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Tinkers: Robots, Makers, and the Changing Face of 21st Century DIY

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A Capstone Project Submitted in Partial Fulfillment of the Requirements of the Renée Crown University Honors Program at Syracuse University

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Honors Capstone Project in Magazine Journalism

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Abstract

Project URL: www.tinkers.lindaggorman.com

My capstone project takes the form of a website, accessible at the URL above. The site features nine different journalistic pieces reported and produced over the course of the past year, all centered on the themes of robotics and cutting-edge DIY communities. I worked in several different media, from traditional print to audio to infographics. Though this project officially falls under the category of magazine journalism, my capstone also had a heavy technical component associated with creating the website and writing scripts to collect and visualize data.

In terms of the content, I reported and wrote about a variety of inventors and creator communities, with a particular focus on robotics. During the course of my research I visited labs and spaces in Japan, Syracuse, Philadelphia, and my hometown of Wilmington, Delaware.

Executive Summary

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For my capstone project, I investigated several different angles of robotics, DIY-style hardware engineering, and maker culture in order to put together a magazine-style multimedia package. Though the project spans a number of topics, the connecting thread throughout is a focus on communites of innovators, particularly those outside of traditional avenues for tech research. During the course of my research I interviewed students, artists, engineers, entrepreneurs, and hobbyists, among others. Regardless of their area of interest, nearly everyone I talked to shared a certain penchant for putting things together and taking them apart, fixing, building, inventing, and innovating. In short, whatever their day job, they shared a common vocation: they were tinkers.

The completed project, presented on a website that I designed and coded myself, includes a collection of interrelated stories all revolving around my central topic. The stories are presented through the lens of several different media, including photo, video, audio, as well as a three traditional text-based stories. I also produced a couple of pieces that fall under the category of data-driven journalism, including an interactive map and a data visualization.

In terms of the web presentation, I aimed for a simple aesthetic that would make it easy for users to navigate the project and understand how the various parts came together. Each piece is featured as an image against a black backdrop, with a title and a short description of the subject. Clicking on a box brings up the corresponding content in a modal window in the center of the page, formatted differently based on what kind of media is being presented.

I did the reporting for this project over the course of about a year, starting during my spring semester abroad in Japan. Given that Japan produces more robots than any country in the

world, and is known for having slightly unusual cultural attitudes towards robots, studying abroad seemed like a natural opportunity to collect interviews and information. After meeting up with a journalist in Tokyo for some background info, I visited robotics scientists at the renowned Asada Lab at Osaka University, and went to a meeting of robotics enthusiasts working on the world's tallest two-legged robot.

The research I did in Japan ended up being the starting point for the first story I put together for the project, a piece on the RoboCup that took place in Brazil last summer (the RoboCup was founded by Minoru Asada, the leader of the lab I visited as Osaka Daigaku). After interviewing students and an advisor at the University of Pennsylvania that were part of one of this year's winning team, I put together a story that was eventually published in October's edition of student publication *Jerk*.

My time in Japan also yielded several pieces of my final project, including a short video of some of my favorite robotics exhibits in Tokyo, and a sort of reported/personal essay about sitting in on a meeting of roboticists trying to build a life-sized version of anime series Gundam fighting robots. Reporting in Japan was challenging -- my Japanese is limited, and I often felt like I was missing cultural cues. But the good outweighed far outweighed the negatives. I never got bored; living and reporting abroad gave me a window into a world that was completely outside of my experience.

As I continued researching robotics and tech after coming back home, I started focusing in more on the topic of hobbyists and amateurs working on robotics hardware outside of traditional academic or corporate environments. I learned about the maker movement, a subculture based around DIY craftsmanship, primarily in the tech space. Richard Hatch's *The Maker Manifesto* and Chris Anderson's *Makers* provided useful background information.

Anderson dubs the maker movement "The Second Industrial Revolution" and points to the widespread commercial availability of programmable microcontrollers and 3D printers for the movement's success. The availability of relatively affordable personal manufacturing software has radically reduced the cost of prototyping, clearing the way for a whole new generation of hardware startups coming out of dorm rooms, basements, and increasingly, makerspaces.

Makerspaces are community spaces that provide members with space, tools, and educations to work on independent or collaborative projects. Since they seemed so inextricably tied up with the whole idea of making and hacking, I started investigating these spaces as a part of my project. I visited makerspaces in my hometown of Wilmington, Delaware and nearby Philadelphia. I also talked to a developer working to turn old industrial buildings in poor areas of Philly into spaces for makers, and an author who recently compiled a book of essays about makers who turned their hobbies into full-time businesses.

I learned that makers came from all kinds of backgrounds -- artists, engineers, craftspeople and more. As Anderson said in his book, it seemed that making these new tools available was opening up new opportunities for hobbyists outside of traditional research or corporate environments. Throughout the history of computing, hobbyists and industry outsiders have had a big role to play. Some the earliest explorations into the possibilities of computing were made by the legendary hackers of MIT's Tech Model Railroad Club, students who often neglected their studies and social lives outside the club to spend endless hours writing scripts on teletype to perform simple tasks. With the help of fellow TMRC members, early computer scientist Steve "Slug" Russell put in over 200 hours of work to design and code the first ever computer game, *Spacewar* in the early 60's.

About ten years later, the creation of commercially available microprocessors by a newly created company called Intel brought the computer revolution to the people. The first DIY personal computer offered at an affordable price was the Altair, released in 1974. The computer was incredibly difficult to put together, and harder still to operate -- without peripherals programmers had to painstakingly flip switches on the front of the box to input code, and interpret blinking leds as output. But after the computer was featured on the front page of *Popular Electronics* thousands of hobbyists eagerly wrote in for their own kits, enticed by the possibility of harnessing the power of computers in their own basements. The new tech brought communities together, most famously in the case of the Homebrew Computer Club in the Bay Area.

Hobbyists and new entrants into the world of hardware have the potential to play a major role in 21st century innovation. The playing field is leveling out with each year that passes, largely thanks to the community groups and shared spaces (on and offline) that provide access to tools and connect people with common interests. Through this project, I hope to provide a little bit of insight into what is on the horizon for the modern day tinker.

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Notes on the Format

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Given that I produced this project with the web in mind, my capstone is best experienced directly in the browser. The website includes a number of multimedia elements that can only be accessed directly on the site, either because they are interactive or because they employ audio or video. That said, for the purposes of this paper submission I attempted to incorporate elements of the project in several ways. First of all, immediately following these notes I included text for the three written articles that appear in the piece. I have also included screenshots of various elements of the project throughout my reflective essay where relevant.

Text-based Stories

#1: Make It or Break It

Six people sit around the table for the Wilmington makerspace's first Arduino meetup of the year, on a day so bitterly cold that the local school district delayed classes. Three of us are here for the first time. Paul is a serious postdoc from the University of Delaware, interested in using the Arduino in combination with pH sensors for his research. Jason, who works for eBay, drove 45 minutes from Pennsylvania to ask about using the programmable microcontroller for a hydroponics project. I pull out my own jumble of wires and 3D printed parts and tell my new acquaintances that I'm trying to build a mini robot. Jason answers my question about controlling multiple motors at the same time, and Paul suggests that I add a speaker for it to say 'kill all humans.'

The two-year-old group, officially titled "Barrel of Makers," just found meeting space a couple of months ago. A makerspace, a close cousin to the hackerspace, is a community space equipped with tools for making -- ideally -- just about anything. The "make" terminology was first used following the launch of *Make: Magazine* in 2005, a niche publication focused on DIY projects and the tools that could be used to make them. Since then, the brand expanded to encompass kits, books, and Maker Faires, events where artists, engineers, and tinkerers demo projects they have created.

Jessica Taylor, the co-founder of Barrel of Makers, got the idea to start a makerspace in Wilmington after attending a Maker Faire in New York City. A former art student, Taylor expected to spend all her time in the art section. Instead, she found herself taken with the tech exhibits. Now, she teaches soldering workshops to kids out of the space in Wilmington. On the night of the meetup, she shows me how to use a wirestripper.

The Wilmington makerspace is bare bones. The modest space the group occupies above a shabby athletic center was the product of a city government initiative to support entrepreneurship, and is only leased temporarily. Barrel of Makers owns just one 3D printer, a temperamental MakerBot that Taylor and her husband built themselves from a kit after soliciting donations in exchange for a promise to pass the machine around.

Makerspaces come in all shapes and sizes. Twenty-five miles by train from Wilmington, the premiere makerspace in Philadelphia is a 21,000 foot workshop downtown called NextFab. NextFab's two story facility is all high ceilings and wide-open spaces, complete with a polished reception area and a kitchenette. There is a full woodshop, a walk-in paint booth, dozens of 3D printers of all varieties, a huge CNC machine that carves out designs with high powered streams of water, and one of the only publicly available pick-and-place machines in the country. All this does not come cheap -- a standard membership costs about $250 a month. NextFab, like TechShop and several other branded makerspaces, is a for-profit company and demonstrates the reality that having nicer tools costs more. It also limits the number of people that can afford to use a space.

Still, my tour guide Marcella points out that members can get their money's worth just by using some of the space's more expensive software programs. Compared to what using similar tools cost 10 or 20 years earlier, NextFab's hefty price tag begins to look like a bargain.

3D printers, in combination with other computer-aided desktop fabrication tools like CNC machines, laser engravers, and 3D scanners, have been central to the maker movement. The availability of these tools at relatively low costs vastly expanded the range of what hobbyists and tinkerers can make without having to sacrifice too much time or money. Ten years ago, having a prototype made would involve paying someone to make a 3D model, paying

to get an injection mould made, and shelling out even more cash to get the product manufactured. Now, a complete novice can design something using CAD software, upload it to a 3D printer, and hold teh physical product within a few hours. In combination with programmable microcontrollers like the Arduino, technically inclined makers can put together all kinds of gadgets, including robots, wireless connected smart objects, and even prosthetics. Within the last few years a number of major entrepreneurial projects have come out of makerspaces, most notably Square Inc. Co-founder Jack McKelvey built the first 50 prototypes of the company's signature credit card reader on a CNC machine at a TechShop makerspace in Menlo Park, California.

McKelvey's style of entrepreneurial spirit is not limited to spaces in the famously startup-crazy Bay Area. In 2013, Syracuse University senior Ben Marggraf was given an assignment for an entrepreneurship class to come up with a problem to solve. As an engineering student he did a lot of 3D modeling, but working with 3D objects on a 2D screen frustrated him. He started to think about the movie *Ironman*, and how Tony Stark could just reach and manipulate the holograms in his lab. "I thought, why can't we just use our hands to do something like that?" Marggraf says.

Two years later Marggraf's company has a name ('Contact'), a slogan ('Feel the unreal'), and a neat $10,000 in startup capital from a university-sponsored pitch competition. But more importantly, Marggraf and his partners Tim Meyer and Tom Buchanan have a fully functioning prototype: a glove than can be used to control a hand in virtual space. The team, all bioengineering students, built and programmed the hand using Arduino and 3D printed parts fabricated at the Syracuse University campus makerspace. Marggraf describes the makerspace as the team's headquarters. "It's a huge asset," he says.

Marggraf's partner Buchanan adds, "And having John here. He's a wizard." The man Buchanan is referring to is John Magicaro, a middle-aged part-time musician with a ponytail who knows everything there is to know about putting things together. He sewed his wife's own wedding dress, maintains a huge garden, and makes his own maple syrup. With the exception of a few years spent touring with his band, Magicaro has worked in the AV department at SU since the '70s. A few decades ago, he was fixing VCR tapes and projectors. Now, he puts together and maintains the cutting-edge machines at the makerspace, incidentally located at a former nightclub where Magicaro's band played in 1979 (he has the poster hung up in his office). "I'm a guy that tinkers and builds stuff," he says. "Since I was born."

'Maker' is a relatively recent term, but people like Magicaro have always existed, tweaking and tinkering and taking things apart and putting them back together. Makerspaces offer a place for these people to get together and share tools and ideas, much like the Tech Model Railroad Club at MIT in the '60s, or the legendary Homebrew Computer Club in the Bay Area in the '70s. But part of what makes current maker communities different from hobbyist groups of the past are the online spaces that live alongside their brick-and-mortar counterparts.

"I think that ultimately it's the Internet ultimately that's the most helpful," says John Baichtal, a blogger for *Make* magazine and author of 10 how-to books on topics ranging from Arduino based robots and DIY Drones to cool tricks for hacking your bike. "You can have groups of people who are interested in very specialized kinds of making."

Baichtal recently published a book titled *The Cult of Lego* about the adult Lego community. He describes how enthusiasts often go through what they label a "dark period" where they stop tinkering with Legos because they worry about being too old to play with toys. Finding an online community with a similar interest can bring that dark period to a close. In

some cases, the growth of niche communities can create demand for products that would be too outlandish for mainstream markets. Chris Anderson's book *Makers: The New Industrial Revolution* recounts the origin story of Will Chapman's company BrickArms, which goes where the Lego corporation is too family-oriented to venture -- he designs and manufactures weapons for Legos. When Chapman's sons wanted to replicate a WWII battle in Lego, Chapman designed a few replicas on CAD software and printed them out on a desktop CNC machine. As it turns out, Lego AK-47s are enough in demand for Chapman to quit his job as a software engineer and ship his Lego arsenal to six different countries.

Anderson's own personal narrative is also a strong testament to the power of the internet. After putting together a Lego autopilot for his son's toy helicopter, the former *Wired* EIC started a website called DIYDrones.com for fellow drone hobbyists. Through the site he connected with a man named Jordi Munoz who had shared a particularly cool Arduino helicopter project. Munoz, who as it turned out was a 19-year-old with a high-school education and a so-so command of English, would eventually team up with Anderson to found 3D Robotics, now a multimillion dollar company.

For the humble club meeting that gathers above the gym in downtown Wilmington, the web has been integral to connecting with new members. Taylor says most people who show up find the group through Barrel of Maker's listings on Meetup.com. That's how I ended up here, and the same goes for Paul and Jason. Jason mentions that he has heard talk about starting a makerspace in Kennett Square, his hometown in Pennsylvania. After about an hour, we pack up our things and bundle up to head out into the night. I leave with more than I came with: I've picked up a coil of wire, a couple of business cards and a head full of ideas about what to make next.

#2: Sakamoto's Workshop:

It's pouring rain the day I meet roboticist Hajime Sakamoto at the Fuku train station. Osaka in the rain is all wet, gray pavement and clear plastic umbrellas as masses of people rush from the shelter of one train station to the next transfer. But on this Monday evening, the Fuku station on the Hanshin Namba line (30 minutes and three transfers from my dorm) is not crowded. I easily spot Sakamoto waiting for me.

Small and slight, he wears jeans and a long-sleeved t-shirt printed with cherry blossoms. A baseball cap covers his shaved head. "Hajimemashite," I say, a formal "how do you do" that literally translates to "It is the first time meeting you." He responds in kind, and leads me out to the street where two other men, Miki and Tsubouchi, wait with the car. Miki is gregarious and speaks very good English. Tsubouchi says little and wears a nicely tailored black suit, and introduces himself as the team's web designer. The workshop is about a five minute drive away. After a month of exchanging clipped, polite emails, I am here to sit in on a monthly meeting, scheduled to begin an hour.

I first learned about Sakamoto's robot from Reno Tibke, a writer for Akihabara News in Tokyo who has covered the robotics scene in Japan for a number of years. Sakamoto's company earned just a short note on a list Tibke compiled of Japan's most notable robotics projects: "Hajime Robot: I know very little about this other than it's insane and awesome."

Sakamoto's website provided a little more background. Sakamoto's company, Hajime Robot, makes humanoid robots used by researchers and universities. Hajime Robot also created a robot that competed in the Nippon Television Network's "Real Robot Battle" TV special, coming away with a big victory and an impressive gold wrestling belt (before I leave, they make me take a picture wearing the belt).

But a newer project has generated the most media attention: a four-meter-tall humanoid robot, modeled after the long running Gundam anime series about fighting robots. Just like the bots in the show, a human in the cockpit pilots the robot.

Sakamoto says that he became interested in robots after watching the *Gundam* series in high school. In Japan, *Gundam* is a hugely popular cultural phenomenon. The first *Gundam* series, started in the late 70's, pioneered the Mecha genre of anime, a style categorized by giant fighting robot suits. Since its creation, the *Gundam* franchise has expanded to include more than a dozen TV series, video games, and a vast array of merchandise. My roommate, a sarcastic redhead from Alliance, Ohio, seems to spend most of her savings on model Gundams kits with hundreds of tiny parts that take weeks to piece together.

Sakamoto has been working toward a life-size Gundam for years. In 2007, he developed a one-meter robot, and in 2009, the team created a two-meter robot, the tallest humanoid robot in the world at the time.

I don't have to wait long to see Sakamoto's latest creation. The meeting won't officially convene until 7:30pm, so after answering a few basic questions, we duck out into the rain and Sakamoto and a few men who have arrived take me to the workshop next door.

The robot is impressive in videos, but in person the machine's sheer scale is still striking. Two square legs thicker than a grown man, lead up to a wire frame body, with a cockpit big enough for a human to sit comfortably. For now the arms are short stubs (the engineers tell me they would like it to be able to hold a beer).

Though they won't turn the robot on tonight (it takes too much time and preparation) we crowd around a laptop to watch videos of Sakamoto piloting the robot from the cockpit about two years ago ago. "It looks almost the same," one man jokes, and the rest laugh. The mood is

light, but he's right to not noting the robot in the workshop looks terribly similar to the robot in the video.

Funding has been difficult. At one point there a robot restaurant in Tokyo expressed interest. The team also mention a theme park as a possible buyer. One man jokes that maybe I should ask my father for the robot as a present. The price is steep: 20 million yen, equal to about $170,000 dollars.

By the time we return to the meeting room, a few more men have arrived. The rain put a dent in attendance, Miki explains. We each get a small glass of green tea. A glass bowl with rice crackers sits in the center of the table. A few wear gray workman-like coveralls; others, khakis and button downs. Several others wear black suits, the ubiquitous uniform of the Japanese salaryman. A couple of the men give me their business cards. I try to accept politely in the Japanese fashion, with two hands.

Most of the meeting, conducted entirely in Japanese, escapes me. From what I can tell, money and possible sponsors are discussed, as are the next stage of the building process. Sakamoto passes around a metal finger joint, which one member jokingly uses to pick up his tea. Miki pushes one rice cracker my way, then another. Sakamoto is soft-spoken and rarely dominates the conversation. But when he speaks, everyone quiets down and listens.

A large portion of the evening is dedicated to interviewing one of the members of the group, an older man named Kanemoto, for the group's website (they features an interview with a different team member every month). I only get the general gist: karaoke, family, drinking. The gathering features a strong social component. All of the men are volunteers, coming once a month after their day jobs to the small workshop to drink tea and talk about the project.

Toward the end they ask how much I've understood. "Amari," I answer honestly. Not much.

The day of the meeting meeting is two days before I am due to get on a plane back to Philadelphia. At the outset of the meeting, I mentioned that I had not decided what to do with my final day in Osaka. Miki-san asks the group for suggestions. "Final mission," one member says in English, mock gravely. After a lively conversation of which I understand very little, they ask if I've been to Tenjinbashi-suji, the longest covered shopping street in Japan. I say I have. The same goes for the the aquarium and Osaka Castle. But finally, the members agree on a famous shrine in Osaka that somehow I've missed so far. "Nihon poi," a thin, intense man in a gray worksuit says. A Japanese school friend later translates for the phrase for me, pointing out the window from where we are eating to a carefully curated miniature garden. "Very Japanese," he tells me. "Japan-ish."

#3: A League of Their Own:

The referee stands at midfield, holding a stopwatch in one hand a whistle in the other as the final seconds on the clock tick away. After two minutes spent lumbering past midfield up to the penalty mark, the Taiwanese robot is finally in position to shoot. This will be its final chance to score. The opposing goalie, a robot modestly named 'Thor' by its creators at UPenn and UCLA, stands centered in between the goal posts waiting for the final shot. Both robots are a little over four feet tall, or about the height of a eight-year-old child. The Taiwanese robot is all white and silver, light and delicate. UPenn's robot looks sturdier, made of shiny black metal plates locked together insect-style. Thor has looked strong throughout this week's competition in Joao Pessoa, Brazil, winning its first three matches without the opposing team making a goal. But today, Pennn Masters student and robotics team member Larry Abraham is less confident. The robot from the National Taiwanese University of Science and Technology, dubbed 'HuroEvoluation', is lighter and faster on its feet. "This was expected to be a good game,"" Abraham says.

A crowd of around fifty people stand pressed up against the white fence along the edge of the pitch, cameras and phones in hand to record. Several kids are in the front row, gripping the barrier and leaning over for a better look.

With just a few minutes left to go the score is a narrow 2-1, advantage Penn. Time is running short, and the white robot is taking its sweet time with NTUST's final chance to equalize. "Forty-five seconds," the referee calls out. Slowly, HuroEvolution maneuvers around the ball to get the right angle to shoot. Twenty seconds. Nineteen seconds. Eighteen seconds. Seventeen seconds...

In some ways, the RoboCup resembles a similarly named competition that took place a week earlier on the other side of the Brazil. The energy of the audience. The dedication of the coaches and crew. The diversity of teams and fans from across the world, united by a common passion. The pride at stake.

Of course, there are a couple of key differences. The RoboCup field is about as long as two adjacent parking spots. One to seven players make up each team, and teams represent universities with strong computer science and mechanical engineering departments rather than countries. And then there are the players themselves: some of the world's most sophisticated bots, ranging from 2-foot tall standing standard-platform bots to human-sized, highly customized machines like UPenn's goalie.

The first RoboCup took place in Nagoya, Japan in 1997, under the direction of University of Osaka academic Minoru Asada. Asada started the competition with a lofty goal--for the RoboCup champions to be able to beat the human winners FIFA World Cup by the year 2050.

While studying abroad in Japan last semester I visited Asada's lab at Osaka University. Associate professor Hiroki Mori went over the lab's main areas of research. Asada's multidisciplinary team focuses on artificial intelligence and machine learning. The lab's best known creation is robot baby Affeto, which is equal parts cool and creepy. The reason for making childlike robots is simple--if robots look like children, people will treat them like children, speaking slowly and gesturing for emphasis. German associate professor Lars Schillingmann showed me an iCub, a friendly looking robot about the size of a 2-year old capable of showing expression with red LCD eyebrows and a mouth. Schillingmann slowly stacked three colored cups, on inside of the other as the robot watches, explaining his actions as he went. The robot clumsily repeated the action, frowning adorably whenever it made a mistake.

A trophy from last year's RoboCup occupies a prominent place on a shelf in the lab. The team from Osaka University took home first place in the adult sized humanoid division, the same competition in which Upenn's 'Thor' was entered this year. The Asada lab team won a narrow victory against the same Taiwanese team that UPenn’s team faced off against in Brazil this summer.

For Mori, the RoboCup has a special significance. He saw the first ever RoboCup in Nagoya when he was 15. , "That’s how I became interested in robotics,"" Mori says.

Japan has a long history with robotics. The island nation produces and employs more industrial robots than any other country on earth. According to data from the International Robotics Federation, Japan employs over 300,000 units industrial robots, making it the world’s most automated country. Outside of manufacturing centers, the Japanese penchant for automation is reflected in the ubiquity of the vending machines at every street corner, dispensing everything from museum entry tickets, to hot coffee, to restaurant orders to beer (no ID required).

Robots also hold a prominent place in Japanese pop culture. A 14-meter model of a giant fighting robot looks across Tokyo harbor, drawing millions of visitors each year. Astro Boy, widely regarded as the first ever anime at the time of its 1952 launch, features a friendly crime-fighting boy robot. Scholars like Heather Knight and Naho Kitano have argued that the traditional Shinto belief in animism (all things animate and inanimate have a spirit) contributes to Japan’s fascination with robots, particular in the consumer sphere.

According to SU computer science department chair Dr. Jae Oh, U.S. robotics research has historically been driven by the military.

"In Asia and other places, people have been more interested in creating robots that can actually live and breathe with human beings,"" Oh says. U.S. robotics is more focused around creating teams of robots to work together like a "platoon," as compared to Asia's focus on one super-robot that performs multiple functions.

Eight U.S. teams made it this year's RoboCup made it to this year's competition in Brazil. Getting involved is a huge investment in money and time, says UPenn advisor Daniel Lee. Abraham mentions that some programs in the U.S. focus more energy on the DARPA challenge, a department of defense sponsored competition that deals with disaster relief. Unlike in the RoboCup, schools actually get paid for competing in the DARPA challenge. Lee uses a sports analogy for comparison: RoboCup is the Olympics, while DARPA is the NFL.

Many U.S. teams may choose to go to competitions closer to home, Dr. Oh suggests. Over the past few years teams from SU have gone to local and regional competitions including Micromouse (robot mice race through a maze), and the ION Robotic Lawnmower competition.

As you might have guessed from the tortoise-like pace of the humanoid division final, the robot Lionel Messi is a long way off. According the Abraham, the biggest challenges teams in the adult-sized humanoid devision face is walking quickly, without falling down--not exactly the stuff of sci-fi legend. Handlers have to stand behind the robots in case they fall over, to make sure no damage is done to technology worth roughly the same as a small suburban home.

That said, Dr. Lee says the competition has come a long way since he first became involved in 2002. He compares the early matches to 5-year old soccer. "Half the kids don't even pay attention to the game,"" Lee says. "Every now and then someone will get the ball but they're not sure what direction they're supposed to kick it in."" Now, he says RoboCup teams have advanced to 11-year old soccer. The robots know to go after the ball, and they have some sense

of how to coordinate as a team. Lee admits that beating a human team is still a long way off. But maybe not as far as you might think.

"If you think about what the world was like 30 years ago, 40 years ago, we didn't even have computers at that time. We didn't have cell phones or smartphones," Lee says. "The pace of technological innovation is incredible right now."

In 1997, the year RoboCup was created, chess-playing robot Deep Blue beat world champion Garry Kasparof in six consecutive matches. In 2011, IBM's Watson computer computed against Ken Jennings in Jeopardy and came away with a 1$ million dollar victory. I for one, am more than ready to see a robot bend it like Beckham.

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Reflective Essay

Project URL: www.tinkers.lindaggorman.com

I began to seriously consider topics for my honors capstone project shortly after deciding to study abroad in Japan during the second semester of my junior year. Studying abroad on the other side of the world seemed like a rare opportunity to report on something new, foreign and outside of my experience -- something I might not encounter in Syracuse, or my hometown of Wilmington, Delaware. My knowledge of Japanese culture was limited -- I was only familiar with the biggest cultural phenomena to make their way across the Pacific over the past few years: popular anime series Naruto, contemporary novelist Haruki Murakami, and the absurdly cute boy band Hey Say Jump. To find something worthy of a project that I would spend the next year working on, I needed to dig a little deeper.

I started looking up recent international news stories about Japan to get a feel for what might be current. One story in particular caught my attention: a piece about the first robot astronaut, launched late in the summer of 2013. Kirobo, as the robot was named, was designed jointly by Toyota and researchers at the University of Tokyo. Kirobo was designed to interact with the astronauts and gather research on how robots could interact with humans in isolated scenarios. In the robot's first recorded conversation with astronaut Koichi Wakata, Kirobo described the launch as "exciting!!" and adorably asked Santa for a toy rocket for Christmas.

I was intrigued. I started digging up all of the articles I could find about Japan and robots. I came up with pages and pages: robots comforting the elderly, playing rock-paper-scissors, cleaning up in nuclear disaster zones. Robots starred in anime series, made ramen at specialty restaurants, and were manufactured in greater numbers than anywhere else in the world. Many of the articles brought up the Shinto belief of animism, that all beings animate and

inanimate, have a soul, to better explain the Japanese fascination with robotics. I decided that for my capstone project, I would try to do a little investigating of my own. What was it with Japan and robots?

When first coming up with ideas for my capstone, I also thought quite a bit about what form I wanted the final project to take. I decided that I wanted to present my reporting on an interactive website. Since I had taken a few courses in web development through my second major in the iSchool and interned at a web design agency over the summer, I felt confident that I could do all of the design and development by myself. I also wanted to produce media in a few different formats. I was not particularly comfortable with producing video and audio stories at the time, but adding a few visual and audio elements seemed like an important way to make my project more engaging, and add some handy new skills to my journalism toolkit while I was at it. Additionally, the subject matter itself seemed to lend itself naturally to multimedia coverage. Robots are at their most fascinating when they are in motion. While moving, they seem most alive, and in a sense, most reflective of their human counterparts. In a project focused on modern robotics, it seemed that not including visual elements would be to neglect something very basic about the story I was trying to tell.

It did not take long after arriving in Japan for me to realize that reporting in a foreign country would be a little trickier than I had anticipated while confidently tapping out my project proposal a few months earlier. The first, and most obvious barrier, was language. Prior to studying abroad I had never taken Japanese. Although I studied diligently and learned as much as I could during the time I was abroad, I never gained any kind of conversational fluency beyond telling the train conductor I had lost my ticket or asking what exactly kind of unusual raw fish was in front of me (and more often than not, I still didn't understand the response).

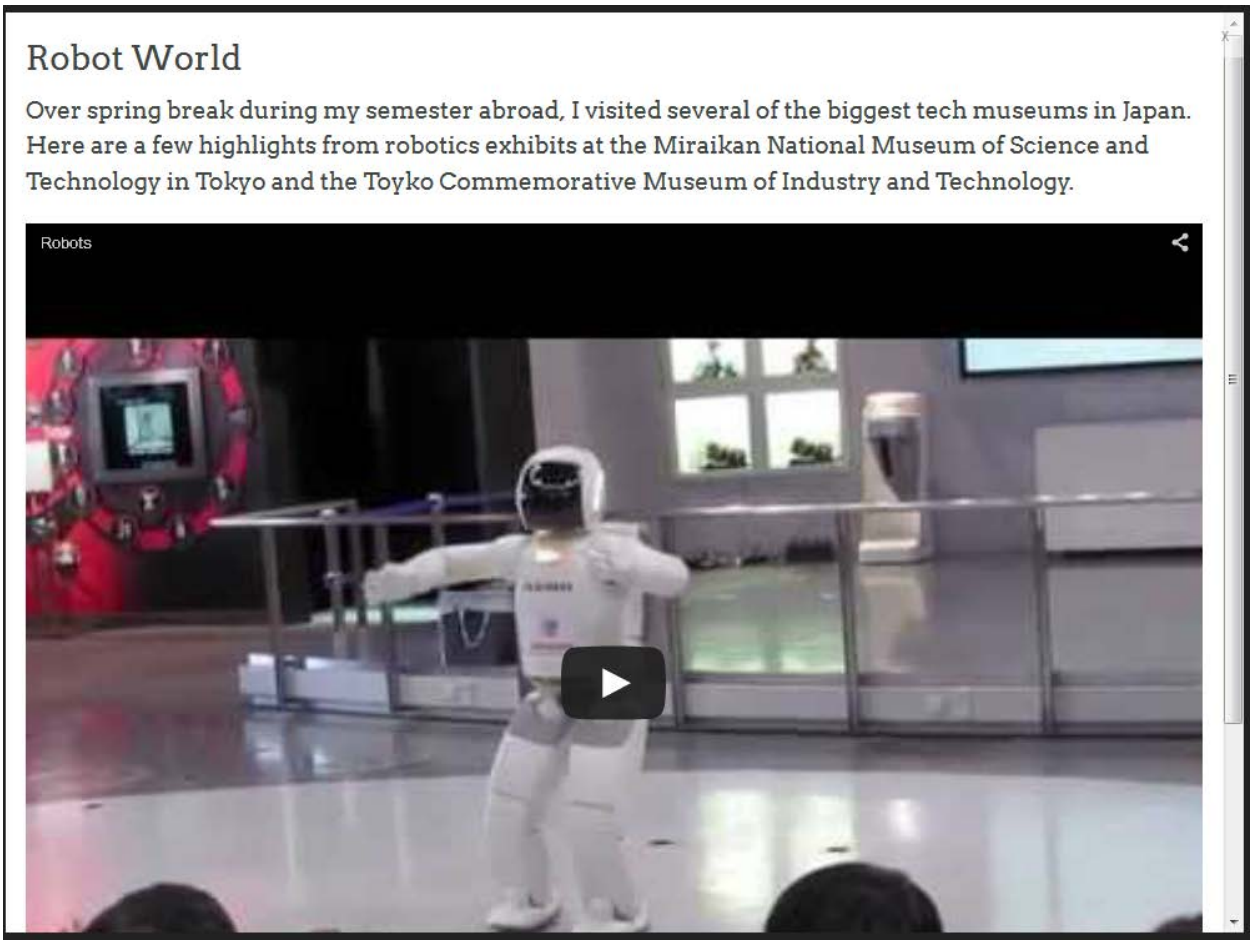
While many people in Japan did speak English (younger people in particular), it was naive for me to ever believe that I could have done the kind of reporting I was used to doing at home in my own territory.

There was also the issue of cultural differences -- in Japan people have generally different standards for what is considered polite. Though as a foreigner you get some leeway I always was concerned about saying or doing something that would be construed as rude, for example talking too loudly on the train, or accepting someone's business card with one hand rather than two. Since Japanese people often avoid saying no outright and tend to be fairly subtle, it was difficult to tell the the differences between invitations that were offered out of politeness, and those that were genuine.

An interesting aspect of reporting in Japan, and in living there more generally, was the degree to which being a foreigner made you an anomaly. Being a fly on the wall was pretty much off of the table given that just by looking different you constantly attracted attention. Sometimes this was fun, like when a whole class of kindergarteners would adorably chant "Hello!" in unison when you got on the elevator to practice their English. Other times, like when no one would sit next to you on a crowded bus, or when you would catch a stranger discreetly taking a picture of you, it could be a bit unnerving. When it came to reporting, I couldn't help but feel like my presence was inherently a bit disruptive, and I might not be getting a full and complete picture of what was going on.

Challenges aside, I did my best to compile some research during my time in Japan. I saw Honda's famous Asimo in action at the Miraikan National Museum of Emerging Science and Technology, and I visited the Toyota Commemorative Museum of Industry and Technology in Nagoya to learn about the Toyota Partner robot, designed to assist the elderly. Over spring break

I dragged my parents, who were visiting for the week, to a robotics store in Akihabara, Tokyo's famous "Electric Town." We knew only that the store was in a building marked Tsukumo, of which it turned out there were three. On our second unlucky attempt we barged in on what seemed to be a conference for something titled "Gamer Republic," provoking some curious looks from the roomful of Japanese men gathered for the meeting. I compiled footage of robots I saw on these visits into a short video, one of the first components I produced for my project. I've included a screenshot below:



One weekend I caught up with American journalist Reno Tibke, who has been reporting on robots in Japan for several years for Akihabara News, a website dedicated to covering the tech scene in Japan. Over the course of a French toast and tea in a crowded basement cafe in

Shinjuku, Tibke gave me the lowdown of what he considered to be the most exciting things happening in Japanese robotics.

Unfortunately, the majority of the players Tibke told me about were in Tokyo or Nagoya, both three hours by expensive bullet train from where I was studying near Osaka. However, Tibke did direct me to a vast online listing of robotics labs and researchers, and I was able to find several based in Osaka. After getting a friend to help me translate my short introductory email into clumsy but serviceable Japanese, I sent out messages to the five or six places that I could reasonably check out in a day trip. I heard back from two: the Asada lab at Osaka University, and robotics engineer Hajime Sakamoto of Hajime robotics.

During my final weeks in Japan, I visited both places and secured several interviews at each. To my immense relief, nearly everyone I met was able to speak with me in English (though at Sakamoto's workshop I did end up sitting through a two hour meeting entirely in very technical Japanese). Both of these yielded much material for my project itself. In general, I was surprised by how kind and willing to help me the researchers were, given that I was a student journalist with little to offer in terms of publicity and with mediocre-at-best Japanese. They took time out of very busy schedules to show me around and patiently explain all kind of things that went way over my head, and for that I could not be more grateful.

After coming back to the U.S. at the end of May, I still lacked confidence in my project. While I had managed to do some reporting in Japan, it was not enough to sustain my project as I initially envisioned it. I also felt like I had made very little headway in terms of the question I had initially set out to answer: where and how do robots fit into Japanese culture? Among the people that I asked, there did not seem to be any clear consensus as to why robots were so big in Japan. I tentatively came to the conclusion that the connection many Western journalists made

between Shinto and robotics was a bit overstated. When I asked my Japanese friends about their thoughts on robots, they were much more likely to reference Transformers than their indigenous beliefs. An anthropology professor I interviewed at my school (who requested not to be quoted in my article) expressed skepticism at the 'animism' explanation and directed me to an unpublished essay by French academic Mary Picone. Picone argues that the influence of ancient Shinto beliefs about the natural world and animism (a terms that Picone says is outdated) tend to be overstated by nationalists.

I came to the conclusion that while Japanese robots could still be a part of my capstone, I was not going to be able produce the stories I had initially envisioned at the outset of my project. After spending just a few months in Japan, I was still too much of an outsider to gather the material I would need to convincingly answer my original question about robots and Japanese culture.

So while I was not exactly back to square one, I was feeling a little bit adrift in terms of where my project should go. Fortunately, I soon got a bit of direction from an outside source. I received an email from a former classmate, who had heard I was doing reporting on robots in Japan, and wondered if I would be willing to write an article for a student publication (*Jerk* magazine) relating to the subject. I said yes, and immediately started thinking of possible angles. What I finally settled on was the RoboCup, a robot soccer competition founded by Minoru Asada, the head of the lab I had visited at Osaka University. Every year, hundreds of teams from universities all over the world come together to compete in an epic robot soccer tournament. While the technology is still far from imitating soccer as played by people, the robots have grown much more sophisticated in the last few years. Upon founding the competition, Asada set an ambitious goal: for a roboCup team to beat the winners of the FIFA world cup by 2050.

The topic was timely; the robot soccer competition had been held earlier in the summer, in Brazil a few hours away from its human counterpart. And better yet, the winners of the humanoid division was a team from the University of Pennsylvania. Since I was working in Philly for the summer, heading over to Penn to speak to the students and their advisor was easy. I gathered a little more research and eventually finished the piece in the beginning of the school year.

As part of the article for *Jerk*, I spoke with a number of students who had built robots for competitions. I was struck by how much they seemed to enjoy the simple process of creation; of starting from basic parts, and putting them together into something that could move, interact, and in a sense, have a life of its own. The competition was really secondary to the satisfaction derived from making.

That satisfaction resonated with me too. I have always been a hands on person. As a kid, glue, beads, and felt, the remnants of half-finished craft projects littered my room. In high school, I sewed my own lumpy but serviceable prom dress, frantically hemming right up until my date rang the doorbell. After spending a few months talking to people about their cool robot projects, it did not take long for me start itching to make something of my own. In fact, I had acted on that urge while I lived in Japan. At one of the robotics stores I visited in Tokyo, I bought a small-scale robot kit of my own on a whim. In a late night effort, I bought a pack of batteries, popped the little pink pieces off of their plastic frame, and put the robot together according to the instructions (fortunately there were enough pictures that I wasn't left to puzzle out the Japanese directions). It wasn't much -- a plastic pig that walked forward and backwards -- but I was absurdly proud.

My education in all things tech and electronics continued in the fall when I started work at a student job at the Syracuse Department of Online Platforms, doing web development. My fellow developers turned out to be a wealth of knowledge, several of them self-proclaimed hackers. On Thursday nights we got together for what was dubbed a “hacker meetup” to eat pizza, talk about our projects, and learn about a topic: soldering, circuits, or, on one particularly interesting evening, lock picking. I quickly learned my place as the biggest newb in the room and asked every question I could think of. One of my coworkers lent me an Arduino, a programmable microcontroller. I followed basic instructions on the Arduino website to make an LED blink and to take record readings off a distance sensor. Around the same time, I heard about the SU Makerspace, a former computer lab on campus now equipped with 3D printers, laser cutters, soldering irons, and basically anything else you would need to make a cool hardware project. I looked up 3D printed Arduino projects, and found a blueprint for a small 3D printed robot that I could program my Arduino to control. 15 hours of printing later (3D printing can be frustratingly slow), I was off and running.

I wish I could say that I became a robot wiz and hacked together a new friend to make me coffee and hang up my laundry. But things didn't quite work out that way; my robot project got about about 75 percent finished before I realized that some of the parts weren’t quite the right size, and I would have to go back to the drawing board. Circuitry also presented a challenge, given that my prior knowledge of electronics was basically limited to putting batteries into my remote in the right direction. At this point the project still isn’t quite finished, though I fully intend on getting it all together by the end of the year.

But even though my robot was not exactly all I had imagined it to be, hanging out at the makerspace introduced me to the “maker” subculture and gave me inspiration for the next

direction my capstone would take. Sure, extraordinarily advanced robots were being made for hundred of thousands of military-funded dollars at universities and corporate labs. But lots of equally exciting hardware projects were coming together in community spaces like the SU makerspace across the country, made by all breeds of creative tinkerers -- software engineers, students, artists, hobbyists.

Makerspaces were putting prototyping tools into the hands of the average Joe and Jane at costs lower than anything seen before. In the same way that Intel's microprocessor put personal computers within the reach of committed hobbyists in the '70s (eventually leading to the acquaintance of two legendary Steves and a computer named for a fruit), 3D printers, CNC machines, and microcontrollers could be bringing about what former *Wired* Editor in Chief Chris Anderson boldly declared "the next industrial revolution." Anderson, whose book *Makers* came out about a year ago, is perhaps the best poster child for the maker movement. After inventing a autopilot-directed toy helicopter for his son, Anderson eventually quit his job at *Wired* to found 3D Robotics, a company he now co-owns with a young man he met through online forums (who incidentally was, at the time, 18, unemployed, and living in Tijuana). Anderson contends that the advent of digital design tools combined with inclination of the web generation to share their creations online has made it far easier for like minded people to connect, collaborate, and even reach out to possible consumers. "Nations have always had their tinkerers and inventors," he writes. "But the shift to digital changes everything about the ability to get those ideas and inventions produced and sold" (21).

The other major book written on the subject of makers is *The Maker Manifesto* by Richard Hatch. Hatch is best known as the CEO of TechShop, a makerspace in the Bay Area that has since expanded into a series of sleek franchises across the country where staff members

are known as “Dream Consultants.” Hatch’s account is more of a call to action than a historical document. “To use revolutionary language, my objective with this book is to radicalize you and get you to become a soldier in this army,” Hatch writes in the introduction (12). “I know that the Maker way, thought, and movement will become a defining characteristic of at least the first half of the century, if not most of it” (8).

Nearly every chapter starts with Hatch approaching some likely-looking youth at TechShop, and ends in said youth raking in millions of dollars making bamboo iPad covers or funny hats or electronic mail box openers, their lives transformed by the joy of making. But while some of Hatch’s stories seem a little overblown, it is undeniable that makerspaces have spawned some major companies. The most notable example is probably mobile payment company Square. Cofounder Jim McKelvey made the first prototypes of the company’s signature credit card readers at a TechShop makerspaces in Menlo Park, California in 2009. Five years later, Square Inc is worth billions of dollars and boasts millions of users. I paid for my latte at Cafe Kubal yesterday on a Square Card reader. McKelvey maintains that the success of the product can largely be attributed to the time he spent laboring over the CNC machine at TechShop, iterating through dozens of prototypes to create the product he had envisioned. In his book, Anderson quotes McKelvey: “If I hadn’t done it myself [...] We’d have a clunky, committee-designed product. Later, more expensive, and it wouldn’t have been as cool” (200).

At the campus makerspace, where I had been printing out my robot, I could see shades of the same kind of energy that Anderson and Hatch described. There was the budding company of bioengineering students who built a glove to control a robotic hand, prototyped with Arduino, breadboards, and 3D printed parts. There was the perpetually sleep-deprived art student trying to design and print out a new sort of lens cover for a filmmaking project. There was an easygoing

senior trying to make the first 3D printed electric car-charging station. And managing it all was John, a middle-aged former musician with a ponytail and an endless supply of restless energy. John, who makes his own maple syrup and sewed his wife's wedding dress, seemed to have an encyclopedic knowledge of how things work -- from the embroidery machine to the vinyl printer to the soldering irons.

In the months that followed, I continued to research tools, spaces, and communities associated with making. While I was home over winter break, I went to an Arduino meetup at a recently formed makerspace in my hometown of Wilmington, Delaware. The space was small and sparse, located upstairs from a dingy athletic center. The group, titled "Barrel of Makers," owns just one 3D printer, built a few years earlier from a kit by board president Jessica Taylor and her husband. Taylor had called up 10 or 12 friends who she thought might be interested, asking if they would be willing to put in $50 in exchange for getting to borrow the machine. A number of people were interested, and Barrel of Makers was born.

The evening of the meetup was so cold that the school district had delayed classes in the morning, and only six people showed up, myself included. Three of us were first timers. There was Paul, a postdoc from the University of Delaware hoping to use Arduino in combination with pH sensors for his research. When I pulled out my robot project, he suggested that I add a speaker to make the robot say "destroy all humans." Jason was a 30-something working at eBay, considering Arduino for a hydroponics project, who had driven from 45 minutes away to come.

The gathering was small, and the facilities were modest, but I did get the sense of a true grassroots effort. Jessica talked about what the group had presented at the last Maker Faire in New York City: a massive reproduction of the classic Lightbrite toy. They presented in a special darkroom area and came away with a ribbon. Jessica, a former art major, talked about how it

had been hard to graduate and all of a sudden lose all of the resources she was used to at school. No easels, no paints, no tools. "I couldn't make art," she told me. The makerspace made it possible for her to start creating again. And though she had started on the creative side, she eventually got into tech, and now teaches soldering classes to kids.

A few weeks later I took the train up to get a tour of the NextFab makerspace in downtown Philadelphia, in an attempt to get some idea of what else was out there. After the meetup in Wilmington, NextFab seemed like the Mercedes of makerspaces. The space, which bills itself as "Philadelphia's Gym for Innovators," was massive at 21,000 square feet. NextFab offers access to literally hundreds of tools -- from engravers to laser cutters, rows and rows of 3D printers, a fully equipped wood shop, to a super advanced CNC machine that blasts out designs with high powered streams of water, and one of the only publicly available pick-and-place machines in the country. That's not to mention the tens of thousands of dollars worth of software members have access to, including the most sophisticated CAD tools. Full-time employees wear matching branded hoodies and walk around at all hours supervising and offering help.

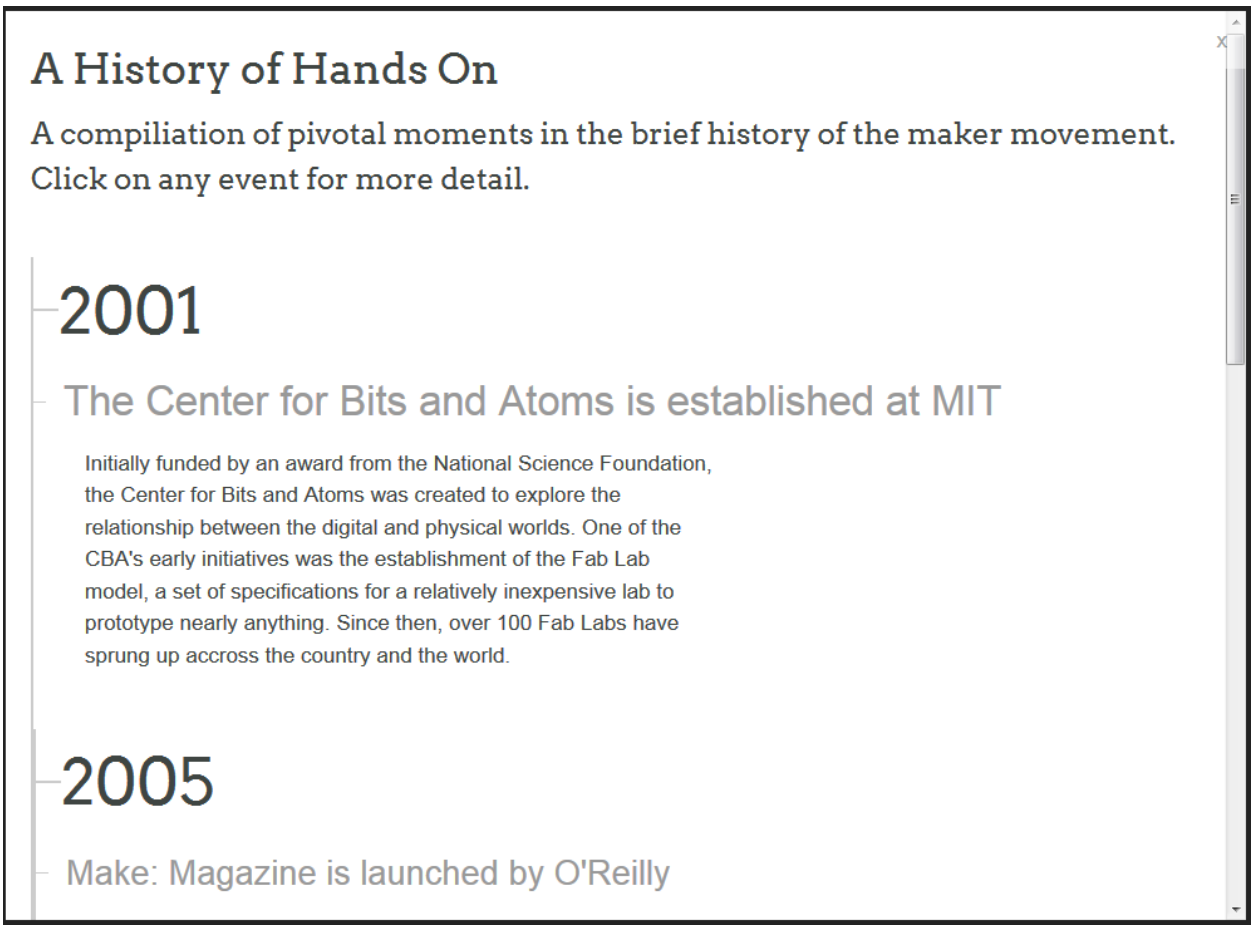
Of course, all this doesn't come cheap. A standard membership cost $249 a month, and classes and time on certain machines costs extra. Like Hatch's TechShop, NextFab is a for-profit company. The vast majority of members, at least that I saw on the afternoon I visited, seemed to be white male hipster types, with just the right amount of facial hair. The stark contrast between the two spaces suggested to me a sort of tension, a problem that no one I interviewed ever quite addressed head on. Was it better to charge more and offer better resources? Or to make do with less, and stay true to the democratic ideals of the maker movement? I can't really offer a good answer to that question, and I didn't attempt to in my

article about makerspaces. But it was something that I reflected on quite a bit. How to make resources available to everyone, while avoiding the tragedy of the commons?

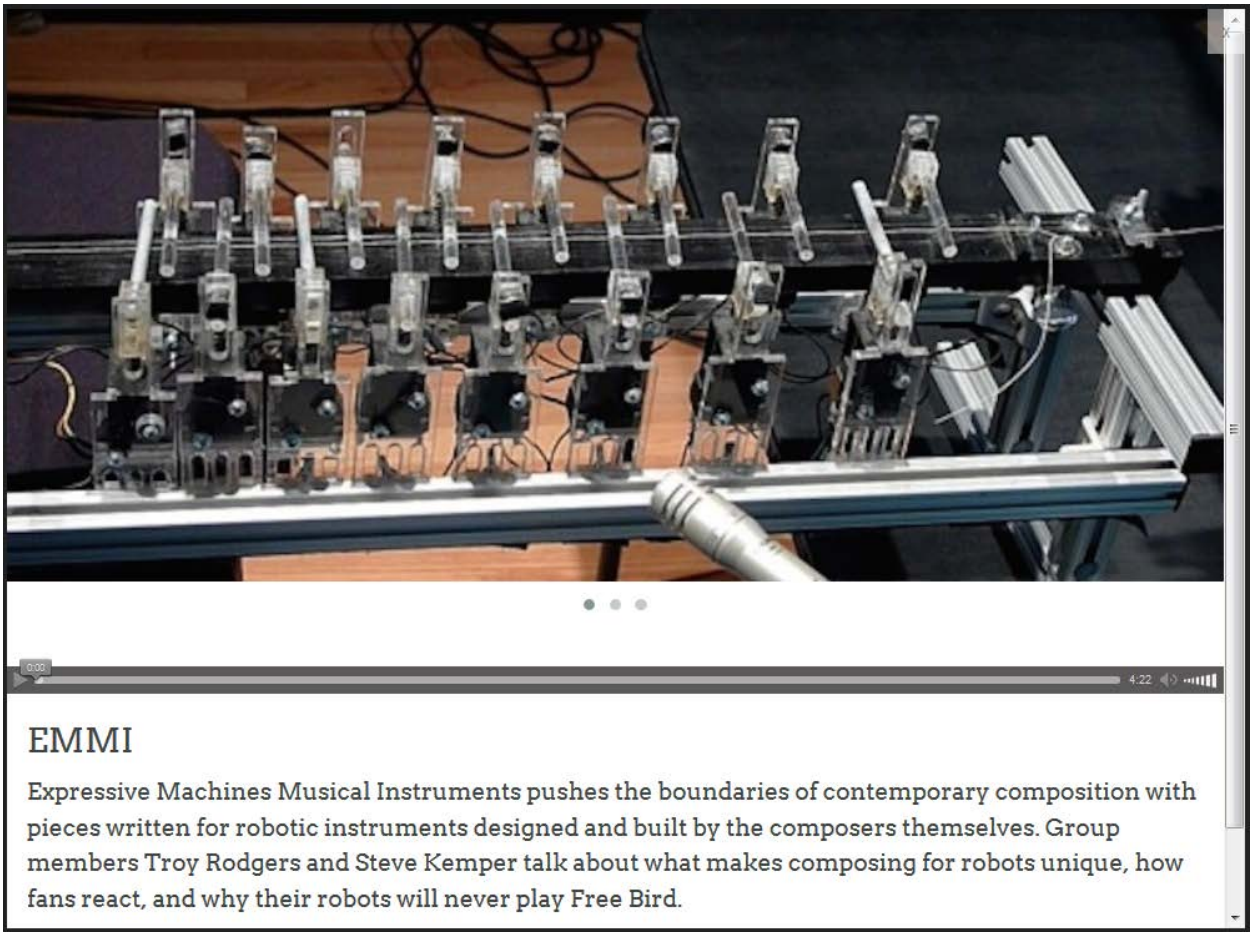
Researching makerspaces and the evolution of affordable personal manufacturing tools led me into an interrelated topic: hardware startups. 3D printing and microcontrollers like Arduino and Raspberry Pi radically lowered the cost of creating prototypes. As a result, the barrier to entry has become much lower for hardware startups producing a physical product rather than something that exists purely in the digital world. I interviewed several early-stage student startups in the hardware scene as well as Doug Crescenzi, the CEO of a startup company that produces wireless connected sprinklers that could be controlled through an an app. They all started out in a similar fashion -- with rough prototypes produced via 3D printing, bread boarded circuits and/or Arduino boards. Nothing like what their final products would like like, but enough to communicate to investors how their vision could become a reality. In some cases this meant pitching at competitions and meeting with VC's. In others, as in the case of Lono, this meant going straight to users with a Kickstarter campaign.

By the spring semester, I felt like I had the majority of the material I wanted to present in my project. I did a few smaller scale projects -- an interview with Newhouse's Bob Thompson about robots and pop culture, a short audio piece on robotic instrument collective EMMI and an interactive timeline detailing the history of the maker movement.

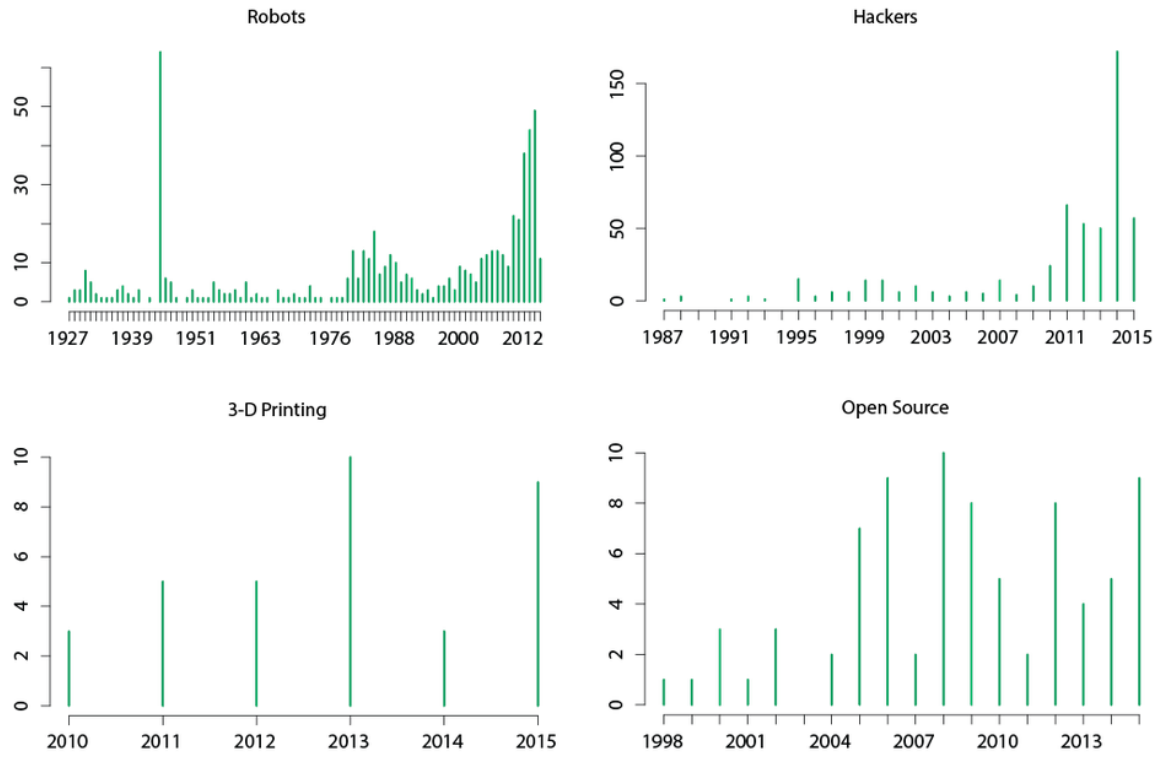
Here's a snippet of my timeline:



The page for my EMMI audio piece (the Bob Thompson piece was formatted similarly):

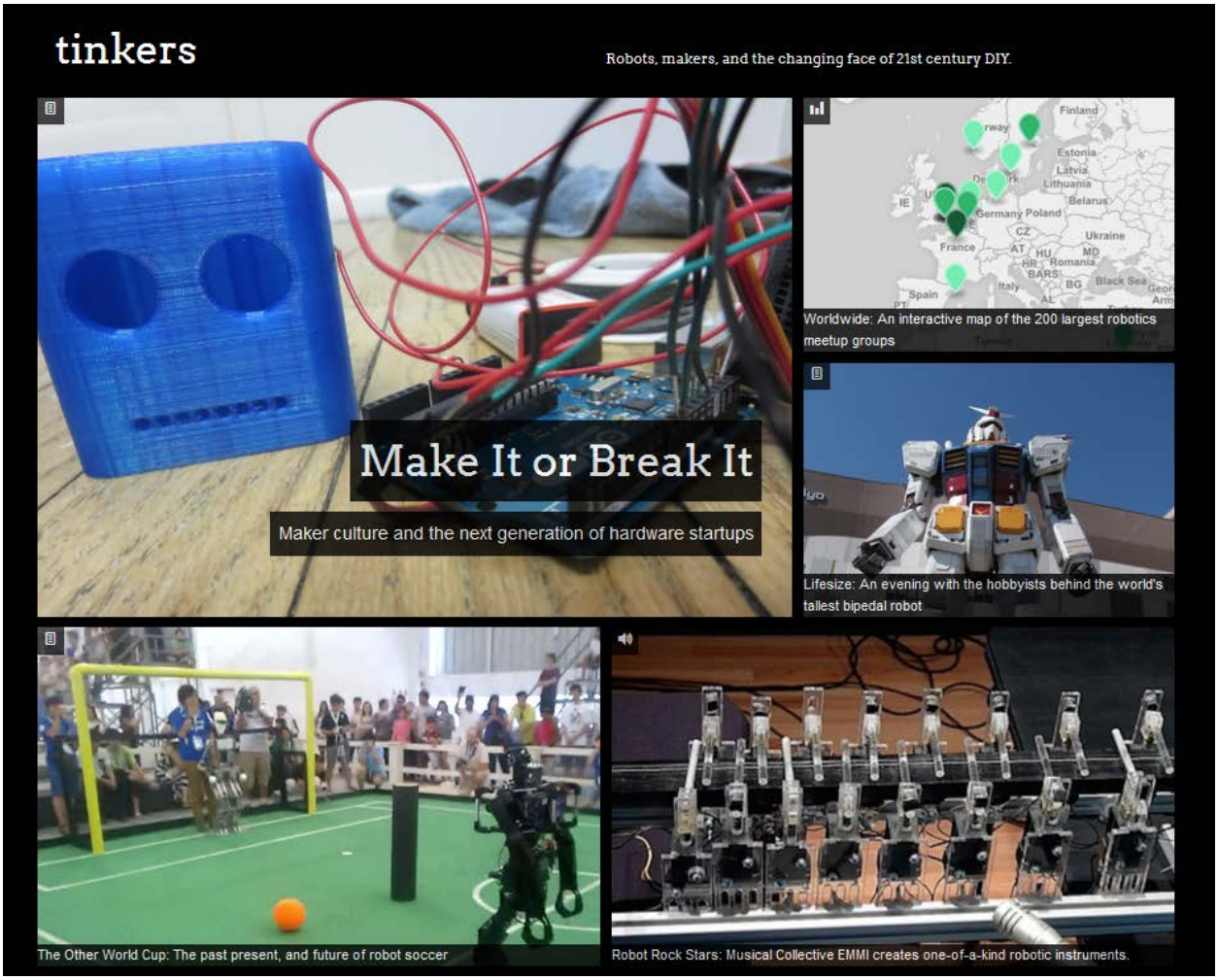


The final piece I completed, and one of my favorites, was a visualization of how often certain key words (‘robot’, ’hacker’, ’open source’) had appeared in the headlines of the New York Times. I wrote a Python script to compile source data from the NYT Article API, and then used the statistical programming language R to plot out the information.

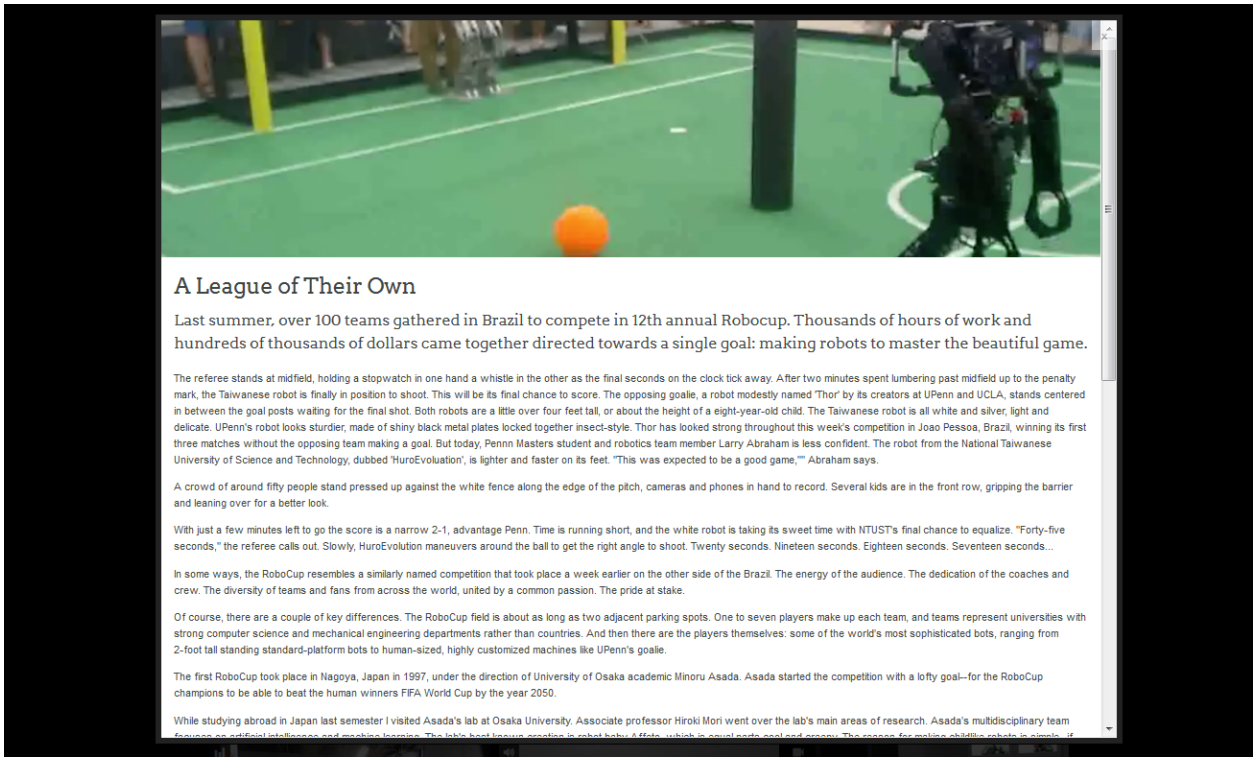


But for the most part, I turned my focus to pulling things together and settling on a final design for my website. My first iteration was super minimalist, a mostly black page with pictures that could be clicked on to access each piece. My advisor recommended I catch up with Adam Peruta, a professor of interaction design at Newhouse. Professor Peruta gave me some valuable feedback, suggesting that I try to create hierarchy and offer a little more context, even suggesting some possible layouts. While I did like my original design, his feedback was spot on. I was too close to the project and couldn’t see how design cue that made total sense to me might not be obvious to an outsider.

My revised design ultimately looked like this:



Clicking on any box brings up a modal box containg the content and darkens the background, like so:



A League of Their Own

Last summer, over 100 teams gathered in Brazil to compete in 12th annual Robocup. Thousands of hours of work and hundreds of thousands of dollars came together directed towards a single goal: making robots to master the beautiful game.

The referee stands at midfield, holding a stopwatch in one hand a whistle in the other as the final seconds on the clock tick away. After two minutes spent lumbering past midfield up to the penalty mark, the Taiwanese robot is finally in position to shoot. This will be its final chance to score. The opposing goalie, a robot modestly named 'Thor' by its creators at UPenn and UCLA, stands centered in between the goal posts waiting for the final shot. Both robots are a little over four feet tall, or about the height of a eight-year-old child. The Taiwanese robot is all white and silver, light and delicate. UPenn's robot looks sturdier, made of shiny black metal plates locked together insect-style. Thor has looked strong throughout this week's competition in Joao Pessoa, Brazil, winning its first three matches without the opposing team making a goal. But today, Pennn Masters student and robotics team member Larry Abraham is less confident. The robot from the National Taiwanese University of Science and Technology, dubbed 'HuroEvoluation', is lighter and faster on its feet. "This was expected to be a good game,"" Abraham says.

A crowd of around fifty people stand pressed up against the white fence along the edge of the pitch, cameras and phones in hand to record. Several kids are in the front row, gripping the barrier and leaning over for a better look.

With just a few minutes left to go the score is a narrow 2-1, advantage Penn. Time is running short, and the white robot is taking its sweet time with NTUST's final chance to equalize. "Forty-five seconds," the referee calls out. Slowly, HuroEvolution maneuvers around the ball to get the right angle to shoot. Twenty seconds. Nineteen seconds. Eighteen seconds. Seventeen seconds...

In some ways, the RoboCup resembles a similarly named competition that took place a week earlier on the other side of the Brazil. The energy of the audience. The dedication of the coaches and crew. The diversity of teams and fans from across the world, united by a common passion. The pride at stake.

Of course, there are a couple of key differences. The RoboCup field is about as long as two adjacent parking spots. One to seven players make up each team, and teams represent universities with strong computer science and mechanical engineering departments rather than countries. And then there are the players themselves: some of the world's most sophisticated bots, ranging from 2-foot tall standing standard-platform bots to human-sized, highly customized machines like UPenn's goalie.

The first RoboCup took place in Nagoya, Japan in 1997, under the direction of University of Osaka academic Minoru Asada. Asada started the competition with a lofty goal--for the RoboCup champions to be able to beat the human winners FIFA World Cup by the year 2050.

While studying abroad in Japan last semester I visited Asada's lab at Osaka University. Associate professor Hiroki Mori went over the lab's main areas of research. Asada's multidisciplinary team

There were challenges on the technical end as well. My project was heavy on images, which could make for slow, jerky page loading. After a bit of trial and error, I came up with a few fixes, including compressing images, adding a quick loading screen, and paying for a slightly faster hosting service. As is always the case with design and development, the most time consuming parts of the process were hammering out the details and testing the site in different browsers. What looks great in Chrome can be a complete disaster on an early version of Internet Explorer. With the exception of a few minor details, my site is currently supported on Chrome, Firefox, and IE 10 and above (though I would highly recommend using Chrome to visit the site). My best resources in terms of the development side were my co workers and one of my former bosses.

But more than anything, my biggest concern was making the project come together as a cohesive unit. I switched directions a few times in the course of my reporting, which made some of the elements I had produced seem a little eclectic. But ultimately, I came to see this project as a sort of a sort of Venn diagram of several different subjects, separate but more than tangentially connected. The project is a little bit about Japan, a little bit about robots, a little bit about entrepreneurship, and a little bit about the maker movement. The main focus is not how those things exists on their own, but where and how they intersect. My own humble little robot project only came about through the access I had to 3D printers at the campus makerspace. I didn't make a business out of it, but others, like biomedical startup Contact, have done so and been very successful. And while the robotics lab at Osaka University and Doug's team in Utah inventing a smart sprinkler are not working toward exactly the same goals, they share a common spirit of innovation. There was a sense of community among creators that ran throughout every group that I met with in the course of researching this project, students, academics, and hobbyists alike. This was true even for the more formal robotics researchers I met in Japan when I was first starting my research; robotics is inherently interdisciplinary, making collaborate efforts key to any major progress.

The spirit of 21st century innovation is all about openness and standing on the shoulders of the smart, creative people who came before. If there is any takeaway from the history of the computer revolution, it is that the most exciting innovations rarely happen in a vacuum. Ada Lovelace's landmark description of the programmable computer came about only after years of close friendship and correspondence with polymath Charles Babbage and other thinkers of the day. Contrary to what *The Imitation Game* might have you believe, Alan Turing worked with a huge team at Bletchley Park to perfect his elaborate code-breaking machine. The first generation

of hackers at MIT stored their teletype programs in a communal drawer, each drawing on each others' work for the next most daring, creative, efficient hack. The Homebrew Computer Club in the Bay Area in the '60s brought together scores of tinkerers who would later become household names.

In the year 2015, I think many of these important encounters could happen at makerspaces and hackerspaces like NextFab, Barrel of Makers, and even the SU Makerspace. The sharply dropping costs of personal manufacturing tools, coupled with the growing prevalence of crowdfunding, are breaking down barriers for a world full of innovators.

In the final few words of this essay, I would like to emphasize that this capstone project did not happen in a vacuum either. In addition to the dozens of people who generously took the time to sit down with me for an interview, I am incredibly grateful for the feedback and encouragement I received from my reader Corey Takahashi and my advisor Melissa Chessher. Their suggestions and thoughtful advice kept me inspired whenever my motivation started to flag. And last but not least, I'd like to thank the staff and students that make up the Renee Crown Honors program. The honors community as a whole shaped my experience here at Syracuse, from freshman forum and my honors courses, countless cups of hot chocolate and late nights in the honors lounge, to this scary yet rewarding capstone project. Through honors, I have done some of my best work, and met many of the most talented, creative people I have ever known. I can't wait to see what we start making next.

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New York Times Article Search API v2: http://developer.nytimes.com/docs/article_search_api

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Miki Seisakusyo, Fember of Hajime Robot team

Jihoon Park, PhD student at the Asada Emergent Robotics Lab

Lars Lars Schillingmann, Specially appointed Associate Professor at the Asada Emergent Robotics Lab

Hiroki Mori, Associate Professor at the Asada Emergent Robotics Lab

Reno Tibke, Tokyo-based journalist for *Akihabara News*

Elizabeth Kenney, Professor of Anthropology at Kansai Gaidai University in Hirakata-shi, Japan

Bob Thompson, Director for the Bleier Center for Television and Pop Culture at Syracuse University

Jae Oh, Associate Professor of Computer Science at Syracuse University

Grant Griffiths, Syracuse University student and participant in Micromouse robot mouse competition

Daniel Lee, Director of the GRASP (General Robotics Automation, Sensing and Perception) Lab at the University of Pennsylvania and faculty advisor to the Penn RoboCup team

Larry Abraham, University of Pennsylvania master's student and member of the Penn RoboCup team

Sagar Poudel, University of Pennsylvania student and member of the Penn RoboCup team

John Magicaro, Manager of the Syracuse University Makerspace

Ben Marggraf, Syracuse University student and co-founder of Contact

Tom Buchanan, Syracuse University student and co-founder of Contact

Jessica Taylor, Board President of Barrel of Makers in Wilmington, DE

Marcella Barker, Manager of Member Services at NextFab in Philadelphia, PA

Nate Forer, Syracuse University student and co-founder of MountTech

Cait Kenny, Outreach and project manager of MaKen Studios in Philadelphia, PA

Annina Ruest, Assoicate Professor of Art, Design and Transmedia at Syracuse University

Steve Kemper, Co-founder Expressive Machine Musical Instruments

Troy Rogers, Co-founder Expressive Machine Musical Instruments

Michael Giannattasio, Founder and manager of the SALT Makerspace in Syracuse, NY

John Baichtal, Blogger for *Make* blog and author of 10+ DIY books

Carol Perrotto, Board member of First State Robotics in Wilmington, DE

Joseph Perrotto, Volunteer with FIRST Robotics Competition in Wilmington, DE

Doug Crescenzi, CEO of smark sprinkler startup Lono