The Purpose-Driven Engineer

A Grand Challenge Scholars Program Portfolio by Jared Kirschner

Grand Challenge: Making Solar Energy Economical

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Olin Grand Challenge Scholars Program requirements.

Reflection

Ever since I was a kid, I have always loved tinkering. I love to build things. Becoming an engineer was never really a choice, I have been an engineer my whole life.

This is the origin story I hear most frequently when I talk to practicing engineers and my peers about why they decided to become engineers. Not me. This isn't to say that I wasn't curious (I started relentlessly asking my parents questions about how the world works from age 4), or that I didn't love math and science (which have always been my strongest academic subjects). I was no more of a tinkerer than my peers who have become scientists, businesspeople, historians, journalists, educators, etc. While my time at Olin has taught me the skills I would need to be a tinkerer, to this day, I am not one. I do not build for the sake of building. I am not an engineer by default. I consciously chose to be an engineer because of the problems it would enable me to solve. I am an engineer by *purpose*.

The oil crisis of the 2000s occurred while I was in high school. I realized for the first time the dangers posed by the finiteness of oil in a society that so completely depends upon its cheap, abundant availability. I thought that I might have something to contribute to solving this challenge and my mind started racing in an attempt to come up with an idea. I decided to enter the Seimens Westinghouse Competition in Math, Science, and Technology[1] as a framework for creating and developing an idea. Inspiration struck on a solar energy idea. Unfortunately, I had few resources at my disposal (basically, what I could convince various companies to donate to me or what I could purchase at Home Depot). I cobbled something together and used equipment from my poorly supplied school physics lab to gather data. The experimental results were inconclusive, but something important came of my work nonetheless. I was now convinced that I needed to become an engineer to acquire the skills, contacts, and resources I needed to help address the oil crisis. Olin College of Engineering, with its focus on project-based engineering education, design, and entrepreneurship, offered an engaging academic environment conducive to learning and the skills I would need to affect change.

So here I am four years later. Looking back at my journey through Olin, I entered with a desire to contribute to the efforts towards a societal transition from finite, climate-change-inducing fossil fuels to renewable, alternative energy sources. At the time, I thought that better solar energy technology was the solution. I took several materials science classes early on in my college career, reasoning that this was the most relevant discipline for my goals. I tended to focus my projects on solar energy. One of my team projects, in particular, evaluated the potential of three very different solar energy technologies (silicon wafer, thin film, and dye-sensitized) to be widely adopted. Our goal was to project the trajectories of these technologies into the future in the context of global energy usage. We wrote our final report from the perspective of anthropologists and archaeologists from the year 3010 looking back on the historical trajectory of solar energy technology from the mid-twentieth century to the "present"-day. At the time, I had an underlying assumption that the world wouldn't be substantially different in 3010 (beyond technological improvements).

It turns out that there are numerous reasons to believe that the world will be substantially different in 3010 (e.g., climate change, fisheries depletion, deforestation, desertification, rapid biodiversity loss, among others). As I continued to explore the issues surrounding energy and climate change, my awareness of the many, many challenges to the continuation of present-day human lifestyles increased

[1] http://www.siemens-foundation.org/en/competition.htm

dramatically. Today I understand that focusing just on the technology to transform solar energy into usable forms (e.g., thermal energy, electrical energy, etc.) is far too narrow. What if we run out of the materials needed to create efficient solar panels? What if our methods of acquiring or disposing of solar panels release significant toxins into the environment which affect human and environmental health? What if existing economic, social, and political structures (e.g., subsidies, fully-depreciated energy infrastructure, externalities) inhibit the wide-scale adoption of solar energy technology? Addressing the world's energy needs in a sustainable way requires a very broad focus; as such, I have tried to acquire the skills, knowledge, contacts, and experience needed to understand the greater context of my mission. There are many ways to solve a problem, and not all of them involve squeezing the last few percentage points of efficiency from a technology. Technology is frequently not enough to solve a problem.

While at Olin College of Engineering, I have had the opportunity to work on many interdisciplinary projects, both individually and with teams. These experiences have broadened my understanding of energy and sustainability concerns. Among the projects I have tackled over the past four years are:

- Consulting for Preserve Products[2] (Massachusetts)—a company which makes consumer products from recycled polypropylene—within the context of a materials science failure analysis course. The goal of the project was to find a way to increase the sustainability of their recycled polypropylene Everyday Plate line[3] while maintaining its product performance.
- Consulting for MetroWest Medical Center (MWMC)[4] (Massachusetts)—a privately-owned hospital with two campuses in Greater Boston—within the context of a sustainability consulting course. The team comprised of team members from Babson (business), Wellesley (liberal arts), and Olin (engineering) Colleges worked to develop and propose strategies for MWMC to reduce its energy usage.
- Conducting research of the social, economic, and political factors driving illegal electric and electronic waste trade from developed nations to developing nations and evaluated life cycle assessments of such products to determine their environmental impact. This was my individual final project for a hybrid political science and environment science course focused on the social, political, and economic causes and consequences of environmental problems.
- A campaign proposal for the town of Wellesley to promote a more sustainable lifestyle and help the town to meet its renewable energy goals. Said proposal was the result of a semester-long study of sustainability on a particular city block in Wellesley performed by a team of Babson, Wellesley, and Olin College students. The campaign proposal addressed what we had identified as the key problems and their respective causes with regards to sustainability for the city block under examination.
- Evaluation of strategies China could employ to drastically reduce its carbon footprint and the potential of the United Kingdom to meet its present energy demand with different renewable energy technologies, including solar; study of the relationship between the historical trajectory of civilizations across the world in different periods of history and their environmental context. Both of these works were performed in the context of a hybrid history and environmental science course focused on investigating the relationship between societies, their environments, and energy.
- Evaluation of the effects of different types of business models on the environmental and economic performance of a start-up automotive company—Lit Motors[5]. I performed this

[2] http://www.preserveproducts.com/
[3] http://www.preserveproducts.com/products/tableware/everyday/preserve-everyday-plates.html
[4] http://www.mwmc.com/home.aspx
[5] http://litmotors.com/

evaluation specifically for Lit Motors in the context of a sustainable business course because I would be working there as an intern over the upcoming summer. I delivered my analysis to the CEO and Founder of Lit Motors and received a very positive response.

From these project opportunities (and many others, including ones not explicitly related to sustainability), I have learned that the scope of the challenge of affordable, abundant solar energy is much broader than it appears and goes far beyond technical considerations. Engineering is just one of many disciplines that will be needed to make a clean energy future a reality: product design and marketing needed to make clean energy technologies appealing; business is needed to make development and deployment of clean energy technologies financially sustainable; political science is needed to understand the political and legal structures which affect the viability of clean energy technologies; sociology, psychology, and behavioral economics are needed to understand and influence people's decision-making regarding clean energy technologies; history is needed to understand why existing social, economic, political, and technological structures came to be; the list goes on and on. I hope that my experiences at Olin College will allow me to further bridge these disciplines, and support my efforts in facilitating the collaboration between scientists, engineers, historians, sociologists, economics, politicians, lawmakers, and others.

As I prepare to graduate, I look forward to the future with mixed feelings. I am pessimistic about the ability of human civilization to reach the consensus necessary to solve some of our largest challenges, such as climate change. From my real-world project experiences, I have realized that making change is, in a word, hard. However, I am optimistic because I know that the solutions do exist and that I am well-equipped to contribute to making a difference. I will no longer be the lonely high school student working by himself without any resources in an attempt to solve grand-scale societal challenges; I have a talented network of multi-disciplinary peers, significant practical engineering experience, access to knowledge and material resources, and, most importantly, a renewed confidence in my ability to contribute to the process of changing the world for the better. I cannot do it alone, but we can do it together.

Grand Challenge Project—Making Solar Energy Economical

As discussed in my reflection, I have spent a considerable portion of my academic career focusing on sustainability issues, many of which related to the Grand Challenge of making solar energy economical. My first experience in this field was in the context of an integrated materials science and history course. For the course final project, my team attempted to forecast the future of the solar energy industry. In order to make a well-informed prediction, we couldn't just look at the predominant commercial solution of the time (silicon wafers); today's emerging or research-stage technologies may become the widespread commercial technologies of the future. After a survey of the field, we chose to evaluate silicon wafer, thin film, and dye-sensitized photovoltaic technologies.

Comparisons of these three technologies could have been done by performing a literature search of recent studies. We could have researched the current commercial-grade efficiencies, research-grade efficiencies, and predicted maximum efficiencies of each of the technologies. And we did. However, conversion efficiency from sunlight to electrical power is not a sufficient performance metric to predict the likelihood of an energy generation technology to be widely adopted. Other metrics, such as cost, mechanical robustness, and long-term degradation, are important as well. For this reason, we purchased

DIY[6]-grade silicon wafer and thin film solar cells. We had to actually make our own DIY dye-sensitized solar cells from scratch, as DIY-grade cells weren't yet widely available for purchase. The energy performance of each technology type was measured for three different lighting conditions (full sunlight, indirect sunlight, fluorescent indoor) as a baseline. The cells were then exposed to a battery of environmental degraded tests (e.g., various levels of sandblasting) and the energy performance was once again characterized for each lighting condition. We found that while silicon solar cells were the most efficient, thin film solar cells were the most robust technology by far. Additionally, all solar technologies seemed poised to reach grid parity[7] in the not-too-distant future.

Looking back on this project (completed during the second semester of my first year), I realize that I have come a long way during my time at Olin. First and foremost, predicting the future is a notoriously dubious task. Solar technology adoption has definitely progressed much less since my first year at the College than I had expected. I came into Olin thinking that widespread adoption of solar photovoltaic technology was the definitive future. I didn't understand that solar photovoltaic technology might have some downsides (despite the "clean, free energy" from the sun). I also didn't understand that there are many factors affecting technology adoption. For example, "grid parity" isn't a sufficient condition. Many individuals and organizations do not adopt solar photovoltaic technology because of the large upfront cost, even if the lifetime return on the investment may be positive when compared to the grid. There is also the concept of a discount rate, where recouping one's investment in a solar array 10 years from now isn't nearly as attractive as keeping one's money and/or investing it in a different, more immediately profitable opportunity. I also did not appreciate the potential role that developing nations could have in fueling the growth of the solar industry; without a fully-depreciated electric grid as in the U.S., distributed generation technologies—such as solar panels—become a much more attractive option. I can now look back on this project and realize that I could do so much better with the additional knowledge and experience I have since gained; I hope that I can say the same thing three more years from now.

Interdisciplinary Experience—Babson-Olin-Wellesley (BOW) Three College Collaboration

Nearly all of my experiences at Olin College of Engineering could be described as interdisciplinary. Most of my work in school takes the form of team projects. Team members often have a variety of different disciplinary backgrounds within engineering. Often the projects require drawing on the knowledge of other disciplines, such as entrepreneurship and design. However, these interdisciplinary experiences are all within the context of Olin—a diverse, but likeminded group comprised exclusively of engineering students.

Recently, Olin College entered into a strategic partnership with Babson (business) and Wellesley (liberal arts) Colleges to form the Babson-Olin-Wellesley (BOW) Three-College Collaboration. One of the goal of this partnership is to expand the interdisciplinary opportunities available BOW students. I participated in two flagship programs that this new collaboration has so far established—Affordable Design and

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[6] DIY stands for Do-It-Yourself

[7] Grid parity refers to whether the cost per unit energy of an energy generation technology is less than or equal to the price of electricity from the electric grid in a region. See the report found at this link (http://www.nrel.gov/docs/fy10osti/46909.pdf) for more information.

Entrepreneurship and the Sustainability Certificate Program. (More information on my experiences in Affordable Design and Entrepreneurship can be found in the Global Awareness section.)

The Sustainability Certificate is a BOW academic program requiring the completion of an introductory program-specific sustainability course, five electives distributed across engineering, liberal arts, and entrepreneurship sustainability, and a program-specific capstone synthesis course. At the outset of my Olin education, I was drifting towards adopting the perspective of the technocrat—that all societal problems can be solved by technological development. But upon taking courses at Wellesley and Babson Colleges, I realized that many disciplines think that their approach can solve all societal problems. From the framework of liberal arts, a sufficient understanding of politics, human psychology, social structures, history, culture, and economics may go a long way in addressing many problems. From the framework of business, a free market, capitalist system with incentives for innovation and entrepreneurship may create an environment in which problems can be solved and solutions can be rapidly replicated and scaled. I realized that my perspective as an engineer was narrow and uninformed as to the sheer complexity of many of the problems I wanted to help solve. Technology is often a necessary part of the solution, but it is never sufficient. One of the strongest arguments against the sufficiency of technological solutions is that, for many sustainability problems, the technology already exists—so why hasn't it been widely adopted and the problem alleviated? There are many structural factors of a society beyond its technology that drive its operation—social, political, economic, legal, and even religious structures are powerful forces which can present an incredibly high inertia to change. I now understand that there are many ways beyond engineering to solve a problem, and appreciate that I will need to assistance of my Babson and Wellesley College peers (among many others) to make significant beneficial change.

Unfortunately, appreciating that I will need to work with non-engineers to solve problems doesn't mean that I will be successful in doing so. Despite a heavy focus at Olin on teamwork, I found working on teams with students from all three schools (Babson, Olin, and Wellesley Colleges) incredibly challenging and frustrating. I didn't understand why some students were so unresponsive to e-mail, passively participating, and unwilling to meet at odd hours. The reasons only came to me upon much reflection and communicating with some of my trusted advisors: students at other schools are not on their computers using e-mail 24/7 as they are at Olin, and cannot be expected to respond to e-mails as quickly or during all hours of the day and night; engineers (myself included) tend to present their opinions very strongly (almost as though asserting a fact) and expect their peers to correct them or respond in kind—a very different communication style than is used by business people or liberal arts students; working and meeting at all hours of the day and night is common at Olin and understood as a necessity, but students at other schools were not culturally expected to make such sacrifices and unwilling to do so just at the request of Olin students. I needed to recognize that I could not treat all students on my team as though they were Olin students—we had different perspectives, working expectations, priorities, and even language. While I still have much room for improvement in working with non-engineers, I am increasingly aware of potential problem spots (there are certainly many more than those articulated above). If I want to make significant change in the world (such as making progress on the Grand Challenges), I will need to understand how to work effectively with people from different disciplinary backgrounds and cultures.

Entrepreneurial Experience—Lead Electrical and Computer Engineer at Lit Motors

The development of cheap, ubiquitous solar energy is not sufficient to address the risks posed by current global energy use patterns. Much of our society depends heavily on fuels rather than electricity. For example, the automotive industry uses fossil fuels largely because of the superior energy density when compared to other sources (e.g., batteries charged by solar energy). While electric vehicles and the supporting infrastructure could play a key role in a robust energy grid powered by renewable sources, few electric vehicles have seen widespread adoption to date.

In the summer of 2012, I was inspired to work with a unique start-up in San Francisco, CA, focused on making full-scale electric vehicle adoption a reality. Lit Motors is developing the C-1—a fully-electric, fully-enclosed, self-balancing motorcycle which drives like a car. The C-1 provides the safety and convenience of a car with the efficiency and compactness of a motorcycle—the best of both worlds. When I arrived, Lit Motors had just completed its first full-scale prototype, which drove at a modest speed of 3 mph while barely maintaining stability. At the time, there were no electrical and no computer engineers at the company; thus, I became the Lead Electrical and Computer Engineer at Lit Motors for the duration of my internship.

One of my first tasks was to decide what it is that I would be working on over the summer. Automobiles are very complex systems with thousands of parts and subsystems which must together achieve the highest level of safety. The first C-1 prototype was nowhere near where it needed to be to enter production. I could have started working on a variety of technical challenges: designing redundant electrical systems, defining a bus communication system and protocol, working on power regeneration from breaking, creating a dashboard touchscreen, and many other interesting electrical and computer engineering challenges that would need to be addressed at some point.

But before diving into solving technical challenges, I took a step back and thought about what Lit Motors needed most at this particular point in time. It was an early-stage start-up that was working on a very capital intensive venture and had yet to receive venture capital backing. What we needed most was funding. In order to secure funding from investors and venture capitalists, we needed to mitigate the largest technical risk to success—the car's gyroscopic stabilizers. Potential investors would only believe that the C-1 could be made a reality if we demonstrated stability under a variety of driving conditions (e.g., vehicle speed, wind, slanted and graded roads, rate of turn). We needed a second prototype which could demonstrate the feasibility of a production-grade stability system. And we decided that the perfect venue for showing off our new prototype would be at Tech Crunch Disrupt SF 2012—a tech start-up competition attended by some of Silicon Valley's top venture capitalists, technologists, and start-ups—that would happen just after the completion of my summer internship.

With the goals of the second prototype defined and a target deadline set for the end of my internship, I began to work on defining a system that would best achieve our goals. We decided to create a development platform that would enable rapid prototyping of the stability system, rather than focusing on production concerns such as cost and scalability. A flexible hardware/software platform was chosen that had much higher specifications than we thought we would possibly need, allowing for experimentation with many different sensors and software algorithms without being constrained by the limitations of our platform. Testing platforms, like the one shown in Figure 1, were constructed and used extensively in lieu of the vehicle prototype itself, where mistakes would be much more time-consuming and costly to fix. I specified electrical hardware, designed and implemented the entirety of the vehicle software, and helped manage the timeline of the overall project and that of other interns, among many other things (it was a start-up, after all). By the end of my internship, the vehicle software was completed and tested, awaiting full hardware integration (see Figure 2). Lit Motors presented at Tech Crunch Disrupt SF 2012 (see Figure 3) and placed a strong 2nd. After watching the vehicle I had worked so hard on drive smoothly onto the competition stage, I realized that I had the skills and mindset needed to build a solution to a complex problem, even in an environment as uncertain as an ambitious start-up.

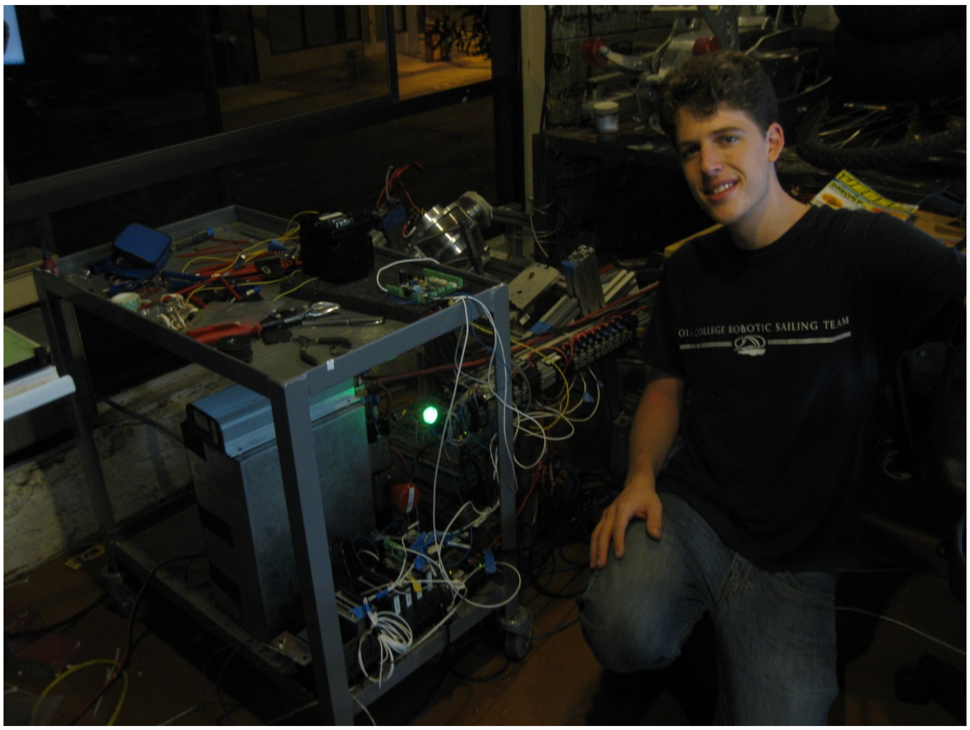

Figure 1. The C-1 stability system test platform used to prototype hardware and software integrated system designs. This test platform allowed me to validate the efficacy of the design without risking the full vehicle prototype.

Figure 2. The C-1 vehicle prototype (version 2) awaiting the integration of hardware and software validated on the test platform.

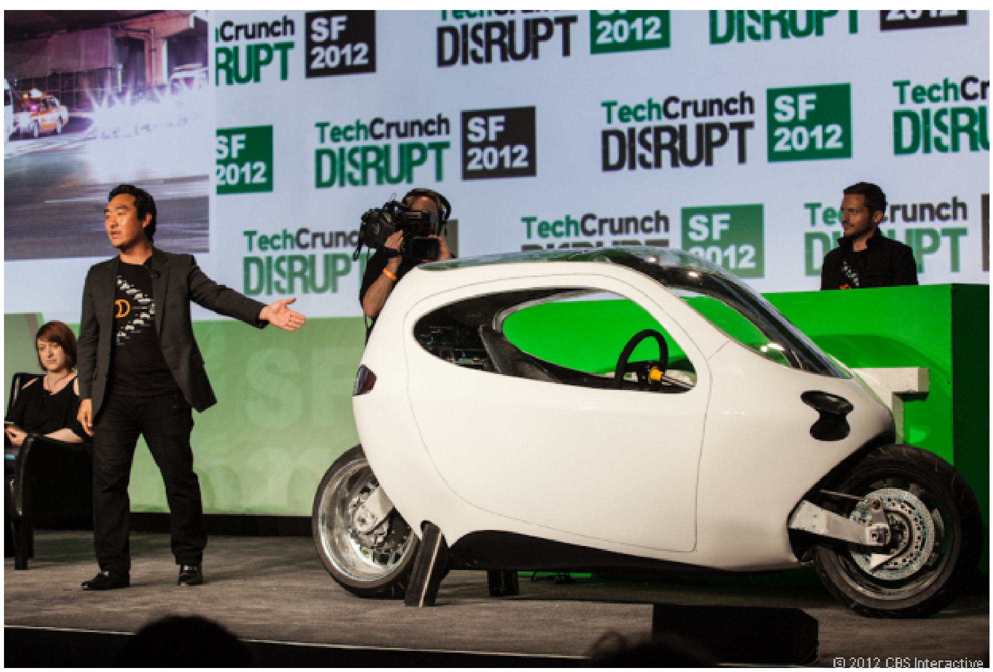

Figure 3. Presentation of C-1 vehicle prototype (version 2) at Tech Crunch Disrupt 2012 [image courtesy of CNET]. The vehicle was driven on-stage to an audience which I imagine was shocked to see anything other than a software start-up in Silicon Valley.

Global Awareness and Service Learning—Affordable Design and Entrepreneurship

The Affordable Design and Entrepreneurship (ADE) program at Olin and Babson Colleges operates as an international development design firm, bringing together engineers and entrepreneurs to work with actors (e.g., governments, NGOs, businesses, activists) in underserved communities to address the needs of those in poverty. Traditionally, the knowledge and experience of engineers is applied to the most fortunate citizens of the world, creating marginal improvements in their quality of life. However, engineering has much to offer to the impoverished majority of the world, for whom small changes can lead to great improvements in quality of life. The ADE program is built on a set of robust principles about the way in which such technical assistance should be given in order to be effective. Solutions cannot be developed by external experts in isolation and then expected to be successful in underserved communities. Without an understanding of the local context, an appropriate solution cannot be developed. Are we addressing the right problem? Can the product be produced and repaired locally? Can the venture be operated and scaled by the target community? Will the venture be successful in the community? And does the venture actually produce a net benefit to the community? None of these questions can be answered remotely, and learning the answer after the development and deployment processes have been completed is extremely costly and wasteful. We learned making long-lasting, sustainable change requires partnering with a local actor who can support venture research, design, development, deployment, and scaling.

During my involvement in ADE, I was working on several projects in India, most of which targeted rickshaw pullers. Rickshaw pullers in India are essentially one small step above rural farmers on the socioeconomic scale in India. Many of them start as rural farmers who come to cities looking for work, ultimately reverting to the bottom of the urban work structure when unable to find other work. They work long hours pulling loads in excess of 400 pounds to earn just enough money feed their families. In partnership with a local NGO (Rickshaw Bank[8]) which provides a rickshaw rent-to-own service to pullers, our team was working on finding ways to improve the lives of these rickshaw pullers. The project I was primarily involved with discovered an area of opportunity in matching customers with rickshaw pullers. Rickshaw pullers often wait at the intersections of major streets for customers, as this maximizes their likelihood to get customers. However, for potential customers which are not close to a rickshaw puller aggregation sites, they may walk up to 30 minutes (or more) to find a rickshaw puller. If we could match up customers with rickshaw pullers more efficiently, the process of taking a rickshaw would take much less time. This might increase the customer pool for rickshaw pullers and increase the amount that rickshaw pullers can charge (due to the increased value provided by expedient service).

But how could we provide this matching service at a cost that would leave some increased profit to rickshaw pullers? We found that nearly all rickshaw pullers in India have basic cell phones (not smart phones), and that, in India, only the caller pays for a phone call. By taking advantage of technology that the rickshaw pullers and potential customers are likely to already own, the service could be adopted quickly and at low cost. The last piece we needed was a way of dispatching pullers to customers. There are many different ways to implement such a service with different levels of automation. Ultimately, after much consideration, we decided to try an automated approach using cell phone triangulation to match the closest customer and participating rickshaw puller. This approach required working with a local telecommunications company (Vodafone) which was willing to work with us to make this a reality.

[8] http://www.crdev.org/rb.asp

After months of hard work culminating in a one-week site visit to Guwahati, Assam, India, we realized that there were several significant problems with our design. Compatibility across operators was going to be a nightmare to arrange between Indian telecommunications companies; Vodafone's primary interest in the project was to fulfill a recently passed Indian law requiring telecommunications providers to begin offering location-based services; rickshaw pullers are regularly abused by customers and police, and were concerned that such abuse could be staged by an abuser calling into the service pretending to be a customer; and many others. Some of these problems could have been identified much earlier if our local partner (Rickshaw Bank) was not pre-occupied with a significant, unexpected threat to its existence. In an attempt to diversify our partners in Guwahati, we initiated a relationship with IIT Guwahati just prior to the site visit. Students from IIT Guwahati worked with us during our visit (see Figure 4); together, we were able to identify problems that could only be understood through an on-site visit and personal interaction with the local rickshaw pullers we were trying to help.

After the site visit, we proposed to move forward in a new direction. There is much competition within the Indian telecommunications market to develop a very cheap, GPS-enabled smart phone. Some of our contacts in the industry suggested that this might occur in the next 1.5-3 years. This would resolve many of the challenges related to working with telecommunications providers directly (required for triangulation data). In the meantime, we suggested continuing to work on the design assuming a GPS-enabled smart phone platform, allowing our service to hit the market early. My hope is that this design will be carried forward by future ADE India team members, eventually leading to the improvement of rickshaw puller's lives.

Figure 4. Students from Tezpur University interning at IIT Guwahati for the summer. We worked together to understand the context of rickshaw pullers working in Guwahati, Assam, India and to improve our venture design.

Figure 5. Interacting with rickshaw pullers at a bird sanctuary in Delhi, India. We spent a day with the rickshaw pullers shown above who ride in the park in order to understand their unique challenges (which turned out to be very different than the street rickshaw pullers in Assam, India). This visit laid the foundation for a new, future partnership with the rickshaw pullers in this bird sanctuary.

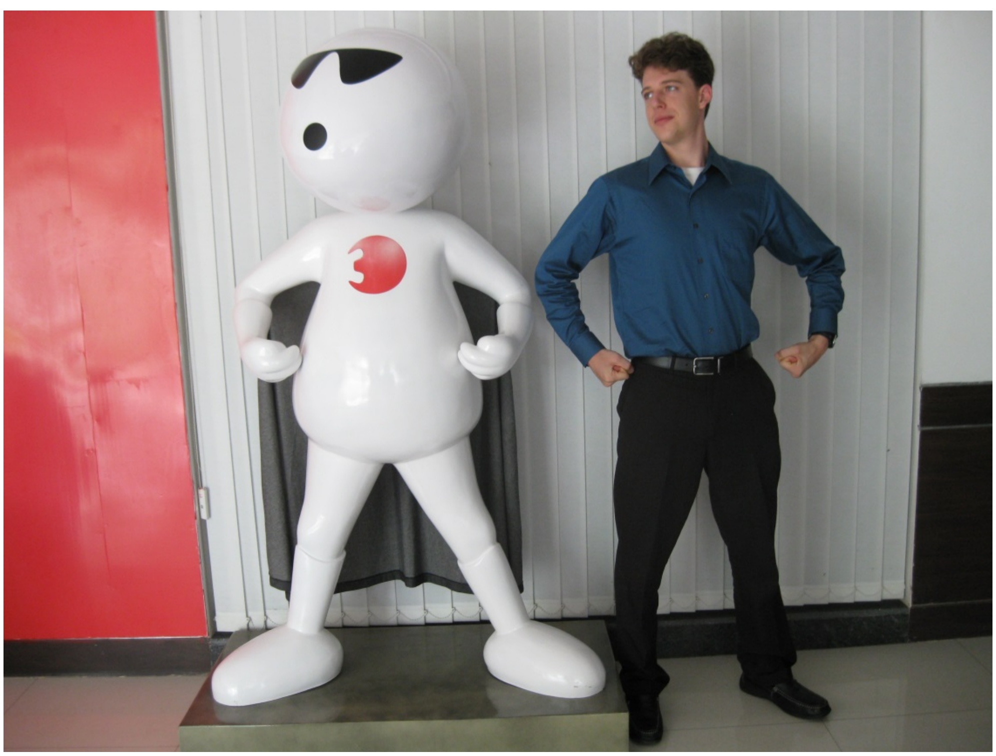

Figure 6. The Vodafone man (left) and I (right) at Vodafone's offices in Guwahati, Assam, India.

Conclusion

I have changed significantly over the course of my time at Olin College of Engineering. I have acquired what I had intended—the skills, contacts, and resources needed to address the oil crisis—but, not in the forms I had expected. For example, I initially intended to graduate from Olin College with a materials science degree, enabling me to address the technical challenges associated with solar photovoltaic technology. Instead, I will graduate as an Electrical and Computer Engineer with a broad, interdisciplinary background that allows me to contribute to solving problems like the oil crisis from any number of angles, including technology. My perspective on the sustainability challenges facing our future is now far broader, and I will continue my mission to address such challenges moving into the future. This is a deep obligation I feel to myself, the world, and to the Olin College of Engineering community for all of the support it has given me and will continue to give me. I cannot stand idly by, for I am an engineer by purpose.