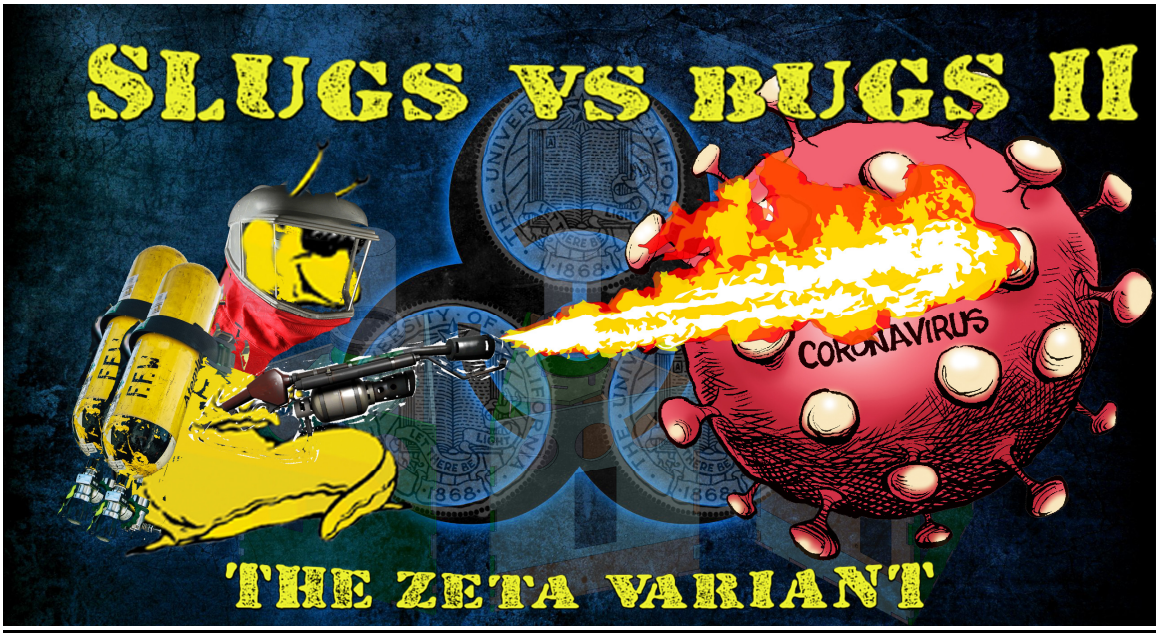
UNIVERSITY OF CALIFORNIA, SANTA CRUZ
BOARD OF STUDIES IN ELECTRICAL AND COMPUTER ENGINEERING

ECE-118/L: INTRODUCTION TO MECHATRONICS

SLUGS VS. BUGS II: THE ZETA VARIANT



Background Briefing:

The year is 2029, the worldwide coronavirus pandemic is well behind humanity and life has returned to normal; the only people wearing masks are in the operating theater or bank robbers on their way to a heist.

News has come out, however, that a deadly strain of the virus, the ZETA variant, has been forgotten in a lab run by the SALT group, who went bankrupt several years ago and abandoned the facility. The CDC, fearing another lab leak releasing the ZETA variant and causing a new pandemic, has decided that human entry into the lab to destroy the remaining virus is simply too risky.

In a bold move, they have commissioned you, the ECE-118 class, to develop droids to go into the lab and place thermite explosives around the vats and consume the virus in the ensuing conflagration. Luckily, there exist blueprints of the lab, and the location of the vats are well known.

Your droid will start out in a corner of the compound and approach the lab vats. There will be a beacon at the top of each lab vat. These beacons will indicate where you must deposit your thermite charge (ping-pong ball) into the lab vat. In the dossier below, find further specifications for your droid.

Purpose:

The purpose of this project is to provide an opportunity to apply all that you have learned in ECE-118 to solve an open-ended problem. Your task is to build an autonomous robot that will navigate the game field, locate and destroy the zeta variant in the three storage vats (using your ping pong ball ammo), and either win by points or by destroying all the vats.

Project Requirements:

A. Team and robot meet three Design Reviews (Brainstorm, Mid-Project Review, Final Check-Off)
B. Team maintains an active lab notebook (or website) detailing their progress and designs
C. Each and every week team satisfies Check-offs and meets with their mentor
D. All loaned parts returned to TAs (IO stack, etc.) after tournament
E. Lab cleaned up before end of finals week
F. Final Report due at end of finals week
G. Participation in Public Tournament (0% of your grade; 100% fun)

If your robot can demonstrate robust Final Check-Off one week before the final deadline the Instructor will personally buy your team beer. The beer check-off has rarely been awarded. See beer checkoff rules below.

Project Overview

Your task is to build a small autonomous robot (droid) that can effectively and robustly navigate a standardized field, locate and advance through the field while avoiding a pit in the center of the field. You must locate the vat locations, recognize the correct side of the vat, and identify the correct hole in which to drop the ball. You will receive points by depositing ping pong balls in the correct holes. You will lose points for dropping them in the incorrect holes. The match is won by earning the most points for depositing balls correctly. You will be doing this in teams of three, over the next five weeks, during which time you will design, implement, test, and iterate until you can reliably complete the task. There will be practice fields in the labs, and lots of help and guidance available to you. Don’t panic. Yet.

The field of play is a large white 8’x8’ surface with a 2” black tape boundary (going out of

bounds disqualifies the robot). There is one standard keepout zone on the field. It is indicated by a perimeter of 2" black tape. There are three "vat towers" on the field which are marked with track wire (at the standard 24-26 KHz) that runs vertically down one of the obstacle faces to the field. You will start in the "starting zone" in a random orientation. You must move to a vat tower, locate the correct side (indicated by trackwire), find the correct hole (indicated by a vertical black stripe) and deposit at least one ball in the hole. If your droid falls into the keepout zone (more than ½ of your bot crosses the black tape) you are disqualified. If your bot leaves the field (more than ½ of your bot outside the external boundary) you are disqualified. After depositing one ball in the correct hole on a vat tower, you must deposit a ball in another valid hole (different vat) before earning more positive points (you can deposit ten balls in a row into the correct hole, but will only receive points for one successful placement.)

The 2kHz IR beacons on each of the vat towers will be illuminated for the entire match. At least half of your robot must remain within the black tape line at all times or your robot is out of bounds and will be disqualified.

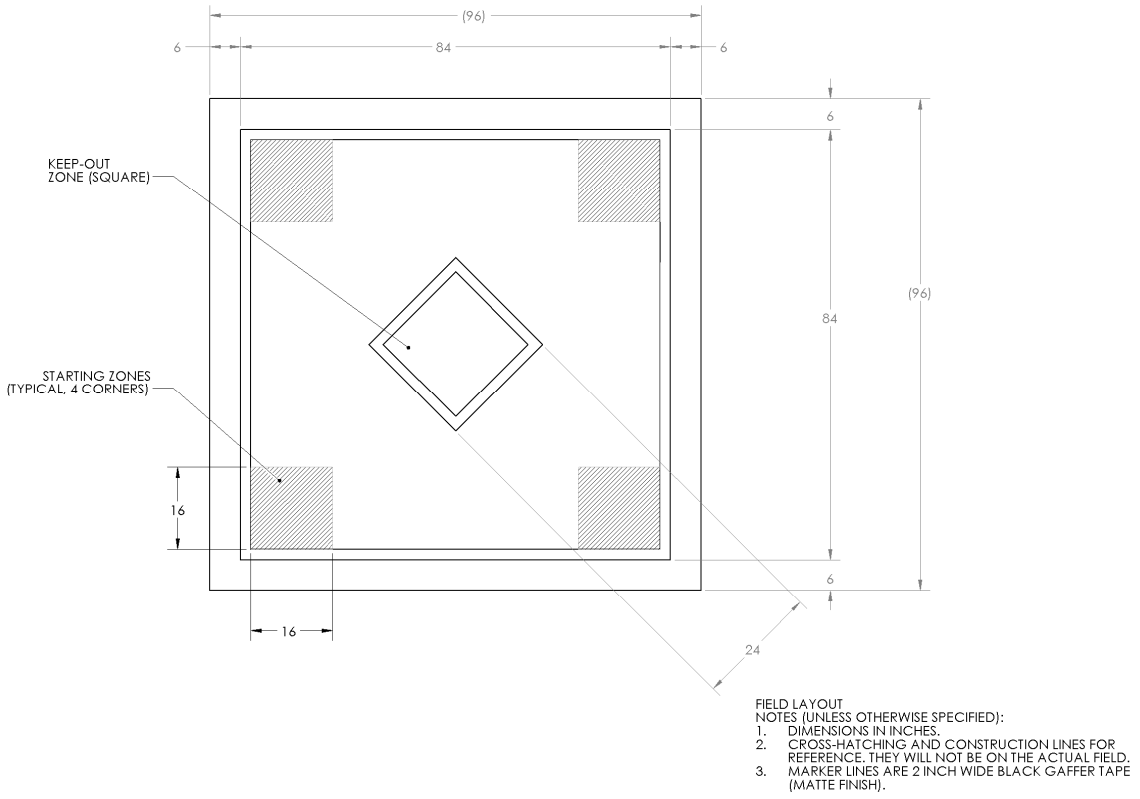


Figure 1: Field of Play for the Slugs vs Bugs II. Black tape boundaries and alignment marks are 2" thick PVC tape. Vat Towers can be anywhere on the field except in the keepout zone.

The vat towers are 10 inches wide and 11 inches tall, and triangular from plan view. They

are marked with 24-26KHz track wire extending vertically from the field and form a perimeter around the active side of the tower. Note that there will be 3 towers on the field.

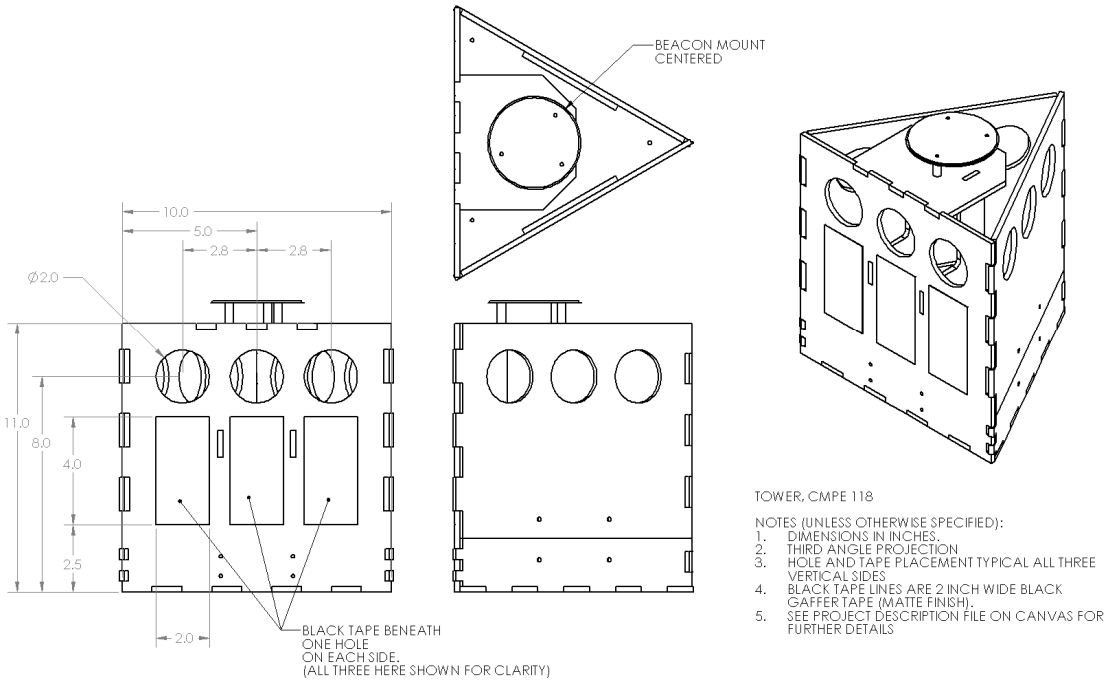


Figure 2: Vat Towers are 10 inches wide and 11 inches tall, and are marked with 24-26KHz track wire extending vertically from the field and form a perimeter around the active side of the tower.

Each droid must start the match within an 11” cube volume (parts may move after the round begins) and remain intact throughout the match. Jamming your opponent in any way is disallowed. Robot sizing will be checked with the *Cube of Compliance*.[†]

Your robot is required to stay within the field (marked by 2” black tape boundary), defined by keeping at least half of the robot within the black tape. Robots exiting the playing field (more than half the robot past the black tape boundary) will be disqualified. Your robot is required to detect collisions and resolve them (e.g. if a tower is blocking your path; you need to be able to maneuver around any immovable obstacle). You are required to break contact within 5 seconds or be disqualified.[‡]

While every attempt has been made to finalize the project specifications and rules, understand that this is a work in progress. As the project evolves, we will be making

[†] We have (and will) require you to modify your robot because it does not fit inside the dreaded Cube of Compliance. Remember to take into account things that stick off your robot (e.g.: wires).
[‡] Pushing an obstacle out of the way is not allowed.

(minor) tweaks to the specs as we discover what flaws we have not anticipated. These will be announced in class, and posted on Piazza. They are not meant to destroy your winning design, but only to make things work smoothly. Your understanding is appreciated.

Minimum Specification Checkoff:
In order to pass this class, your robot must demonstrate that it can complete the task.[§]

While the rules and specifications are below, teams are free to embellish, go beyond, and otherwise have fun—however, we suggest you aim for "min spec" first, and then go back (and go nuts).

Your robot begins the round randomly placed within the starting zone of playing field in a random orientation (see Fig.3 for an example min-spec scenario). The towers on both your field and the opposing field are randomly distributed.

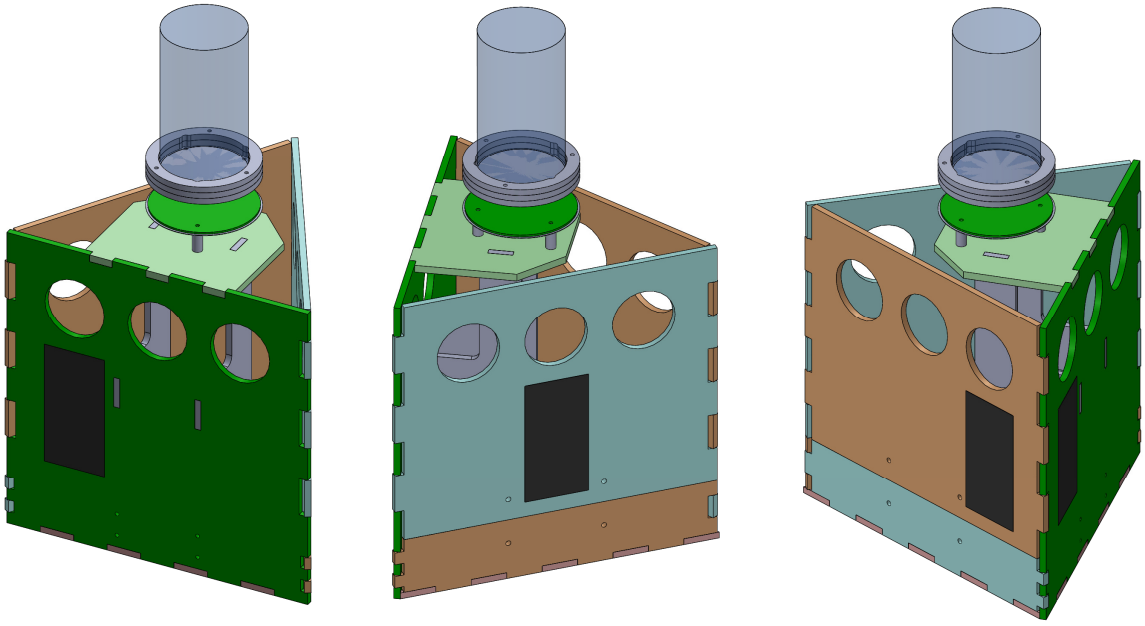


Figure 3: CAD model of the vat tower. Note each side has three holes but only one black tape strip (order randomly selected). Positive points are awarded for depositing balls in the correct hole (black stripe on the correct side as indicated by the track wire). Negative points are given for depositing balls in the incorrect hole.

At the start of every round, your droid must contain all ping pong ball ammo that will be used during the match. Each of the obstacles will have their IR beacons (2KHz) illuminated.

[§] Yes, we have had teams go well into the break before they finished. No team passes the class without passing min-spec.

Your robot should move from the starting zone to at least one tower location and locate the appropriate side in which to deposit the ball. You must find the correct hole in which to deposit the ball, and deposit it in the correct hole.

Min-spec is defined as two balls to two correct vat tower hole locations (not the same hole).

Should it become apparent that a robot will not complete a round (for example, if it fails to resolve a collision for more than 5 seconds, or lacks sufficient ammo for completing the task, your robot will be disqualified and the round will end.

Tournament:
In the tournament, you play against another team; each will start on a different starting zone (with randomly set towers)

If you win the match, your robot advances in the tournament, *victory will be awarded by points*. Should a tie occur, we will attempt a rematch.[**]

Points are awarded as follows (each may be invoked exactly once per robot per round):

10 points:	Locate and orient relative to the correct side of a tower
50 points:	First ball in a correct vat tower hole
0 points:	Each subsequent ball through the correct vat tower hole
-50 points:	Each ball deposited in the incorrect vat tower hole

Robots will be disqualified for going out of bounds (more than half the robot over the black tape boundary), or for failing to resolve collisions (must break contact by 5 seconds).

We may (will) update these rules and/or points should (when) flaws become apparent.

The Droid

The droid must be a stand-alone entity that fits in an 11”x11”x11” cube at the beginning of the round. Your machine must contain all ping-pong balls at the beginning of the round (no reloading allowed). It should be capable of meeting all specifications while drawing power only from batteries. It must be able to detect bumps at a height of 3.0” above the ground. The droid must be able to detect and resolve collisions with an obstacle (break contact after 5 seconds). Droids should be able to keep themselves on the field (half of the robot within the black 2” tape boundaries). Droids should be able to avoid the keepout

[**] If you both continuously tie, we will flip a coin and move on.

zone at the center of the field

Droids will be programmed in C, using the standard MPLAB-X IDE. Your droid behavior will be constructed using the ES_Framework from Lab 0 (however you may NOT use the Roach projects you wrote).[††] You may reprogram your droid between rounds if you desire, but you may not alter it once the field configuration is established.

Each droid must be equipped with a remote power switch (using the remote switch header on the Uno stack). At the beginning of the round, you will switch on your droid, and may not interfere with it until the round ends.

Materials

Each team will be provided with one Uno Stack, one L298N H-Bridge, one Stepper Board (if needed), one DS3658 board (if needed), one battery, and one ULN2003 (if needed). There will be also wire, regulators, and solder freely available in the 118 labs.

Each team should not exceed a budget of $150 total for other parts on the robot, and must maintain an up-to-date bill of materials (BOM). If we spot a nice $5K gyro on your bot, we will hand you $150 and take it. We don't want the project to be an arms race over who can purchase better stuff. We will have MDF and Foamcore available for purchase at cost. BELS, Ace Hardware, Fastenal, and Home Depot are all decent local sources. HSC and Tap Plastic (Acrylic for $1) are most excellent resources in the Bay Area (get together and caravan). McMaster-Carr will deliver nearly any piece of hardware within a couple days but they tend to be expensive. Amazon Prime is free to students for a three-month trial, and will get things to you in two days (or in one day for an extra $5 for shipping).

Available Tools

It should go unsaid that all work needs to be done by the team and not contracted out. You will have the resources in Mechatronics Labs, as well as the drill press, tool chest, and Laser cutter in BE138. Your circuits must be soldered on perfboards, no breadboards. Those of you thinking about PCB houses, you most likely won't get turn-around in time without blowing your $150 budget. Off-the-shelf sensor boards, such as those sold by Sparkfun or Adafruit, are fine (but understand that the software integration for these sensors can take much longer than you anticipate—manage your time carefully).

Field Specifications:

We will have a Solidworks model of the field, vat towers, and beacon mount available after the midterm. The model in Fig. 1 will be available on the website in higher

[††] If we see a Roach_HSM file we will delete all of your code. Seriously, write it from scratch.

resolution, and is drawn to scale. Modifications (if any) to the field will be noted on Piazza.

Further questions or clarifications about the field specifications should be posted to the Piazza forum.

Safety:

The machines should be safe to the user, the lab, and the spectators. For this project, excessively high velocity ball delivery will be discouraged (so go ahead and forget about that CO2 PVC pipe launcher you were thinking about.) Voltages are limited to the rechargeable batteries in the lab (you may purchase your own if you'd like, but consider 10V an upper limit), and intentional jamming or blocking of the opposing robot or masking of any beacon/trackwire is considered foul play and not allowed. 'Bots deemed unsafe will be disqualified.

NOTE: Young children line the competition field; take this into consideration when designing your launch mechanisms. Each team will be required to take three Ping-Pong ball shots from their own robot on bare flesh at a distance of 3ft from the barrel of their 'bot. All members of the team must do this.[‡‡]

Prior to competition your robot should not transcend space or time in any way, nor should your robot alter gravity within our Solar System. However, during competition, gravity and space-time may be altered at will.

Evaluation:

Performance testing procedures: All machines will be operated by at least one of the team members. There will be one round for grading purposes done in the lab to evaluate 'droid performance. The public tournament is purely for entertainment purposes (though if you have not yet checked off, successful completion of the min-spec tasks during the public demo counts as a valid late checkoff).

Grading evaluation: Each machine will be graded based on its performance in the testing before the class competition at the end of the quarter. Each machine will have up to 2 minutes to solve the challenge. Grading is not based on point values, but how robustly your robot performs.

Grading Criteria:

1. Concept (20%): 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

[‡‡] Yes, we have pictures of students with ping-ping ball induced welts on their backs.

solution, as well as innovative hardware and software and use of physical principles in the solution.

2. Implementation (20%): This will be based on the prototype displayed at the evaluation session. Included in this grade will be an evaluation of the physical appearance of the prototype and the quality of construction. We will not presume to judge true aesthetics (though we might comment on it), but will concentrate on craftsmanship and finished appearance.

3. Report (10%): 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.

4. Performance (20%): Based on the results of the performance during the evaluation session.

5. Design Evaluations (30%): Based on check-off completion.

Project Milestones:

Each week, your team will need to achieve a list of check-offs to stay on schedule and each partner will need to work as part of the team. **IF YOU DO NOT STAY ON SCHEDULE WITH THE CHECK-OFFS** you will NOT finish in time and be forced to stay through winter break until your robot is complete: **STAY ON SCHEDULE**.

Your weeks will essentially break into the following (see Canvas for specific dates):
Week 1: Design, Schedule, and Group Order (Design Review I)
Week 2: Electronics and Mechanical Prototyping
Week 3: Working Prototype for moving robot and ball launcher; State Machine (Design Review II)
Week 4: Finalizing robot and getting everything to work together.
Week 5: Competition and Final Check Off (Design Review III)

There will be **weekly checkoffs**, **three design reviews** throughout the project, **one lab report**, and **one and only one competition.**

Half of this project is communicating well and documenting progress to stay on schedule. With that in mind, we expect each team to maintain and update a lab notebook with everything you are doing and copious notes.[§§] We very (very) strongly recommend that your lab notebook stays with the robot in lab. We will use this to verify your check-offs for each week. We recommend sharing some form of file/team drive/GIT repo to help

[§§] If you want to use WordPress, Wiki, or Google website for the project posting block diagrams, sketches, pictures, schematics, videos, etc., we don't mind but a paper and pencil version is still required.

you keep your selves on task, but do not require it. That said, each team will need to submit their lab notebook and schedules for the Design Review #1. See "check-offs" section for further details. Note that if you want to use GIT for your storage for the project, you will be able to create a repo on the UCSC GITLAB server.

A report describing the technical details of the machine will be required. The report should be of sufficient detail that any skilled ECE118 alum could understand, reproduce, and modify the design.

Design Review 1: Thursday, post midterm (PDR)

Team Concepts, present your best design to the class for three minutes

Come up with 3 team concepts for your design from your individual ideas and a bit of brainstorming (you will present your best 2). Mix and match between the best of your designs. How are you and your team going to accomplish your project goals? Schedule out your time as well as your team's.

You will need to upload your designs to CANVAS, and present your lab notebook to the tutors/TAs for checkoff. Submit your best team design and backup design before class on Thursday (see CANVAS assignment). You will have 5 minutes to present your design (and get some feedback on it). Have a primary and a backup in case it is too similar to someone else's.

Design Review 2: Mid-Project Review:

Full Prototype, presented to the staff for 15 minutes.

Present your currently working parts and your full design to the instructors for review and insight into potential roadblocks. Every system (both mechanical and electrical) should be prototyped at this point.

Mechatronics Beer Challenge:

Each team gets exactly three consecutive tries on the field to successfully complete your final check-off. If you can complete the task 3 out of 3 attempts, AND your robot still functions (i.e.: meeting min spec) in the public demo, you get beer. In the history of mechatronics only three teams have succeeded (and it was easier then). Note that in the beer challenge, the field is NOT random, but (possibly) set in a way to be difficult for your particular robot. We reserve the right to be evil here.

Design Review 3: Final Check-Off:

Present your final check-off robot to the staff. You get three tries to succeed on the field in each session.

Deliverables are:

- Robot that meets all requirements and completes the challenge.

Competition/Public Demo: the public demo off your finished, operational machines. This

fun performance will likely have a large and enthusiastic audience. Demo will be on December 3 at 6:00 pm (location will be forthcoming).[***]

There will be a post-tournament beer, dancing, decompress at one of the Santa Cruz watering holes (traditionally Woodstock Pizza). We will post plans on Piazza.

Clean-up and Class Review: Monday after Public Demo

Lab Report:

Electronic copy of your lab report, turned in as a group assignment in CANVAS.
Create a section for each design and write an evaluation of each aspect of your design: what went well and what didn't. Make sure to include pictures and links to video as necessary. Also include your final BOM.

Check Off Schedule:

Check-Off's are used to ensure that you are on track and keeping up. It allows the teaching staff to allocate their resources to help teams out in an appropriate way. Treat them seriously and your project will be completed well and on time.

Check-off 1:

Using the five concepts that each of you created for the midterm, now that you are assigned to teams, come up with 3 team concepts for your design. Mix and match between the best of your individual designs. How are you and your team going to accomplish your project goals? Get some details written down in your engineering notebook.

Deliverables are:

- 3 detailed TEAM concepts for solving the project.
- Make copies of them for your teammates and yourself.

Check-off 2:

Basic project management and system component design. This is where you define who is primary/secondary on which tasks. How you will coordinate time and schedules, etc.

Deliverables are:

- Time schedules
- Personnel assignments

[***] This is assuming that the University lets us have a big public demo. If so, we expect you to show up with your robot by 5:20PM. We will do everything we can to give you access to the room beforehand so you can test your robot in the tournament environment.

- System Block Diagram
- Mechanical Design Sketches
- Working beacon detectors on perf-board with LEDs (at least one) with accompanying schematics[†††]

Check-off 3:

Mechanical and Software Designs. You should at this point have your final robot design completed in appropriate CAD software, and your state machines should be entirely drawn out (neatly). Your mechanical design should easily fit within an 11" cube. While both of these may need to be updated as you progress, they should be in close to final form.

Deliverables are:

- State Machine(s)
- Final Mechanical Design (Solidworks)

Check-off 4:

Sensors and Actuators. Your full sensor suite should be functional and documented at this point. All ball launch mechanisms should be prototyped and tested for range and accuracy (this gives time to redesign if necessary).

Deliverables are:

- Working sensors (breadboard is ok) and schematics
- Actuators (breadboard is ok) and schematics

Check-off 5:

Final Sensor and Actuator designs. Final working (perfboard) prototypes of all sensors and actuators that your robot will use. Fully tested, fully documented.

Deliverables are:

- Final sensors and final schematics
- Final actuators and final schematics

Check-off 6:

Mobile platform with basic reactive navigation. Your platform should be integrated into a moving droid, which can keep itself on the field (tape sensing) and resolve collisions (bump sensors).

Deliverables are:

[†††] This should be the best one from Lab 2 among your team. If you really, truly, have to build a new one, make sure you use the best of the designs from the lab. This is not the time to redesign a better filter.

- Autonomous platform that can move and sense
- Reverse off of a collision sensor
- Keep itself on the field

Check-off 7:

Basic Navigation. Robot that can move from the starting zone to the first vat tower and locate the correct side. Your ball launch mechanism should be able to deposit a ball into a hole in the vat tower. You should be able to navigate and find the 2nd vat tower.

Deliverables are:

- Robot that can autonomously navigate to the vat tower, and score points
- Robot fits entirely within the *Cube of Compliance*.

Specifications Check-Off:

Min Spec. Your robot should be able to meet the minimum specifications. After that you may go home and celebrate (or sleep).

Deliverables are:

- Robot that meets minimum specifications

Notes on successful projects management: There are a few rules of thumb to follow that will make your project much more successful, and keep you working well as a team.

The first rule is a bit paradoxical, but nonetheless important: *Do what you are bad at*. That is, if you are good at software but bad at mechanics, then you take the lead on mechanical stuff, and take a secondary role in software design.

The second rule: Double-team every single task you need done. That means one person is primary/lead the other is secondary. Note that if you follow the first tip, then likely the secondary is better at the task than the primary. Do **NOT** attempt to split tasks up so that each one of you go off and do it and then come back—this never works and is *always* slower in the long run.

When crunch time comes, you can run a rotation with your three team members such that one sleeps, two work (the just woken up one works under the one who has been up). Then the lead goes to sleep, the secondary goes into lead position (on another task), and the sleeping one gets woken up to be secondary. While this is not sustainable beyond a couple of weeks, you can get an enormous amount done this way.[‡‡‡]

[‡‡‡] I personally have kept this up for approximately 21 days—not recommended but boy did we get a lot

Be careful about sleeplessness and cars/bikes/etc. There are plenty of couches around to crash on, and a number of students live in GSH (200 ft. from the lab). Don't think you can keep yourself awake long enough to drive/bike home. Be smart about this. We really don't want to see anyone get hurt through a senseless crash.[§§§]

PS: With this many people in the lab, it is going to be very important that you keep the lab clean and not leave your things lying around. We will be assigning I/O boards and batteries to each team, and they will be yours until the project is over. You will also get a milk crate to keep your robot in.

People occasionally donate random parts, and if you happen to find surplus printers, or other random electronics that people no longer want, feel free to dismantle and salvage what you want. However, please discard all parts that are not salvageable in an appropriate e-waste container so as to reduce clutter in the lab.

Drive motors have, in general, been a make-or-break part of the project. I would strongly suggest you consider purchasing some gearhead motors from Jameco, MPJA.com, or Amazon.com. Ordering them early (i.e.: now) would ensure that you have a set that will work by the time you need them. I will post on Piazza what I think are decent motors—if you have prime, they will get here quickly.

PPS: *The Mechatronics Beer Challenge*—any team that is able to complete the beer challenge spec (see above) with a fully functioning and finished 'droid a full week ahead of the deadline gets a case of beer or other equivalent adult beverage (within reason) supplied by Instructor. Only three teams have ever collected this. See rules above.

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done (DoD deadline)

[§§§] If you need a ride home and are too sleepy, call one of the staff—we will come get you or find a couch for you.