply your knowledge to solve an open-ended problem. The task is to design and build a machine that can autonomously navigate around the Arcade and deposit shrunken Skee-Balls into a basket located at the end of the Arcade.

Purpose:

The underlying purpose of this project is to give you some experience in integrating all that you have learned in ME218 as well as your prior courses. To gain this experience, you will design and implement an autonomous mobile robot that can compete in a game of speed, skill and strategy against machines constructed by other teams from the class.

Background:

In 2014, the Full Circle Bar in Brooklyn, NY was sued for trademark infringement by Skee-Ball Inc. as a result of their tournament called Brewskee-Ball. In classic American legal fashion, Full Circle promptly counter-sued SBI. Though the two did eventually come to an undisclosed settlement, Full Circle were not entirely happy with that result and have approached your team to design an alternative game. Your task will be to develop, implement, and test a Kinetic OrB Elevator (KOBE) that will participate in a game comprised of Shooting Kinetic Energy Elements By Autonomously Launching Layups (SKEE-BALL) for bragging rights across the Galaxy (prelims on March 1, with the tournament scheduled for March 3).

The Task:

Your KOBEs will be operating on the Arcade located in the SPDL, and then competing against each other on the same Arcade after it has been moved to the Atrium of Bldg. 550 (our classroom building) during the public presentations.

> *Me shooting 40 percent at the foul line is just God's way of saying that nobody's perfect. If I shot 90 percent from the line, it just wouldn't be right.*
>
> *Shaq*

Specifications

The Arcade:

- ☐ The Arcade is an approximately 244×244 cm area with exterior walls 8.25 cm tall. A top view is shown in Figure 1 .
- ☐ The Arcade is divided into two equal Linear Arenas Nourishing Excitement (LANEs) to be used by Team A and Team B as shown in Figure 1.
- ☐ Balls delivered into the basket while the KOBE is in the different colored regions earn differing points, as indicated in Figure 1.
- ☐ The Arcade will be covered by a 3 mm thick clear PETG protective sheet.
- ☐ At end of each LANE there is a basket measuring 30×30 cm
- ☐ Each basket has a modulated IR beacon mounted above it, with the emitters located 40 cm above the surface of the Arcade. The modulation frequencies are shown in Table 1.
- ☐ 2.54 cm wide black tape line runs through the center of each LANE.
- ☐ An arc of 2.54 cm wide black tape marks the transition from the 2-pt to 3-pt scoring regions.

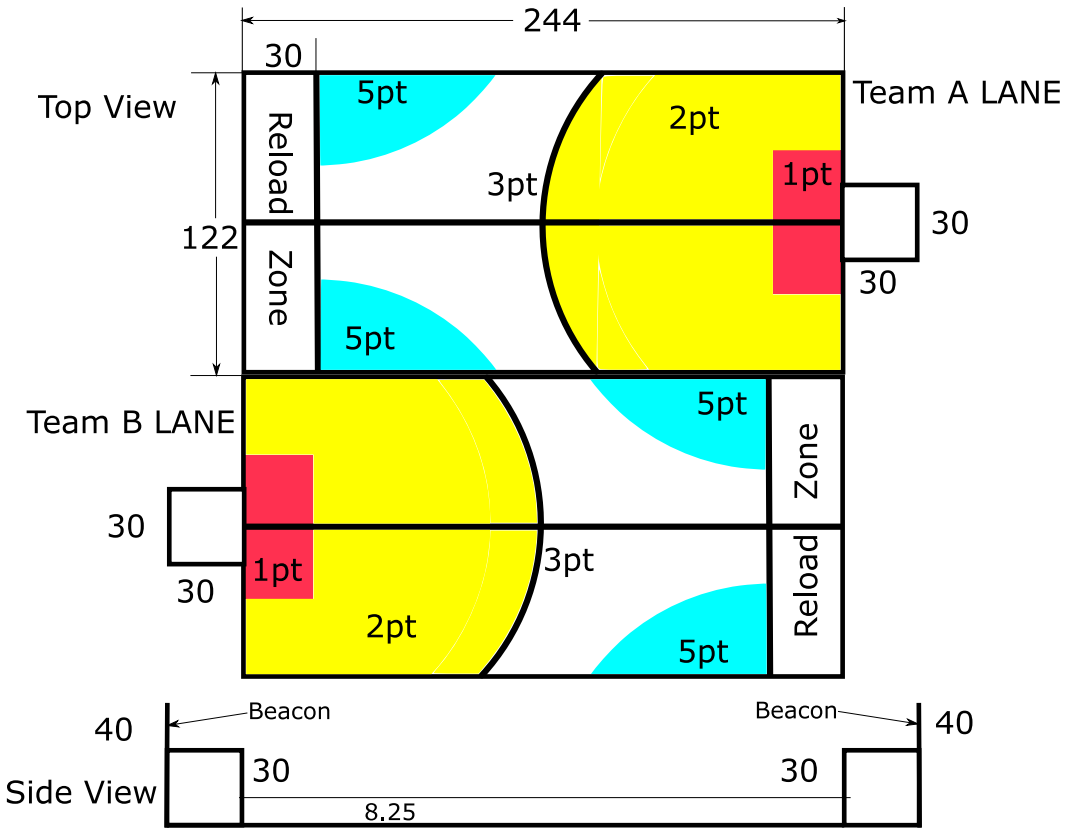

Figure 1: Overhead and side views of the Arcade. All dimensions in cm and approximate. Refer to the actual field for exact dimensions.

Beacon	Frequency	Period
TEAM A	3333 Hz	300 µs
TEAM B	909 Hz	1100 µs

Table 1: Beacon Modulation Frequencies

The KOBE:

- ☐ Your KOBE must be a stand-alone entity, capable of meeting all specifications described in this document. Only SPDL supplied (or equivalent) battery power is allowed. No more than two batteries may be used to drive the motors that transfer force to the ground.
- ☐ Each KOBE must be able to automatically determine if the KOBE as owned by TEAM A (red) or TEAM B (blue).
- ☐ Each KOBE must include a means to clearly indicate to the audience its team status.
- ☐ Each KOBE must include an electro-mechanical means to clearly indicate to the audience when the game is underway.
- ☐ KOBEs must be autonomous and untethered.
- ☐ The only parts of the KOBE that may ever touch the playing surface are wheels, ball casters, or slippery supports used to balance the KOBE.
- ☐ Only the supplied motors may be used to drive anything that transfers force to the ground.
- ☐ Your KOBE must be fully contained within a square 30cm on a side projected into the field at the beginning of the game and never expand in the plane of the Arcade beyond the perimeter defined at the beginning of the Game.
- ☐ Each KOBE shall contain a network of processors consisting, at a minimum, of one SPI leader and one SPI follower device. How the necessary functionality is partitioned among the networked processors is up to the team.
- ☐ Different team members must assume responsibility for the hardware and software for each PIC.
- ☐ Each KOBE must carry an easily accessible switch which shall cut power to the KOBE in case of a software or hardware malfunction.
- ☐ Each KOBE must be constructed as part of ME218b. It may not be based on a commercial or otherwise preexisting platform.
- ☐ The accounting department has limited you to an expenditure of **$150.00/team** for all materials and parts used in the construction of your project. Materials supplied to each team by SPDL or from the lab kit do not count against the limit. All other items count at their fair market value.
- ☐ Each KOBE may have as many user accessible switches/buttons as the team desires but these switches/buttons may only be activated/modified while the KOBE is stationary in the Reload Region.
- ☐ Each KOBE must provide a clearly visible indication of when it thinks that a Game is in progress. This indicator should be activated when the KOBE determines the Game has started and be deactivated when the KOBE thinks the Game has ended.
- ☐ There must be a bumper surrounding the perimeter of your KOBE extending for at least 5 cm vertically, and must fully cover the region between 1.3 cm and 6.3 cm (± 0.3 cm) from the floor.
- ☐ each KOBE needs to have a clearly designated 'front'.

The Game:

- ☐ The Game is a head-to-head race between two competing teams of KOBEs on two adjacent LANEs. The objective is to score as many points as possible by launching or depositing balls into the baskets at the ends of the LANEs.
- ☐ Your KOBE may deposit balls into a basket by either dumping them into the basket (the dunk shot) or launching with a substantially above-horizontal trajectory such that, the ball may land no more than 275 cm from the KOBE and reach a peak height of no more than 244 cm above the floor of the playing field.
- ☐ At the beginning of the Game, each team will place their KOBEs along the center line and within the

reload regions on the Arcade (refer to Fig. 1) and with an orientation designated by a member of the teaching staff.

- ☐ At the beginning of the Game, each KOBE may be pre-loaded with up to 3 balls.
- ☐ While the Game is in progress, if the KOBE returns to the Reload Area, a member of the team may load up to 3 additional balls while in the loading area. This re-load process may be repeated as many times as desired within the time of the Game.
- ☐ The Game will begin when a member of the Teaching Staff announces that the Game has started. At this time, a member of each team is permitted to press the start button on their robot. Any further interaction between team members and their KOBEs is limited to loading more balls or pressing buttons or flipping switches and those interactions are only permitted while the KOBE is stationary in the Reload Region.
- ☐ Each Game will last for 2 minutes, 18 seconds.
- ☐ The entire perimeter of your KOBE must be fully within a scoring region in order to earn points for that region.
- ☐ When each robot detects that the allotted time has expired, that KOBE must cease moving and deactivate its game-in-progress indication.
- ☐ At the end of 2:18, the team which has scored the most points is the winner.
- ☐ If both teams have scored an equal number of points at the end of the 2:18 regulation time, there will be a sudden-death round. The KOBEs will be re-placed into the reload zone and, after the start command is given, the first team to complete placing a ball into their basket wins. If neither team completes the sudden death round, the game will be decided by an extremely dramatic coin flip.

Rules:

- ☐ No solderless breadboards are permitted in the final project.
- ☐ Intentional interference with the operation of another team's KOBE is prohibited.
- ☐ Each KOBE must start and remain in once piece during the round. Any locomotion of the KOBE should cause all parts of the KOBE to move.
- ☐ Your KOBE may not **IN ANY WAY** alter the condition (e.g. mar the floor) of the playing field.
- ☐ Intentional jamming of your opponent's senses is prohibited.
- ☐ All projects must respect the spirit of the rules. If your team is considering anything that may violate the spirit of the rules, you must consult a member of the teaching staff.

Safety:

- ☐ The KOBE should be safe, both to the user and the spectators. The teaching staff reserves the right to disqualify any KOBE considered unsafe. This also applies during testing, so keep the KOBE and ball velocity low enough so as not to cause problems.
- ☐ You should make a stand to support your KOBE on the table for testing. The purpose of the stand is to prevent an errant KOBE from running off of the table during testing.
- ☐ KOBEs must be stable in the presence of a 15 m/s wind.
- ☐ No part of the machine other than a ball may become ballistic.
- ☐ All liquids, gels, and aerosols must be in three-ounce or smaller containers. All liquids, gels, and aerosols must be placed in a single, quart-size, zip-top, clear plastic bag. Each KOBE can use only one, quart-size, zip-top, clear plastic bag.
- ☐ Red, Green, and Blue shells are prohibited. Any banana peels must stay within the confines of your KOBE at all times.

- ☐ Any early celebrations will be penalized.
- ☐ Your KOBE is not permitted to steal talent from any other KOBEs.
- ☐ KOBEs may alter the space-time continuum only during the public presentations.

Checkpoints

Design Review:

During the day on **February 8** we will conduct design reviews. Sign-ups for the hour-long slots for 3 teams will happen via a Google Sheet. Each group should prepare a few **simple** PowerPoint slides (scans of sketches are OK). **No code, no state diagrams, no circuits.** The focus should be on the overall design and how you are tackling what you think are the critical subsystems and how you will partition responsibility between the processors. You will present these to other members of the class, members of the teaching staff and coaches so that all may hear about your ideas and provide feedback and advice.

I think you Jedi would have more respect for the difference between knowledge and wisdom.

Dexter Jettster

First Checkpoint:

On **2/10/22**, you will turn in a system block diagram, a set of KiCad schematics, textual descriptions and software design documentation (including a state chart) that describes the state of the design *at that point in time*. The designs need not be tested at this point, but must include designs to address all of the major subsystems. For your submission to GradeScope, create a single PDF document that includes the system block diagram, an KiCad schematic, your state charts, and a document describing, in words, your strategy for meeting the project requirements and identifying your robot's core functionality. Only one team member needs to submit your checkpoint documentation.

Hold on. This whole operation was your idea.

Anakin

Second Checkpoint:

On **2/17/22**, you must demonstrate communications between at least two PICs. Between them, these PICs must demonstrate the ability to control the motors of the locomotion system and the ability to detect the beacon. This demonstration may be a table-top demonstration and may be demonstrated while connected to a PC.

The Dark Side clouds everything. Impossible to see, the future is.

Yoda

Third Checkpoint:

On **2/20/22**, you must demonstrate an instance of your untethered, motorized platform moving under autonomous software control. Your platform must be able, starting from the start position on the Arcade, to locate the beacon and then drive in a straight line in the direction of the beacon under coordinated control from multiple processors.

I don't like checkoffs. They're coarse and rough and irritating and they get everywhere.

Anonymous 218er

Fourth Checkpoint:

On **2/22/22**, you must demonstrate your team's ability to deliver a ball into the basket using your intended delivery mechanism.

This is getting out of hand! Now, there are two of them!

Nute Gunray

Project Preview:

At the Project Preview on **2/24/22**, each team's KOBEs must demonstrate, in an integrated physical form, though not necessarily with integrated software,

1. The ability to move around the Arcade under software control.
2. The ability to locate the beacon above the basket
3. The ability to deliver at least 1 ball into the basket when starting from the standard start position on the Arcade.

This will be tested by following the normal starting procedure for a Game, followed by the team's KOBE performing the required maneuvers.

> *Victory? Victory, you say? Master Obi-Wan, not victory. The shroud of the dark side has fallen. Begun, the [grading session] has!*
>
> *Yoda*

Grading:

The grading period will open on **2/24/22** and will remain open until 11:59 pm on **3/1/21**.

During a grading round, each team will be required to demonstrate a complete Game.

During the Game, your KOBE must demonstrate in a completely integrated form all abilities detailed in the Project Preview specification.

Evaluation for grading purposes will only occur during these rounds. If your KOBE fails at its first attempt to demonstrate its ability, it must then demonstrate the ability two times in succession at its next attempt. These increases continue after repeated failed attempts to a maximum of 4 required successive demonstrations.

> *So this is how liberty dies... with thunderous applause.*
>
> *Senator Padmé Amidala*

Public Presentation:

This will take place on **3/3/22** starting at **7:00 pm** in the Atrium of Building 550. (building in which our classroom is located)

> *It's treason then.*
>
> *Chancellor Palpatine*

Report:

Draft due on **3/7/22** by 4:00 pm. The final version with revisions is due by 5:00 pm on **3/11/22**.

> *This party's over.*
>
> *Mace Windu*

Evaluation

Performance Testing Procedures:

One or more team members will operate the KOBE during the performance evaluation. A competition among the class' KOBEs will take place after the performance evaluation.

Performance Evaluation:

Performance evaluation will take place twice during the project duration, at the Project Preview and at the Grading Session. Everyone will participate at this level.

The Competition:

On the night of the public presentations, a tournament will be held. **Performance during the tournament has no impact on your grade.**

Grading Criteria:

- ☐ **Concept (10 %)** This will be based on the technical merit of the design and coding for the machine. Included in this grade will be evaluation of the appropriateness of the solution, as well as innovative hardware, software and use of physical principles in the solution.
- ☐ **Implementation (15 %)** This will be based on the prototype displayed at the evaluation session. Included in this grade will be evaluation of the physical appearance of the prototype and quality of construction. We will concentrate heavily on craftsmanship and finished appearance.
- ☐ **Checkpoint Performance (10 %)** Based on demonstrating the required functionality at the **checkpoints**.
- ☐ **Preliminary Performance (10 %)** Based on the results of the performance testing during the **Project Preview**.
- ☐ **Performance (20 %)** Based on the results of the performance testing during the **Grading Session**.
- ☐ **Coaches' Evaluation (5 %)** Evaluation by your coach: did you make use of their input before the design review and during the course of the project.
- ☐ **Report (20 %)** This will be based on an evaluation of the written report. It will be judged on clarity of explanations, completeness and appropriateness of the documentation. The report should be in the form of a stand-alone web site and must include schematics, pseudo-code, state charts, header & code listings, dimensioned sketches/drawings showing relative scale, a complete Bill-of-Materials (BOM) for the project as well as a 1 page description of function and a "Gems of Wisdom for future generations of 218ers" page.

  To submit your report you must **enter the URL to your site into a Google sheet that will be made available for that purpose**. The only file types in your final report should be HTML (including style sheets if you choose), JPEG or other viewable image files and PDF files. Schematics should be PDF files, not bitmaps (PNG, JPEG, GIF, etc.). A reasonable resolution bitmap place-holder with a link to a PDF is the best solution to readability. **Do not simply place a link to the PDF of the schematic without a viewable preview on the web page.** Do not include `.doc`, `.docx`, `.xls`, `.xlsx` or other files that require opening a separate application outside of the browser. Your site should be fully functional on both desktop and tablet browsers. **Do not embed video files directly** into your site. If you want to include video, link to YouTube or other video sharing site.

  It is critical that the URL of your report be in the Google sheet on time so that the peer reviewing team will have an adequate opportunity to review it before class the following day. Final versions of the reports, incorporating the review comments are due (again, as a URL in the Google Sheet; update the URL if it changed) by 5:00 pm on 3/11/22. Make sure to test all of your links before submitting. If we can't simply open the link and read it on our machines, then we can't grade it.
- ☐ **Report Review (10 %)** These points will be awarded based on the thoroughness of your review of your partner team's report. Read the explanations, do they make sense? Review the circuits, do they look like they should work? Could this KOBE realistically be built for $150? If, during grading, we find things that don't make sense or circuits that won't work we will consult your review. If the review caught them, then the team will lose points on their report. If the reviewers missed it, then the reviewers will lose points for their review. The report review should submitted be in the form of a word document that you place into one of your team members folders by 4:00 pm on 3/8/22.
- ☐ **Housekeeping** Based on the timely return of SPDL components, cleanliness of group workstations as well as the overall cleanliness of the lab. No grades will be recorded for teams that have not returned or paid replacement costs for the items borrowed from the SPDL, including but not limited to the oscilloscope, power supplies, logic analyzer, tools, etc.
- ☐ **Peer Reviews** Completing the peer review on CATME is a **required** component of the project. These reviews are not optional and the project work will be considered incomplete unless the reviews are

completed by the due dates.

Team Organization

While each member of your team has principal design responsibility for a specific functional area, I believe that turning these team members into dedicated specialists will be a mistake in the long run. I have heard from many 218 alumni who did this and reported that they were sad that they had done this because they didn't get, for example, communications experience. I would like to encourage you to remember that, first and foremost, **the purpose of the project is to enhance your learning of the material**. An organization that deeply involves all of the team members in the details of the design, implementation and debugging of all subsystems will not only provide a better learning experience, it will also prevent you from getting hung up during the integration and testing phase because the "expert" on that subsystem is not available.

Mechanical Design and Robustness

Your machine must be rugged enough to survive your testing.

While the emphasis in the lecture has concentrated on the electronics and software, don't forget the mechanical aspect. Historically, project failures are often due to poor mechanical design or implementation. Pay attention to craftsmanship, and put thought into how your design supports all of the loads your robot will be subject to—not just when it's operating as intended, but also when it receives bumps from other robots that may also be testing on the field.

While we have focused largely on software implementation details in class, keep in mind that although computers are deterministic, the real world is not[1]. Make sure your software is built not just to handle what you hope will happen, but also everything you think might happen that could cause you problems.

This year's project has more "smart" subsystems than other projects in the past. When integrating several subsystems, although it may seem (and feel) slower, it is absolutely worth your time to make sure each subsystem is as bug-free as you can get it prior to integration. Fast is slow and slow is fast.

Preventing Disaster

It is unlikely, even given the advice in the paragraph above, that your robot will be robust to a fall from the table-top to the floor. To avoid the possibility of that happening, you should create a stand/platform for your 'bot that it can sit on with its wheels not touching the table-top. With this stand in place and your robot perched upon it whenever it is on the bench-top, even if your code or hardware goes haywire and starts the wheels spinning unexpectedly , those spinning wheels will not drive your 'bot off the bench-top.

Resources

Websites:

SparkFun	Seeed Studio	Jameco	Mouser
Newark	Ponoko	Adafruit	Hackaday
DigiKey	McMaster-Carr	HobbyKing	ServoCity

You may also find PlantUML and PlantText helpful for creating message sequence diagrams or system diagrams.

Local Stores:

Anchor Electronics in Santa Clara
Jameco in Belmont
TAP Plastics in San Mateo

[1] Well, at small length scales. But in this case, you don't have enough information on the details of your robot's interaction with the world to treat it as deterministic, so don't.

Gems of Wisdom:

Be sure to check out The ME218 Archive for guidance from past generations.

Team Names:

Team names are a tradition in ME218b. For some very Tongue-in-Cheek inspiration, take a look at The History of SkeeNation Team Names.