# Laser Target Gallery

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***Abstract* -- The Laser Target Gallery is an arcade style game using a laser gun and a board with several targets on it. In a timeframe of 30 seconds, the player will shoot an indicated target on the board, where a microcontroller will score points based on the accuracy of the shot. The targets are made up of four photoresistors in a small chamber behind a green light filter. The laser gun itself houses a frequency doubled green laser diode, the fire rate being controlled by a microcontroller in the gun.**

## I. INTRODUCTION

When most people think of carnivals and arcades, it is almost inseparable from the ideal of the games played for prizes. A large portion of these are score based, such as Whack-A-Mole or a ring-toss variants. While the idea of these kinds of games is generally enticing and can be quite fun, we find that there is some ways that it can be improved upon. As such, one of the inspirations for the project came from the enchantment of the carnival game, but adding a competitive edge that challenges both the speed and accuracy of a player as opposed to just one of these traits.

There is some similar technologies that exist near the realm of our project. One example is the LaserLyte Game. This is a similar product that uses a single target with photo sensors to take input from a laser. Using several photodetectors, it reads the laser emission from their laser gun and gives points on where on the large target the board was hit. However, this board only has one target, reflecting where on the board you hit it.. Not often in any type of target driven training is it good practice shooting at targets that don't move, the human bodies natural reflexes are best trained on targets that are challenging to hit(targets that move unpredictably). The Laser Target Gallery game is designed with multiple targets that flash randomly at random intervals, such as one would find in Wack-A-Mole, while still giving points based on the accuracy of your shot.

The project is divided up into four separate functional parts: The laser gun, the board, the wireless microcontroller used to run the game, and the phone application.

The goal of the laser gun is to emit controlled bursts of light that are powerful enough to be registered by each target on the board, where the light maintains a reasonably uniform distribution of light. The laser gun will contain an eye safe laser, a small microcontroller, and a lens and aperture system to create a controlled beam shape. The casing for the laser gun will be 3D printed after creating the design in CAD software. Inside the laser gun's handle, we have the power supply which will be connected to microcontroller, which in turn control the laser through a transistor. The microcontroller is used to control the fire rate and duration of the laser shots.

The goal of the board is to house targets which can effectively communicate which target to hit as well as what receive adequate signals from the laser gun itself. When a target is meant to be hit, it will be lit by surrounding LEDs. A shot is detected through an array of photoresistors. The resulting voltage read across them as the incoming light from the laser changes the array's resistance, letting us use the change in voltage to register a hit and the variance between the photoresistors as a way to determine how centered the shot was. Ambient light will be largely filtered out by a green light photography filter, which allows green light to pass but absorbing much of the other light in the visible spectrum, creating a much clearer response from the laser.

The goal of the microcontroller is to capture data from the target board and deliver information to the phone app. This microcontroller reads the change of voltage in the photoresistors and registers that as a hit. By comparing the initial resistance of the photoresistors to its current photoresistor, we can calculate the response. The more even the response of all four resistors, the more accurate the shot. We compare these four responses to determine score. The score and accuracy is then sent to the phone app.

The goal of the phone app is to analyze and record data sent from the board during each game session. By pairing with the onboard bluetooth device, the phone app will send an encoded message to start the game session. Upon the end of a game session the phone app will wait for the microcontroller to transmit the stored data and create a record of the values transmitted. The data is stored locally on the phone and will be unique to the user.

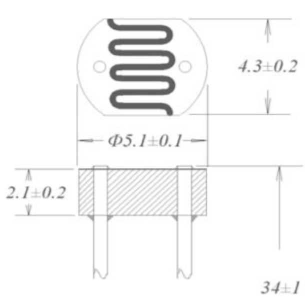
## II. SYSTEM COMPONENTS

*A. ATMEL ATMega328P Microcontroller*

The ATmega328P is a low-power C-MOS 8-bit microcontroller based on the AVR enhanced RISC architecture. This microcontroller executes instructions in a single clock cycle, and ATmega328P achieves throughputs approaching 1 MIPS per MHz which is useful in allowing the system designer to optimize power consumption versus processing speed. The ATmega328P chip comes with many different features. Features such as: 32 KB of In-System Programmable Flash with R.W.W. capabilities, 1 KB of EEPROM, 2 KB SRAM, 23 general purpose input/output lines, 32 general purpose registers, three timers and three counters with compare modes, internal/external interrupts, a serial programmable USART, a byte-oriented 2-wire SI, an SPI serial port, a 6-channel 10-bit ADC, a watchdog timer with its own internal Oscillator, and many different power saving modes.

We are using 2 Atmega328Ps for our project, the first one is the microcontroller and brain of the laser gun, this will be modulating fire rate for the gun, and the second will be used for data capture. The main factors to consider were the low voltage, ample memory, sufficient number of pins and inclusion of a board for testing purposes. The ATMega328P chip which was accompanied by the Arduino Uno development board. This chip was Arduino compatible and allowed us to complete all of our coding tasks much more easily than we would have otherwise

*B. GL5526 Photoresistor*




Since our project required a photodetector that gave a range of responses depending on the intensity of light on a flat surface, we decided to go with the GL55 series photo resistors. The wider flatter surface of the photoresistor as well as the wide range of responses that the photoresistor could give was the deciding factor to use this technology over a photodiode. The photoresistor also offered fast response times and had a range of resistances we could choose from in our circuit.

Since we are targeting the 532 nm wavelength, we chose a CdS photoresistor, where the peak response is at this wavelength. Additionally, we will be using a light filter to reduce the ambient light of different colors from interacting with the photoresistor as much. At 10 Lux, the resistance is 10-20 KΩ, which should be approximately the Lux received by a shaded target indoors. By aligning this target in series with another 10 KΩ resistor and measuring the voltage over either the resistor or photoresistor, we can receive signals based on how much light is being cast over the photoresistor.

*C. 532nm Dot Laser Module*

The beam we chose in this case was a frequency doubled laser. Wanting to use a cheap visible light laser so we can see where a shot landed on the board, we narrowed our search to the common red and green laser diodes before finally settling on the green laser diode. The reason this was done is because the frequency doubling crystal acts as a bit of beam shaping, causing the output laser to be circular in nature as opposed to the red laser diodes more rectangular beam shape.

- ❏ 12mm diameter x 51 mm length
- ❏ Output Wavelength: 532nm
- ❏ Output Power :<50mW
- ❏ Working Voltage: DC = 3.7V
- ❏ Working Current: I <250mA

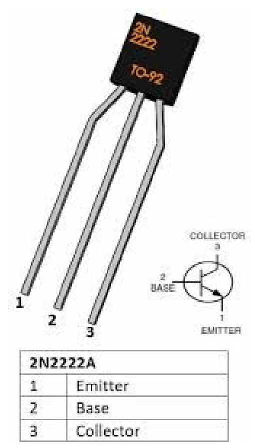
The beam expected to hit the board must be at some considerably larger size compared to the diode’s regular output, so we must expand the beam over the course of its journey. What this means is while the beam does not have to be completely collimated when it hits the board, it should be large enough to cover at least the full width of the target and powerful enough such that an offcentered hit will still be registered and calculated. To manipulate the output beam created by the laser diode, we send it through a lens and aperture system.

*D. HM-10 Bluetooth Module*

The HM-10 Bluetooth Module was the bluetooth module chosen for this project because of its compatibility with both Android as well as IOS. This module uses UART communication that allows us to interface with all the controllers and processors necessary for our project. Its low-energy feature allows for it to consume little power, which effectively allows it to be used with mobile systems. It has a connection distance of up to 100 metres. With our project being played from about the range of 5 metres this module is the best fit for our project.

*E. 2N2222A BJT Transistor*

The 2N2222A semiconductor is a silicon NPN BJT used for amplification or as a switch. In this case, we used it as a switch for our laser since the current draw from the laser would be much greater than the microcontroller can support.




By connecting a digital output pin on the microcontroller to the base of the semiconductor, we can safely give power to the 532nm Dot Laser Module the power it needs straight from the power supply.

*F. 3.7 V Lithium Ion Battery Power Supply*

This CR123A Battery is a simple 3.7 V battery. We use two of them in series for the power supply to make a net total of 7.4 V. Due to the small size and convenient mounts that can be installed in the gun handle, we decided to use this as a way to power the gun. The battery is rechargeable up to 1200 times, way past what we need for our project.

*G.ATMEGA2560 Microcontroller*

The microprocessor chosen was the Atmega2560. It is available on the Arduino Mega 2560 development board provided by Arduino. Using this development board, allowed for all of our project needs to be met. This board features 86 GPIO pins, including 16 analog input pins. Allowing for us to capture all the data needed from the four targets we have set up on our board. We were also able to build our final PCB with ease by using the files provided by Arduino. There is also lots of resources and documentation online for this microprocessor which allowed for help troubleshooting any issues we may have had. The extra pins provided by this microcontroller would allow for further addition of features to this product if ever commercialized.

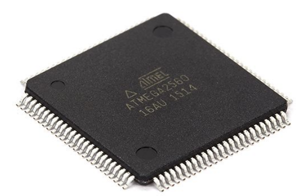


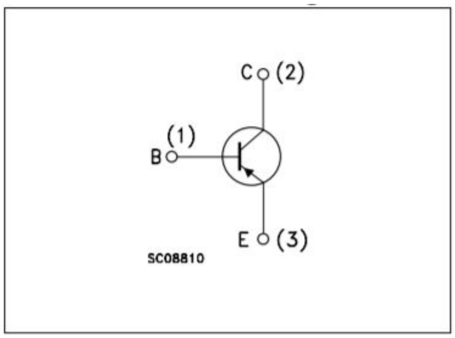
*Figure : ATMEGA2560 Microprocessor along with all the pins provided. Allowing for easy development of our project.*

This processor was chosen this processor because of the high number of analog input pins. This chip also has the highest amount of FLASH, which is more of a priority than RAM. It is beneficial to use this type of data because it is non-volatile. There is high transferring making the read and write time.

There were a few components that were attached to the processor. The bluetooth module was used to connect the users device to the system. This will give the user the ability to start the game from their phone by pressing the “start game” button.

*H. TIP32C BJT Transistor*

The TIP32C is a silicon Epitaxial-base PNP power transistor in Jedec TO-220 plastic package. It is intended for use in medium power linear and switching applications.




The complementary NPN type is TIP31C. This transistor for the sake of our project will help supply correct voltages to our LED strips.

*I. Switch Driven Hammer Trigger*

The switch that was chosen here is a simple trigger that could be mounted into the gun. When the trigger is pulled, it shorts two pairs of terminals together. This was a simple means to cause the microcontroller to read a digital input when the trigger on the gun was pressed.

## III. SYSTEM CONCEPT

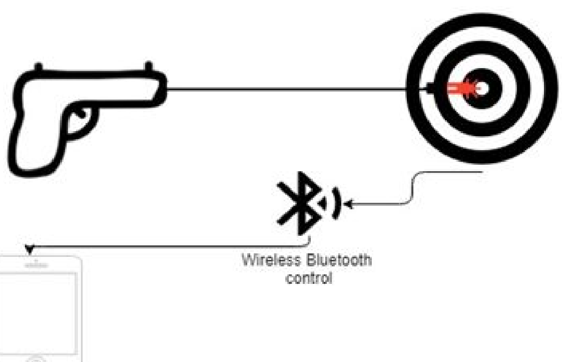



*Figure: Full System Concept*

The core of our design runs through the PCB attached to the back of the target board. This major part of the game is responsible for handing the game script, and sending information to the web application.

The game script itself has a couple built in capabilities, one of them is taking in inputs from the various photoresistors(16 total). Another is lighting up LEDs on the surface of the target board indicating which target is accepting inputs from the photoresistor. Lastly the game needs microcontroller has to do game calculations to configure a score and associate it with the accuracy of the shot that the target intakes. Once the PCB brain does these calculations we use a bluetooth chip attached to the same respective circuit board to send that data over to our front end web application.

The web application will receive data transmitted by the Bluetooth microcontroller and parse the data accordingly. Depending on the data received, a score will be assessed based on the margin of error found relative to the distance from the center of the board. Under the allotted time frame given to the user, the score will be updated in real time to track their progress. Once the run is complete, users will be able to compare their scores with previous attempts in order to track their progress. Along with personal records we will implement a leaderboard that allows the user to compare their scores with that of a database of other users

Another instrumental part of the game system is the wireless microcontroller in the laser gun. The main component of this part of the system will be taking input from a switch driven trigger, and limiting the length of the shot taken by the player. The important part of this is adding difficulty to the game not allowing the player to hold the trigger down, if this were possible the laser would be able to oversaturate the target, buffing the players scores.

## IV. HARDWARE DESIGN

The power supply for our the target boards microcontroller is a 9 V Alkaline Duracell battery. The reason we chose this is because this type of battery carries enough power storage to run the game for a good amount of time, but also allowing an easy changing out of batteries.. We need the 9 V battery since we have to power not only the PCB board with at least 5 V, but also the LED power strip between 7 - 12 V. To do this we had to use 4 MOSFETs to regulate what voltage is going to each respective power strip.

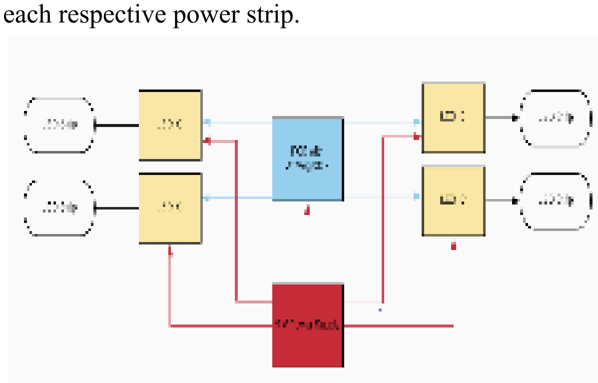


*Figure: LED Hardware Flow Chart*

The target board system's main functionality is to capture and send data to the wireless microcontroller, as well as output information to the viewer. By housing a set of 4 distinct LED arrays which can be controlled independently, the board can display to the player which target to shoot at. By housing 4 plastic hollow cubes with a printed circuit board mounted to the back of each cylinder, we create a chamber of which the laser is to be fired into, in front of the opening to the chamber is a green filter paper that reflects all light except green, this allows for more concise readings by the photoresistors.

Behind the green filters are going to be four targets, these targets are made up of a printed circuit board, photoresistors, 10KΩ, and jumper wires. Each of the photoresistors should be connected to a 10 KΩ resistor in series with the voltage measured across each resistor. As the amount of light hits the photoresistor increases, the resistance will decrease, causing an increase in voltage and current over the 10 KΩ resistor. This can be done by supplying a bias voltage of 3.3 V across each resistor/photodetector in series with a reference cable between the two, connected to one of the microcontroller's I/O pins.

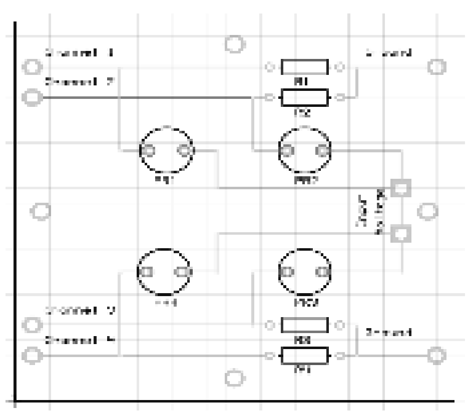


*Figure: Simplified Game Target PCB design*

The microcontroller used in this case is the Arduino Mega. This is due to the 54 pins that the Arduino Mega has. Each target will have 4 signal wires, and with 4 targets, we are looking at 16 input signals alone. This is not including the incoming power, the ground, and the LED indicators surrounding each target.

The signals read by the printed circuit board attached to the back of the target board can be read through the function analogRead() in the Arduino IDE(C code). This works by outputting 0 when 0 V is read and 1023 when 5V is read. Any value in between is represented by an integer between 0 and 1023. From this, we can expect an increase of an integer value to a threshold value to count as a hit. From then on, we can sample the peak threshold for four signals associated with said target. These values are to be stored and analyzed for points.

After these points of data are collected, we can compare these values as signal1, signal2, signal3, and signal4. Each value incoming value at ambient light is recorded. The offset that the light reads is then recorded for each signal in the array. To compare the x axis, we can average the left two inputs and right two inputs, then compare the values. Similarly, we compare the top two inputs and the bottom two inputs to compare the y offset. Thusly, we can calculate the score and relative position of the beam by the four values obtained from the photoresistors.

$$Score\ = 500\ *\ (Horizontal\ Weight\ +\ Vertical\ Weight)$$

$$Horizontal\ Weight\ = \frac{(averageLeftSide + averageRightSide)}{(MaxAverageHorizontalValue * 2)}$$

$$Vertical\ Weight\ = \frac{(averageTopSide + averageBottomSide)}{(MaxAverageVerticalValue * 2)}$$

$$Horizontal\ Position\ =\ (averageRightSide\ -\ averageLeftSide)$$

$$Vertical\ Position\ = (averageTopSide\ -\ averageBottomSide)$$

## V. EMBEDDED SOFTWARE DESIGN

After including any necessary libraries, initializing global variables, enabling interrupts, and setting up and enabling the timers, the process is ready to enter its main loop. Inside the main loop for the microcontroller associated with the target boards, the main job is to increment counter when the photoresistor shows a resistance output, along with that this microcontroller has other jobs that will be touched on in another section. The microcontroller associated with the gun has a similar game loop, it needs to count when there is input signal from the triggers hardware, and send a power signal to the laser diode. After each has completed their respective jobs the last job of the microcontroller on the back of the target board sends the information stored in registers wirelessly to our web application server database.

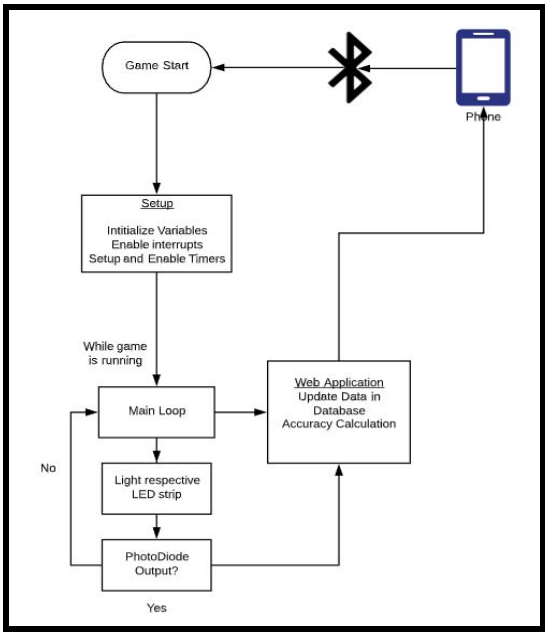



*Figure: Embedded Flow Chart*

## VI. SOFTWARE DESIGN

The mobile application is in charge of enhancing the users experience. Users will have immediate access after installing the mobile application to either an iOS or Android platform device. Upon opening the application users will be directed to the page shown in the figure.


*Figure: Laser Target Gallery Home Screen*

This menu will teach the user how to navigate the application for future sessions. Users who already have data records will be navigated directly to their unique home screen. At the home screen, users can choose to view previously recorded game sessions or start up a game-session.

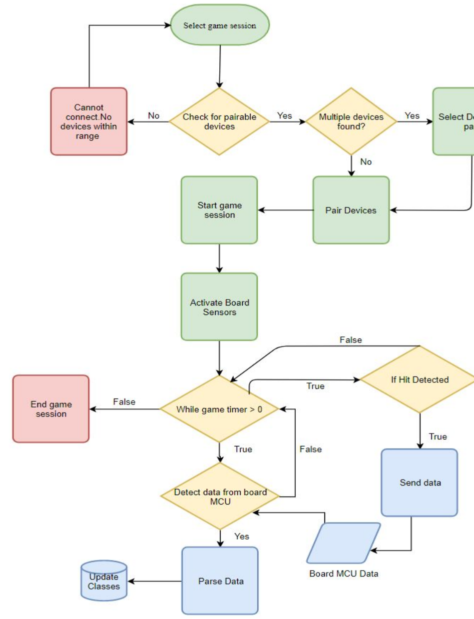



*Figure: Mobile Application Game Session Flowchart*

When starting up a game session, the mobile application will first check to see if it can detect and pair with a game board nearby through bluetooth. If the application cannot detect a game board an error message will trigger to notify the user. Then the application will back out to the user's home screen. Otherwise, the application will pair with the game board. In cases where there are multiple boards detected in the area, the application will prompt the user to select the desired game board. The game session will start once the application receives confirmation from the user and detects that the two devices are paired. During the game session, the sensors on the board will be actively receiving data.

This data varies based on the proximity of the laser pulse in relation to the location of each sensor. The data is then transmitted from the bluetooth microcontroller to the phone application. This process will be looped for the entirety of the game session. Each packet of data transmitted will be detected then parsed according to the specific guidelines that our team has set. Finally, the data will be inserted into the local database stored on the user's mobile device where it will be analysed. When the timer for the game session ends the user will be directed to another screen that tallies the final results of the session.

## VII. LASER SYSTEM

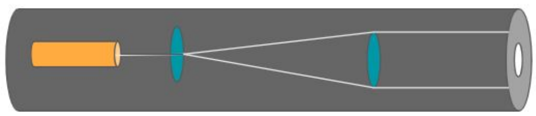


*Figure: Lens, Laser, and Aperture System*

The laser system itself is simply designed to expand and shape the output beam of the laser diode. The laser diode system itself is bundled with a diode and lens glued together, which cannot be easily changed without damage. However, by unscrewing the surrounding housing, we can manually adjust the position of a collimating lens to change the focus of the beam. Also attached to the collimating lens is a filter which removes the infrared light, which has unknown properties in terms of beam shape for project. This way, we do not have light from the laser interacting with the photoresistor that we cannot see. We then place an aperture closely in front of the second collimating lens. The apertures larger size, where the beam shape is in the width of a few mm, causes a lot less ringing and visible Airy Disk formations in the resulting beam projections.

## VIII. USER MANUAL

Step One: Download Application and Pair Device

Before starting the application, the user will attempt to pair their mobile device with the Laser Target Gallery Game. The game is bluetooth enabled and needs to be paired through the application.The user will be notified of the success or failure of pairing and at that point the user would be directed to the setup of the application or prompted to retry to connect

Step Two: Press Play Game

For the score to read accurately we recommend taking a few steps back(around 10 feet) from the target board. The next step is to press the play game button on the phone application, Once pressed there is a counter that will give the player ~5 seconds to prepare to play.

Step Three: Shoot The Targets!

Next is to actually play the game! A tip for playing is taking your time between shooting each target, the challenge of the game is not just hitting as many targets as possible, its to get the best possible score by hitting the targets directly in the middle. As mentioned before there are 4 total photoresistors on the target PCB, that means hitting the middle of the target will give you the best score possible. You have 30 seconds to hit as many targets as you can and hit them accurately(Data is sent to the database after each shot).

Step Four: Check Score On Records

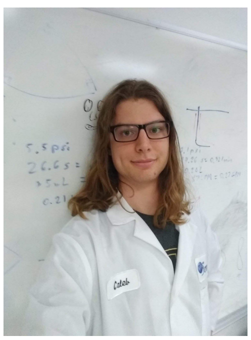
After the game has ended no more targets will light up and the player will know to check the application. There is a button on the application labeled “Records”, this will show the player their score at the end of each game. Show your friends your hand eye coordination by clocking the best score possible!

## IX. CONCLUSION

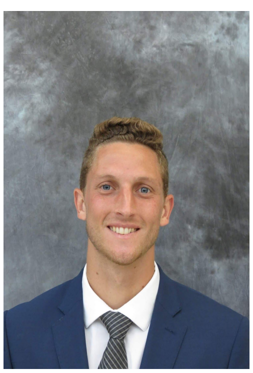
In conclusion, the motive of our project was for entertainment, with the positive byproducts of improving hand eye coordination, improving reaction time, and economically enhancing personal defense through non destructive means. A lot of different approaches to solve problems were poured into this collaborative projects, which was a lesson on how to use multiple brains to analyze, break down, and solve a larger more complex problem. Along with that all of us had to step outside of our comfort zone to practice something we have never done before, overall our project granted us a great opportunity to acquire practical skills in our respective fields.

## X. THE ENGINEERS

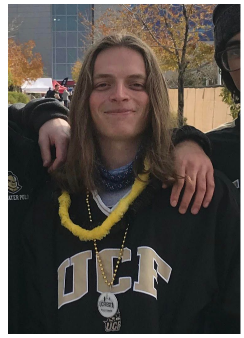
**Edward Plummer -** Edward Plummer is a student at the University of Central Florida studying for a Bachelor of Science in Computer Engineering. He was born and raised in Miami, Florida where he grew to have a passion for mathematics and inventions. In the future, he hopes to work for a company which strives to be on the leading edge for new technology.



**Caleb Dobias** - Caleb Dobias is a student at the University of Central Florida studying for a Bachelor's of Science in Photonic Science and Engineering. Born in Nashville, Tennessee and raised in Orlando, Florida, he works for nScrypt, a company specializing in 3D microdispensing, on the production team. He aims to continue his education at CREOL's Optics and Photonics Ph.D. program with research within the Optical Imaging System Lab.



**Travis Hughes** - Travis Hughes is a student at the University of Central Florida studying for a Bachelor of Science in Computer Engineering. He grew up in Boynton Beach, Florida. He has worked with a Cancer History Software company implementing algorithms to help patients determine their chance of getting cancer and preventing it. He hopes to one day work for a software company that helps make a difference in people's lives.



**Triston Hernandez** - Triston Hernandez is a student at the University of Central Florida studying for a Bachelor of Science in Computer Engineering. Along with Computer Engineering he has completed his minor in Mathematics. Triston was born in Sarasota and lived his whole life in Florida, his family grew was popular amongst the circus community where both of his parents were prefermores in Sailor Circus. He hopes to work with as an embedded software engineer in the aeronautical field.


## ACKNOWLEDGEMENT

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