



**ME 218c Spring 2024: 218,000 Leagues Under The Pond**  
**The Glorious Adventures of Captain NEDMO and The OILUS**  
Project Preview on May 27 from 1-5 pm. Grading Session on May 28 from 1-5 pm.  
Project Presentation on May 29 starting at 5:00 pm.  
**Revision 0: 5/2/24**

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**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 Zero-Ingress, Lightweight Uncrewed Scuttlebutt (OILUS), which is a watercraft capable of navigating up to 18-inch-deep blue waters, and an accompanying Nautical Electromechanical Device for Mobile Operation (NEDMO), composed of one Nonspecific Assignable Vessel CONTroller (NAVCON) and one Free Uninterrupted Energy Laboratory CONsole (FUELCON), each constructed and operated by your team. All of the OILUSs will navigate in the SEA. During play, each team will attempt to control their wirelessly paired OILUS to sink the Towed External Non-Directional Rigs (TENDRs) of opposing OILUSs, while navigating in the Shimmering Extent of Ambition (SEA)

**Specifications**

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**General:**

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

**Basic Game Play:**

- ☐ At the beginning of each game, the participating OILUSs will be paired to NEDMOs either at random, or at the discretion of the teaching team.
- ☐ All TENDRs will be emptied of any contents and placed afloat on the SEA prior to the start of a game round.
- ☐ A game round consists of an attempt by each OILUS to sink the TENDRs of all other operational OILUSs.
- ☐ A game round ends when there is only one OILUS left with a floating TENDR.
- ☐ A game round proceeds in real time, with no turn-taking.
- ☐ When a craft's TENDR is sunk, it may continue to pursue other OILUS to sink their TENDRs, however, a sunk TENDR must remain sunk for the entire game round.

**The SEA:**

- ☐ The SEA is located adjacent to Thornton (SPDL) and forms the body of water in which your OILUS is expected to operate.
- ☐ The approximate depth of the water in the SEA is 18 in.
- ☐ Every effort will be made to have the fountains in the SEA disabled for the duration of play, however, your OILUS should be robust enough to operate in the SEA with the fountains running.
- ☐ A OILUS may venture into any part of the SEA, but must not exit the water.

### **The OILUS:**

- ☐ Each OILUS is a watercraft capable of operating in the SEA.
- ☐ Each OILUS shall be equipped with a propulsion and maneuvering system controlled by the NEDMO.
- ☐ Each OILUS shall tow a TENDR by means of a standardized, fixed-length, thin tow line anchored at the OILUS's center of mass at a height of no more than 20cm above the waterline.
- ☐ The TENDR tow line shall be given sufficient clearance so that it can reach its full, straight length when the OILUS is traveling forward in a straight line.
- ☐ There is no constraint on the type of propulsion system used, nor on achievable speed, nor on total mass of the OILUS.
- ☐ Each OILUS shall have around its largest perimeter, at the waterline, a SPDL-issued closed-cell foam bumper.
- ☐ Each OILUS shall display the number of the team that built it with digits at least 15cm tall.
- ☐ Each OILUS is limited to a total waterline circumference of 6 ft.
- ☐ Each OILUS must implement an eletromechanical indication of its state of association with a NEDMO. Exactly which association states must be displayed, is at the discretion of the Communications Committee.
- ☐ Each OILUS must have a means of sinking the TENDR of other OILUSs that does not involve simple ramming.
- ☐ Each OILUS must keep track of its own fuel status, counted in seconds. A full fuel tank on a OILUS is 15 seconds.
- ☐ Each action that a OILUS takes that does work (as defined by physics) deducts fuel for the duration of the action. Such actions may include, but are not limited to, propulsion, pumping, moving water vessels, etc. A OILUS that is sitting idle, whether paired with a NEDMO or not, is not considered to be actively consuming fuel.
- ☐ When a OILUS reaches 0 fuel remaining, it may not perform any more work until refueled through a refueling action from the FUELCON of its paired NEDMO.
- ☐ No part of the OILUS may protrude beyond the circumference of the foam bumper, with exception of any implement designed to collect water from the SEA. Any such implement must be retractable such that the OILUS can start a game round with nothing protruding from the bumper. Any such implement must not contact any TENDR, which is cause for disqualification of a OILUS for a game round.
- ☐ Each OILUS 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 OILUS's sensitive instrumentation and propulsion systems must be protected against damage from ingress of objects and water to a rating of IP-24.
- ☐ Each OILUS shall contain a SPDL-issued XBee radio module used to communicate with a NEDMO.
- ☐ Each OILUS must implement the class-wide protocol for coordinating game information (See [Communciations](#)).

### **The TENDR:**

- ☐ The TENDR is a 125mm diameter, circular metal vessel with a 29mm dish.
- ☐ The TENDR and its tow line will be supplied by the teaching staff.
- ☐ The TENDR is buoyant when its hull is empty. However, if it takes on water, it will sink.
- ☐ The TENDR shall not be modified in any way.
- ☐ A TENDR tether may not be deliberately interfered with through winding, cutting, bending, folding, or

other means not listed. It must remain free to tow the TENDR.

- ☐ A severed TENDR tether results in disqualification of both the OILUS that owns the TENDR, and the OILUS that severed the tether, for a game round.

### **The NEDMO:**

- ☐ Each team will construct a NEDMO composed of a NAVCON and a FUELCON.
- ☐ Each NEDMO 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 NAVCON and FUELCON of a NEDMO may be connected by one or more cables.
- ☐ The NEDMO must provide the user controls for all required functions determined in the class-wide communications protocol.
- ☐ The NAVCON and FUELCON shall each be operated by different crew members. One crew member alone may not operate both the NAVCON and FUELCON simultaneously. It is encouraged to make such simultaneous operation physically impractical.
- ☐ The NAVCON shall contain all controls and displays relevant to navigation of a OILUS.
- ☐ The FUELCON shall contain all controls and displays relevant to fuel status and refueling, as well as all controls and displays relevant to wireless communication (e.g. pairing, OILUS number...)
- ☐ NEDMOs must incorporate at least 1 analog input and at least 1 electromechanical output.
- ☐ The user at the NAVCON is granted complete control over the paired OILUS's propulsion and maneuvering systems.
- ☐ The actions required by the user of the FUELCON to issue refueling and wireless communication commands to the OILUS should be inventive and interesting for the audience to watch.
- ☐ The actions required by the user of the NAVCON may be simple and streamlined to aid in controlled navigation of a OILUS.
- ☐ The refueling action of the FUELCON must implement an activity consisting of large-scale human body movements. Use of actions that make the FUELCON operator look and feel foolish are encouraged.
- ☐ During refueling, no inputs may be registered on the NAVCON. If such an input occurs during refueling, the refueling process is terminated, no partial fuel award is granted to the OILUS, and the user of the FUELCON must restart the refueling process after the user at the NAVCON has released all controls.
- ☐ The required FUELCON refueling action must last continuously for at least 2.5 seconds. Partial completion of a refueling action should result in partial refueling of the OILUS, proportional to time spent performing the refueling action.
- ☐ The FUELCON must include, at minimum, an indicator to display the remaining fuel level in a OILUS with a resolution of 1 part in 5.
- ☐ Each NEDMO shall contain a SPDL-issued XBee radio module used to communicate with a OILUS.
- ☐ Each NEDMO must implement the class-wide protocol for coordinating game information (See [Communications](#)).
- ☐ Both crew members at a NEDMO shall stay within shouting range of each other during play in order to coordinate actions.
- ☐ The size, shape and mass of the NEDMO and its associated NAVCON and FUELCON are constrained only to what is portable by your team, from one end of the SEA to the other. Bear in mind that you may need to move the NEDMO to keep up with a OILUS.

### **Game Details:**

- ☐ The game progresses in real time.

- ☐ Messaging between NEDMOs and OILUSs is limited to 5 Hz. That is to say that a single NEDMO shall transmit one message every 0.2 s, with the paired OILUS transmitting one message also during this period.
- ☐ Because of the inherent unpredictability in wireless latency, NEDMOs and OILUSs 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 OILUSs will be unavoidable. Ensure that your OILUS is designed to robustly absorb crash energy at the waterline bumper.

### Communications:

- ☐ Communications between OILUSs and NEDMOs will take place over the airwaves using SPDL-supplied XBee radio modules in API mode.
- ☐ Each NEDMO and OILUS **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.<sup>1</sup>
- ☐ The communication protocol shall cover all communication handled through the XBee, including pairing, operation, unpairing, and exception handling between a OILUS and a NEDMO. 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 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 NEDMO 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 NEDMO 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 OILUS.
- ☐ 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.

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<sup>1</sup>That is, Layer 3 of the OSI model.

- ☐ 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.
- ☐ NEDMOs or OILUSs 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 NEDMOs should be safe, both to the user and the spectators.
- ☐ Caution: being on a OILUS may cause motion sickness.
- ☐ Warning: no virtual lifeguard on duty in the SEA.
- ☐ Intentionally ramming other OILUSs is encouraged. However, prohibited actions include, but are not limited to, fouling the propulsion systems of OILUSs, and/or jamming communications between NEDMOs and OILUSs. Unless it's raspberry.
- ☐ No part of the OILUS 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 5/7/24 we will conduct a design review, one team at a time. Each team should prepare a few images showing your proposed designs for the NEDMOs. You will have 5 minutes to walk us through your ideas. **The focus should be on system level concepts<sup>2</sup>, 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.

*It is the winnowing fan of death that makes for the development of animal life.*

*Chapman Cohen*

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<sup>2</sup>I/O, signal conditioning architecture, etc.

### First Draft of Communications Standard:

Due by 5:00 pm on 5/10/24. This draft will be made available to the entire class, so that everyone is ready to deliver feedback at the in-class review.

*May I suggest that we no longer belabor the question of whether or not we should have gone after the creature? The matter has now been rendered academic. The creature is now after us.*

Spock

### In-Class Communications Standard Review:

In class on 5/14/24 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:

Due by 5:00 pm on 5/15/24. 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

### First Checkpoint:

On or before 5/17/24, you must demonstrate your approved 1<sup>st</sup> 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.

*Just keep swimming. Just keep swimming, swimming, swimming. What do we do? We swim, swim.*

Dory

### Second Checkpoint:

On or before 5/20/24, you must demonstrate your approved 1<sup>st</sup> and 2<sup>nd</sup> checkpoint functionality according to your defined testing procedure. The functionality demonstrated at this time must include full implementation of the communications protocol.

*Fishes live in the sea, as men do a-land; the great ones eat up the little ones.*

William Shakespeare

### Project Preview:

On or before the Project Preview date of 5/27/24, each team must demonstrate (in addition to the 1<sup>st</sup> & 2<sup>nd</sup> checkpoints' functionality) your approved project preview functionality. The functionality demonstrated at this time must include a demonstration of interaction between at least 2 teams' OILUSs and NEDMOs.

*You're gonna need a bigger OILUS.*

Chief Brody

### Grading Session:

During the Grading Session on 5/28/24, 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 OILUS constructed by another team;
2. Demonstrating all required functionality of the NEDMO, including user interface and implementation of the Communications Committee-designed communications protocol, including:

- (a) All functionality of the NAVCON.
- (b) All functionality of the FUELCON.
- 3. Demonstrating all required functionality of the OILUS, including propulsion, refueling, pairing, and error handling.
- 4. Successful execution of at least sixty seconds of play, including sinking at least one TENDR.

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 **5/29/24** starting at 5:00 pm at the SEA (outside of Thornton). At this event, members of the public will be encouraged to watch you fight for shipping dominance of the Terman Harbor.

*...because sharks have been around for a very long time. There were sharks before there were dinosaurs, and the reason sharks are still in the ocean is that nothing is better at being a shark than a shark.*

*Douglas Adams*

### Report:

Draft due on **6/3/24** by 4:00 pm. The final version (with revisions incorporated) is due by 5:00 pm on **6/7/24**.

*Fish are friends, not food.*

*Bruce*

### Celebration:

A celebration of the past 3 quarters of ME218 will take place at the Alpine Inn on **06/13/2024** starting at 3:00 pm. Mark your calendars now and save the date.

*Where others have failed, I will not fail.*

*Captain NEdmo*

## Evaluation

### Performance Testing Procedures:

Each team will demonstrate their NEDMO and OILUS during the first & second checkpoints and project preview. Members of the teaching team will randomly assign a OILUS to each NEDMO 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 5/17/24.
- ☐ **Second Checkpoint (10%)** Based on the results of the performance demonstrated on 5/20/24.
- ☐ **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.

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## Resources

### Websites:

[SparkFun](#)  
[Newark](#)  
[DigiKey](#)

[Seeed Studio](#)  
[Ponoko](#)  
[McMaster-Carr](#)

[Jameco](#)  
[Adafruit](#)  
[HobbyKing](#)

[Mouser](#)  
[Hackaday](#)  
[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.

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## Revision History

**Revision 0:** Initial (5/2/24)