ME 218c Spring 2022: Supply Chain Mismanagement
Harbor Pilots Compete for Fame and Glory

Project Preview on May 23 from 1-5 pm. **Grading Session** on May 24 from 1-5 pm.
Project Presentation on May 25 starting at 5:00 pm.
Revision 0: 4/28/22

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.

The Task:

Design and build a Terman Unmanned Guider (TUG), a watercraft capable of navigating up to 18-inch-deep harbors, and an accompanying Precariously Integrated Leader Of TUGs (PILOT), composed of one Connected Over-the-air Navigation CONsole (CONCON) and one Generic Ampere Storage CONsole (GASCON), each constructed and operated by one of your crew members. All of the TUGs will navigate in the Terman Pond. During games, each team will attempt to control their TUG to move the heavy cargo ships into the harbor terminal areas of their respective guild.

Specifications

General:

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

Basic Game Play:

- ☐ A game round will be a guild vs. guild competition among all operational TUGs, with the class being divided at random between two guilds before the start of each round.
- ☐ Each TUG will be randomly assigned to a PILOT, and the pairing process is to take place, prior to each round.
- ☐ A game round proceeds in real time, with no turn-taking.
- ☐ The goal of the game is for each guild to move as many cargo ships as possible into their harbor.
- ☐ The game ends when the majority of cargo ships are in place at any one guild's harbor, or after 4 minutes and 36 seconds of game time have elapsed, or when people become bored.

The Terman Pond:

- ☐ The Terman Pond is located adjacent to Thornton (SPDL) and forms the body of water in which your TUG is expected to operate.
- ☐ At the beginning of each game the participating TUGs will be initialized to an assigned starting area in the Terman Pond.
- ☐ Each guild will have designated harbor areas into which the cargo ships are to be moved. (See diagram)
- ☐ The cargo ships will start each round in random locations near the center of the Terman Pond.
- ☐ The fountains in the Terman Pond shall be disabled for the duration of play.

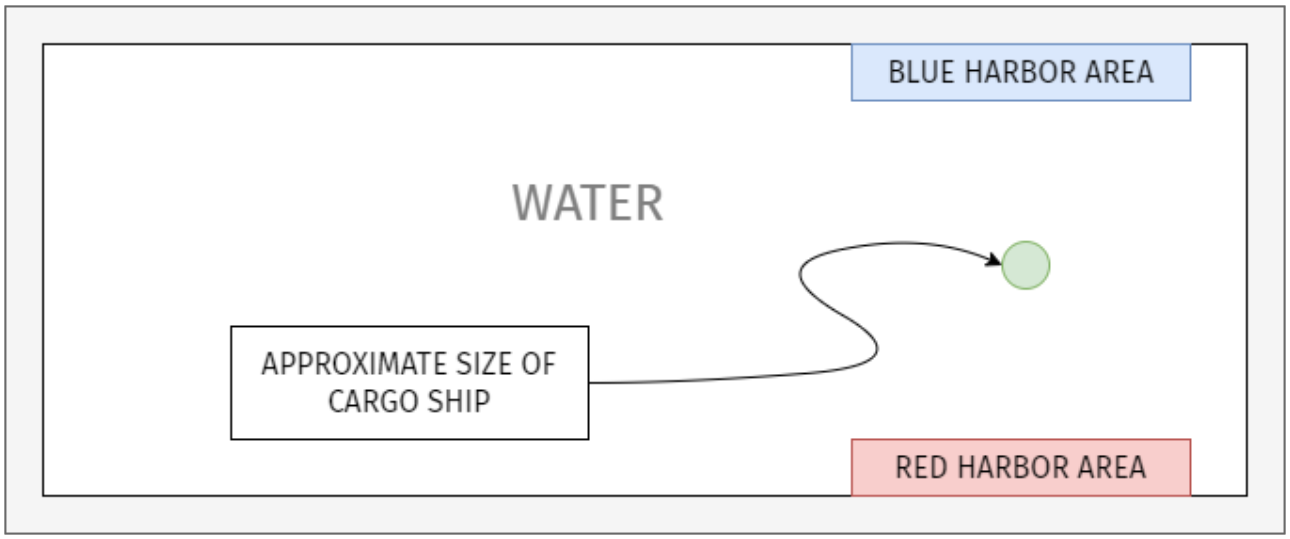

Figure 1: The Terman Pond. The Blue and Red harbor areas exist at opposing sides of the pond's short edge. Floating cargo ships will be distributed at random throughout the entire pond at the start of each round.

The TUG:

- ☐ Each TUG is a watercraft capable of operating in the Terman Pond.
- ☐ Each TUG shall be equipped with a maneuvering system controlled by the PILOT.
- ☐ There is no constraint on the type of propulsion system used, nor on achievable speed, nor on total mass of the TUG.
- ☐ Each TUG must track its fuel usage. The fuel storage of each craft is 100% thrust for 10 seconds, after which a refueling action must be performed. Lower amounts of thrust reduce fuel consumption linearly: a full tank provides 50% thrust for 20 seconds, 25% thrust for 40 seconds, etc.
- ☐ Each TUG shall have around its largest perimeter, at the waterline, a SPDL-issued closed-cell foam bumper.
- ☐ Each TUG is limited to a total circumference of 6 feet.
- ☐ No part of the TUG may protrude beyond the circumference of the foam bumper.
- ☐ Each TUG 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 TUG's sensitive instrumentation and propulsion systems must be protected against damage from ingress of objects and water to a rating of IP-24.
- ☐ Each TUG shall contain a SPDL-issued XBee radio module used to communicate with a PILOT.
- ☐ Each TUG must implement the class-wide protocol for coordinating game information (See Communications).

The PILOT:

- ☐ Each team will construct a PILOT composed of a CONCON and a GASCON.
- ☐ Each PILOT 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 CONCON and GASCON of a PILOT may be connected by one or more cables.
- ☐ The PILOT must provide the user controls for all required functions determined in the class-wide com-

munications protocol.

- ☐ The CONCON and GASCON shall each be operated by different crew members. One crew member alone may not operate both the CONCON and GASCON at the same time.
- ☐ All CONCON and GASCON must each provide their users a display of information relevant to that crew member's role.
- ☐ PILOTs may use serial terminal I/O, but must incorporate at least 1 physical input, and at least 1 LED output. It is preferred that these physical I/O devices are used for the most dramatic of functions.
- ☐ The user at the CONCON is granted complete control over the paired TUG's propulsion and maneuvering systems.
- ☐ The actions required by the user of the CONCON to issue movement commands to the TUG should be inventive and interesting for the audience to watch.
- ☐ The user at the GASCON has control over the paired TUG's refueling system only.
- ☐ The fuel status (remaining capacity) of a TUG may only be displayed on a GASCON and must not be visible to the user of the CONCON.
- ☐ The GASCON interface must implement a refueling action consisting of large-scale human body movements. Use of actions that make the refueling operator look and feel foolish are encouraged.
- ☐ The refueling action must last for at least 3 seconds. It is encouraged to devise a refueling action that lasts for 3 seconds at intense user effort, or up to 6 seconds at a moderate effort level.
- ☐ Each PILOT shall contain a SPDL-issued XBee radio module used to communicate with a TUG.
- ☐ Each PILOT must implement the class-wide protocol for coordinating game information (See Communications).
- ☐ Both crew members at a PILOT should stay within shouting range of each other during play in order to coordinate actions. The CONCON shall not be viewable by the crew member at the GASCON and vice versa.
- ☐ The size, shape and mass of the PILOT and its associated CONCON and GASCON are constrained only to what is portable by your team (from SPDL to Terman Pond and back).

Game Details:

- ☐ The game progresses in real time.
- ☐ Messaging between PILOTs and TUGs is limited to 5 Hz. That is to say that a single PILOT shall transmit one messages every 0.2 s, with the paired TUG transmitting one message also during this period.
- ☐ Because of the inherent unpredictability in wireless latency, PILOTs and TUGs 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.
- ☐ Collisions between TUGs will be unavoidable. Ensure that your TUG is designed to robustly absorb crash energy at the waterline bumper.

Communications:

- ☐ Communications between TUGs and PILOTs will take place over the airwaves using SPDL-supplied XBee radio modules in API mode.
- ☐ Each PILOT and TUG **shall** communicate with the XBee over an asynchronous communications channel using 9600 baud, 8N1 at 3.3V levels.

- ☐ 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 of each project group. 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 TUG and a PILOT.
- ☐ While a clear division of labor is not obvious, we strongly encourage making an effort to have the team members who did not serve on the Communications Committee implement the majority of the communications in software.

General Requirements:

- ☐ Automation of the setting of any control input is prohibited. That is to say that an algorithm may shall not set thrust magnitude, direction, fire a shot, allocate power, etc. An algorithm may advise the human operator of a PILOT 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 TUG.
- ☐ 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, 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.
- ☐ PILOTs based substantially on purchased platforms are not allowed.
- ☐ 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 PILOTs should be safe, both to the user and the spectators.

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

- ☐ Caution: being on a TUG may cause motion sickness.
- ☐ Warning: no virtual lifeguard on duty in the Terman Pond.
- ☐ Intentionally ramming other TUGs is encouraged. However, prohibited actions include, but are not limited to, spraying water on to TUGs or PILOTs, fouling the propulsion systems of TUGs, and/or jamming communications between PILOTs and TUGs. Unless it's raspberry.
- ☐ No part of the TUG may become ballistic.
- ☐ Approved small portable electronic devices may now be used while away from harbor.
- ☐ 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 **5/3/22** we will conduct a design review, one team at a time. Each team should prepare a few images showing your proposed designs for the PILOTs. 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 two checkpoints and the project preview 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.

First Draft of Communications Standard:

Due by 5:00 pm on **5/5/22**. This draft will be made available to the entire class, so that everyone is ready to deliver feedback at the in-class review.

In-Class Communications Standard Review:

In class on **5/6/22** 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.

Communications Standard:

Due by 5:00 pm on **5/7/22**. This is the working draft of the communications standard.

First Checkpoint:

On **5/9/22**, 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.

The final working version of the communications standard is due. No further changes are allowed to the standard. This protocol will be evaluated with respect to its completeness and suitability for the proposed system.

Second Checkpoint:

On **5/16/22**, 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.

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

Project Preview:

At the Project Preview on **5/23/22**, each team must demonstrate (in addition to the 1st & 2nd checkpoints' functionality) your approved project preview functionality. The functionality demonstrated at this time must include a demonstration of interaction between at least 2 teams' TUGs and PILOTs.

Grading Session:

During the Grading Session on **5/24/22**, 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 TUG constructed by another team;
2. Demonstrating all required functionality of the PILOT, including user interface and implementation of the Communications Committee-designed communications protocol, including:
   (a) All functionality of the CONCON.
   (b) All functionality of the GASCON.
3. Successful execution of at least sixty seconds of play, and at least one fuel emptying/re-fueling cycle.

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

Public Presentation:

This will take place on **5/25/22** starting at 5:00 pm at the Terman Pond (outside of Thornton). At this event, members of the public will be encouraged to watch you fight for shipping dominance of the Terman Harbor.

Report:

Draft due on **5/30/22** by 4:00 pm. The final version (with revisions incorporated) is due by 5:00 pm on **6/3/22**.

Celebration:

A celebration of the past 3 quarters of ME218 **may** take place at the Alpine Inn on **6/07/2022** starting at 3:00 pm. Mark your calendars now and save the date.

Evaluation

Performance Testing Procedures:

Each team will demonstrate their PILOT and TUG during the first & second checkpoints and project preview. Members of the teaching team will randomly assign a TUG to each PILOT 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 5/9/22.
- ☐ **Second Checkpoint (10 %)** Based on the results of the performance demonstrated on 5/16/22.
- ☐ **Preliminary Performance (10 %)** Based on the results of the performance demonstrated during the Project Preview.
- ☐ **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 (Not applicable while quarantine is in effect):

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 (4/28/22)