

# **Electrical & Computer Engineering ECE 492 Senior Project Proposal**

By

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## **Electrical & Computer Engineering Design Project Proposal**

For the past five years, the electrical and computer engineering department at Lafayette College taken on the task of building a fully functional, competition-standard electric vehicle. As the car nears completion, there is need for a new project; something that should retain the positive aspects of the previous project, and innovate where necessary. This past semester I have researched the various avenues in which the department could go for its next big project. Before I present my conclusion, however, it is first necessary to understand the conditions under which I made my decisions. My criteria were the following. One aspect of the electric car project that I aimed to keep was the need for digital and analog solutions. Because this unique major provides proficient training in both analog and digital systems, it only makes sense to choose a project that would allow students to exercise both analog and digital design skills. Furthermore, in an effort to more greatly benefit the students, the faculty, and the college as a whole I aimed for a unique project that Lafayette College would be proud to advertise, and which would serve as a challenging, industry-realistic experience for college seniors preparing to enter the real world. With that in mind I designed my decision around projects that I felt reflected the College's values in some capacity. Additionally I tried to retain the relevance of the project impact that the electric car had. Electric vehicles are directly relevant to current industry trends, and the impact of research on them has the potential to cause serious positive impact in the world, which made the project an asset to both the students and the college. As a small liberal arts college, Lafayette

stands alone as one of the only in that category to boast such a prestigious engineering program. Impactful senior projects like the one that we are on the verge of completing put Lafayette on the map not just among liberal arts colleges, but among leading technical institutions as well. For example, MIT has attempted to submit an all-electric vehicle to the same competition we have and, like us, have yet to succeed. That type of marketing is sure to help the college attract the best of the best as they look to expand student population in the near future. In summary, my initial criteria I used while narrowing down my options were to choose a project that...

1. Required both digital and analog solutions.
2. Would serve as a gateway experience and prepare the seniors for graduation by immersing them in an industry-realistic environment
3. Reflected the values of Lafayette College
4. Held relevance to current events, and had great potential impact in the real world

With all of this in mind, I began limiting options based on the fourth piece of criteria, whether or not the project was relevant to current events, and could potentially bear impactful results.

Our world is currently facing a near uncountable number of problems, only some of which have the potential to be solved by technologic innovation. Of these issues I tried to narrow down the few that held the most immediate relevance. In an initial list I determined that general safety issues, environmental issues and security issues were the three categories under which the most relevant opportunities fell. For example, the project we are currently working on has strong ties to environmental

issues. As humans continue to warm their atmosphere, gasoline-powered vehicles are always near the top of the list of contributors. Research into building our own electric vehicle had the potential to break ground in such research, and help push the world we live in toward fully switching over from gasoline-powered vehicles to fully electric vehicles. The final list of projects contained opportunities that all held similar relevance to issues of safety, security, and our environment. The magnitude of this relevance, in addition to analysis of my other criteria, is what helped lead me to my final decision.

Once my decision had been made, assessing the feasibility of the winning option was done utilizing George Heilmeier's nine Critical Questions for Research Proposals. Referred to as the "Helmeier Catechism", Helmeier developed this set of questions in the 1970's while he was the director of the Advanced Research Projects Agency (ARPA) in an effort to help guide those seeking to properly communicate what they plan to accomplish with any given research proposal. The questions are as follows.

1. What are you trying to do? Articulate your objectives using absolutely no jargon. What is the problem? Why is it hard?
2. How is it done today, and what are the limits of the current practice?
3. What's new in your approach and why do you think it will be successful?
4. Who cares?
5. If you're successful, what difference will it make? What impact will successes have? How will it be measured?
6. What are the risks and payoffs?
7. How much will it cost?
8. How long will it take?
9. What are the midterm and final "exams" to check for success? How will progress be measured?

Even if a particular project fulfilled the criteria mentioned above, it was critical to evaluate the project's feasibility. The meaning of the research, and how Lafayette's students could potentially contribute are taken into consideration by these questions. If we were to return to a project that merely assessed the students' abilities to spit back out what they learned without a "why?" component, then there would be no need for these questions. By turning this project into a research opportunity, the department would be enabling the students as engineers and professional thinkers, rather than just graduating students qualifying for a degree. Thus Heilmeier's nine questions are necessary to properly evaluate the merit of the chosen project.

After a full semester of research, the final list of projects I chose to examine closely was as follows. In no particular order, facial recognition technology, further investigation into electric vehicles, and the facets of implementing electric vehicles that currently stand as roadblocks for designers, wind turbine technology, autonomous/self-driving vehicles, and GPS technology research. There were several of these designs which were easily eliminated simply due to lack of certain qualities that I required. For convenience sake, I will explain my evaluation of those options first, before addressing the more worthy opportunities.

### **GPS Technology Research**

GPS research has a lot of interesting applications, and the design of a full system requires a comprehensive understanding of analog systems, digital systems, and signal systems. Additionally, similar to the electric car project, implementing a GPS system can be broken down into subsystems, which could theoretically be handled by sub-teams designed with members who would produce the best results for that particular subsystem. Unfortunately, a lot of the work is simply too large scale for a senior class to handle. The three subsystems of a functioning GPS system are the space segment, the control segment, and the user segment. The space segment is the organization and operation of many satellites circling the earth, and optimizing their position in relation to each to each other, as well as their angle in relation to the earth's surface. The control segment is the monitoring of these satellites on earth. It goes without saying that our department does not have the resources to engage in that kind of research. So although engineering a full GPS system fills many of the criteria set earlier, it simply is not feasible. Additionally, the only portion that could realistically be worked on by our students would be the user segment, the receiver, which would not amount to enough work to occupy an entire senior class for a semester.

### **Facial Recognition Technology Research**

I chose to look into the possibility of proposing a project based around designing a facial recognition system for multiple reasons. As a world issue, facial recognition technology has very serious security-based applications, and companies like Apple

are even on the verge of using this type of technology to replace fingerprint identification technology in their products. Famously, facial recognition technology was pivotal in the location and capture of the Boston Marathon bomber, but this is just one example of the many ways in which facial recognition technology could be useful in the coming years. In addition to the industry relevance of the research, a large part of the project requires a team to figure out how best to generalize a human face, i.e. what points of the face do we sample to identify eye location and shape, mouth location and shape, nose location and shape, and so on. This facet of the project offers an opportunity for collaboration with art majors on this campus. Working with a team of ECE's I believe a group of art and/or photography majors would be essential. Together the team as a whole would work collaboratively to solve what to look for when identifying a human face, and then how best to engineer that recognition technique. This collaborative opportunity combines engineers with artists, and provides a unique project setting in which the students will be forced to exhibit good communication and team building skills in order to succeed.

Although facial recognition research is relevant and poses an opportunity to produce impact, there are several reasons why I did not decide to go forward with proposing this project. For one, there are no real analog components to it. The vast majority of the work is based on digital systems and digital image processing. In order to really be a thorough assessment for an entire class of ECE seniors, the project I want to propose has to allow students the opportunity to demonstrate their proficiency in both digital and analog problem solving. Furthermore, there

simply is not enough work to be done to supply an entire class of graduating ECE's with a semester's-worth of work. What made the car project such an effective and long-lasting project was the presence of subsystems, and the ability to break students up into sub-teams based on their respective strengths. Engineering facial recognition technology does not have enough separate components to break up into teams like that, and is probably a project best suited for a smaller team. Engaging in a project like this would be a really great opportunity for a Capstone Project with a smaller team, or maybe even for thesis work, but the system does not provide enough material for me to feel comfortable proposing it as the next big senior project for the ECE department.

### **Wind Turbine Technology Research**

In the spirit of searching for projects that posed an opportunity for students to accomplish impactful research, it only made sense to look into wind turbine technology. As a renewable energy source, wind power is becoming increasingly desired, and it would be an interesting project for a group of ECE's to delve into detailed research on how wind energy is transformed into electrical energy.

Unfortunately, without sugarcoating anything, the solution to wind power simply is not an electrical engineering problem. Force of wind spins several propeller-shaped blades, which are connected to a rotor. The rotor spins an electrical generator, which produces electrical energy that can then be sent straight to the electrical grid to help power homes and buildings. At the most, this project could be a collaborative



project with the Mech-E's, where the ECE team would focus on the optimal design of the electrical generator. Even with that option, there is no digital aspect to this project, and the assignment would alienate those students whose strengths lie with digital problem solving. Additionally there is no real sub-team structure to the project, and the amount of work required could easily be completed by a small team of ECE's, as opposed to an entire class. Excluding those issues, however, building an electrical generator turns out to be more of a physics problem anyway. In conclusion, there is no real opportunity here for ECE's to properly demonstrate the design skills acquired over the course of their curriculum. I think it goes without being said that for these reasons, this would not qualify as a proper senior project for the ECE department.

### **Further Electric Car Research**

Aside from being a massive achievement for both the engineering program, as well as the school, the impact of simply building an electric car designed to competition standards is quite low. If we want to talk relevance to the world we currently live in, a seriously impactful project would need to be based around the specific roadblocks that engineers in the real world are facing today as they attempt to help move our world into an era where we can hopefully eliminate the harmful effects of gasoline powered cars on our planet. Back in 2012, Barack Obama, in cooperation with the Environmental Protection Agency (EPA), introduced the EV Everywhere Grand Challenge (Electric Vehicle Everywhere Grand Challenge). This initiative was

designed as part of the country's "all-of-the-above" energy strategy, and aims to design electric plug-in vehicles that are as affordable and convenient for the American family as gasoline-powered vehicles are today by the year 2022. The blueprint associated with this challenge outlines the technical requirements that need to be met in order for such a goal to be achieved. In this blueprint, the Department of Energy (DOE) outlines several different subsystems that need to be present in a basic electric vehicle, and the specs that need to be met for each respective subsystem. These subsystems include the battery, electric motor, power electronics, and on-board chargers. I broke down and analyzed each of these subsystems using the criteria above.

To begin my analysis, it is important to recognize that further researching the specific issues with electric cars that puzzle today's engineers fulfills the fourth piece of criteria by default, regardless of which subsystem is chosen, which is not to say that multiple cannot be chosen. Furthering the EV Everywhere Grand Challenge goal is a potential direct outcome of engaging in research on any of the previously mentioned subsystems. As mentioned earlier, gasoline-powered vehicles are a bane to our world's atmosphere, and to aid in the push to switch over to predominantly electric vehicles would serve as impactful research that students could be proud to put their names on. Furthermore, success in any capacity of any of these projects would be a testament to the prestige of the ECE department, the school's engineering program, and Lafayette College as a whole. The subsystems in need of

improvement as detailed by the EV Everywhere blueprint are the battery, the electric motor, power electronics, and on-board chargers.

## **Battery Research**

The main issue with each of these subsystems is not to achieve functionality, but to achieve functionality in a cost efficient manner. Electric vehicles can be made, but until they are cost efficient enough to be sold at the affordable prices that gasoline-powered cars are today, employing them on a mass scale is a lost cause. For the battery, The EVEGC blueprint specifies that costs must be reduced to \$125/kWh. In order to achieve this goal, there is necessary research into exploratory battery materials research. Such work addresses the fundamental issues associated with lithium batteries and the materials out of which they are made. Research is also needed to look into optimizing new high-energy lithium ion electrochemistries that incorporate new battery materials, and systematic ways to effectively test these electrochemistries. Lastly, research is required to help assess the cost efficiency of new battery designs. Currently there is a push to develop models that help researchers calculate potential costs of batteries in parallel with the rise of new battery technologies. All of these research opportunities are what the DOE determines will help them achieve their goal of reducing battery costs to \$125/kWh. For my first piece of criteria, the solution for the issues with batteries would be exclusively analog. However, a large portion of what is holding back the innovation of batteries has to do with electrochemical processes, and the materials used in

making the battery. This serves as an opportunity to collaborate with the chemical engineering department. Additionally, help could be needed from math and economics majors in reference to the modeling component of the project. Creating statistical/mathematical models to represent cost efficiency and total cost for developing battery technologies is a task best suited for those with advanced math training. Both math and economics majors at this school are trained proficiently in data modeling, and collaboration with such students could prove to be helpful. Such collaboration would provide students with the opportunity to work in a team environment in which success would be dependent on strong team building and communication skills. This type of setting is the industry-realistic environment I am looking to immerse our students in. As I see it the most effective way to prepare our seniors for post-graduate life is to simulate it as best we can. Collaborative opportunities achieve that goal seamlessly. However, the downside I see to this project is the lack of need for ECE's. The large majority of the design work needed would fall into the Chem-E realm, and no more than 2-4 ECE's would be needed to work on this subsystem. If the department decides to pursue research on batteries, it would need to be supplemented by work on another subsystem of the car.

### **Electric Motor Research**

Currently the Vehicle Technologies Office (VTO) is funding and supporting research into electric motor technologies, as a part of the electric motor contribution to the EVEGC's goal. In short, an electric motor takes the electric energy stored in the

batteries, and converts that to mechanical energy, which can be used to move the car. Any basic electric motor consists of a rotor and a stator (the moving and stationary parts of the motor, respectively). The issue with current motor technologies is once again cost efficiency, and as per the EV Everywhere blueprint, costs must be reduced by 50% come 2022. There are several major areas of research being done on electric motors in pursuit of this goal that could potentially be taken on by students at Lafayette. Currently research efforts are being lent to discovering low-cost permanent magnets and magnetic materials, and improving electric motor thermal management, performance, and reliability. The positives of pursuing such research as a part of a collaborative ECE492 project are similar as those for the battery system. Such efforts would require collaboration, namely with geology majors, mechanical engineers, and potentially physics majors. A large portion of the problems facing electric motor engineers today concern the magnetic materials used in the construction of the motors. A team of geology and physics majors would be crucial in determining optimized design in this respect. Furthermore, it would be wise to employ the help of mechanical engineers, who would aid in the construction of the motor. However, once again, the ECE contribution to this particular subsystem of the car would be small, and limited to the thermal management system. Although this subsystem provides a good opportunity to collaborate in a team setting, R&D in this area would once again need to be supplemented by research on another one of the subsystems. I cannot see a situation in which more 2-3 ECE's would be needed to work on the electric motor's thermal management system.

## **Power Electronics Research**

In order to reach the goals set in the EV Everywhere blueprint, a considerable amount of funding and support is being lent to lowering the cost, and improving the performance of power electronics in electric vehicles. As outlined by the blueprint, in any electric car there are power electronics technologies that function in many different ways; from processing and controlling the flow of electrical energy to controlling the speed of the motor, to distributing electrical power to other vehicle systems such as heating, ventilation, lighting, etc. Amongst these electronics is an inverter, which converts DC energy from the battery to AC energy used in the drive motor. An inverter also acts as both a motor controller and a filter in the vehicle. As a filter, the inverter helps protect the battery from stray current. Not only are researchers today focusing on reducing inverter volume and part count, but they are also looking into the improvement of the specific components that make up each inverter, namely the semiconductors. Researchers are working on inverter topologies that shift away from using silicon-based semiconductors, and instead implement wide band gap semiconductors (WBG semiconductors). WBG semiconductors are much more resilient than their silicon-based counterparts, and can withstand much higher temperatures. In this way, inverter architectures that implement WBG semiconductors effectively reduce cost by reducing the need for a thermal management system. Working on producing inverters with such technology

in them could prove to be a good collaboration project between chemical and electrical engineers.

In addition to inverters, improvements to DC/DC converters are also in demand. In the car, these converters are used to alter battery voltage to accommodate the voltage ranges of the motor and other systems inside the vehicle. Current efforts to innovate in this area aim to develop next generation topologies that are more efficient and reduce part count. This in particular would be a great endeavor for a team of ECE's. The need to not only create an efficient design but also effectively test that design would be an excellent opportunity for senior ECE's to demonstrate the design and analysis skills they accrued over the course of their curriculum. The research of power electronics, unlike the previous two subsystems, relies heavily on contribution from the ECE department. It is a relevant and impactful project, which the department can assign to the students knowing full well that success is directly proportional to the quality of the education received by the students in previous years. Furthermore, it is an excellent opportunity to collaborate with chemical engineers, as noted earlier. The downside to this is that there is still no real way in which this project reflects the ideals of the college. Although this is not the most important piece of criteria out of the four, I would like to reiterate that it was important to me that it be included. As a major piece of criteria in my decision-making process, I was hoping to help maximize the impact and the meaning of the project. As Heilmeier would put it, the mission statement of the college is Lafayette's answer to his question four, "so what?" If the project can somehow reflect the

college's mission statement, then the project has a "so what" for the department, the students, and for Lafayette as an institution.

### **On-Board Chargers Research**

As per the blueprint, on-board charging technologies convert AC energy from the electrical grid into the DC energy needed to charge the batteries. Currently, these chargers are based on traditional, high-frequency charger circuits. In an effort to maximize cost efficiency, research to optimize circuit architectures is required. Additionally, researchers are looking into the integration of charging with existing power electronics on the car. Allowing already present electronics in the car to aid in charging will in turn reduce part count and weight, thus improving cost efficiency. Although not quite its own separate project, the consideration of the integration of on-board charging could prove to be a supplementary task for any teams working on the power electronics or the electric motor. Thus the positives and negatives for each of those subsystems ring true for this project as well.

### **Car Research Summary**

In summary, furthering research on electric cars has the potential to test senior students as engineers, as well as expose them to a collaborative team environment in which they are forced to exercise good team building and communication skills. In addition to fulfilling the criteria of providing an industry-realistic experience, the



work being done would be relevant, impactful, and would properly assess the students' proficiency in electrical engineering. Instead of simply designing a car based on a set of competition requirements, students would be striving to help the world's engineers reach a goal that stands to benefit us all, based on the same design specifications being used by today's top engineers. Unfortunately, there is little room in this project to incorporate digital systems solutions, and although the project presents the opportunity for positive impact from an environmental solutions standpoint, there seems to be no truly powerful way to connect the project back to the core values and ideals of the college. In the end, this project represents a feasible opportunity for an impactful project, and one that provides students a set of options for research depending on each student's particular strength. Having made this point, I am confident that this would make for a great project to follow the current electric car assignment. That being said, the largest concern is that these options are limited to analog design, and the project does not necessarily cater to students who excel in digital design. Additionally, many of the solutions to the project requirements ask arguably more of students from other disciplines than it does of ECE students. What was intended to be an interdisciplinary experience is liable to turn into a project for the engineering department as a whole as opposed to just for the ECE 492 course. If this is a desired avenue, this must be taken into account.

### **Self-Driving/Autonomous Vehicle Research**

My final topic for consideration in my proposal for the ECE department's project following the completion of the electric car is research into self-driving vehicles. Not only are autonomous vehicle systems a young technology with serious technologic and ethical implications, but also the system itself is intricate enough to provide an entire class of ECE senior students sufficient work for many years in the same way the electric car did. In reference to my initial criteria, this project hits all four major points. As will be explained, designing a self-driving system for a car requires the implementation of both analog and digital solutions. Additionally, the sheer amount of work, supplemented by the interdisciplinary collaboration opportunities that this project would provide offers an industry-realistic setting, which would more than prepare the graduating students involved for their professional endeavors in the real world. As I will explain in my summary of the project opportunity, this project reflects directly the values of the school, and thus inherently answers Heilmeier's "who cares?" question. Finally, self-driving car research is not only incredibly relevant in the world we live in today, but also it holds a particular relevance to this school. With technology like this on the verge of commercialization, many are curious as to the subsequent impact on vehicle accidents and associated deaths. In reference to the Lafayette Community as a whole, embarking on an in-depth research project of self-driving vehicles would be a noble and proactive gesture in response to the two vehicle-related student deaths that Lafayette has seen in the past two years alone.

Self-driving vehicles need to be able to sense, evaluate, and respond to the surrounding environment the way a human driver would. To accomplish this, any self-driving car should be equipped with a GPS system, an inertial navigation system, and a series of sensors that help the car perceive its surroundings. These sensors range from laser rangefinders to radar systems to video cameras. All of these systems cooperating with each other allow the car to perceive its location, and refine its position in relation to its surroundings. Data from the cars ability to perceive its position is filtered through to a control system, which makes navigational and reactive decisions based on the incoming data. There are a lot of moving parts to this system, and the above explanation was simply a watered down version of what it would take to implement a system like this. To get a better sense of how feasible such a project would be, we need to take a closer look at specific components, and how they translate into a senior project setting.

### **Mapping and Localization Functionality**

In order to make a navigation decision, the car must know where it is and what its surroundings look like. To do this laser rangefinders and cameras are vital. Laser rangefinders scan the surrounding area using swaths of laser beams to calculate the distance at which the car is from nearby objects. Some forms of radar systems perform similarly and can be used for this purpose as well. Engineering such radars could prove to be an excellent project for a group of ECE seniors. To supplement these radars, video cameras are ideal for extracting color and image from the

surrounding area. Aggregating the data from these two methods of perception allow the car to create a three dimensional map of its surroundings. Creating a sensor driven mapping system would on its own be a hefty, yet feasible task for this school's ECE seniors. Mapping systems like this are used to help localize the vehicle with the aid of the GPS unit. GPS readings can be off by many meters due to signal delay, and mapping systems like the one described above are vital to the proper functionality of the whole system. Of course, as the car moves, it must react to new incoming data. Designing a system that seamlessly and reliably updates the control system with new information is a real problem plaguing self-driving vehicle researchers today. Whose to say the ECE's at Lafayette College are not equipped with the right tools to tackle such a problem? Having received a comprehensive education in signals, signal systems, and communications systems, I see no reason why such a task would be too difficult for our department's seniors.

### **Obstacle Avoidance**

Although the car can perceive its surroundings, it still needs to be able to react as quickly as possible to keep its passengers safe. Unfortunately simply reacting to new and incoming data is not sufficient to guarantee safe driving. In order to truly react to its moving surroundings the vehicle must be able to predict, similarly to the way a human driver would. The vehicle must implement an internal map system that contains both the current and predicted locations of all identified objects in its immediate surroundings. These objects are categorized based on how well they

match up with a database of pre-determined shape descriptors. A probabilistic model would then need to be designed to track the predicted future path of each object. This model would make its prediction based on the prior position, and trajectory of the object. This is the part of the project where digital solutions become necessary. The need for a program implementing a probabilistic model would call for the expertise of both digitally inclined ECE's and potentially math majors. Using a probabilistic model like this has strong ties to AI and machine learning, and would be an incredibly relevant and helpful endeavor for any graduating senior wishing to take on similar problems in the real world. Using this information, the vehicle's control system can react much quicker to its moving surroundings, maximizing safety. This predictive decision-making process allows the vehicle to react just as quickly, and in most cases more quickly than the average human driver. This is where the technology begins to have real impact. As soon as the car begins driving more safely than the average human, then the research has merit; it has a "so what?"

## **Path Planning**

Now that the vehicle can perceive its surroundings and avoid obstacles while moving, it is time to engineer a way for the vehicle to tell itself where to go. No matter how our engineers choose to design it, a path-finding algorithm must be developed to help the vehicle plan its trips from point A to point B. This task, however, is more intricate than just implementing a shortest path algorithm. The algorithm must take into account all feasible short-term paths and maneuvers while

analyzing the feasibility of its long term plan to move from point A to point B. Such a problem would be a sufficient assessment for a small sub-team of ECE's. Any students who passed CS 150 and CS 205 should more than sufficiently trained to tackle this algorithmically based problem.

### **Interconnect**

All of these subsystems need to be able to cooperate with each other. Similar to the interconnect team currently working on the electric car, this project calls for a team of ECE's to figure out how each system is going to physically work with one another. In many cases this is going to require not just the building of wires, but also the design of cables made specifically to send certain signals to certain parts of the system. Currently Professor Wallace teaches an entire course dedicated to the design of these types of cables, and this would be a wonderful opportunity for the department's students to exercise the skills learned in that course.

### **Collaborative Opportunity**

One very exciting characteristic of this project in particular is the collaborative opportunity it provides. The mass production of affordable self-driving vehicles has a considerable amount of baggage associated with it. There are serious policy-based implications associated with car companies offering cars which operate without a driver. Should there be different rules of the road now that we rely on electrical

systems to make decisions on the road for us? What type of regulations should be imposed on the design specifications of these vehicles? For example, should they not be allowed to travel over certain speeds? Furthermore, the most common way that cars are hacked is via satellite connection to the vehicle. With vehicles that rely on GPS units and connected electrical systems to operate, what kinds of policies should be implemented to keep these vehicles safe from hackers? The deployment of these vehicles presents a whole new realm of problems for policy makers, and this would be a fantastic opportunity for the college to encourage senior non-engineering students to work with the ECE team and research the industry and policy implications of such technologies. Additionally, with companies and federal institutions creating high demand for research relevant to self-driving cars currently, it would be advantageous for Lafayette to proactively recognize this economic and social trend and begin addressing potential solutions to these industry trends. Most importantly, these solutions could feasibly be seen as both opportunities for students and assets to our academic institution. The collaboration of an engineering discipline with a liberal arts discipline transforms the whole endeavor into an incredibly unique research opportunity unlike the vast majority of undergraduate experiences offered in this country. Currently, Lafayette's IDEAL Center is focused around creating unique research opportunities very similar to the one I am proposing. The IDEAL Center boasts the benefits of its programs which allow engineering and non-engineering students to combine their skills to solve real world problems. Unfortunately, these programs all take place outside of the classroom. This research presents the school with the opportunity to internalize this

kind of experience by embedding it in the curriculum of the Electrical/Computer Engineering Major. This project opportunity would serve as a direct representation of everything the IDEAL Center stands for, and it would not be out of the question to appeal to the center for funding on this project.

This collaboration opportunity also fulfills a requirement that no other project I have researched has met, which is that it directly reflects the college's values.

Lafayette College's mission statement reads as follows.

“...The College strives to develop students' skills of critical thinking, verbal communication, and quantitative reasoning and their capacity for creative endeavor; it encourages students to examine the traditions of their own culture and those of others; to develop systems of values that include an understanding of personal, social, and professional responsibility; and to regard education as an indispensable, lifelong process.”

What this research opportunity provides is a chance for engineering students to attack an engineering problem that has serious ethical implications, thus affording them the chance to not just complete an assignment the way most students are encouraged to, but rather think about the impact and implications of such design work. This type of work would test not only our students' quantitative reasoning and design skills, but also assess their ability to analyze the real world results of their work. Paraphrased, the mission statement essentially states the college's desire to produce professional adults who take pride in their work, and utilize the quantitative skills they've gained to attack problems that they deem worthy based on their own set of values. The integration of the policy piece of the puzzle achieves



that goal seamlessly. This allows Lafayette to more proudly advertise the strength of their engineering program, a program which is already abnormally prestigious for a liberal arts institution. Lastly, all of this work is being done in a collaborative team environment, which would be designed to exercise our students' team building and communication skills. This is a unique undergraduate project, which breaks ground in multiple areas, and provides an experience that the department, the engineering program, and the institution as a whole can proudly advertise.

### **Self-Driving/Autonomous Vehicle Research Summary**

A long-term research project on the development of self-driving technology for vehicles would offer an intricate, impactful, and unique opportunity for the ECE department, and Lafayette College as a whole. Not only would this project offer students the chance to exhibit their proficiency in both analog and digital problem solving, but it does so on a topic that is incredibly relevant to current social and technologic trends. Its relevance does not end there, however. Lafayette has seen two vehicle-related student deaths in just the past two years, and it would be a positive gesture in response to those deaths for the college to engage in research like this. The collaborative opportunity that this project offers would allow our engineering and non-engineering students to work together in an industry-realistic setting. This meeting of the minds would create a project setting that encourages the development of communication skills, as well as an understanding of social and professional responsibility. Students would perform real, impactful research, all the

while developing an understanding of the consequences of that work as it pertains to the rest of the world. This will prepare students for the challenges of the real world, and allow them to take away lessons that they can carry with them for the rest of their professional lives. These benefits all accompany this project even if the research fails to bear fruits. However, if Lafayette students could achieve improvements of current self-driving technology or even just improve the cost efficiency of systems already in use, Lafayette would stand among a select few of academic institutions contributing to this particular type of technology, which has the potential save an immense number of lives. In an effort to stray away from a static and unoriginal senior project, this research opportunity would strongly reflect the values of the college, and highlight the value of a liberal arts education. As for the issue of project funding, the department's monetary contribution to the project could potentially be supplemented by funds from Lafayette's own IDEAL Center, which encourages the school's students to engage in experiences exactly like this one.

In summary I propose that the Electrical & Computer Engineering department begin putting forth efforts to realize the active student research of self-driving vehicle technology. None of the other projects that I have previously researched have fulfilled as many of the criteria as this opportunity. In addition, this project is one of the only projects I researched that provides enough work to occupy an entire ECE class for multiple years similar to the way the electric car project did. What really separates this project from the rest, however, is its relevance to the Lafayette

Community. One of the central motivations for deciding to depart from the electric car project was to engage in more meaningful work. The car project culminated in simply racing a car against other cars, which in practice allowed the students to take ownership of a design and compare it against other designs. Beyond that, however, the project really did not present any additional significance. With that in mind I wanted to design a project that had a “so what?” for the students, the faculty, and the school as a whole. Considering this project’s significance to both the values of the school and its student body, which has faced two vehicle-related deaths in as many years, the research and development of this technology serves as the single most relevant project idea.

### **Heilmeier’s Nine Critical Questions for Research Proposals**

In defense of my choice of project, I will now answer the Heilmeier Catechism in reference to the project. Answering these questions should help make clear the feasibility of actually implementing the project.

- 1. What are you trying to do? Articulate your objectives using absolutely no jargon. What is the problem? Why is it hard?** What we are trying to do is build a system for autonomous vehicles that allows the car to drive itself. In addition to simply designing the technology, the focus is to work with non-engineering students to design both a system and a set of policies that would maximize functionality and safety. Secondarily, the aim of the engineering side is research. This technology

is very young, and has yet to be released to commercial markets for consumers to use. With this in mind, I hope that our students would be able to contribute in some capacity to the furthering of R&D on such technology. The issues that plague today's autonomous vehicle engineers will do the same for our students.

**2. How is it done today, and what are the limits of the current practice?**

The number one issue associated with this type of technology is reliability. It only takes a split second of error for someone to die in a vehicle, and thus both the hardware and software inside the vehicle need to operate at as close to 100% of the time as possible. Currently, engineers are having trouble with software glitches and circuitry issues, both of which are preventing companies from placing drivers inside these vehicles with full confidence in their safety and wellbeing. Current testing has yielded results that show autonomous vehicles traveling over 630,000 miles with only 124 disengagements (moments in which there was an error or the driver needed to manually take over the system). While this only yields a 0.2 disengagement rate per thousand miles, there is no telling how many more errors will arise once these cars begin travelling roads populated by predominantly other self driving vehicles. Furthermore, there is simply not enough autonomous vehicle testing currently taking place to properly assess that situation. In short, while this technology is improving day by day, there still remains a long way to go before engineers can sign off on a product they feel is completely safe

for the average consumer. My hope is that a student perspective on such problems may produce a breakthrough in this area.

- 3. What's new in your approach and why do you think it will be successful?** The approach is simple. The leading institutions currently researching this technology are made up of working engineers, most of whom have long since ended their academic careers. If anything, a student perspective on the problem should provide a fresh viewpoint from the minds of those who have very recently been trained in both the fundamentals and detailed aspects of electrical and computer engineering. Sometimes the most effective solutions are the simplest, and tend to stem from a relapse to the fundamental components of the solution. I believe allowing a student body to attack the problem from scratch could provide an interesting angle on the research and development of autonomous vehicle technology, and possibly even produce meaningful and innovative results.
- 4. Who cares?** As one of the questions that guided me in my decision, it was imperative that my answer to this question be thorough. Technically anybody who drives a car should care about this research, considering vehicle related deaths rose by 10.5% last year. However, as stated previously, this research has significance not just to the students, faculty, and administration from an academic perspective, but also to the Lafayette Community as a whole. From an academic standpoint, the students and faculty get the opportunity to work in an immersive and

collaborative setting on meaningful research, which will help serve as a major stepping-stone in the transition from student to graduate. From an administrative perspective, this project reinforces the school's values as described by the college's mission statement, producing students who excel both in their quantitative reasoning abilities and their ability to assume moral and social responsibility. Finally, from the viewpoint of the Lafayette Community, a group which has lost two of its members to vehicle related accidents in the past two years alone, this research would serve as both a relevant and meaningful experience.

5. **If you're successful, what difference will it make? What impact will successes have? How will it be measured?** The measure of successful research will come down to testing. Put simply, if the systems designed by the Lafayette students surpass current leading systems in this field, then the research has been successful, whether it is the functionality of the system as a whole, or just the individual components of the system. Of course extensive testing will be needed for all subsystems to draw any sort of conclusive argument. If research is successful the impact is the contribution to the research and development of technology that I am confident will save hundreds of thousands of lives in the future.
6. **What are the risks and payoffs?** One particularly attractive aspect of this project is the lack of risk. Let us assume the worst case scenario, in which the department undertakes a large scale project to research autonomous vehicle technology, which culminates in failed research.

Even in this scenario, the students have still gained a unique and memorable experience from which they can take many lessons as they transition into post-grad life. Even further, failed research can in some cases be almost as impactful as successful research. Particularly when working with new, incomplete technology, knowing what does not work can be just as valuable to engineers as knowing what does. This is not to say that I can guarantee a positive result from the research and development of this technology at Lafayette, because I cannot. Even if the research done at the school contributes nothing to the R&D of this technology around the world, what really matters is that we have provided an amazing opportunity for our students to engage in a project that forces them to exercise their design, team building, communication, and creative thinking skills in an industry-realistic environment.

7. **How much will it cost?** Unfortunately, there really is no telling how much this project would cost. Until a team of engineers sits down and works out the design that they wish to pursue, there is no real way of gauging what kind of funds will be needed. What is known is what goes in any basic self-driving system, and from that we can make rough estimates.
8. **How long will it take?** As stated previously, without a design, there is no way to tell how long it will take to engineer. Especially because our students would essentially be starting from scratch, to even estimate a timeline for the project would be foolish. What I can provide is likely

bounds but nothing more. After seeing what kind of work can get done in a semester of 492, I cannot see the department producing a fully functional system in less than 5 years. However, that does not mean that impactful research cannot be achieved on the systems subsystems in that timeframe. Once the students sit down and hash out their designs for the system, a more accurate timeline will begin to take shape.

- 9. What are the midterm and final “exams” to check for success? How will progress be measured?** Assuming this project works the same way the electric car project did, the midterm and final “exams” for this project will be different for each team. However, each semester an ATP-style assessment, demonstrations, poster presentations, PowerPoint presentations, and weekly meetings will be used in the evaluation of the progress of the project.

## **Conclusion**

There are many avenues which the department could take to realize a perfectly suitable senior project for ECE492. It would be sufficient from an academic standpoint to simply choose a project which properly evaluates the students’ engineering and design abilities, qualifying them for their degree. I think it is clear that by Lafayette’s standards as an academic institution, however, that this would not be enough. Both the school and the department want to produce well rounded students who can think quantitatively, and interact with the world they live in on an



intellectually and socially mature level. In light of that goal, why not implement a project that highlights those qualities in our students? Why not challenge our students to accomplish real research in a collaborative group environment? Why not provide our students with unique and helpful experiences, from which they can grow as individuals and as professionals? In the real world, professional work always has a “so what”, so it only makes sense that we should be training our students to attack their work similarly. If we are to properly prepare our students for post-graduate life we need to be providing more for them than just the opportunity to race a car; I feel that there needs to be more to it than that.

I would like to take this time to thank the faculty for their time as well as for their consideration of my proposal. My work this semester was supplemented by aid and support from Professor Chris Nadovich.

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