ME 218c Spring 2025: Jailbreak!!
Navigate the Flood to Escape the Warehouse

Grading Session on May 27 from 11-5 pm.
Project Presentation on May 28 starting at 5:00 pm.

Goal:

The goal of this project is to provide a framework in which you can apply your knowledge of microcontrollers and multi-processor communications to a task that will provide an enjoyable experience for users and observers alike!

Purpose:

The underlying purpose of this project is to provide you with an opportunity to integrate all that you have learned in the ME218 course sequence, with an emphasis on the new material in ME218c.

Background:

It has been three months since the CARRYER Competition. Unfortunately, Pharryl Dilbin did not allow the winning team to return to Earth, instead forcing all the teams to mass produce Schrödinger's CAT for the warehouse. However, this betrayal of trust has sparked the divided teams to reunite in hopes of hatching a plan for all to escape. During the planning, you discover two aircrafts in the warehouse, each big enough to fit half of the reunited team. However, the fuel tanks of both aircrafts are completely empty, and while the warehouse has loads of aircraft fuel called COAL (Circular Object for Aircraft Longevity), it is kept in a vault that is heavily guarded to prevent workers from hijacking the aircrafts. Thus, the following plan is agreed upon: create a distraction by busting the nearby dam to flood the warehouse, steal/transport COAL to the two aircrafts, and blast off this planet! However, since the flood will be too deep to navigate through when transferring COAL, you will need to build some sort of remote controlled watercraft to transport the COAL from the vault to each aircraft.

The Task:

Since there are two aircrafts, the class will break into two groups, each responsible for loading their aircraft. Each group will be composed of three teams, each of which will be responsible for designing and building a BARNACOAL (Bustling Aquacraft Remotely Navigated to Arm COAL) - a watercraft capable of navigating 18-inch-deep waters - as well as a SPECTACOAL (SPectral Emitter of Commands To Arm COAL) to operate the BARNACOAL. During the flood, each team will use their BARNACOAL to transport COAL from the COAL Vault to the aircraft's RECEPTACOAL (RECEiver Passively Taking Any COAL). Since any jailbreak plan must be flexible enough to handle unexpected developments, each SPECTACOAL must be capable of controlling any BARNACOAL at the start of the flood.

Specifications

General:

- ☐ Each team will construct a BARNACOAL and a SPECTACOAL.
- ☐ The SPECTACOALs are I/O devices which control various aspects of the BARNACOAL functions, and will contain an SPDL supplied XBee radio module to communicate wirelessly between SPECTACOALs and BARNACOALs.
- ☐ The class will form a Communications Committee to draft a class-wide standard communications protocol that will permit any SPECTACOAL to effectively control any BARNACOAL with which it is paired.

COAL:

- ☐ COAL is an approximately 27 mm diameter, 8 gram spherical object with the properties of rubber. Due to inconsistent process control across COAL manufacturing, **significant tolerance variations should be expected**.
- ☐ All COAL will be supplied by the teaching staff.

- ☐ COAL is generally neutrally or negatively buoyant, meaning it likely will NOT float on the surface of water.
- ☐ COAL shall not be modified in any way.

The SPECTACOAL:

- ☐ The SPECTACOAL is a controller capable of pairing with **any** BARNACOAL.
- ☐ The SPECTACOAL shall contain all controls and displays relevant to propulsion, COAL emptying functionalities, charge status, recharging, and wireless communication with the BARNACOAL (these are each elaborated on below).
- ☐ The aliens of this planet have advanced technology capable of detecting any action that does work (as defined by physics). This is problematic since BARNACOALs will be doing a lot of work. While you have stumbled upon alien microchips that block the aliens' work sensors, the microchips only have enough charge to block 30 seconds worth of work, and thus need to be recharged constantly.**Thus, the BARNACOALs cannot do any work (as defined by physics) when there is no charge remaining (See The BARNACOAL for a more thorough explanation of this).**
- ☐ The SPECTACOAL shall have two modes: Drive Mode and Recharge Mode. The SPECTACOAL shall enter Drive Mode while right-side up and shall enter Recharge Mode while upside down (holding the SPECTACOAL upside down makes it less obvious to the aliens that you are controlling something). It **must be impossible** to be in both modes simultaneously.
- ☐ **Drive Mode**
    1. When in Drive Mode, the SPECTACOAL shall be capable of controlling the propulsion and emptying the COAL out of the BARNACOAL.
    2. Any recharging input shall be ignored while in this state.
    3. The actions required by the user for propulsion and COAL emptying may be simple and streamlined to aid in efficient control of a BARNACOAL.
- ☐ **Recharge Mode**
    1. When in Recharge Mode, the SPECTACOAL shall be allowed to recharge the alien microchip.
    2. Any driving or COAL emptying inputs shall be ignored while in this state.
    3. While in this state, recharging should only occur while the user of the SPECTACOAL partakes in some sort of recharging action.
    4. The recharging action of the SPECTACOAL must implement an activity consisting of large-scale human body movements. It should be inventive and interesting for the audience to watch. Use of actions that make the SPECTACOAL operator look and feel foolish are encouraged (this will dissuade the aliens from thinking that you are smart enough to pull off an elaborate jailbreak).
    5. The required SPECTACOAL recharging action must last continuously for at least 5 seconds. Partial completion of a recharging action should result in partial recharging of the BARNACOAL, proportional to time spent performing the recharging action.
- ☐ The SPECTACOAL must include, at minimum, an indicator to display the remaining charge level in a BARNACOAL with a resolution of 1 part in 5.
- ☐ The SPECTACOAL shall have some method of displaying whether or not is is paired with a BARNACOAL. If a SPECTACOAL is paired with a BARNACOAL, it shall have some method of indicating which BARNACOAL it is paired to.
- ☐ SPECTACOALs must incorporate at least 1 analog input and at least 1 electromechanical output.
- ☐ The SPECTACOAL shall only be operated by a single individual.

- ☐ Each SPECTACOAL shall contain a SPDL-issued XBee radio module used to communicate with a BARNACOAL.
- ☐ The SPECTACOAL must provide the user controls for all required functions determined in the class-wide communications protocol.
- ☐ Each SPECTACOAL must implement the class-wide protocol for coordinating game information (See Communications).
- ☐ Each SPECTACOAL may only be powered by 5V LiIon battery packs.
- ☐ The size, shape and mass of the SPECTACOAL are constrained only to what is portable by your team. Bear in mind that you may need to move the SPECTACOAL to keep up with a BARNACOAL.

The BARNACOAL:

- ☐ Each BARNACOAL is a watercraft capable of operating in the flooded warehouse.
- ☐ Each BARNACOAL shall be equipped with a propulsion/maneuvering system controlled by the SPECTACOAL.
- ☐ Each BARNACOAL shall have a mechanism for carrying/dumping COAL into the designated RECEPTACOAL which is also controlled by the SPECTACOAL.
- ☐ There is no constraint on the type of propulsion system used, nor on achievable speed, nor on total mass of the BARNACOAL.
- ☐ Each BARNACOAL shall display the number of the team that built it with digits at least 15cm tall.
- ☐ Each BARNACOAL shall have around its largest perimeter, at the waterline, a SPDL-issued closed-cell foam bumper.
- ☐ Each BARNACOAL is limited to a total waterline circumference of 6 ft.
- ☐ No part of the BARNACOAL may protrude beyond the circumference of the foam bumper, with exception of any implement designed to dump COAL. Any such implement must be retractable such that the BARNACOAL can start a game round with nothing protruding from the bumper.
- ☐ Collisions between BARNACOALs will be unavoidable. Ensure that your BARNACOAL is designed to robustly absorb crash energy at the waterline bumper.
- ☐ Each BARNACOAL must implement an electromechanical indication of its state of association with a SPECTACOAL. Exactly which association states must be displayed is at the discretion of the Communications Committee.
- ☐ Each BARNACOAL must keep track of its own alien microchip charge status, counted in seconds. A full charge on an alien microchip is 30 seconds.
- ☐ Each action that a BARNACOAL takes that does work (as defined by physics) deducts charge for the duration of the action. Such actions may include, but are not limited to, propulsion, dumping COAL, moving water vessels, etc. A BARNACOAL that is sitting idle, whether paired with a SPECTACOAL or not, is not considered to be actively consuming charge. Note that simultaneously performing multiple actions that do work does not deplete charge more quickly. Instead, charge is always depleted at a rate of 1 second per second (interesting unit of measurement when fuel is measured in units of seconds) as long as there is at least one action that does work occurring.
- ☐ **Once there is zero charge remaining, a BARNACOAL <u>cannot</u> perform any more work (as defined by physics) until recharged through a recharging action from the SPECTACOAL.**
- ☐ The maximum amount of COAL that a BARNACOAL may transport is roughly 80 pieces. This will be enforced via an SPDL-issued bucket that will be sized to hold the maximum amount of COAL. In other words, when getting COAL from the COAL vault, teams must fill their bucket with COAL and unload the bucket into the BARNACOAL.

- ☐ When reloading the BARNACOAL with COAL, the BARNACOAL cannot be removed from the water, nor can any team member enter the water (while working at the warehouse, you witnessed many employees dumping toxic chemicals into the water that you're using to flood the warehouse). As long as these two rules are followed, teams can reload their BARNACOAL via any means, including the use of a team-designed mechanical instrument.
- ☐ Each BARNACOAL may only be powered by SPDL-supplied 7.2V NiMH and 5V LiIon battery packs. Up to 2x 7.2V NiMH packs and 1x 5V LiIon pack may be used.
- ☐ The enclosure of each BARNACOAL's sensitive instrumentation and propulsion systems must be protected against damage from ingress of objects and water to a rating of IP-24.
- ☐ Each BARNACOAL shall contain a SPDL-issued XBee radio module used to communicate with a SPECTACOAL.
- ☐ Each BARNACOAL must implement the class-wide protocol for coordinating game information (See Communications).

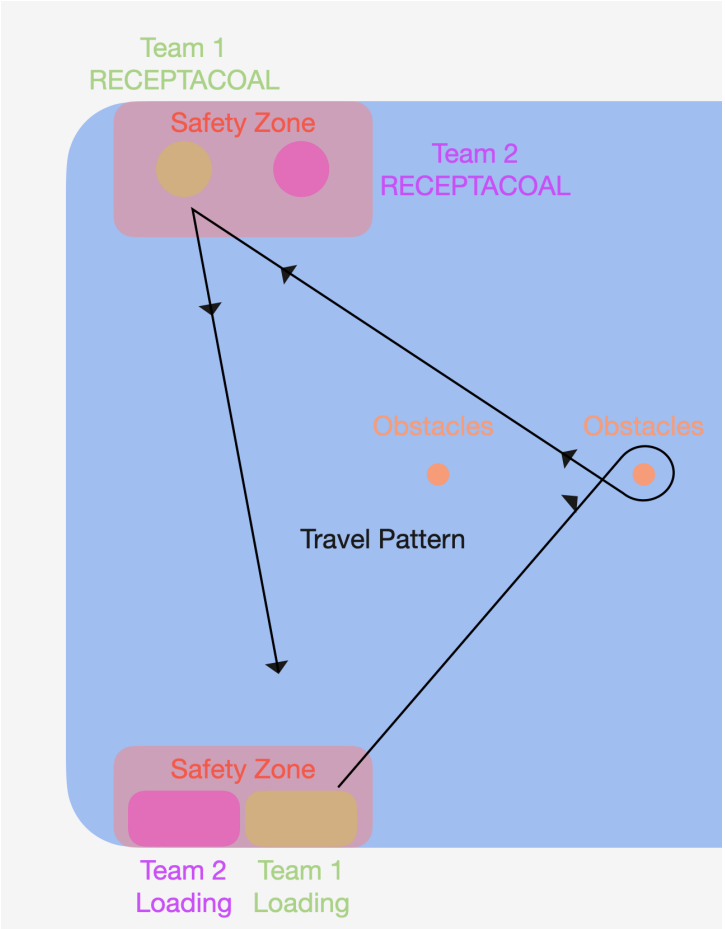

Figure 1: The Flooded Warehouse with the required path to take and safety zones.

The Flooded Warehouse + RECEPTACOAL:

- ☐ The Flooded Warehouse is the pond located adjacent to Thornton (SPDL) and forms the body of water in which your BARNACOAL is expected to operate.
- ☐ The approximate depth of the Flood is 5 in.

- ☐ Every effort will be made to have the fountains in the pond disabled for the duration of play, however, your BARNACOAL should be robust enough to operate with the fountains running.
- ☐ The RECEPTACOAL and COAL loading zone shall be laid out in the left side of the Flood (viewed from the SPDL) per Figure 1.
- ☐ To avoid attracting attention from any alien warehouse workers, each BARNACOAL must follow the path shown in Figure 1 when going to dump COAL/returning to reload COAL. If a team doesn't follow this path, the alien warehouse workers will catch and punish you (grand larceny of COAL with the intent to hijack an aircraft is a serious offense in the warehouse - much more serious than a CARRYER trespassing - carrying a heftier sentence of 10000 years in jail, 1000 years of community service, and a fine of 1 *million* Blipper-Blops!).
- ☐ Each RECEPTACOAL is no less than 36" in diameter with its edge aligned approximately with the waterline. However, there will be some minimal but unavoidable distance between the waterline and the RECEPTACOAL lip.
- ☐ The loading zone for each team will be no smaller than 4 ft.
- ☐ Opposing teams RECEPTACOALs and loading zones will be separated by at least 1 ft.
- ☐ An area extending 1 ft out from the loading zones and RECEPTACOALs is dedicated as the safe zone. No blocking nor intentional BARNACOAL-to-BARNACOAL contact or interference is allowed within this area.

Basic Game Play:

- ☐ At the beginning of each game, the participating BARNACOALs will be paired to SPECTACOALs either at random, or at the discretion of the teaching team.
- ☐ Each BARNACOAL will start by holding the maximum amount of COAL that it was designed to hold and with full charge on the alien microchip.
- ☐ A game round proceeds in real time, with no turn-taking.
- ☐ A game round consists of each BARNACOAL continually racing through the pattern described above to dump COAL in the designated RECEPTACOAL and then return to collect more COAL.
- ☐ Any team caught intentionally violating the pattern will be disqualified for the rest of a game round.
- ☐ Any team caught removing their boat from the water/wading into the water to refill will be considered dead/disqualified for the rest of the game round.
- ☐ Between the six teams, there will be a fixed amount of COAL.
- ☐ A game round ends once all COAL has been dumped. Whichever group's RECEPTACOAL has the most COAL is the winner of the game round (as the aircraft with more COAL is more likely to escape the aliens and make it back to Earth).
- ☐ Playing defense or ramming another team's BARNACOAL is acceptable, except within safe zones.

Communications:

- ☐ Communications between BARNACOALs and SPECTACOALs will take place over the airwaves using SPDL-supplied XBee radio modules in API mode.
- ☐ Each SPECTACOAL and BARNACOAL **shall** communicate with the XBee over an asynchronous communications channel using 9600 baud, 8N1 at 3.3V levels.
- ☐ Messaging between SPECTACOALs and BARNACOALs is limited to 5 Hz. That is to say that a single SPECTACOAL shall transmit one message every 0.2 s, with the paired BARNACOAL transmitting one message also during this period.
- ☐ Because of the inherent unpredictability in wireless latency, SPECTACOALs and BARNACOALs must be

able to accept any message at any time, and may not have a fixed time window in which they are open to message reception.

- ☐ Human inputs, such as button presses and direction changes, may only take effect on the following transmitted message. Extra messages (and thus a greater than 5 Hz message rate) may not be generated as a result of a human action.
- ☐ Any other hardware or implementation requirements or recommended practices are left to the Communications Committee.
- ☐ The details of the communications protocol will be defined and specified by a Communications Committee, which will consist of a designated representative from each team. The specification must be in a written form and with sufficient detail that someone skilled in ME218 material could implement it.
- ☐ The class communications protocol must be defined to support the functional requirements listed earlier in this document. The Communications Committee is free to write a protocol of any complexity that fulfills the functional requirements. If a particularly clever messaging definition reduces overhead while maintaining the required functionality, this is perfectly acceptable. Or, if the Communications Committee implements a superset of the functionally required messaging, that would also pass.
- ☐ The communication protocol must define any addressing and packet formats if required.[1]
- ☐ The communication protocol shall cover all communication handled through the XBee, including pairing, operation, unpairing, and exception handling between a BARNACOAL and a SPECTACOAL. Interruptions in wireless communication are frequent and occur at irregular intervals, and the protocol should include some robustness against such interruptions.
- ☐ While a clear division of labor is not obvious, we strongly encourage making an effort to have all team members implement some portion of the communications in software (as opposed to just the member on the Communications Committee).

General Requirements:

- ☐ Automation of the setting of any SPECTACOAL input is prohibited. That is to say that an algorithm shall not set thrust magnitude, direction, etc. An algorithm may advise the human operator of a SPECTACOAL how to set the various controls to achieve a desired outcome, however, in the end it is the human who must dial the setting, using the inputs provided, that generates a measurable effect in the BARNACOAL.
- ☐ There is no class-imposed upper limit on the number of processors employed; however, you must use only the PIC32MX170F256B or PIC10F322. Tivas, Arduinos, Raspberry Pis, Teensys, Jetsons, and other microcontrollers are not permitted.
- ☐ You are limited to an expenditure of **$150.00/team** for all materials and parts used in the construction of your project. Materials supplied to each team by SPDL, from the lab kit, or the Cabinet Of Freedom do not count against the limit. All other items count at their fair market value. **If it's an issue with something from the kit, we will provide a replacement for free, but we can't guarantee latency. Be careful with your components.**
- ☐ A project logbook must be maintained for each group. A blog is appropriate to meet this requirement as long as it is made available to the teaching staff for review. This log should reflect the current state of the project, planning for the future, results of meetings, designs as they evolve, etc. The project logbook will be reviewed at irregular intervals for evaluation.
- ☐ A report describing the technical details of the system will be required. The report should be of sufficient detail that a person skilled at the level of ME218c could understand, reproduce, and modify the design. The report must be in website format, and be suitable for posting on the SPDL site.
- ☐ SPECTACOALs or BARNACOALs based substantially on purchased platforms are not allowed.

[1] That is, Layer 3 of the OSI model.

☐ All projects must respect the spirit of the rules. If your team is considering anything that may violate the spirit of the rules, you must consult a member of the teaching staff.

Safety:

☐ The SPECTACOALs should be safe, both to the user and the spectators.

☐ Intentionally ramming other BARNACOALs is encouraged. However, prohibited actions include, but are not limited to, fouling the propulsion systems of BARNACOALs, and/or jamming communications between SPECTACOALs and BARNACOALs. Unless it's raspberry.

☐ No part of the BARNACOAL may become ballistic.

☐ There have been no proven negative health effects due to radiation from XBee networks.

☐ The teaching staff reserves the right to disqualify any device considered unsafe.

Checkpoints

Design Review:

On **5/6/25** we will conduct a design review in lecture, one team at a time. Each team should prepare a few images showing your proposed designs for the SPECTACOALs. You will have 5 minutes to walk us through your ideas. **The focus should be on system level concepts[2], not detailed hardware or software.** We will spend the balance of the time giving feedback and asking questions. In addition to your concepts, you must present, as a PDF, your plan for the development, integration and testing steps that you will follow to complete the project. The plan must identify what functionality you will demonstrate at the three check-points along with the test procedures that you will use to prove that your team has met the checkpoint. Checkpoint tests must follow an incremental integration strategy with each successive checkpoint demonstrating all of the functionality of the prior checkpoint(s) as well as the new functionality. This plan must be approved by the teaching staff. If we feel that it is seriously flawed, we will ask you to revise and resubmit the following day. Lastly, each team must inform the teaching team of their representative for the Communications Committee during their design review.

"Splish-splash, I was taking a bath"

Bobby Darin, Splish Splash

First Draft of Communications Standard:

Due by 5:00 pm on **5/9/25**. This draft will be made available to the entire class, so that everyone is ready to deliver feedback at the in-class review.

"I'm the tidal wave of power to wash you away! Put out the fire, Crasher Wake!"

Crasher Wake, Brilliant Diamond and Shining Pearl

In-Class Communications Standard Review:

In class on **5/13/25** we will conduct a top-to-bottom review of the Communications Committee's draft protocol. Bring your prepared questions, concerns, and suggestions for improvement! Everyone should attend, if possible—the more eyes we can put on the protocol early, the earlier we can catch the weird edge cases.

"It is only in deep waters that a fish knows how strong it is."

Matshona Dhliwayo

Communications Standard Working Draft:

Due by 5:00 pm on **5/14/25**. This is the working draft of the communications standard.

"As for me, I am tormented with an everlasting itch for things remote. I love to sail forbidden seas, and land on barbarous coasts."

Herman Melville

[2] I/O, signal conditioning architecture, etc.

Finalized Communications Standard:

The final working version of the communications standard is due by 5:00 pm on **5/16/25**. No further changes are allowed to the standard. This protocol will be evaluated with respect to its completeness and suitability for the proposed system.

"And if anybody asks, just say a flood is coming."

Evan Almighty

First Checkpoint:

On or before **5/17/25**, you must demonstrate your approved 1st checkpoint functionality according to your defined testing procedure. Note: this is a functional evaluation only. The focus should be on demonstrating functional hardware and software. You may submit for approval a final revision of your checkpoint plan at this time.

"Just keep swimming. Just keep swimming."

Dory

Second Checkpoint:

On or before **5/21/25**, you must demonstrate your approved 1st and 2nd checkpoint functionality according to your defined testing procedure. The functionality demonstrated at this time must include full implementation of the communications protocol.

"[barnacle noises]"

Barbaracle, Pokémon X and Y

Third Checkpoint:

On or before **5/24/25**, each team must demonstrate (in addition to the 1st & 2nd checkpoints' functionality) your approved 3rd checkpoint functionality. The functionality demonstrated at this time must include a demonstration of interaction with at least one other teams' BARNACOALs in addition to your own. Note that this checkpoint can be completed inside SPDL (it's the Grading Session that will be completed in the fountain).

"You're gonna need a bigger BARNACOAL."

Chief Brody, an alternate version of Jaws

Grading Session:

During the Grading Session on **5/27/25**, each team will be required to demonstrate the ability to successfully participate in a game. This will include

1. Pairing with, and successfully operating, at least one other BARNACOAL constructed by another team;
2. Demonstrating all required functionality of the SPECTACOAL, including user interface and implementation of the Communications Committee-designed communications protocol, including:
   (a) All functionality of the Drive Mode.
   (b) All functionality of the Recharge Mode.
3. Demonstrating all required functionality of the BARNACOAL, including propulsion, recharging, pairing, and error handling.
4. Successful execution of at least sixty seconds of play, including at least one successful attempt at dumping COAL into the RECEPTACOAL and one successful attempt at reloading COAL into the BARNACOAL.

A detailed grading check-off procedure will be published at a later date.

"When I left you I was but the learner, now I am the master."

Darth Vader

Public Presentation:

This will take place on **5/28/25** starting at 5:00 pm at the Flooded Warehouse (outside of Thornton). At this event, members of the public will be encouraged to watch you Navigate the Flood to Escape the Warehouse!

Report:

Draft due on **6/2/25** by 4:00 pm. The final version (with revisions incorporated) is due by 5:00 pm on **6/6/25**.

Celebration:

A celebration of the past 3 quarters of ME218 will take place at the Alpine Inn on **06/12/2025** starting at 3:00 pm. Mark your calendars now and save the date.

Evaluation

Performance Testing Procedures:

Each team will demonstrate their SPECTACOAL and BARNACOAL during the three checkpoints. Members of the teaching team will randomly assign a BARNACOAL to each SPECTACOAL during the grading session.

Grading Criteria:

- ☐ **Concept (10 %)** 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, software and use of physical principles in the solution.
- ☐ **Implementation (15 %)** This will be based on the prototype displayed at the evaluation session. Included in this grade will be evaluation of the physical appearance of the prototype and quality of construction. We will not presume to judge true aesthetics, but will concentrate on craftsmanship and finished appearance.
- ☐ **First Checkpoint (10 %)** Based on the results of the performance demonstrated on 5/17/25.
- ☐ **Second Checkpoint (10 %)** Based on the results of the performance demonstrated on 5/21/25.
- ☐ **Third Checkpoint (10 %)** Based on the results of the performance demonstrated on 5/24/25.
- ☐ **Performance (20 %)** Based on the results of the performance testing during the Grading Session.
- ☐ **Report (10 %)** This will be based on an evaluation of the report. It will be judged on clarity of explanations, completeness and appropriateness of the documentation.
- ☐ **Report Review (5 %)** These points will be awarded based on the thoroughness of your review of your partner team's report. Read the explanations, do they make sense? Review the circuits, do they look like they should work?
- ☐ **Log Book (5 %)** This will be evaluated by the evidence of consistent maintenance as well as the quality and relevance of the material in the log book.
- ☐ **Housekeeping (5 %)** Based on the timely return of SPDL components, cleanliness of group workstations as well as the overall cleanliness of the lab. No grades will be recorded for teams who have not returned all loaned materials.

Resources

Websites:

SparkFun	Seeed Studio	Jameco	Mouser
Newark	Ponoko	Adafruit	Hackaday
DigiKey	McMaster-Carr	HobbyKing	ServoCity

You may also find PlantUML and PlantText helpful for creating message sequence diagrams.

Local Stores:

J&M Hobby House in San Carlos
Jameco in Belmont
TAP Plastics in various locations

Gems of Wisdom:

Be sure to check out The ME218 Archive for guidance from past generations.

Communication is relatively more fundamental this year than most years; however, keep in mind that there's still plenty to be doing while one of your teammates is getting the Comm Protocol sorted. Make effective use of this time to develop and test other systems.

Revision History

Revision 0: Initial (5/2/24)