Smart Cooler

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***Abstract* — People deserve to enjoy their life to the fullest. This is done through hobbies, activities, among other items that actively promote happiness and fulfillment to themselves. These various pursuits can often be draining so many times food and beverages are brought along to be stored in a cooler. Often coolers are quite standard without much functionality besides the intended use of temperature-controlled items. The Smart Cooler's implementation of different technologies aims to change that and improve the user's quality of life. It is an improvement to existing coolers, with a sense of purposefulness.**

***Index Terms* — Smart Cooler, PDLC, Solar, Panels, Sensors, Adafruit HUZZAH32.**

I. Introduction

A cooler is widely used throughout the world as a means of having a proper temperature-controlled environment. This makes it a popular commodity amongst people no matter the area. From tropical islands to frozen tundras, it serves as dual purpose insulation for either heat or cold. Developing this Smart Cooler is important due to its implementation of technologies to combat everyday hindrances that people encounter.

Many standard coolers are chilled by ice or some external cold-producing object like an ice pack. The more people open the lid of their cooler, the faster the outside heat transfers in and melts the ice, even further so when they do not know the contents of the cooler. This creates extra time wasted spent looking at the items while the lid is open for an extended period of time. To help reduce this, the Smart Cooler has integrated a polymer-dispersed liquid crystal film (PDLC) into the cooler lid, which acts as a window for the cooler to be able to see the contents inside.

There is also the issue of privacy because a cooler will not always just hold food and drinks, it serves as a container hosting anything temperature-sensitive which can oftentimes be private items as well. The introduction of PDLC glass is due to its ability to be opaque while in an inactive state, and transparent while in an active state that is controlled through a voltage. So no one is able to see through it without actively turning on the film and protects the user's privacy.

Everyone has a phone nowadays and brings them everywhere as it is quite an important and integral part of people's daily life. People continually use them throughout the day and eventually the battery is going to drain until the phone dies. It is very inconvenient to find an outlet in places like the outdoors or somewhere very remote in order to charge your phone, so the Smart Cooler has a USB-A charging port for times like these. This applies to any device that uses USB-A and not just phones.

Another problem with standard coolers is the lack of light production, which becomes a problem when in dim-lit rooms or outside during the night. The Smart Cooler has water-proof LED lights inside of it that activates through a motion sensor upon the opening of the lid. So the contents of the cooler are fully visible even while in a dark environment, and the LED lights are power-efficient by only activating while the sensor is triggered.

Some other hindrances people encounter involve portability. The Smart Cooler encompasses every component onto itself, acting as a single unit. Solar panel, PDLC film, SLA battery, etc. are all mounted and less cumbersome than for users to carry individually.

The Smart Cooler is very versatile, having uses for many wants and needs. It is equipped to improve QoL that can be quite lackluster when using other coolers. Its creation was in hopes that it can contribute to the overall enjoyment of the people that use it.

II. Background

To obtain a general idea of what the Smart Cooler would encompass in terms of features when the project first began, further researching into existing smart cooler products needed to be done. There are a few advanced cooler designs out there that have been put into production already and comparing them to one another may show some signs of overlap and/or uniqueness that may inspire this smart cooler.

A. BODEGA

The BODEGA is classified as an electric compressor, 53 quart, 12 volt, portable freezer/car fridge. It supports control through a mobile application with additional features such as compatibility with multiple power sources.

B. ACOPOWER

ACOPOWER has an outdoor solar, compressor, freezer and cooler/fridge that comes in 16, 32, 42, and 52 quarts. It is cordless due to being battery powered, and charged by solar panel. The DC compressor is for both refrigeration and freezing. Like the BODEGA, this one can also be controlled through a web application.

C. JOYTUTUS

JOYTUTUS is another portable, electric, compressor cooler that goes up to 63 quarts. A key feature that separates this cooler seems to be that the compressor is above rather than below like the BODEGA. It does not have mobile application support so everything is done manually on the cooler itself.

TABLE I
ADVANCED COOLER PRODUCTS COMPARISON

Cooler Product Brand	**Cooler Maximum Size**	**Cooler Type**	**Mobile App Support**
BODEGA	53 Quart	Compressor	Android IOS
ACOPOWER	52 Quart	Compressor	Android IOS
JOYTUTUS	63 Quart	Compressor	None

III. Requirement Specifications

To have some measure of testing and successful implementation of this project, requirement specifications were created to ensure a quality product. The requirement specifications are listed below with explanation behind the idea.

Time to Activate: The time to activation specification refers to the polymer-dispersed liquid crystal film. The film's activation time needs to be less than 5 seconds to have the product be practical. If the activation time for the film is longer than 5 seconds, it could prove to be a nuisance rather than a feature.

Accuracy: The accuracy specification refers to the included sensors that are included in the Smart Cooler. The sensors need to have an accuracy of around 95% or higher. The data produced by the sensors are displayed to the user and need to be accurate. The specific sensors are mentioned later in the Project Components section.

Opaqueness: The opaqueness refers to how much can be seen when the film is being powered on and when it is powered off. The opaqueness should have a range from 10 to 90% when it comes to how much light comes through the film.

Discharge Time: The discharge time is the minimum time required for the battery to last when having the components being powered. The specification time is 4 hours at a minimum to make sure that the battery does not run out of power when the user is planning a longer run time.

Power Output: The power output refers to the power output of the photovoltaic panel that is implemented on the Smart Cooler. The output of the panel should be able to produce over 10 watts when the sun is fully hitting the solar cells within the panel. This specification allows for a longer usage of the cooler and allows the battery to be charged by excess energy.

Power Consumption: The power consumption of the whole system should consume less than 10 watts total when being powered on. The less power that the system consumes, the better it is for the discharge time.

Weight without Foods or Drinks: The weight refers to the final product overall. When all of the components are included, the total weight of the cooler should be less than 30 pounds. If the cooler is too heavy, then the cooler would become less intuitive for the user.

Costs: The costs of building and prototyping everything should cost less than $600. The budget is set low because the team is being self-funded during the whole project. The lower cost is also because of the widely available components to choose that apply well to the product and are cheap.

There are also some marketing specifications to consider to make this product possible such as low-cost, reliability, ease-of-use, low-power consumption. Marketing specifications allows the product to be more easily marketable and gives the push needed towards final production.

TABLE II
REQUIREMENT SPECIFICATIONS

Engineering Specification	**Marketing Specification**
Time to Activate	Reliability
Accuracy	Reliability
Opaqueness	Ease-of-Use
Power Consumption	Low-Power Consumption
Cost	Low-Cost

The first three engineering specifications are demonstrated to show the overall functionality of the product. The time to activate for the film is tested by recording the film turn on and off using a stopwatch. The accuracy of the sensors are tested by comparing the readings gathered by the sensors and comparing them to more accurate data gathered by known products. The opaqueness of the film is measured by using a light meter to measure the lux levels when the film is powered on and when it is off.

IV. Project Components

This section covers the details of the project components, discussing the hardware used to create the base system. Each section goes into detail about why the part is chosen and how the group came to the conclusion to use the specific part.

A. Cooler

The cooler is the foundation of this project, and holds all of the components together. The Coleman 48 Quart cooler is quite standard for coolers, as it only offers the insulation and is essentially a blank-canvas to develop the Smart Cooler. It is lightweight at 7.3 lbs and large enough (25.25” x 13.63” x 14.13”) to hold all of the additional peripherals while leaving enough room for storage. It has fair portability due to its size and attached handles. It is also at a decent price of $34.99, which helps with replacement in the case of error.

B. Microcontroller

The microcontroller for this project handled the software interactions between the different components (temperature/humidity sensor, UV sensor, LCD, motion sensor). The ESP32 WROOM-32 was chosen for this project based on its hardware capabilities. The details of the product are mentioned below.

<u>36 General Purpose Input/Output Pins</u>: The pins allow for the components to connect easily to the microcontroller without having issues of space. This is important since the Smart Cooler will be housing 3 different sensors and they all need to connect to the microcontroller to transmit their data.

<u>Dual Core Processors</u>: The dual core processors allow for the microcontroller to compute instructions at a faster rate than most single core processors would. The fast computations allow for the sensors to update data quickly and give a more accurate reading.

<u>Integrated Wi-Fi and Bluetooth</u>: This microcontroller also has the capabilities to use Wi-Fi and Bluetooth. However, this feature was not used in the final product since there were time constraints that led to the features that used Wi-Fi/Bluetooth not being implemented. Even though these features are not used, they provide an excellent improvement for future iterations of the Smart Cooler.

<u>Memory Type</u>: The memory type, compared to the other microcontroller we looked at, was much higher. The microcontroller holds a 4 MB SPI Flash memory. This provided the capability to hold longer code if needed.

<u>Arduino IDE Capability</u>: The Arduino IDE is an easy to implement IDE for the group. Our group had more experience using Arduino.

<u>Costs</u>: The cost of this microcontroller is relatively cheap compared to the other microcontrollers that the group decided on. The cheap cost helps with the budget as this project tries to be as efficient as possible.

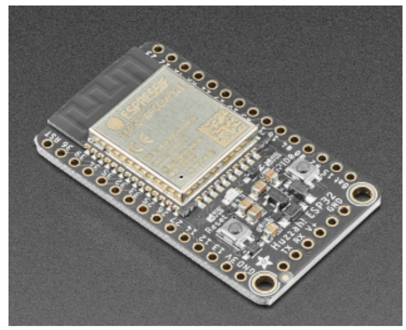

Fig. 1. ESP32 Breakout Board

C. PDLC Film

Polymer Dispersed Liquid Crystals or PDLC film will allow users to see the contents of the cooler, acting as a window panel. It is opaque while in its inactive state, but becomes transparent while in its active state. The state change is activated when an AC current is run through the film. The film is a plastic polymer full of these micron-sized holes, which is where the liquid crystal microdrops reside. These microdrops are dispersed throughout the film in random orientations and scatter light in different directions, which is why the film appears opaque normally. Once the voltage is applied to the film, all of the crystals align their orientations in the same direction, which allows light to pass through and the film becomes transparent.

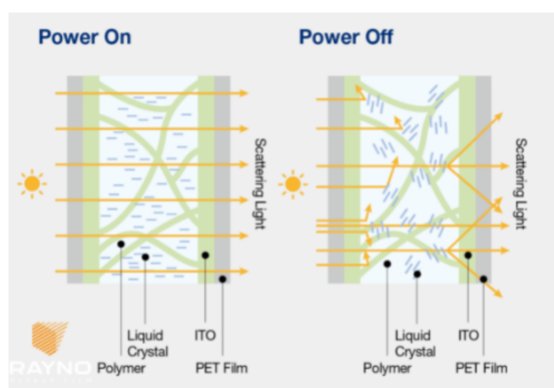

Fig. 2. Layers of PDLC technology and its mechanism

D. Solar Panel

The solar panel is the technology that will be used to recharge the battery of the cooler while it is not in close proximity to an outlet. The solar panel is monocrystalline, meaning it was created from a single silicon crystal and tends to have a higher efficiency at the cost of a higher price.

Fig. 3. Solar Panel

E. DHT22 Digital Temperature & Humidity Sensor Module

Temperature sensors are used almost everywhere as temperature is a very useful quantity to know. The measurement can dictate whether something is hot or cold either within the cooler or outside the cooler. This will be information that the user can see when it is displayed onto the LCD of the cooler. There is a lot of value placed in knowing the temperature of something so choosing the right sensor for the intended application is worth spending some time on.

Humidity plays a large part in how comfortable a certain temperature feels. The more humidity in the air the stickier the air feels. This is an important measurement to consider for the Smart Cooler since the user would want to know how the air inside will be in comparison to outside. The same humidity at different temperatures can make the air feel different causing condensation to occur on/in the cooler.

F. STEMMA QT LTR390

With the UV sensor this will allow for the system to detect how much light is coming through the glass and determine the state of the glass. This will help to either block out light from coming in/going out of the cooler through the glass. With that, depending on the situation, if there is not enough light to see, this will trigger the sensors to turn on inside the cooler to allow the user to view through the glass.

G. HC-SR501

With this sensor, it will allow for the detection of motion that is closest to the smart cooler. With that, it will allow you to turn on/off lights and such depending on how close or how far the user is from the system. From there, this will allow certain features to turn on and off and be of use. This will help to detect when the system needs to use certain features and will help and turn them off when they are not in use.

H. LED

The introduction of these LED lights is to increase the surrounding light of the cooler. They are waterproof and run around the interior of the cooler. They work in conjunction with the motion sensor as previously mentioned to turn on/off the LED lights when the lid is opened. This allows the use of the cooler in darker environments and adds to the versatility of the Smart Cooler.

I. LCD Screen

The LCD screen is being used to display the various output readings from the temperature/humidity sensor and UV sensor. It is a LCD1602 module with pin header due to its simplicity and availability. One with I2C was not needed, as we could output our readings without it so we opted for staying with the normal LCD1602. It was also widely available as each of our group members had one, which reduced cost and allowed for replacements in case one malfunctioned.

J. USB

The USB port is powered by the battery to act as a charging station for all USB-A compatible devices. USB-A was selected due to the abundance in different technologies that utilize it and has become widely abundant in today's ecosystem.

K. Power Source

The cooler system is powered by a 12 V 7.2 Amp. hours lead acid battery that is charged from either Mains electricity or from the solar panel. It outputs the 12 VDC to be used in the rest of the electrical components 12 VDC or stepped down by the 5 V regulator and 3.3 V regulator. Below show the schematic of the 5 V regulator and the 3.3 V regulator. The 5 V regulator uses the LMR51420 and the 3.3 V regulator uses the LM27341MY_NOPB.

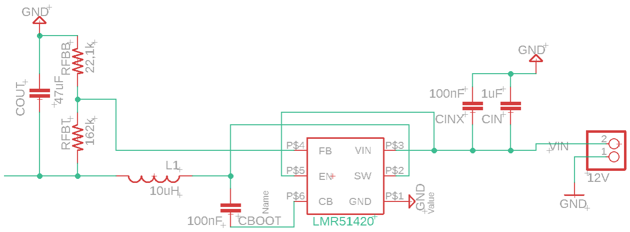

Fig. 4. 5 Volt Regulator

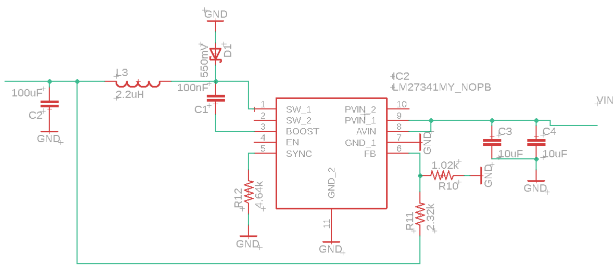

Fig. 5. 3.3 Volt Regulator

V. Hardware Design Details

This section gives the hardware design details for this project. The section goes over the overall hardware block diagram that shows the process of the hardware design used in the product.

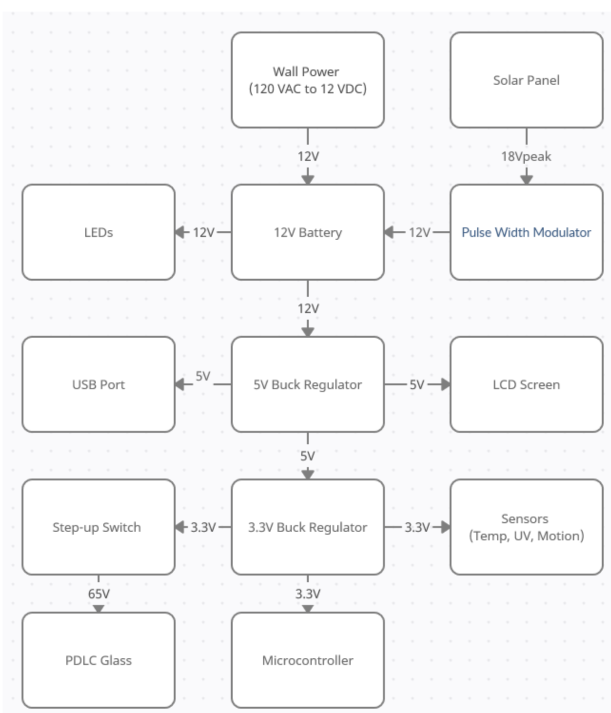

Fig. 6. Hardware Power Flow Diagram

The first stage of the project's hardware design is making sure that the power is working well. The main power supply comes from a 12 V lead-acid battery that is charged using 120 VAC wall power or using the solar panel. If 120 VAC is used, then that needs to be stepped down to 12 VAC and then be rectified to 12 VDC before it becomes usable to the lead-acid battery. If the solar panel is used, the pulse width modulator is used to maintain the current so that the battery is not damaged from the varying current. The 12 VDC from the battery is then used to power the LED lights. The lead-acid battery then goes into the buck converter to be stepped down to 5 VDC. The 5 VDC is used to power the USB port and the LCD screen. The 5 VDC regulator is then stepped down to a 3.3V regulator which powers the rest of the components. The block diagram above shows the hardware design.

VI. Cooler Lid Design

This section covers the details of the construction of the cooler layout. The cooler lid will be the main item that needs to be modified to fit all of our peripherals in an organized way.

The cooler design is made by cutting out specific sized holes in order to fit the components that are needed on top of the lid. The cutting is done by a computer numerical controlled machine so that precise cuts can be done. The components that are fitting on top of the cooler are the solar panel, PDLC film, switch that turns on/off the film, USB port, LCD screen, and UV sensor. The rest of the components are stored within the cooler.

The initial design of the cooler lid had some issues since the model had assumed that the lid was solid. However, the lid was hollowed out and the depth between the top layer and bottom layer was unknown. The bottom side of the lid also had a ribbed pattern making the design even harder to model around.

The easiest thing to consider was the solar panel since it only needs a hold to be supported. The rest of the components that are sitting on top of them are relatively simple as well. The only thing that causes trouble is the PDLC film. The PDLC film needs something to hold it in place or else it would just fall out.

To solve the issue with the PDLC film a frame is designed to hold the film in place. The PDLC film is sandwiched between 2 acrylic sheets to protect it and give the frame more rigidity. The frame is then 3D printed and the frame is held in place by bolting it down to the lid. Images of the evolution of the lid and the frame are shown below. Every single version of the model will not be shown, just a few to show how the versions improved.

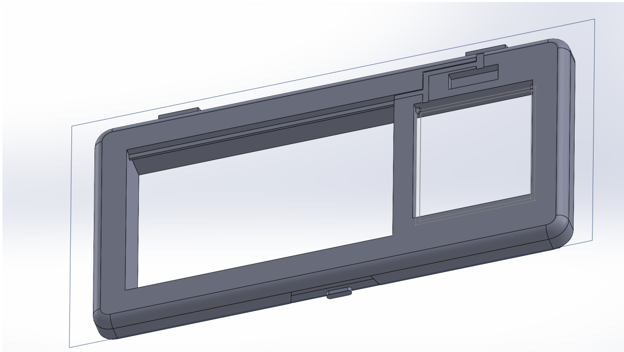

Fig. 7. Lid Design Version 3

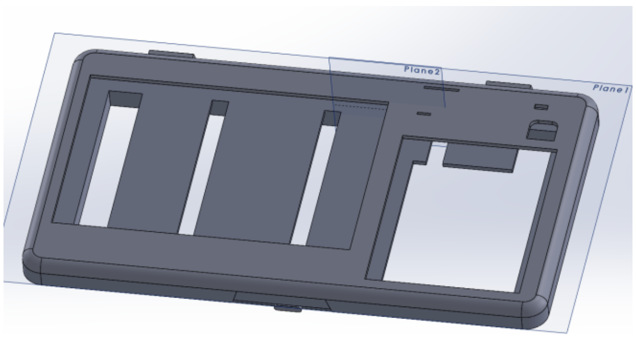

Fig. 8. Lid Design Final Version

Version 3 of the lid design is shown above and this version of the lid included the solar panel, LCD screen, and the PDLC film. The problem with this design is that the design was modeled to be 3D printed. This design was changed since the cost of 3D printing everything was too expensive. The final version of the lid changed to include the other components and include a bigger opening to fit the PDLC film with the frame. The small cutouts near the top of the lid are for the pins of the LCD and UV sensor. The sensors will be protruding out from the top of the lid slightly. These design decisions were made since the group had run out of time to make more adjustments and we needed to begin manufacturing a design to make deadlines.

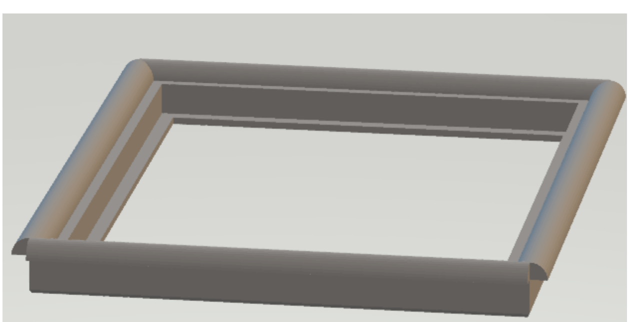

Fig. 9. Frame Design Version 1

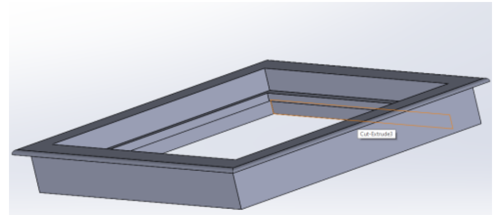

Fig. 10. Frame Design Final Version

The frame designs are shown in the images above and the first version varies slightly differently than the final version. The first version of the frame uses semicircular shapes to form the top of the frame. The top of the frame is meant to protrude outwards slightly to create a lip that hangs onto the top of the cooler lid. The final version of the frame makes the lip just a straight rectangle to save filament material when 3D printing.

VII. Results

The first engineering specification is the time to activate for the PDLC film. The test is simply done by using a stopwatch to time how long it takes for the film to turn on and off. However, the tests included some human error by around 200 milliseconds but the end results lead to the PDLC film turning on in less than a second.

TABLE III
TIME TO ACTIVE SPECIFICATION RESULTS

Trial	Time (s)
1	.45
2	.43
3	.38
4	.48
5	.42
6	.45
7	.47
8	.37
9	.48
10	.44
Average Time	.437

The second engineering specification is the accuracy of the sensors. Each sensor had a specific test that was done to check that it was accurate in their own respect. The UV sensor measures the UV index and compares it to the UV index from the local area at the time. The motion sensor tests the range of activation within 30 inches. The temperature and humidity sensor tested the temperature and humidity compared to the local weather in the area. The table below shows the results for the temperature sensor. The other results for the sensors are displayed in the demonstration.

TABLE IV
TEMPERATURE SENSOR RESULTS

Trial	Sensor Temperature(F) (Compared to 94 ^{o}F Weather)
1	94.31
2	94.29
3	94.3
4	94.31
5	94.26
6	94.3
7	94.3
8	94.29
9	94.28
10	94.29
Average Temperature	94.293

The final testing was for the opaqueness of the PDLC film. The test was done by using a light meter to record the different lux levels when the film was powered on vs. powered off. On average, the film being turned off blocks about 100 lux levels. However, the test that was done may not have been the most accurate since it was difficult to simulate the same situation that the cooler film will be in. In the product, the film will block more light from coming through because of the better sealing that the final product provides.

TABLE V
OPAQUENESS SPECIFICATION RESULTS

Trial	Film On (lux)	Film Off (lux)
1	150	60
2	157	59
3	160	60
4	155	59
5	148	59
6	142	60
7	138	60
8	155	60
9	146	59
10	150	60
Average Lux	150.1	59.6

VIII. Conclusion

Overall, this project had its successes, its failures, and its setbacks, but was able to make it to the end. With the time that this group was formed since the beginning of Senior Design I and up until now, everything was planned and executed to the best of our abilities to make it possible. Through our teamwork and decision making as a whole, the Smart Cooler became something that people would want and have as well as make a big difference in their lives. In the end, this project gave everyone in the group something to be proud of and look forward to in the future the abilities that we each have and to make something of it.

Though this is the end of this project specifically, the smart cooler can be built upon even further and be better optimized if other groups would want to include stretch goals such as bluetooth speakers, mobile integration, and GPS. There are endless ways to improve the Smart Cooler, both mechanically and electrically.

Acknowledgement

As a group we would like to thank Dr. Wei for giving us assistance by guiding us through the whole process of this project to ensure that it would be successful to the end. With that, we would also like to thank our review committee for joining in the Q&A session over our project on July 27th. We would also like to thank the Innovation Lab and Machine Shop for being able to work with our project to make it possible. In the end, this project would not have been possible without all the help from the people listed above.

The Engineers

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Thomas Huynh is a graduating student in Electrical Engineering at the University of Central Florida. His hobbies and interests are rock climbing, exercising, and going on hikes. In his down time, he also enjoys playing Dungeons and Dragons or video games with his friends. After college he hopes to apply his skills in the power/utility industry. He is currently applying to different job applications all around the state.

Matthew Schmit is a graduating student in Computer Engineering at the University of Central Florida. Matt enjoys spending his time playing soccer, video games, spending time with friends and family, and watching tv shows/movies. After college he plans to work towards his master degree and looks forward to a future in the engineering field.

Michael Villarante is a graduating student in Computer Engineering at the University of Central Florida. Michael enjoys going to theme parks, playing video games, and spending time with friends and family. He plans to get his masters degree in the future and is looking forward to finding a successful career in software development.

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