Securing Our Most Personal Devices and Networks in the Internet of Things

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Montana State University
Barnard Hall 108
Friday, February 01, 2019
4:00 PM

About the Presenter:
Travis Peters is a doctoral candidate in computer science at Dartmouth College, working in the Mobile Health (mHealth) Security & Privacy Lab, led by Professor David Kotz. He received his B.S. in computer science and mathematics from Western Washington University prior to his arrival at Dartmouth College. While at Dartmouth, he has worked on two large, multi-university NSF projects, completed two internships at Intel's Security & Privacy Research Labs, and published in top systems and security venues such as SenSys, HASP, and MobiCom. His primary research interests are in computer and network security and privacy, particularly as it applies to mobile and wearable health systems.

About the Presentation:
In the *Internet of Things (IoT)*, everyday objects are equipped with the ability to compute and communicate. These *smart things* have invaded the lives of everyday people, entering into our homes, our offices, our cars, and are even being constantly carried or worn on our bodies; they have intimate and daily access to our most personal data as well as all of the other devices that we own and encounter throughout our day. Without a doubt, the devices and networks of today are more personal than ever. It should, therefore, come as no surprise that our personal devices and data are frequent targets of ever-present threats. Securing these devices and networks, however, is challenging. In this talk, I present my work on developing designs, techniques, and tools to harden software and systems in a way that aims to *prevent* and *detect* prominent threats to our most personal devices and networks.

First, I present our Trusted I/O solution for protecting sensitive user data transferred between wirelessly connected (Bluetooth) devices. Specifically, I will discuss our BASTION-SGX project, which shows how in-transit data can be protected from privileged threats (e.g., compromised OS) on commodity systems. I present insights into the Bluetooth architecture, Intel's Software Guard Extensions (SGX), and how a Trusted I/O solution can be engineered on commodity devices equipped with SGX. Second, I discuss how we can both improve the utility and security of microcontroller-based devices. Specifically, I will discuss our Amulet project and how we successfully built a wearable health hub that can run multiple health applications, provide strong security properties, and operate on a single charge for weeks or even months at a time. I will present the mobile health scenario that Amulet addresses, dig into the software and hardware architectures of the Amulet platform, and present some of the interesting results that Amulet achieves. This talk will conclude with a discussion on some of my planned future work towards improving the state of security within personal devices and networks, as well as a glimpse into some of my ongoing work on the active detection of threats within this context.

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Dr. John Paxton
Gianforte School of Computing
357 Barnard Hall
Montana State University
Bozeman, MT 59717

Dear Dr. John Paxton and Members of the Search Committee,

I am writing to apply for the position of Assistant Professor of Computer Science at Montana State University, as advertised on your website. I am currently a doctoral candidate in Computer Science at Dartmouth College, and expect to complete my PhD no later than Summer 2019. I am extremely interested in working with you all at Montana State University because of the value you place on diversity and inclusivity, as well as quality education and research.

In my research, I am motivated by work that has clear and meaningful connections to problems that impact everyday people. As a graduate student I have primarily studied security and privacy with an emphasis in mobile health (mHealth). I have ***collaborated with large, multidisciplinary teams*** that span computer science, computer engineering, and healthcare. I have ***spearheaded innovative projects*** in large companies such as Intel. My work has been ***published in top systems and security venues***, and demonstrates both ***technical depth*** (in my CV, see papers from SenSys'16 and HASP'18) as well as ***broad perspective*** in challenges and future areas of work (see SafeThings'17). I believe my experience and plans will lead to fruitful research with undergraduate and graduate students, as well as others across MSU's academic departments, campus research centers and industry. For more details on my scholarly work and future research objectives, please see my Research Statement.

I am also unequivocally committed to the education of undergraduate and graduate students. Indeed, some of my most fond memories and experiences have been in classrooms and working one-on-one with students. As a graduate student, I have served as a teaching assistant for numerous classes, as well as an instructor for a large introductory course at Dartmouth; my abilities to cultivate inclusive environments and successfully mentor and teach others have been ***recognized by students, my department, and my school*** (see Awards & Honors). For more details on my teaching, mentoring, and all around care for students, please see my Teaching Statement and Statement of Diversity & Inclusivity.

Not only do my skills and background make me a good fit for your department and Montana State University as a whole, but also ***our desires and values are highly aligned***. I desire to work in an environment where diversity is celebrated, where inclusivity is prioritized, and where service and outreach is at the foundation of teaching and research. I am seeking an environment where I can work with, and continue to learn from, highly multidisciplinary teams and groups. All of this seems to be at the core of what MSU stands for and engages in on a daily basis; for this reason, I am seeking an opportunity to come alongside you at MSU and continue to strive together in this mission.

I greatly appreciate your time and consideration of my application. I believe my heart and character, my experience, and my objectives are illustrated throughout my statements included in this application. Specifically, I believe my CV and statements will demonstrate that I am passionate about teaching and mentoring, research, and service and outreach. I believe they will also convince you that I have exceptional experience and potential to thrive as a scholar-educator at Montana State University. If there are any additional materials or information that I can provide, however, please do not hesitate to ask. I look forward to hearing from you.

Respectfully,

Travis W. Peters

Travis W. Peters

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Research Interests

Computer and Network Security; mHealth and IoT security; Trusted Computing; Mobile and Wireless Systems

Education

Ph.D., Computer Science *2013 - Present (Expected: June 2019)*
Dartmouth College, Hanover, NH
Dissertation Title: "Securing Personal Devices and Networks in the Internet of Things (IoT)"
Advisor: Dr. David Kotz
Doctoral Committee: Dr. David Kotz, Dr. Sean Smith, Dr. Xia Zhou, Dr. José Camacho

B.S., Mathematics & Computer Science *2008 - 2012*
Western Washington University (WWU), Bellingham, WA

Teaching Experience

Instructor

Problem Solving via Object-Oriented Programming (COSC 10), *Dartmouth College* *Winter 2015*
Class details: approximately 120 students; majors and non-majors; course staff of 13 TAs
My course website is available at https://traviswp.github.io/cs10/.

Teaching Assistant

Software Design & Implementation (COSC 50), *Dartmouth College* *Spring 2016*
Class details: approximately 50 students; majors

Introduction to Programming & Computing (COSC 1), *Dartmouth College* *Spring 2014*
Class details: approximately 180 students; majors and non-majors

Problem Solving via Object-Oriented Programming (COSC 10), *Dartmouth College* *Winter 2014*
Class details: approximately 100 students; majors and non-majors

Introduction to Programming & Computing (COSC 1), *Dartmouth College* *Fall 2013*
Class details: approximately 120 students; majors and non-majors

Programming Fundamentals in C++ (CSCI 140), *Western Washington University* *Fall 2012*
Class details: approximately 40 students; majors and non-majors

Teaching Assistant (K-8), *Family House Academy* *Summer 2009*

Guest Lecturer

Debugging with GDB and Valgrind, *Dartmouth College (COSC 50)* *April 2016, April 2017, January 2018*
A 65-minute lecture on debugging program logic and memory leaks with GDB and Valgrind.
Notes available at https://traviswp.github.io/classes/debugging-gdb-valgrind/.

Introduction to Pebble Development, *Dartmouth College (COSC 50)* *April 2016*
A 65-minute lecture on programming on Pebble smartwatches and a culminating team project.
Notes available at https://traviswp.github.io/classes/pebble-project-intro/.

Three Kinds of Memory, *Dartmouth College (COSC 50)* *April 2016*
A 65-minute lecture on understanding the different kinds of memory and basic memory management in C.
Notes available at https://traviswp.github.io/classes/memory/.

Research Experience

Research Assistant, *Dartmouth College, Hanover, NH* *January 2014 - Present*
I collaborate with multidisciplinary teams to research security and privacy threats in mobile health (mHealth). My work focuses on system and network security within personal area networks and body area networks of health and wellness devices. My work achieves security through the design and experimental validation of novel hardware and software architectures. My current research is investigating how to detect malicious or errant devices in networks of personal devices by developing models based on network traffic and conducting comparative analysis.

Security Research Intern, *Intel Labs, Hillsboro, OR* *June 2016 - September 2016*
Worked with industry experts to conduct a survey on security and privacy threats in the Internet of Things (IoT). Presented findings to researchers and product groups; aided team in developing a larger IoT security research agenda.

Security Research Intern, *Intel Labs, Hillsboro, OR* *June 2015 - September 2015*
Designed and implemented a security architecture to enhance Bluetooth security on Intel's SGX-enabled platforms. Published and presented a paper in *HASP'18*, and filed for a related patent.

Industry Experience

DevOps Engineer, *Attachmate, Bellingham/Seattle, WA* *January 2013 - August 2013*

- Designed and built an automated virtual machine (VM) template management infrastructure using Chef and VMware's vCloud Director. The infrastructure automated how VMs running various operating systems (Windows, Red Hat Linux, SUSE) are deployed and maintained (patched & updated).
- Developed automation routines in Ruby, Bash, and Batch (install software, configure machine settings, etc.).
- Wrote and maintained design specifications and unit tests.

Software Engineer Intern, *Attachmate, Bellingham, WA* *August 2012 - December 2012*

- Extended Luminet (enterprise fraud management system) to integrate with various Security Information & Event Management (SIEM) systems. The extensions used our customizable XML configuration file to enable network operators to configure Luminet to log to various SIEMs.
- Demonstrated correctness of code through implementation of unit tests & automated testing methods.
- Presented project results and live demo to the Luminet product team.

Mobile Developer & Intern Team Lead, *Emergency Reporting, Bellingham, WA* *January 2012 - June 2012*

- Designed and implemented a mobile application to aid Fire/Rescue and EMS responders. This application enabled better in-the-field access to Emergency Reporting's cloud-based record and reporting management system. (Our work spearheaded what is now the InspectER mobile app.)
- Led team of four interns to implement compatible mobile application on iOS and Android platforms.
- Implemented data security (at-rest and in-transit), database access, and integration with Google Maps.

Other Work Experience

Vice President for Business & Operations, *Associated Students of WWU* *June 2011 - June 2012*

- Elected by the student body of Western Washington University (more than 15,000 students).
- Charged with overseeing the internal operations of the Associated Students programs, services, and facilities.
- Managed six other student managers of departments with as many as 20 employees each.
- Facilitated organizational budgeting process, employee hiring process, and internal program assessment.
- Chaired committee to develop operating & non-operating budget for fiscal year 2012 ($3.1 million budget).

Marketing & Technical Associate, *Caso Inc., San Antonio TX* *June 2010 - January 2011*

- Collaborated with the marketing team to implement search engine optimization of company website.
- Advised a team of department leaders to pilot a new organizational management system.

Publications

Timothy Pierson, Travis Peters, Ronald Peterson, and David Kotz. **Proximity detection with single-antenna IoT devices (accepted)**. In *Proceedings of the Conference on Mobile Computing and Networking (MobiCom)*, October 2019.

Travis Peters, Reshma Lal, Srikanth Varadarajan, Pradeep Pappachan, and David Kotz. **BASTION-SGX: Bluetooth and Architectural Support for Trusted I/O on SGX**. In *Proceedings of the Workshop on Hardware and Architectural Support for Security and Privacy (HASP)*, pages 1–9, June 2018.

David Kotz and Travis Peters. **Challenges to ensuring human safety throughout the life-cycle of Smart Environments**. In *Proceedings of the ACM Workshop on the Internet of Safe Things (SafeThings)*, pages 1–7, November 2017.

Josiah Hester, Travis Peters, Tianlong Yun, Ronald Peterson, Joseph Skinner, Bhargav Golla, Kevin Storer, Steven Hearndon, Kevin Freeman, Sarah Lord, Ryan Halter, David Kotz, and Jacob Sorber. **Amulet: An Energy-Efficient, Multi-Application Wearable Platform**. In *Proceedings of the ACM Conference on Embedded Network Sensor Systems (SenSys)*, pages 216–229, November 2016.

Andres Molina-Markham, Ronald Peterson, Joseph Skinner, Tianlong Yun, Bhargav Golla, Kevin Freeman, Travis Peters, Jacob Sorber, Ryan Halter, and David Kotz. **Amulet: A Secure Architecture for mHealth Applications for Low-power Wearable Devices**. In *Proceedings of the Workshop on Mobile Medical Applications - Design and Development (WMMADD)*, pages 16–21. ACM, November 2014.

Travis Peters and Puneet Jain. **MobiSys 2014**. *IEEE Pervasive Computing*, 13(4):93–96, Oct.–Dec. 2014.

Chip Jackson, Lucas Bourne, and Travis Peters. **Computing Along the Big Long River**. *The UMAP Journal for Undergraduate Mathematics & Research*, 33(3):231–246, Fall 2012.

Patents

Srikanth Varadarajan, Reshma Lal, Steven B. McGowan, Hakan Magnus Eriksson, and Travis W. Peters. **System, apparatus and method for providing trusted input/output communications (patent pending)**, May 2018.

Demos, Posters, and Tech Reports

Timothy Pierson, Travis Peters, Ronald Peterson, and David Kotz. **Poster: Proximity detection with single-antenna IoT devices**. In *Proceedings of the International Conference on Mobile Computing and Networking - Posters (MobiCom'18 Posters)*, October 2018.

Travis Peters. **A Survey of Trustworthy Computing on Mobile & Wearable Systems**. Technical Report TR2017-823, Dartmouth Computer Science, May 2017.

Josiah Hester, Travis Peters, Tianlong Yun, Ronald Peterson, Joseph Skinner, Bhargav Golla, Kevin Storer, Steven Hearndon, Sarah Lord, Ryan Halter, David Kotz, and Jacob Sorber. **The Amulet Wearable Platform: Demo Abstract**. In *Proceedings of the ACM Conference on Embedded Network Sensor Systems (SenSys)*, pages 290–291, November 2016.

Travis Peters, Srikanth Varadarajan, and Reshma Lal. **Poster: Security in IoT: What is IoT Security, Really?!** *Intel Labs Open House*, September 2016.

Travis Peters, Srikanth Varadarajan, Pradeep Pappachan, and Reshma Lal. **Poster & Demo: Protecting Bluetooth Input from Malware**. *Intel Labs Open House*, September 2015.

Travis Peters, Srikanth Varadarajan, Pradeep Pappachan, and Reshma Lal. **Poster: Trusted I/O and Bluetooth Devices**. *Intel Labs Intern Poster Show*, August 2015.

Travis Peters. **An Assessment of Single-Channel EMG Sensing for Gestural Input**. Technical Report TR2015-767, Dartmouth Computer Science, September 2014.

Talks & Presentations

[**Workshop Talk**] BASTION-SGX: Bluetooth and Architectural Support for Trusted I/O on SGX. Workshop on Hardware and Architectural Support for Security and Privacy (HASP) at the International Symposium on Computer Architecture (ISCA), Los Angeles, California, June 2018.

[**Workshop Talk**] Physical Emanations and Potential Applications. Annual Trustworthy Health and Wellness Workshop, University of Illinois at Urbana-Champaign, Champaign, IL, September 2017.

[**Invited Talk**] An IoT Survey: Security, Privacy, and Safety in the Future of IoT. Intern Tech Talk Series, Intel Labs, Hillsboro, Oregon, September 2016.

[**NSF Research Outreach**] Fitbit Project: Discussing the Fitbit System, Data, and Security & Privacy Awareness. Hanover High School (Statistics Class), Hanover, New Hampshire, May 2015.

[**Invited Talk**] Delivering Secure Bluetooth Device Input to a Trusted Execution Environment. Intern Tech Talk Series, Intel Labs, Hillsboro, Oregon, September 2015.

[**Poster Presentation**] Security in IoT: What is IoT Security, Really?! Intel Labs Open House, Intel Labs, Hillsboro, Oregon, September 2016.

[Poster Presentation & Demo] Protecting Bluetooth Input from Malware. Intel Labs Open House, Hillsboro, Oregon, September 2015.

[Poster Presentation] Trusted I/O and Bluetooth Devices Intern Poster Show, Intel Labs, Hillsboro, Oregon, August 2015.

Technical Skills

Programming Languages: Python, C, Java, Javascript, Matlab, x86 assembly, Bash, Ruby, SQL, LaTeX, HTML/CSS. ***Software Development & Prototyping:*** Linux, Android, OSX, iOS; Linux and Android Bluetooth stacks; Raspberry Pi, Arduinos, and other custom platforms (e.g., Amulet); Git, SVN, Perforce; Vagrant, Docker, Chef. ***System & Software Inspection & Diagnostics:*** software inspection, e.g., GDB, dtrace, strace, ptrace, perf; physical inspection, e.g., oscilloscopes, spectrum analyzers. ***Data Collection & Analysis:*** Wireshark, GNU Radio, Jupyter, MATLAB. ***Wireless and Software Defined Radios (SDRs):*** Ubertooth; USRP, LimeSDR; GNU Radio. ***Databases & Web Frameworks:*** MySQL, MongoDB; Node.js.

Awards & Honors

Funding Acknowledgements *2014 - 2018*
My research as a PhD student has been conducted under the guidance of my advisor, Dr. David Kotz, and has been funded by two large, multidisciplinary NSF grants: Amulet (https://amulet-project.org/), a collaboration between Dartmouth College and Clemson University; and Trustworthy Health and Wellness (https://thaw.org/), a collaboration between Dartmouth College, U. Michigan, UIUC, Johns Hopkins, and Vanderbilt.

Best Teaching Assistant Award, Department of Computer Science, Dartmouth College *2014 - 2015*
An award voted on by all CS faculty at Dartmouth.

Outstanding Graduate Student Teacher, Dartmouth Center for the Advancement of Learning *2015*
An award given annually through DCAL; nominated by students.

Graduate Student Teaching Award, Dartmouth College *2013 - 2014*
An award given to only three graduate students across Dartmouth.

Dartmouth Fellowship, Dartmouth College *2013 - 2014*

Outstanding Winner, Frank Giordano Award, Contest in Mathematical Modeling *2012*
Less than 3% of teams (10 out of more than 3,600) are selected as Outstanding Winners of the contest.

Oscar Edwin Olson Scholarship, Western Washington University *2012*

Kaiser Borsari Scholarship and Giusti Scholarship, Western Washington University *2011*

Leadership & Volunteer Experience

Topo Athletic Ambassador, Topo Athletic *2018 - present*

Co-Webmaster, Upper Valley Running Club *2018 - present*

Couch-to-5k Volunteer Coach, Upper Valley Running Club *2016 - present*

Lead Sunday School Teacher, Christ Redeemer Church *2014 - present*

Assistant Track Coach, Hanover High School *2016 - 2017*

Free Geek Build Volunteer, Free Geek (Portland, OR) *Summer 2016*

Organizer & Facilitator, Graduate Student TA Orientation *December 2015*

Graduate Student Council Rep., Dartmouth College Computer Science *2013 - 2015*

Graduate Student Web Team, Dartmouth College Computer Science *2014 - 2015*

Lead Teacher & RK Coordinator, Redeemer Kids at Redeemer Church *November 2011 - June 2013*

Vice President of Business & Operations, Associated Students of WWU *June 2011 - June 2012*

- **Chair**, AS Management Council & AS Facilities & Services Council *June 2011 - June 2012*
- **Vice-Chair**, AS Board of Directors & AS Budget Committee *June 2011 - June 2012*
- **Member**, Academic Honesty Board *June 2011 - June 2012*

Big Brother, Big Brothers Big Sisters of Whatcom County *September 2010 - September 2011*

WWU Cross Country and Track & Field, Western Washington University *2008 - 2012*

References

David Kotz (PhD Advisor)
Professor
Department of Computer Science
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Email: david.f.kotz@dartmouth.edu

Chris Bailey-Kellogg (Teaching Mentor)
Professor
Department of Computer Science
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Email: cbk@cs.dartmouth.edu

Thomas Cormen (Teaching Mentor)
Professor
Department of Computer Science
Dartmouth College
Email: thc@cs.dartmouth.edu

Reshma Lal (Manager)
Security Research Scientist
Intel Security & Privacy Research Labs
Intel Labs
Email: reshma.lal@intel.com

Teaching Statement

Travis W. Peters
Computer Science
Dartmouth College

I took my first computer science class shortly before I turned 20. I wasn't like many of my peers: I wasn't raised programming Apple II's; I didn't grow up obsessed with Bill Gates or Steve Jobs. And after struggling through my first few computer science classes, I couldn't escape the thought that I didn't belong. But something kept me coming back to computer science classes. I have since realized that what kept me coming back is that when I found computer science as an undergraduate, I didn't just find a new subject to study or a potential skill for a future job – I found a vehicle by which I could explore virtually any interest I'd ever had. This vehicle is precisely what motivates my passion for teaching and lies at the foundation of what I strive to share with students in my role as an educator.

Teaching Experience

I have served as an educator in various settings and capacities. For example, I spent a summer as a teaching assistant in a small private school with children who required more individualized attention and education plans. I have also worked as a tutor, teaching assistant (TA), and instructor in college mathematics and computer science courses. For the purpose of highlighting my teaching experience, I'll concentrate on recent examples from my time at Dartmouth.

In my first year of graduate school I had the opportunity to be a TA for our introductory computer science courses: CS1 (Introduction to Programming and Computing) and CS10 (Problem Solving via Object Oriented Programming). I held regular office hours, and organized a staff of undergraduate TAs who led weekly recitation sections. Indeed, a major part of my role as a TA in these classes was to mentor undergraduate TAs: helping them lead their small group discussions, and giving them feedback on how they graded assignments. Throughout the year we took more than 500 students on a whirlwind tour of foundational ideas in computer science including data structures, algorithms and algorithmic analysis, program design, machine learning, networking, graphics, mobile device programming, and security and privacy.

After garnering exceptional feedback as a TA, I received multiple awards. Among them are: the *Outstanding Graduate Student Teacher Award* – an award in which undergraduate students nominate graduate student TAs; the *Best Teaching Assistant Award* – an award in which professors in the Computer Science Department vote and select only one CS graduate student; and the *Graduate Student Teaching Award* – a college-wide award in which professors nominate students across the college (only three students were selected the year I won this award).

In addition to these awards, I was offered my favorite award of all: the opportunity to be a course instructor for CS10[1] at Dartmouth. For this class of more than 100 students I prepared and delivered interactive lectures, held office hours, met 1-on-1 with students, coordinated with undergraduate deans to make accommodations for students with special learning needs, managed a staff of 13 TAs, organized recitation section topics and activities to reinforce learning outside of class, and wrote exams and assignments to assess my students. *What an incredible learning opportunity!* Without a doubt, this experience was remarkably defining. In fact, in the next section I discuss my teaching philosophy, which has absolutely been shaped by this experience. Throughout this text I draw on student comments[2] that highlight my philosophies put into action in my teaching.

Since teaching CS10, I have spent more time focused on my research, but I have stayed active in developing my teaching abilities and pursing more teaching opportunities. An example worthy of note is my time as a TA for CS50 (Software Design and Implementation) in Spring 2016, which was taught by my Ph.D. advisor, Professor David Kotz. As a TA I delivered guest lectures, composed class notes, and designed exercises for students. I also worked closely with my advisor to develop a large culminating team project[3] for the course. For this project, we purchased 50 Pebble smartwatches,

[1] CS10 (Problem Solving via Object Oriented Programming) website available at https://traviswp.github.io/cs10/.
[2] The complete collection of reviews from my term as an instructor of CS10 can be made available upon request.
[3] Guest lecture notes and project spec. available at https://traviswp.github.io/classes/pebble-project-intro/.

and had teams of students design and implement software to carry out a cooperative and competitive game. The software spanned multiple platforms: some ran on the Pebble smartwatches, some ran on laptops, and some ran on servers; to support the project I designed and built an infrastructure that allowed their Pebble smartwatches to communicate with their servers via a smartphone app. Through this project, my advisor and I were able to teach students about wearable devices and event-oriented programming (which closely resembled one of our research projects known as *Amulet*[4]). This project also promoted good software engineering practice; we organized design reviews and implementation reviews to provide early feedback to students on their plans and code. At the end of the class, each team delivered a live demonstration of their project, as well as a testing plan that detailed how students thought about testing the various components of their project.

Teaching Philosophy

My teaching philosophy stems from my past experiences, both as a student and a teacher. Informally, there are simple and fairly commonsensical philosophies that guide my teaching. Among them are *talk with students as you would like to be talked with – positive engagement comes through mutual respect,* and *care about the interests of students – new concepts make more sense when related to something familiar,* and *show off your own passion and enthusiasm – if you are bored it is likely they will be as well.* Over the years, these philosophies have been refined and molded into five pillars that make up my teaching philosophy and provide a framework for my pedagogy.

Growth Mindset. First and foremost, I believe in having a *growth mindset* in my teaching. To facilitate my own growth, I seek input from peers and more seasoned educators. For example, in my years at Dartmouth, I have attended countless workshops at the Dartmouth Center for the Advancement of Learning (DCAL)[5] – a hub for scholar-educators to share resources and learn about teaching practices. I also actively seek feedback from my students. For example, as an instructor of CS10 I collected midterm feedback from students through anonymous surveys, which enabled me to make informed improvements throughout the term. As a result of the survey results I adjusted the days and times that student help was provided, and tweaked the style of lectures to use more prepared slides and code snippets.

Engagement and Active Learning. I love many facets of computer science, but a challenging reality exists: it can be dry and outright boring at times! One cannot entirely avoid discussing concrete matters, such as syntax and low-level details; in my teaching, however, I aim to weave this information into compelling stories, helpful analogies, and culturally and temporally relevant lectures and projects. To this effect, one student commented:

> *"...someone providing help should balance explanation of concepts with demonstration of code/syntax/technique. Travis was very helpful in both areas, he did an excellent job."*

Furthermore, I believe that teaching needs to be active; we learn best through interaction, experience, exploration, and even failure. In my classes, I regularly ask questions and incorporate activities where students can be active. For example, as a TA for CS50 I designed a lecture and activities[6] on debugging programming logic and memory leaks. I taught students basic concepts and tools, then let them explore a buggy program. Using their new tools, students were able to discover and fix a buffer overflow. This activity also created an opportunity to share my own research interests in security and illustrate to students how programming errors can be exploited in practice. This session was so successful that I've been invited back multiple times to give this guest lecture in other classes.

Equity and Inclusivity. I strive to create an environment that is welcoming to people of all backgrounds and skill-levels, and one that encourages students to ask questions – in my classrooms and in my office *there is no such thing as a stupid question.* My own past struggle with feeling like I did not belong in computer science has helped me to relate and connect with many students, especially introductory students. One student stated:

> *"...He never made me feel stupid for asking questions that the other kids in class, who have coded in 1000 different languages already, understood just by attending lecture."*

[4] Amulet project website: https://amulet-project.org/.
[5] DCAL website: https://dcal.dartmouth.edu/.
[6] Lecture notes and activity files available at https://traviswp.github.io/classes/debugging-gdb-valgrind/.

Differentiated Instruction. I believe instruction should incorporate knowledge of students' background and learning styles. (I do not believe it is enough to be competent in a particular area to teach well.) Indeed, some of my most fond memories from my time as a student have been interactions with professors that did just this; interactions where it was evident that they paused to take time to digest my question, incorporate what they knew about me, and *only then* respond. Because of this, I always try to take time to really listen to a student, consider who they are and what I know about them, identify where the problem is in their understanding, and then craft a response. One student stated:

> *"I found Travis to have a clearer idea of what the confused CS student was asking about and provided specific guidance."*

Trust. I strive to establish trust with students by conveying my own work ethic, my own fallibility, and the fact that I am committed to them as people and their work as students. In my experience, this can be as simple as demonstrating that I care about their success and that I am willing to do what I can to see that they can be successful. One student commented:

> *"Now, Travis was amazing. He had this motto, 'I won't leave you with broken code.' He stuck by this, always..."*

Looking Forward: Future Goals & Teaching Interests

At Dartmouth I have applied my philosophies with the specific goals of gaining the trust of my students, instilling a problem-solving mindset in them, and helping them to establish a strong foundation in computer science. While doing this, I have continually invited feedback from students and professors, constantly looking for ways to improve how I teach and foster learning. I feel fortunate to have received highly positive feedback on my teaching thus far, yet I know that the job of an educator is never done. Looking forward, my goals are oriented around further developing my abilities as a teacher, establishing connections between my research and classes that I will teach, and learning more about creating environments that are inviting to diverse people groups.

In the future, I look forward to teaching both introductory and advanced courses. I am comfortable teaching a variety of levels and subjects that intersect with my area. These include data structures, algorithms, operating systems, computer architecture, networking, and security and privacy. I am also interested in developing courses that more closely relate to my research in computer security and mobile health. These classes could span topics such as mobile and wearable systems, pervasive computing, trustworthy computing, and security and privacy in the Internet of Things.

Last Updated: January 31, 2019

Research Statement

Travis W. Peters
Computer Science
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I aspire to design security solutions that can be woven into the fabric of our most personal devices – devices like smartphones, wearables, and even implantables. These devices are extremely "personal" in the sense that they are constantly with or around us; they are carried with us or worn on (or implanted inside) our bodies; they are scattered about our homes, our cars, our places of work, and beyond; and they handle our most sensitive information. They promise to make our lives easier. They promise to make our families safer. They promise to provide better and more personalized healthcare. These opportunities have led to an explosion of ubiquitous, smart, connected *things* (the Internet of Things). Unfortunately, our ability to secure devices and to empower everyday people to manage their devices and secure their data is lacking. As a result, we have devices (and networks of devices) that are frequently compromised and exploited, which can harm people. I posit that these problems are rooted in (1) ill-founded assumptions around trust, and (2) a lack of mechanisms and techniques that empower system designers and application developers to build more secure systems.

To this effect, ***my research*** confronts issues with (in)security within computer systems and networks, centered around the theme of *trust*. My work spans two broad dimensions in security [6, 7, 5, 2, 1, 3]: I work with others to develop designs, techniques, and tools to harden software and systems that help to *prevent* well-understood threats; and I work with others to develop systems and techniques that help to *detect* new and emerging threats.

My goals are to make security practical and to make it relevant in the early stages of design and composition of systems and software. For this reason, I explore and develop designs, architectures, techniques, and tools, that make security fit seamlessly with systems and that make it easier for developers to develop software that is secure and efficient.

My methods are focused around real-world systems and networks to make my work both relevant and realistic. I enjoy grounding my work in relevant, real-world technologies that have direct impact on end-users (i.e., you, me, our friends, our families, and so on). For this reason, my research has gravitated towards the most personal devices in our lives: our laptops, our smartphones, our health and wellness devices, and smart home devices; as well as one of the most popular ways for these devices to interact with one another: Bluetooth.

Secure Foundations & Increased Awareness in Ubiquitous Computing

Trusted Computing and Trusted I/O. We live in the age of computing where malware and viruses run rampant. A common objective of these threats is to compromise applications in personal computers and smartphones in order to steal or tamper with user data (e.g., account credentials, health data). A common approach to protect applications and their data from such threats is to employ trusted computing technology. Specifically, technologies such as Intel's Software Guard Extensions (SGX) and ARM's TrustZone technology are popular for protecting applications by isolating sensitive code within *Trusted Execution Environments (TEEs)*. These technologies, however, do not provide sufficient protection for all data in transit to and from their TEEs [5] – a property commonly referred to as Trusted Input/Output or *Trusted I/O*. To address this issue, I developed BASTION-SGX [6], a security architecture for protecting applications on personal devices (e.g., smartphones, PCs) from attacks *within* the device, such as a compromised operating system, drivers, or other variants of malicious software. Because my work is concerned with personal devices and interactions between them, this work demonstrates how Trusted I/O can be realized for real personal devices (PCs and user interface devices) using a prominent wireless I/O technology (Bluetooth) that connects personal devices. In addition to the published paper, I worked with a team of researchers at Intel to file a related patent, *System, apparatus and method for providing trusted input/output communications* [7].

Secure and Energy Efficient IoT Devices. Tiny, battery-powered devices, such as mobile health (mHealth) and other IoT devices, generally lack traditional hardware and software that can offer strong security. To offer some semblance of security on such devices, there are two conventional approaches:

(1) build closed, single-purpose devices that cannot be extended by consumers; or (2) build semi-open, multi-purpose devices that can at least run a full-fledged operating system. These approaches present inherent trade-offs: open systems offer better security but lead to higher energy consumption and therefore short-lived devices, which is inconvenient and potentially unsafe for end-users; closed systems offer inferior security but can optimize the platform to consume less energy, resulting in long-lived devices that are preferable to end-users. To offer a better approach, we developed Amulet [1, 3], a novel platform that enables developers to create secure and efficient mHealth applications that co-exist on resource-constrained devices, such as wearable health devices and other IoT devices. This work focuses on how these devices and their software can be composed and verified in a more trustworthy way, fortifying them from being compromised by errant applications that might attempt to interfere with other applications or the underlying system.

Devices with the properties of our Amulet Platform are of great interest to research communities in sensing, health, and other domains. In fact, our work has stimulated follow-on work by others including developing mHealth applications, new techniques and systems to secure mHealth data, (between clinicians and patients, or coaches and athletes, for example), user studies and human-computer interaction (HCI) studies, sensor design, further enhancements to the underlying design and security of the platform, and patents.

Securing Personal Devices & Networks. My past research has shed light on the looming reality that our work and work like it – while valuable and necessary – is not sufficient. *Hardening* devices and networks to make them more robust against attacks can only go so far in defending against attacks – at some point, the attacker may still be successful. In such an event, I desire a solution that can both *detect* the breach, and *respond* in a meaningful way. This motivates the final portion of my dissertation work, which asserts that an effective way to detect threats to end-user devices and networks is by monitoring network traffic observed within the end-user's personal devices. Specifically, I have proposed a novel analytics framework that analyzes local network traffic between centralized devices (e.g., smartphones, PCs, smart home hubs) and their peripheral devices (e.g., mHealth wearables, human interface devices, smart home devices). This framework maintains different *profiles* of legitimate device behavior along multiple dimensions, and detects anomalies relative to historical data. In this work, I draw on ideas from network monitoring, multivariate statistics, and machine learning, which have enabled me to design a system that collects and analyzes network traffic to detect anomalies that may be indicative of compromised devices or network threats. I believe (and I am currently working towards establishing experimentally-validated grounds for these beliefs) that certain properties of mHealth and other IoT devices make anomaly-based networking monitoring a viable option for achieving insight into the state of personal devices and networks. Again, because my work aims to be practical and relevant, I ground this work in monitoring traffic in Bluetooth-based networks. These networks consist of many devices centered around the end-user's centralized personal devices.

Future Research Directions

Using Physical Properties for Security. While security often has its foundation in cryptography, it may also be promising to use physics as a foundation for security. I plan to study how physical properties of devices and wireless channels between devices can be leveraged to solve problems in computer and network security. For example, past works have relied on physical proximity between two or more devices to establish trust and exchange secret information between devices that have never met before. But how can all devices be sure that other devices are actually physically proximate? We recently published a paper [4] that shows how devices can use properties of wireless signals in close proximity to have confidence that other devices are sufficiently close before exchanging secret information. This work utilizes software-defined radios and exploits unique properties of wireless channels to demonstrate how to thwart distant attackers that may use directional antennas, custom radios, or signal processing techniques to eavesdrop on, or interfere with, wireless communications between physically proximate devices. Furthermore, my dissertation work focuses on the analysis of network traffic between devices that actively communicate in order to detect compromise within personal devices and networks. I believe similar inferences can be made through the analysis of passively collected network traffic (i.e., a third-party that passively monitors communication between nearby devices), and unintentional side channels of devices (e.g., electromagnetic emanations from

computing devices). Both of these directions are ideas I plan to explore in the future.

Usability in the Internet of Things. In my dissertation work I focus on techniques to *detect* threats in personal IoT devices and contexts, but a key challenge is how to best *respond* to threats once they are detected. Today, detection schemes such as Intrusion Detection Systems (IDS) are generally only used in corporate settings where technical staff can examine network logs and diagnose issues in their networks. As a result, technical staff can, for example, identify affected devices and patch them or remove them from the network. This does not translate to personal contexts where non-technical people are responsible for managing their own devices and networks and diagnosing issues. My vision is to use risk models to correlate anomalies with the potential risk they pose to the end-user; using this information, I can design a prototype that has built-in response handlers that range from 'severe harm' (disconnect devices/disable network communication and alert the user) to 'moderate harm' (alert the user; this approach is similar to tools like Little Snitch that seek user feedback to refine its rule set), to 'no apparent harm' (record the anomaly; long-term records are kept to ensure that repeated occurrences of that anomaly can be escalated and handled).

Security, Privacy, and Safety in the Internet of Things. In the Internet of Things (IoT), ordinary objects in our lives are replaced with smart objects (smart things). These smart things have digital electronics and network interfaces that allow them to communicate with other things and, directly or indirectly, through the Internet with remote services. As more of these devices are created and placed in homes or public places that people frequent (e.g., stores, schools), this gives rise to *Smart Environments* – environments with collections of smart things interacting with the environment, with human occupants, with each other, and with remote services, to accomplish one or more applications. In past work [2], we surveyed challenges to ensuring human safety (as well as security and privacy) in the context of Smart Environments. In the future, I plan to continue to explore the challenges and fundamental limitations of IoT devices, both offensively (to unearth new issues) and defensively (to design meaningful defenses and solutions).

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Statement of Diversity & Inclusivity

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I grew up in a single parent household. My mother worked long, hard hours as a nurse to see that my sister and I had the things we needed. While our circumstances were not always ideal, my sister and I grew up in an environment where we were safe, where we were encouraged to try hard, and where we were loved regardless of our successes or failures. In my years as a student, friend, mentor, and teacher, I've seen firsthand that not everyone is raised in, or lives in, such an environment. I am aware of the privilege that I have grown up in, and as a result, I strive to elevate others around me. In all of my work, I am determined to create relationships and environments that are inclusive and inviting to a wide range of people groups.

Fostering community *with* and *for* students. As an undergraduate, I was elected by my peers to serve as a member of the Board of Directors for the Associated Students of Western Washington University.[1] In service to our students, I oversaw the programs, services, and facilities that exist to assist students and foster community; among these, I worked with other student leaders to maintain student centers for ethnic students, women, veterans, students with disabilities, and students that identify as LGBTQ+. As a faculty member, I am interested in forming relationships with similar groups on campus to create bridges between student programs/services and academic departments.

Advocating for women and other minority groups. As an instructor for CS10 I formed meaningful relationships with students, which lived on long after my course ended. Notably, I have worked with female and minority students to pursue internships at top-tier tech companies and graduate programs at high-caliber universities, as well as to apply for competitive travel-abroad learning programs and scholarships. As a faculty member, I will continue to advocate for students, especially students that have historically faced disproportionate barriers in industry and academic settings.

Engaging the broader community of students. As a graduate student I have helped to organize opportunities to share my research and interests with broader communities. For example, we purchased a collection of Fitbit wearable devices and used them as a tool to reach out to local high-school students.[2] The goal of our outreach was to engage young students with technology in order to educate them on the complexity of these devices and some of the security and privacy challenges around mobile health technology. We also connected these topics to what students were learning in their statistics class and used this context to discuss topics like algorithms and machine learning. We concluded our time with the students discussing the sorts of skills and career paths that they might explore in the future. As a faculty member, I am interested in exploring similar outreach efforts to reach K-12 students as well as students at other post-secondary institutions (e.g., community colleges, technical colleges).

Raising up others to practice inclusivity and diversity. After attending *many* workshops organized by the Dartmouth Center for the Advancement of Learning (DCAL),[3] I partnered with other graduate students to organize a "TA Orientation." This orientation taught more than 25 new graduate student TAs from various departments about campus resources to aid their students, how to create inclusive learning environments, and how to navigate "tricky situations" (such as owning your mistakes, friendships with students, and disputes between group members). As a faculty member, I am interested in exploring partnerships with similar learning centers where I can continue to learn from others, and use this knowledge to instill these lessons in other teachers and mentors.

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[1] Learn more about the Associated Students of Western Washington University at https://as.wwu.edu/about/.
[2] STEM Outreach Activity: https://traviswp.github.io/papers/stem-outreach.pdf.
[3] DCAL website: https://dcal.dartmouth.edu/.