ME218

ME 218c Spring 2019: Ed? Carryer!

Project Preview on May 24 from 1-5 pm. **Grading Session** on May 28 from 1-5 pm.
Project Presentation on May 29 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 the users and the observers.

Purpose:

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

Background:

You've heard of the game Marco……Polo!, you've loved the game Marco……Polo!, now get ready to play the game Marco……Polo!

The game has to be updated for modern sensibilities however: swimming pools are too dangerous; running around with your eyes closed is too dangerous; doing both at once is *certainly* too dangerous, and ingesting large amounts of dihydrogen monoxide can cause death. As a result, you will be playing these through a virtual reality interface, using robots to do the dangerous work while you sit safe and secure in your well-protected VR Command Pod™.

The Task:

Design and build a Wireless Human Analogue: Land-based Emulator (WHA:LE[1]) and a companion Good [Or Great] Geo-Location Enabler (G[OG]GLE). All of the WHA:LEs will play Marco……Polo! in the Swimming Pool Simulator 3000™[2] outside SPDL. During games, each player, through their G[OG]GLE, will attempt to control their WHA:LE to tag or avoid being tagged by another WHA:LE and win the game of Marco……Polo!

Specifications

General:

- ☐ Each team will construct a WHA:LE and a G[OG]GLE.
- ☐ The WHA:LEs are devices capable of navigating on an asphalt surface while seeking and avoiding other WHA:LEs.
- ☐ The G[OG]GLEs are remote controllers and sensory data displays for the WHA:LEs, communicating wirelessly between the G[OG]GLEs and the WHA:LEs.

Basic Game Play:

- ☐ A game round will be a competition among all teams, with each G[OG]GLE paired to and controlling a WHA:LE.
- ☐ At all times, one WHA:LE will be designated as "it".
- ☐ The goal of the game is for the WHA:LE that is "it" to tag another WHA:LE, who will then become "it".
- ☐ At any time, the WHA:LE that is "it" may sing "Ed", at which point all other craft must respond by singing "Carryer".
- ☐ The game proceeds in a series of timed rounds; at the end of each timed round, the craft that is "it" will be removed from the Swimming Pool Simulator 3000™.
- ☐ The game ends when only one WHA:LE remains in the Swimming Pool Simulator 3000™, or when people get bored.

[1] Pronounced WAH·lee
[2] The asphalt area right behind SPDL.

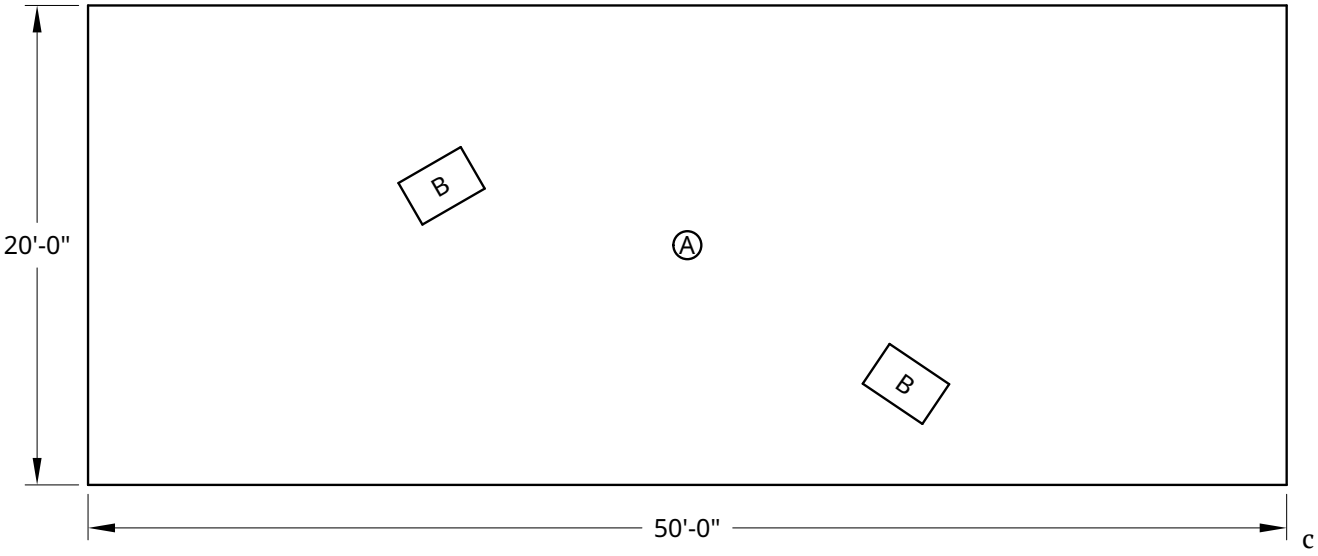

Figure 1: The Swimming Pool Simulator 3000™. Audible beacon at center will sing at periodic intervals to aid localization (A). Arbitrary obstacles will be placed within the Swimming Pool Simulator 3000™ (B).

The Swimming Pool Simulator 3000™:

- ☐ The Swimming Pool Simulator 3000™ comprises a region of asphalt behind the lab, measuring approximately 20 ft by 50 ft (see Figure 1).
- ☐ The boundaries of the Swimming Pool Simulator 3000™ will be marked on the ground in chalk, and will be enforced by spectators and/or the teaching staff.
- ☐ At the beginning of each game the participating WHA:LEs may be placed anywhere fully within the Swimming Pool Simulator 3000™.
- ☐ There will be obstacles in unknown locations within the Swimming Pool Simulator 3000™.
- ☐ There will be an audio beacon at the center of the Swimming Pool Simulator 3000™ which will sound at regular intervals.

The WHA:LEs:

- ☐ Each WHA:LE must be capable of moving under its own power within the Swimming Pool Simulator 3000™.
- ☐ WHA:LEs must be battery powered and operate without a tether. NiCd or NiMH batteries are the only approved power sources.
- ☐ WHA:LEs are limited to an upper speed limit of 2 m/s. Propulsion and steering systems are not restricted, subject to this constraint.
- ☐ Control of WHA:LE functions must be achieved via a G[OG]GLE using the provided RF hardware (XBee24 modules)
- ☐ The WHA:LE must proudly display its team number.
- ☐ The WHA:LE must carry a display indicating whether the WHA:LE is “it” or not.
- ☐ The WHA:LE must have a display that is active whenever it sings.
- ☐ All displays defined in the above specifications must be clearly interpretable in direct sunlight at a distance of no less than 20 m in all directions.
- ☐ All WHA:LEs should have an indicator of whether they are under active control by a G[OG]GLE.
- ☐ The indicators defined in the above specifications must be clearly interpretable in direct sunlight at a

distance of no less than 2 m in all directions.

- ☐ The WHA:LE should have a speaker in order to sing "Ed" and "Carryer". This song should register between 2 levels to be specified later, as measured by the SPL meter on Ed's phone at a distance of 1 m from the center of the WHA:LE.
- ☐ The WHA:LE should implement an "inside voice" for testing, which should be non-annoying for your classmates.
- ☐ Each WHA:LE must implement a pair of microphones, and route these signals to a class-provided stereo FM transmitter. This stereo audio signal should allow the person controlling your WHA:LE to hear the direction of sounds relative to your WHA:LE.
- ☐ Each WHA:LE must have a clearly marked momentary button to designate the WHA:LE as "it".
- ☐ WHA:LEs must incorporate an easily accessible switch that disables all moving systems.
- ☐ WHA:LEs must incorporate an "easy pick-up" handle[3]. The purpose of this handle should be obvious by design, as it may be used by spectators to re-orient your WHA:LE towards the Swimming Pool Simulator 3000™.
- ☐ WHA:LEs must incorporate a class standard bumper around their perimeter, and must be tolerant of moderate bumping from other WHA:LEs. The bumper must cover the entire perimeter between 5 cm and 10 cm above the surface of the Swimming Pool Simulator 3000™.
- ☐ Your WHA:LE must be able to detect contact to the bumper from all directions, and must trigger at a force threshold of no more than 5 N, and at a displacement of no more than 2 cm. This will be inspected by applying quasistatic forces at three randomly chosen points around the perimeter of your WHA:LE and measuring the force and displacement required to trip the sensor.
- ☐ The entire vehicle, projected vertically onto the Swimming Pool Simulator 3000™ surface, must lie within its outer perimeter as defined by the bumper. Height is not restricted.
- ☐ Every WHA:LE must be controllable through any of the G[OG]GLEs via the class-wide protocol (See Communications).
- ☐ The WHA:LE may issue messages to the G[OG]GLE at a rate no greater than 5 Hz.
- ☐ If the WHA:LE fails to receive a message from its controller for 1 second, it will assume that there is a problem and revert to the controller search process described under Game Details.

The G[OG]GLEs:

- ☐ Each team will design and construct a G[OG]GLE that will relay commands from a human operator to a WHA:LE, and receive and display connection status with the WHA:LE and sensory data from the WHA:LE.
- ☐ The G[OG]GLE must be capable of displaying to the operator an indication of active communication with its associated WHA:LE.
- ☐ The G[OG]GLE must have an indication of whether the controlled WHA:LE is "it".
- ☐ The G[OG]GLE must provide a method for the operator to use to indicate which WHA:LE (by team number) the operator would like to control.
- ☐ The G[OG]GLE must have a method for commanding the WHA:LE to sing "Ed".
- ☐ The G[OG]GLE must incorporate the class-supplied FM receiver, and must provide access for tuning it to different frequencies.
- ☐ G[OG]GLEs must be battery powered, and shall have sufficient battery capacity for at least 8 hours of continuous operation. The report shall show documentation and calculations to support meeting this requirement.

[3]This handle should function as a handle. That is, it should remain attached to your WHA:LE when picked up by an untrained user, and should be located so that your WHA:LE remains approximately upright when picked up.

- ☐ G[OG]GLEs must be untethered and portable by one person.
- ☐ Input to the G[OG]GLE should involve at least 3 sensing modalities (e.g. position, force, audio, acceleration, etc.). Use of unusual interface methods is encouraged.
- ☐ The actions required by the user of the G[OG]GLE to issue commands to the WHA:LE should be inventive and interesting for the audience to watch.
- ☐ The G[OG]GLE may issue commands to a WHA:LE at a rate no greater than 5 Hz.
- ☐ G[OG]GLEs should be intuitive to operate, and/or have sufficient visual instructions that a typical spectator (even a non-engineer) would be able to learn its controls within a minute or so. IKEA[4] format instructions are preferred.

Game Details:

- ☐ Upon power-up, voluntary un-pairing, or in the event of a loss of communication with its current G[OG]GLE, the WHA:LE will activate its indicator that it has no current G[OG]GLE and wait for a request for pairing from an eligible G[OG]GLE.
- ☐ The operator of a G[OG]GLE that wishes to control a particular WHA:LE must select that WHA:LE (by WHA:LE number) using the G[OG]GLE, and make a unique control action to initiate taking control of the WHA:LE. This action will result in the G[OG]GLE sending a message to the WHA:LE requesting control of the WHA:LE. The details of the request process will be defined in the class-wide communications protocol.
- ☐ Setup for the game will consist of: pairing your G[OG]GLE with your WHA:LE, and tuning your FM receiver to the correct channel.
- ☐ During the game, operators of the WHA:LEs will be positioned such that they cannot see the Swimming Pool Simulator 3000™, and must navigate using only information provided by the WHA:LE through the G[OG]GLE and the FM audio.
- ☐ The game will be started by pressing the "it" button on one of the active WHA:LEs.
- ☐ During the game, the WHA:LE that is "it" may tag other WHA:LEs by bumping them. Suspected tags will be negotiated through the classwide communication protocol, as defined in the section on Communications. A successful tag will transfer "it" status to the tagged WHA:LE.
- ☐ During the game, a WHA:LE may attempt to localize other WHA:LEs by singing "Ed". At this point, all other WHA:LEs will respond audibly, and will avoid singing over each other using the protocol defined in the section on Communications.
- ☐ The game ends when only one WHA:LE remains in the Swimming Pool Simulator 3000™, or when people get bored.
- ☐ At the end of the game, the remaining WHA:LE is declared victorious.
- ☐ Any WHA:LE that exits the Swimming Pool Simulator 3000™ will be repositioned, by the handle, to point towards the center of the Swimming Pool Simulator 3000™.
- ☐ Any paired G[OG]GLE may voluntarily un-pair from its WHA:LE at any time. The WHA:LE then reverts to a pairing state.

Communications:

- ☐ Communications between the WHA:LEs and G[OG]GLEs will take place over an SPDL-supplied 802.15.4 radio (Xbee24) using the Non-Beacon API mode of operation.
- ☐ Each XBee module will communicate with your device at 9600 baud.
- ☐ Any G[OG]GLE should be capable of controlling any WHA:LE.

[4] Intragalactic Knowledge Enforcement Agency

- ☐ Once a game begins, communication will take the form of bidirectional communications between a WHA:LE and its paired G[OG]GLE.
- ☐ Each WHA:LE and G[OG]GLE will be assigned a unique ID in the form of the source address of each SPDL-supplied radio.
- ☐ The details of the communications protocol will be defined and specified by a Communications Committee, which will consist of one member from each project group. The specification must be in a written form and with sufficient detail that someone skilled in ME218 material could implement it.
- ☐ In order to better balance the workload and learning among team members, each of the following tasks must be completed by a different member of the team:
  - serve on the communications committee.
  - implement communications on the WHA:LE.
  - implement communications on the G[OG]GLE.
- ☐ The class communications protocol must include a procedure for validation of communication between the WHA:LE and G[OG]GLE. The WHA:LEs must provide a visual indication of when a functioning communications link between the WHA:LE and G[OG]GLE exists.
- ☐ The WHA:LE will respond to the first received request for control from a G[OG]GLE by sending a message back to the requesting G[OG]GLE confirming receipt. At this time, the WHA:LE will also activate its indicator of active communication with a G[OG]GLE.
- ☐ If a WHA:LE receives a request for control while it is already under control, it will silently ignore the request.
- ☐ Within 100 ms of un-pairing from its paired G[OG]GLE, a WHA:LE must reset its indication of active control.
- ☐ Within 100 ms of un-pairing from its paired WHA:LE, a G[OG]GLE must reset its indication of active control.
- ☐ A G[OG]GLE may issue messages to its paired WHA:LE at a rate not to exceed 5 Hz.
- ☐ The communications protocol should include a means to support any auxiliary sensing methods[5] that WHA:LEs and G[OG]GLEs may implement.
- ☐ The communications protocol should include a method for ensuring that no WHA:LEs may sing over one another[6]. This protocol should be specified such that the beacon may avoid singing over WHA:LEs singing "Carryer" by listening only to relevant broadcast packets.
- ☐ The communication protocol should provide for negotiation of suspected tags by the following algorithm:
  1. On detecting contact, the WHA:LE that is "it" shall send a broadcast message indicating contact. This message may be sent only once per actuation of the bumper.
  2. All other WHA:LEs which detected a bumper hit within a time offset T_{bump} prior to reception of the message from the WHA:LE that is "it" will reply to that WHA:LE with a directed message indicating that they were bumped.
  3. The craft that is "it" will process the returned messages as follows:
     (a) If there are zero responses received within T_{timeout}, continue as "it".
     (b) If there is exactly one response received within T_{timeout}, send a directed message in reply indicating transfer of "it" status, and un-set "it" status on itself. The other WHA:LE should then mark itself as "it" on receipt of this message.

[5] Stereo sound alone may be difficult to interpret and navigate with, and so other senses may be useful, although not required. For example, your users may find things like ambient air temperature, compass heading, humidity, measured ranges to objects, barometric pressure, proximity to the nearest In-n-Out, remaining magic smoke level, etc. to be useful for successfully locating and tagging other robots without visual cues.

[6] That is, no two WHA:LEs are permitted to be generating sound at the same time

(c) If there are multiple responses received within T_{timeout}, select the nearest other robot as measured by RSSI, and perform the "it" transfer as described in (b).

The implementation should allow for compile-time adjustment of T_{bump} and T_{timeout}.

General Requirements:

- ☐ At a minimum, either the G[OG]GLE or the WHA:LE must contain two actively communicating processors. There is no class-imposed upper limit on the number of processors employed; however, you are limited to a total of one Tiva between your WHA:LE and G[OG]GLE.
- ☐ You are limited to an expenditure of **$220.00/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.
- ☐ 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.
- ☐ WHA:LEs or G[OG]GLEs 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:

- ☐ Both the WHA:LEs and the G[OG]GLEs should be safe, both to the user and the spectators.
- ☐ Caution: motion G[OG]GLEs may cause motion sickness.
- ☐ Warning: no virtual lifeguard on duty in the Swimming Pool Simulator 3000™.
- ☐ Intentionally disabling or damaging other WHA:LEs is not allowed. Prohibited actions include, but are not limited to, the following: ramming at excessive speed (as determined solely at the discretion of the teaching staff).
- ☐ No part of the WHA:LE may become ballistic.
- ☐ Approved small portable electronic devices may now be used during taxi, take-off, and landing.
- ☐ The teaching staff reserves the right to disqualify any device considered unsafe.

Checkpoints

Design Review:

On **5/7/19** we will conduct a design review, one team at a time. Each team should prepare a few images showing your proposed designs for both the WHA:LE and the G[OG]GLE. You will have 5 minutes to walk us through your ideas. **The focus should be on system level concepts, 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, in printed form, 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 turns out that the killer application for virtual reality is other human beings. Build a world that people want to inhabit, and the inhabitants will come.

Charles Stross

First Draft of Communications Standard:

Due by 5:00 pm on **5/8/19**. Karl and/or Ed will meet with the communications committee on the evening of 5/9/19 to provide feedback on the specification.

Ocean is a mighty harmonist.

William Wordsworth

Communications Standard:

Due by 5:00 pm on **5/11/19**. This is the working draft of the communications standard.

The WHA:LEs do not sing because they have an answer, they sing because they have a song.

Gregory Colbert

First Checkpoint:

On **5/14/19**, 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.

The skeleton of the WHA:LE furnishes but little clue to the shape of his fully invested body.

Herman Melville

Second Checkpoint:

On **5/20/19**, 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.

Swimming is a confusing sport, because sometimes you do it for fun, and other times you do it not to die. And when I'm swimming, sometimes I'm not sure which one it it.

Demetri Martin

Project Preview:

At the Project Preview on **5/24/19**, 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 interoperability between at least 2 teams' WHA:LEs and G[OG]GLEs.

Going outside is highly overrated.

Anorak's Almanac, Chapter 17, Verse 32

Grading Session:

During the Grading Session on **5/28/19**, each team will be required to demonstrate the ability to successfully participate in a game. This will include

1. Establishing communications between your WHA:LE and G[OG]GLE and between your WHA:LE and the G[OG]GLE from another team.
2. "Respond to "Ed" by singing "Carryer" without causing a song collision" .
3. Displaying the correct status of communications on both the G[OG]GLE and the WHA:LE.

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

I know what you're thinking, 'cause right now I'm thinking the same thing. Actually, I've been thinking it ever since I got here: Why oh why didn't I take the BLUE pill?

Cypher

Public Presentation:

This will take place on **5/29/19** starting at 5:00 pm behind SPDL (aka the Swimming Pool Simulator 3000™). At this event, members of the public will be encouraged to act as operators of the G[OG]GLEs.

You will hear it for yourself, and it will surely fill you with wonder.

Marco Polo

Report:

Draft due on **6/3/19** by 4:00 pm. The final version (with revisions incorporated) is due by 5:00 pm on **6/7/19**.

That's a good name—ground! I wonder if it will be friends with me?

A WHA:LE above Magrathea

Celebration:

A celebration of the past 3 quarters of ME218 will take place at the Alpine Inn on **05/31/18** starting at 3:00 pm. Mark your calendars now and save the date.

Regardless of its purpose, the humpback-WHA:LE song is the most complex piece of nonhuman composition on earth.

Christopher Moore

Evaluation

Performance Testing Procedures:

One or more of the team members will demonstrate the WHA:LE and G[OG]GLE during the first & second checkpoints and project preview. Members of the teaching team will operate the WHA:LE via the G[OG]GLE during the grading session.

Grading Criteria:

- ☐ **Concept (15 %)** 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 5/14/19.
- ☐ **Second Checkpoint (10 %)** Based on the results of the performance demonstrated on 5/20/19.
- ☐ **Preliminary Performance (10 %)** Based on the results of the performance demonstrated during the Project Preview.
- ☐ **Performance (15 %)** 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 Mountain View

Gems of Wisdom:

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