V. Hunter Adams Dossier

Last updated January 4, 2025

The conclusion that I hope you draw from this dossier:

Hunter has a low threshold for wonder and deep love for computers, space, and everything else.

He builds things constantly, both by himself and alongside his students. He builds things because he believes that doing so is the best way to learn engineering, the best way to become a better engineering teacher, the best way to learn about topics outside of engineering, and because it makes him happy.

Hunter also has some far-out ideas about the relationship between computing and the natural world. He hopes that his projects demonstrate that he enjoys a comfortable relationship with reality, which (hopefully) increases the likelihood that folks take his crazier ideas seriously.

Hunter wants for Cornell to be known across the world as the best source of new talent in embedded systems, and he wants to remove barriers between fields of study. Through his courses, his student projects, his personal projects, his contributions to the open source community, and his student advising, he has made significant progress toward both of these goals.

Please see Hunter's website, vanhunteradams.com, for an organized description of everything he's done and built for the past 11 years.

Click any image/plot in this dossier to download in high resolution.

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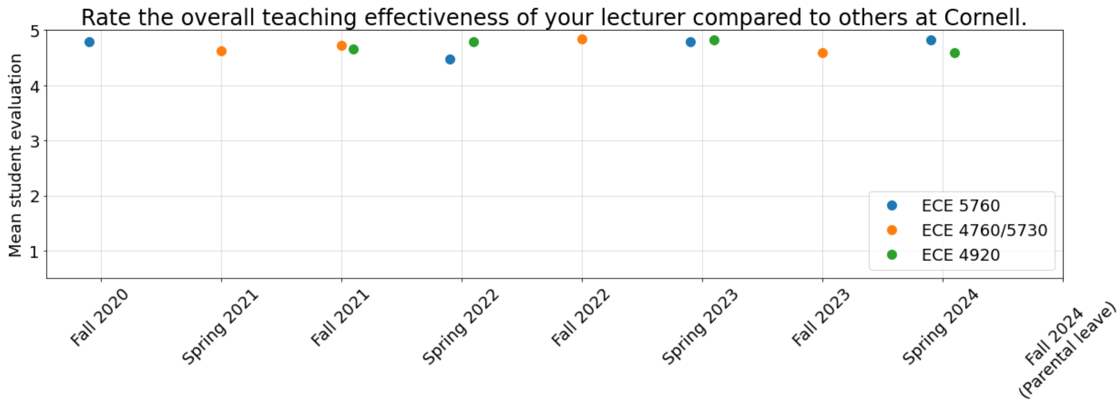
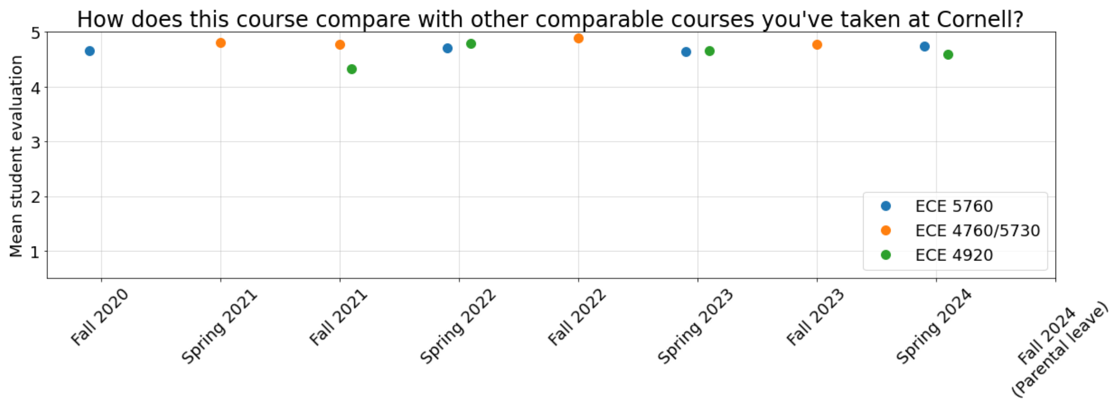
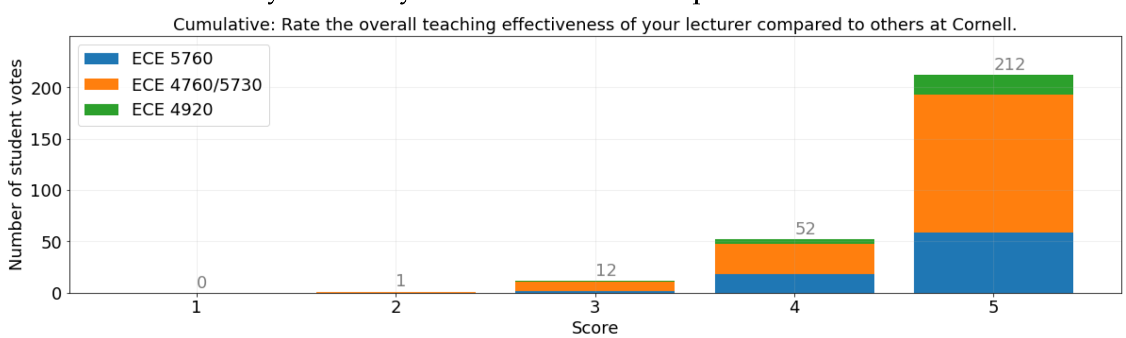
Some summarizing statistics

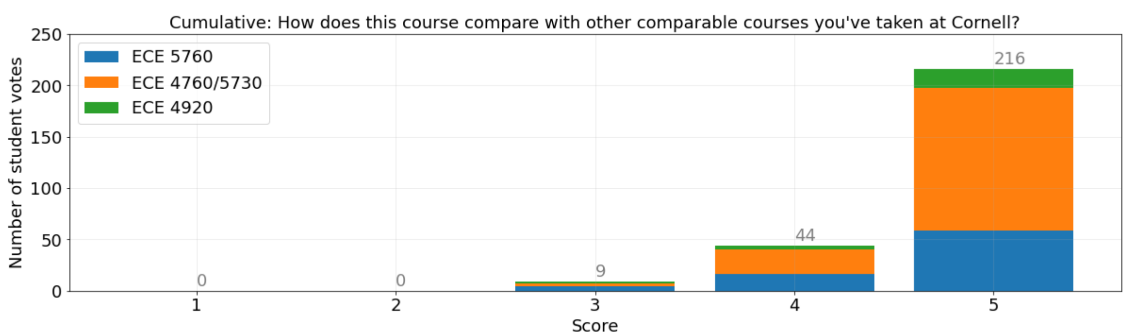
Semester-by-semester course evaluations: In all his courses, Hunter consistently receives mean evaluations that exceed 4.5 on both questions 91 and 92 of student course evaluations.



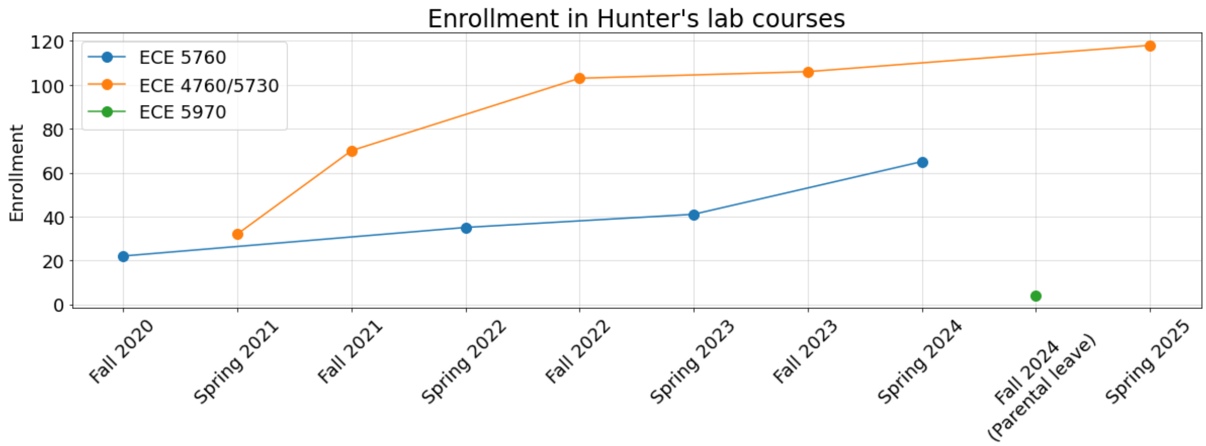


Cumulative course evaluations: Since he started teaching in ECE in 2020, Hunter has received more than 3x as many 5's as any other evaluation for question 91 on student course evaluations, and more than 4x as many 5's as any other evaluation on question 92.





Enrollment by semester: Hunter's lab courses have seen increased enrollment every academic year.



Some additional metrics and notes:

1. Through 4760/5730, Hunter has advised **119** student projects
   - **Student projects from 2022-present**
   - **Student projects from 2021**
   - These articles have been featured repeatedly in places including the **Chronicle, Raspberry Pi's website, and Hackaday**
2. Through ECE 4920, Hunter has helped **66 students** publish **27** of these projects in trade magazines. **Two** of these were cover articles.
   - **All published student articles**
3. Through ECE 5760, Hunter has advised **58** student projects
   - **Student projects from ECE 5760**
4. Hunter has graduated **45 MEng students** across **33 projects.**
   - **All of Hunter's graduated MEng projects**
5. Hunter has **15 active MEng students** across an additional **10 projects**.
6. Hunter completely re-designed ECE 4760 two times: once for remote instruction, and a second time to update to the RP2040 microcontroller.
   - His lecture videos and student demos have received **>500,000 views on YouTube**
   - His demo code has **212 stars on GitHub, and 59 forks**
   - He **re-wrote all course documentation and laboratory assignments for the RP2040**
   - This made Cornell the first university course based on this (now ubiquitous) microcontroller.
7. Hunter has received **two Cornell teaching/advising awards**.
8. Hunter's engineering work has been featured in the **Chronicle**, and in an **IMAX movie** now playing at the Syracuse Museum of Science and Technology.
9. Through his projects, Hunter has collaborated with **7 departments at Cornell and 4 outside companies**

Course instruction, enrollment, and evaluation history

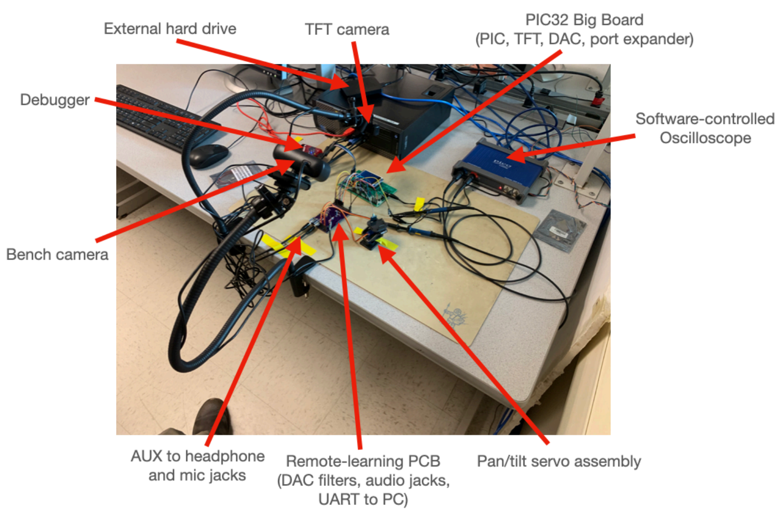
Fall 2020

	Enrollment	Evaluation responses	Average (question 91)	Average (question 92)	Commentary
5760	22	16	4.8	4.67	Built all infrastructure for remote instruction. Each student remotely accessed FPGA's, observed them via webcams, and listened to generated audio via Zoom. See Fig. 1.

Fig. 1: Collection of remotely-accessible workstations for ECE 5760, Fall 2020. Each VGA screen shows a student in progress on the Mandelbrot lab assignment. Each workbench includes an FPGA and VGA, each observable via webcam, and an AUX cable from line out of the FPGA audio codec to the PC.

Spring 2021

	Enrollment	Evaluation responses	Average (question 91)	Average (question 92)	Commentary
4760	32	21	4.62	4.81	Completely re-designed the course and course infrastructure for remote instruction. See Fig. 2 below. All new labs (1, 2, 3, and 4), workflow, and debugging methodology.



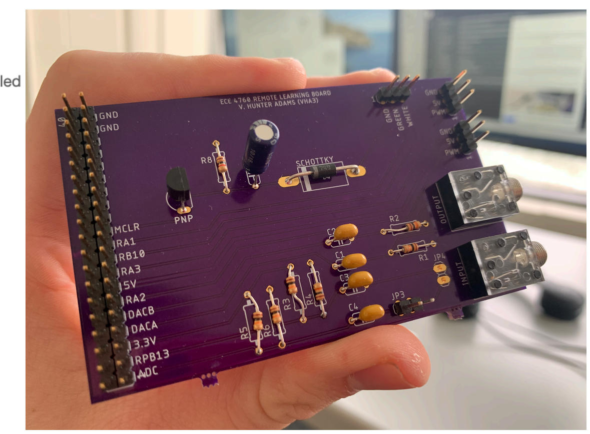


Fig. 2: Built and maintained 22 of the remotely-accessible workbenches shown above for the Spring 2021 version of ECE 4760. Each workbench included a custom PCB, target MCU, webcams, TFT display, audio input/output via Zoom, servo assembly for lab 3, software-controlled oscilloscope, and external hard drive.

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Fall 2021

	Enrollment	Evaluation responses	Average (question 91)	Average (question 92)	Commentary
4760/5730	70	32	4.72	4.78	Reverted the course to in-person instruction, changed one lab.
4920	6	4	4.67	4.33	3 of 4 student articles published in Circuit Cellar magazine.

Spring 2022

	Enrollment	Evaluation responses	Average (question 91)	Average (question 92)	Commentary
5760	35	21	4.48	4.71	Reverted the course to in-person instruction. Minor update to Lab 1.
4920	26	10	4.8	4.8	12 of 15 student articles published in Circuit Cellar and Servo magazines, including one cover article, shown in Fig. 3 below.

Fig. 3: Martinez/Hales cover article from ECE 4920

Fall 2022

	Enrollment	Evaluation responses	Average (question 91)	Average (question 92)	Commentary
4760/5730	103	62	4.84	4.89	**Total** re-design of ECE 4760 for RP2040 microcontroller (**all new labs, infrastructure, and documentation**). First university class to use this device. News about the class: • **Hackaday** • **Raspberry Pi**

Spring 2023

	Enrollment	Evaluation responses	Average (question 91)	Average (question 92)	Commentary
5760	41	20	4.80	4.65	
4920	31	8	4.83	4.67	Published 9 of 12 student articles in Circuit Cellar and Servo magazines, including one cover article shown in Fig. 4.

Fig. 4: Guo/Fernandes cover article from ECE 4920.

Fall 2023

	Enrollment	Evaluation responses	Average (question 91)	Average (question 92)	Commentary
4760/5730	106	54	4.83	4.77	Created new audio synthesis lab (old, new), updated animation lab (old, new), and created new motor control lab (old, new) News articles • **Cornell** • **Raspberry Pi** • **Chronicle** • **And *dozens* of articles on Hackaday**

Spring 2024

	Enrollment	Evaluation responses	Average (question 91)	Average (question 92)	Commentary
5760	65	23	4.83	4.74	Swapped order of labs 2 and 3
4920	25	6	4.6	4.6	Published two student articles in Circuit Cellar. (They got a new editor that is de-prioritizing project articles, time to pivot publications!)

Fall 2024 - HALF-TIME FOR PARENTAL LEAVE

	Enrollment	Evaluation responses	Average (question 91)	Average (question 92)	Commentary
5970	4	0	N/A	N/A	Offered a modified version of 5760 that I could teach on my half-time parental leave. Students watched lecture recordings asynchronously, and I attended all lab section in-person to help them.
4920	2	0	N/A	N/A	Submitted one student-written article to Circuit Cellar, currently under evaluation.

Teaching philosophy statement

Curiosity and engineering

The path to the frontier of every field, but particularly to the frontier of engineering, is longer than it has ever been. That path used to be shorter, and the walls that separate it from the paths associated with other fields used to be lower. You could peek over the walls and see the nearby paths associated neurobiology, ecology, oceanography, and all the other sciences. That view is not so clear anymore. A side-effect of advancement seems to by hyper-specialization and wall-building between fields.

One of my great joys, first as a graduate student and then as a lecturer, has been to bushwhack my own trails from engineering to some of these other fields. At various times, I've collaborated with researchers in plant sciences (Justine Vanden Heuvel and Tim Martinson), veterinary science (Francisco Yeal- Lepes), ornithology (Julian Kapoor), electrical engineering (Kirstin Petersen and Amit Lal), animal science (Mario Herrero Acosta), archeology (Frederick Gleach), and the Johnson Museum of Art (Andrew Weislogel). I started doing this simply out of curiosity, but I soon discovered that it was making me a better engineer. I started having ideas that would have never come to me otherwise. The ways in which learning about dairy cattle will help with spacecraft engineering are not always obvious, but I have never found it unproductive to indulge a curiosity.

This has had a profound effect on my teaching. I cannot make the path to the frontier any shorter, but maybe I can lower the walls between paths. In my microcontrollers course, we build devices that allow for exploration of topics from ornithology (a birdsong synthesizer), neurobiology and behavior (a bee swarm animator, which demonstrates swarm consensus), aerospace engineering (a reaction-wheel-based inverted pendulum), and applied mathematics (a cricket chirp synthesizer and synchronizer). In my FPGA's course, the students explore topics from computational physics (a 2D wave equation accelerator) and pure mathematics (an accelerated Mandelbrot Set renderer). The students are encouraged, in each of these courses, to use engineering as the *mechanism* by which they explore other fields and topics. Many of their final projects end up being devices of this exploratory variety.

And I'll often say it explicitly. When I'm addressing a class that I haven't met, I will start the talk by saying the thing that I wish my instructors had said to me: *Be curious*. There is a growing sentiment that a diversity of interests indicates a lack of commitment to one's particular field of study. It doesn't. It makes for better engineers.

Teaching to all levels of abstraction in engineering

My favorite part of teaching project-based lab courses like 4760/5760, or about supervising undergraduate and masters-level hardware projects, is the moment when a student discovers one of the deepest truths of engineering: **nothing ever just works**. Many of the students at this university have grown very accustomed to success, and it can be jarring to discover that building things is fraught with so much failure. Coaching students through this is a delicate process that must be done thoughtfully.

At this first moment of frustration, I like to tell the students that they've discovered something very deep. There are levels of abstraction to engineering. There is theory, which they have learned in the classroom, and there is the building of things, which they are learning now. Each informs the other. Being good at theory helps you build things, but it does not get you all the way there. Problem solving in the lab is different from problem solving in the classroom.

I attempt to get them into the appropriate psychology for debugging hardware. Many will begin with the same mindset that they use to approach a problem set, which is generally one of frenetic stress. The goal is to get them into the mindset of *play*. Rather than being entirely goal-focused, I help them get into the mindset where debugging is an enjoyable process on its own. This is critical when working with hardware, where almost all of one's time is spent fixing things that don't work. Debugging must be a joy, or the student will not be happy in the class or in her career.

There are circumstances which can prevent this mindset, the most significant of which is stress. Removing as much stress as possible is one of my principle responsibilities as an instructor or project advisor.

Making learning and creativity possible

Engineering students lead incredibly stressful lives, which is not conducive to learning or to creative thought. Many of these sources of stress are outside the control of an instructor, but there are some things that they can (and must) do to help.

Perhaps most significant is making certain that the student has the resources that they require in order to be productive when they sit down to work. This means the obvious things, like having impeccably organized notes and figures, but what it really means is *access to the instructor*. It is absolutely imperative that the instructor for a project-based course, or the advisor to a hardware- based project, spend a significant amount of time *each day* in the laboratory with the students. This is true for any sort of class, but it is particularly true for hardware.

There are some bugs that are instructive for students to work through on their own. Getting a microcontroller to communicate with a sensor, for example, is an incredibly instructive problem to tackle. Hardware debugging is also filled with the sorts of bugs that add no value to the learning experience, but which can hold up a project for hours or days. For all of the student projects I've advised and hardware courses that I've instructed, I've been certain to be in the lab with the students for at least an hour each day to move them past these sorts of errors. Being in the lab also helps me celebrate each of their small victories with them. That's an important part of developing the play-mindset toward hardware work.

Absolute respect for the student

I treat students identically to the way that I treat colleagues in another field. The operating assumption is that they are of equivalent intelligence to me, but that they lack information in the particular topics covered in the class. That respect has, in my experience, made students feel much more comfortable contributing their ideas to a discussion, or proposing a new project.

Above all, I care. I care about the topics that I'm teaching and how well I am teaching them. I care how well the students are learning and about their mental health. Teaching, indulging curiosities, and building projects are the things that make me happiest.

What makes a good laboratory exercise?

(Content copied from a 4760 webpage presented to the students on the first day of class)

Creating a laboratory assignment for a microcontrollers design course is harder than you might think! Designing these labs is a multi-objective optimization problem. No lab is perfect, but this webpage describes the properties that the perfect laboratory assignment would have.

The intended audience for this webpage is 4760 students.

The perfect laboratory assignment

1. is self-motivating

Students often begin a laboratory assignment in a mindset of ***work***. The goal is to get them quickly into the mindset of ***play***. We learn much better when we're playing rather than working!

A laboratory assignment should never ask the student to do anything that's contrived. Instead, it should ask them to build tools, toys, and devices that are interesting in their own right, *completely* separate from the techniques and algorithms that are required to create them. These tools, toys, and devices should use the techniques and algorithms of interest in some critical and unavoidable way, so that the student must understand them to actualize the device.

For example, one of the topics that we introduce in ECE 4760 is Direct Digital Synthesis, an algorithm that produces sine waves of a specified frequency. We could introduce this topic via a lab that asks the students to generate a frequency sweep through a speaker, ***but that's boring and unmotivating***. Instead, we can ask the students to use this algorithm to generate birdsongs and cricket chirps.

The students are then motivated to finish not because they want to learn a particular algorithm, but instead because they want to build a birdsong synthesizer! Both a frequency-sweep lab and a birdsong synthesizer lab teach the same topics, but the former is ***work*** and the latter is ***play*** (for many students).

2. is extensible

At Max Planck's 60th birthday party, Albert Einstein gave a speech. In it, he describes the three personality types that he observes among scientists. I think those personality types also apply to engineers. I'm paraphrasing, but they include include:

- The competitors: These folks derive great pleasure from setting and achieving goals. Science [engineering] is the domain in which engage in this activity.

- The artisans: These folks get pleasure from the act of doing science [engineering]. The objective is incidental, it's the process that's enjoyable to them.
- The searchers: These folks do science [engineering] because the can't not do it. Whether or not they actually enjoy it doesn't particularly matter.

For what it's worth, I think we all have some competitor, artisan, and searcher in us. The relative weights change with age, experience, and circumstance.

A laboratory exercise must have clear enough objectives to satisfy the competitors in the class, but must also be extensible for the artisans in the class. For students that develop deep interests in a particular lab, there must be interesting directions that they can take it that are beyond or adjacent to the written specifications. If any student wants to take an idea from a lab and run with it, there should be interesting places to run to.

(And I have no idea how to appeal to the searchers.)

3. adds new tools to the students' tool-belts

This one is obvious, but not always easy to implement! A new lab should introduce new hardware peripherals, new algorithms, new techniques, etc. But, as explained in the first criterion, it cannot do so in a contrived way. If a lab introduces Direct Memory Access (DMA) to interact with some peripheral, there must be a good reason that DMA is the best idea for interacting with that peripheral. Perhaps, as in the animal flocking lab, DMA frees up CPU time to animate a larger swarm of animals, which looks cooler! Or maybe DMA is the only way to sample the ADC fast enough to see some high-frequency signal in an audio spectrogram.

4. appeals to students with a variety of interests

Electrical and computer engineering is a broad department which includes students that are interested in topics as varied as MEMS design, computer architecture, robotics, digital signals processing, computer graphics, analog circuits, control theory, and more. A particular lab (and, more importantly, the sequence of labs which compose a course) should aim to appeal to students with a variety of interests. The big ones that I aim to hit include audio synthesis and digital signal processing, computer graphics, algorithms, control theory, robotics, and sensor integration/fusion.

5. makes the students notice new things about the world.

This one can be the hardest to achieve, but the most important for long-term information retention. A well designed lab can sometimes fundamentally change the way that a student sees some aspect of the world, or make them notice and appreciate things that they never have before. After the birdsong lab, for instance, students report that they notice birds singing. Previously, birdsong was background noise. After the lab, it's something that they notice and appreciate. The same is true of the the animal flocking lab (students report noticing flocking behavior in nature and movies after this lab).

This criterion is hard to achieve, and seems to never be universal, but when it works it's really valuable.

6. is interesting to the instructor!

This is extremely important!. It makes my job infinitely easier if we're doing projects that I find fascinating, and I find every one of our lab assignments absolutely fascinating. So much so, in fact, that for each I'll ask you to indulge me a lecture or a half-lecture just going over what makes these projects cool, and how they connect with the real world (nature, industry, etc.). Being interested in these projects makes them a pleasure to teach, and (hopefully) a pleasure to be taught. Last semester I jokingly described myself as "a guy with a crazy low threshold for wonder." I think you'll quickly discover that's a pretty accurate description of me.

7. is at the correct level of abstraction

Every laboratory exposes some concepts and hides others. The perfect laboratory assignment exposes the "right" concepts, and clearly communicates the concepts that are being hidden. For instance, all of the laboratory assignments use the C SDK for the RP2040. This SDK abstracts away low-level register manipulations to function calls. The lab should ask for the student to use the SDK (otherwise we'd spend weeks getting all the register manipulations right for even the simplest applications), but it should be obvious that, under the hood, these SDK functions are touching registers.

8. is teachable in 2-3 weeks

The definition of "teachable" changes throughout the semester. In the beginning of the semester, it means covering the vast majority of the topics (SDK functions, hardware peripherals, etc.) relevant to the lab in lecture, and discussing how to use datasheets and technical documentation to find information about those topics. As students become more competent with using technical documentation, "teaching" a lab becomes signicantly more high-level.

9. is scalable and maintainable

It must be affordable to procure the materials for 30-50 copies of the lab, and it must be possible to build and store 30-50 copies of the lab in the teaching laboratory. A fully assembled lab musn't take up more than a tabletop, and should be able to be stored compactly. Furthermore, it must be relatively simple to fix the system when it breaks. Modular designs and mechanical connections are good! Avoid glue whenever possible, and utilize off-the-shelf solutions like Legos!

Teaching accolades and successes

Cornell teaching awards

- Canaan Family Award for Excellence in Academic Advising, 2022
- Robert '55 and Vanne '57 Cowie Teaching Award, 2023

Articles about my classes

- 44 student teams were given RP2040s to create anything. Here's what they made [Cornell]
- What did computer engineers students at Cornell make with RP2040 last term? [Raspberry Pi]
- Cornell updates their MCU course for the RP2040 [Hackaday]
- Cornell University's Digital Systems Design course is taught on RP2040 [Raspberry Pi]

Contributions to broader community

- Lecture videos and student project videos have received 494,000 views on YouTube
- Tog Hackerspace (Dublin, Ireland) collectively took ECE 4760 by watching lecture recordings and using my posted course materials. Blog post about it from them linked here.
- My demo code for the RP2040 has 212 stars on Github, and my course documentation has become some of the most trafficked resources on the Internet related to the RP2040 microcontroller (as determined by Google Search analytics).

Teaching goals

Goal 1: I want for Cornell to be known across the world as the best source of new talent in embedded systems.

Goal 2: I want to remove the barriers that have been erected between fields of study.

I've made progress toward each of the above goals, and I've more progress to make. For each of my classes, I've enumerated the actions that I've taken toward achieving these goals, and I've enumerated my plans for the coming years. **Please note that I also aim to achieve these goals through my MEng and student project advising, described at length in a later section.**

ECE 4760/5730

Actions taken in the direction of Goal 1:

- In keeping with the precedent set by Bruce, I'm continuing to generate and publish **course materials**, **code**, and **lectures**. For many aspects of the microcontroller that I use in 4760, these course materials have become the most-trafficked resource on the Internet (as measured by Google Search analytics). Some international groups are even **taking the class together**.
- **Published all student projects**
- I updated the course to a new microcontroller last year (this was a ~1 year project), ours is the first university course which uses the RP2040 microcontroller.
- I'm reaching out to relevant news sites in embedded systems about the course, some of whom have written really nice articles that have driven more traffic to the course (e.g. Raspberry Pi and Hackaday, see articles linked **above**)

Actions taken in the direction of Goal 2:

- Each of our laboratory exercises in ECE 4760 draws inspiration from *other fields of study*. In 4760, we use engineering as the mechanism by which we learn about these other interesting fields. I've enumerated some examples below. I often invite guests from these fields of study to lecture, including Steve Strogatz and Mason Peck.
  1. **Birdsong**
  2. **Cricket chirps and synchronization in nature**
  3. **Animal flocking**
  4. **Spacecraft attitude control**
  5. **High-speed robotic controllers**
  6. **The Central Limit Theorem, collision physics, and topics from statistics**
  7. **Distributed consensus in animal groups**

- ECE 4760 now counts toward the robotics minor for MAE students, and is cross-listed with MAE. With my approval of their prerequisite preparation, MAE students can now take 4760 and have it count toward their degree. I hope to increase the cross-pollination between MAE and ECE, this is a step in that direction.

Planned future actions in the direction of Goal 1:

- I hope to offer seminar classes (no credit hours, fully voluntary) that are associated with ECE 4760. These would be couple-day crash courses on skills of relevance for 4760 final projects (PCB layout/fabrication, 3D printing, laser cutting, basic mechanical engineering concepts, etc.). My goal is to have students design and fabricate the PCB's that they then use in 4760.
- The topics covered in 4760 continue to expand. I'm working on adding Bluetooth, WiFi, low power engineering, radio, linker scripts/compilers, etc. Very soon, it will make sense to create a "Microcontroller II" course that covers these more advance topics. More information on the materials that I've generated for this class later.

Planned future actions in the direction of Goal 2:

- A huge component of ECE 4760 is the **final project.** These projects feel like an opportunity for interdisciplinary collaboration. For my MEng projects, I am in the habit of reaching out to colleagues in other fields for project proposals and problems of value to their work (much more on that later). I'd like to start doing this too with our final projects, and allow for students to *either* come up with their own, or develop a device of utility to a colleague in another department. I've started this with MAE. In the Spring 2025 semester, students will have the opportunity to develop an RP2040-based drone for the MAE motion learning studio for their final project in ECE 4760, if they would like to.

ECE 5760

Actions taken in the direction of Goal 1:

- As with 4760, all of my **course materials** and **lectures** are posted publicly.

Actions taken in the direction of Goal 2:

- As with 4760, our laboratory exercises in 5760 draw upon other fields of study. In particular, we draw upon chaotic dynamics, physics/music, and pure math. I've also developed a candidate new lab, not yet assigned to students (it might be too hard) that draws from fluid mechanics. All lab exercises enumerated below.
  1. **Lorenz system visualization and sonification**
  2. **Drum synthesis via the 2D wave equation**
  3. **The Mandelbrot Set**
  4. **Lattice-Boltzmann (candidate)**

Planned future actions in the direction of Goal 1:

- My next ~~big~~ huge undertaking will be to update the hardware for 5760. We currently use the DE1-SoC from Altera. I'd like to switch to a Xilinx system on a chip, in particular the

Zynq-7010. I expect that it will take me about a year to generate all the new documentation for the course. That's about how long it took to fully update 4760 in 2021.
- I do think the course might need a name change (perhaps synchronously with my planned hardware update?). "Advanced microcontrollers" is a bit of a misnomer, since the course is all about hardware acceleration via FPGA's.
- I'd love to eventually teach an *additional* hardware acceleration course similar to 5760 that utilizes GPU's rather than FPGA's. Out in the world, when folks want to perform hardware acceleration, they'll either go with a GPU or an FPGA. Each has its advantages, and I think it would be interesting to offer a class for each, and compare performance on similar labs across classes. Students that take both will be very adept at hardware acceleration.

Planned future actions in the direction of Goal 2:
- More labs! The heat equation? Molecular dynamics? Diffusion reaction systems? Particle systems? Possibilities abound.

ECE 4920

Actions taken in the direction of Goal 1:
- I have helped publish 27 student projects in trade magazines including Circuit Cellar, Servo, and AgriTech Tomorrow. These 27 student projects include 66 student authors.
- Two of these articles have been cover stories for Servo Magazine

Actions taken in the direction of Goal 2:
- Though we don't submit to them as frequently as engineering publications, students are encouraged to read and investigate potential publications in fields relevant to their project. Students that build instruments, for instance, are encouraged to investigate music magazines. Students that build aesthetically interesting objects are encouraged to investigate art magazines. Etc. You can read about these policies here.
- As of last year, ECE 4920 is now cross listed with CS. CS students that take 4760 can now take 4920 and have it count toward their graduation requirement. I expect for this to expand enrollment even further.

Planned action in the direction of Goal 1:
- I would like for a student from *any engineering department* that took 4760 to be able to take 4920 and have it count toward their technical writing requirement. This will be a project for the coming year.

Planned action in the direction of Goal 2:
- I think that part of the reason for our low success rate with non-engineering magazines is that the editors of these publications don't have any context for the student submissions. In the coming year, I intend to introduce myself and the class to the relevant folks at these publications, so that our student submissions aren't completely jarring to them.

Activities in support of ECE's educational mission and environment

My primary activities in support of ECE's educational mission and environment have been in the form of **interdisciplinary student projects**, **public outreach events**, **open-source contributions**, **participation in department and College committees, and student advising.**

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1. Interdisciplinary student projects

As mentioned previously, one of my two primary teaching goals is to remove barriers that have been erected between fields of study. ECE's interdisciplinary potential and its prioritization of collaboration were the primary reasons that I wanted to make a home in this department. I've done my best to realize that potential through interdisciplinary projects with colleagues and collaborators in other departments and from outside organizations.

The Johnson Museum of Art (Andrew Weislogel)
- Digitizing museum artifacts, for augmentation of museum displays
- Distributed Environmental Sensing System for the Johnson Museum

Cornell Department of Archaeology (Frederick Gleach)
- Digitization of an Egyptian ibis mummy —> **As featured on CNN, and in the Chronicle**

Cornell Neurobiology and Behavior (Bruce Johnson, Madineh Sedigh-Sarvestani)
- Low cost extracellular voltage amplifier
- Visual and auditory stimulus generation for a small fish —> ongoing MEng project
- Head-mounted sensory substitution device for tree shrews —> ongoing MEng project

Cornell Animal Science (Mario Acosta)
- Low-cost virtual fencing for livestock management —> part of Bezos Earth fund project, of which I am a part

Cornell Mechanical and Aerospace Engineering (Brian Kirby)
- Hacking a power wheelchair —> ongoing MEng project

Cornell School of Integrative Plant Sciences (Rebecca Nelson)
- RPee2040 plant care device —> **As featured in the Chronicle**

Cornell Department of Ecology and Evolutionary Biology (Meredith Holgerson)
- Methane flux chamber —> Hunter is a Co-PI on this project, funded by Atkinson Center

Woods Hole Oceanographic Institute (Jonathan Pfeifer)
- Open-source handheld pH sensor with mobile app
- Low-cost depth sensing module for deep-water instruments —> ongoing MEng project

Revimo (company at Rev startup accelerator) (Aleksandr Malaschenko)
- Robotic mobility assistive device

ASML (Olaf van Bruggen)
- FPGA-based real-time video 2D FFT accelerator

Spinlaunch (Eric Gustafson)
- Chipsat test on Flight Test 10 —> **As featured in the Chronicle, and Gizmodo**

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2. Public outreach events and interdepartmental talks

I take advantage of opportunities to represent ECE publicly, and to other departments.

- Public works talk, The Downstairs Bar April 5 2023, "Spacecraft Small and Mighty: Exploring Space and Studying Cows with Chip-Scale Spacecraft"
- Syracuse Museum of Science and Technology public talk, October 5 2024 "Exploring Space with Tiny Satellites"
- Annual guest lectures in MAE 5220
- Guest lecture in GOVT 2020, spring 2020,, "Chipsats and spacecraft politics"
- Guest lecture in MAE 6530, fall 2023, "R-selected spacecraft"
- Featured in Spinlaunch promotional video
- Talking head in an IMAX movie about space, currently playing in Syracuse (Fig. 5)

Fig 5: Clip from *Space: The New Frontier* IMAX movie

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3. Open-source contributions

ECE 4760 has become famous among the community of hobbyists and hackers that use the RP2040 microcontroller. I wrote all of our course demo code, linked below, which has become a starting point for projects around the world.

- RP2040 Demo Code, with over 200 stars and 59 forks on GitHub
- This Bluetooth Gatt Course is a Must Watch [Hackaday]
- RP2040 bootloader is a worm [Hackaday]

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4. Participation in department and college committees

- I have been a member of the ECE MEng Committee since December, 2023
- I was a member of the Project Team Taskforce, tasked with figuring out how project team grading and credits should work for the College of Engineering
- I am a member of the Commercialization Fellowship advisory committee

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5. Student advising and student ambassadorship for ECE

Because there is a whole section dedicated to student advising, I will just summarize here.

- I have advised 45 graduated MEng students since Spring, 2021
- I am currently advising 15 MEng students
- I am an advisor of 4 project teams
- I am the faculty advisor to the Maker Club (with Joe Skovira)
- Regular participation in Major Days, Diversity Programs in Engineering days, etc.
- Regular judge of the Makeathon
- Participate in scheduled ECE tours
- Guest presentation in ENGRG 1050 on Oct. 16 2023
- **I have helped 66 students publish their projects in trade magazines <— click to see them**

Course materials generated for courses within my teaching schedule

This section links to all of the materials that I've generated for ECE 4760, ECE 5760, and ECE 4920 that are (or were) **explicitly** part of the student experience. This includes lab assignments, required reading for those lab assignments, required reading with regard to course policy and infrastructure, etc.

ECE 4760/5730 - link to course homepage

Code
- RP2040 Demo Code: A GitHub repository that contains all the demo-code for the class, written by me.
- Custom 4760 VSCode Extension: A fork and hack of Raspberry Pi's VSCode Extension, which simplifies toolchain installation and compilation for the RP2040

Tutorials
- VGA driver for RP2040
- Audio FFT to VGA
- DDS via Timer interrupt on RP2040
- Dual-core DDS via timer interrupts on RP2040
- Chained-DMA signal generator thru SPI DAC on RP2040

Infrastructure
- What makes a good laboratory exercise?
- Understanding the RP2040 C SDK architecture
- Using the RP2040 C SDK (dissecting a simple example)
- Installing toolchain and building demo code
- Course bill of materials
- Policy
- Final projects policy
- Student final projects

Lab exercises
- Synthesizing and synchronizing snowy tree cricket chirps
- Animating leadership and decision making in animal groups on the move
- PID control of an inverted pendulum with a reaction wheel
- Animating murmurations of starlings
- Synthesizing birdsong
- Digital Galton Board
- PID control of a 1D helicopter
- Realtime audio spectrogram [for PIC32]
- Robot that gets bored in Zoom meetings [for PIC32]

Algorithms and techniques
- Fast Fourier Transforms
- Direct Digital Synthesis
- Fixed point arithmetic
- Interfacing with a keypad
- Synchronization of integrate-and-fire oscillators
- Synthesizing birdsong
- Boids, plus distributed consensus
- Boids, plus predator
- Synthesizing cricket chirps
- Complementary filters
- Digital lowpass filters
- PID control (phenomenological introduction)
- PID control (analytical introduction)
- Mechanical construction of inverted pendulum
- Tuning reaction wheel PID
- Electrically isolating DC motors
- The physics of colliding balls
- The statistics of a Galton Board

Communication protocols
- SPI
- I2C
- UART

ECE 5760 - link to course homepage

Code
- Verilog VGA driver for the DE1-SoC

Labs - relatively minor re-rewrites of existing labs
- Lorenz system solver/visualizer with sonification
- Multiprocessor drum synthesizer
- Mandelbrot visualizer

Laboratory supplements
- Getting the DE1-SoC up and running
- Verilog basics
- Discretizing the 2D wave equation
- Parallelizing the 2D wave equation
- Implementing the Mandelbrot Set

ECE 4920 - link to course homepage

Infrastructure

- Policy
- Published student articles

Extracurricular teaching materials

This section links to materials that will eventually become a critical part of a current class, will eventually become a critical part of a future class, which are presently optional additional reading for current classes, or were assembled for extracurricular purposes.

Materials for a future Microcontrollers II class
- GATT server on Pi Pico W
- GATT client on Pi Pico W
- Custom serial bootloader for the RP2040
- Worm-like serial bootloader for the RP2040
- CAN driver implemented with PIO on RP2040
- Non-blocking UDP transmitter using PIO on RP2040
- AM radio voice transmission with PWM on RP2040
- Resistive touchscreen to VGA display with RP2040
- Enigma machine emulated on a microcontroller
- The RP2040 boot sequence
- Introduction to estimation
- Wireless UART via infrared
- BTstack and RP2040: HCI layer
- Picasso, by way of Fourier

Materials for potential inclusion in ECE 5760
- Lattice-Boltzmann accelerator

Talks
- Power management in IoT devices
- Natural computing
- A love letter to embedded systems

Conferences or educational avenues pursued

At the invitation of Brett Wood, President & CEO of Toyota Materials Handling North America, I attended a meeting at the forklift manufacturing plant in Columbus, IN to discuss opportunities for collaboration between Cornell ECE and Toyota (April 9, 2024).

Student advising

I advise students in a variety of capacities. This section divides discussion of my student advising into **project teams**, **maker club**, **independent studies,** and **4760/5760 projects.** I also advise a large number of MEng projects, but those are treated in a subsequent section. Though the 4760/5760 projects take place in the context of my courses, each of these projects occur with tremendous input and oversight from me. For that reason, this seems like an appropriate section of the dossier in which to highlight a few exceptional examples.

As mentioned previously, student advising is one of the mechanisms by which I attempt to achieve both of my teaching goals: for Cornell to be known across the world as the best source of new talent in embedded systems, and to remove barriers that have been erected between fields of study. To the end of the former, I help my students' work get publicized in Cornell media, trade magazines, and news outlets. To the end of the latter, I offer them a strategy for choosing a project. The following is lifted from one of my 4760 webpages:

How do I come up with an idea??

In this class, we use engineering not only as a means of solving problems, but also as a way to explore curiosities that are totally separate from engineering. An "interesting" engineering project is, in the context of this class, just as valuable as a "useful" engineering project. As you begin to brainstorm project ideas, you might consider going through the following exercise:

1. Make a list of things you are curious about. This should be stuff that you may know little-to-nothing about, but that you find interesting. Astronomy? Birdsong? Art? Archeology? History? Make a long list, and then think about ways that you can build something to learn more about something on that list.

2. Make a separate list of activities, totally separate from engineering, that you enjoy. Do you like to ride bicycles? Play music? Play video games? Watch movies? List your hobbies, and then think about ways that you can engineer something to explore that hobby.

For students that are used to being told what to do, identifying a goal for a completely open-ended project can be surprisingly daunting. The strategy outlined above works fabulously.

Project Teams

- Co-founding faculty advisor of C2S2, a student project team dedicated to undergraduate semiconductor design. **To be clear, Chris Batten is the force of nature behind this project team**. That said, I have been able to contribute advice to the embedded software team, and to help facilitate a campus partnership with the Lab of Ornithology.
    - Chronicle article
    - Chronicle article II
- Faculty advisor to AutoBoat: I participate in 1-2 technical design reviews per year with the Autoboat team.

- Faculty advisor to CUAUV: I meet with team leadership and sub teams upon request, which is generally a few times per semester.
- Faculty advisor to Autobike: I meet with team leadership and sub teams upon request, which is generally a few times per semester.

Maker Club

- Co-advisor to the Maker Club with Joe Skovira. He and I approve purchase requests, and provide any administrative help that the club requires.
- Serve as judge in the Make-a-thon every year.
- Facilitated a Make-a-thon sponsorship from ASML

Independent studies

- Because my courses offer students the opportunity to do a project under my supervision, I have relatively few independent study students. One of particular note is Jack Defay. In 2022, Jack did an independent study with me to digitize a mummy from the Cornell archeological collections, and a collection of artifacts from the Johnson Museum.
    - **CNN article**
    - **Chronicle article**
    - **Smithsonian article**

4760/5760 student projects

- **Since Spring 2021, I have advised 119 student project via ECE 4760**
    - Projects from 2022 and 2023 (RP2040)
    - Projects from 2021 (PIC32)

- **Since Fall 2020, I have advised 58 projects via ECE 5760**
    - Link to all student projects

- **These projects have been featured in Cornell media and elsewhere**

    - 44 student teams were given RP2040s to create anything. Here's what they made. [Cornell ECE]
    - What did computer engineering students at Cornell make with RP2040 last term? [Raspberry Pi]
    - Grow as you go: 'Peecycling' helps plants and compost thrive [Cornell Chronicle]
    - "Raspberry Pi Pico becomes MIDI-Compatible Synth," Lewin Day, Hackaday.com, December 22, 2023, https://hackaday.com/2023/12/22/raspberry-pi-pico-becomes-midi-compatible-synth/

- "Infrared following robot built as proof-of-concept for autonomous luggage, Lewin Day, Hackaday.com, December 23 2023, https://hackaday.com/2023/12/23/infrared-following-robot-built-as-proof-of-concept-for-autonomous-luggage/
- "Talking ohmmeter also spits out color bands for you," Lewin Day, Hackaday.com, December 24 2023, https://hackaday.com/2023/12/24/talking-ohmmeter-also-spits-out-color-bands-for-you/
- "Audio synthesizer hooked up with ChatGPT interface," Lewin Day, Hackaday.com, December 24 2023, https://hackaday.com/2023/12/25/audio-synthesizer-hooked-up-with-chatgpt-interface/
- "Radiochat is a simple LoRa interface over WiFi," Lewin Day, Hackaday.com, December 25 2023, https://hackaday.com/2023/12/25/radiochat-is-a-simple-lora-interface-over-wifi/
- "Raspberry Pi Pico Parallel Mandelbrot Computation," Julian Scheffers, Hackaday.com, December 27 2023, https://hackaday.com/2023/12/27/raspberry-pi-pico-parallel-mandelbrot-computation/
- "CoreXY on the Pi Pico," Jenny List, Hackaday.com, December 28 2023, https://hackaday.com/2023/12/28/corexy-on-the-pi-pico/
- "Sound-reactive light saber flips allegiance via vowel sounds," Donald Papp, Hackaday.com, December 29 2023, https://hackaday.com/2023/12/29/sound-reactive-light-saber-flips-allegiance-via-vowel-sounds/
- "An electronic orchestra baton," Navarre Bartz, Hackaday.com, December 31 2023, https://hackaday.com/2023/12/31/an-electronic-orchestra-baton/
- "Raspberry Pi Pico becomes emotionally-aware music visualizer," Lewin Day, Hackaday.com, December 31 2023, https://hackaday.com/2023/12/31/raspberry-pi-pico-becomes-emotionally-aware-music-visualizer/
- "Precise positioning with the RP2040," Stephen Ogler, Hackaday.com, January 1 2024, https://hackaday.com/2024/01/01/precise-positioning-with-the-rp2040/
- "A deep dive into quadcopter controls," Bryan Cockfield, Hackaday.com, January 1 2024, https://hackaday.com/2024/01/01/a-deep-dive-into-quadcopter-controls/
- "Wii-inspired controller built using Raspberry Pi Pico," Lewin Day, Hackaday.com, January 1 2024, https://hackaday.com/2024/01/01/wii-inspired-controller-built-using-raspberry-pi-pico/
- "Impressively responsive air drums built using the Raspberry Pi Pico," Lewin Day, Hackaday.com, January 2 2024, https://hackaday.com/2024/01/02/impressively-responsive-air-drums-built-using-the-raspberry-pi-pico/
- "Gyro-controlled labyrinth game outputs to VGA," Donald Papp, Hackaday.com, January 3 2024, https://hackaday.com/2024/01/03/gyro-controlled-labyrinth-game-outputs-to-vga/
- "Building a loop station with an RP2040," Lewin Day, Hackaday.com, January 11 2024, https://hackaday.com/2024/01/11/building-a-loop-station-with-an-rp2040/
- "Raspberry Pi Pico powers digital audio looper," Ash Hill, Tom's Hardware, January 12 2024, https://www.tomshardware.com/raspberry-pi/raspberry-pi-pico-powers-digital-audio-looper
- "Simon Says with an RP2040," Chris Lott, Hackaday.com, January 30 2024, https://hackaday.com/2024/01/30/simon-says-with-an-rp2040/

- **Through ECE 4920, I've helped <u>27 of these projects</u> get published in trade magazines**

  - Catching Lightning in an IMU - Simulating Diffusion-Limited Aggregation with a Raspberry Pi RP2040 MCU, by Angela Cui, Nathaniel Navarro, and William Yoon, Circuit Cellar Magazine #412, pp. 12-20
  - Video Game Inspired by The Legend of Zelda, by Tangia Sun, Emily Speckhals, and Max Klugherz, Circuit Cellar Magazine #406, pp. 18-24
  - The Self-Playing Xylophone, by Harris Miller, Karina Melgar, and Zoe Chen, Servo Magazine 2022 Issue 5 (released 2024), pp. 56-60
  - Table Top Garden, by Jessica Henson and Leo Davies, AgriTech Tomorrow Magazine, April 18 2024, link here
  - Build a Universal Infrared Remote using a Raspberry Pi Pico, by Owen Louis and Liam Sweeney, Circuit Cellar Magazine #404 March 2024 pp 22-28
  - Machine Learning using an RP2040 and the Edge Impulse Platform, by Taylor Stephens and Adam Fofana, Circuit Cellar Magazine #403 February 2024 pp 16-2022
  - Identifying Musical Chords, by Tiffany Chou and Jeff nan, Circuit Cellar Magazine #402 January 2024 pp 20-26
  - A Modern Take on a Classic Game: Using an RP2040 Chip, GPS, Music, and More, Circuit Cellar Magazine #401 December 2023 pp 20-26
  - Recreating the Red Light Green Light Game from Squid Game, by Katherine Fernandes and Tiffany Guo, Servo Magazine 2023 Issue 4, **COVER ARTICLE**
  - RPiano: A Playable MIDI Synthesizer, By Samiksha Hiranandani, Circuit Cellar Magazine #400 November 2023 pp 22-30
  - Building a Holographic Persistence-of-Vision Display, By Michael Crum, Joseph Horwitz, and Rabail Makhdoom, Circuit Cellar Magazine #400 November 2023 pp 4-12
  - Real-time Automatic Music Transcriber Using a Raspberry Pi RP2040, By Chris Schiff, Jacob Lashin, and Romano Tio, Circuit Cellar Magazine #398 August 2023 pp 18-24
  - Small-Scale Game of Life Using PIC32, By Ian Kim Riley, David Wolfers, and Connor Thomas, Circuit Cellar Magazine #387 August 2022 pp 20-26
  - Build a Play-Along Keyboard Using a PIC32 Microcontroller, By Elias Hanna, Marek Chmielewski, and Matias Goldfeld, Circuit Cellar Magazine #386 September 2022 pp 12-20
  - PIC32 Based Home Arcade, By Alga Peng and Xiangyi Zhao, Circuit Cellar Magazine #386 September 2022 pp 20-26
  - Around Sound: Digital Echolocation for the Visually Impaired, By Amulya Khurana, Krithik Ranjan, and Aparajito Saha, Circuit Cellar Magazine #386 September 2022 pp 38-44
  - Build a Bluetooth Controlled Robot Tank, By Luis Martinez and Matt Hales, Servo Magazine 2022 Issue 2, **COVER ARTICLE**
  - A Rubik's Cube Solving Guide Based on a PIC32 Microcontroller, By Alexander Drazic, Tushar Khan, and Myles Cherebin, Circuit Cellar Magazine #385 August 2022 pp 6-12
  - Oscilloscope Music: Visualizing Sounds and Hearing Images, By Ruby Min, Samantha Cobado, and Eric Khan, Circuit Cellar Magazine #385 August 2022 pp 12-20
  - Build an LED Amusement Park at Home, By Jenny Wen, Jasmin An, and Aratrika Ghatak, Nuts and Volts Magazine, 2022 Issue 2, pp 50-56
  - Building a Tri-Effect Guitar Pedal Using a PIC32 MCU, By Kingsley Odae, Jade Pinkenburg, and Jake Saunders, Circuit Cellar Magazine #384 July 2022 pp 28-34

- Designing and Building a PIC32 Video Game: Sharks and Minnows Multiplayer Game, By Tyler Bisk and Chidera Wokonko, Circuit Cellar Magazine #384 July 2022 pp 14-20
- Asynchronous High-Bandwidth, Low-Latency Communication: CPU-Intensive Devices, By Joseph Whelan, Akugbe Imudia, and Devlin Babcock, Circuit Cellar Magazine #384 July 2022 pp 20-28
- Sunrise Alarm Clock: Wake up with a Natural Sunrise Simulation, By Jonathan Pfeifer, Circuit Cellar Magazine #384 July 2022 pp 28-34
- Asymmetric VR Game with Custom Microcontroller Peripherals: Collaborative Game, By Cameron Haire, Michaela Bettez, and Daniel Batan Circuit Cellar Magazine #383 June 2022 pp 20-27
- Make a Stochastic Music Generator: PIC32-Based Design, By William Salcedo, Rishi Singhal and Raghav Kumar, Circuit Cellar Magazine #380, March 2022, pp 18-23
- Build a Maze Generator and Game: Using a PIC32 MCU, By Kyle Infantino, Jack Brzozowski and Dilan Lakhani, Circuit Cellar Magazine #379, Feb 2022, pp 18-24

MEng projects

- Please see the subsequent section!

MEng project advising

As mentioned previously, MEng project advising is another one of the mechanisms by which I attempt to achieve both of my teaching goals: for Cornell to be known across the world as the best source of new talent in embedded systems, and to remove barriers that have been erected between fields of study. This section includes some information about how I approach project selection and project advising, and then discusses the projects that I have advised.

To see all information provided to my MEng students, click here. To see all my projects, here.

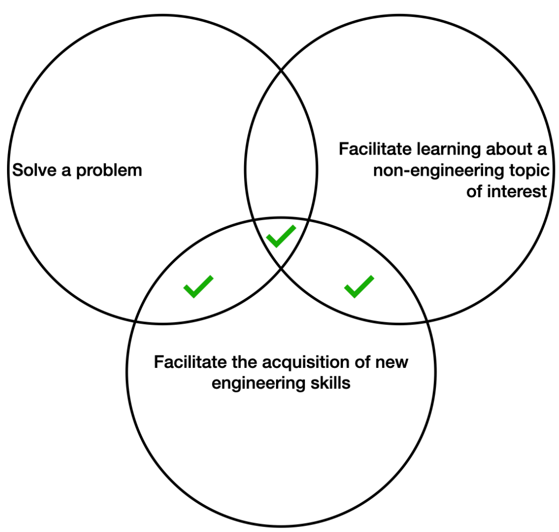
Information provided to students: **deciding on a project**

(Information copied from **my webpage**)

As a new MEng student, you may either choose a project proposed by a faculty member, or you can propose a project to a faculty member to advise. If you opt to propose a project, you should have a written proposal available to share with a faculty member that specifically outlines your intended goals of the project and how you intend to achieve them. This should be done well in advance of the five week deadline to selection a project.

Either way, it is wise to consider the type of engineering project that best suits your interests and goals.

I divide engineering projects into three (overlapping) categories: those which solve a problem, those which facilitate learning about some other (non-engineering) topic of interest, and those which facilitate the acquisition of new engineering skills. These categories are represented in the Venn diagram shown below, on which I've also indicated the regions of overlap that I prefer in MEng projects. Let us consider each of these categories in turn.



Engineering as a mechanism for solving problems
This sort of project is, generally, the most familiar to engineering students. For these sorts of projects we identify a problem (or, more generally, an objective), and we build something to solve that problem or meet that objective. This is a broad category which includes video games, lab infrastructure, communications infrastructure, and products for clients around campus. As a specific example, I currently have two students working on an IoT sensing system for the Johnson Museum of Art on campus. These projects are rewarding because they tend to be useful, but usefulness is not the only metric by which I judge an MEng project.

Engineering as a mechanism for learning about other topics
Personally, I love using engineering in a way that people often use reading -- as a mechanism for learning about something interesting. If you are interested in WWII history, create an Enigma machine. If you are interested in birds, create a birdsong synthesizer or a flocking animator. If you are interested in aesthetic mathematics, create a Mandelbrot visualizer. For almost any curiosity, one can think up an engineering project that allows for you to explore that curiosity in a unique way. I have seen students explore interests in music, art, wildlife, and countless other topics. For me, an "interesting" engineering project is just as valuable as a "useful" engineering project. As a specific example, I had a student in a previous semester build a synthesizer to reproduce the sound of the Cornell chimes. It ended up sounding indistinguishable from the real thing!

Acquisition of new engineering skills
The perfect MEng project is one which involves some skills which are familiar to the student, and other skills which are brand new to the student. A lack of balance in one direction or the other can make the project boring or frustrating. If you like one of the projects that I have listed but you're worried that your background would make the project too difficult or too simple, come talk to me! It is often the case that we can find a different technical approach to the problem that suits your particular skillset.

Still not sure?
If you're not sure what you'd like to do for your project and it would be helpful to talk, send me an email! We can setup a meeting. In preparation for that meeting, it would be helpful for you to go through the following exercise:

- Make a list of things you are curious about. This should be stuff that you may no little-to-nothing about, but that you find interesting. Astronomy? Birdsong? Art? Archeology? History? Make a long list, and then think about ways that you can build something to learn more about something on that list.
- Make a separate list of activities, totally separate from engineering, that you enjoy. Do you like to ride bicycles? Play music? Play video games? Watch movies? List your hobbies, and then think about ways that you can engineer something to explore that hobby.

Bring these lists to our first meeting and we will brainstorm project possibilities.

Information provided to students: **signing up for a project**
(Information copied from **my webpage**)

I advise projects of two varieties: those which I propose and those which a student proposes to me. The enrollment process for each is different.

Signing up for a project that I have proposed

1. **Set up a meeting with me before you enroll.** Email me at vha3@cornell.edu to setup this meeting. The purpose of this meeting is to make sure that the goals of the project are clear (i.e., to make sure that there aren't any misunderstandings about the project) and to make sure that it will be of appropriate technical scope for that particular student or students. If the scope is wrong, I may adjust the project or recommend a different one. We will also decide on the number of credits for which you should enroll (expectations associated with various credit hours are listed in the Expectations section).

2. Only after we have met and agreed upon the number of credits for which you should enroll, enroll in ECE 6930 under my section number.

Proposing your own project for me to advise

1. **Set up a meeting with me to discuss your project**. Please email me at vha3@cornell.edu to setup this meeting.
2. In that meeting, we will make sure the project is appropriate, and that I am the appropriate advisor for that project. In particular:
    1. For me to be the advisor, the project must be (at least partially) in my technical wheelhouse. This means that it should involve microcontrollers, systems on chip, physics simulation, FPGA's, estimation, control, or robotics. It can definitely involve things that I don't know much about (in fact, I love it when projects involve things I'm unfamiliar with, because I get to learn from the student), but it can't be entirely outside of my domain of understanding.
    2. For me to be the advisor, your project must involve building something physical. I am deeply hardware-focused. I'm willing to make exceptions, but generally speaking I will ask for you to build something in the lab.
    3. Your proposed project must lead to the acquisition of new engineering skills.
    4. Your proposed project must be of appropriate scope (not too hard or too easy), given your particular engineering background.
3. Only after we have met and agreed upon the number of credits for which you should enroll, enroll in ECE 6930 under my section number.

Information provided to students: **expectations**

(Information copied from **my webpage**)

My expectations depend on the number of credits for which you are enrolled:

- 1 credit: One credit represents 5 hours/week of work. For 1 credit, I will expect to see extensive research conducted for your MEng project. If your system is already built, you may enroll in 1 credit to create documentation for that system.
- 2 credits: Two credits represents 10 hours/week of work. For 2 credits, I expect a fully-specified design for the system that you will build (though you needn't have anything actually built yet). If your system is already built, you may enroll in 2 credits to create documentation for that system.
- 3 credits: Three credits represents 15 hours/week of work. For 3 credits, I expect a prototype. It doesn't have to be pretty, it can have bugs, but you have to have something built and working.
- 4 credits: Four credits represents 20 hours/week of work. For 4 credits, I expect a polished product (if it has already been designed), or design+prototype, or prototype+extensive documentation.

We will meet weekly or biweekly (depending on the project and the student) to monitor progress, discuss bugs, and make plans for the coming week or weeks. *Never hesitate to reach out to me if you're encountering a problem! You don't need to wait for our meeting for us to talk.*

Information provided to students: **deliverables**

(Information copied from **my webpage**)

Weekly progress reports

Each week, I'll ask for you to submit a progress report through Canvas. These do not need to be long, 1-2 pages is fine, but they should include the following information:

- What was accomplished this week?
- How many hours did you spend on the project this week?
- Are there currently any problems impeding your progress?
- What are your objectives for the coming week?

It is a good idea to take these seriously! The more organized and thorough you are in your weekly reports, the easier it will be to write your end-of-semester and final reports. *Take lots of pictures! Save plots! Document things!!*

End-of-semester report

At the end of your first semester, you will be asked to submit an end-of-semester report. This report will only be seen and evaluated by me (as opposed to your final report, which is submitted to me and the department). As with your weekly progress reports, be as thorough as possible. In terms of format, please model it off the final report submission guidelines. This should be submitted through Canvas, and is due on the last day of classes.

Poster

Each spring, Cornell ECE M.Eng. students present their Finalized Design Projects with a Poster Session. Presenting their posters to judges, the students highlight and describe their work through a combination of images, text and a two-minute elevator speech. Prizes are awarded for the best posters in each area, as well as best overall poster.

Final report

- Please use the final report submission guidelines to format your report.
- Be particularly thoughtful about your abstract and executive summary!
- I need this submitted to me at least one week before the deadline. This gives me time to read and provide feedback, and you time to make any necessary changes.
- Here are reports from previous semesters.
- This is a particularly good report from a previous semester
- Remember that you own your intellectual property! If you are considering patenting your project, let me know so that the university does not publish it anywhere!

Information provided to students: **grading**
(Information copied from **my webpage**)

Weekly preparedness and progress (30%)

- You will be asked to submit a weekly progress report through Canvas, which should include:
  1. Tasks accomplished in the previous week.
  2. Hours spent on project in the previous week.
  3. Problems impeding progress
  4. Objectives for the coming week.
- Your preparedness and progress grade will come from these lab reports, and from the quality, quantity and character of the work done during each week as observed by Hunter.

Final demonstration or product (30%)

- A project which works according to specification (which we will establish together).
- Thoughtfulness toward usability and user experience.
- Your poster is incorporated in this aspect of the grading.

Final report (40%)

- Completeness and understandability of the final report. My advice to students is to consider the audience of their lab reports to be themselves in 5 years. Assume that you haven't been working on this design problem since you wrote the report, and that you must re-create your work. Could you do it (and justify the solution to a boss) using only the report? If you only had this report as a resource, could you:

  1. Understand what the objectives of the project were?
  2. Independently recreate your work (without looking at provided code) using the same development and debugging methods that were used previously?
  3. How easily could you repeat your work using this report as a resource? In other words, how clear is this report?
  4. Could you understand why (quantitively or otherwise) you chose a particular strategy over another strategy for meeting the requirements of the project?
  5. Could you understand the metrics by which you evaluated your solution? Could you evaluate your independently re-created version of your project by the same metrics and get the same results?

Remember that you own your intellectual property! If you are considering patenting your project, let me know so that the university does not publish it anywhere!

Projects!

I have graduated 45 MEng students across 33 projects. 6 of these have been category winners at the poster session, and one was the overall winner. I have 15 active MEng students across an additional 10 projects.

These projects fall into 3 categories:

1. Those which I propose, and which usually explore my research interests (discussed later).
2. Those which the students propose, or which the students and I come up with together to explore their own interests.
3. Interdisciplinary collaborations (see previous section).

Graduated projects:
(Find all reports and posters at my webpage)

Fall, 2024

1. Lightweight embedded thrust vector control on the RP2040
   Max Klugherz
   Third place runner-up
2. Audio spatialization toolkit for personal music production
   Antti Meriluoto

Spring, 2024

3. Threading and Networking Developments for the Raspberry Pi Pico W
   Harris Miller and Liam Kain
   Category winner
4. Speed of Light Measurement using Time Domain Reflectometry on RP2040
   Spencer Davis
5. Low-Cost Virtual Fencing for Livestock Management
   Yiyang Zhao and Ang Chen
6. Translation of CNN Model for Hardware Acceleration
   Nikhil Mhatre, Devin Singh, and Junze Zhou
7. Robotic Mobility Assistive Device
   Zhihao Xu, Yiqi Sun
8. Natural Timers for IoT continued
   Chris Yang
9. FPGA-Based Realtime Video 2D FFT Accelerator
   Ruyi Zhou, Yibin Xu
10. Hardware acceleration of Computer Vision Algorithms using Field Programmable Gate Arrays
    Dengyu Tu

Category winner

11. Open-Source Handheld pH Sensor with Mobile App
    Yuzhong Zheng, Yapeng Teng
    Category winner
12. Design of a Low Cost Extracellular Voltage Amplifier
    Pawan Perera
13. Design of a Large-Scale Robotic Swarm
    Eshita Sangani
    Category winner
14. Sportek: The Coach and Athlete's Third Eye
    Nikhil Satheesh Pillai
15. FPGA-based Robotic Effect Voice Changer
    Shuzhe Liu, Jiacheng Tu, and Xiangzhou Wei

Fall, 2023

16. Natural Timers for IoT
    Michael Awad
    Category winner
17. Real-time Computer Vision Bird Feeder on Raspberry Pi
    Tyler Bisk
    Overall winner
18. Light Seeking Braitenberg Vehicle
    Tangia Sun
19. Hardware Acceleration of Boids Flocking Algorithm
    Romano Tio
20. Steering Sound with a Phased Speaker Array
    Christopher Bakhos
21. Standalone Wi-Fi Based IoT Systems Using the Raspberry Pi Pico-W
    Chris Chan
    Category winner

Spring, 2023

22. Naloxone Safety Kit
    Yilu Zhou and Zane Parker
23. Chaotic System Module for Acoustic Signal Processing
    Liam Sweeney

Fall, 2022

24. Solar Powered GPS Tracker
    Stefen Pegels

Spring, 2022

25. Distributed Environmental Sensing System for the Johnson Museum
    Mingyang Feng and Yingjia Zhang
26. Chaotic Oscillator as Sound Synthesis Controller
    Zifu Qin
27. Intelligent Dash Cam
    David Pirogovsky
28. Designing a Camera Module Driver Using Programmable I/O On Pi Pico RP2040
    Yibo Yang

Fall, 2021

29. Lab Prototype Board for the Pi Pico RP2040
    Andrew Tsai and Felipe Shiwa
30. Analysis and Resynthesis of the Cornell Chimes
    Alex Koenigsberger
31. Programming the Pi Pico RP2040 I/O Processor
    Parth Sarthi Sharma
32. Lab Prototype Board for the RPi Pico 2040
    Emily Wang

Spring, 2021

33. Remote I/O for an FPGA
    Anthony Viego

Ongoing projects:

34. Expanding the resolution of an ultrasonic imager (collaboration with Amit Lal)
    Tony Ye and Zhixing Fan
35. Visual and auditory stimulus generation for a small fish
    Jack Strope
36. Low-cost depth sensing module for deep-water instruments
    Nikolai Nekrutenko
37. Low-cost field methane sensors
    Ao Ruan, Nicholas Ricci, Dikshanya Ramaswamy
38. Design and construction of a low-cost extracellular voltage amplifier
    Gilbert Liang
39. Hacking a power wheelchair
    Peng-Ru Lung
40. Microcontroller-based synthesizer
    Kaniskaa Mohan Sangeetha
41. Physical drum machine robot
    Elise Vergas

42. Head-mounted sensory substitution device for tree shrews
    Sabian Grier, Cicci Chen, Vidhula Pallovor
43. RISC-V processor with DSP instruction extensions and hardware accelerators on FPGA
    Han Mo

Other opportunities to engage with honorary organizations

Nothing much to report in this respect. Only two items of potential relevance(?).

The first is an invitation to participate in a Spring, 2025 conference dedicated to the search for computational Dyson Spheres (hypothesized extraterrestrial megaengineering structures). Some of the investigation into these machines is based on my PhD work.

The second is my very recent involvement with Greg Pass on his Altamira Comet art project.

Philosophy toward engineering

The requested materials for this dossier provide some insight into my teaching and advising philosophy and performance. *Because essentially all of my teaching involves building things, it seems very important that the reviewer have some understanding also of my philosophy toward engineering as a discipline.* The materials below summarize my thoughts about the practice of building things. **Please include these in your evaluation**.

- Slides
- Recorded talk

A few more miscellaneous items of potential interest

- Though it has been on the back burner for a few years, I do intend to revitalize a podcast that I started with Reeve Hamilton's help a couple years ago, in which I engage in conversation with colleagues. These conversations aren't necessarily about that faculty member's research, but instead wander around topics for which their particular expertise may give them an interesting perspective. For instance, I **recorded a conversation with Mason Peck** (MAE spacecraft specialist) last month in which we talked about science fiction, literature/stories, creativity, and the relationship between art/engineering.
- I have engaged in paid engineering consulting for Geegah (Amit's company) and on behalf of one of David Erickson's projects in MAE.
- I maintain my ambitions to become an astronaut, and applied in 2024. This application appears to have been unsuccessful, but I will be re-applying at every opportunity.

Research goals

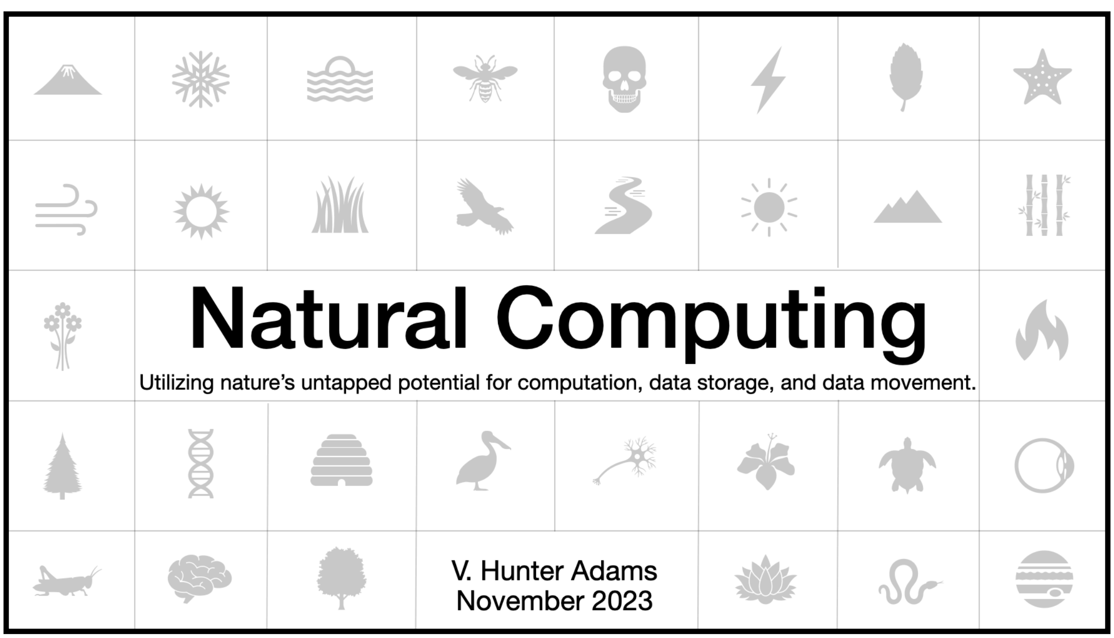
Though I don't have the kind or quantity of resources available to me for research as my tenure-track colleagues, I am not without any resources. This section of the dossier describes the questions on which I aim to deploy these resources. My research interests have changed dramatically since my PhD, I would deeply appreciate it if my colleagues read them and offered criticism.

Goal: I aim to unlock **nature's latent computational potential**. Doing so will radically increase global computational availability, and fundamentally change the relationship between nature and machines.

Research talk

Please find links below to a recording of a "research talk" (or something approximating it), and the slides associated with that talk. The slides are the most comprehensive collection of my thoughts.

- Slides ⟵ the most comprehensive collection of my thoughts
- Recording of the talk



Research statement

Introduction

I would like to build machines which utilize nature's untapped potential for computation, data storage, and data movement. Nature abounds in computational processes, evolved systems with behavior that can be described algorithmically. Nature also offers repositories for information, and mechanisms for moving that information *en masse*. The similarity to computers is tantalizing. If we can affect the inputs to these systems, comprehend the computations performed on those inputs and ingest the outputs, then we can deploy these evolved, special-purpose computers on problems of interest to humans. This is not biomimicry, as the objective is not to replicate nature. Neither is it bio- or geo-engineering, since these natural systems will not be altered. Instead, the aim is to make nature a *subsystem* in a high-performance "natural computer." Success in this endeavor will increase global compute capacity by unlocking the latent computational power available in nature. It may also help solve the environmental crisis. Tapping these natural computational processes with even a fraction of the efficiency with which we've tapped natural power-generating processes will radically affect technology's relationship with nature. If machines that exploit or abuse nature got us into this crisis, then machines for which healthy natural systems are a critical component may help us out of it.

Natural computation

Development for "natural computers" will proceed similarly to the development of conventional computers. Like the original ENIAC and its predecessors, the first natural computers will be special-purpose. High-performance computing often makes use of application-specific hardware which interfaces with a general-purpose computer and accelerates a particularly expensive algorithm or operation. These are "hardware accelerators." I propose to build *naturally* accelerated computers, which are similar to hardware-accelerated computers except that they interface with a natural system rather than application-specific hardware. The algorithms and operations best suited for natural acceleration are those which are difficult for computers and easy for nature. Random number generation and optimization problems are two such examples.

Natural memory

Nature includes many high-entropy environments with degrees of freedom that are effectively invisible to the organisms inhabiting that environment. These invisible degrees of freedom can be used for information storage without adversely affecting any life or natural processes. As an illustrative example, consider one cubic-meter section of beach. One could fully specify the state of that natural system in one very large vector. Limiting ourselves to non-quantum states, this vector would include 6 degrees of freedom for *each* grain of sand to specify its position and orientation. If a grain of sand is approximately 0.1mm across, we'd expect to find approximately 1000 billion in one cubic meter of beach. That's 6000 billion degrees of freedom. Life is a matrix which acts on that vector, and it's a matrix with a tremendously large null space. We are free to store data (a lot of data) in that null space without having any effect on local life. It is worth noting that *every* degree of freedom is available for information storage in environments that contain no life, like the Moon and asteroids. Excitingly, some of these repositories for data *move*.

Natural data transfer

Nature excels at moving tremendous quantities of matter over tremendous distances. Examples include animal migrations, ocean currents, water and carbon cycles, and the movement of celestial objects. Humanity has a long history of using this moving matter to generate energy, but has underutilized these processes for data transfer. There is some precedent for doing so in the form of homing pigeons and sailing vessels (among other examples), but we've yet to approach the channel capacity for these systems. There exist both near-term opportunities and long-term possibilities for injecting information into these epic movements of matter.

In the near-term, we can add matter in the form of conventional data storage devices to these systems, such that they are swept along from origin to destination. This method for data transfer makes the communication channel "bursty" in the sense that the information arrives all at once rather than bit by bit, but it enables shockingly high average data transfer rate. It's worth pondering, for instance, that the data rate for a single humble homing pigeon carrying 1TB SD cards from New York City to Boston is approximately 3 GB/s. And there exist natural migrations of matter with far more capacity for excess mass than pigeons (e.g. ocean currents, trade winds, and whales). In the long term, it may be possible to embed the information in the matter itself, by looking for and modifying the non-volatile null space degrees of freedom discussed in the previous section.

Getting there from here

Developing natural computers will occur in phases, the first of which resurrects the naturalist of previous centuries. Like those naturalists, the natural computing researcher will go into the wilderness to look for new things. Rather than searching for new plants and animals, this person seeks natural computational processes, natural repositories for data, and natural migrations of matter. These processes will be studied and modeled to gain an understanding of their algorithmic qualities, and then the researcher will design and build devices which make these evolved systems components of a larger machine. The person conducting this research requires a depth of knowledge in computing and hardware accelerators, a breadth of knowledge that includes mechanical engineering and the natural sciences, and practical experience designing, building, and debugging devices that interface with the natural world. My background makes me well qualified to make foundational contributions to natural computing.

Why am I the right person to do this?

I have spent my career straddling the boundary between the natural world and the computational world, and making excursions into each. Every excursion into one has led me back to the other. The first of these occurred during my PhD with Mason Peck, while I was designing, building, and deploying gram-scale spacecraft and the infrastructure for communicating with them. These tiny spacecraft (affectionately dubbed "Monarchs") forego conventional risk mitigation strategies for radiation exposure, extreme temperatures, and nearly all other threats to the healthy operation of a spacecraft in space or on the surface of a celestial body. Instead, they are designed to be capable of mass production and deployment on orbit. This means that standard mission assurance strategies for computing probability of mission success do not apply to the Monarchs. I learned how best to plan missions involving Monarchs by studying sea turtles, rabbits, and other "R-selected" species on Earth. These creatures deploy a very similar "quantity over quality" approach to their own much-higher-stakes mission of perpetuating their species from one generation to the next. The calculus of sea turtle reproduction maps remarkably well to that of mission assurance with gram-scale spacecraft. I recently became one of the first external partner payloads for SpinLaunch, a space launch company that aims to replace the first stage of orbital rockets with a centrifuge. We shot two of these Monarchs toward space at Mach 1.5, and confirmed that they survive the stresses of a centrifugal suborbital launch. Hopefully, millions will follow.

And I've had many excursions since. I created a distributed sensing system for measuring environmental conditions in vineyards and orchards in collaboration with plant scientist Justine Vanden Heuvel, which has led since to an investigation of the stochastic processes which occur in these locations and the extent to which they can be integrated into such systems. If we can recruit the birds, bees, and wind to enforce our low-power transmitter's sleep/wake cycles, we may be able to decrease the device's average power consumption *and* make nature a subsystem in our machine. I built a similar system for gathering data from dairy cattle with veterinarian Francisco Yeal Lepes, which has led to similar lines of inquiry. I've also collaborated with Andrew Weislogel, a curator at the Johnson Museum of Art, and Frederic Gleach, curator of the Cornell Anthropology Collection, on projects at the intersection of art, engineering, and history. I collaborated with Amit Lal, an ultrasonic MEMS specialist that built a camera which can image some of nature's smallest creatures in realtime. I constructed the embedded systems infrastructure for controlling the camera and extracting the data that it generates. Most recently, I've been collaborating with David Erickson of mechanical engineering and Mario Herrero Acosta of animal science on a Bezos Earth Fund project to engineer a system for fenceless cattle management. This has been a wonderful opportunity to learn about the algorithmic properties of herding behavior.

In fact, the interplay between the natural and computational worlds has become my obsession, and I'm quite certain that it will remain so for the rest of my days. In both my microcontroller and FPGA design courses, we explore the reciprocal relationship between nature and computing. The students build cricket synthesizers (and synchronizers!), birdsong synthesizers, flocking animators, drum simulations, and Mandelbrot Set generators. My Masters of Engineering students are building systems that generate random numbers with cosmic rays, use waterways for data movement, and store data in tree rings and ice cores. The more of these natural computational processes, repositories for data, and mechanisms for data transfer that I discover, the more filled with wonder I become.

Conclusion

Engineering is my preferred mechanism for learning about the natural world. In addition to reading books and articles, watching documentaries, and listening to podcasts about nature, I enjoy building devices that allow for exploration of its algorithmic qualities. This practice has left me with an information-based outlook on the natural world. In the forests, oceans, and mountains I see data being stored, computed upon, and moved. I see the pieces of new kinds of computers and machines with healthy natural systems as critical components. I look forward to a career devoted to assembling these computers piece by piece. It will not be easy, but it is worth doing. Natural computing has the potential to increase global compute capacity and to generate a symbiotic relationship between technology and nature.

Vision statement

(A fictional description of the future that I would like to help bring about through my research)

It's the year 2200, and you've just arrived at Yellowstone National Park.

Well, what *used* to be Yellowstone National Park. National parks and forests have become obsolete since nature merged with machines. Such places made sense when we could only preserve nature by quarantining it from industry, but now the two are inextricably entangled. Each benefits from the other to such an extent that destroying any natural place for its raw materials is as absurd as destroying a luxury car for its bumper sticker. Ever since the forest became more economically valuable than the lumber, humanity stopped putting protective fences around the forest. All that remains now is the old "Welcome to Yellowstone!" sign, left in place as a historical oddity. You take a quick picture of the sign, grab a compass, and walk into the wilderness.

As you walk, you encounter a very familiar placard, like thousands of others that you've seen in cities and towns across the globe. "Please remain on the path, this natural environment is engaged in computation." These placards used to amuse you, but they're so commonplace anymore that you barely even glance at this one. It just leaves you with a subconscious gratitude. It is a small reminder of the epiphany which saved the natural world from human destruction only a century ago. Humanity finally realized that these natural systems offer a different (and more valuable) set of "natural resources" intact than they do disassembled. When disassembled, natural places only offer raw materials. But when intact, they offer computers, repositories for data, and mechanisms for moving data. Humanity became symbiotic with nature by finding and using these "natural computers." As you walk, the wild around you includes naturally and artificially engineered systems so intertwined that you pity the future archeologist who may try to disambiguate them.

The trail carries you up a volcano which only recently stopped leaking molten material. Trudging along the hard, igneous ground, you glance at your compass and notice that its twitching back and forth. Of course! You've stumbled upon Repository Mountain. 50 years ago, engineers built a bridge which stretched across the river of lava that has become the trail beneath your feat. As it flowed underneath, this bridge generated large magnetic fields which toggled one direction and then the other, reorienting the tiny magnetic materials in the lava like so many little compass needles. As the lava cooled, these needles became locked in place. Your twitching compass retrieves this data one bit at a time. You chuckle as you wonder how much time it would take for you to recover every bit and decode it into the text which it represents: the entirety of Wikipedia as of the year 2150. Concerned about another solar flare which might destroy electronically-stored data, humanity created Repository Mountain as a resource from which it could recover knowledge. There are no legal protections for this mountain, because it doesn't need them. Everyone values the data that it holds much more than the raw materials that it offers, and thus it will remain pristine for generations.

Glancing into the gorge off your right, you see a strange looking boulder just underneath the surface of a sparkling blue river. Only its right angles betray it as being the product of human engineering. This strange monolith is covered with life, as it has become an artificial reef in and on which fish, plants, and crustaceans proliferate. You've read about these! It's a reef computer, powered by the water which flows through it and affected by the life which inhabits it. Liquid computers existed long before the digital electronic computers which dominated the previous century, and engineers resurrected them as special-purpose devices for performing Monte Carlo analyses. Humanity realized that it needn't spend energy on generating random numbers in digital electronic computers if it instead engineered computers which allowed for the intrusion of nature's randomness. As tiny apertures open and close in the reef computer, the water itself becomes the computational medium.

You round a bend to encounter a small detour which takes you around a section of trail. A plaque explains the reason for the diversion:

> *Computational naturalists have discovered that the crack patterns on this section of trail approximate the street patterns in lower Manhattan. A slime mold is currently running an optimization over these cracks, which will be used to inform a redesign of the city subway system. Please do not disturb.*

You chuckle. How many millions of dollars would have been spent in previous centuries on optimizations and calculations of this variety? Why did it take so long for people to realize that nature offers computers that will solve problems of such complexity and value? Nobody dares destroy any natural places anymore, for fear of the unrealized computational wealth that they may be destroying in the process.

At the rim of the sleeping caldera, you're met with an astonishing view of what appears to be an unbroken wilderness out to a distant horizon. These vistas still confuse you, because you know that the city from which you drove exists in your field of view, but it's so intertwined with nature that it's difficult to discern. You see large herds of migratory megafauna on their thousands-of-kilometers march. In previous centuries, people nearly hunted these animals to extinction for their furs. Now, they've become mechanisms for moving data. They carry tiny memory cards on their fur, like the seeds stuck to your own jacket, along with them on their journey. In the process, a single herd will move petabytes of information in a fraction of the time that it would take to move that information via the Internet. They're far more valuable as an information transport network than they are as jackets and blankets. The same is true for rivers, ocean currents, and the trade winds. Nature's incredible ability to move matter, long used only as a source of energy, is now used to move information. In a few more years, engineers anticipate storing that information in the matter itself. The rivers won't carry memory cards, the water molecules themselves will hold the information.

The world around you has become a computer. Storing information, moving information, and processing information. It always was this way, of course, but you thank God and the universe that humanity started using it as such. Machines that exploited and abused nature generated the environmental crisis of the previous century, and machines for which healthy natural systems are critical components solved it in this one. When humanity unlocked the latent computational potential in nature, it unlocked the incredible economic potential of healthy, intact natural systems. The explosive growth of the economy improved everyone's quality of life, and guaranteed nature's preservation for generations to come.

CV appended below. Please also find it here for download.

V. Hunter Adams

LAST UPDATED 12/29/2024

Personal Website

Please see Hunter's website for documentation of everything he's done and built since 2015.

Education

Cornell University

BA, Physics — August 2011 - December 2014

MS, Aerospace Engineering — January 2015 - June 2017

PhD, Aerospace Engineering, Advised by Mason Peck — June 2017-December 2019

Research and Professional Experience

Lecturer, Cornell University — January 2020 - Present

Electrical and Computer Engineering

ECE 4760: Digital Systems Design with Microcontrollers: This is a project-based laboratory class focused on bare-metal microcontroller programming and prototyping. The course includes three guided laboratory assignments and concludes with a four-week independent design project. My professional responsibilities include assembling and delivering all lectures, designing all laboratory assignments, and designing/debugging electronics and embedded C programs in the laboratory with the students. Through this class, I have advised **119 student projects**.

- Course webpage
- Course demo code (>200 stars on GitHub)
- Course lectures (>150,000 views on YouTube)
- Student projects from 2022-present.
- Student projects from 2021

ECE 5760: Advanced Microcontroller Design and System-On-Chip: This too is a project-based laboratory class for which I have the same set of professional responsibilities as ECE 4760, but based on FPGA's rather than microcontrollers. Through this class, I have advised **58 student projects**.

- Course webpage
- Course lectures (>47,000 views on YouTube)
- Student projects from 2020-present

ECE 4920: ECE Technical Writing: I help students write magazine and journal articles about their projects from my two design courses. Since 2022, I've gotten **27 student-written articles published from 66 student-authors**, **two of which were cover articles**.

- Course webpage
- Published student articles

Mechanical and Aerospace Engineering

MAE 4160/5160: Spacecraft Technology and Systems Architecture (Spring, 2020): This course offers a survey of contemporary space technology from subsystems through launch and mission operations, all in the context of spacecraft and mission design. The course is modeled off the NASA Systems Engineering Handbook.

- Course materials

Monarch Chip-Satellites — January 2015 - July 2020

PhD Candidate

- I designed, built, debugged, and tested gram-scale spacecraft called "chipsats."
- Gained competence in embedded systems programming, electronics prototyping, printed circuit board design/assembly, and channel coding
- Performed Earth-science experiments with these chipsats in collaboration with plant scientists and veterinarians at Cornell. I deployed chipsats on the surface of the Earth (in vineyards and dairy farms) where they gathered environmental data. I then used these datasets to substantiate claims that chipsats will be good tools for conducting similar experiments on other planets and celestial bodies.

Cosmoptera, Inc. — January 2019 - July 2020

Co-Founder and CEO

- Co-founded a company with my PhD advisor, Mason Peck, to commercialize the Monarch Chip-Satellites that I developed during my PhD.

- Deployed 20 chipsats at Cornell's research vineyard in Lansing, NY to perform distributed environmental sensing. Successfully gathered five weeks of environmental data.
- Deployed 10 Monarchs onto dairy calves at Sunnyside Farms in Scipio Center, NY to monitor activity levels.
- Closed the company to accept my current lecturing position in the Electrical and Computer Engineering department at Cornell.

Violet Satellite Project February 2013 - January 2015

Program Manager

- Managed a team of 30 engineers constructing a high-agility satellite, and acted as liaison to project sponsors at the Air Force Research Laboratory.
- The spacecraft project ("Violet") was part of the University Nanosat Program.
- The faculty advisor for the project was Mason Peck, who later became my PhD advisor.

SpaceX June 2014 - August 2014

Dragon Development Intern

- Wrote a de-orbit simulation in Python to support Dragon re-entry.
- Designed and built a rig that simulated the environmental conditions to which Dragon propulsive components would be exposed after a water landing. The rig was used to perform corrosion tests on components from the Dragon capsule to determine reusability for subsequent missions.

Cornell Laboratory for Elementary Particle Physics May 2012 - September 2013

Research Assistant

- Wrote software in C++/Python to analyze data from the Compact Muon Solenoid particle detector at the European Institute for Nuclear Research (CERN).

Publications

- Probabilistic Packet Transmission Through a Limited-lifetime Deletion Channel with Arbitrary Deletion Probability. [first author] EngrXiv. 2020.
- Theory and Applications of Gram Scale Spacecraft. PhD Dissertation. 2020.
- R-Selected Spacecraft. [first author] AIAA Journal of Spacecraft and Rockets. 2020.
- A Scalable Packet Routing Mechanism for Chip-Satellites in Coplanar Orbits. [first author] IEEE Transactions on Aerospace and Electronic Systems. 2020.
- A Probabilistic Network Formulation for Satellite Swarm Communications. [first author] AIAA Guidance, Navigation, and Control Conference. 2018.
- Interplanetary Optical Navigation. [first author] AIAA Guidance, Navigation, and Control Conference. 2016.
- Lost in Space and Time. [first author] AIAA Guidance, Navigation, and Control Conference. 2017.
- Data Prognostics Using Symbolic Regression. [first author] EngrXiv. 2015.

Teaching Experience

Lecturer (Cornell University)

- ECE 4760, Digital Systems Design with Microcontrollers, spring 2021-present
- ECE 5760, Advanced Microcontroller Design and System-On-Chip, fall 2020-present
- ECE 4920, Technical Writing, fall 2021-present
- MAE 4160, Spacecraft Technology and Systems Architecture, spring 2020

Guest Lectures (Cornell University)

- ENGRG 1050, Enginering Seminar, Oct. 16 2023, "Love letter to embedded systems"
- MAE 6530, Space Exploration Engineering, fall 2023, "R-selected Spacecraft"
- MAE 4220, Introduction to IoT, spring 2022, 2023, 2024, "Power management in IoT systems"
- MAE 4220, Introduction to IoT, spring 2021, 2022, 2023, 2024 "Electrical/mechanical engineering in IoT systems"
- GOVT 3042, The Politics of Technology, spring 2020, "Chipsats and spacecraft politics"
- ECE 6680, Bio-inspired Coordination of Multi-Agent Systems, spring 2020, "Chipsats: swarms in space"
- MAE 4060, Introduction to Spaceflight Mechanics, fall 2019, "Attitude Sensing Technologies"
- MAE 3780, Mechatronics, fall 2019, "C for folks that prefer Matlab"
- MAE 4060, Introduction to Spaceflight Mechanics, fall 2019, "Orbit and Constellation Design"
- NBA 5070, Entrepreneurship for Scientists and Engineers, fall 2019, "Customer Discovery"
- NBA 5640, Entrepreneurship & Business Ownership, spring 2018, "Monarchs for vineyard monitoring"
- MAE 6060, Spacecraft Attitude Dynamics, Control, & Estimation, spring 2018, "Estimation methods"

Teaching Assistant (Cornell University)

- MAE 3780, Mechatronics, fall 2019 (Lab TA)
- MAE 4160, Spacecraft Technology and Systems Architecture, spring 2019 (TA)
- MAE 6060, Spacecraft Attitude Dynamics, Control, and Estimation, spring 2018 (TA)
- ASTRO 1104, Our Solar System, spring 2017 (TA)
- MAE 3260, System Dynamics, spring 2016 (Lab TA)

Outreach and Student Engagement

Student Project Advisor January 2018 - Present

- Through ECE 4760, I have advised 119 student projects.
- Through ECE 5760, I have advised 58 student projects.
- I have graduated 45 MEng students across 33 projects. These include collaborative projects with 7 departments at Cornell and 4 outside companies/organizations.
- I have 15 active MEng students across an additional 10 projects.
- I advise four student project teams, one of which I co-founded with Chris Batten (CUAUV, AutoBike, AutoBoat, and C2S2).
- I am faculty advisor to the Cornell Maker Club, with Joe Skovira.
- I have advised a handful of independent study projects, one of which was covered by CNN.

Syracuse Museum of Science and Technology October 5, 2024

- Presented to public audience about space exploration before a presentation of an IMAX movie in which I am featured.

Public Works Talk April 5, 2023

- Public presentation about my gram-scale spacecraft research.

New Zealand Chipsat Workshop and Hackathon March 16 - March 17, 2019

- Developed a version of the Monarch chipsat that was capable of interfacing with new sensors.
- Developed a series of tutorials for using that chipsat, and put together development kits for a hackathon hosted at the University of Auckland.

NYC Maker Faire September 23 - September 24, 2017

- Co-hosted a chip-satellite booth at the NYC Maker Faire.
- Developed spacecraft hacker kits for Maker Faire visitors to use at the event and at home.

Intrepid Museum July 17, 2016

- Co-hosted a chip-satellite booth at the Intrepid Sea, Air & Space Museum.

Fellowships and Grants

- Cornell Scale-Up and Prototyping Award, 2019
- National Science Foundation Innovation Corps Fellowship, 2018
- Cornell Commercialization Fellowship, 2018
- New York Space Grant, 2017

Honors and Awards

- Canaan Family Award for Excellence in Academic Advising, 2022
- Robert '55 and Vanne '57 Cowie Teaching Award, 2023
- Best Presentation in Session, 2017 AIAA SciTech conference
- Best Presentation in Session, 2016 AIAA SciTech conference

Invited Talks

- "Spacecraft for vineyard monitoring." Cornell University Robotics Seminar, 28 April 2020, Zoom, Ithaca, NY.
- "Science of Cosmos: Seven Wonders of the New World." Carl Sagan Institute Science of Cosmos web series, 20 April 2020. Remotely recorded and available at https://www.youtube.com/watch?v=83gtXl5m8Ao
- "Tales of Commercialization." Cornell entrepreneurship event, 6 February 2020, Upson Hall, Ithaca, NY.
- "Monarchs for vineyard monitoring." Technology and business mixer, 3 September 2019, Big Red Barn, Ithaca, NY.
- "Customer Discovery Lessons Learned." Rev hardware accelerator program, 6 June 2019, Rev Ithaca Startup Works, Ithaca, NY.

- ”Distributed vineyard sensing with Monarchs.” Rev Hardware Heroes January Networking Night, 30 January, 2019, Rev Ithaca Startup Works, Ithaca, NY.
- ”Space Exploration with Chip-Satellites.” Carl Sagan Institute Coffee Hour, 13 December 2018, Upson Hall, Ithaca, NY.
- ”Monarch Customer Discovery.” Cornell commercialization fellows reception, 13 December 2018, Upson Hall, Ithaca, NY.
- ”Monarchs: Lab to Customer.” Technology Entrepreneurship at Cornell mixer, 5 December 2018, Upson Hall, Ithaca, NY.
- ”Customer Discovery Lessons Learned.” High Value Talent Retreat, 26 October 2018, Remote.
- ”Monarchs for digital agriculture.” Cornell Engineering College Council annual dinner, 25 October 2018, Lab or Ornithology, Ithaca, NY.
- “History, State of the Art, and Future of Gram-Scale Spacecraft.” Breakthrough Femtosatellite Workshop, 29 September 2018, Grand Hotel, Bremen, Germany.
- ”Monarch Chip-Satellites.” Cornell Multi-Robot Symposium, 14 March 2018, Upson Hall, Ithaca, NY.

Conference Talks

- ”Distributed, In-Canopy Environmental Sensing with Monarchs.” Nelson J. Shaulis Digital Viticulture Symposium, 17 July 2019, Anthony Road Winery, Penn Yann NY.
- ”A Probabilistic Network Formulation for Satellite Swarm Communications.” AIAA SciTech, 9 January 2018, Gaylord Palms, Kissimmee, FL.
- ”Lost in Space and Time.” AIAA SciTech, 5 January 2017, Gaylord Texan Hotel, Grapevine, TX.
- ”Interplanetary Optical Navigation.” AIAA SciTech, 8 January 2016, Manchester Grand Hyatt, San Diego, CA.

Invited Workshops

- Starshot Communications Workshop, 8-9 May 2020, Zoom.
- Breakthrough Femtosatellite Workshop, 29 September 2018, Grand Hotel, Bremen, Germany.

Committees

- Masters of Engineering Committee, Cornell ECE. December 2023-present.
- Cornell Project Team Taskforce. Feb. 2021-present.
- Commercialization Fellowship Advisory Committee.

Things I’ve built

RP2040 (Raspberry Pi Pico) projects

- GATT server on Pi Pico W
- GATT client on Pi Pico W
- Digital Galton Board on RP2040 (written up as lab assignment)
- Custom serial bootloader for the RP2040
- Worm-like serial bootloader
- CAN driver implemented with PIO on RP2040
- Non-blocking UDP transmitter using PIO on RP2040
- AM radio voice transmission with PWM on RP2040
- Birdsong synthesizer implemented on RP2040 (written up as lab assignment)
- Stepper motor driver written in PIO assembly for RP2040
- VGA driver written in PIO assembly for RP2040
- Decision making in animal groups on the move (written up as lab assignment)
- PID control of an inverted pendulum with a reaction wheel (written up as a lab assignment)
- Cricket chirp synthesis and synchronization with RP2040 (written up as lab assignment)
- Animating Boids and a predator with RP2040 (written up as a lab assignment)
- Realtime Audio FFT to VGA Display with RP2040
- Resistive touchscreen to VGA display with RP2040
- PID control of 1D helicopter with RP2040 (written up as lab assignment)

PIC32 microcontroller projects

- Enigma machine emulated on PIC32
- Boids algorithm on PIC32 (written up as a lab assignment)
- Realtime audio spectrogram on PIC32 (written up as a lab assignment)
- Zoom-interactive robot on PIC32 (written up as a lab assignment)
- Particle systems on PIC32

DE1-SoC FPGA projects

- Lattice-Boltzmann accelerator and visualizer
- Multiprocessor drum synthesizer on the DE1-SoC
- Verilog VGA driver for the DE1-SoC
- GFSK demodulation in Verilog on the DE1-SoC
- Mandelbrot visualizer on the DE1-SoC
- Lorenz system solver/visualizer on DE1-SoC (written up as a lab assignment)

CC1310 microcontroller projects

- Monarch chip-satellite

Raspberry Pi projects

- GFSK demodulator on Raspberry Pi for use with CC1310 microcontroller

Mathematical projects

- Picasso, by way of Fourier
- Attempting to understand something beautiful
- Bayesian approach to analyzing differences in proportions