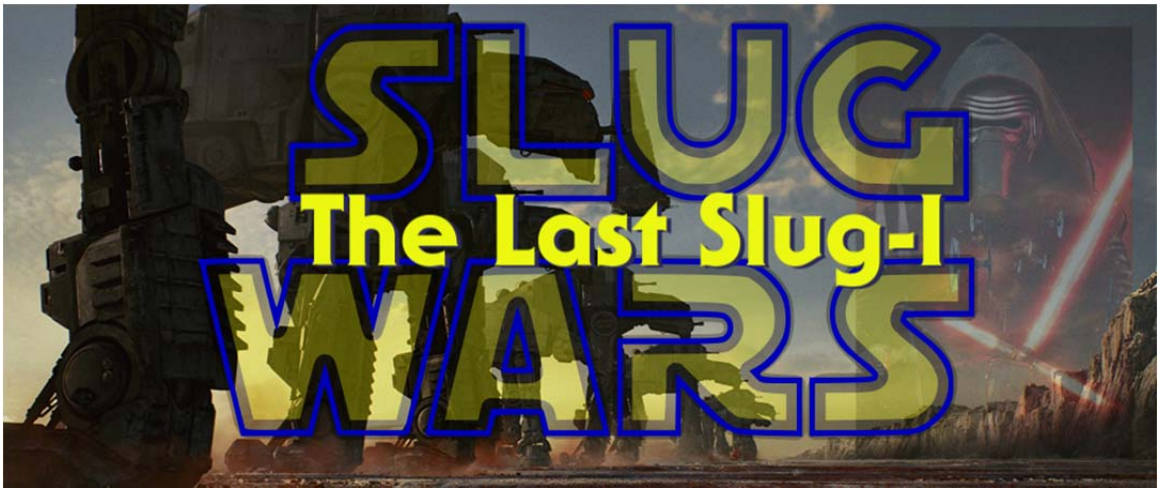
UNIVERSITY OF CALIFORNIA, SANTA CRUZ
BOARD OF STUDIES IN COMPUTER ENGINEERING

CMPE-118/L: INTRODUCTION TO MECHATRONICS

SLUG WARS: THE LAST SLUG-I



Background Briefing:

The Rebel Alliance dealt a massive blow to the reconstituted Empire, the First Order, defeating their dreaded Starkiller Base, and giving rise to the voices of freedom throughout the galaxy. The First Order, however, has not been idle after this setback, and has massed forces ready to wipe out the Rebel Resistance.

First Order, led by the evil Kylo Ren, is preparing an assault on the Resistance Base on the planet Crait. A Resistance spy, Rey, aided by a sympathetic ex-storm trooper, Finn, is leading the defense of Crait against a battalion of AT-M6 armored walkers and Ren's TAI Silencer ship.

The battle is critical to the survival of the Rebel forces. The Rebel Alliance has commissioned the CMPE-118 class to game out possible solutions to the impending attack. Will you be able to help the Alliance survive the onslaught?

Purpose:

The purpose of this project is to provide an opportunity to apply all that you have

learned in CMPE-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 enemy AT-M6's (using your ping pong ball ammo), and then shoot down Ren's ship with a very well-aimed shot.

Project Requirements:

A. Team and robot meet three Design Reviews (Brainstorm, Mid-Project Review, Final Check-Off)
B. Team maintains an active website detailing their progress and designs
C. 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 Gabe will personally buy your team beer. The beer check-off has rarely been awarded.

Project Overview

Your task is to build a small autonomous robot ('droid) that can effectively and robustly navigate a standardized field, locate and destroy multiple AT-M6 targets by shooting a ping pong ball through the targets. Once you have destroyed all three, the final target will illuminate an IR beacon, requiring a precision shot to destroy it and win the match. You will be doing this in teams of three, over the next five weeks (31 days), 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 4'x8' surface with a 2" black tape boundary (going out of bounds disqualifies the robot). There are three AT-M6 targets randomly placed on the perimeter of the field marked with track wire (at the standard 24-26 KHz) that runs vertically down the target faces from the hole to the field level. You will be required to destroy each of the targets by shooting a ping pong ball through the hole in the target. When destroyed, the track wire will shut down. There are no restrictions on how to get balls into the hole—that is entirely up to you.

Once you have destroyed the three AT-M6 targets, a final target fixed at the end of the field will illuminate its 2KHz IR beacon, and may be destroyed at that time by launching a ping pong ball through its (much smaller) target hole.

You will start in the starting area (2 ft. from the edge of the field, and at least half of your robot will be within the tape) in a random orientation. The 2KHz IR beacon on the Ren Ship Target will be illuminated for the first 15 seconds of the round. 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.

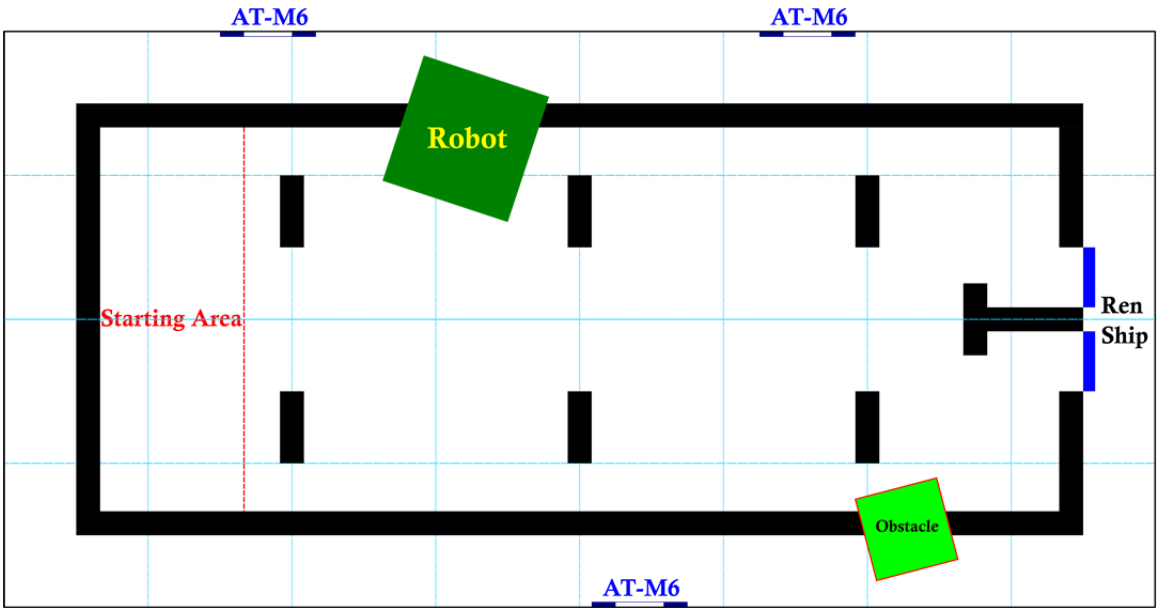


Figure 1: Field of Play for SLUG WARS: The Last Slug-i. Black tape boundaries and alignment marks are 2" thick PVC tape, AT-M6 Targets are 8 inches wide and 12 inches tall, and are marked with 24-26KHz track wire extending vertically from the field to 6" height. There is a target hole, 4" in diameter, centered at 8" vertically. The Ren Ship Target located at the end of the field, is 12" wide and 16" tall, with a 2" diameter target hole centered vertically at 14" above the playing field. The Ren Ship has a set of fiducial holes spaced on its face.

The AT-M6 Targets are 8 inches wide and 12 inches tall, and are marked with 24-26KHz track wire extending vertically from the field to 6 inches in height. There is a target hole, 4 inches in diameter, centered at 8 inches vertically. Note that you will have at least three AT-M6 Targets for each round, they will always be randomly placed on the perimeter of the field, and will always be on at least two sides of the field. Shooting a ping pong ball through the target hole results in the track wire shutting down. The AT-M6 is considered "destroyed."

At the end of the field, in front of the "T" shaped black tape, is the Ren Ship Target. The Ren Ship Target is 12 inches wide and 16 inches tall, with a 2 inch diameter target hole centered vertically at 14 inches above the playing field. The Ren Ship has a set of fiducial holes spaced on its face, and is topped by a 4" wide beacon that is transmitting an IR signal at 2KHz with a 50% duty cycle. Note: the fiducials will be cutouts in the MDF

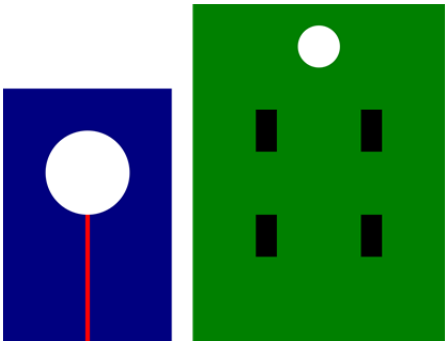


Figure 2: AT-M6 Target is 8" wide and 12" tall with a 4" diameter target hole centered 8" above the field. It has a 24-26KHz track wire running vertically down its face from 6" to field level. The Ren Ship Target is 12" wide and 16" tall and have a 2" target hole centered 14" above the field. It is topped by a 2KHz IR beacon transmitting at 50% duty cycle.

target, at least one MDF layer deep, and symmetric about the target hole. The IR transmitter on the Ren Ship will illuminate for the first 15 seconds of the round, and then again once all three AT-M6 targets have been destroyed. SolidWorks models of the field, AT-M6's, and Ren Ship Target will be available.

There will be a (possibly moving) obstacle on the field, randomly located up to 7" square. Collisions with the obstacle must be resolved within 5 seconds.

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.

Your robot is required to stay within the field (marked by 2" black tape), defined by keeping 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 the obstacle 'bot 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 following specifications and rules, understand that this is a work in progress. As the project evolves, we will be making (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 randomly placed within the starting area of playing field in a random orientation. The Ren Ship 2KHz IR beacon is illuminated for the first 15 seconds of the match. Within 2 minutes, your droid must find the AT-M6 Targets (indicated by the active vertical 24-26KHz trackwire) and destroy them by firing a ping pong ball

through the target hole. Once all three are destroyed (their track wires go off), the Ren Ship beacon will illuminate (designated by a 2KHz IR beacon), and a ball must be placed into the much smaller target hole to end the game.

At the start of every round, your droid must contain all ping pong ball ammo that will be used during the match. A random placement of AT-M6 target on the field perimeter will have their track wires illuminated, and the Ren Ship target will have its beacon turned on for the first 15 seconds.

Once the three AT-M6 targets have been destroyed, the Ren Ship Target will turn on its 2KHz IR beacon. Sending a ping pong ball through the target hole destroys the Ren Ship and the game ends. Note that there will be an immobile obstacle for checkoff, and it will be randomly located on the field.

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 destroying the targets, the robot will be disqualified and the round will end.

Tournament:
In the tournament, you play against another team; teams will start on identical fields that are back to back. The AT-M6's will be arrayed in a symmetric pattern such that each robot is running the identical field. When either robot destroys its AT-M6 targets, the Ren Ship Target on both fields will illuminate (only one beacon). When the Ren Ship is destroyed (be either robot), the game ends, and the winner is awarded by points.

Your droid needs to destroy *at least* one of the AT-M6 targets before destroying the Ren Ship Target. If you win the match, your robot advances in the tournament. *If neither team succeeds in this challenge*, *the victory will be awarded by points*. Should a tie occur, both teams will lose and neither will advance.

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

10 points:	First AT-M6 target destroyed
20 points:	Second AT-M6 target destroyed
40 points:	Third AT-M6 target destroyed
50 points:	Ren Ship Target destroyed

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.

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 ball ammo 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 3.5” 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 (within the black 2” tape boundaries).

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 may reprogram your droid between rounds if you desire, but you may not alter it once the field configuration is established.

Each droid will 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 H-Bridge, one Stepper Board (if needed), one DS3658 board, one battery, and one ULN2003. 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. We will do a major order to Digikey and will maintain a list of Amazon suggestions for motors, perf board, and other components within the first week. 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 BE111, BE113, and BE115 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 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 a while).

Field Specifications:

We will have a Solidworks model of the field and targets available after the midterm. The model in Fig. 1 will be available on the website in higher resolution, and is drawn to scale. Modifications (if any) to the field will be noted on Piazza.

Further 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 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 submit a simple partner evaluation. 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 such:
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 to stay on schedule. With that in mind, we expect each team to maintain and update a small WordPress, Wiki, or

Google website for the project (posting block diagrams, sketches, pictures, schematics, videos, etc). We very (very) strongly recommend having a lab notebook that stays with the robot. We will use this to verify your check-offs for every week. We recommend sharing some form of file/team drive to help you keep your selves on task, but do not require it. That said, each team will need to submit their website and schedules for the Design Review #1. See "check-offs" documents for further details.

A report describing the technical details of the machine will be required. The report should be of sufficient detail that any skilled CMPE118 alum could understand, reproduce, and modify the design.

Design Review 1: Thursday, 09-Nov-2017

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. 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.

Submit your website URL, 3 designs, and schedules to the form (on check-off sheet). Submit your best team design and backup design before class on Thursday. You will have 3 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: Tuesday, 21-Nov-2017/Wed., 22-Nov 2017

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 should be prototyped at this point.

Mechatronics Beer Challenge: Tuesday 28-Nov-2017 before 6pm

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: Tuesday, 05-Dec-2017 to Thursday, 07-Dec-2017 at midnight.

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: **Friday 08-Dec-2017,** the public demo off your finished, operational machines. This fun performance will likely have a large and enthusiastic audience. It will be held in Media Theater M110, starting at 6:00 PM. You will be expected to arrive at 5:20.

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 11-Dec-2017 @ noon in Jack's Lounge

Lab Report: Thursday 14-Dec-2017 at 6pm.
Electronic copy of your lab report.
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.

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.

Again, 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.

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.

We will be bringing down our “box of freedom” with random parts that people have donated over the years, and if you happen to find surplus printers, or other random electronics that people no longer want, feel free to dismantle and put parts in. 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 (Tuesday after Thanksgiving, 28-Nov-2017) gets a case of beer or other equivalent adult beverage (within reason) supplied by Gabe. Only three teams have ever collected this.