Background: The infinite number of ways STEM can improve the lives of individuals and societies have driven my curiosity about technology throughout my life. My experiences with computer engineering during high school and college built on my eagerness to learn and grow as an individual and have instilled a spirit for innovation and design in me. As I enter the field of robotics and artificial intelligence, I have noticed that current technology is designed to serve wealthy and educated classes. Thus, after my graduate studies I wish to join industry research in Human Robot Interaction and eventually pursue a startup dedicated to designing affordable and accessible task-oriented robots.

My programming classes in high school showed me the foundation of computer science: lines of code were pieces of logic I could manipulate and form anything my mind could fathom. Often, I came home from class and experimented with code, creating programs to accomplish tasks such as converting roman numerals, reading morse code, and doing my math homework. My passion for technology amplified in college. Challenging coursework frustrated my peers, but I discovered I had the patience to approach complex logic manipulation problems and the perseverance required to solve them and thus loved finding and implementing tough solutions. I continued to feel this way through all my courses, whether it be coding an operating system, implementing a logic processor on a breadboard, or creating an AM radio circuit. Every challenge gave me purpose, forcing me to be resilient during setbacks and explore the endless solutions computer engineering had to offer.

Intellectual Merit: With my obsession for technology following me into my final year of high school, I interviewed 10 professors at the University of Minnesota (UMN) in the Computer Science and Engineering department and was amazed by the size and diversity of disciplines in the field. Allured by a Graphics and Visualization lab, I initiated a project under Dr. Victoria Interrante. **I created a virtual environment in UnrealEngine4 to enable a user to see their hands in virtual reality (VR), using an Oculus Rift and a Leap Motion sensor**. I applied this design in a user study on 10 participants to determine the effect of haptic feedback on the agency and ownership they felt over their hands in VR. The results showed ($p=0.0208$) that haptic feedback without visualizing an object increases the agency, i.e. the level of control, a user feels over their hands. Being able to effectively utilize hands in virtual reality without losing a sense of agency has numerous applications in education, such as training physicians for surgeries and astronauts for foreign missions. Seeing how this human computer interaction (HCI) research directly benefitted the community urged me to consider improving accessibility by providing a natural way to interact with technology while requiring no technical background. After submitting a research paper and presenting a poster of my project to the Minnesota Department of Education, I received the 2017 Minnesota Scholars of Distinction Award for contributing new knowledge to our current understanding of VR.

Motivated to continue contributing knowledge to a discipline with implications for widespread impacts, during the summer of 2018 I pursued a National Science Foundation **Research Experience for Undergraduates (REU)** at the UMN under Dr. Volkan Isler. I studied the effectiveness of a random trajectory-generation navigation algorithm and Simultaneous Localization and Mapping (SLAM), as well as the potential for reinforcement learning navigation in agricultural robotics. The results highlighted the shortcomings of the navigation system in paths with cycles as the SLAM algorithm resulted in loop closure problems, yet simulation demonstrated the potential for navigation through reinforcement learning. This work had direct implications for agriculture as robots are being used by farms to fulfill a rising food production demand amidst food scarcity concerns. Realizing how my work can serve the agricultural sector in combating food scarcity was eye-opening. I documented my REU in a 17-page report and GitHub repository, which was published on the UMN Robotic Sensor Networks Lab website.

I started my REU with no prior knowledge regarding robotics or artificial intelligence and left having successfully **implemented an autonomous indoor navigation system and simulated a Q-learning navigation algorithm**. Professor Isler and his group provided much support, but my steep learning curve was self-driven. I read textbooks such as Sutton and Barto's "Intro to Reinforcement

Learning" and LaValle's "Planning Algorithms." I completed online Q-Learning tutorials and practiced by solving the cart-pole problem on OpenAI. I read documentation to learn about the Robot Operating System (ROS), the Create2 iRobot and the Hokuyo lidar and wrote algorithms from scratch. Many challenges arose during my REU, such as handling noise from the lidar, path closure problems in SLAM, adjusting training parameters for Q-learning and bugs in the simulation and navigation algorithms. However, I persisted and sought out solutions by widening my knowledge base, which demonstrates my passion and intrinsic motivation to learn as is needed for research.

Research in agricultural robotics in the Isler group, where a colleague founded a startup using his lab-developed technology, advanced my interest in how technology is commercialized. Because of my academic success in computer engineering, I had the opportunity to enroll in a dual degree program at my university, called **Innovation, Leadership, and Engineering Entrepreneurship (ILEE),** that taught me how to take theoretical and experimental knowledge from technical courses and design and market a product based on it. One lesson that resonated with me was that despite how technologically advanced and enticing a product may seem, if it is not necessary or beneficial to an individual it will not be successful, which is why customer discovery is critical. This shifted me into a user-oriented mindset when studying scientific concepts, and I began to focus more on applications of my work. Aside from my new perspective, ILEE taught me essential soft skills needed to make an impact outside of computer engineering. Through taking classes such as Emotional Intelligence, Leadership Theory, Leading Sustainable Change, and Law and Intellectual Property, I was encouraged to critically consider the importance of factors outside of STEM when developing technology.

As a result of my new product-oriented mindset, my next endeavor was a hands-on circuit design project at an aerodynamics research lab at University of Illinois Urbana-Champaign (UIUC). I was tasked with **designing the circuit around a Maximum Power Point Tracking charge controller** for a fully autonomous aerial vehicle with solar panels spanning its wings. This vehicle was built for 24/7 flight for practical applications such as crop or weather monitoring, and surveillance. The charge controller I designed in EagleCAD optimally switches the power among the solar panels, battery and load depending on the state of the system. Coming in with more software experience, this project critically tested my circuit analysis skills and forced me to consider product design factors such as the form factor and layout of the Printed Circuit Board. I presented this work at the UIUC Undergraduate Research Symposium.

To gain an industry perspective of product design and commercialization, in the summer of 2019 I joined a **software engineering internship at Collins Aerospace in Cedar Rapids, Iowa**. Instead of an individual self-motivated project, I worked in a team of 30 others on an operating system (OS) for software-defined radios sold to the US Military. This OS was too large and modular for me to self-learn, requiring close collaboration with my team members to debug and troubleshoot. Using the debugged system, I created a boot configuration for the Ultrazed EV Xilinx development board for other teams to test their radio software, coordinating carefully with my manager and the other teams. This internship taught me how to develop the inner workings of a product by fostering essential teamwork and coordination skills.

Immediately after my internship, during Junior year, I had the opportunity to **study abroad at École Polytechnique Fédérale de Lausanne** (EPFL) in Switzerland. Being free from the constraint of required courses, my eagerness to learn drove me to take as many courses as I could handle, including Machine Learning, Functional Programming, Computer Networks, Embedded Systems, Algorithms and French. It was an arduous, but rewarding, opportunity to learn about so many thrilling topics in a new learning environment. Furthermore, adapting to the French language, culture and societal norms taught me to be flexible and appreciate differences in culture. I engaged with students, researchers, and professors from around the world who have learned their computing basics differently than I had which provided me with a refreshing perspective of my field. For example, for my Machine Learning course's final project 2 peers and I collaborated with a Civil Engineering Lab at EPFL. We used the GoogleMaps API to automatically pull images from Zurich, **used Torchvision ResNet CNNs to classify the buildings by their**

window to façade ratio, and wrote a paper studying the number of training samples needed to effectively classify the buildings. Machine Learning is a notoriously difficult graduate level courses at EPFL and it was rewarding to apply the material to a task for a research lab in a different country. This project provided me with a global perspective and appreciation of STEM research, showing me that my scientific contributions and collaborations are not confined to America.

After my junior year, I accepted an **internship with Western Digital as a Big Data Platform Engineering Intern**. As part of a team, I helped maintain the company's internal web applications, created visualizations using Splunk, and learned many beneficial software development tools such as Jenkins, Spinnaker and Docker. Due to my contributions to the company, I was offered a full-time job post-graduation. I realized that although I enjoyed working in industry, there was still so much more I needed to learn before making the impacts I aspire to on accessibility in communities. I reflected on my experience in HCI and autonomous navigation and reached out to Dr. Katherine Driggs-Campbell's **Human-Centered Autonomy lab at UIUC.** I began working on interfacing agricultural robots to humans via a learned audio interface. This is the perfect starting point to pursue my goal of making technology more accessible, and I seek to expand upon my existing skillset by applying to graduate school for a PhD in computer science and engineering.

Broader Impacts: Outside of school, research, and internships, I have always been dedicated to outreach and volunteering. Along with passion and hard work, a major factor in my success includes the support I receive from family, friends, colleagues, and mentors, which motivates me to give back by supporting my community. In high school, I volunteered as a teacher's assistant for summer STEM programs and loved introducing the world of science and its infinite possibilities to young and eager minds. I also volunteered as a Computer Tutor at the public library to assist people in accomplishing tasks on the computer, such as applying to jobs or community colleges, or scanning documents and sending an email. In college, I continued volunteering at the library, teaching kids how to solder circuits and write computer programs. Through the Electrical and Computer Engineering (ECE) Honor's Fraternity, Eta Kappa Nu, I also led individual tutoring sessions and open review sessions for ECE courses.

My preliminary research has shown that in the agriculture industry, low literacy rates in rural areas impact many farmers' abilities to effectively operate robots, perpetuating the food shortage problem. This parallels my experience as a Computer Tutor, where many adults struggled using computers for simple tasks. I contrasted this experience with the one in Dr. Isler's lab, where we operated the robots by writing commands to a ROS node on a laptop or using a special controller, which would likely be inaccessible to farmers without specialized training.

I intend to **bridge this gap between accessibility and innovation** in the HCI space by using my time in graduate school on research that could enable an interface that makes a task-oriented robot available to any user that may need it. Unlike the current generation of technology, it is necessary to make the new generation of robots more accessible and affordable to avoid perpetuating existing disparities. Big companies with skilled technical expertise may thrive without accessible technology but introducing user-friendly human-robot interfaces means smaller businesses or farms could then have an extra hand without needing technical expertise. Productivity and equality would increase in society by narrowing the disparity in technological education between high and low-income communities.

Future plans: Graduate school will provide me with experts to learn from and the means to research and define the best interfaces for robots to enable their equitable integration into society. The NSF GRFP will allow me to conduct research and gain the expertise necessary to achieve this goal of making technology more accessible. I will use my time in graduate school to research requirements and design an effective interface system in pursuit of a Ph.D., and intend to apply this knowledge to products by launching a startup to transition into a non-profit organization focused on affordable and accessible technology.