Lucas Peña - Personal, Relevant Background and Future Goals Statement

My father fled the oppressive regime of Cuba, but died when I was just three years old. I feel that it is my obligation to honor his legacy by making a difference and helping to improve our world. I am thrilled that I am able to fulfill this goal and utilize my passion for the mathematical foundations of computer science to pursue my Ph.D. in the field of formal methods, in which I develop and use formal techniques to provide mathematical assurance of properties of computer programs. I intend to develop techniques for language-independent program verification that will allow verification to be more widely used. We rely on software for medical purposes, to maintain safety and order on land, sea, and air, in education, and in commerce. The ability to assure the validity of software can alleviate the risk of failure, and improve our world in innumerable ways.

As I embark on my journey to perform important research, either as a professor or in industry, my experience as a Ph.D. student at UIUC has been one of great intellectual discovery. I delved deeply into the study of formal methods, studying Maude and program verification, and learning about applications of software verification, machine learning, and program synthesis. I read and presented a variety of complex papers regarding applications of coinduction, model checking, verification, and much more, allowing me to fully engage with and understand the research, as well as to perfect my skills in the art of explaining and edifying this research. Moreover, I commenced my research to introduce a technique for program verification using coinduction. This research has allowed me to enhance my complex mathematical problem solving acumen. Further, working collaboratively with experts in the field, I had the opportunity to develop creative ways to move our research forward, as I learned to analyze the existing frameworks to understand how to forge ahead with a new framework. I was honored to utilize these skills when I was accepted to present this work at the Midwest Verification Day 2016 conference. I am also refining my scientific writing skills, as I collaborated on a paper regarding this research that we submitted to the conference Principles of Programming Languages. The reviews were promising, and although the paper was not accepted, I am working to integrate the comments we received, and we intend to resubmit the paper for publication.

I have always sought to challenge myself and learn as much as possible to further my goals. As a Ph.D. student, I was accepted to two acclaimed programs. At the Marktoberdorf Summer School on Dependable Software Systems in Germany, I studied the safety and security of technical software systems. I attended lectures with leading researchers from around the world, and I studied cutting-edge problems in formal methods. At the Sixth Summer School on Formal Techniques at Menlo College, I delved further into formal techniques that are frequently used to solve these pressing issues. These programs not only deepened my expertise, but also gave me the opportunity to share my research, to learn about the related research of esteemed colleagues from many continents, and to engage in lively discussions about formal methods.

The challenging research I undertook as an undergraduate at Penn reflected my passion for the mathematical foundations of computer science, and ignited the spark for my current research and for me to pursue my Ph.D. The mathematics behind programming languages first piqued my interest in my Advanced Programming class in Haskell at Penn. I noticed connections between Haskell and the Algebra class I was taking. I then took Software Foundations where I first learned about the Coq proof assistant. As a computer science major, I had assumed the correctness of code I would write, frequently with the help of seemingly comprehensive test cases. However, the mathematics side of me was never happy making this assumption. After
studying Coq, the interactive theorem prover, I was intrigued with the idea of using Coq to provide formal guarantees about programming languages, and created a research project to prove the type soundness of System FC using Coq. I worked with Professor Stephanie Weirich as well as Ph.D. student Richard Eisenberg. System FC, or GHC Core, is the core language of the Haskell compiler. To formally verify System FC would ensure the type safety of Haskell, a language on which many programmers rely heavily. The bulk of our preliminary work involved figuring out how to approach this in such a way that would not be overwhelming. To overcome this, we first decided to verify polymorphic lambda calculus, or System F. Then, our plan was to iteratively add features (coercions, datatypes, and type families) until we arrived at System FC. It was in performing this research that I had my most rewarding experience. Our complex research was the first to succeed in formally verifying the type safety of System F with coercions, and was the first step in providing assurance that this system on which some programmers rely so heavily is not at risk. Although time did not permit us to attempt to verify the type safety of datatypes and type families, by actually experiencing the success of formally verifying even one part of our project, I understood the significance of being able to perform verification on a broader level, and its many implications to improve software use. We were awarded the Computer and Information Science Senior Design Third Prize Award for the project.

My affinity for teaching is also a factor that led me to seek my Ph.D. At Penn, I applied and was selected to be a teaching assistant for multiple different computer science classes and professors, including advanced high level classes. For some of these classes, I taught lab sessions, where I covered material from some of the recent classes in a more in-depth fashion. I developed my own lesson plans in order to creatively help my students understand the material. I enjoyed facilitating the lively class discussions. When a student would ask me a question, I would often pose that question to the rest of the class to start a discussion, or I would “cold-call” on students to both keep them engaged and help me gauge their level of understanding. I look forward to the opportunity to expand my teaching abilities, and to influence and engage with students while pursuing my Ph.D. and perhaps as a career.

My decision to pursue a Ph.D. is also a result of my experience as a software engineering intern at Amazon, Inc. I worked on designing a new system for uploading batches of log files to a central location. I worked in Seattle, and had a phenomenal experience. I worked on a team that included a great group of diverse and motivated people, and we all genuinely liked one another. Through our weekly meeting with colleagues from around the globe in which we discussed and resolved issues we faced, I learned the importance of collaboration in industry. At the end of my internship, I was offered a full-time position at the company. However, despite my positive experience, I rejected the offer without much deliberation. I did not feel that this trajectory would enable me to make a significant impact on society. I wanted to solve more meaningful problems that may have not yet been contemplated.

Although my experiences at Amazon and in teaching contributed to my decision to pursue a Ph.D. and a career in research, the true guiding forces are my passion for the research I am conducting, my quest to be challenged, and my overall passion for research and the infinite ways in which research can solve problems. At Penn, I sought out and took graduate level computer science and mathematics classes while still an undergraduate. I applied for and received funding to attend the Symposium on Discrete Algorithms and the Foundations of Computer Science conferences. These conferences were my first exposure to research outside my university. I learned about a myriad of interesting problems, as well as unique approaches
and solutions to these problems, and became inspired to discover issues and techniques to solve them.

I was fortunate to have the opportunity to perform university level research while still in high school, and I continue to draw upon the skills I learned from this early research. I was selected as one of eight students to participate in my high school’s prestigious Science Research Program. I worked independently under Dr. Luc T. Wille, a Professor at Florida Atlantic University on a topic in which I was not only able to utilize my love of math but also ignited my passion for computer science. My research project evaluated and compared the potential power that can be extracted from nonlinear and linear oscillators that would otherwise be wasted, and used an entirely new theoretical methodology developed to maximize such energy harvesting. Utilizing computer simulation, I compared and evaluated at varying tuned frequencies the harvesting capabilities for nonlinear and linear oscillators. It was my introduction to science research and my eyes were opened to its incredible power, as my project had significant applications, including curing diseases with the use of nanotechnology, improvement of cell phone charging, as well as military uses. Moreover, my eyes were opened to the power within me to accomplish things I never thought possible, from working independently with a university professor, to mastering software I had not even known to exist, to painstakingly evaluating and solving complex mathematical problems.

I cultivated these passions at the selective Summer Science Program, a research program sponsored by CalTech, MIT, and NMT. I now had the opportunity to collaborate with other students. I learned Python, and gained hands on experience in computer programming. Our research consisted of observing an asteroid through a telescope. We then worked together to write software to enable us to determine the orbital elements of the asteroid, and we wrote a research paper detailing the results. I experienced the joy of working with like-minded scientists from all over the world to develop innovative ways to solve problems. We all brought differing histories and outlooks to the table, and I learned to listen and collaborate to produce a well thought out and reasoned research paper.

I have worked hard to develop strong research skills. I was selected by UIUC to receive the Graduate College Distinguished Fellowship, awarded to outstanding graduate students from historically underrepresented populations. I am one of the few Hispanics in my field, and it is my responsibility to make a lasting impact for this reason, as well as to honor my father. I was also awarded the Computer Science Excellence Fellowship to honor promising incoming graduate students. Having succeeded in one aspect of verification, I know what is needed for this challenging research. My analytical prowess, problem solving abilities, tenacity, and creativity in my research are important tools in my arsenal. I am able to collaborate with people from all over the world, and can engender meaningful discussions to develop results of which we are all proud. I not only understand complex research, but can successfully analyze and distill the research in a way that makes it clear and understandable. As I pursue the use of mathematics to prove the function of computer programs, these skills will enable me to develop and use innovative techniques to verify software. Language-independent program verification has the capacity to continue the evolution of computer science and simplify the process of verification, making our lives safer and easier, such as the validation of airline safety software or medical software. My research also has the potential to increase computer security, as verification of such programs is an important tool in that quest. My research has the power to instill greater confidence in the software we use, and this fellowship will enable me to pursue these goals.