Background Briefing:

The 31st Summer Games of the Modern Olympiad in Rio de Janeiro have come and gone. The chaos of the venue, the pollution of the water, the unexpected victories, and the terrible defeats are all a thing of the past; the city by the bay has retreated back into her beauty, her music, and her beaches. All told, 10,500 athletes from 206 countries came to compete in 306 medal events, over 17 days; 42 different sports, in 32 competition venues. 7.5 million tickets were sold, and untold millions watched it around the world.

For the first time in 112 years, Golf has returned as an Olympic sport, featuring the newly designed Olympic golf course specially built in Barra da Tijuca, south of Rio de
Janeiro. The battle between Australia’s Jason Day and the US’s own Jordan Spieth proved epic, with the mid-winter winds off the Atlantic coast wreaking havoc on the long drives.

In an effort to improve the ratings for the tech nerds around the world, as well as save significantly on costs, the Olympic committee has decided that a new sport of robo-golf will be added to the games. However, since they are broke after the Rio games, they have decided to engage the UCSC CMPE-118 class to develop the robo-golf game and demonstrate the excitement and strategy that can only come from droid on droid action.

**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, pick up balls from fixed depots, and get a total of three balls into two distinct golf targets.

**Project Requirements:**

A. Team and robot meet three Design Reviews (Brainstorm, Mid-Project Review, Final Check-Off)
B. Team maintains an active website and engineering logbook 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 the instructor will personally present your team with beer. The beer check-off has rarely been awarded.

**Project Overview**

Your task is to build a small autonomous robot (‘bot, ‘droid) that can effectively and robustly navigate a standardized field, locate a ball loader and load ping-pong balls, locate multiple golf ball targets, navigate to them, and drop three balls in at least two distinct targets (2 in 1, and 1 in the other). 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 disqualifies the robot). There are four ball loaders at the four corners of the field marked with track wire (at the standard 24-26 KHz) that will illuminate to designate a valid ball loader. You will be required to retrieve the balls, get at least two scores on two separate golf ball targets (balls in the hole) while your opponent tries to do the same. There are no restrictions on how to get balls into the hole—that is up to you.

Your robots will start somewhere on the edge of the field, in a random orientation. For check-off only, the opponent droid will be located somewhere on the field and not moving.
Not all of the Ball loaders will be available for use at any given time; those that are valid will have their track wires turned on (those that are not will have their track wire turned off).

The golf target itself is symmetric.

The ball loaders 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. Ball loaders will be restocked after they are depleted. In front of each ball loader is a 24-26KHz track wire perpendicular to the face of the loader (see Fig. 1), on a line towards the center of the field.

Placed at random within the floor area will be three tower/targets, consisting of a circular ramp, 9” in diameter with a 6” cutout in the center. Each ramp has a 2” wide circular black tape ring on the outside, and at the center of the target is a 1” diameter rod that is 12” tall, and is topped by a 4” wide beacon that is transmitting an IR signal at 2KHz with a 50% duty cycle. 

Note: the material of the center pole of the target/tower can be made of any material and be of any color (your design should be robust to these variations).

Each droid must start the match within an 11" cube volume (parts may move after the round begins) and remain intact throughout the match. Blocking the view of target beacons from your opponent 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 opponent ‘bot or one of the targets is blocking your path, you need to be able to maneuver around an 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 yet 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 once you can meet min spec robustly.

Your robot begins the challenge on one of the four sides of the playing field in a random orientation. Within 2 minutes, it must find one of the four ball loaders (indicated as valid by the 24-26KHz trackwire) and collect ping-pong balls, find and locate one of the three tower/targets (designated by a 2KHz IR beacon), and deposit two balls into the hole, then find a second tower/target, and deposit another ball into that target. The first team to get 3 balls into two separate targets ends the game.

At the start of every round, all ball loaders will be loaded with 3 ping pong balls. A random selection of them (1-4) will have their track wires illuminated, and all three of the tower/targets will have their beacons turned on.

Once a balls is deposited in the second target, the game ends. Note that the opponent robot for checkoff will be immobile (and simply act as an obstacle), and 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 cannot load sufficient balls to complete the task), the robot will be disqualified and the round will end.

**Tournament:**
In the tournament, you play against another team; teams will start on different sides of the playing field, but may be on any side of the field except your own.

If your droid successfully loads ping pong balls and deposits balls into two separate targets (ping pong ball must be completely separate from your droid), and completes
if you complete this task before your opponent, 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 balls from Ball loaders (only once)
- 20 points: First ball into tower/target
- 40 points: Second ball into tower/target
- 50 points: First ball into secondary tower/target
- 10 points: Any additional balls into tower/targets for tie breaking play

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 may not contain any ping-pong balls at the beginning of the round, and will need to retrieve the balls from a valid ball loader (trackwire illuminated) 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 (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 (from BELS), and solder freely available in the 118 labs.

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 Perfboard, MDF and Foamcore available for purchase from BELS. 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 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 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 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 (Design Review I)
Week 2: Electronics and Mechanical Prototyping
Week 3: Working Prototype for moving robot and ball loader; 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 will use this to verify your check-offs for every week. We recommend sharing Dropbox folders or SLACK 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.

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, 03-Nov-2016**
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 website). 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, 17-Nov-2016/Friday, 18-Nov 2016**
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 22-Nov-2016 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 (possibly) set in a way to be difficult for your particular robot.

**Design Review 3: Final Check-Off:** Tuesday, 29-Nov-2016 to Thursday, 01-Dec-2016 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 02-Dec-2016, the public demo off your finished, operational machines. This fun performance will likely have a large and enthusiastic audience. It will be held in the Media Theater, starting at 6:30 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 05-Dec-2016 @ noon in Jack’s Lounge

**Lab Report:** Thursday 08-Dec-2016 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 before Thanksgiving, 22-Nov-2016) gets a case of beer or other equivalent adult beverage (within reason) supplied by the Instructor. Only three teams have ever collected this.