Personal Statement: My mother was furious. She bellowed "why is my five-year-old son using a soldering iron?" The only response my mad-scientist-engineer of a father could muster up was a meek "He wanted to learn how to build a circuit." As time progressed, projects with my dad became complex: as soldering at five evolved to building leaf blower hovercrafts at ten, I quickly uncovered my love of robotics before starting high school. Then, without warning, my dad died of a sudden heart attack when I was fifteen. I was devastated; not only had I lost my father, but I thought that I lost my crazy projects and future robotics endeavors. Then, dad's friends banded together, investing hundreds of hours of their time teaching me circuit design and introductory control theory, which solidified my love of robotics. I recognized the magnitude of their investment; although I had lost my father, I gained a team of intellectual mentors to inspire me, an opportunity that most of my high school friends lacked. None grew up with a team of engineers to help with their calculus homework or review designs for a new gizmo. I wanted to pay dividends on my mentors' investments, but all actions and gifts seemed insignificant. Further, my mentors wanted nothing in return. After introspection, I realized I could use my robotic pursuits to reciprocate my mentor's kindness by paying it forward. Now, in my second year of graduate school, I intend to continue applying my engineering education to help others discover a similar love for STEM and to improve the lives of the differently-abled.

Intellectual Merit and Research Experience: I stumbled upon the field of assistive robotics as a sophomore at Penn State by accidentally submitting an application intended for graduate researchers to Dr. Sean Brennan's lab. Amused by my mistake, Dr. Brennan placed me on a new project to augment the capabilities of an electric wheelchair and thereby enhance the experience of the nearly 3.3 million American wheelchair users. Working on a small team with a graduate student, I retrofitted the wheelchair with sensors and computing hardware while developing, in C++ and Python, drivers to interface sensors with the Robotic Operating System. As a junior with the support of the Penn State College of Engineering Research Initiative grant, I continued to work with Dr. Brennan's team to improve the capabilities of our robotic wheelchair. I helped with the testing of an algorithm used to detect wheel slip in low-friction environments, such as an icy sidewalk, resulting in co-authorships on both a paper for the 2016 ASME Dynamic Systems and Controls Conference (DSCC) and a 2018 journal article in ASME Journal of Dynamic Systems, Measurement, and Control.

One afternoon, despite the wheelchair indicating completely charged batteries, I found myself with dead batteries in a faculty parking lot during rush hour blocking angry faculty commuters. While I could push the wheelchair to the lab, most wheelchair users would have been stranded. As a senior supported by Penn State's Rodney Erickson Summer Discovery Grant, I discovered that energy models commonly used by electric wheelchairs perform inadequately in many common scenarios, similar to my parking lot experience. Applying battery estimation methods commonly used by electric vehicles, I developed an improved State-of-Charge (SOC) estimator. At the extreme regions of the battery's charge, a coulomb accumulator presents users with conservative SOC estimates. Otherwise, a linear Kalman Filter estimates the battery's SOC. To test my estimator and simulate real-world usage, I drove the wheelchair around campus following a typical class schedule. My data showed that the new SOC estimator tracked the battery pack's voltage with a mean error of 0.85%. This indicated estimator efficacy and validated my method as an improvement upon the state-of-the-art. Subsequently, I authored and presented my findings in the 2016 ASME DSCC. This work resulted in my undergraduate thesis, an invitation to present my work to Penn State's new president, and a feature on Penn State's nationwide STEM recruiting materials.

Emboldened by my early successes and fascinated by the broader impacts of his work on the BioSleeve, I cold emailed Dr. Chris Assad of NASA's Jet Propulsion Laboratory (JPL) to learn more about his research. The BioSleeve maps dynamic hand and forearm gestures using the surface potentials generated on the skin by muscle movement to robotic commands for use by amputees to control their robotic prosthetic limbs. Dr. Assad invited me to join his team at JPL during the summer before my junior year of college to develop the next generation BioSleeve. Supported by a fellowship from the Pennsylvania Space Grant Consortium, I helped to miniaturize the BioSleeve's signal acquisition system from the size of a small desktop computer to the size of an index card by developing, in C, the system's embedded software. Furthermore, I wrote software and hardware drivers in MATLAB, C++, and Python to interface and benchmark the new BioSleeve with existing computer systems. My efforts with the BioSleeve team resulted in an acknowledgement in their 2015 technology review paper and an internal presentation.

To hone a deeper understanding of robotic hardware, after college I accepted a position as a staff electrical engineer at the National Robotics Engineering Center (NREC), an operating unit within The Robotics Institute at Carnegie Mellon University (CMU). I leveraged the opportunity to learn and refine the skills necessary to rapidly build practical, cutting-edge robots under the guidance of world-leading roboticists and work with a multi-disciplinary team. I was appointed lead electrical engineer on two multi-million-dollar projects funded by both industry and DARPA. By leading these projects, I developed valuable project management skills. I ensured that all electrical designs were delivered on time, met sponsor specifications, and outperformed expectations in field testing. Presently, my contributions to are undergoing invention disclosure review, the first step in the patent process.

During my time with NREC, Dr. Brenna Argall presented, as an invited speaker at CMU, her work in human-robot control sharing at Northwestern University. After pouring over her papers, my desire to contribute to the field of assistive robotic technology was reignited – I immediately applied to, and was later accepted by, Northwestern for graduate school. Situated in the Shirley Ryan AbilityLab, the nation's premier rehabilitation hospital, her lab is uniquely equipped to develop assistive machines through clinical collaborations and studies with diverse patient populations. As a first project, I worked on a five-person team to investigate which robotic arm task features, individually and when combined, contribute most to perceived human difficulty. I designed the robotic autonomy algorithms, experiments, and collected data from twenty subjects for this study. We discovered robotic assistance is most beneficial near kinematic singularities and whenever a rotational feature is detected. Varying user experience indicated the need for assistance to be tailored to meet an individual's abilities. This work lead to a co-authorship on an under-review paper submitted to the 2019 IEEE International Conference on Robotics and Automation (ICRA).

Now, I am researching robotic trust, a measure presently founded in optimal control theory, that quantifies the extent a robot should act upon a partner's control signals, skill level, and understanding of their robotic platform. My prior experiences in control and estimation theory drew me to this understudied topic as it blends familiar topics with new-to-me concepts in machine learning and optimization. I am excited to study the immediate applications of this research within rehabilitation, and I hope to use this work as the foundation of my dissertation.

Broader Impacts and Leadership Experiences: As a freshman at Penn State, I was eager to help others as my mentors had helped me. I became one of the youngest officers of the Penn State IEEE chapter as the club's outreach chairperson, where I used my role to bring STEM education to underserved communities across Pennsylvania. In this role, I worked in conjunction with state and

local educators to organize both the 2013 (as a freshman) and 2014 (as a sophomore) annual Penn State IEEE-sponsored, statewide K-12 robotics competitions. These competitions hosted over one hundred budding engineers and scientists, mostly from low-income communities. I managed an all-volunteer team of fifteen people, an annual budget of $3,500, and a commitment that this event remained free for every K-12 student to attend. As I developed this event, I learned about the financial struggles of STEM educators in low-income regions of Pennsylvania as many relied on this free competition as a core component of their annual science curriculum. For some students, fees or event cancellation may have resulted in school boards further cutting STEM education funds; I believe financial inequality should not hinder access to STEM education.

As a sophomore, I recognized the IEEE chapter's tremendous potential. I ran for and was elected president of the IEEE chapter on a platform of helping both local communities and my peers, something I continue to be passionate about. As president, I increased funding to the annual robotics competition and worked with my officer team to establish three new annual, county-wide outreach events focused on teaching K-12 students the basics of circuitry and programming; each event impacted more than one hundred underserved students. Additionally, I used my research connections to increase research accessibility for my peers by working with department faculty to design an annual career fair style event for undergraduates. Nearly 200 students and almost half of the EE department faculty attended the inaugural event. To promote extracurricular learning, I mentored a freshman officer in creating the first open-to-the-public, student-funded and -organized makerspace on campus to support student-led projects. This makerspace has affected hundreds of engineering students. Finally, while leading the IEEE chapter, corporate sponsorship nearly quintupled from $12,000 to $55,000, active membership quadrupled from 30 students to over 120, and the number of annual club events nearly tripled from 20 to 55, fortifying the IEEE chapter as an organization and spurring the group's continued growth. Since graduation, I have remained connected to my Penn State EE community by serving as an alumni mentor to undergraduates interested in pursuing graduate studies.

I am excited to continue my outreach and peer-support efforts in graduate school. Presently, in its nascent phases, a colleague and I are co-founding and leading the Shirley Ryan AbilityLab's first student organization. I seek to enhance the research experience of AbilityLab students through regular research symposia and social events to help students build a local support system, as well as encourage research collaboration within the hospital. I intend to use this organization as a vehicle to host STEM outreach events for the hospital's pediatric patients; I believe extended hospital stays should not impact a child's access to STEM resources. This past year, I demonstrated my lab's robotic technologies at the Chicago Museum of Science and Industry's annual robotics week. Impacting hundreds of children, these exhibits communicated the importance of and challenges addressed by our research to a diverse audience.

Future Goals: My research experiences have shown me the necessity of assistive robotics and their impacts on differently-abled communities. I seek a deeper understanding of the technical and clinical obstacles facing this field so that I may one day found a company focused on bringing cutting edge assistive technologies into the homes of patients following my graduate studies. Motivated by my upbringing and continued volunteering, I want to become a national policy maker in my late career so that I may use my background to advocate for, among other things, equal access to STEM education across America. The NSF Graduate Research Fellowship Program will allow me to help others and apply the lessons of my father, mentors, and educators throughout my graduate school career and beyond.