My life experiences have led me to the conclusion that intellectual merits and broader impacts are hard to separate. My own intellectual merit stems from the broader impacts others made on my life. The broadest and most enduring impact in my life has been my mother's courage in obtaining an education. Both my mother and father were born into the conservative Protestant sect known as Old Order Mennonites. This sect is known for shunning 'worldly' things, especially education. As a result, my mother attended a one room schoolhouse that ended in eighth grade. As she neared twenty she was expected to marry, start bearing children (she herself was the youngest of twelve), and become a homemaker. This prospect did not excite he or pique her curiosity the way learning did, so she took the GED and applied to college in secret. She was accepted at a local state college, but when she told her father of her desire to attend he disowned her, telling her that education turned the heart from God. She attended the college anyway, and graduated summa cum laude with a degree in education.

When I was born she was committed to making it easier for me to obtain an education than it had been for her. She stuck true to this goal despite financial struggles stemming from a complete lack support from any of my grandparents. For example, in the summers our lack of air conditioning made the house uncomfortable, so my mother used the free air conditioning at the library as an incentive to get my brother and me to spend the days there. It was in the third grade on one of these trips where I discovered a DK Eyewitness book with an illustration of Schrödinger's cat that caught my attention. When I read the simplified description of quantum mechanics I quickly decided that I wanted to become a physicist. This was the beginning of my lifelong goal to become a professor of physics at a research university.

Were it not for my mother's courage in leaving the small Mennonite community in which she spent her early life, all without the support of parents or friends, I would likely never have even known what a physicist was. Part of my motivation for working as hard as I can to pursue my lifelong goal of becoming a physicist is due to the broader impact this decision left on me. I have been given a great privilege to be able to pursue my passion, and to not work as hard as I can in pursuit of this passion is an insult to the sacrifices my mother made. An equally important motivation for me is that I simply love doing physics. Taking a complicated physical/mathematical concept apart and finding the simplified pictures and symmetries that make it tick gives me joy like few other things.

In high school this joy motivated me to campaign to be the first at my small rural school to take online university classes, in physics and mathematics. These classes helped me with my goal of becoming a physicist by allowing me to be the first person from the district to go to a top tier university in decades. More importantly, they also allowed me to engage with a physics education that focused on the pictures and mathematics undergirding complex physical ideas. To say that education has had a major impact in my life would therefore be an understatement, from my mother's courage in obtaining it, to my own experience. My realization of the importance of an intuitive, pictures first physics education, and my recognition of the broad impact education has had in my life leads me to want to leave a similar broader impact on other physics students.

However, as I mentioned, it is hard to separate broader impacts from intellectual merit. I can't leave a broader impact by showing students clear visions of physics without first making sure I understand every part of the physics concepts I am explaining. Nor would I want to. I deeply enjoy learning and researching physics as well as explaining it. This is why I am currently a double major in mathematics and physics, and am on track to graduate from the University of Chicago with honors degrees in both. My dedication to physics and interest in the subject also explains why I currently possess a 4.0 GPA in my major, and why most of the classes I am taking this year are graduate level physics classes. I love the challenge of graduate level physics, such as my quantum field theory sequence, as well as the greater insight they provide. My enjoyment of the challenge explains why last year I was the top score of everyone, including graduate students, in my graduate Advanced Mechanics class. My achievements in the classroom also extend to mathematics. Often mathematics is what reveals beauty and symmetries lying behind physical ideas, something I encountered all the way back in high school in my online electrodynamics lectures. Recognizing this fact is why I have endeavored to take the most advanced mathematics courses I could. For example, in my second year I took the famed Honors Analysis sequence at UChicago, and was one of only a couple of students to get an A in every quarter. I have further taken all other possible honors sequences in mathematics. Challenging myself academically like this and focusing on learning as much as possible has ensured that I was awarded Phi Beta Kappa in my junior year.

I don't just strive for excellence in the classroom, however. To fundamentally understand physics requires one to actively participate in research, forcing a synthesis of all physics learned in the classroom in pursuit of a problem. One particular topic of research that has always interested me has been fluids and nonlinear dynamics. In high school, after being fascinated by books about chaos I built my own chaotic waterwheel and studied its dynamics for my science fair project. Seeing with my own eyes an example of chaos held my interest in nonlinear dynamics. Thus the summer following my freshman year at university I attended the mathematics REU at UChicago and studied the nonlinear dynamics of the weakly nonlinear oscillator. With the help of my mentor I learned various methods in classical mechanical perturbation theory. I then independently demonstrated that regular perturbation theory fails to properly address the weakly nonlinear oscillator with analytic forcing. I further demonstrated the utility of another perturbative approach, 'two-timing', to address the weakly nonlinear oscillator.

During my sophomore year, despite the approximately 30-40 hours of work a week I dedicated solely to Honors Analysis, I was interested enough in learning more nonlinear dynamics that I contacted Professor Norman Lebovitz in the department of mathematics at UChicago. His research interests were in fluid dynamics, and together he and I worked through seminal papers in the field so that I could build up my understanding of fluid dynamics research. When the summer approached he wanted to apply my knowledge to a problem he had been involved with since his doctoral work with Chandrasekhar. It focused on the problem of self-gravitating inviscid incompressible fluids (IIFs), with the restriction to those with a linear velocity profile confined in an ellipsoidal shape, known as Riemann ellipsoids. The problem involved a disagreement between Riemann and Chandrasekhar about stability of the ellipsoids.

Professor Lebovitz wanted to restrict the recently developed Poisson bracket formulation for inviscid fluid mechanics to Riemann ellipsoids in order to develop a more useful energy criterion with which to evaluate their stability. In order to investigate the theory behind this restriction I again attended the mathematics REU at UChicago and wrote a paper on Poisson geometry as a subfield of differential geometry. This paper helped reveal to me that the passage to the Poisson bracket formulation of the problem made obscure conserved quantities into obvious consequences of geometry. Thus this project revealed the pictures that undergirded the complex physical processes governing the ellipsoids, exactly the type of physics that motivates me. Simultaneously I did original work to numerically analyze whether the proposed Energy-Casimir functions obtained from the Poisson bracket formulation would result in a more useful energy criterion. It for this work that I received the Goldwater scholarship. In the winter of my junior year my code revealed definitively that the proposed functions were not useful, at which point Professor Lebovitz suggested finishing the project, unfortunately partially because of his wife's declining health.

Despite this turn of events, I resolved to continue studying fluids due to my interest in the subject. In fact, in the early spring when I heard that Professor William Irvine was investigating the similarities between vortex knot dynamics in IIFs and superfluids I saw a potential to use the intuition I had gained with IIFs while working with Professor Lebovitz. Thus in the spring of my junior year and in the subsequent summer, I worked with Professor Irvine building a simulation of an airfoil moving in a superfluid (see proposal). I built the simulation and subsequent analytic tools completely independently, succeeding at a task Professor Irvine had been trying unsuccessfully with undergrads for several years. In fact, I did this all with minimal coding experience, teaching myself enough to be currently running my optimized simulations and analysis on the Argonne computing facilities. I devoted such significant time because the question and the broader impact of the research is fascinating to me, as my proposal will reveal.

It is not enough for me to simply study physics, even though I deeply enjoy it. I also have a passion for giving back. I want to help others to see the pictures and symmetries that make physics fun and intuitive, and pay forward the enormous impact education has had on my life. As such, ever since my sophomore year I have been involved as a tutor for the introductory calculus sequence at UChicago. I've made it my mission to engage all of the students and to ensure even if they didn't ultimately end up pursuing mathematics that they still have an enjoyable and challenging experience with it. I meet one on one with the students who are behind to identify and assist with their problem spots. I give optional challenging problems to make sure the students that are doing well aren't bored. I also do my best to explain the motivation behind concepts, using all of my experience with mathematics, whether that means connecting what we are studying to abstract mathematics or applications to physics or scientific computing. Connecting the subject to all the academic and research experiences I've had is both great fun for me and very instructive for the students, as they have told me. But most importantly, with the help of the instructor Zana Tran, I made a concerted effort to link their work to pictures so they developed an intuition. Work like this helps me to leave a broader impact, and to give back the great gift of education given to me. It also extremely rewarding to use the intellectual merit I've obtained in an effort to improve the lives and understanding of others.

I plan to continue this in the future. I will attend graduate school to study vortex knot dynamics in superfluids, with a broad interest in topologically conserved dynamical quantities of these systems. I therefore plan to continue working in the Irvine lab at UChicago, where I plan to attend graduate school. I will also learn as much physics theory as possible, as it should prove illuminating in simplifying and explaining the complex physical systems I will study. Much as I have done thus far I plan to use both my rigorous academic experiences along with my extensive research experiences to reveal to students the simple pictures and symmetries lying behind complex physical ideas. I will have this broader impact by being a teaching assistant for undergraduate physics courses at UChicago. After graduate school I plan to do postdoctoral work, and then get a tenure track position at a research university. Eventually I want to be a professor of condensed matter theory, researching the types of fluids that have always held my interest, and educating students to pay forward the huge impact education has had on my life. I would be extremely grateful to receive the NSF GRF to assist me in this goal, and would use it to continue to make possible the intellectual merits and broader impacts that have been dual themes in my life thus far.