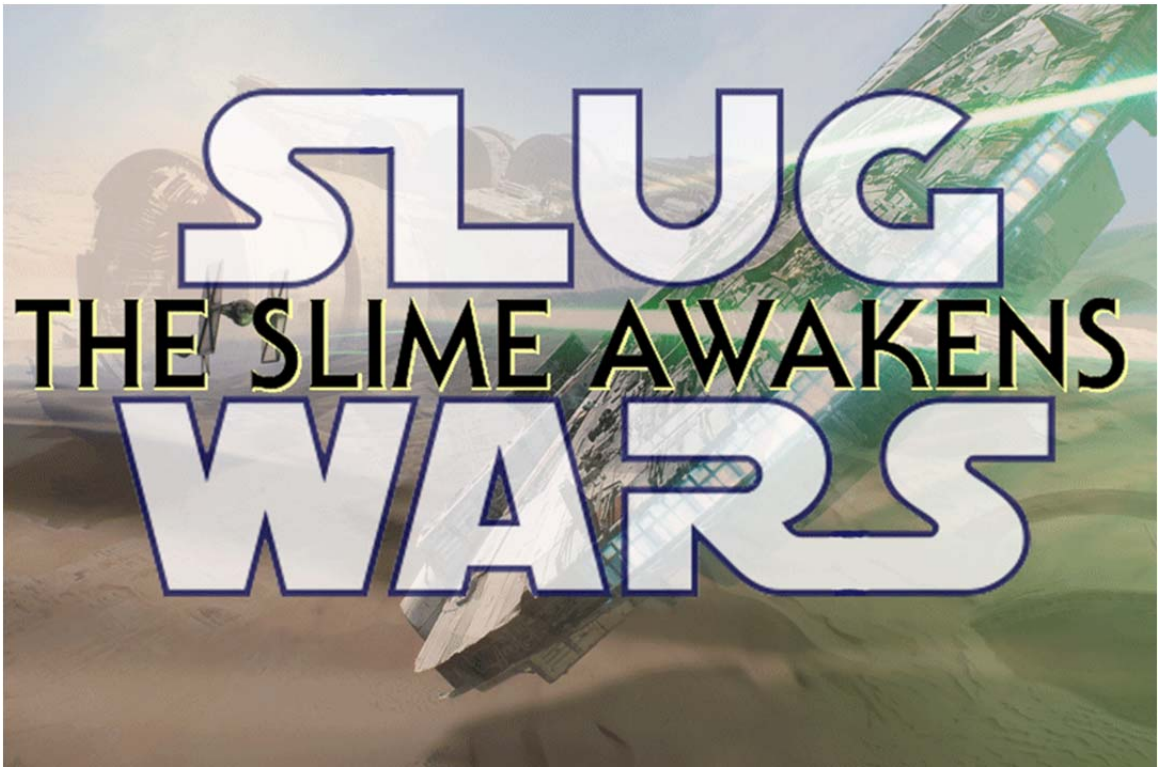
UNIVERSITY OF CALIFORNIA, SANTA CRUZ
BOARD OF STUDIES IN COMPUTER ENGINEERING

CMPE-118/L: INTRODUCTION TO MECHATRONICS

SLUG WARS: THE SLIME AWAKENS



Background Briefing:

It has been thirty years since the Rebel Alliance dealt a massive blow to the Empire, defeating their dreaded Death Star, and giving rise to the voices of freedom throughout the galaxy. The Empire, however, has not been idle during the interim, and has massed forces ready to wipe out the Rebel Resistance.

The new First Order, led by the evil Kylo Ren, is preparing an assault on the Resistance Base on the far side of the planet Jakku. A Resistance spy, Rey, aided by a sympathetic ex-storm trooper, Finn, have escaped from a Star Destroyer with crucial information of Kylo Ren's plans. Rey and Finn have slipped away in a small fighter, intent on delivering

their information (and victory) to the Resistance.

Their escape, however, was detected and a patrol was sent after them to capture or destroy them. In an effort to evade capture and complete their mission, Rey and Finn maneuver their ship into an asteroid field and search for a hyperspace portal to make their escape. Will the Rebels escape and give their fellow fighters crucial information, or will the Empire destroy the spy ship and ensure their victory over the Resistance?

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 asteroid field, pick up ammo from fixed depots, engage your opponent with deadly ping-pong balls, and escape through the hyperspace portal.

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 you 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 predetermined field, locate an ammo dump and load ping-pong ball ammo, engage the opponent robot, and navigate to the exit. 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 8x8’ surface with a 2” black tape boundary (going out of bounds disqualified the robot). There is a fixed 4” tall obstacle in the middle of the field, and three moving asteroids that begin at random locations in the middle of the field. There are four ammo dumps, marked with black alignment tape, and track wire (at the

standard 24-26 KHz) that will illuminate to designate the escape portal. You will be required to retrieve the ammo, fire at least two hits on your opponent, then find the hyperspace gate to end the game.

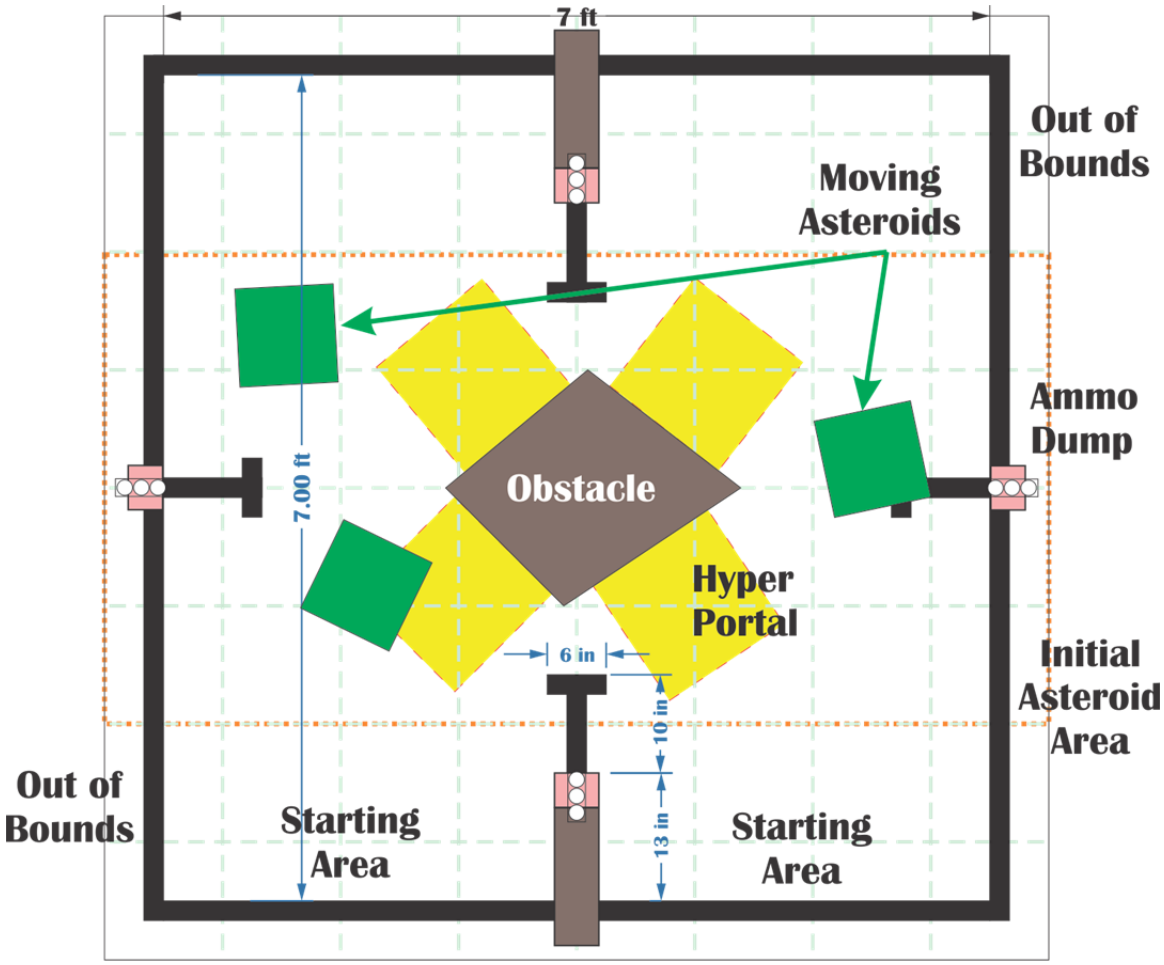


Figure 1: Field of Play for SLUGWARS. Black tape boundaries and alignment marks are 2" thick PVC tape, Ammo Dumps are 12" tall and 4.5" wide, and there are 13" long walls at the top and bottom of the field. The Asteroids are moving, and will begin within the center band of the field (however, they will move somewhat randomly).

Robots begin in one of four designated areas, in a random orientation. Moving asteroids begin in the center band of the field. Asteroids will bounce of collisions and keep moving. They will move in random ways around the field, and may, at any point in time, be located on the field.

After two hits on the opponent droid, the hyperspace portal will open (indicated by the trackwire oscillating at the standard 24-26KHz signal). There are four hyperspace portals, one centered on each edge of the obstacle in the center of the field. Each hyperspace portal consists of a 14" square trackwire loop, and to exit the portal, half

Figure 2: Ammo dump tower. The tower is 4.5" wide, and 12" tall with the feel mechanism plunger between 4 and 8" from the ground.

your entire robot must be inside the loop. The position of the loop will be indicated on the field with light colored 10mm electrical tape (for judging and audience visibility).

The obstacle itself is an asymmetric rhomboid shape that is 3.5” tall, and will be securely fixed to the field. Note that the obstacle shape may change between practice fields and final checkoff and tournament play. The obstacle may have foamcore walls that extend up to 12” (or not). Exact angles are unlikely to remain true.

The ammo dumps consist of a 4.5” x 12” tower (Fig. 2), with a plunger mechanism centered on the tower between 4” and 8” off the ground. Depressing the plunger will cause 3 ping pong balls to roll out of the ammo dump at a height of 12” and roughly proportional to the velocity of the plunger. All 3 balls roll with a single plunge. Ammo dumps will be restocked after they are depleted. In front of each ammo dump is an alignment fiducial “T” consisting of 10” of black tape capped by a 6” black tape stripe, as shown in Fig. 1.

The moving asteroids consist of two wheel robot chassis (the roach base) with a 12” tall black foamcore body. They will block the opponent beacon, and will meander somewhat randomly across the field, bouncing off the center obstacle, and edges of the field.

Both droids will carry a standard 4” wide beacon that is transmitting an IR signal at 2KHz with a 50% duty cycle. (See the class website for a sketch of the machine specs for mounting details.) Note that you must have the beacon on your robot and ON to check off for min. spec.

Each droid must have a set of locating holes to mount the beacons/targets (SolidWorks part provided) with at least ¾” of depth from the top of the holes. The beacon base must stay at 11” +/-.05 off the ground, and must not be blocked by any part of your droid.

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 opponent 'bot or one of the asteroids is blocking your path, you need to be able to maneuver around an immovable obstacle).

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 challenge in one of the four corners of the playing field. Within 2 minutes, it must find one of the four ammo dumps and collect ping-pong ball ammo, find and shoot the opponent robot (designated by a 2KHz IR beacon), and maneuver to the illuminated hyperspace gate (24-26KHz trackwire).

At the start of every round, all ammo dumps will be loaded with 3 ping pong balls. All possible hyperspace gates are turned off, and both your own and the opponent robot have their beacons turned on.

Once two hits are scored on an opponent, the hyperspace gate is turned on, and the robot ends the game by moving until it is fully inside the trackwire loop. Note that the opponent robot for checkoff will be immobile.

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 if it becomes trapped by the asteroids), the robot will be disqualified.

Tournament:
In the tournament, you play against another team; teams will start on opposite sides of the asteroid field, but may be either directly across from your robot, or diagonally positioned.

If your droid successfully shoots your opponent twice (ping pong ball must be completely separate from your droid), and navigates to the hyperspace gate, you win

the match and advance 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:	Loading ammo from Ammo Dump (only once)
20 points:	First hit on opponent
40 points:	Second hit on opponent
10 points:	All subsequent hits on opponent
50 points:	Enter into illuminated hyperspace gate

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 (not counting the beacon). Your machine may not contain any ping-pong ball ammo at the beginning of the round, and will need to retrieve the ammo from either the ammo dumps or from the field. 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. 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.

Each team is limited to a budget of $150 total for other parts on the robot, and must maintain an up-to-date bill of materials (BOM). We will have MDF and Foamcore available for purchase at cost. We will do a major order to Digikey and MPJA 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.

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.

Field Specifications:

We will have a Solidworks model of the field available after the midterm. The model in Fig. 1 will be available on the website in higher resolution, and is drawn to scale. Modifications 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 of the opposing robot or masking of your own beacon is considered foul play and not allowed. 'Bots deemed unsafe will be disqualified.

NOTE: Last year, young children lined 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 win the match. Grading is not based on point value, but how robustly your robot solves the challenge.

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 (DRI)
Week 2: Electronics and Mechanical Prototyping
Week 3: Working Prototype for moving robot and ball loader; State Machine (DR II)
Week 4: Finalizing robot and getting everything to work together.
Week 5: Competition and Final Check Off (DRIII)

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 will use this to verify your check-offs for every week. We recommend sharing Mavenlink or Evernote 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 a skilled CMPE118 alum could understand, reproduce, and modify the design.

Design Review 1: Thursday, 05-Nov-2015
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 name, 3 designs, and schedules to the form (on check-off sheet). Bring your best design on paper and team name to class. 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: Thursday, 19-Nov-2015/Friday, 20-Nov 2015
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 26-Dec 2015 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 2 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 set in a way to be difficult for your particular robot.

Design Review 3: Final Check-Off: Tuesday, 01-Dec-2015 to Thursday, 03-Dec-2015 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 04-Dec-2015, the public demo off your finished, operational machines. This fun performance will likely have a large and enthusiastic audience. It will be held in Classroom Unit 2, 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. We will post plans on Piazza.

Clean-up and Class Review: Monday 07-Dec-2015 @ noon in Jack's Lounge

Lab Report: Thursday 10-Dec-2015 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 or MPJA.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—gang the order together and you can get expedited shipping very reasonably.

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 before Thanksgiving, 24-Nov-2015) gets a case of beer or other equivalent adult beverage (within reason) supplied by the instructor. Only three teams have ever collected this.