Detecting Explosive Material via Optical Systems Observing the Behavior of Bees

Group 2

Introductions

We'll be right here!

Cole Correa

Computer Engineering

Hussein Shelleh

Electrical Engineering, Photonic Science & Engineering

Nicholas Johnson

Photonic Science & Engineering

Trevor Van Baulen

Computer Engineering

Overview and Motivation

Detection Technology is critical for security. However, it tends to be expensive or limited in some way:

-Dogs and Mice require months of effort, trainers to bond with, and thousands of dollars, plus upkeep with specialized diets.

-PIDs only ever detect a handful of compounds, and it must both be attuned and a filter paid for.

-GC-MS machines and ETDs are exceedingly expensive.

Bees mostly **circumvent** these issues:

-They take hours to train, which lasts for four to five days.

-They cannot be trained for multiple compounds at once, but multiple groups of bees can be trained simultaneously instead.

-The training requires a lab setting, but no bonding or attunement is needed beyond that.

-The cost of using the bees is only raised by the technology used to house, transport, and observe them.

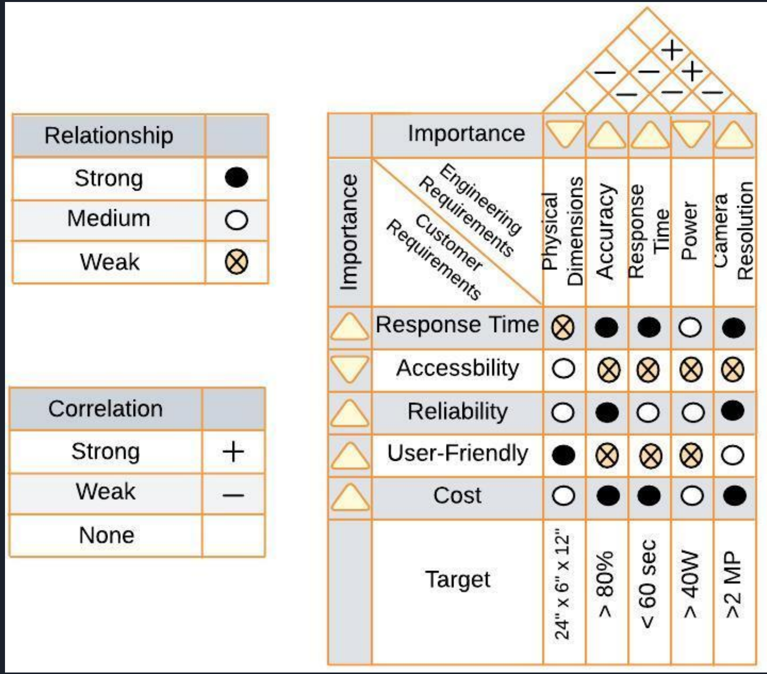
Goals and Objectives

The overall goal of this project is to create a handheld portable device used to monitor trained bees for bomb detection. The device will be user-friendly and easily accessible given the user has access to trained bees. The prototype device should help decrease overall cost and time in bomb detection.

Basic Goals	Advanced Goals	Stretch Goals
Detect substances with greater than eighty percent accuracy	Detect substances with greater than eighty five percent accuracy	Detect substances with greater than ninety percent accuracy
	Response given within a minute.	Add more advanced statistics to the LCD display

Engineering Requirements

Overall Device Requirements	
Response Time	< 1 Minute [Visual Spectrum] <5 Seconds [Infrared Spectrum]
Battery Life	>30 Minutes
Weight	< 15lb
Accuracy	≥ 80% [Visual Spectrum] ≥ 60% [Infrared Spectrum]
Device Communication	LCD Screen, LEDs, USB
Device Dimensions	30" x 6" x 12"
Power	≤ 40W
Bee Chambers	2



The Bees

Trainability

Small form factor vs dogs

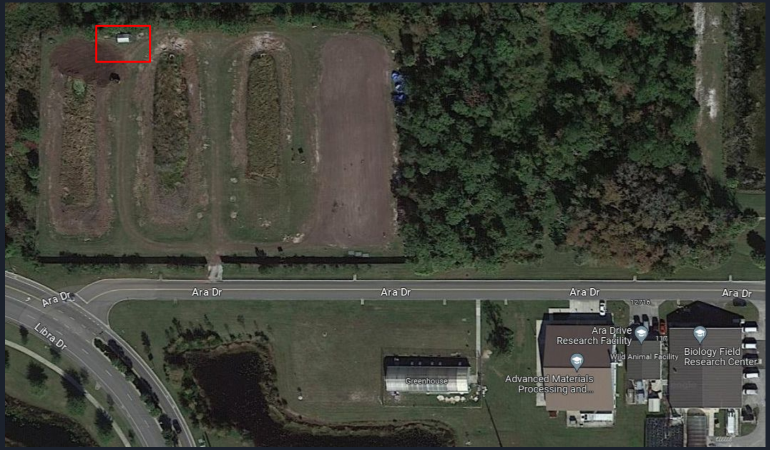
Equal vapor sensing threshold at 40 parts per billion

The Training the Bees

To train the bees, we have partnered with Patrick Bohlen the head of the bee research division at UCF

The bees will be harvested from hive 2 at the biological observation field 3

Train will be done by Nicholas Johnson (speaking) and one of Dr Bohlen's grad students



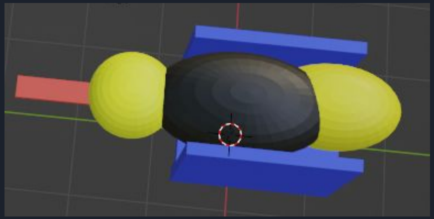
The Training the Bees

The train will be done by Nicholas Johnson (speaking) and one of Dr Bolen’s grad students

After collection the bees will be refridgerated to slow their metabolism and make them easier to manipulate in to harnesses

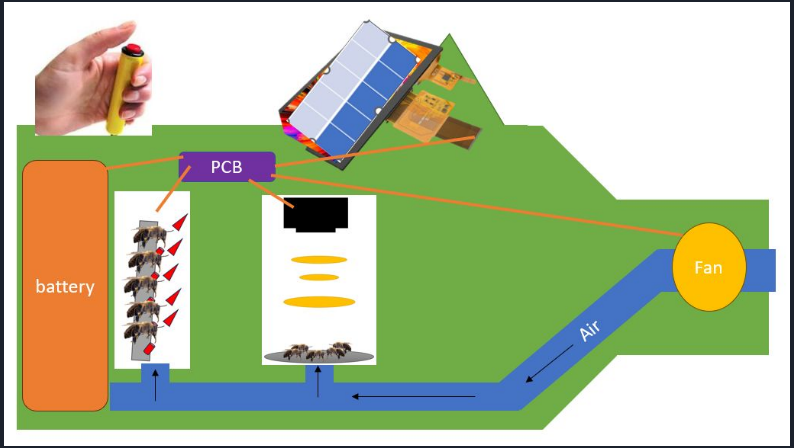
To pavlov the bees the will be exposed to liquid TNT for 6 seconds at a time with the last 3 seconds of it being offered sugar water as a reward

This process will take about 4 hours for each bee



Physical Design of the Device

- Hand-held
- Compact
- Light
- Efficient airflow
- 2 bee chambers
- Visual representation output located at the top

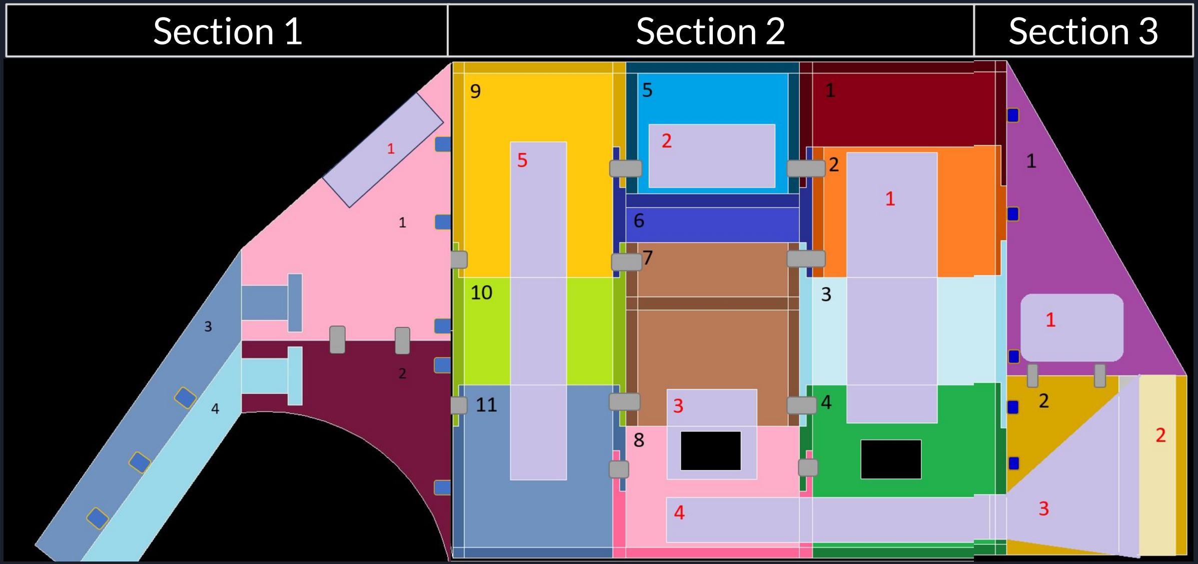


Fabrication of device structure

The device is made to be extremely modular in design.

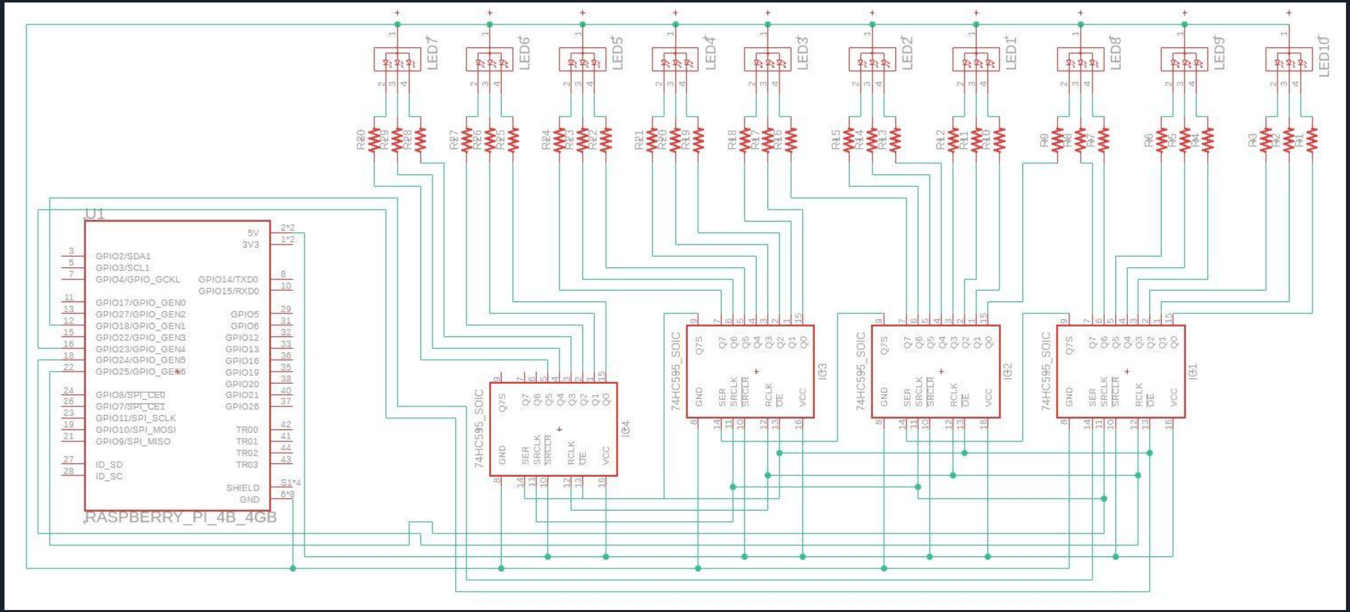
This will allow onsite maintenance on the device to be as efficient and streamlined as possible and eliminate the risk of workers opening the bee sensing areas and unalignment of the optical components.

Also offers an easy slide and lock mechanism for loading the bees in.



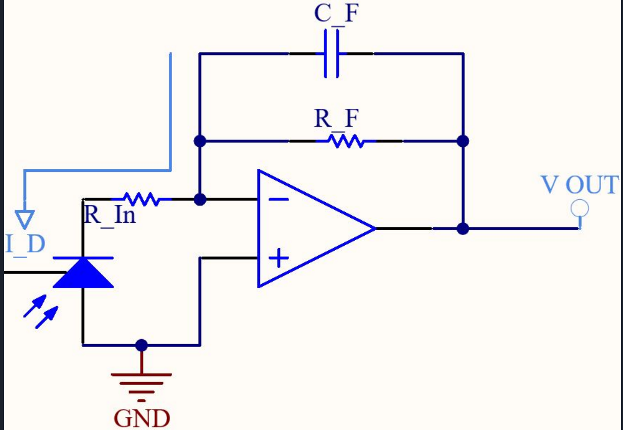
LED Schematic

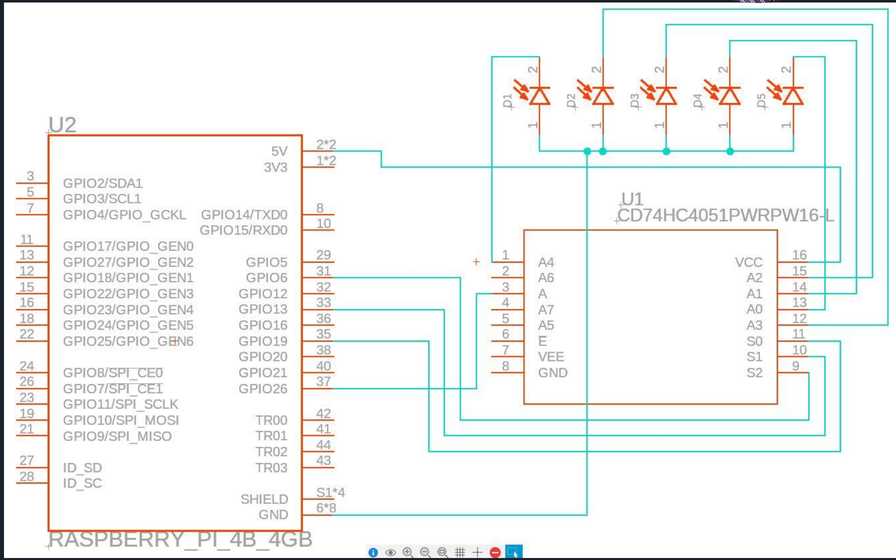
- 10 RGB LEDs
- 4 74HC595 shift registers



IR Sensor Schematic

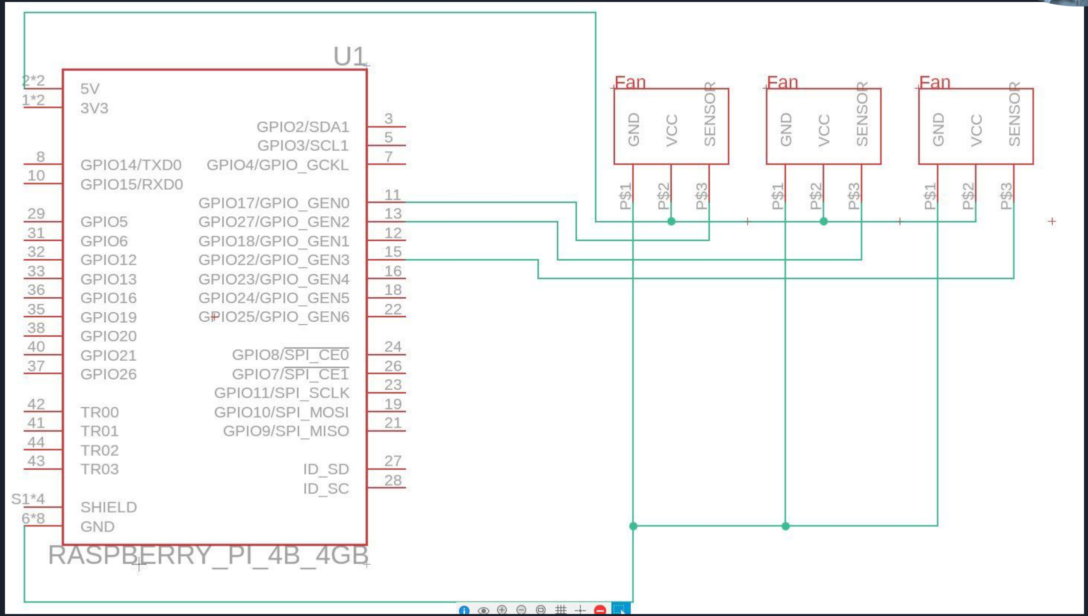
- Each Photodiode will be connected to a Transimpedance Amplifier to bolster the signal.
- Signals will be fed into Multiplexor due to analog pin limitations.
- Microcontroller can ‘read’ the spike of electricity, which marks the bee as a ‘detect’.





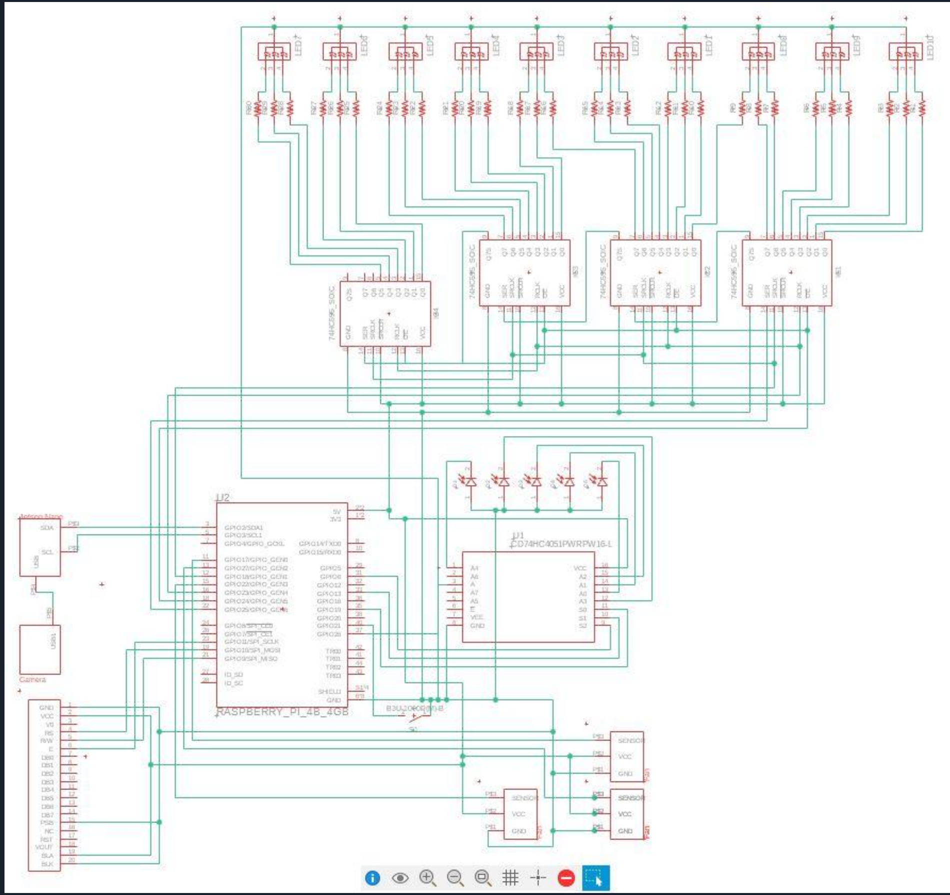
Fan Schematic

- Control airflow
- Three fans located at the nozzle, between the chambers, and the exit vent of the device.



Hardware Design Schematic

- Raspberry Pi 4
- LEDs
- IR Sensors
- Fans
- Jeston Nano
- LCD
- Switch/Button



Microcontroller (MCU)

- ESP32-S3-Wroom
- We chose to use this MCU because of the amount of GPIO pins (36) we will utilizing for this device.
- Controls fan, IR sensor, LCD, and LED sub-systems.

Name	RAM	Power	GPIO Pins	Clock Frequency	Price
ESP32	16 MB	3.0-3.6 V	36	40 MHz	$3.62
ATmega48A	512 B	1.8-5.5 V	14	16 MHz	$1.81
RP 2040	2-8 GB	1.8-5 V	30	133 MHz	$1.00

Battery Pack selection

- Wanted to ensure battery provided enough power while remaining slim.
- Selected Philips Respironics Battery.

Battery Pack	Philips Respironics Battery	AT:Tenergy Li-ion 14.4 V
Watt-Hour (Wh)	~98 Wh	~100 Wh
Voltage (V)	14.4 V	14.4 V
Miliampere Hour (mAh)	6300 mAh	7000 mAh
Dimensions (mm)	107.95 x 190.5 x 31.75 mm	147 x 73 x 20 mm

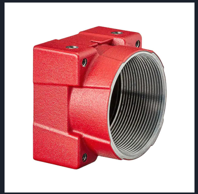
Voltage Regulator

- Texas Instruments 7805 linear voltage regulator
- The output will be five volts
- This part will help supply a steady voltage throughout the device

Manufacturer Product Number	Max Input Voltage	Output Voltage	Current Output	Price
UA7805CKCS	25V	5V	1.5 A	$0.85
TLV76150DCYR	16V	5V	1 A	$0.74
MC7808CTG	35V	8V	1 A	$0.72

Camera Selection

- MD310C-BS was the first choice, ran into issues with the camera.
- Second choice was the Alvium 1500 C-120C.



Camera	MD310C-BS AmScope	Alvium 1500 C-120C	BoliOptics 5MP CMOS
Megapixels (MP)	3.1 MP	1.2 MP	5 MP
Frames Per Second (FPS)	83 FPS	52 FPS	60 FPS
Resolution	680 x 510	1280 x 960	640 x 480
Connection	USB 2.0	MIPI CSI-2, up to 4 lanes	USB 2.0

AI Development Board Comparison

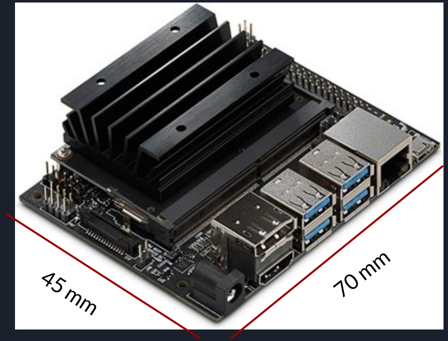
- The design of the system uses two subsystems.
- One of the subsystems utilizes Object detection software for the bee proboscis.
- Since this requires decent computing power, an AI development board is being used.

Technology		Jetson Nano		Google Coral		Raspberry 4 Pi	
Factors	**Weight**	Raw	Weight	Raw	Weight	Raw	Weight
Cost	35%	7	2.9	5	1.75	10	3.5
Performance	30%	9	2.7	7	2.1	4	1.2
Size	20%	5	1	8	1.6	6	1.2
Camera Port	15%	10	1.5	2	0.3	5	0.75
Total:			**8.1**		**5.75**		**6.65**

NVIDIA Jetson Nano Development Board

Purpose:

- Will execute object detection model on camera input and return the results.
- Utilizes GPU.
- Designed specifically for AI development.

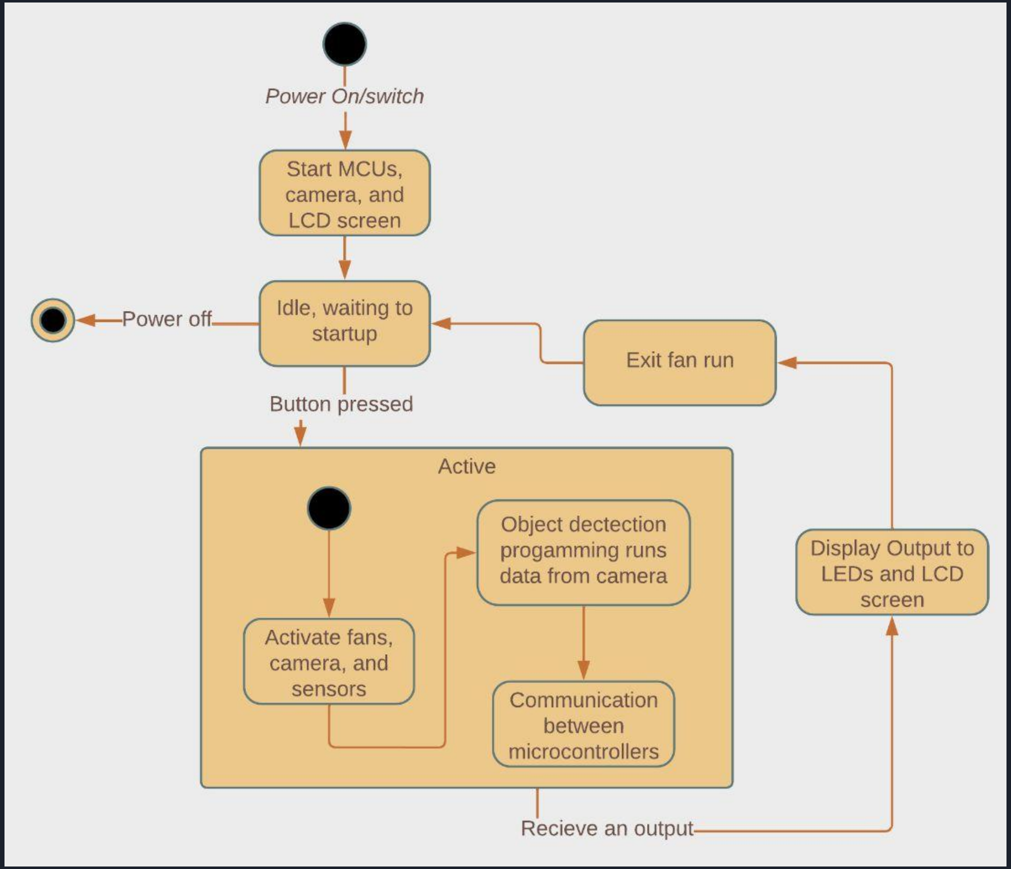


Specifications	Values
GPU/AI Accelerator	128-core Maxwell @921 MHz/472 GFLOPS
CPU	Quad-core ARM A57 @1.43 GHz
Memory	4 GB 64-bit LPDDR4 25.6 GB/s 1600 MHz
Camera Ports	MIPI CSI-2 camera connection

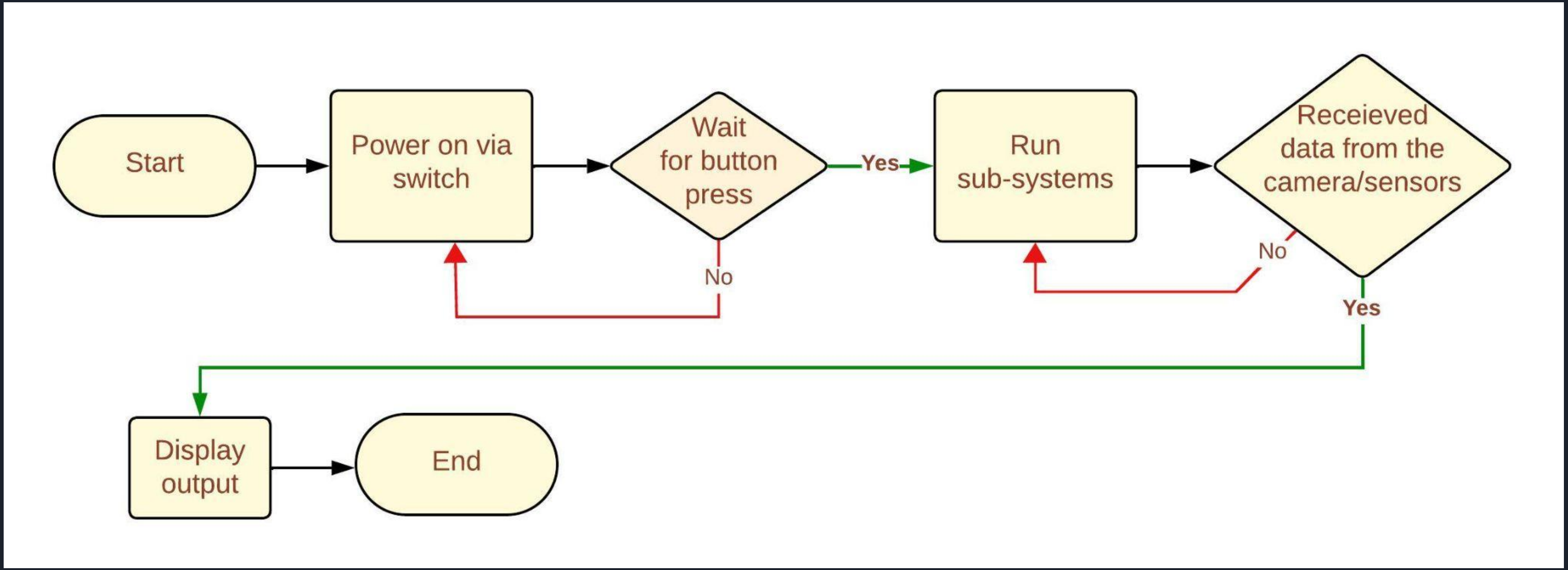
Software Design

- Our software design is split into two main parts the embedded programming and artificial intelligence (AI).
- The embedded programming will control many of the functions throughout our device and peripherals.
- Our AI software will deal with machine learning algorithms and object detection found within our camera system.

Software Design State Diagram



Software Design Input Flowchart



User Interface

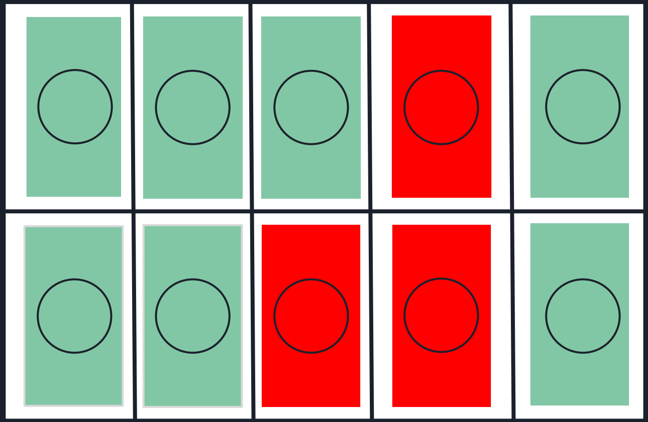
- We decided to use two visual aid representations for our device.
- The LCD screen will show the results found from the IR sensor and camera systems. It will also display statistics relating to accuracy and response time.
- The LED interface will be made up of ten LEDs that will light up based on the results of each system.

LCD Screen

System	1	2	3	4	5
Camera					
IR Sensor					

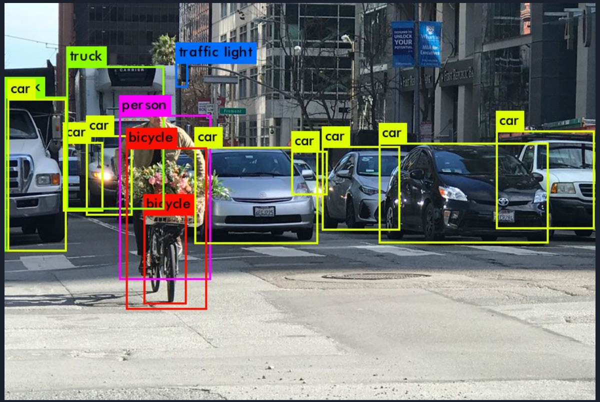
Accuracy Percentage: xx%

LED Interface



Object Detection Model

- The secondary sub-system is utilizing an object detection model.
- Many models of object detection exist allowing for choice.
- The two main factors were FPS and accuracy.



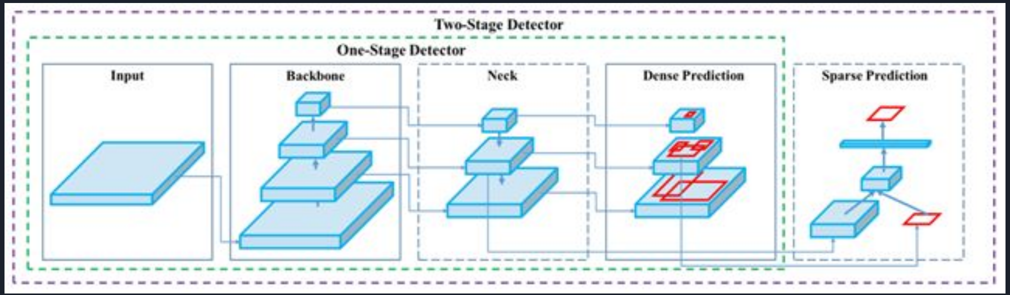
Choosing our model

- Considered three separate models based off FPS and accuracy.
- FPS and accuracy can vary depending on the dataset used to train.
- For fair comparison, the MS COCO dataset was used.

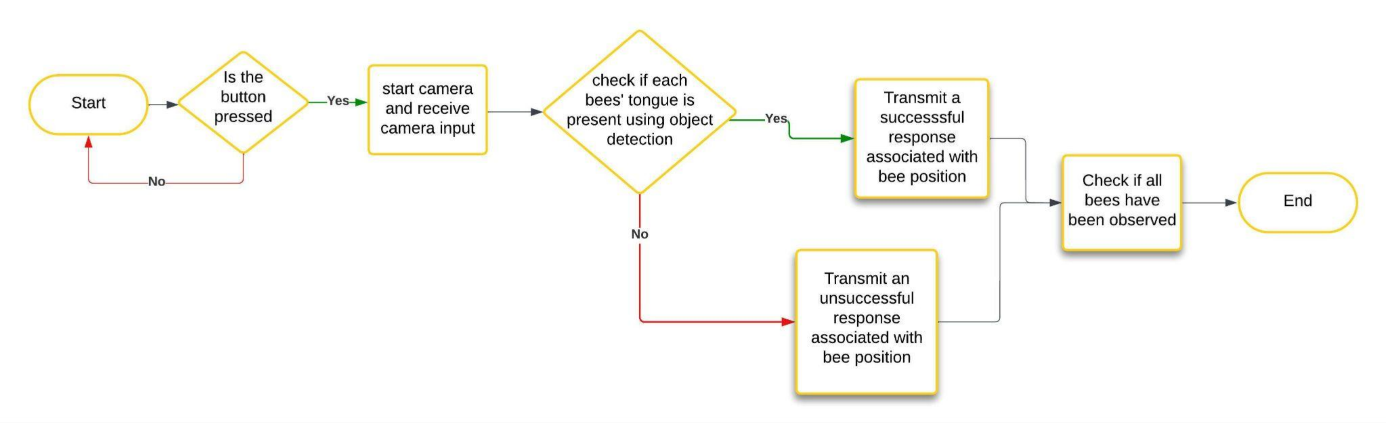
Model	YOLOv4	Faster R-CNN	SSD300
mAP (Mean average precision).	43.5%	43.9%	34.9%
FPS	~40	~5	~22

YOLOv4

- YOLO (You only look once) is the object detection model that is being implemented.
- Using both bag of freebies and a bag of specials for dataset.
- A dataset is being created to train the model for our purposes.



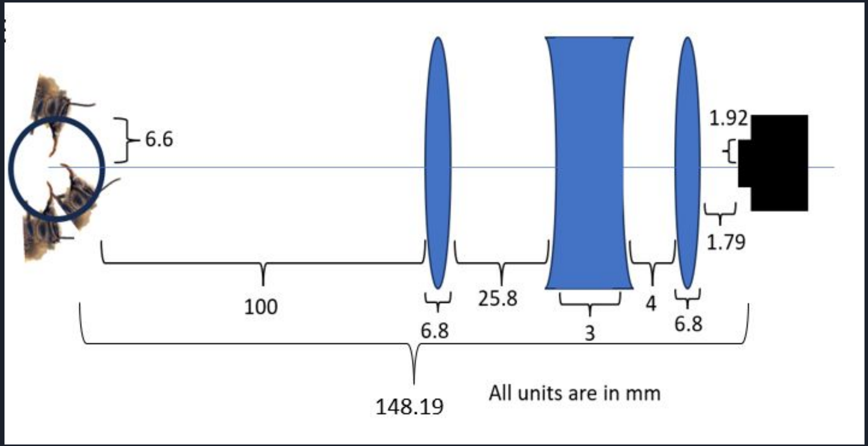
Camera input for ML



Visual Spectrum Optical Design

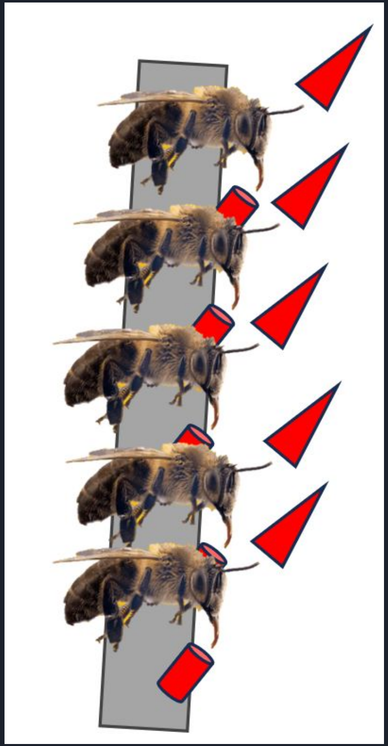
The optical lens and camera system has been perfectly optimized so that the camera can see the tongue of the bee that ranges from .7 - 1 mm in thickness.

The lenses are also optimized the accommodate the range of heights of the bees, from 3 - 5 mm.



Infrared Spectrum Optoelectronic Design

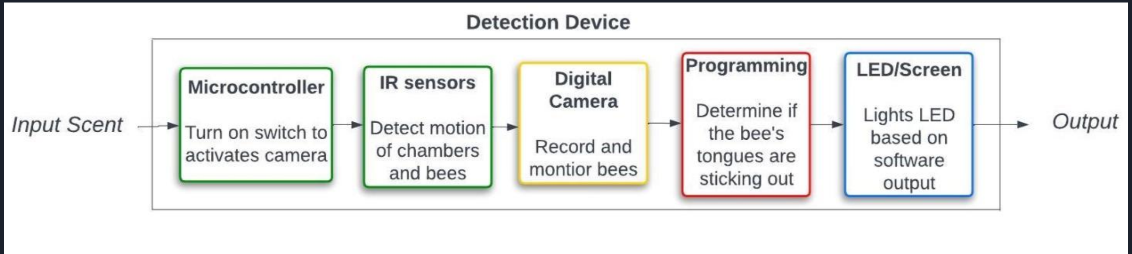
- Objects that radiate heat still have an optical effect - just not (usually) on the visible spectrum.
- Bee proboscises emit a relatively small amount of heat - but enough to be detected through photodiodes.
- White Light will not affect the process - the difference in wavelength and intensity is significant enough to ignore it.
- The radiation from the proboscises will cause a spike in electricity when interlinked with a transimpedance amplifier, which feeds back into the microcontroller.

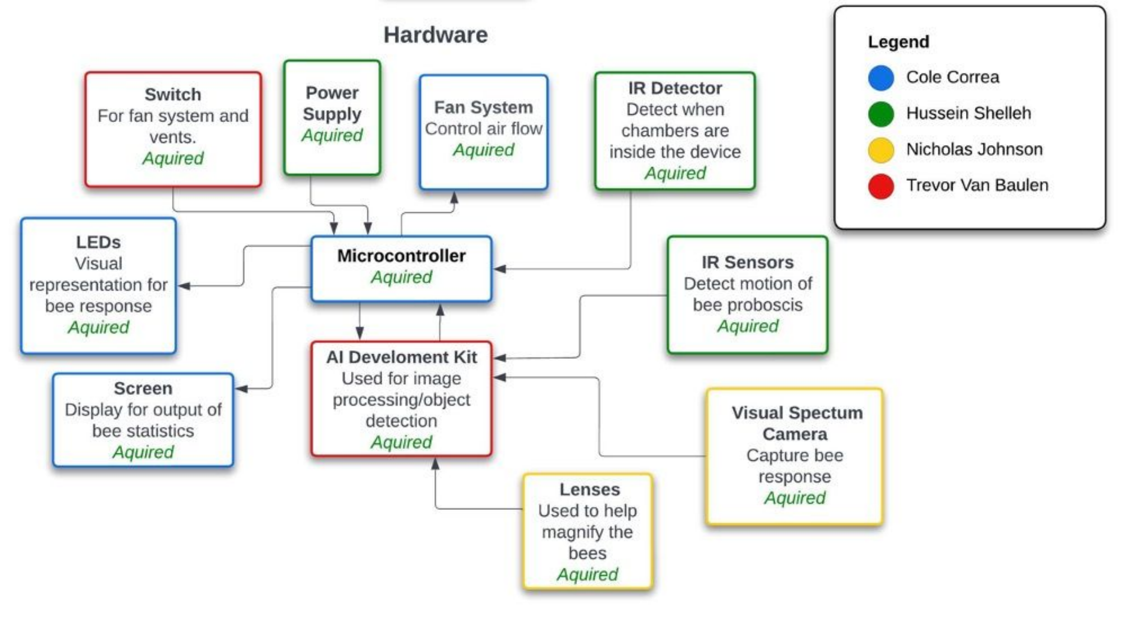


Testing

For testing our explosive detection device, we'll have several bags. Half will be sprayed with liquid TNT to mimic explosives found in more dangerous circumstances.

Work Distribution





Challenges and Triumphs

Challenges:

- Initial uncertainty with project design.
- Growing budget, lacking sponsor.
- Infrared System complications.
- CMOS Camera difficulties.
- Training Object Detection without easy proboscis access.

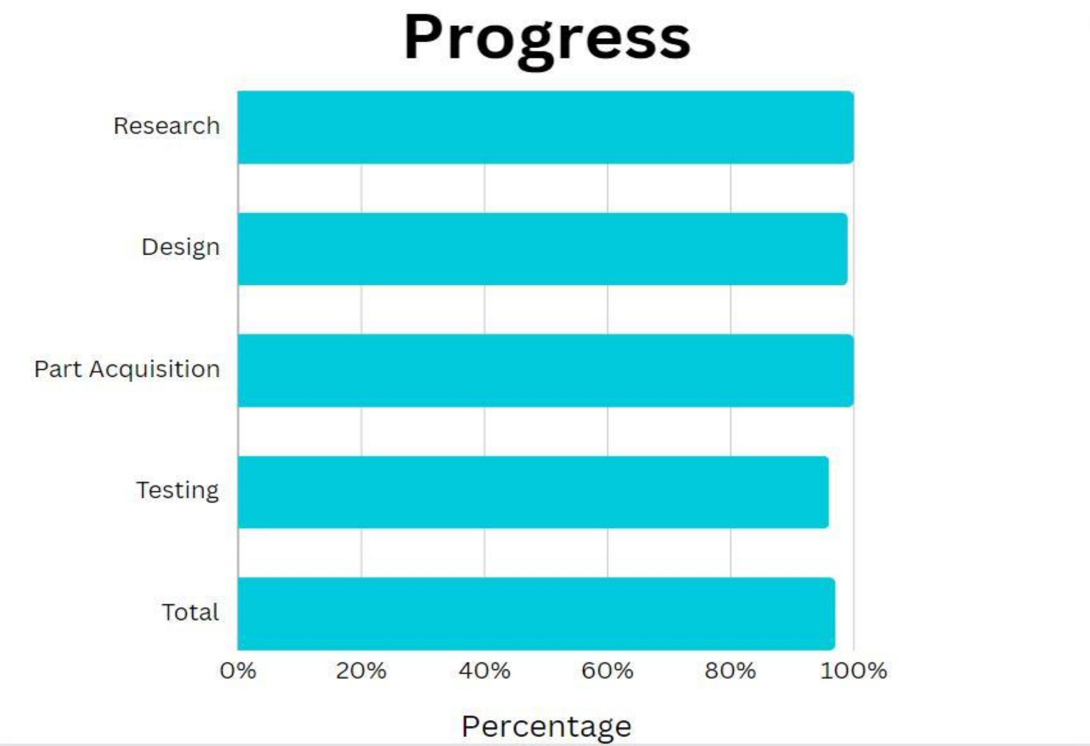
Triumphs:

- Visual Spectrum Lens System already completed and ready.
- Battery Component for ‘free’.
- CNC Mill and 3D Printing Models completed.

Budget (By End of Senior Design 1)

Item	Quantity	Price
RGB LED	15	$16.19
LCD	1	$40.88
Photodiode	10	$20.64
MCU	1	$45.28
AI Dev Kit	1	$166.79
CMOS Camera	1	$181.04
Lens	3	$169.98
Multiplexer	1	$10.56
Shift registers	3	$4.08
3D Printer Filament Reel	1	$21.00
Total		$658.76

Progress



Progress
Research
Design
Part Acquisition
Testing
Total
0%
20%
40%
60%
80%
100%
Percentage

To Do?

Task	Means of Accomplishing It
Finalize Infrared Research	Contact with Lab who originally used Bees
Object Detection Training	Slow and Steady practice
3D Printing and Milling	Printing/Milling is all that’s left to do
PCB	Awaiting Delivery for Testing
Test Runs	Awaiting Prior Tasks
Final Demo Preparations	Awaiting Prior Tasks

Thank you!

We appreciate your time and attention, and we hope to hear back from you all.