Engineers' Forum

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Letter from the Editor

Welcome back Hokies!

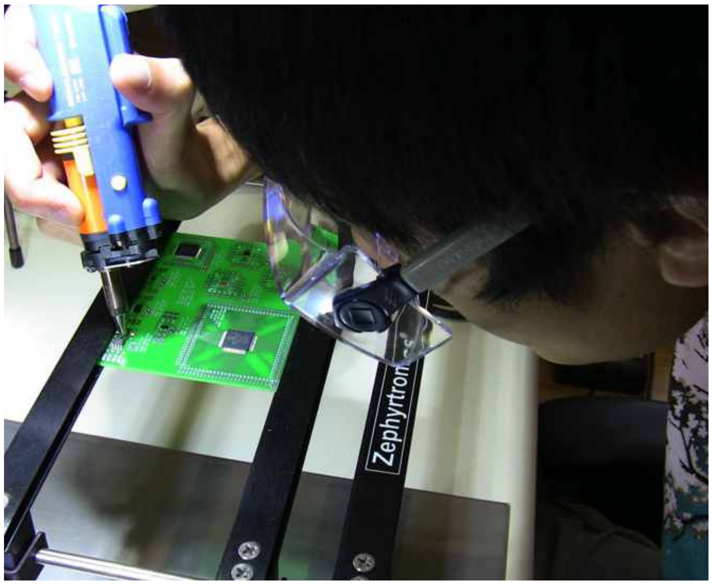
Fall has arrived in all its colorful glory! Whether you're basking in every moment of the season or just struggling to keep the chills away on an dark Monday morning, we are glad you stopped to pick up a copy of the Engineers' Forum's latest issue. Here we are dedicated to bringing you the newest and brightest stories about engineering science and research at Tech. The weather may decide to stop working, but we continue to keep you informed.

We've got some interesting articles for this issue, including Ryan's latest coverage on Dr. Bickford's research with nanoparticles and their applications in cancer treatment. Sarah gives you the inside scoop on Durham Hall's Prototyping Laboratory, where students can research, design, and develop their own technologies based on their interests without worrying about a grade. Want to know how this one of a kind undergrad lab got started? Find out inside!

If you're into the visual side of science, come take a virtual tour of our manufacturing processes lab and see Eileen's up-close coverage of ISE and ME undergrads working with different hands-on, practical applications of their majors. Also included this issue is an analysis from Joseph on what it takes to earn a Ph.D in engineering at Tech, as well as Robel's and Ben's review of the newest projects that the Sailbot and Human Powered Sub programs are working on this year. Please read and enjoy, and stay out of the cold when you can Hokies!

Coleman Merenda

Editor in Cheif



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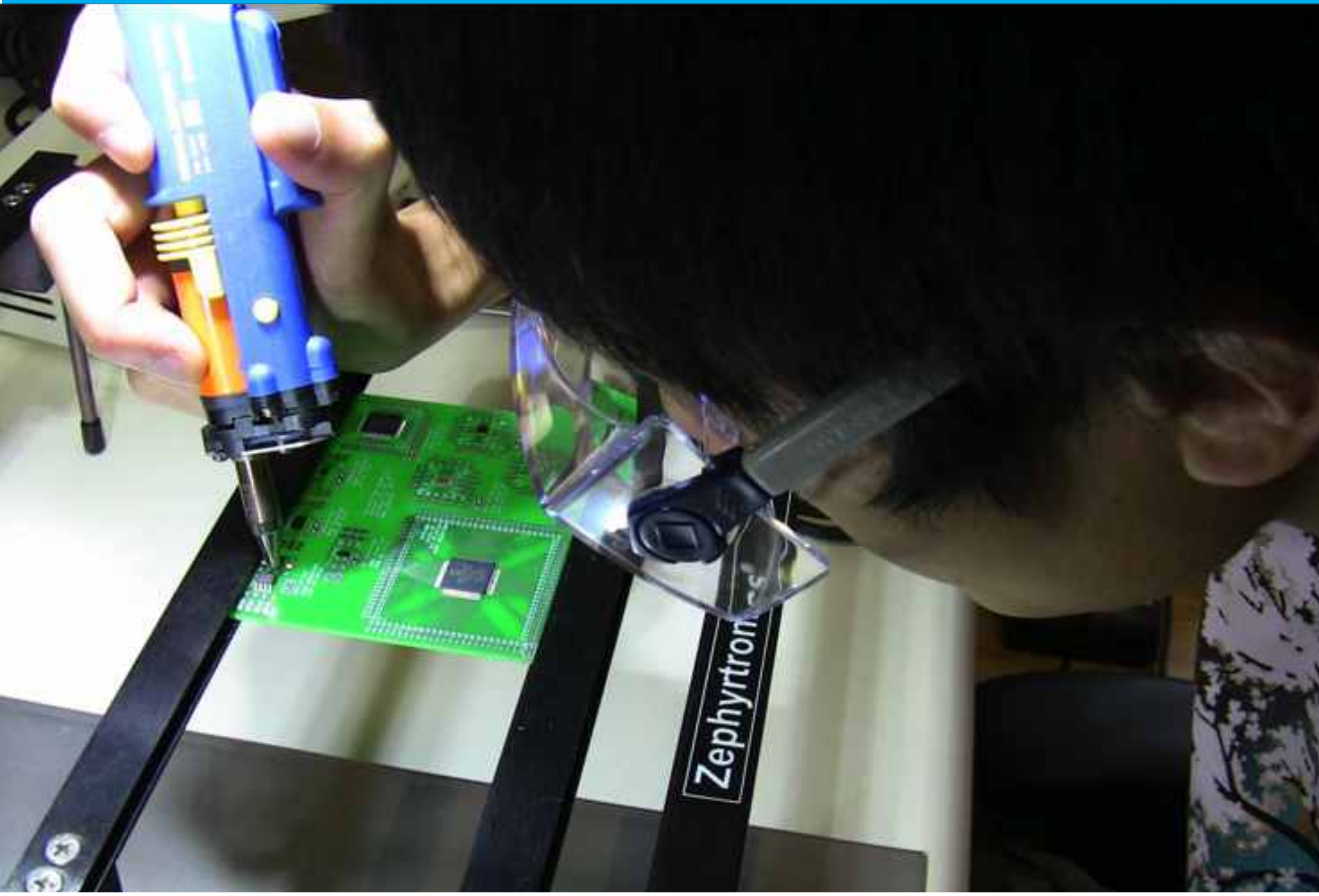


Kevin Lee is removing solder from a surface mount printed circuit board.

Autonomous Mastery Prototyping Laboratory

Sarah Stewart, Junior in Industrial and Systems Engineering

If you're an electrical or computer engineering student (ECE), you've probably spent hours in the Computer Engineering Lab on the third floor of Durham, but have you ever noticed the lab room caddy-corner to it? In Durham 373 resides the Autonomous Mastery Prototyping Laboratory, aka the AMP lab. The AMP lab is a student-run laboratory for electrical and computer engineering students to work on personal projects. With AMP lab membership comes funding, mentors, and 24-7 Hokie Passport access to the lab room. And the best part about it–there are no grades or credit hours; just you working on what interests you.
So how did this lab get started? It all started with a YouTube video. Bob Lineberry, an ECE professor who runs the computer engineering labs, received a video link from one of his teaching assistants, Gordon Kristie. The RSA Animate video is based on Daniel Pink's novel Drive, which describes how individuals are not motivated by the means we expect; monetary rewards for productivity will not increase employee productivity in non-physical labor jobs. After watching the video three times, Bob Lineberry began thinking of a way to implement and harness that motivation and use it to motivate students to achieve more. Thus the formation of the AMP lab began. Bob Lineberry developed and sent a proposal to the department head, and after three months of waiting, the AMP lab was officially formed in fall 2012.

Students seek out the AMP lab for many different reasons. Some

like the idea of free funding that allows them to explore their interests without the bounds of personal cost. Some like the idea of a supportive environment where mentors are present to assist you when you encounter a challenge. A few look at it as an opportunity to gain skills and experience they would not likely have acquiredelsewhere. Dennis Shen, a senior in computer science and computer engineering, thought of himself as just a programmer, but he experimented and gained much knowledge in electronics through his AMP lab projects.

Right now in the AMP lab, many projects are in progress,including: musical LEDs, facilitated echo location, and an MP3 amplifier. Along with every project comes a mentor, most of whom are also students. Many of the mentors also conduct seminars that teach students various skills. Alex Mosolgo, a senior in electrical engineering, teaches seminars in basic and advanced soldering. Computer engineering senior, Brian Lilienthal, who also created the AMP lab's official website, teaches seminars in board design.

In the AMP lab, students are free to work at their own pace. Some students spend as little as two hours working per week, while others spend as much as ten hours. Hunter Long, a senior in electrical engineering, describes the AMP lab as a place to take the theory you learn in your classes and actually apply it.

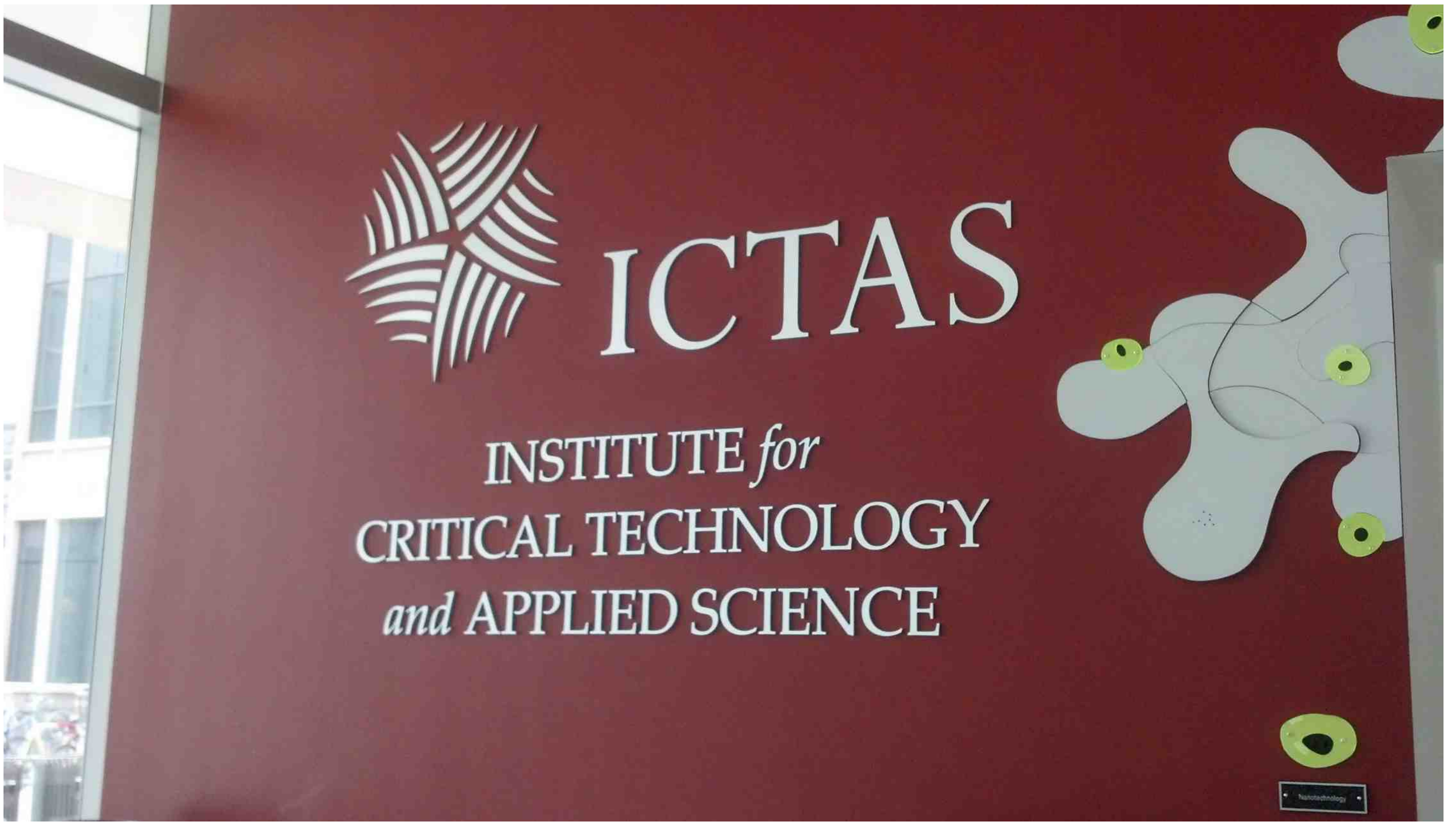
This motivates students in those classes, and in future classes because they see how the theory actually works and how it can be applied in a real world sense. Brian Lilienthal is going to work with a mentee on projects involving the Cerebot microcontroller that is used in Microcontroller Interfacing class. Because of this, the student will gain experience with the Cerebot before she takes the class next spring. So not only can the AMP lab be a place to pursue your personal interests, but it can also be a place to help motivate you in your classes and allow you to better excel in them. Also, Hunter Long added that AMP lab projects are great for your resume because they can give you something to talk about with recruiters when searching for a job, internship, or co-op.

As an industrial and systems major who is interested electronics, I wondered, can ISEs become AMP lab members too? According to Bob Lineberry, other engineering majors are welcome, but cannot receive funding unless an electrical or computer engineering student is the project team leader for the project you want to pursue. There are open meetings for any students interested in joining the AMP lab every Thursday at 7:00 p.m. The AMP is always looking for new members who are interested in pursuing projects that interest them, whether they are in the Electrical and Computer Engineering Department or not.

Research Spotlight: Nanoparticle Cancer Treatment

Ryan Martin, sophomore in Crop and Soil Development

Right next door to the bustling Turner Place dining hall is the Institute for Critical Technology and Applied Science, better known as ICTAS. A recent research publication has been conducted by Dr. Lissett Bickford, an assistant professor in the School of Biomedical Engineering and Sciences under the Department of Mechanical Engineering, in conjunction with staff at the University of North Carolina at Chapel Hill. Dr. Bickford's research focused on creating a drug delivery platform for inflammatory breast cancer patients. This type of breast cancer differs from the well-known form of breast cancer because instead of having the usual lump in the breast, this cancer involves the lymphatic system. Because of this incorporation of the lymphatic system, traditional chemotherapy is not as effective because the cancer is not centrally located in a single tumor–rather, it is located systemically and is much more difficult to "track" down and combat. Additionally, an extremely low survival rate is associated with this form of cancer and usually involves the use of large drugs for treatment; this is where Dr. Bickford's groundbreaking research comes into play.



The result of this research was the creation of a nanoparticle-based micro-needle patch that administers treatment drugs transdermally. This form of treatment differs from the systemic use of drugs because the transdermal application can more accurately deliver drugs where they are needed. On the other hand, systemic drug applications usually use larger doses of drugs with the hope that the chemicals will travel to where they are needed and in the correct quantities. Dr. Bickford's research also improved on a pre-existing platform developed by her advisor at UNC-Chapel Hill. Her focus was on improving the platform by making it more efficient in order to cope with the particular nature of inflammatory breast cancer. Many times, patients undergo mastectomies and other surgeries to help treat the disease, thus creating a dermal surface that is not perfectly fitting to all fabricated patches. As such, making the patches larger allowed for the patch to better 'match' with the patients' own skin surface.

Dr. Bickford's work was performed with the Department of Chemistry, and required working with many chemists for the design of the patch platform. One of the problems associated with the production of the patches was that, many times, the nanoparticles were washed off of the patch's backing and thus proved to be ineffective. As a result, Dr. Bickford's engineering skills came into play as she designed a better system for using nanoparticles while having them stay applied to the backing during fabrication. Even more, Dr. Bickford sought out clinical oncologists in order to examine how her work would be utilized in the field. The oncologists provided feedback and also showed Dr. Bickford how her products would be implemented in real-life treatments.

This particular technology is moving forward with the commercialization process. It has practical uses based upon its improvements on preexisting technology, as well as the potential to radically change cancer treatment as we know it. Going forward, Dr. Bickford wishes to pursue additional research into nanoparticle-based devices used for minimally invasive treatment for cancer patients. This research should be noted as a testament to the power of interdisciplinary cooperation and the ramifications of researching novel technologies.

I thank Dr. Bickford for her time, as well as her determination to help the oncology field provide technologies that assist in delivering treatment in a more practical and effective way.

source: www.teslamotors.com

A Look at the Phenomenon That is Tesla

Dennis Elias, Junior in Finance

Long known for its great contributions to society's technological cravings, the Silicon Valley (Facebook, Apple, Asus, etc.) is once again causing a stir in the news and markets around the world. This time though, it is because of a different type of product than we have come to expect from The Valley: automobiles. Tesla Motors has been making quite some noise for years now, but as of late their technological advancements are being displayed on a worldwide scale. Media, markets, and people are all chattering away about the advancements of what was once seen as a failing startup that had the right idea, but not enough attention. Founded by Elon Musk, co-founder of the pay service PayPal, Tesla started up in 2004 with a six million dollar contribution from Musk. As he gathered additional funding from venture capitalists, he began to gather his vision of not only creating a high-end sports car (the Roadster) and a luxury sedan (the Model S), but to eventually reach the masses with an all-electric vehicle available to all consumers.

There is little doubt that at first, Tesla suffered through some turbulent times. They had to work through a hard-headed automotive industry, along with the recession brought along with the housing crash. In addition to these external factors, they were met with several engineering struggles in creating a 100 percent electric-dependent car. As they developed the vehicle, they found themselves searching for what exactly they would use to power not only a car, but a luxury sports car that ac-

The 17 inch screen inside the Model S is one of the major components that sets Tesla's apart from their competition.

celerates from 0 to 60 MPH in 4.2 seconds. As they searched for answers, engineers at Tesla found a simple solution. Why not just use what we use to power our laptops: lithium ion. The same small batteries that power our PC's and Mac's became Tesla's ticket to fame. This would be the first vehicle of any kind to feature lithium ion batteries as its power source. As they worked on how to prevent the batteries from exploding due to overheating and depletion, they were able to put together a 1,000 pound lithium battery pack featuring 7,000 lithium ion batteries. Next, they created a heating and cooling system to allow the vehicles to run in any conditions. As their vision became a reality, Tesla was once again hit with hard times.

Tesla's first release was the Roadster sports luxury vehicle, which was released as the recession in the US began to take a toll on consumers. Not only was money scarce, but Tesla began to face engineering faults in their vehicles. From door handles not opening to recalls for faulty parts, Tesla was faced not only with financial problems, but with consumer dissatisfaction also.

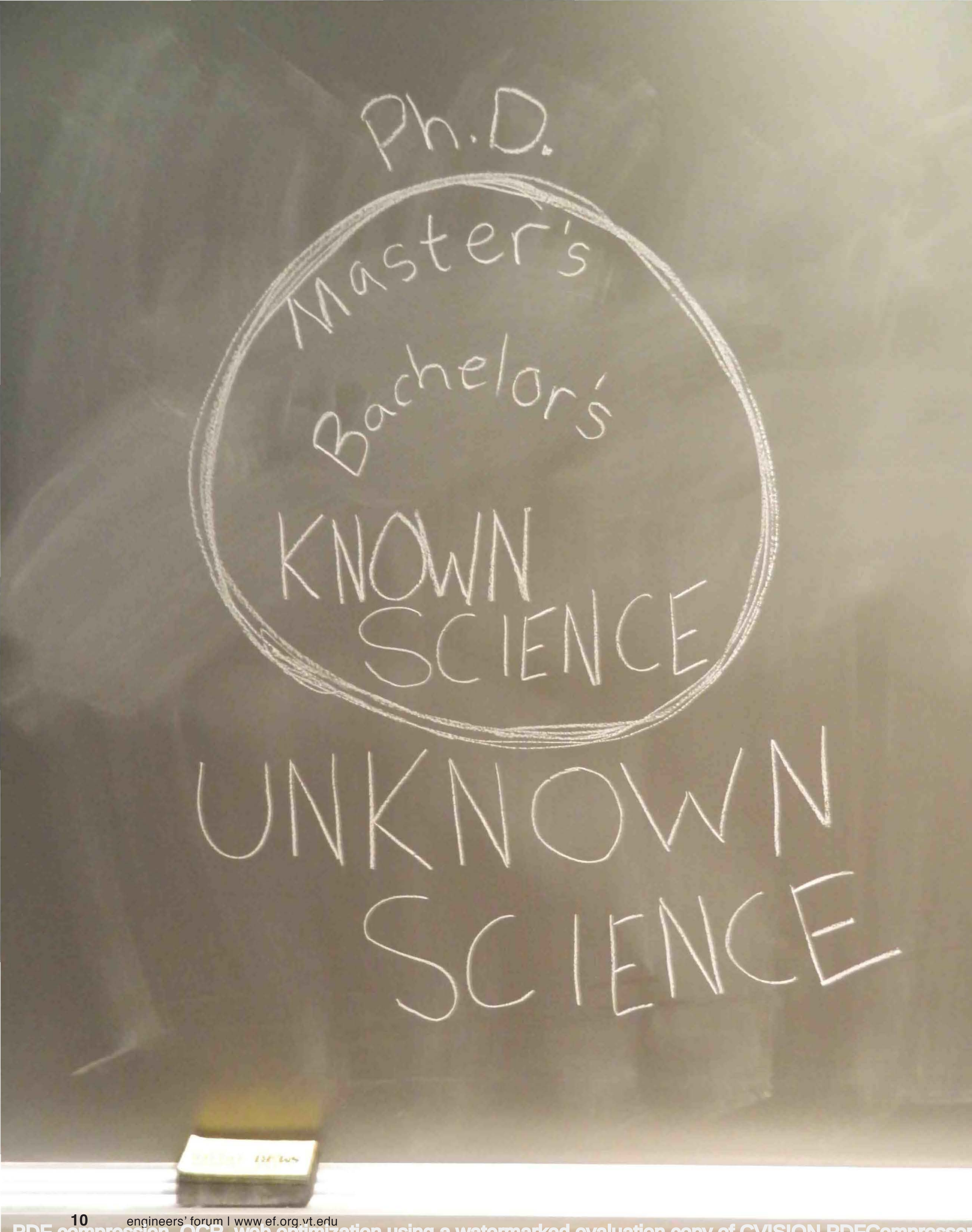
Just as things were starting to look bleak and near bankruptcy approached, Tesla was given a second chance at life and awarded a government grant to further their development. Given a chance at trying once more, engineers and software developers got back to working to achieve their goal. They went back and fine-tuned all of the problems they had previously faced. In the process, they introduced their new, and now famous, Model S luxury all-electric sedan.

Introduction to this new line was a huge boost for the company. With its luxurious silhouette and smooth interior, the new vehicle caught the eyes of many. Not only did it have the look of luxury, but it had features that would make a buggy seem impressive. Equipped with a battery pack that can last 300 miles on a single charge the Model S also features a 17-inch touch screen that eliminates all buttons and knobs. This gives the dashboard a clean and crisp look. Included with the screen is a web browser and apps to make tasks such as finding your car easier. It even lets you warm up your car from the comfort of your couch.

Possibly the most distinguishing aspect of the Model S is that it has essentially no transmission. With a single-speed transmission located at the rear of the car, the engineers at Tesla have made a smooth single-speed reduction transmission that changes torque as the car experiences different driving conditions. Additional benefits of this innovation are that there is significantly greater space throughout the car. Under the hood, where most of us would see a big gas guzzling engine, there is a frunk (a trunk in the front of a car), in addition to the regular trunk and storage space. Most importantly the car loses none of that sporty power, keeping its 416 horsepower and a top speed of 130 miles per hour.

With all of these features and engineering marvels, it is no wonder why Tesla has found the eyes of consumers fixated on them. In May of this past year, Tesla recorded its first profitable quarter and has now paid back the loan given to them by the government in order to stay afloat. Stockholders took note and since the beginning of this year, Tesla's stock has risen by close to 500 percent, an enormous amount in terms of market growth. With all of this attention, even General Motors and Ford have begun a mass hiring of software engineers and developers to help them keep pace with this new-age vehicle.

Overall, as Tesla continues to grow, and as they find themselves going overseas to new markets with new incoming models such as the Model X (a cheaper and more family-oriented model), it is hard to believe that they will not be one of the more profitable companies at the forefront of the automobile industry in the coming years. They now find themselves ahead of the curve in auto making, and it will be interesting to see how they manage their growth with greater demand for their cars, and an inevitably cheaper price point that will allow them to reach the masses. Elon Musk's vision of succeeding in an area where many others have tried and failed is becoming reality. It will be interesting to see what he comes up with next.


Ph.D.
Master's
Bachelor's
KNOWN SCIENCE
UNKNOWN SCIENCE

So You're Considering the Ph.D.?

Joseph Davis, senior in Mechanical Engineering

A light fog settles over the Virginia Tech campus at 7:58 in the morning and the cool air reminds students that winter is coming but isn't here quite yet. Vibrating off Hokie Stone buildings, classical music from Burruss Hall attempts to uplift the spirits of the students who haven't made it to their classes. As you take in this beautiful yet often-overlooked scene, you notice the time on your watch and remember your professor promised a quiz at the beginning of your 8 am class. Happy feelings freshly vanquished, you take off across campus toward McBryde when a thought enters your mind, "Maybe I should get a Ph.D.?"

The thought is gone almost as quickly as it arrived and you fasten your seat belt in preparation for the reckless school day that you're sure to crash into as an engineering student.

Pause here before next week's test calls your attention. Today's the day you think about it.

To an engineering student, the doctor of philosophy degree typically doesn't seem like something that is practical, manageable, or worthwhile. "Engineers get doctorates when they want to spend the rest of their life at a University," some students may think. Others cite time spent in school or money spent on tuition as reasons to avoid the ominous Ph.D. However, a doctorate in engineering is something that will drastically impact a person's life although, admittedly, is not for everyone. Amy Elliott, just a few months from completing her doctorate in Mechanical Engineering at Virginia Tech, spent about 2 months this past year as a contestant on Discovery Channel's "The Big Brain Theory" and ended up being the grand prize runner-up. "A Ph.D. is for people who really, really want to do research," she said.

Elliott has spent her time at Virginia Tech doing research in the field of Additive Manufacturing (3D printing) and working with DreamVendor. After she graduates, she expects to be a researcher in the field. Ken Brown, a Master's student expecting to continue his research as a Ph.D. candidate in the spring, is currently working with the Center for Renewable Energy and

Aerodynamic Testing (CREATe) at Virginia Tech under Dr. William J. Davenport of the Aerospace and Ocean Engineering department. Brown conducts his research on wind turbines at the Stability Wind Tunnel (on the side of Randolph Hall), specifically focusing on increasing wind turbine efficiency by lengthening turbine blades. Brown hopes to graduate and become a researcher in the field of renewable energy. Both Elliott and Brown hope to conduct research in the same field that they will graduate in, a common trend among doctoral candidates of any discipline.

Yet the question looms, "is it for me?"

Elliott said she wasn't sure she wanted to pursue a Ph.D. until her second year in graduate school. "My advisor must have seen some potential in me," she said, citing encouragement from her advisor as a reason she chose to pursue the doctorate degree. "In any organization," Elliott continued, "the people with Ph.D.'s are usually the ones who get to make big decisions about what projects to pursue and what direction to take the company as a whole." Elliott believes that a doctorate in engineering allows her to have more say in what project she works on, which is usually not the case for engineers that stop at the Bachelor's or even Master's degree.

Brown just recently decided to pursue a doctorate in Mechanical Engineering after spending a year in his Master's program. "You're putting yourself into a spot to get a different kind of job," Brown said of pursuing a doctorate in engineering. "As long as you don't take a huge career turn," he continued, "you will likely work in research and development for the rest of your life." Brown explained that, oftentimes, with a Bachelor's degree, engineers end up working in design under a project manager and, with a Master's degree, engineers could end up working in either design or research. Ken wanted to work with "ground-breaking research" which usually isn't possible with a Bachelor's or Master's degree alone.

When considering the doctorate degree, engineers must look at the good a degree can bring along with the bad that may result. "If you're not careful," Elliot explained, "you can get so specialized in your Ph.D. work that you won't be able to find a job." The economy and job market are huge factors effecting the viability of a doctorate degree. "You're old when you graduate," Brown said, only half joking. Even if you pursue a Ph.D. right after your undergraduate education, you're easily 4 or 5 years older entering the job market than you would be if you had stopped at a Bachelor's. Brown explained that, overall, there are much less research and development jobs than design jobs. "You can't get a Ph.D. in aerodynamics and then work in design later," he said. In this sense, the Ph.D. is much more limiting than other degrees. "You have fewer options for where you want to live," Brown continued, "you have to go where your research is being conducted." Brown also discussed his disappointment over the likelihood that, as an engineer with a doctorate degree, he will not be working with mechanics or other blue-collar workers who often provide practical knowledge and experience.

Elliot explained, "In undergrad, you are taught basic facts and theories that already exist, and you basically just have to memorize and understand. In your doctorate, you learn to think on your own, develop your own theories, and perform the science or research that needs to be done to prove your theories." She continued by saying that engineering doctorates have "been trained to do research. Getting a Ph.D. is a 4-5 year long guided exercise in the scientific process… So, when companies are looking to develop new and innovative technology, they look to Ph.D.'s because they are 'certified' in navigating uncharted territory."

Now, resume your life. While you're studying for next week's test, consider the possibilities of pursuing a doctorate in engineering.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Introducing the SailBOT

Robel Fasil, junior in Industrial and Systems Engineering

The SailBOT program has just expanded to Virginia Tech! The SailBOT team is run by a group of students currently designing and constructing an autonomous sailboat for competitions against other schools. Aerospace and Ocean Engineering (AOE) majors have the largest presence on the team, although members of any major may join. This group is an offshoot of the Society of Naval Architects and Marine Engineers (SNAME) at Virginia Tech and is funded by Virginia Tech's engineering program, the Student Engineering Council (SEC), the Ware Lab as well as corporate and personal donations.

I had the opportunity to speak with AOE seniors Wes Downs, the executive officer, and Thomas Shea, the commodore (or president) of the SailBOT team.

With assistance from the U.S. Naval Academy, the SailBOT program was brought to Virginia Tech thanks to the combined effort of Downs and fellow AOE senior Allison Oswalt. Oswalt and Downs were aware of the program's activity at other colleges and became interested; so interested that they created a new team at Virginia Tech.

"We were inspired to do this because of the lack of options for design teams related to Aerospace and Ocean Engineering majors, specifically those relating to the development of surface ships," Downs mentioned.

The SailBOT competition consists of five scored parts to test for the overall design, construction and control logic of the boat. These parts test the boat's performance in a short distance race, a long distance race, navigation ability and stability. The SailBOTs are designed to travel the full length of each course entirely on their own, but can be operated by remote control if necessary. The teams are given GPS locations of buoys of the course, which are then programmed into the boat 's on board computer system.

The SailBOT team at Virginia Tech is divided into the following teams: hull team, sail team, electrical and computer engineering (ECE) team, mechanical team, and the keel and rudder team all tasked with designing and constructing different features of the boat.

The hull team works to design a functioning hull and deck of the boat. It is their job to make sure that both the hull and deck remain watertight so that water does not enter the internal compartments and disrupt the mechanical and electrical components housed within the hull.

“The material for the hull should be durable and lightweight. We are considering using carbon fiber or fiberglass because they fit the criteria and are within our budget,” Downs and Shea said.

The sail team’s focus is on how the sail (along with the boom and mast that hold it) affects the movement of the boat, while the keel and rudder team’s focus is on how their parts assist in turning and keeping the boat stable while moving efficiently. The keel is a long vertical extension of the hull that also keeps the boat stable by preventing the boat from being blown sideways by the wind. The keel holds the ballast, which by lowering the center of gravity, keeps the boat from capsizing, or turning over on itself. The rudder is attached to the back of the hull under the water and it assists the sail in steering the boat by redirecting water past the hull. These teams work together to accomplish this by using a massive keel to weigh the boat down so that it does not flip over when the sails are blown.

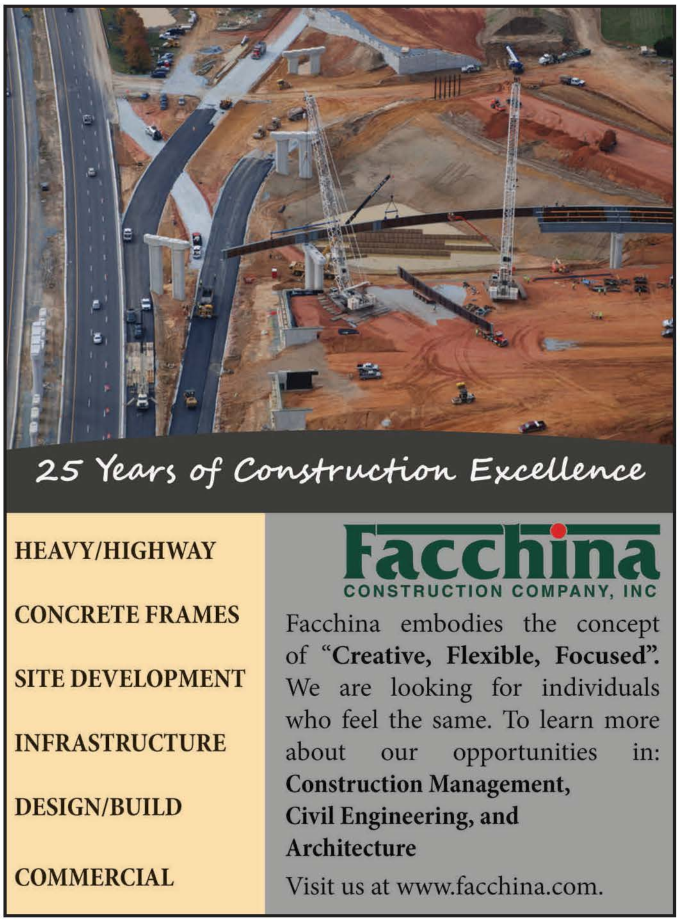
“A little known fact is that sailboats never actually move straight. The sail is hit by winds from both port and starboard (or the left and right sides, respectively), which is corrected by the keel and results in the seemingly forward motion of the boat,” Shea explained.

The ECE team is responsible for the logic behind getting the boat going in the desired direction. They use the coordinates of the course given to them and program them into the boat so that it can complete the course. The mechanical team

develops the rudder and boom controls, winches and pulleys of the boat. The work of the ECE team is linked with the work of the mechanical team so that the commands from the controller translate into the physical operations of the controls and pulleys to result in the desired movement and actions of the boat.

The SailBOT team will be competing in its first competition this spring in San Francisco , California. The University of British Columbia and the U.S. Naval Academy have historically been the leading competitors, but we hope that Virginia Tech can start the program off strong and make a name for our school!

More information can be found at http://www.sailbot.aoe.vt.edu and http://sailbot.org.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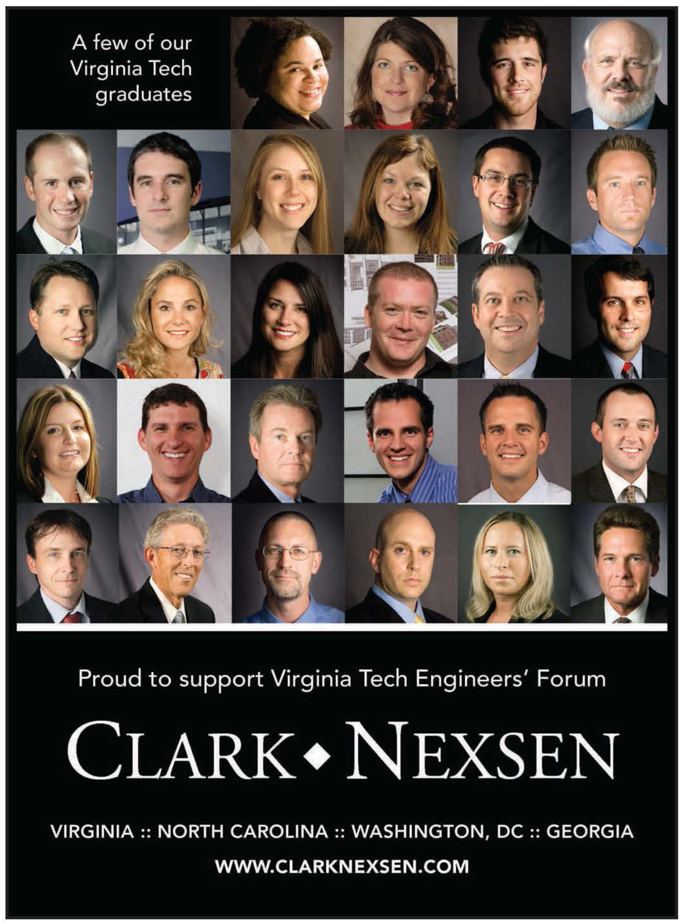
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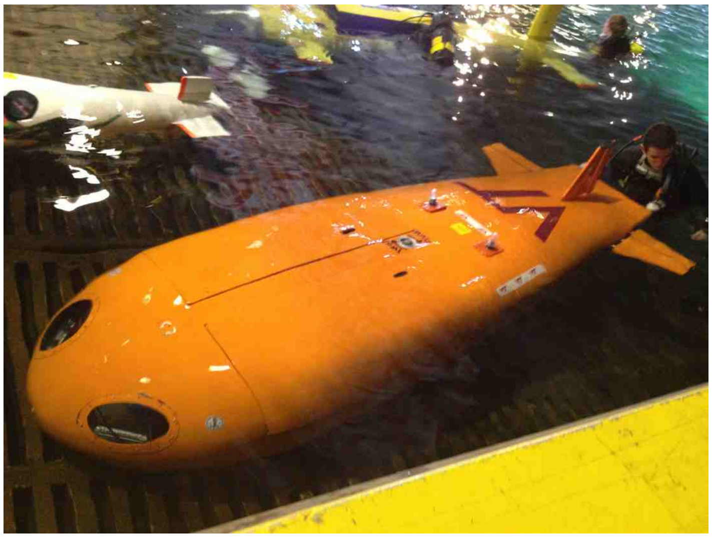
VT Human Powered Submarine: A Glimpse of Phantom 7

Ben Gringras, Freshman in General Engineering

Set apart from the everyday foottraffic on Stanger Street is a large gray metal door that reads "Virginia Tech: Human Powered Submarine." Push it ajar, step over the basement threshold, and you've now entered the Sub Lab, inhabited by the last remnants of a coalition of super-villain engineers working tirelessly to create a submarine of diabolical capabilities. In reality, it's a friendly, easy-going family that meets to dream up underwater vehicles. But it's easy to let your imagination wander when it comes to submarine design, especially with the project goals that the team has in the works for Phantom 7.

Virginia Tech's Human Powered Submarine team (VT HPS) has its eyes on the prize again. This time, the team hopes to double down on a single-pilot submarine design and take both the Fastest Submarine award and the Innovation prize home to mom. For those who have never heard of the Human Powered Submarine team before, the team designs, constructs, and tests a new submarine for competition in the International Submarine Competition Races (ISR) which occurs biennially at the Naval Surface Warfare Center in Bethesda, Maryland. What makes the competition unique is that each team must design its submarine to use power supplied by its pilot(s) to propel the submarine.

The VT HPS team already has a proven track record, having won third place in Innovation in 2009 and first place in



Innovation this past June. They accomplished this feat with the novel two-man side-by-side design of Phantom 6, an interior layout that, up until then, had never been attempted. Phantom 6 implemented a linear drive train (LDT) consisting of two sets of two pedals (a pair of pedals for each pilot) arranged side-by-side. The pilots input power into this system much like one would on a stair climber machine at a gym. The difference is that the pilots lie horizontally on their stomachs in the submarine. These two different power inputs are combined via a differential, or a gearbox assembly, allowing the combination of two collinear shafts which permit one shaft to turn faster than the other while still delivering a unified power output to the propellers. To get a sense of the differential's importance to the design of the propulsion system, without it, the propellers would turn at different rates because the two pilots are not capable of inputting the same power for a given length of time. This makes a straight-line trajectory nearly impossible.

Another innovation employed in Phantom 6 is its electronic system consisting of a data acquisition system and an LCD heads-up display. Because of the addition of various sensors to the body of the submarine, its roll, pitch, yaw, speed, RPM, and depth can all be measured and displayed to the pilots in real time on an LCD screen within the submarine. Not only is this an invaluable tool for the pilots during competition, but it also served the team well during pilot selection. By recording this data on an SD card during the testing of Phantom 6, the performance of different combinations of pilots could be compared afterward to determine the optimal crew for competition, as well as recording data for future submarine design.

When asked to discuss the major design innovation goals for Phantom 7, Brian Cain, president of VT HPS, replied, "Phantom Six was obviously successful in the innovation category, but not so much with speed, and that's to be expected from a submarine her size. But what we're trying to do with Phantom 7 is, now that we've proven that we can waterproof the electronics and that the system actually reads accurately, we want to try and put an electronic control system on it. [This would consist of] an electronic joystick that the pilot can manually operate, but could also have an auto pilot mode to make us go straight during competition. That way all we would need to focus on is pedaling; we wouldn't have to focus on steering the sub, which would be really important to the psychology of the [pilot]. Eliminating one of the biggest thought processes you have to do underwater would be huge for speed."

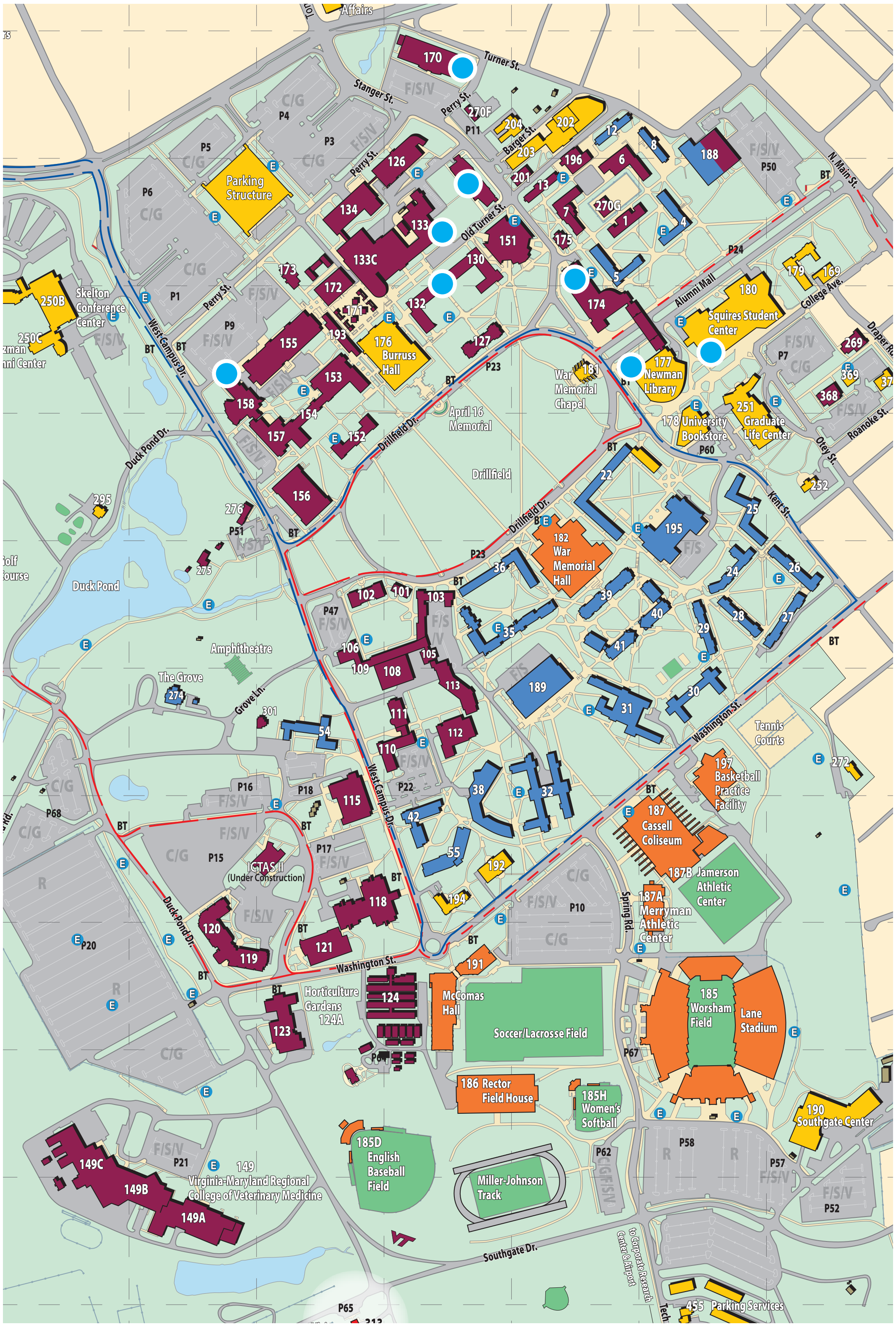
From this response, it's apparent that innovation is not the only item on HPS's laundry list of design considerations. The ISR competition is a race after all. Brian went on to say, "The other thing we are trying to do is go back to a single-person design and volume optimize Phantom 7 so we can go really fast. We saw that (human-powered) subs can reach up to seven knots, so we want to try and make that."

However, the team is not shying away from its tradition of innovative solutions either. As Brian mentioned, one huge design aspiration for Phantom 7 is to equip it with an electronic control system, perhaps even an auto pilot mode. The propulsion sub-team is also investigating the implementation of a propeller, the pitch angle of which could be varied with increasing speed by the proposed electronic control system. This would allow the submarine to generate the maximum power and thrust at a given speed, allowing faster acceleration and reduced performance deficiencies resulting from off-design operating conditions. While the LDT will likely reappear in Phantom 7 for the simple fact that "we know how to build it and we know it works," according to Brian, it may be augmented with a continuous variable transmission (CVT). This allows the change of gear ratios without the discrete jumps from gear-to-gear exhibited in a car or bike transmission. It "continuously varies" these ratios, which would produce benefits similar to those of the variable pitch propeller concept.

Clearly, ambitions are high. With lessons learned from the design of Phantom 6, HPS is taking a "systems approach to design," as Brian put it. In so doing, the hope is to create more communication and collaboration between sub-system teams within HPS resulting in a better overall submarine. With this approach, if HPS successfully implements a fraction of these design concepts in Phantom 7, the 2015 ISR competition should not be overlooked.

Engineers' Forum Rack Locations

1. Norris Breezeway
2. Surge
3. Squires
4. Torgersen
5. Randolph
6. Turner Place
7. Library (first floor near study area)
8. Library (second floor near study area)
9. Hahn North



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