ME 218a Fall 2019: A Space Oddity
Make Mars the Kind of Place to Raise Your Kids

Grading Session on November 20 from 1-5 pm.
Project Presentation on November 20 starting at 7:00 pm.

Goal:

The goal of this project is to provide a framework in which you can apply your knowledge of microcontrollers to provide an enjoyable experience for users and observers.

Purpose:

The underlying purpose of this project is to give you some experience building an electromechanical widget. We expect that this will involve working with sensors, driving actuators, designing event-driven software, and implementing that software in C on a Tiva LaunchPad. We expect to see all of these elements in every solution. Your lab kit contains sensors and signal & power transistors, although you are not limited to using only these. You are limited to an expenditure of **$175.00 / team** for all materials and parts used in the construction of your project. Materials from the lab kit, the Cabinet of Freedom and any consumable supplies do not count against the limit; all other items count at their Market Value.

Background:

Congratulations! You have been selected for a free ~~return~~ one-way trip to Mars!

Elon Musk and SpaceX have made surprisingly fast progress on Starship, and the rocket launches on November 20. However, Elon hasn't figured out anything else about this plan: what you'll eat, what you'll do for fun, what you'll wear, where you'll sleep, how to get around, how you'll breathe, how you'll avoid freezing, how you'll avoid sublimating, how you'll avoid being irradiated, how you'll operate the life support systems — you know, the basics. You do have some help in the food department: Mark Watney has already figured out how to grow potatoes on Mars, so you won't need to grow those—though it might still be nice to have some variety in your life on the Red Planet.

To that end, more practical minds at SpaceX have put out a request for proposals (RFP) for solutions that solve any or all of these challenges. Your task will be to develop, implement, and test a Portable Offworld Training And enTertainment Object (POTATO) before you're strapped into the rocket and shipped to Mars (on November 20).

The Task:

Your POTATO will be installed in Starship (that is, distributed around the Atrium of Bldg. 550 (our classroom building)) to be presented to the Terrans Aboard The Enormous Rocket (TATERs). The TATERs will wander around the room interacting with the POTATOs[1] to prepare for life on Mars. You should strive to make your POTATO exciting, active, durable, educational, and electromechanical.

> *All civilizations become either spacefaring or extinct.*
>
> *Carl Sagan*

Specifications

POTATO Operation:

- ☐ The POTATOs will power up into a welcoming mode, offering TATERs the Opportunity to interact with your POTATO. Whenever it is in this mode it should inspire Curiosity and a Spirit of exploration in the TATERs.
- ☐ To quickly bring people up to speed on how to pursue life, liberty, and happiness on a new planet, it should take the average TATER approximately 60 seconds to interact with your POTATO. No one except Elon Musk should be able to completely master your POTATO in less than 30 seconds.

[1] Remember that this is an acronym. *The New York Times* has addressed this in the past. This is how you pluralize an acronym.

- ☐ To emphasize the urgency of establishing life on an inhospitable world, each POTATO should include a creative display of the passage of the time since the TATERs have started using the POTATO. **7-segment displays don't count.**
- ☐ Power is in short supply, so to conserve resources your POTATO must only operate when in active use by TATERs. The POTATO should reset to the welcoming mode within 30 seconds after the TATER stops interacting with the POTATO.
- ☐ To account for any unforeseen situations that could arise on Mars, your POTATO should involve at least 3 distinct TATER interactions.
- ☐ Your POTATO should require large scale motion on the part of the TATER for at least one of its interactions.
- ☐ When the POTATO completes its task, it should provide a clear audio and/or visual indication that will celebrate the TATER's new life on Mars. This indication may last no more than 30 seconds before the POTATO resets.
- ☐ The POTATO should be usable without the guidance of a Martian Engineer of the 218th Rank. To respect the diverse languages of Earth and Mars, any static instructions must be only in pictorial form (Think IKEA[2] instructions).

Basic Specifications:

- ☐ A team of four class members will construct a POTATO.
- ☐ The POTATO must have parts that visibly move under the control of the Tiva LaunchPad.
- ☐ While it is permissible to use consumer devices as components in a POTATO, payload regulations require that such devices must be substantially modified before being incorporated into your project. We don't want you to just buy significant portions of your project. If there is any question as to whether or not the purchased component has been modified significantly enough, please see the teaching staff.
- ☐ Each POTATO must respond to at least three distinct inputs/interactions.
- ☐ At least one of the user interactions must be interpreted as an analog input to the Tiva from the user. The analog input must be used to produce some behavior by the POTATO that makes use of the analog nature of the input. No simple thresholds.
- ☐ In addition to the analog input, at least one of the user interactions must involve non-contact sensing.
- ☐ Each POTATO must provide the user with feedback about his/her actions. The feedback must include at least one of: haptic/audio/tactile feedback. Multiple modes of feedback, including modes not listed here, are encouraged.
- ☐ The complete POTATO must be a self contained entity, capable of meeting all specifications while connected only to the provided project power supply.
- ☐ In order to fit into a standard cubesat dispenser, all components of the POTATO **MUST** fit into a total volume no more than 50 cm wide by 50 cm deep by 100 cm high. During operation, the POTATO should not require user input from more than 75 cm away from any part of the POTATO. Two teams' POTATOs must both be usable while sitting together on one of the 1.5 m wide tables in our classroom. The entire POTATO must be easily and safely moved from the construction site to the grading session and then shipped to SpaceX headquarters (i.e., to the Atrium) for evaluation. Make sure that you plan for this.
- ☐ The emphasis in the project is on robust electronics, software and mechanical systems built with real craftsmanship. Paint alone does not add to either functionality or craftsmanship. This is not to say that you may not decorate the machine, simply that it should not become a focus. Any painting that is done near the SPDL must be done using appropriate masking so that no paint residue is left on the building, furniture, sidewalk, driveways, grass, or trees. No painting in the SPDL! And no glitter!

[2] Intragalactic Knowledge Enforcement Agency

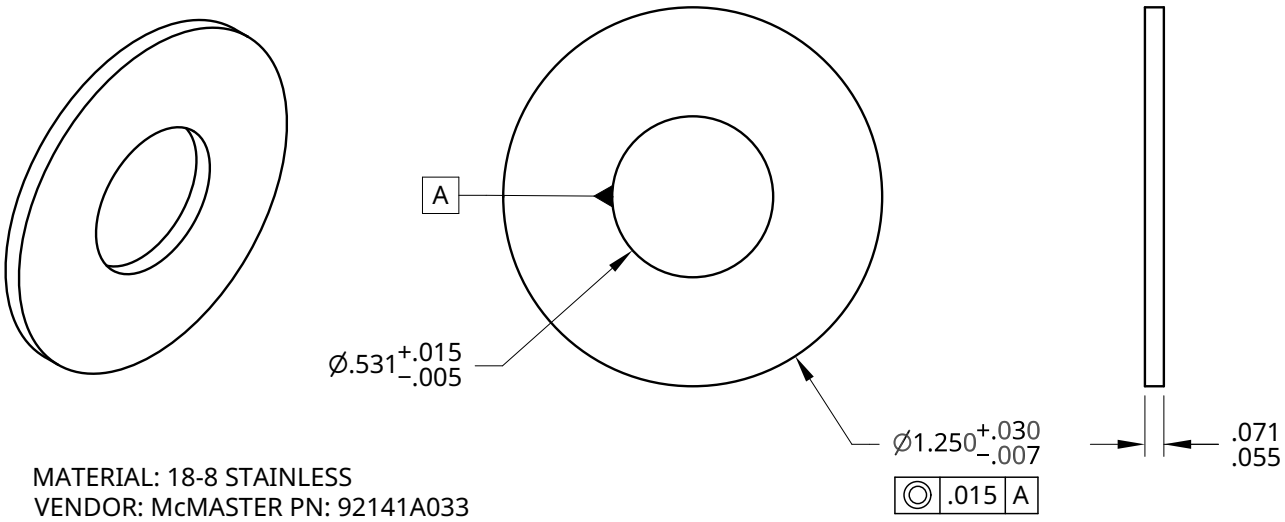

Figure 1: Schematic of the TOT. The TOT is a stainless steel washer, and will be provided by SPDL to all teams for testing, as well as for the public presentations. All dimensions in inches.

- ☐ While it is normally not a good practice, the finished circuitry may be constructed on your solderless bread-boards. This has been done to allow you the maximum time to spend on your project, without having to learn electronic prototyping techniques as well. Be sure to secure the bread-board and connections so that they will not be disturbed by the moving process.
- ☐ Accurate schematics and state diagrams are such a useful aid in debugging that you should be prepared to show your up-to-date schematic or state diagram to any coach or TA whenever you ask them for help on your project.

The TOT:

- ☐ To authenticate TATERs as Genuine Martian Inhabitants, each TATER will be provided with a standard Tactical Operation Token (TOT) by SPDL, as shown in Figure 1.
- ☐ The POTATO should only operate when a TATER correctly inserts a TOT, and should return the TOT to the TATER upon completion of the training or entertainment session.
- ☐ The POTATO should return the TOT to the TATER on any reset of the POTATO.
- ☐ Sensing and interaction elements required to interface with the TOT do not count towards project requirements defined in the previous section.
- ☐ All POTATOs should have clear markings indicating the location into which the TATER should insert the TOT.
- ☐ The POTATO should permit easy manual removal of the TOT in case of a mechanism fault.

Safety & Hygiene:

- ☐ The POTATOs must be safe for both users and spectators.
- ☐ No glitter!
- ☐ Be considerate of your neighbors in the lab when debugging any audio output; use headphones.
- ☐ There is a strict ban on toxic materials. This prohibition includes Volatile Organic Compounds (VOCs) (i.e. hydrocarbon based spray paints or other noxious fumes). This prohibition also includes while you are working on the POTATO in the SPDL.
- ☐ No painting in the SPDL (or anything attached to the SPDL).

- ☐ No part of the POTATOs may become ballistic unless completely constrained within the POTATO.
- ☐ No pyrotechnics or fire of any kind! Fire in a closed habitat is **EXTREMELY HAZARDOUS**, so do not test the fire suppression system. Be advised that smoke contains chemicals known to the State of California to cause cancer, birth defects, or other reproductive harm[3].
- ☐ If the POTATOs contain any liquids, they may not be conductive (with the exception of water) or corrosive, and **MUST** be packaged in a fail-safe manner.
- ☐ Uncooked potatoes are slightly poisonous, so exercise caution.

Checkpoints

Design Review:

During the day on **November 6** in room 162 & the Grove of the Peterson building (our classroom building) we will conduct design reviews. Signups for the hour-long slots for 4 teams will happen via a Google Sheet. Each group should prepare a few **simple** PowerPoint slides (scans of sketches are OK). **No code, no state diagrams, no circuits.** The slides should show your concepts, a preliminary event list with responses, and a list of how you are going to meet the user interface requirements. One member of the team must bring a laptop and any necessary adapters to produce a VGA or HDMI video signal to connect to the screen for your presentation. You will present these to other members of the class, members of the teaching staff and coaches so that all may hear about your ideas and provide feedback and advice. At this time you will be required to identify the core functionality of your proposed design and how it meets the interaction requirements.

If the schedule is long, it's wrong; if it's tight, it's right.

Elon Musk

First Checkpoint:

On or before **11/8/19**, you must submit a schematic of at least the core functionality initially identified on 11/6/19 and a refined set of events with details on the responses. Modifications to the core functionality may take place up to this point. An Altium schematic in a word document describing your core functionality should be uploaded to Gradescope. Only one team member needs to submit your checkpoint documentation.

It is a mistake to think you can solve any major problems just with POTATOs.

Douglas Adams

Second Checkpoint:

On or before **11/14/19** you will be required to demonstrate a minimal level of function:

- The hardware & software necessary to do each of the following:
  - sense inputs (at least 3 user inputs)
  - detect the correct insertion of a TOT
  - make decisions (state machine with at least 3 states driven by keyboard input)
  - implement electromechanical actuation and user feedback
- Submission of an Altium schematic of your circuit will also be required.

It has been seven days since I ran out of ketchup.

Mark Watney

Third Checkpoint:

On **11/18/19** you will be required to demonstrate integrated functionality of all sensing inputs, plus software and timing, plus activating all actuators that will be required. In other words, everything should be complete with the exception of improvements in user experience and fit, finish, and appearance.

If [the fire] starts pointing toward space you are having a bad problem and you will not go to space today.

Randall Munroe, Up-Goer Five

[3] Proposition 65, California Health and Safety Code §25249.6 et seq.

Grading Session:

On **11/20/19** from **1:00 pm to 5:00 pm** you will be required to demonstrate your fully integrated and finished machine.

As I hurtled through space one thought kept crossing my mind: every part of this rocket was supplied by the lowest bidder.
John Glenn

Public Presentation:

This will take place on **11/20/19** at **7:00 pm** in the Atrium of Building 550. At this event, members of the public will be encouraged to act as TATERs, and will interact with your POTATOs.

I would like to die on Mars. Just not on impact.
Elon Musk

Report:

Draft due on **12/2/19** by 4:00 pm. The final version (with revisions incorporated) is due by 5:00 pm on **12/6/19**.

We can lick gravity, but sometimes the paperwork is overwhelming.
Wernher von Braun

Evaluation

Performance Testing Procedures:

All POTATOs will be tested by a demonstration, performed by a team member, that should show all of the possible user interactions.

Grading Session Presentation:

Each team should prepare a 30 second (no more) presentation to introduce their POTATO. This presentation should highlight the unique features of the design, **not the circuit or software details.** As an example, think back to the xylophone descriptions that were played on the first day of class. You will be setting up your POTATO, one at a time, and delivering your presentation in room 202 Thornton between 1:00 pm & 5:00 pm on the day of the presentations. During this time each team and their POTATO will be photographed. Starting at 5:00 pm you will move your POTATO into the Atrium for the public presentation, which will begin at 7:00 pm.

Grading Criteria:

- ☐ **Concept (20 %)** This will be based on the technical merit of the design and coding for the POTATO. 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 (20 %)** 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 concentrate heavily on craftsmanship and finished appearance.
- ☐ **Performance (40 %)** Half of this (20 %) will be based on the results of the checkpoints, the other half will be based on the results of the performance testing during the evaluation session. Full performance credit will be given only if the machine works on the first attempt during the grading session. Performance will be judged first on the ability to demonstrate the core functionality and second on any embellishments to the core functionality. **To earn the performance points, you must demonstrate at least the core functionality.**
- ☐ **Report (10 %)** Preliminary project reports are due **December 2, 2019** at 4:00 pm. The report should be in the form of a stand-alone web site and must include schematics, pseudo-code, header & code listings, dimensioned sketches/drawings showing relative scale, a complete Bill-of-Materials (BOM) for the project as well as a 1 page description of function and a "Gems of Wisdom for future generations of 218ers" page. The actual website must be submitted as **a single Zip file** (7-zip is installed on all the workstations in the lab). In addition, if your website is hosted, you must **include a text file with the URL to your site**. It is critical that your report be in the Reports folder on time so that the peer reviewing team will have an adequate opportunity to review it before class the following day. Final versions of the reports, incorporating

the review comments are due (also in the form of a single zip file plus URL) by 5:00 pm on 12/6/19. The front page of your project description must be in a file called `index.html` at the root folder of the web site. Test your zip-file by unzipping it into an empty folder. Once un-zipped, you should be able to view the entire site starting from the `index.html` file. **Do not embed video files directly into your site.** If you want to include video, link to YouTube or another video sharing site.

- ☐ **Report Review (10 %)** 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? Could this POTATO realistically be built for $175? If, during grading, we find things that don't make sense or circuits that won't work we will consult your review. If the review caught them, then the team will lose points on their report. If the reviewers missed it, then they will lose points for their review. The report review should submitted be in the form of a Word document that you place into one of your team members folders by 4:00 pm on 12/3/19.

Suggestions

We understand that the project definition is probably a bit more open than you might be used to. To help you get your creative juices flowing we offer some reflections that you might want to consider.

- ☐ Don't just think buttons. Think about novel ways to sense an action and give feedback. Remember, you have more than just fingers available to actuate and you are mechanical engineers (at least most of you). Think fun linkages!
- ☐ **The Tao of 218:** Simplicity Leads to Reliability. Remember, you only have 18.49 sol available to complete the project (and tend to the other things in your life) before it is due.

Exercise your creativity:

We encourage, and hope to foster, a wide range of solutions to the problem. This will make for the most enjoyable presentation for your audience. There is no "best" way to solve this problem (or best problem to solve), so don't spend time looking for it. While brainstorming, consult your favorite science and science fiction media for inspiration.

Remember that we interact with electronic devices every day. People tend to have more fun with projects that don't try to emulate the look and feel of actual products. ME218 is an opportunity to design things that are **fun** and **whimsical**. Take advantage of that.

Make your project robust:

Your machine must be rugged enough to survive your testing as well as "testing" by the audience. Don't be timid about playing with your project before the presentation. Play with it as if you didn't know its weaknesses. Let your friends play with it. Find out if it can survive people playing with it before the presentation.

While the emphasis in the lecture has concentrated on the electronics and software, don't forget the mechanical aspect. Historically, project failures are often due to poor mechanical design or implementation. Pay attention to craftsmanship. It will pay dividends in many ways.

Resources

Websites:

SparkFun (www.sparkfun.com)
Mouser (www.mouser.com)
Adafruit (www.adafruit.com)
McMaster-Carr (www.mcmaster.com)
Seeed Studio (www.seeedstudio.com)
ServoCity (www.servocity.com)
Hackaday (www.hackaday.com)
HobbyKing (www.hobbyking.com)
Jameco (www.jameco.com)
Ponoko (www.ponoko.com)
DigiKey (www.digikey.com)
Newark (www.newark.com)

Local Stores:

Anchor Electronics in Santa Clara
Jameco in Belmont
J&M Hobby House in San Carlos
TAP Plastics in San Mateo

Gems of Wisdom:

Be sure to check out The ME218 Archive (me218archive.stanford.edu) for guidance from past generations.