



ME 218b Winter 2024: Squrling Ed and Karl go nuts!

Project Preview on March 1 from 1-5 pm. Grading Session on March 6 from 1-5 pm.
Project Presentation on March 7 starting at 7:00 pm.

Revision 4: 2/8/24

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, from scratch, a machine that can autonomously orient, navigate, and manipulate various elements of a pre-designed game in order to best an opponent, whether or not that opponent is an active player.

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, with a particular emphasis on material learned in ME218b. To gain this experience, you and your team will design and implement an autonomous, untethered mobile robot.

Background:

Ed and Karl are locked in fierce, passive-aggressive battle for dominance in the 2024 HOA Most Beautiful Lawn awards. To this end, they strive to keep the areas around their homes neat and free of debris. Being the cunning mechatronic engineers that they are, "working smart" rather than "working hard" is in their blood, so they each call upon robotic sentinels to not only clear the debris, but also move it to their neighbor's property, so as to shift the balance of power prior to a visit by the HOA inspector.

The Task:

Your team is assigned to design and build a System for Quick Removal of Litter (SQRL), which is an untethered, autonomous, mobile platform, capable of moving ACORNs (A Cylindrical Object Representing a Nut) into the neighboring YARD (Yet Another Region for Dumping) by sliding them under the FENCE (Fortification Ensuring No Crossing, ExceptforACORNs). Additional ACORNs can be gathered by your SQRL from two TREES (Tubular Repository of Excess Eject-ables) located at fixed locations on your side of the FENCE. During play, you may be facing an opponent on the other side of the FENCE who is also attempting to slide ACORNs into your YARD, or there may be no opponent at all. The winner of each HOA inspector match-up is the SQRL whose YARD scores fewer points, as measured by the count of ACORNs in the YARD. During the development phase, the arena will be located in SPDL, and for public presentation, it will be moved to the Building 550 Atrium.

SQUIRREL!

Dug, Up (2009)

Specifications

Overview:

- Each team will construct a SQRL.
- The SQRLs compete in the arena to move ACORNs under the FENCE into the opposing side's YARD.
- While the goal of the project is to have SQRLs compete head-to-head, the grading standard is to score in the absence of an opponent.

The Arena, The ACORNs, The TREES The YARDs, and The FENCE:

- The Arena is an approximately 244 cm by 244 cm with exterior walls 8.25 cm tall. A top view is shown in Figure 1.
- The Arena is divided into two equal-sized YARDs by the FENCE.
- The FENCE is a solid barrier, impassable by SQRLs. There is an approximately 8 cm tall gap from the surface of the Arena to the rigid portion of the FENCE.

- No portion of any SQRL may trespass to the opposite side of the FENCE. This is punishable by up to 1 year in county jail and a fine of up to \$1000. ([California Penal Code \[CPC\] §602\(k\)](#))
- The FENCE gap is filled with a lightweight flexible material that blocks the transmission of light, but allows for ACORN movement from one side of the FENCE to the other.
- The ACORNs are round, lightweight polymer cylinders approximately 7.24 cm in diameter and 24.5 g in weight.
- A sample drawing of a ACORN is shown in Figure PUCK-FIGURE.
- ACORNs have around their circumference a strip of retro-reflective material. The important property of a retro-reflector is that it very effectively reflects any light incident upon it straight back towards the source of the light.
- There are four TREES located at the indicated positions in the Arena. These TREES are cylindrical tubes that each contain five ACORNs.
- The bottom-most ACORN in a TREE is completely exposed, sitting on the surface of the arena, with all remaining ACORNs in the TREE stacked on top of it.
- Moving the bottom-most ACORN outside of the footprint of the TREE causes the stack to fall by one ACORN height, exposing the next ACORN in the stack.
- Moving the final ACORN in a TREE outside of the footprint of the TREE does not cause a new ACORN to fall.
- A side view of a TREE is shown in Figure 2.
- Each TREE is marked by a modulated IR beacon, with emitters located 36 cm above the surface of the Arena. The modulation frequencies of each beacon are shown in Table 1.
- A strip of 2.54 cm-wide black tape runs along the centerline of the Arena, orthogonal to the FENCE. This tape is designed to aid in navigation.
- On each side of the Arena, there is a second strip of 2.54 cm-wide black tape, parallel to the FENCE, that extends from one TREE to the other. This strip has, at each end, a 12.7 cm wide orthogonal "tee" to denote the end of the tape. No tape strip extends into the footprint of the TREE.
- Each YARD has areas shaded in various colors to denote scoring value. These colors are not designed to be machine-readable, and are solely for human reference.

Table 1: TREE IR Beacon Frequencies

Beacon	Frequency (Hz)	Period (μS)
TREE E	3333	300
TREE D	1427	700
TREE K	2000	500
TREE A	909	1100

The SQRL:

- Each SQRL must be a stand-alone entity, capable of meeting all specifications described in this document. Only SPDL-supplied battery power is permitted. No more than two batteries may be used to drive motors that transfer force to the surface of the Arena.
- Each SQRL must be able to automatically determine if it has been placed in Ed's YARD or in Karl's YARD.
- Each SQRL must include an electro-mechanical indicator that changes based on which YARD it is in at the start of a game round.

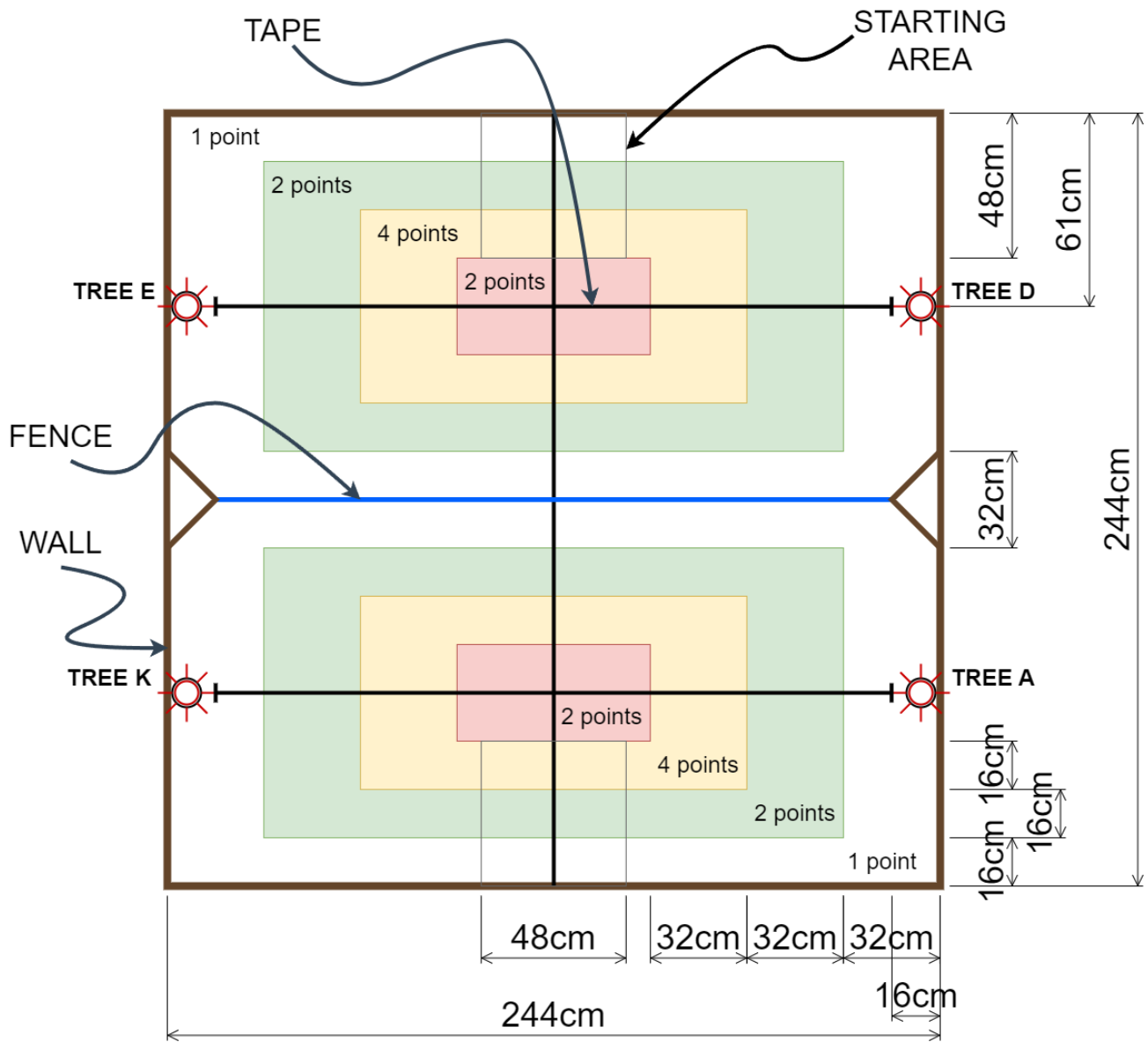


Figure 1: The playing Arena. Ed's YARD is on top, Karl's YARD is on the bottom. All dimensions are ± 2 cm.

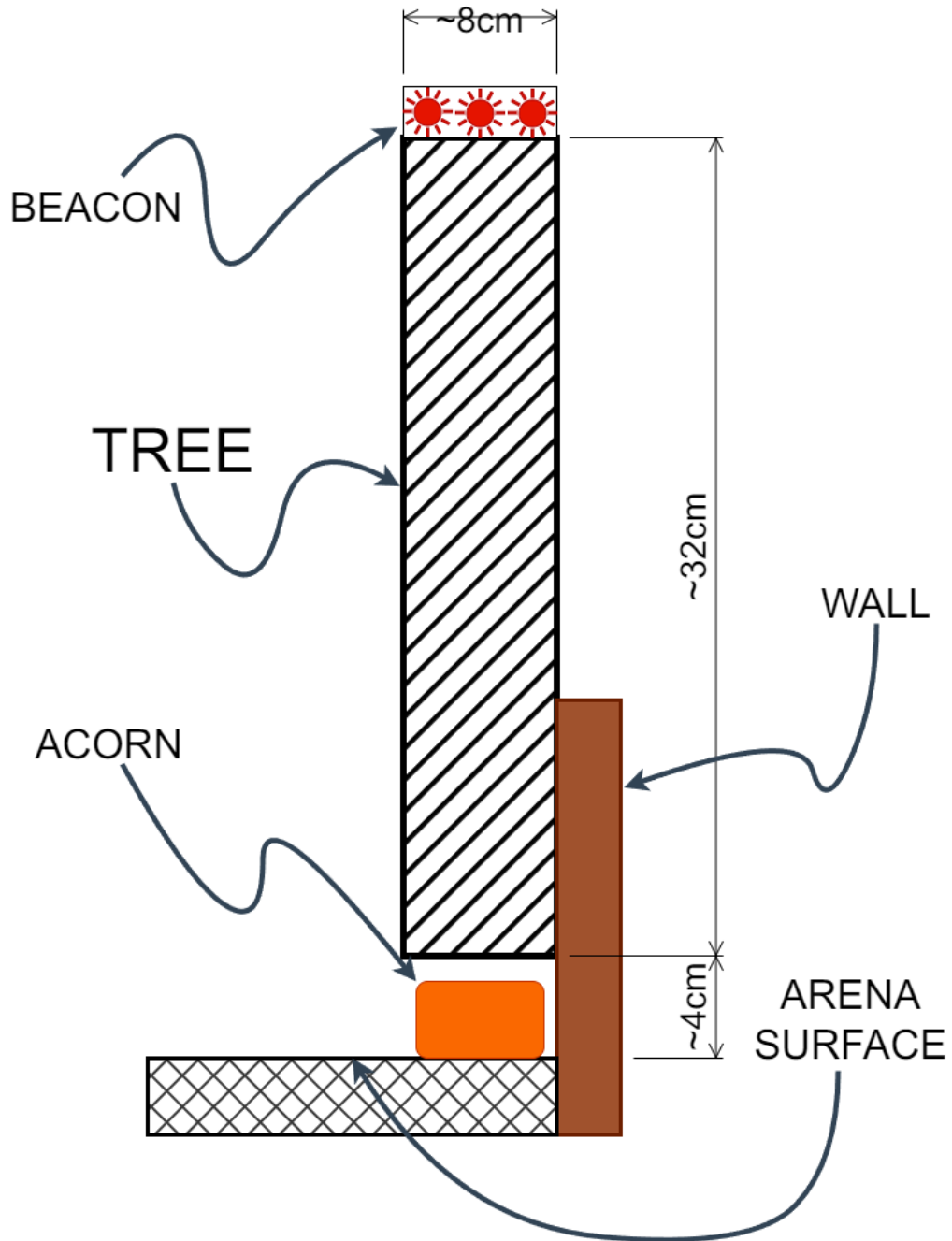


Figure 2: Side view of a TREE. All dimensions are ± 1 cm.

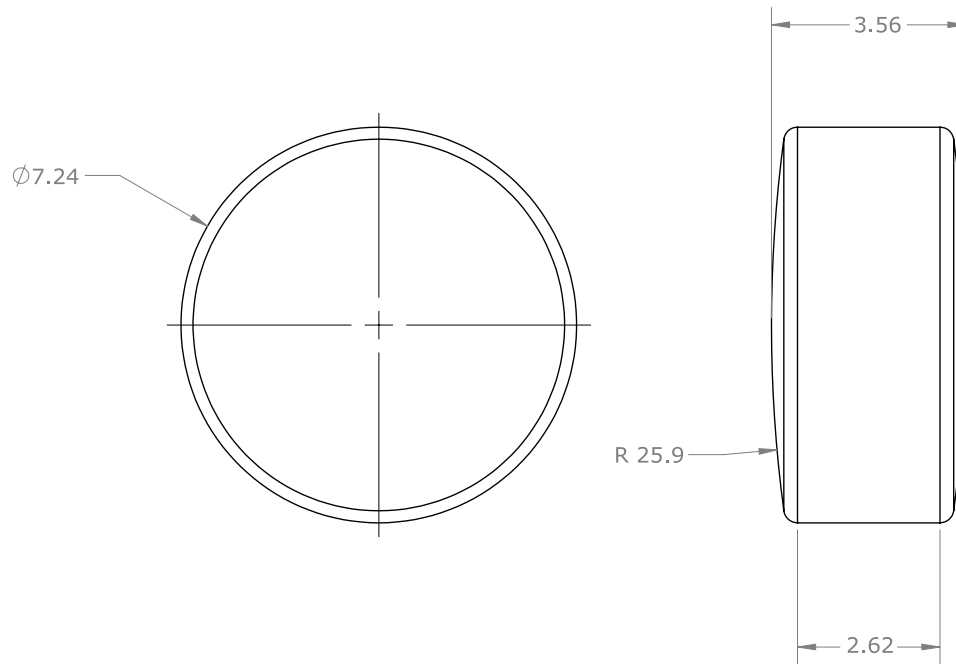


Figure 3: CAD Drawing of an ACORN. Dimensions are in cm. All dimensions are ± 0.2 cm.

- SQRLs must be autonomous (no tele-operation) and untethered (battery power only).
- Parts of a SQRL that touch the Arena floor must roll or slide, and **must be non-marking/non-marring**.
- Only the SPDL-provided motors may be used to drive anything that transfers force to the surface of the arena.
- At the beginning of a game round, your SQRL must fit within a cube measuring 32 cm per side.
- After a game round starts, a SQRL may expand to occupy a square footprint of 48 cm side length, but it may never exceed the maximum height of 32 cm.
- Each SQRL shall contain a network of processors consisting of, at a minimum, one PIC32 SPI leader and one PIC32 SPI follower device. How the necessary functionality is partitioned among the networked processors is up to each team to design.
- Each SQRL must carry an easily accessible switch which shall cut power to the SQRL completely. This switch is for safety, in case of software or hardware malfunction.
- The motor power supply for the SQRL must be fused for protection in case of a hardware malfunction.
- Each SQRL must be constructed as part of ME218b. It may not be based on a pre-existing or commercial off-the-shelf platform.
- The HOA has limited you to a total 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 SQRL must provide a indication of when it thinks that a game round is in progress that is clearly visible from 7 m away. This indicator should be activated when the SQRL determines that the game round has started, and be deactivated when the SQRL thinks that the game round has ended.

Basic Game Play:

- The game is a head-to-head competition between two SQRLs to move ACORNS into the opposing side's YARD.

- ACORNs may be moved by any mechanism that otherwise does not violate the rules, however, ACORNs must never become ballistic (they may not have an upward velocity component).
- Before the start of each game round, each competing team will place their SQRL in the marked starting area in their YARD, centered on the black tape line. The teaching staff will choose the starting orientation of the SQRLs.
- After the starting orientation of a SQRL is chosen, the team responsible for the SQRL may place one, and only one, ACORN directly adjacent to the SQRL in a location of their choosing.
- The game round begins when a member of the teaching staff announces the start. At this time, a member of each team is expected to press a button on their SQRL to commence gameplay. Any further interaction with the SQRLs is prohibited until the game round ends.
- Each game round lasts for 2 minutes, 18 seconds.
- When a SQRL detects that the round time has elapsed, the SQRL must cease movement and deactivate its game-in-progress indicator.
- At the end of a game round, the YARD with the lowest total score, as calculated by multiplying the number of ACORNs in each colored area by the point value of that area, and taking the sum, is declared the winner.
- If both teams have an equal score at the end of a game round, then a new "sudden death" round is played. In "sudden death", the first SQRL to move a ACORN to the opposite side of the FENCE wins.

General Rules and Requirements:

- No solderless breadboards are permitted in your SQRL.
- Intentional interference with the operation of another team's SQRL is prohibited.
- Each SQRL must start and remain in one piece during a Game. Any locomotion of the SQRL should cause all parts of the SQRL to move.
- Your SQRL may not, **IN ANY WAY**, alter the condition (e.g. mar the walls, or floor) of the playing field.
- Your SQRL may not, **IN ANY WAY**, damage, including, but not limited to, jamming or toppling, the TREEs.
- The use of gases or liquids to impart force on any object is prohibited.
- Intentional jamming of your opponent's sensors is prohibited.
- There is no class-imposed upper limit on the number of processors employed; however, you must use only the PIC32MX170F256B. Tivas, Arduinos, Raspberry Pis, Teensys, Jetsons, and other microcontrollers are not permitted.
- You are limited 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, from the lab kit, or the Cabinet Of Freedom do not count against the limit. All other items count at their fair market value. **If it's an issue with something from the kit, we will provide a replacement for free, but we can't guarantee latency. Be careful with your components.**
- A project logbook must be maintained for each group. A blog is appropriate to meet this requirement as long as it is made available to the teaching staff for review. This log should reflect the current state of the project, planning for the future, results of meetings, designs as they evolve, etc. The project logbook will be reviewed at irregular intervals for evaluation.
- A report describing the technical details of the system will be required. The report should be of sufficient detail that a person skilled at the level of ME218c could understand, reproduce, and modify the design. The report must be in website format, and be suitable for posting on the SPDL site.
- SQRLs based substantially on purchased platforms are not allowed.

- 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:

- Your SQRL should be safe, both to users and to spectators. The teaching staff reserves the right to disqualify any SQRL considered unsafe. This also applies during testing, so keep your SQRL speeds low enough so as to not cause problems.
- You should make a stand to support your SQRL on a benchtop for testing. The purpose of the stand is to prevent an errant SQRL from driving itself toward rapid unscheduled disassembly.
- SQRLs must be stable in the presence of a 15 m/s wind.
- No part of any SQRL 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 SQRL can use only one quart-size, zip-top, clear plastic bag.
- Red, Green, and *especially* Blue shells are prohibited. Any banana peels must stay within the confines of your SQRL at all times.
- Any early celebrations will be penalized.
- Your SQRL is not permitted to steal talent from any other SQRLs.
- SQRLs may alter the space-time continuum only during the public presentations.

Checkpoints

Design Review:

During the day on 2/13/24 we will conduct design reviews. Sign-ups for 1-hour time slots of three teams each will take place on a Google sheet. Each team should prepare a few **simple** presentation 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, as well as how you will partition responsibility between team members. You will present to members of the teaching team as well as to your classmates, so that all may hear about your ideas and provide feedback and advice.

...

Scrat, Ice Age (2002)

First Checkpoint:

On 2/16/24, your team must submit 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, but they must be comprehensive, addressing all major subsystems. For your submission to Gradescope, create a single PDF document that includes the system block diagram, KiCad schematic(s), 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.

The creation of a thousand forests is in one ACORN.

Ralph Waldo Emerson

Second Checkpoint:

On 2/22/24, 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 an IR beacon. This demonstration may be a tabletop demonstration and may be done while tethered to a development computer.

Fear the TREE.

as heard at Leland Stanford Junior University

Third Checkpoint:

On 2/27/24, you must demonstrate an instance of your (possibly) tethered, motorized platform moving, though not necessarily with integrated software. Your platform must be able to, starting from the start position on the field, locate an IR beacon and move towards it under coordinated control from multiple PICs.

Project Preview:

At the Project Preview on 3/1/24, each team's SQRL must demonstrate, untethered and in an integrated physical form, under autonomous software control:

1. The ability to move around the field.
2. The ability to locate the IR beacons and to identify your side.
3. The ability to move a ACORN under the FENCE to the opposing side's YARD.

This will be tested by following the normal starting procedure for a Game, followed by your SQRL performing the required actions.

There are squirrels in my pants!

Candace Flynn, Phineas and Ferb

Grading:

The grading period will take place on 3/6/24.

During a grading round, each team will be required to demonstrate that their SQRL can complete a single round of the Game.

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

Evaluation for grading purposes will only occur during these rounds. If your SQRL fails at its first attempt to demonstrate the required functionality, it must demonstrate that functionality twice in succession at its next attempt. This increase continues after repeated failed attempts up to a maximum of four required successive demonstrations.

In a world full of nuts, be a squirrel.

Unknown

Public Presentation:

This will take place on 3/7/24 starting at 7:00 pm in the Building 550 Atrium. (Building 550 is where our classroom is located.)

At this event, members of the public will be encouraged to watch your SQRLs battle for YARD dominance.

The early squirrel gets the nut.

Unknown

Report:

Draft due on 3/11/24 by 4:00 pm. The final version (with revisions incorporated) is due by 5:00 pm on 3/15/24.

I'm a crazy rabid squirrel, and I want my cookies!

Hammy, Over The Hedge

Evaluation

Performance Testing Procedures:

One or more team members will operate the SQRL during the performance evaluation. A competition among the class SQRLs will take place after the final performance evaluation.

Performance Evaluation:

Performance evaluation will take place twice during the project, the first time at the Project Preview and the second time at the Grading Session. These are the only functional evaluations that impact your grade.

Competition:

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

Grading Criteria:

- Concept (10 %)** This will be based on the technical merit of the design and the implementation of all technical aspects of your machine. Included in this grade will be the evaluation of the appropriateness of the solution, as well as innovative use of hardware, software, and physical principles.
- Implementation (15 %)** This will be based on the prototype displayed at the evaluation session. Included in this grade will be an assessment of the physical appearance of the prototype and the quality of its construction. Particular focus is placed on craftsmanship and finished appearance.
- Checkpoint Performance (10 %)** Based on demonstrating required functionality at the various **check-points**.
- Preliminary Performance (10 %)** Based on the results of the performance demonstrated 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: whether you made 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 your written report. It will be judged on clarity of explanations, completeness and appropriateness of the documentation. Your report should be in the form of a stand-alone website and must include schematics, pseudo-code, state charts, header and 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/CSS, JPEG/PNG or other viewable bitmap image files, and PDF files. Schematics should be vector PDF files, not bitmaps. 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 an application other than a web browser. Your site should be fully functional on both desktop and tablet web browsers. **Do not embed video files directly** into your site. If you want to include video, provide a link to a video-sharing site.

It is critical that the URL of your report be entered in the Google sheet on time, so that the peer reviewing team has adequate opportunity to review it before class. Final versions of the reports, incorporating the review comments, are due by 5:00 pm on 3/15/24. Make sure to test all of your links prior to submitting your report. If the teaching team cannot open and browse your report website, then they cannot grade it!

- Report Review (5 %)** 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 SQRL realistically be built for 150? If, during grading, we find things that don't make sense, or circuits that don't work, we will consult your review. If your review caught them, then the partner team will lose points on their report. If the review missed it, then the reviewing team will lose points for their review. The Report Review should be submitted in the form of a text document submitted to Gradescope.
- Housekeeping (5 %)** 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 who have not returned all loaned materials.

- **Peer Reviews** Completing a peer review on CATME is a **required** component of the project. These reviews are not optional, and project work will be considered incomplete unless reviews are completed by the due dates.

Team Organization

While each member of your team has principal design responsibility for a specific functional area, the experience of the teaching team is that turning team members into dedicated specialists will be a mistake in the long run. Many 218 alumni from such silo-ed teams report that they regret not sharing in all of the technical aspects of the project, feeling that they have lost out on some of the experience. The teaching team encourages 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 all details of the design, implementation, and debugging of all subsystems will not only provide a better learning experience, it will also prevent hangups during the integration and testing phase when the team "expert" on a specific subsystem is not available.

Mechanical Design and Robustness

Your machine must be rugged enough to survive your testing.

While the emphasis in lectures has been on 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 that your robot will be subjected to—not just when it's operating as intended, but also when it receives bumps from other robots or humans that may also be testing on the field.

While in-class work sessions have focused largely on software implementation, keep in mind that, although computers are deterministic, the real world is not. Make sure that your software is built not just to handle what you hope will happen, but also to deal with everything that might happen that could cause problems.

When integrating several subsystems, although it may seem (and feel) slower, it is absolutely worth your time to make sure that 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 section above, that your SQRL will be robust to a fall from tabletop height to the floor. To avoid the possibility of that happening, your team should create a stand/platform for your SQRL that raises its wheels above the surface. With this stand in place, and your SQRL perched upon it, if your electronics or software go haywire and your SQRL spins its wheels uncontrollably, it will not drive itself off of a cliff edge.

Resources

Websites:

[SparkFun Newark](#)
[DigiKey](#)

[Seeed Studio](#)
[Ponoko](#)
[McMaster-Carr](#)

[Jameco](#)
[Adafruit](#)
[HobbyKing](#)

[Mouser](#)
[Hackaday](#)
[ServoCity](#)

You may also find [PlantUML](#) and [PlantText](#) helpful for creating message sequence diagrams. [WaveDrom](#) can be used for timing diagrams.

Local Stores (Not applicable while quarantine is in effect):

[Anchor Electronics](#) in Santa Clara
[J&M Hobby House](#) in San Carlos
[Jameco](#) in Belmont
[TAP Plastics](#) in various locations

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. Get inspired by your favorite neighborly duels, either real or fictional!

Revision History

Revision 0: Initial, figures still being worked on (2/7/24)

Revision 1: Figures and tables added (2/8/24)

Revision 2: Added diagram callouts, dimension tolerances, date fixes and minor edits (2/8/24)

Revision 3: Clarification on how TREES work. (2/8/24)

Revision 4: Add ACORN weight. (2/8/24)