The S.P.E.C.I.A.L. Project

(Technical Paper)

The Power of Water

(STS Paper)

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Bachelor of Science, School of Engineering

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Technical Project Team Members

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature Jack Craddock _____ Date 5/6/2020

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Approved _____ Date _____

Tsai-hsuan Ku, Department of Engineering and Society

Overall Introduction

For my technical topic, I am planning to design a solar powered fan. The goal of this project is to provide low income areas with cheap cooling options that can be implemented without any connection to a power grid. The project will feature an implementation which will allow for simultaneous charging and cooling capabilities which should allow for continuous cooling coverage.

For my STS topic, I am planning to research how well the Charlottesville community is informed about the importance of stormwater management infrastructure. The goal of this project is to gain information about the community which will help to create a dialogue with the local government about how to spread awareness of the current state of stormwater infrastructure. This project will feature a value centered design approach in order to ensure that the end result of the project is aligned with the goals and values of the local community.

Technical Topic

The S.P.E.C.I.A.L. Project

Hieu Le, Kristian Johnson, Jack Craddock

Abstract

Solar Powered Electronic Cooling In Any Location, or The S.P.E.C.I.A.L Project, is a portable, low-cost, durable, solar-powered fan to be used primarily in developing countries. This project will be designed to be affordable, to withstand everyday use, to be easy to repair and maintain, and most importantly, to efficiently provide cool air to those around it. The fan is designed primarily for outdoor use and is intended to provide simultaneous charging and cooling; where cooling is defined as the redistribution of air directly and autonomously induced by the fan.

Background

The S.P.E.C.I.A.L. Project was chosen to provide a solution to developing countries' cooling issue. "Cooling in developing countries is a major problem that affects health, disease treatments and hunger… Many developing countries do not have access to electricity and consequently do not have proper cooling systems either… Although air conditioning ownership has gone up from 2 million in 2006 to 5 million households in 2011, that number still only represents around 3 percent of Indian households. Restricted energy access prevents many from being able to purchase air conditioners."[1]

There are other solar powered fans available on the market; but they don't properly address the needs of these developing countries and impoverished locations. The other options on the market are either too high priced, with several unnecessary features that drive the cost upwards, or so inexpensive that there is no durability; and the product isn't worth repairing when it inevitably breaks. The inexpensive models are also designed such that the fan cannot be on while the solar panel is charging the battery, and the battery cannot be charging while the fan is on. The S.P.E.C.I.A.L. Project is a perfect medium. It will only feature aspects that are required to provide cool air without normal means of electricity. This allows our product to be more affordable than the majority of the quality, solar-powered fans on the market. The S.P.E.C.I.A.L. Project will also durability and ease of maintenance. This allows the users to carry on with their everyday lives without the fear of damage to the product. In addition, if the product were to be damaged, disassembling The S.P.E.C.I.A.L. Project would be a breeze. The low-cost parts allow for replacement by the user, and the design allows for simultaneous solar-powered charging and power to the fan. These qualities provide The S.P.E.C.I.A.L. Project with an advantage over all of its competition on the market.

Hieu is an Electrical Engineering major and he has experience with solar panel technology and he is also familiar with AutoCAD[2] software. Kristian is also an Electrical Engineering major who has some AutoCAD experience and 3D printing experience as well. Jack is a Computer Engineering major who will be using his programming skills with the MSP430[3] that will be used in our project. All of the members in this group have experience with designing a PCB with MultiSim[4] and UltiBoard[5]. In addition, we are all capable of testing with the Virtual Bench[6], and programming in Code Composer Studio[7].

Description of Project

The Solar Powered Electronic Cooling In Any Location, S.P.E.C.I.A.L, is a solar powered fan which is also portable, low-cost, and highly durable. The device will be designed to be affordable, to withstand everyday use, to be easy to repair and maintain, and most importantly, to efficiently provide cool air to those around it. The fan is designed primarily for outdoor use and is intended to provide simultaneous charging and cooling.

The user will place the device into an open space and open up all the foldable, solar panel wings to face directly towards the sun. The process begins with the solar panel generating 12-15V in full sunlight. The solar panel is connected to the Solar Charger Controller which converts the fluctuating voltage and current to a steady voltage and current, for the charging of a 12V battery. The Solar Charger Controller will also be designed to prevent overcharging the battery, hence lengthening the life of the battery, and preventing the discharge of the battery itself. The battery then stores electricity, and because the MSP430 runs on 3.3V, we need a voltage convertor to step down the voltage. There will be an On/Off switch to cut off the power from the battery pack to the MSP430. This will provide the ability to completely turn off the device to save power. The MSP430 will be programmed to alert the condition of the battery pack using LEDs. It will also be programmed for the header board Pulse Width Modulation (PWM) to control the speed of the fan. PWM will be used to regulate the output voltage, which will determine how fast the user wants the fan to spin. It will have three speed settings after the fan is turned on: slow, medium, and fast. The fan will be specifically designed to be detachable from the whole unit. It will be connected to the unit by a wire, which also allows the user to charge the battery and use the fan at the same time.

The figure below, Figure 1, describes the electrical flow through each subsystem.

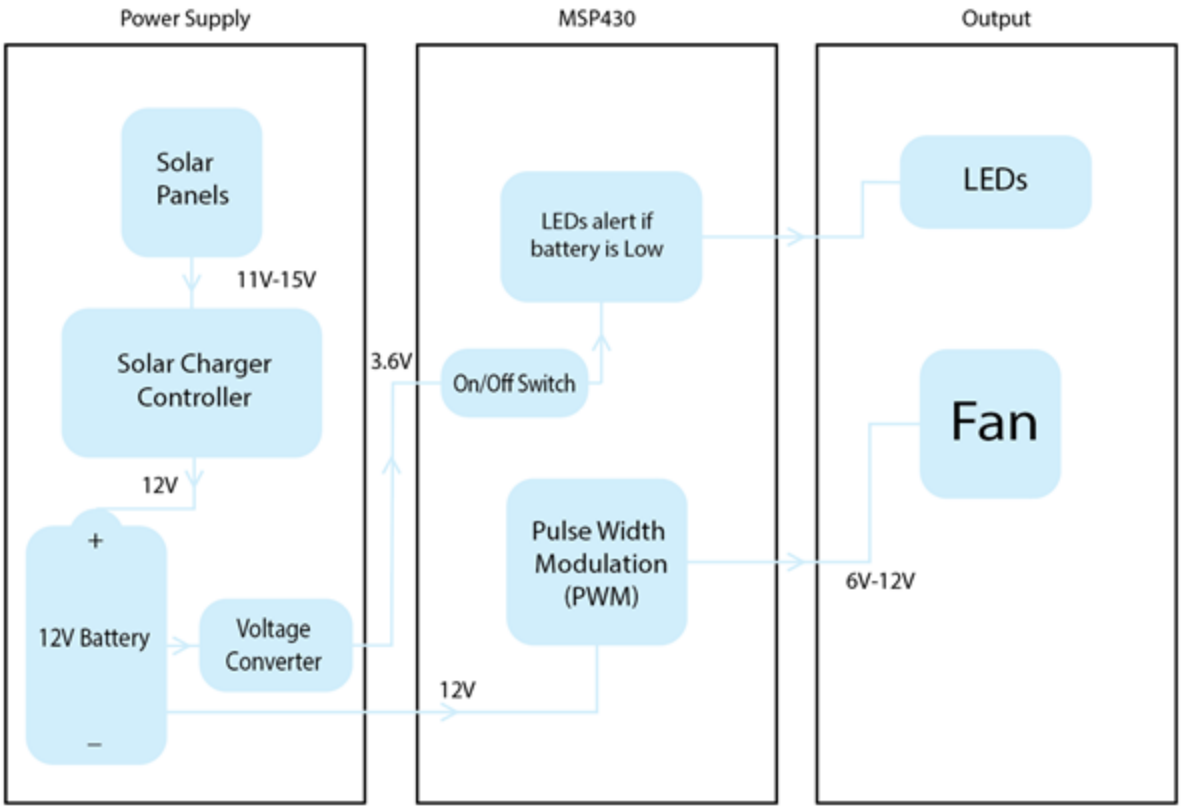

Figure 1: Subsystems of the Electrical Flow of the Design

Choosing the right solar panels is one of the top priorities of this project. They will be balanced between cost and efficiency. In addition, the solar panels selected will be framed and ready to produce the required voltage. We are building our own Solar Charger Controller PCB, it will be crucial for this project. First, as an experimentation step, the method of the Solar Charger Controller we use will be the simplest way to manage the input power, battery, and loads. Choosing the battery pack will be our next task. After we get a grasp of all the factors in play, we'll expanse our SCC to maximize the power we can harvest from our solar panels using Maximum Power Point (MPPT) method. We are planning on making our own battery pack by adding smaller lithium ion batteries together to reduce cost. Building our own PWM PCB which will be similar to the projects we encountered in the Embedded Systems course. Lastly, designing the external components of the device will be done on AutoCAD. We will use 3D printer to produce most of our components. We'll need to have our measurements to be extremely precise. We also need to manage our budget very carefully. We allow rooms for foreseen errors such as components being destroyed or broken, manufacture defects, and wrong product ordered. For example, we are planning to build our own battery pack to save the net cost. However, none of our team members is considered an expert at such task so we will order 4-6 extra battery cells; in case of a couple of them being destroyed during experimentation process, we still have some left without having to order new ones.

The expected outcome of this project is a fully functional, rechargeable, solar-powered fan. The user would place the device in an open space (on a sunny day) to start recharging the battery. The Fan will have 3 speed settings. Most of the parts are easy to// remove and replace. Beyond the ECE lab equipment, there will be no required resources for this project. The required software tools are AutoCAD, MultiSim, UltiBoard, MatLAB, Code Composer IDE, VirtualBench.

External Considerations

Constraints

It seems that some components required to complete a prototype for this project may already be owned by the department. These items include a MSP430 Launchpad, LEDs, and a DC motor. Some materials will require a custom design which will encompass the PCB board, and the frame of the fan. Additional materials are also required, such as a solar panel configuration with sufficient power supply to power the fan and a rechargeable battery. Given this part list the total cost is estimated to be in the $50 to $100 range.

Manufacturability

The project is required to be cheaply and easily manufacturable. When this does happen, the PCB and MSP430 chip should be replaced by a significantly more compact device in order to produce the fan as cheaply as possible and to make the design as durable as possible. Another area to explore is adjusting the model of solar panels used from small, developer quality panels to production quality panels with a more custom size. This measure should also lower overall costs and increase the durability of the design.

Sustainability and Ethical Issues

The major sustainability concern is the rechargeable battery required for the design. The battery, which will likely use Lithium, will most likely require a highly energy intensive process to produce.[8] In addition, the process of mining Lithium often pollutes nearby water supply, introducing severe health risks to local communities and animal populations.[9] The major tradeoff which must be weighed in this case is the portability provided by the battery against the footprint of the battery.

Health, Safety, and Standards

The primary health concern of portable fans is for the system to erupt into flames. This consequence is especially relevant to this project considering that using the product is intended for use while camping in the woods. An oversight in this area could potentially start a wildfire. In addition, solar panels may also be a contributor to starting fires if connected improperly.[10] In order to combat these issues the product will abide by the *Underwriters Laboratories Standard for Safety for Electric Fans*, UL 507. The specific points of failure which will have to meet this standard are the DC motor and the internal wiring. In addition, the internal circuitry

may require further insulation to protect against water. In order to combat the negative effects of water, the fan will be designed in accordance with the IP66 standard[11] established by the International Electrotechnical Commission.

Deliverables

The S.P.E.C.I.A.L. Project will have three main deliverables. The first deliverable is a multi-speed fan, the second deliverable is a solar-powered battery pack, and the third deliverable is a PCB that will be used as a Solar Charger Converter and for Pulse Width Modulation. The solar panels will receive the sunlight, which will then charge the battery by passing through the Solar Charger Controller. We will utilize Pulse Width Modulation in order to disallow the batteries to continue to be charging infinitely. The battery pack will then power either the multi-speed fan, or the LED that notifies the user that the battery power is low. For the midterm demo of The S.P.E.C.I.A.L. Project, we plan to demonstrate a functional PWM program which will be used to vary the speed of the fan.

Required Components and Prototype Budget:

- MSP430 Launchpad ($10)
- Solar Panels ($50)
- 3D Printed Frame ($50)
- 12V Lithium Battery ($25)
- PCB ($100)
- Circuit Components ($33)
- Fan Blade ($10)
- DC Motor ($15)

We plan to purchase the majority of our components through DigiKey[12], Mouser[13], and Newark[14]. While our prototype budget may be high, we plan to undercut these costs. Additionally, the manufacturing cost will be much less expensive in comparison to the prototype cost.

Timeline

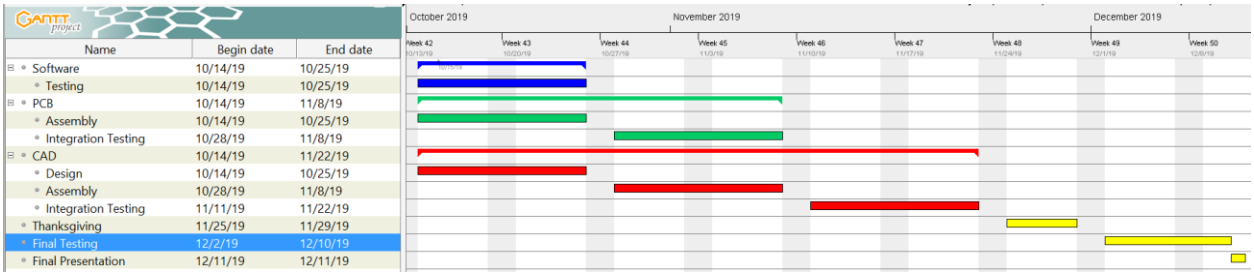

Figure 2: Gantt Chart Timeline

The Gantt[15] chart shown in Figure 2 illustrates the schedule for developing the final product. The three main systems of the product are Mechanical, Electrical, and Computer Engineering. In order to achieve maximum efficiency, these systems will be started in parallel and then integrated together to form the final product. The project will start with the programming being implemented and with the PCB and CAD models. Then the models will be created remotely and then assembled together with the MSP430 to create a working fan.

Since Jack is a computer engineer and has experience with embedded programming, he is in control of the MSP430 functionality and will ensure proper integration with the remainder of the system. Hieu and Kristian, the electrical engineers, will be jointly in control of the PCB and AutoCAD designs. When all of the systems are completed individually, it will be the responsibility of all members to put the pieces together to create a working final product.

Expectations

Letter Grade	Criteria for The S.P.E.C.I.A.L. Project
A	• A variable speed setting for the fan • On/Off button for fan blade • Battery able to charge while the fan is off • Able to charge the battery and have the fan working simultaneously • LED on for low battery
B	• Does not meet one of the requirements listed for an “A” grade
C	• Does not meet two of the requirements listed for an “A” grade

D	• Does not meet more than two of the requirements listed for an “A” grade

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STS Thesis

The Power of Water

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Introduction

The stormwater management system and infrastructure in Charlottesville, Virginia, are in dire need of improvement. The city's poor stormwater management practices can lead to a wide variety of pollutants entering the local watershed of the Chesapeake Bay, the ultimate destination of Charlottesville's stormwater. In addition to damaging this ecosystem, poor stormwater management can cause local flooding and erosion that directly harms the community. I am part of a team working to solve stormwater issues in Charlottesville and to improve the city's management practices. Community engagement is essential to the success of this initiative. To better protect and serve the community, it is important to ascertain local awareness about the issue, to understand individual values, behavior, and habits that affect the environment, and to identify the specific ways that stormwater is having a personal impact on Charlottesville residents. My project will focus on conducting this research. This outreach will involve individual interviews and surveys to determine the needs of community members. Information obtained through this research will be instrumental to developing more effective management strategies that will improve stormwater infrastructure and related practices.

One of the ways Charlottesville and Albemarle County have attempted to fund better infrastructure has been through a so-called rain tax. The local government advocates taxation in proportion to the damage that one's property causes to the Chesapeake with the hope that forcing people to pay for the damage they create will encourage better individual stormwater management practices. However, some community members contend that the benefits stemming from a clean Chesapeake are a public good and, consequently, that the cost should be shouldered by the community as a whole, with each tax payer paying an equal share. This approach acknowledges that the issue is a shared responsibility and provides incentive for the entire community to play an active role in minimizing the personal impact each person has on the Chesapeake Bay. These two contrasting viewpoints have implications for policy and practice. Determining which approach would be more effective in influencing positive behavior that benefits the local environment is another goal of my project.

My individual research will seek answers to the following questions: How knowledgeable are the different stakeholder groups in the community about the best stormwater management practices? Does a knowledge of the best stormwater management practices incentivize community members to apply those practices to their personal lifestyle? How do stormwater issues affect the local community? What is the perspective of different stakeholder groups about the local government's efforts to combat stormwater management issues? Answering these questions is important for providing a better understanding of how the local government and the University of Virginia can best engage with the local community to promote and implement safe and effective stormwater management practices. It is important for the local community to manage stormwater utilizing practices designed to preserve the local environment as well as the Chesapeake Bay.

Literature Review

Before starting the community outreach component of this project, I consulted scholarly sources to get a better sense of prior studies in this field. One of the papers detailed how researchers engaged with community groups in Nepal to manage stormwater (Molden, 2017). This paper is a great example of how important community engagement is for the development of infrastructure. The water spouts of the local Nepali community were of great religious significance to them. Unfortunately, they were not taken care of well under centralized government management and became unsanitary, which was harmful to the community since community members use them as a major water source. To effectively refurbish the spouts, The researchers developed a close relationship with community leaders to ensure an improvement to the sanitation of the spouts, which required them to fully respect their religious symbolism. This paper uses value centered design to determine the core values of the Nepalese community. In this case, it was important to focus on the cultural significance of the community's water spouts to develop policies and practices that would be effective in the region.

Another paper detailed how quality stormwater management systems contribute to the UN goals (Oldham, 2013). One of the key points of this paper is that, historically, community engagement has been a low priority in the development of new infrastructure. The paper finds that it is much more beneficial for both the local government and the local community if community engagement is used as a central component to the design process. Specifically, the paper finds that the most effective methods for developing new infrastructure include identifying a need, recognizing the potential affects a policy or infrastructure change could being to the community, and engaging with the community to solve any problems in a way which is acceptable to them. This paper uses the Social Construction of Technology framework to show how different stakeholder groups in the community can view problems from different perspectives and that the values of all stakeholder groups may not necessarily coincide together.

Both of these papers are very relevant to my research because it will be important to engage the local community in our efforts to improve the process of stormwater management in Charlottesville. A key element of our success will be understanding and respecting the values of the local community and taking them into account in the development of recommendations for stormwater infrastructure and practices. From these sources, I learned that establishing a relationship with the local community is essential for creating policies and infrastructure that provide a tangible and lasting benefit to the community. In addition, these articles inspired the research topic of this proposal by revealing that the first step to any policy or infrastructure change should be to engage with the community through interviews and other relationship building activities. That is why the proposed research focuses on how much the community knows about stormwater management practices and seeks their feedback on what they observe about the current system.

In addition to studying scholarly papers concerning stormwater, our group interviewed Jon Goodall, a UVA professor of Civil Engineering specializing in water management. Professor Goodall talked about his research concerning the flooding issues in Norfolk. To address the issue, they have been setting up sensors around the city to monitor the water's behavior. The main focus of the research centered around keeping the community engaged with the local government throughout the process so that they would feel comfortable with the

increased monitorization. One of the most important distinctions that he made was how the social climate in Norfolk differs from that of Charlottesville. The residents of Norfolk are much more inclined to trade privacy for increased monitorization of stormwater because their streets are regularly flooding. However, in Charlottesville, where the streets do not flood frequently, there may be more resistance to increased monitoring because stormwater management is not perceived to have as high of a threat level. We must make sure to take this social disposition into account when developing custom solutions for Charlottesville.

Framework

In order to outline the complex relationships between the various stakeholder groups in Charlottesville and stormwater management issues, I will use the Social Construction of Technology framework (SCOT). This framework will allow me to examine the relationships between each community group, any stormwater related problems, and potential solutions to those problems. The first step to implement this framework is to identify the relevant stakeholder groups.

There are many key stakeholder groups that would be affected by an initiative to improve Charlottesville's stormwater management system. These stakeholder groups include taxpayers, the local government, private landowners, and environmental advocates. Taxpayers have an interest in stormwater control because they have to pay for the water to be properly filtered to remove pollutants. Poor stormwater management can lead to a higher concentration of pollutants in the water, which can result in higher costs for the taxpayers. The local government has an interest in stormwater control because it is responsible for creating and maintaining the policies and infrastructure related to stormwater. Since it is in the government's purpose to provide as much safety to the local communities as possible, it will likely err on the side of over-regulating stormwater management if it deems that it poses a large enough risk to the community. Landowners have an interest in stormwater management because infrastructure designed to resolve stormwater issues can involve intrusive construction that impacts their private property. Since this would pose a moderate to large inconvenience to landowners, they would likely advocate for controlling stormwater only in areas where it is creating issues and having a negative impact, and not necessarily at its purported source. Environmental advocates may also be considered a stakeholder since stormwater management patterns can affect the spread of certain pollutants and the erosion of key land areas. Conservation experts are working diligently on behalf of the environment to preserve its long-term sustainability and can influence both policy and practice.

Each stakeholder group comes to this issue from a different perspective, depending on how stormwater affects them personally or professionally. Proposing a viable strategy that will protect the environment while minimizing negative externalities will require thoughtful consideration of contrasting viewpoints.

Methods

For the remaining information necessary to complete this project, I will need to engage with community members belonging to each stakeholder group. It I critical to collect input from each social group contained in the SCOT analysis so that everyone’s voice is heard. I will collect information via two methods. First, I will conduct several interviews, which should help to

contextualize stakeholders' opinions on stormwater. I will specifically target farmers, environmental groups, and local government officials to gain a better understanding about how this issue is perceived and understood from as many perspectives as possible.

While conducting interviews is a great way to collect quality information, it has its limitations when it comes to collecting a high quantity of information, which leads to higher accuracy. For this reason, I will also create a survey that can be distributed to community members throughout the Charlottesville area. This survey will be aimed at engaging farmers since historically in Charlottesville, they seem to be the most marginalized group on the issue of stormwater management. The survey will be offered through email and through physical mail. It is important to include both to remove any bias that might be introduced into the data if the survey were only distributed through one medium. The information collected through these methods can then be used to create hypotheses for my research questions.

Discussion and Next Steps

In an attempt to help solve Charlottesville's stormwater management issues, my group will use value centered design to create a solution that will be appropriate for the community. Developing that solution will require a thoughtful and intentional approach to community engagement to ensure that we have input that will lead to successful outcomes. My individual research as detailed in this paper will be used to determine the values of the Charlottesville community and to identify local sensitivities and considerations that should be factored into our recommendations. We hope that a community centered design approach can both combat stormwater management issues effectively and prevent the alienation of certain community groups that may not otherwise have their voices heard. Most importantly, we hope that actively involving the community in designing a solution to this issue will help to ensure long term success that will positively benefit the Charlottesville area and the greater region for generations to come.

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