Project F.I.R.E.

Fire Intelligent Response Equipment

Group 4
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SIEMENS energy

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The Project

- Project F.I.R.E. is a device that is placed into remote areas where a fire may pose a potential threat to people or the environment.
- Using a mesh network, the device transmits data about the environment if a fire is detected
- A base station stores the data and that data can be retrieved for use by any kind of software

Meet the Engineers:

Jonathan Kessluk
Computer Engineering

Primary Focus:
- Wireless Communication
- Software Design
- PCB Design

Secondary Focus:
- Sensor System

Arisa Kitagishi
Computer Engineering

Primary Focus:
- Machine Learning
- Computer Vision
- Data processing

Secondary Focus:
- Data collection

Nicholas Hainline
Electrical Engineering

Primary Focus:
- Power System Design
- Device Enclosure
- PCB Design

Secondary Focus:
- Sensor System

Noora Dawood
Electrical Engineering

Primary Focus:
- Sensor System
- Data collection
- Data processing

Secondary Focus:
- PCB Design

Goals, Objectives, Specifications, and Requirements

Objective:
To design a system to alert authorities to the potential of a fire (or forest fire)

Goal:
The system is small, lightweight, low power, and self sufficient

Requirements

- The system shall detect the presence of a fire nearby
- The system shall communicate wirelessly to nearby nodes
- The system shall read all sensors and camera and store the data
- The system shall charge a battery with solar panel
- The system battery shall last 36 hours without charging

Specifications

- The system reads Temperature, Gas, IR, and camera periodically and store data internally
- The system processes all sensor data and images to determine if a fire has started
- The system uses LoRa for wireless communication
- The system contains a network controller and a sensor controller

Requirements Completed

Read sensors periodically and store the data

Process sensor data to determine if a fire has started

Monitor environment with temperature and humidity sensors

Power with a battery and solar panel simultaneously

Charge the battery with the solar panel

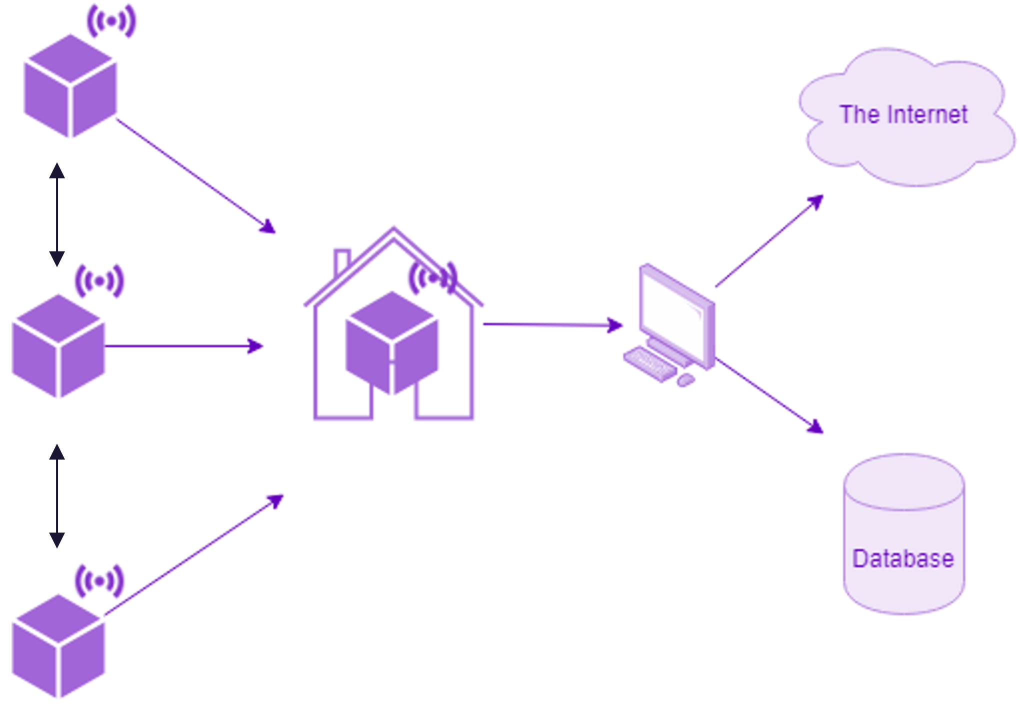
Differentiate between nodes in the network

Communicate data wirelessly to nearby nodes

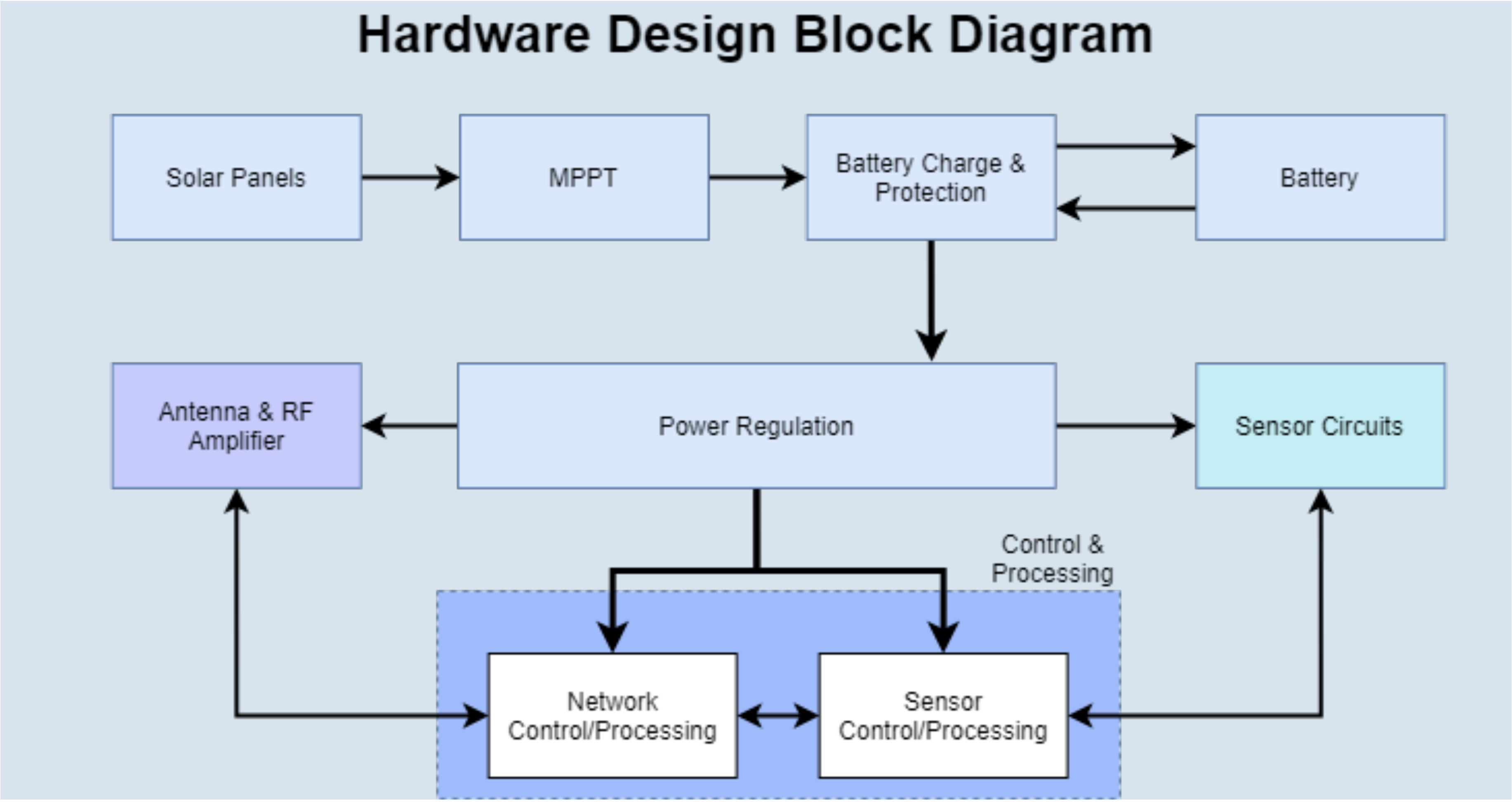
Use Machine Learning to detect forest fire

The Entire System

- Multiple Nodes that can sense fire within their local area
- Each node can send data to other nodes
- Endpoint acquires data and determines what to do with that data
- Every node must communicate with the Endpoint

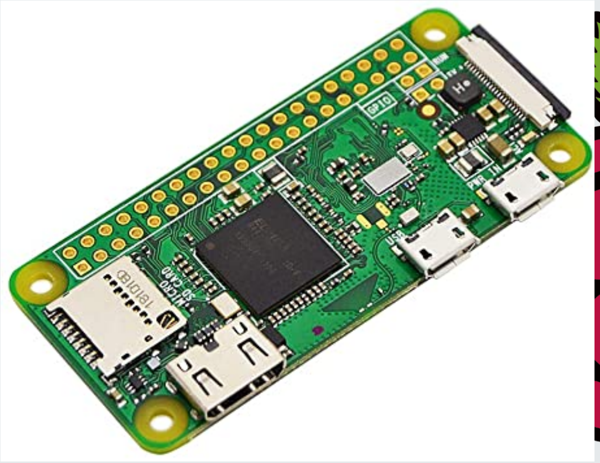


Block Diagram of a Single Node

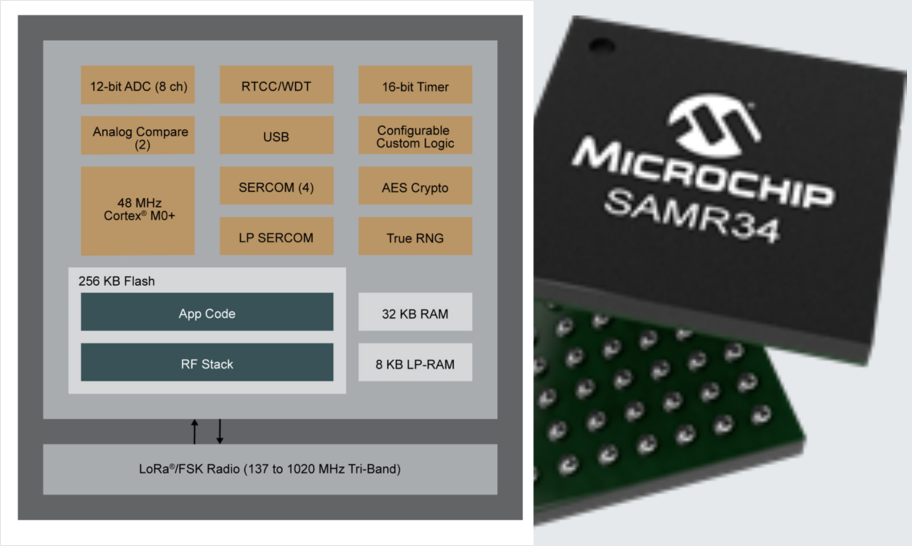


Processing & Network Subsystem

Raspberry Pi
- Easy to program (can use Python)
- Provides many communication interfaces
- Many resources available



SAMR34/5
- Sleep current is 790nA
- Built in LoRa UHF transceiver communication interface



Network Software

Jonathan Kessluk
Computer Engineering

Mesh VS Star Topologies

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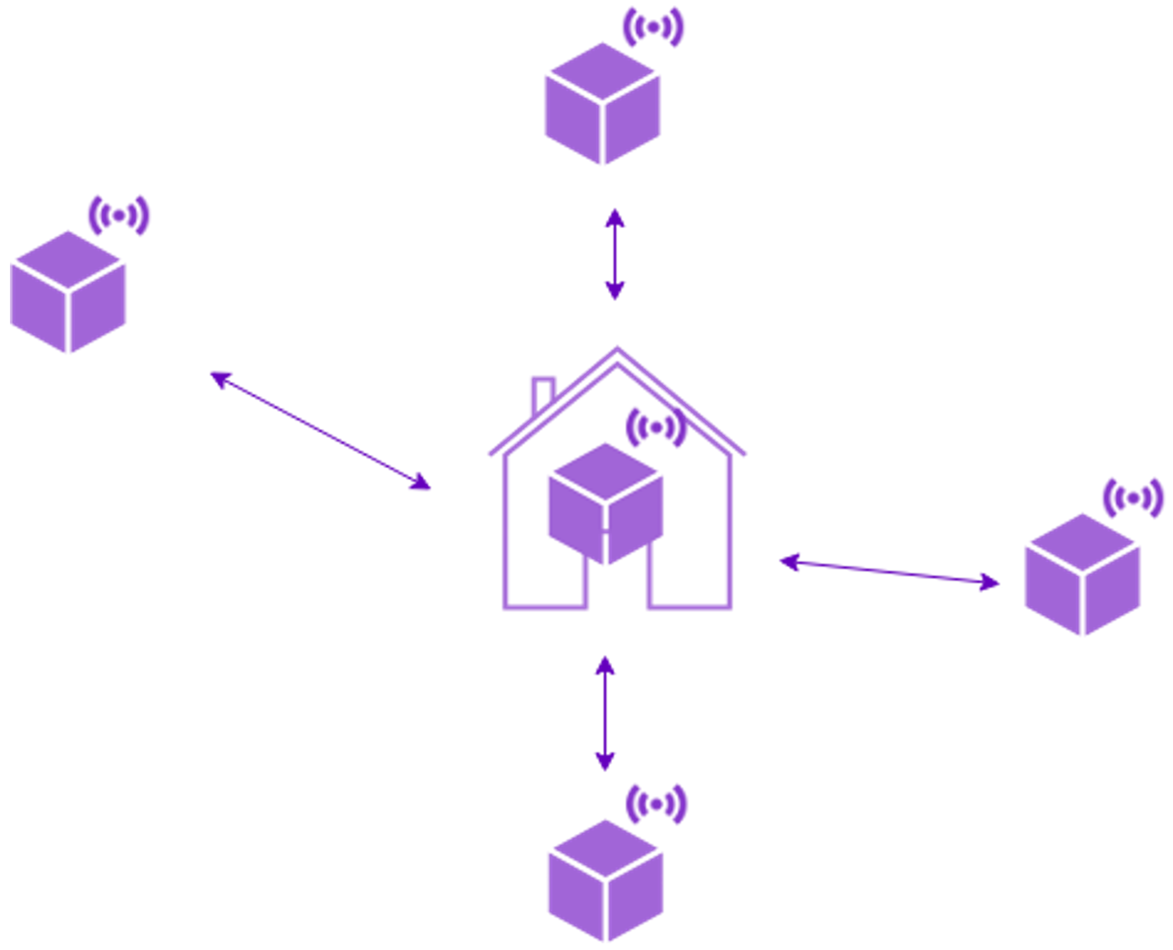
Ingenuity for life

Star Topology

- Complexity is localized at a central node.
- Nodes can sleep after transmission.
- Loss of central node results in the entire system disconnecting.

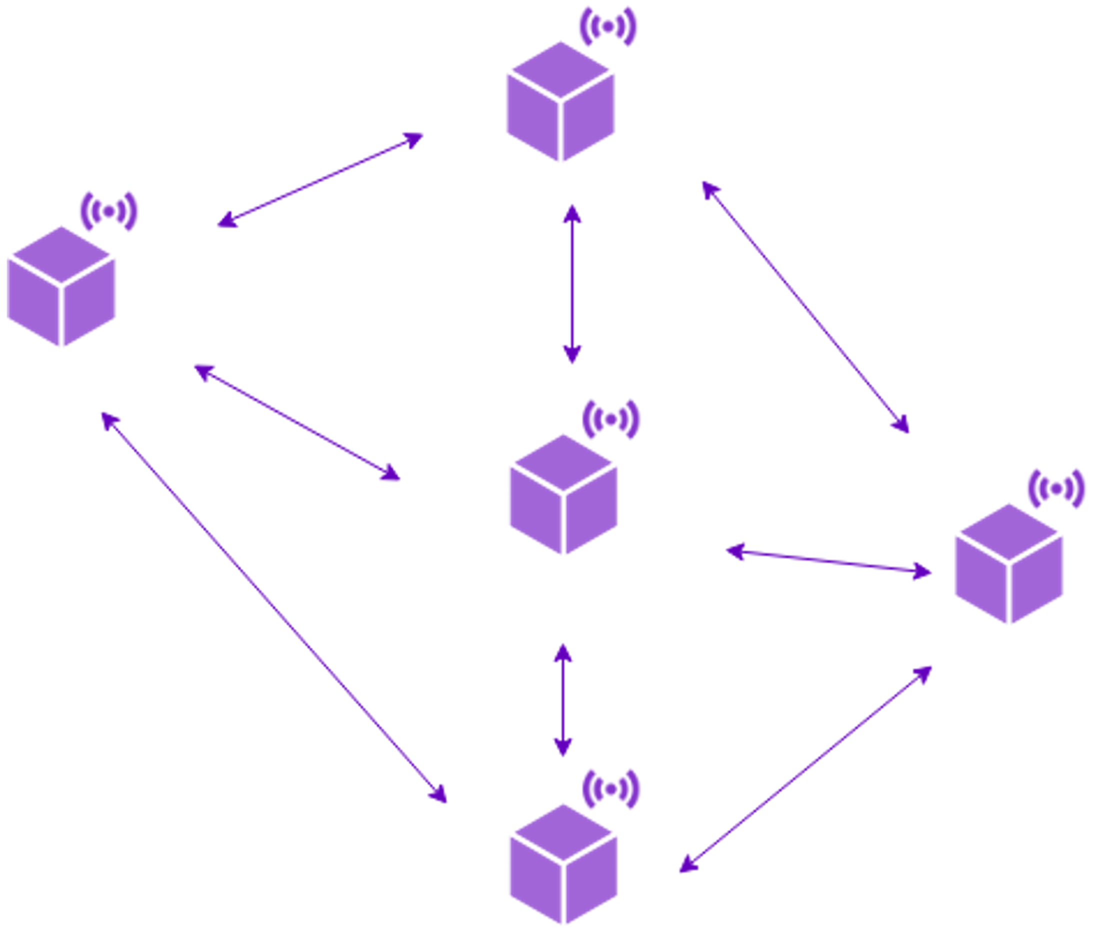
- Examples: LoRaWAN, Wifi



Mesh VS Star Topologies

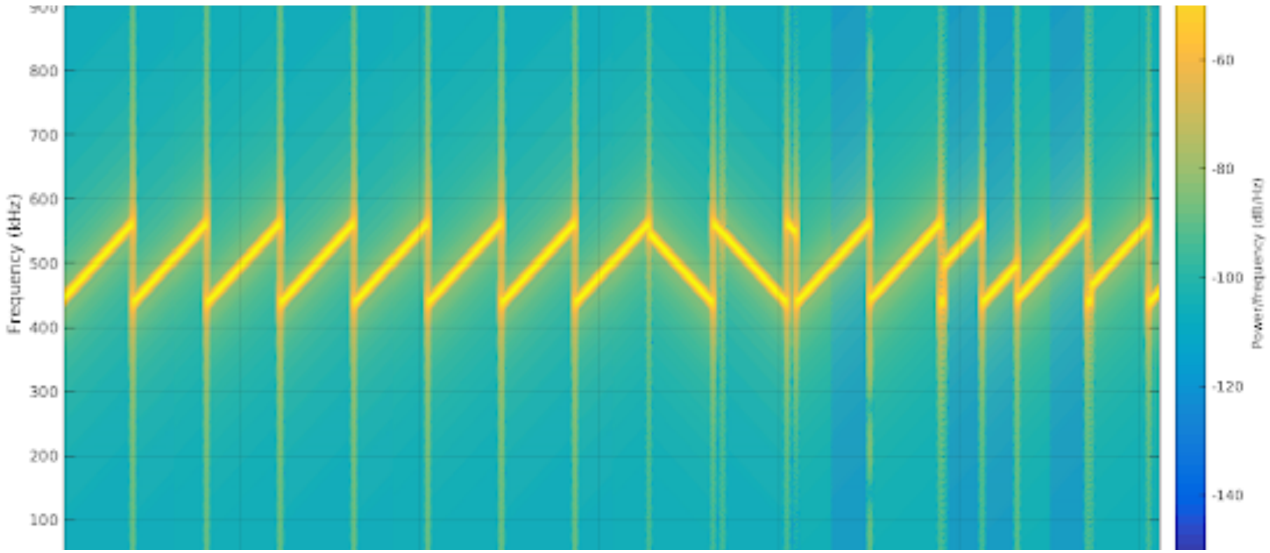
Mesh Topology

- All nodes cooperate to distribute data
- Loss of node is acceptable: all other nodes can still communicate (assuming no bottlenecks)
- Nodes must actively listen for transmissions at all times

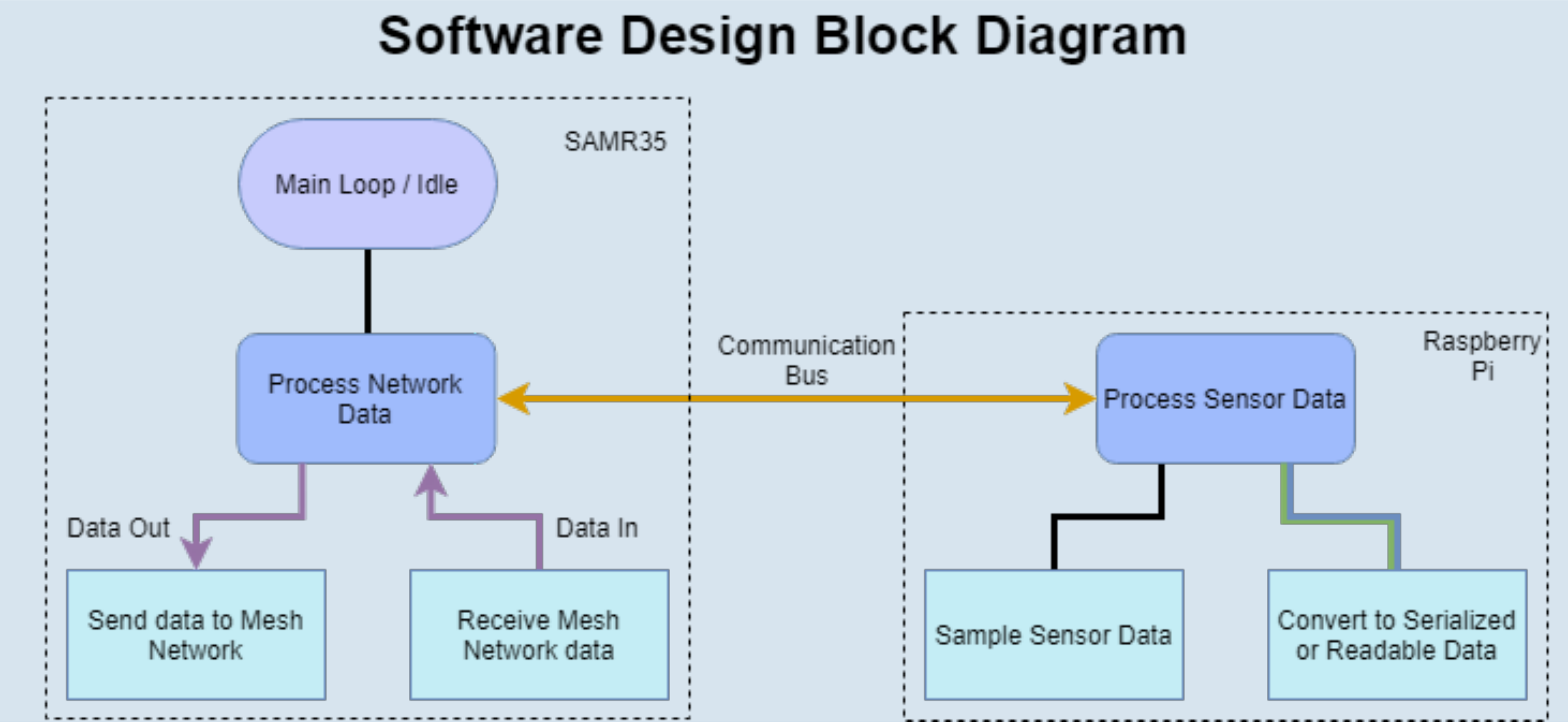


LoRa: Long Range

- Uses a derivative of Chirp Spread Spectrum Modulation (CSS)
- Can use the 400MHz and 900MHz bands
- Link budget of 155-170dB
- In ideal conditions, can reach 30 miles



Software Design



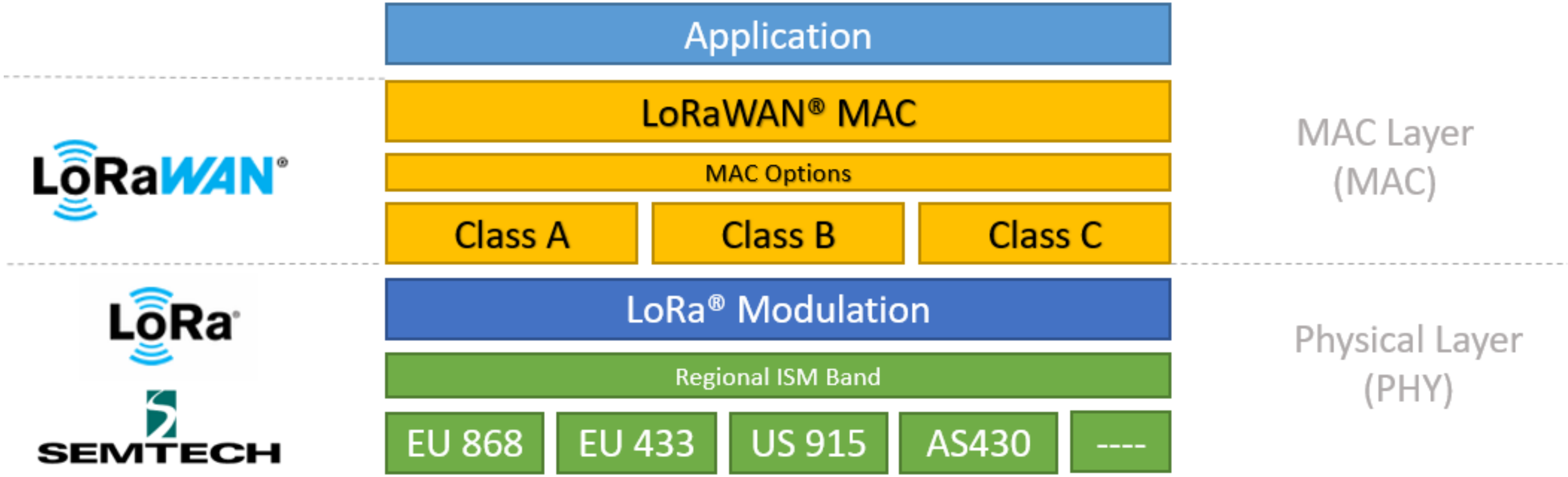
The Problems With New Technology

Limited Resources

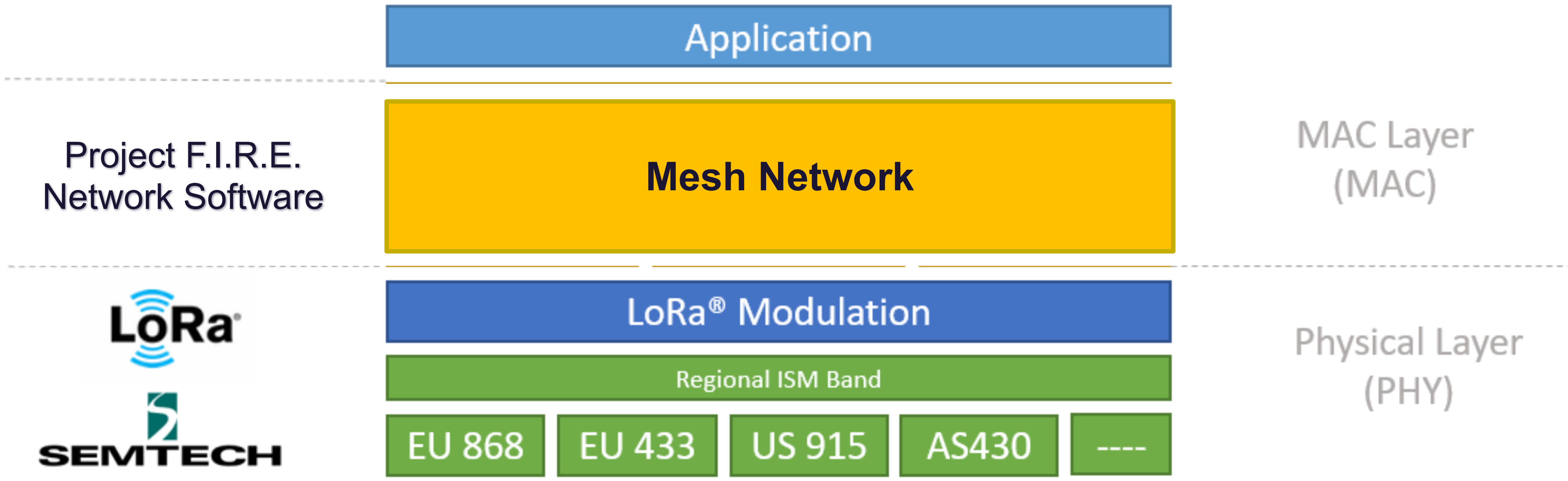
Conflicting Use Cases

Confusing Documentation

LoRa Vs LoRaWAN



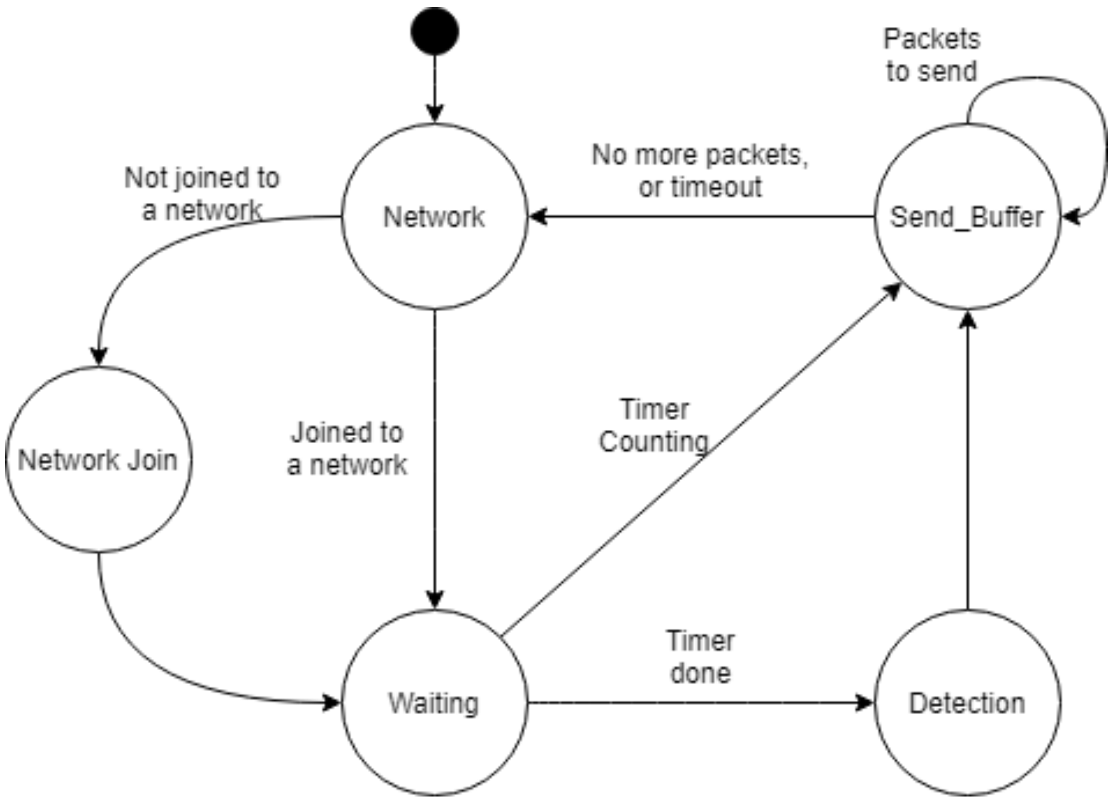
LoRa Vs LoRaWAN



State Diagram of Network Software

Order of operations:

1. If not joined to a network, join the network.
2. Wait for the timer to finish and allow packets to be received
3. Send responses and forward packets through the network if necessary
4. After some time, wait for the raspberry pi to finish looking for a fire.
5. Send any fire detected packets if applicable



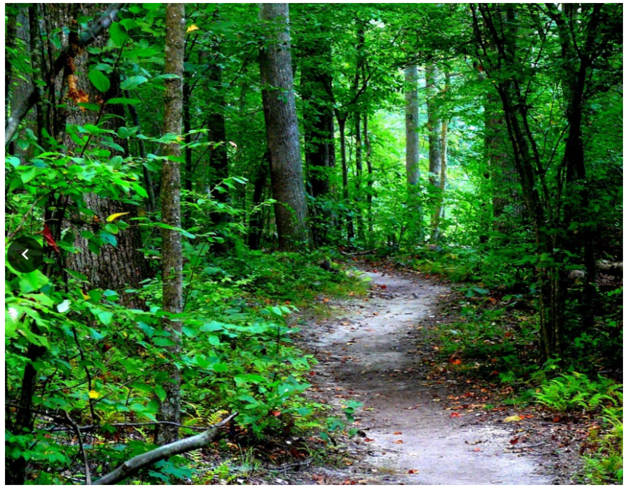
Computer Vision

Arisa Kitagishi
Computer Engineering

Computer vision

- Dataset:
  - Contains fire and non-fire images
  - Obtained from online images using Microsoft API
  - ~600 images total
  - Challenges:
    - Getting the right images
    - Appropriate for versatility?



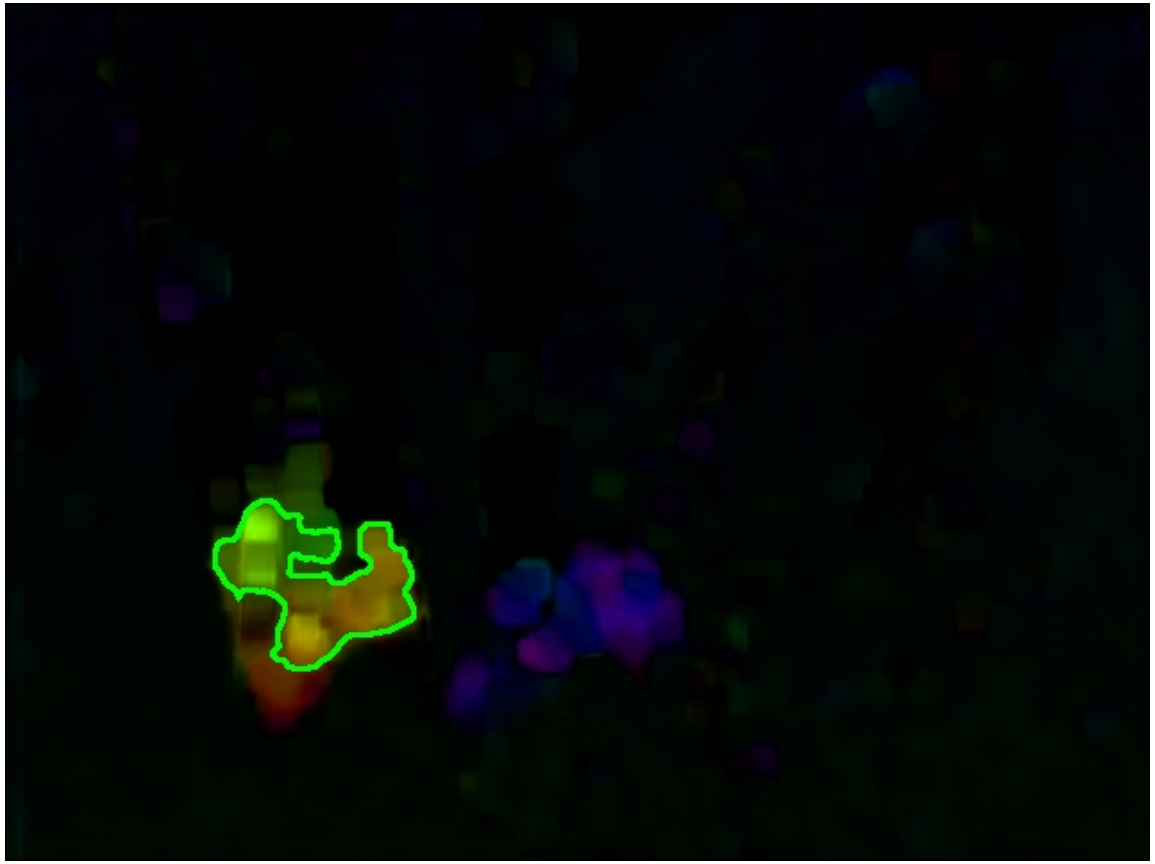
Computer vision

- Color Classification:

Computer vision

- Optical Flow:

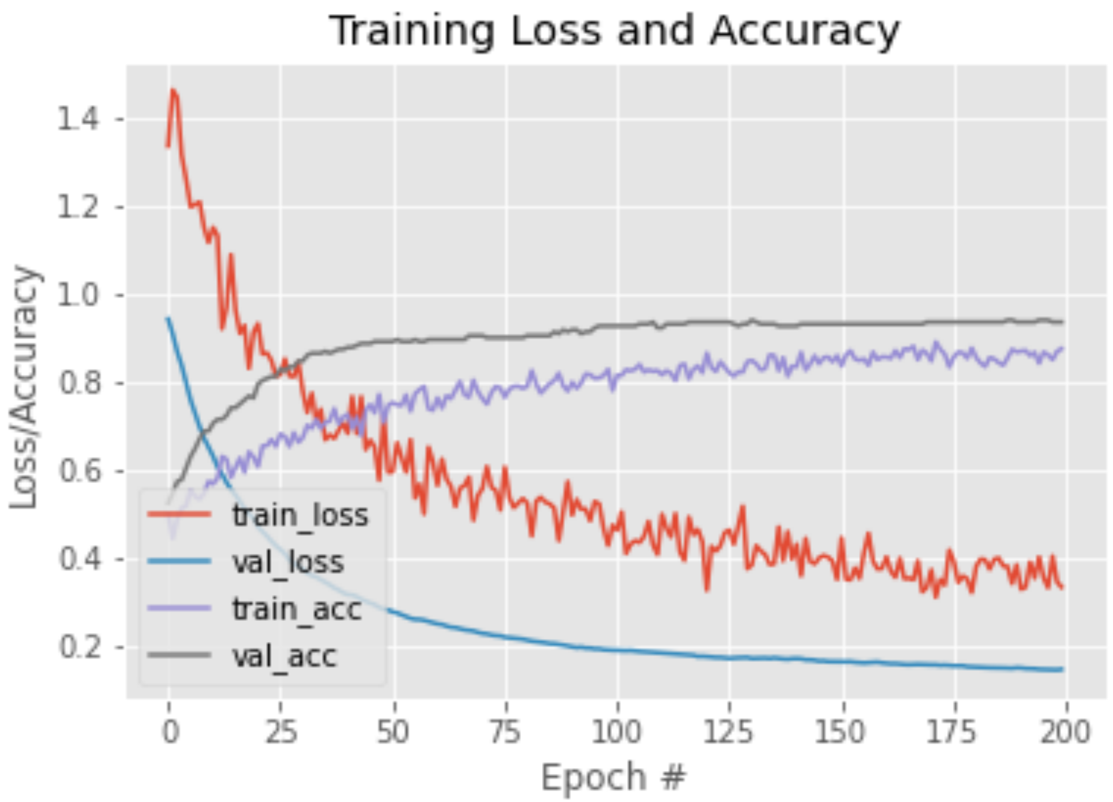
Original image sequence



Machine Learning

- Final Model:
  - Batch size: 32
  - Learning rate: 1e-5
  - Epochs: 200

•Epoch 200/200
•21/21 [=============] - 42s 2s/step - loss: 0.3438 - acc: 0.8701 - val_loss: 0.1441 - val_acc: 0.9336



Computer vision

- Challenges:
  - Limited memory and processing power
  - Limited packages and libraries
  - Limited versions of tensorflow and keras
  - Limited models available online such as YOLO
  - Dataset: not as versatile

TensorFlow

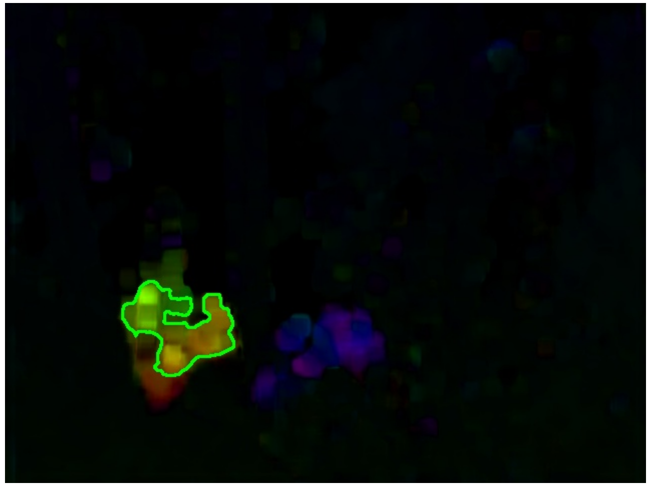
Keras

TensorFlow Lite

≠

Computer vision

- Challenges:
  - Fine tuning color classification
  - Fine tuning optical flow
  - Analyzing the overlaps
  - Fine tuning the model



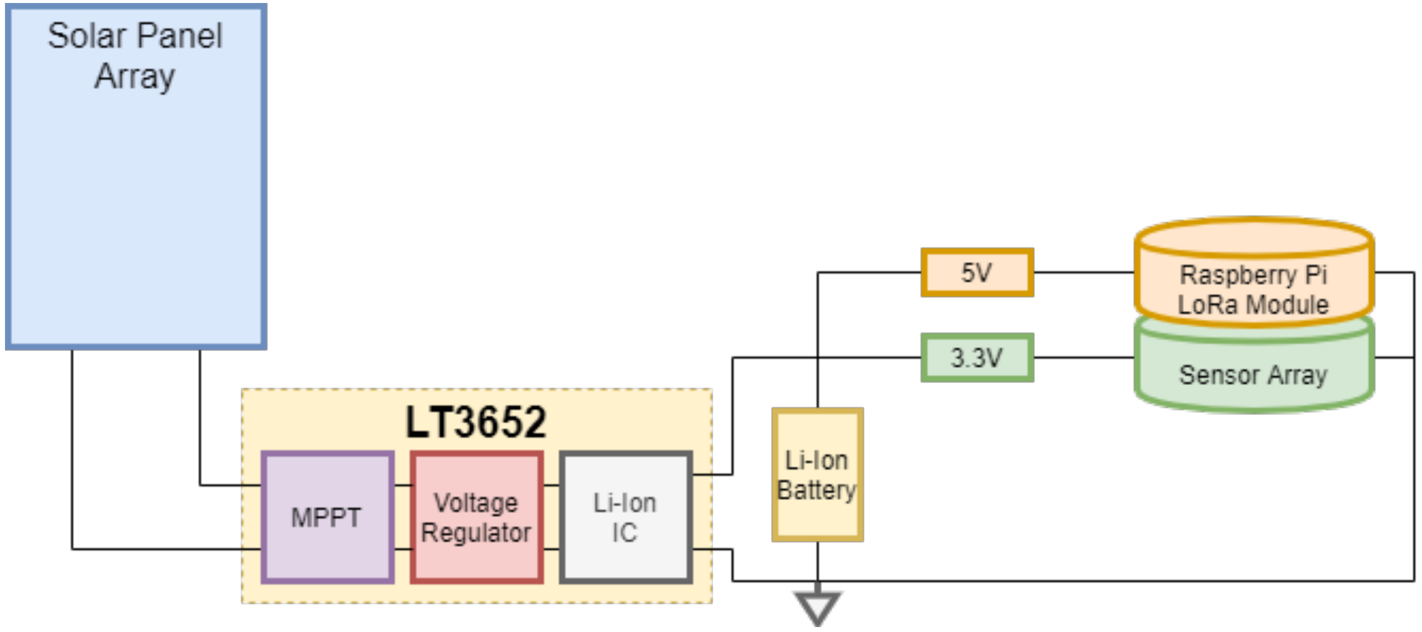
Power System & Enclosure

Nicholas Hainline
Electrical Engineering

Power System Design

Requirements:

- Power Storage
- Charging system
- Two power rails, one 5-volt and one 3.3-volt rail



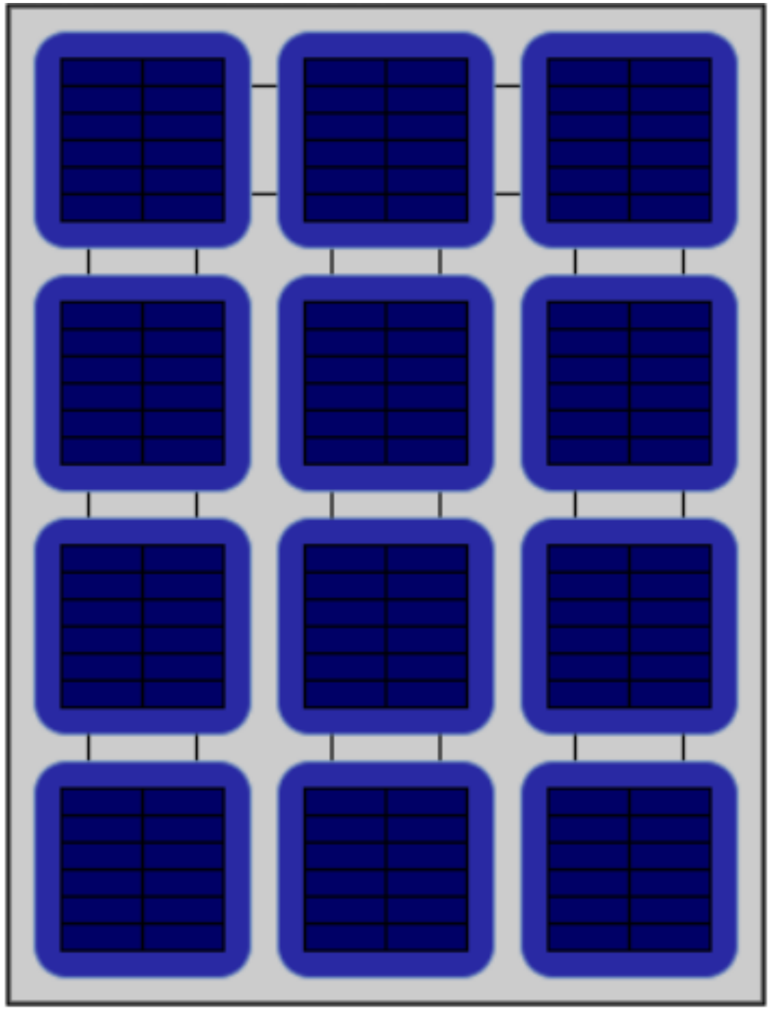
Choosing The Right Battery

- Two 18650 Lithium Ion Cells were chosen for power storage.
- The LT3652 chip will handle the battery protection and charging.
- Provide the best discharge curve and size to storage ratio.

Integration of Solar Array

The solar array for this prototype.

- The two 1.5-watt panels are in parallel
- This set up keeps the 18650 cells charged all day.
- The panels are used for trickle charging the two 18650's in series.

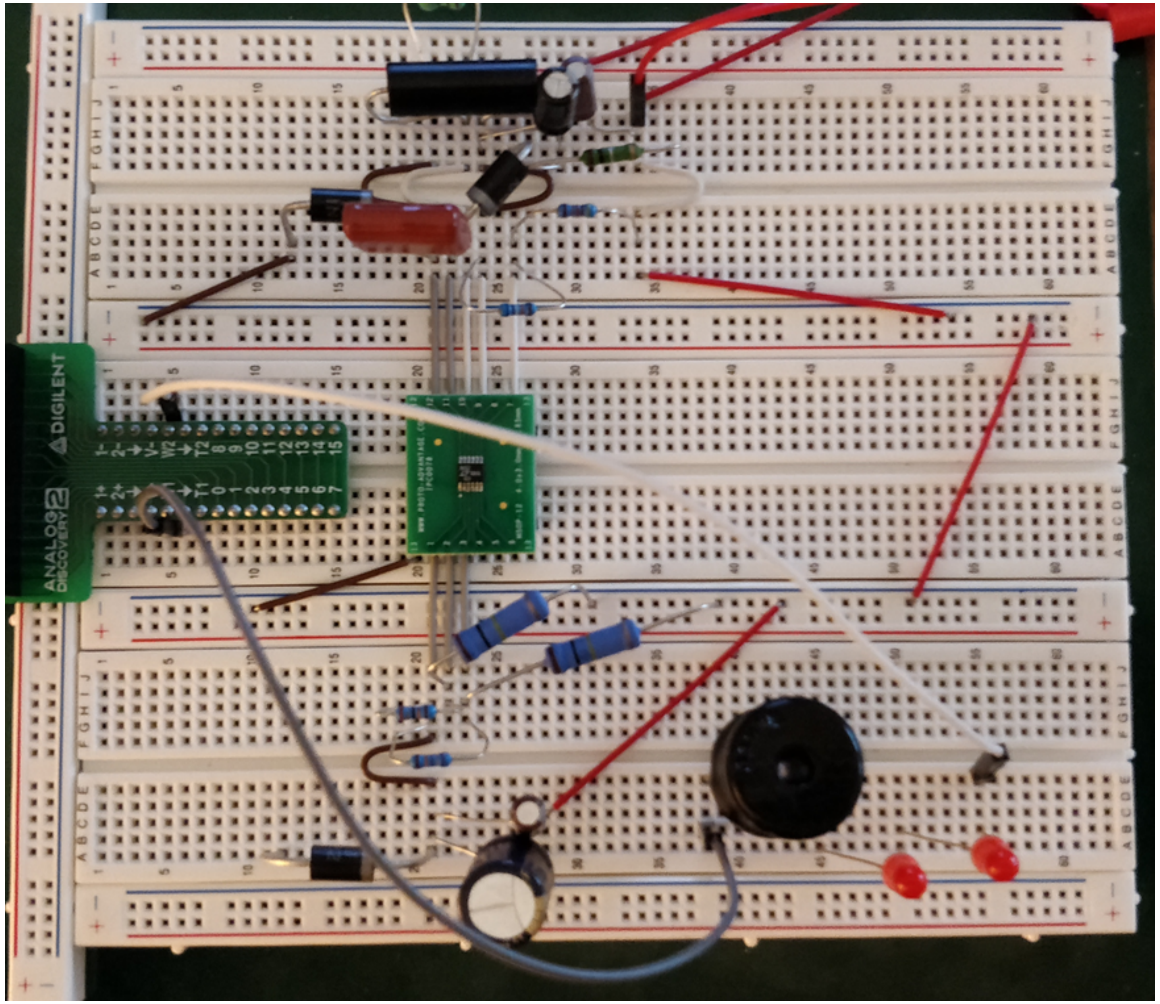


Power System Implementation

1. **Two solar panels:** Both in parallel to run the charging IC.

2. **LT3652 IC:** Charges the two 18650 cells

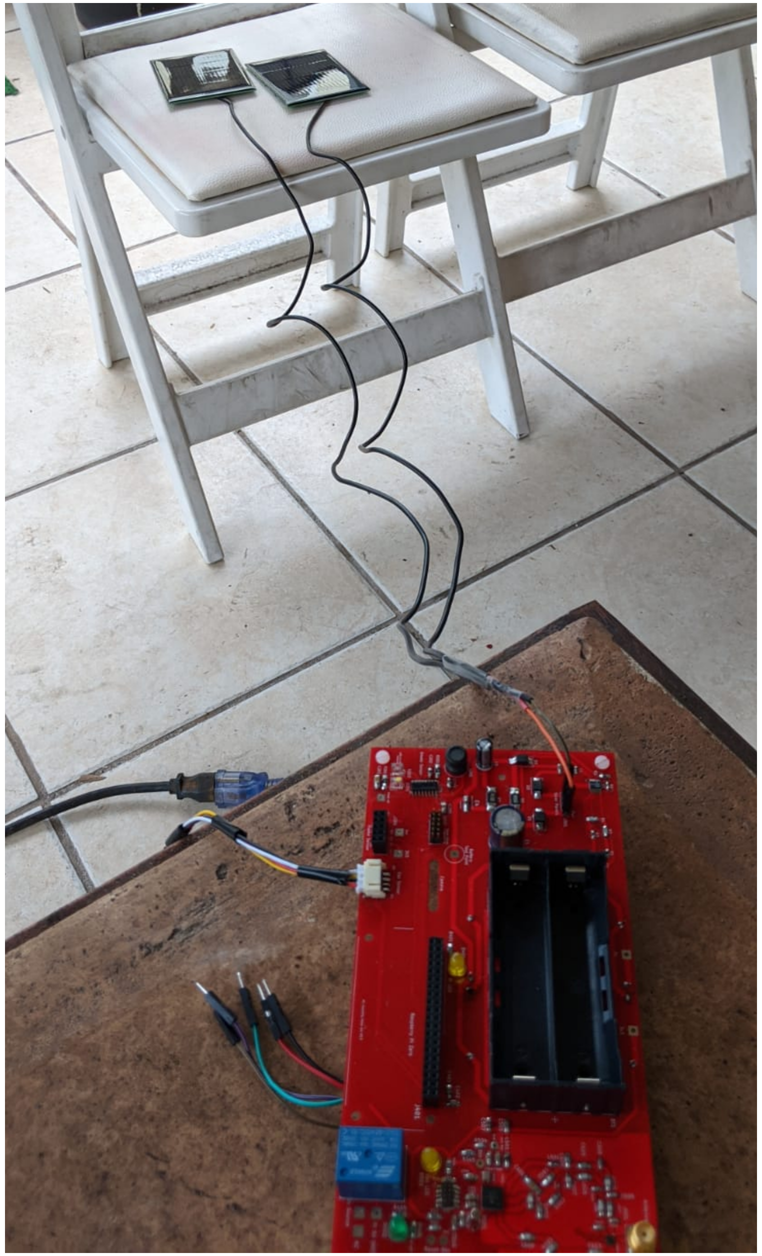
3. **Two Buck-Boost converters:** output 5 volts and 3.3-volts to run the Raspberry Pi and the sensor array.



Testing the Solar Charging System

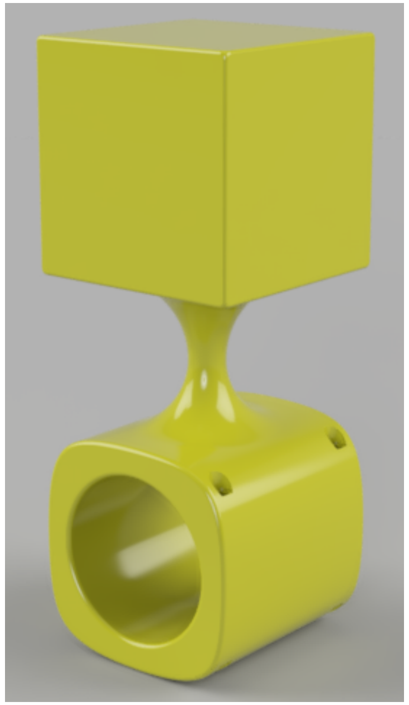
Purpose:

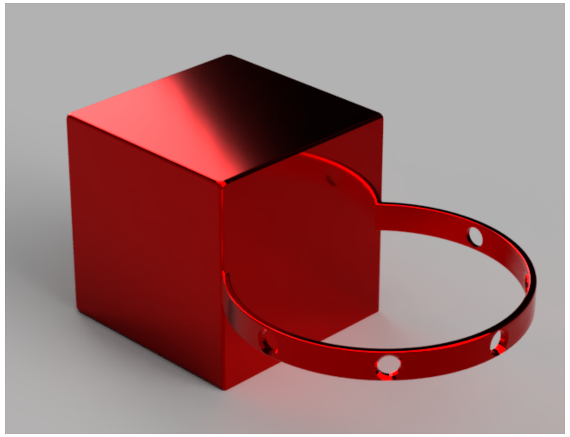
- To verify the design
- To verify charging rates
- To ensure correct solar panel sizing
- To test if the panels could handle low light conditions

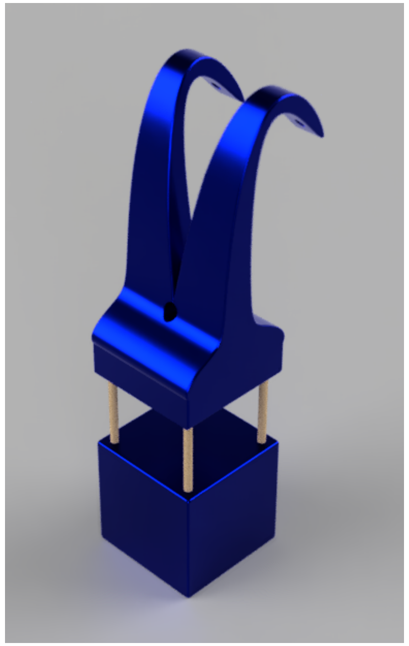


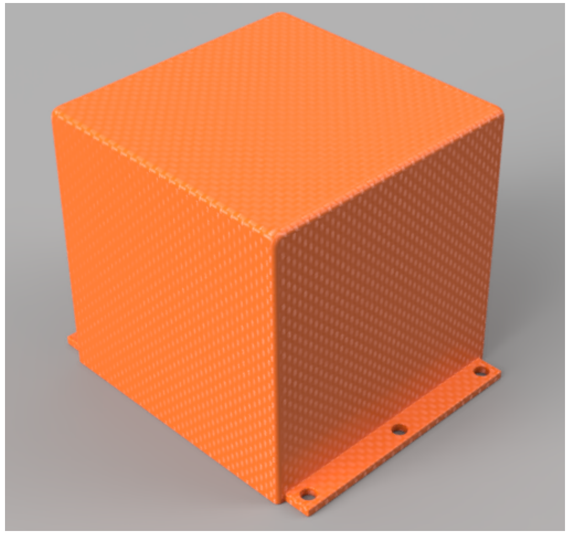
The Enclosure

- Design Constraints:
  - Budget limits the material choice
  - The size of our parts
  - The size of the 3D printer which will be used to print this enclosure for prototyping.







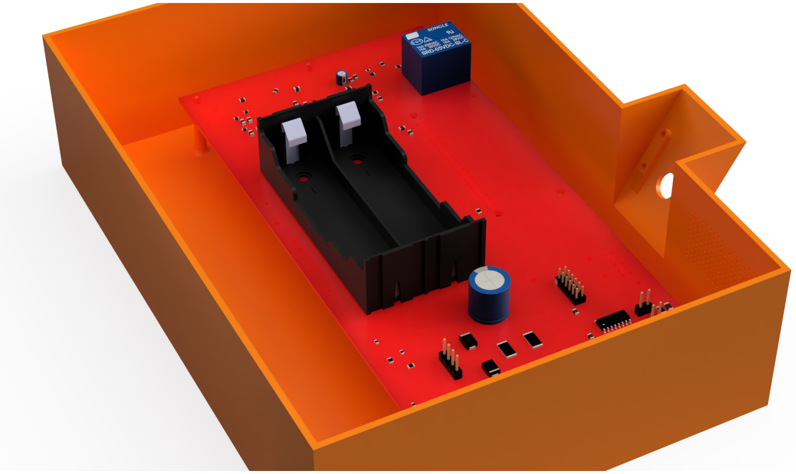


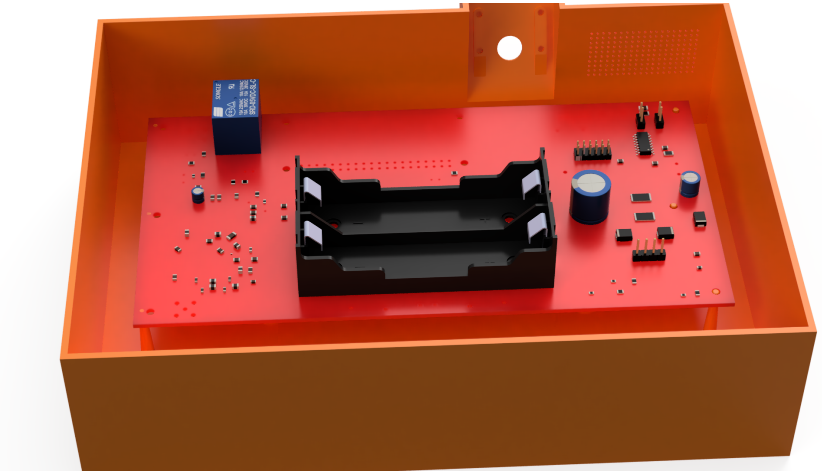
*Rough draft designs.

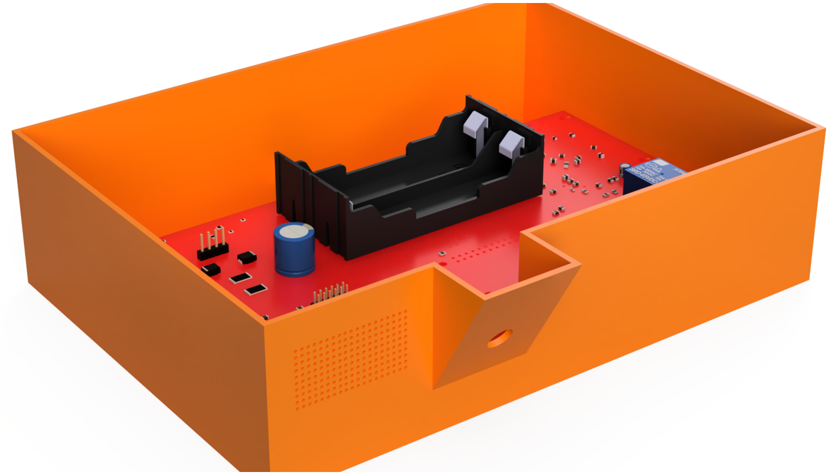
The Enclosures Final Design

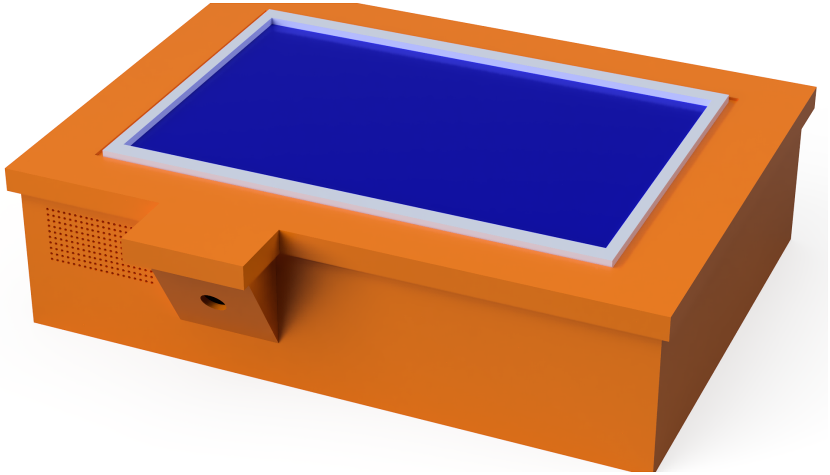
Points of interest.

- Two-part design
- 26 hours of printing
- Pi Cam is tilted at 25 degrees of inclination
- Wire management under board





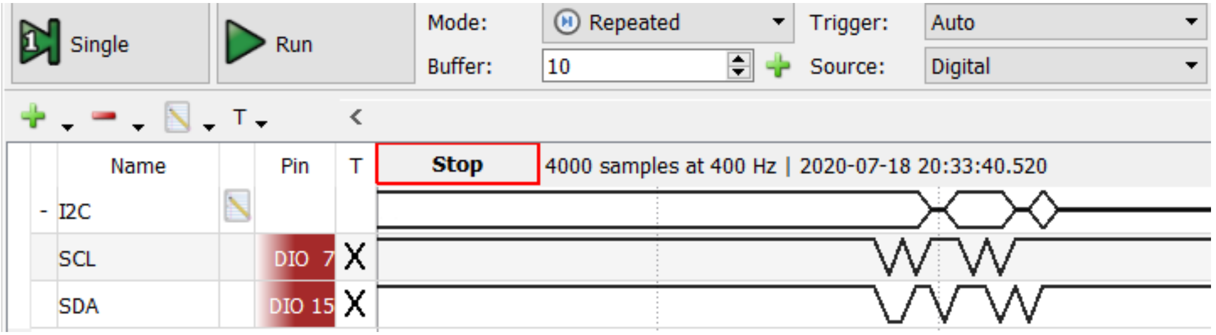




Issues With I2C

Using the Digilent Analog Discovery 2:

- Used the logic analyzer to find out that a ground was ruining the connection to I2C
- Moving each sensor from breadboard to PCB the ground plane was discovered to have an issue on the gas sensor connection point.



Sensor System

Noora Dawood
Electrical Engineering

Fire Detection Sensors

Flame:	• Detect pulsation of flames: flame flicker
Smoke:	• Detect presence of smoke using optical smoke detector IC
Gas:	• Detect resistance in the sensor’s hot plate

Sensor requirements

Voltage Supply:

Between 3.3V to 5V

Signal protocol:

I2C

Component Packages:

SOIC, WSOIC, mSOIC, SOJ, SOP, SSOP, TSOP, TSSOP, SOT, TO, THT, DO, SIP or SIL

Cost:

$10 - $30

Average Current

Average active current of the system: 100mA

Sensors should use lowest possible current

Flame Sensor: Pyreos EPY12241

- Key characteristics:
  - Output sensitivity
  - Signal to noise ratio
  - Noise equivalent power
  - Specific sensitivity
  - Response time
- I2C signal
- Set High pass and low pass filter
- Set capacitance (gain), and transimpedance (ohms) which effects time response (tau)

Flame Sensor: Pyreos EPY12241

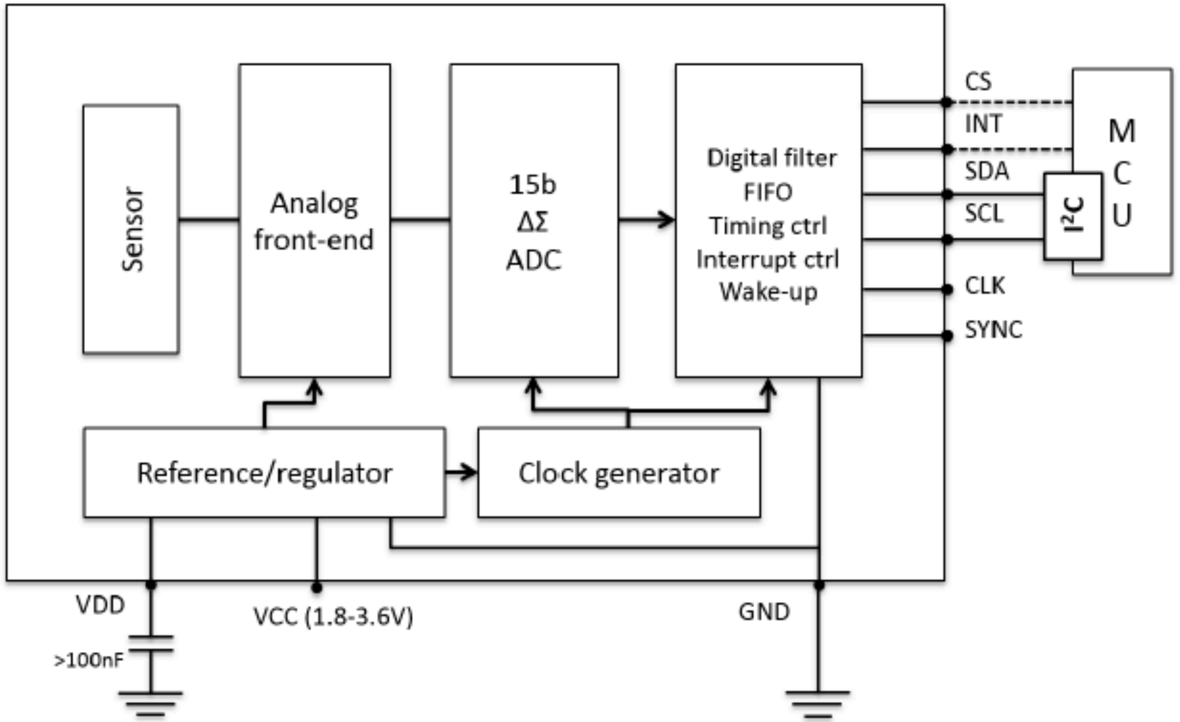


Figure 8 Block Diagram - ezPyro Sensor with Single Element

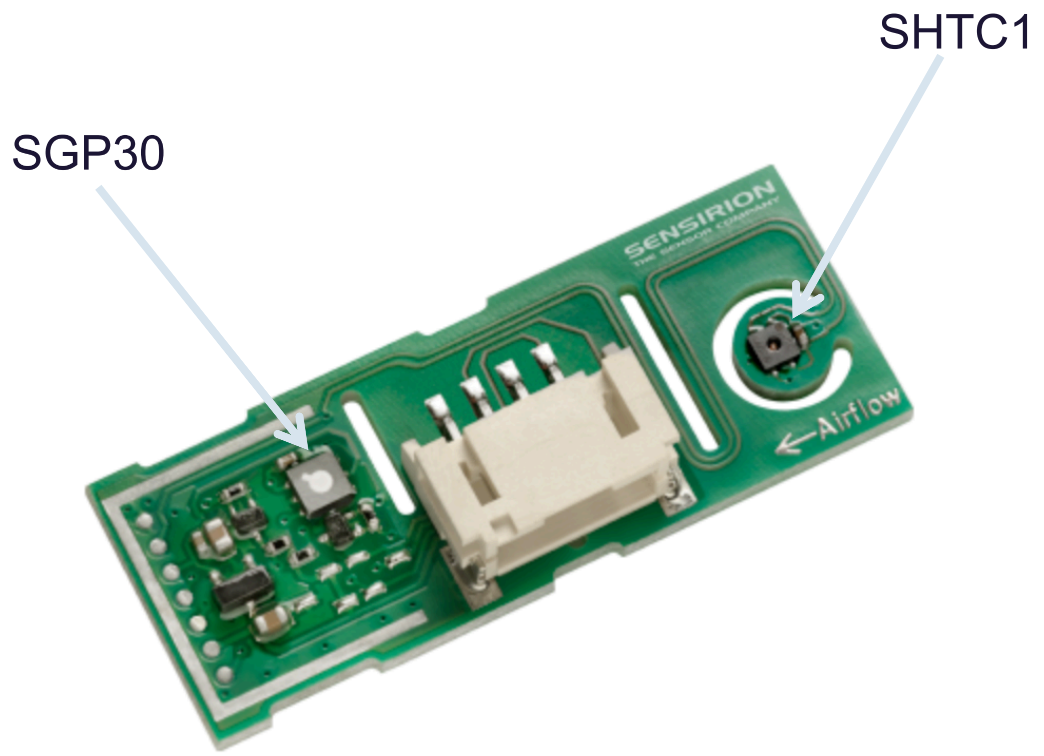
Figure 14 Signal Processing Block Diagram

Flame Sensor:

- Channel and Analog Settings:
  - High pass filter: 1 Hz, Low pass filter: 45 Hz
  - The gain was set to 64x (50 fF)
  - The transimpedance was to (1.2TΩ)
  - Sample rate of 1ms
- Data processing:

Initial Gas Sensor: Sensirion SVM30

- Sensirion SVM30
  - SGP30 (gas)
  - SHTC1 (for temperature and humidity)
- Issues during integration:
  - Gas, Flame, Raspberry pi each had pull-up resistors
  - High capacitance on the I2C bus
  - Flame sensor was not functioning with this gas sensor.
- Switched to Adafruit BME680



Gas Sensor: Adafruit BME680

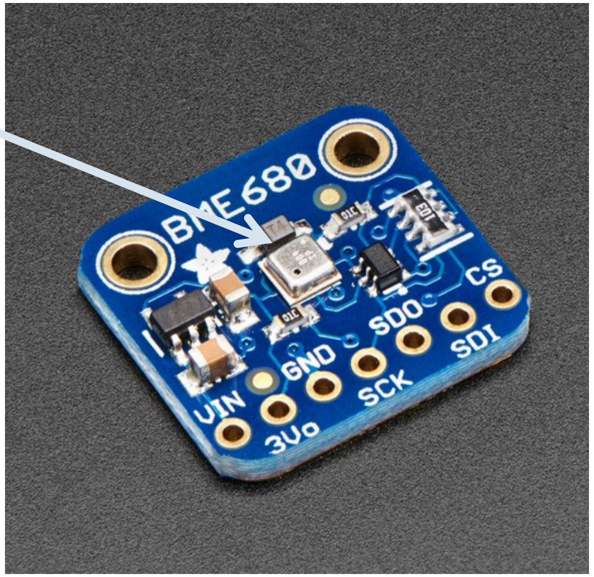
BOSCH BME 680:

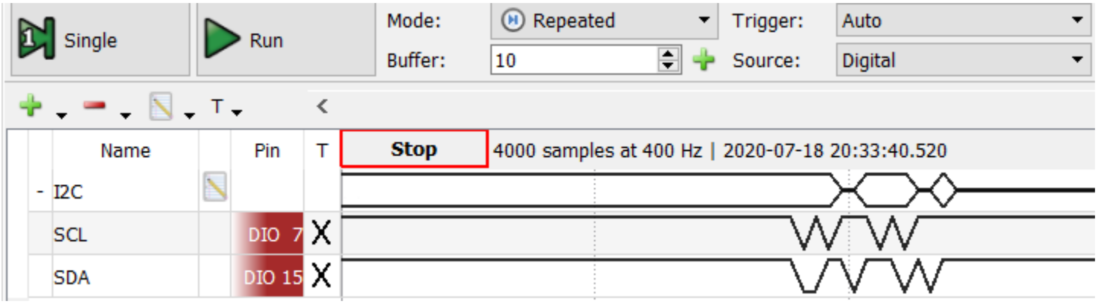
- Gas (Volatile Organic Compounds) in Ω
- Temperature in °C
- Humidity in % RH
- Pressure in hPa
- IIR filter for compensation for temperature and pressure
- I2C protocol

Data collection

- Convert ADC values and account for disturbances to obtain gas resistance, temperature, and humidity

BME 680





Smoke Sensor: PIM-438

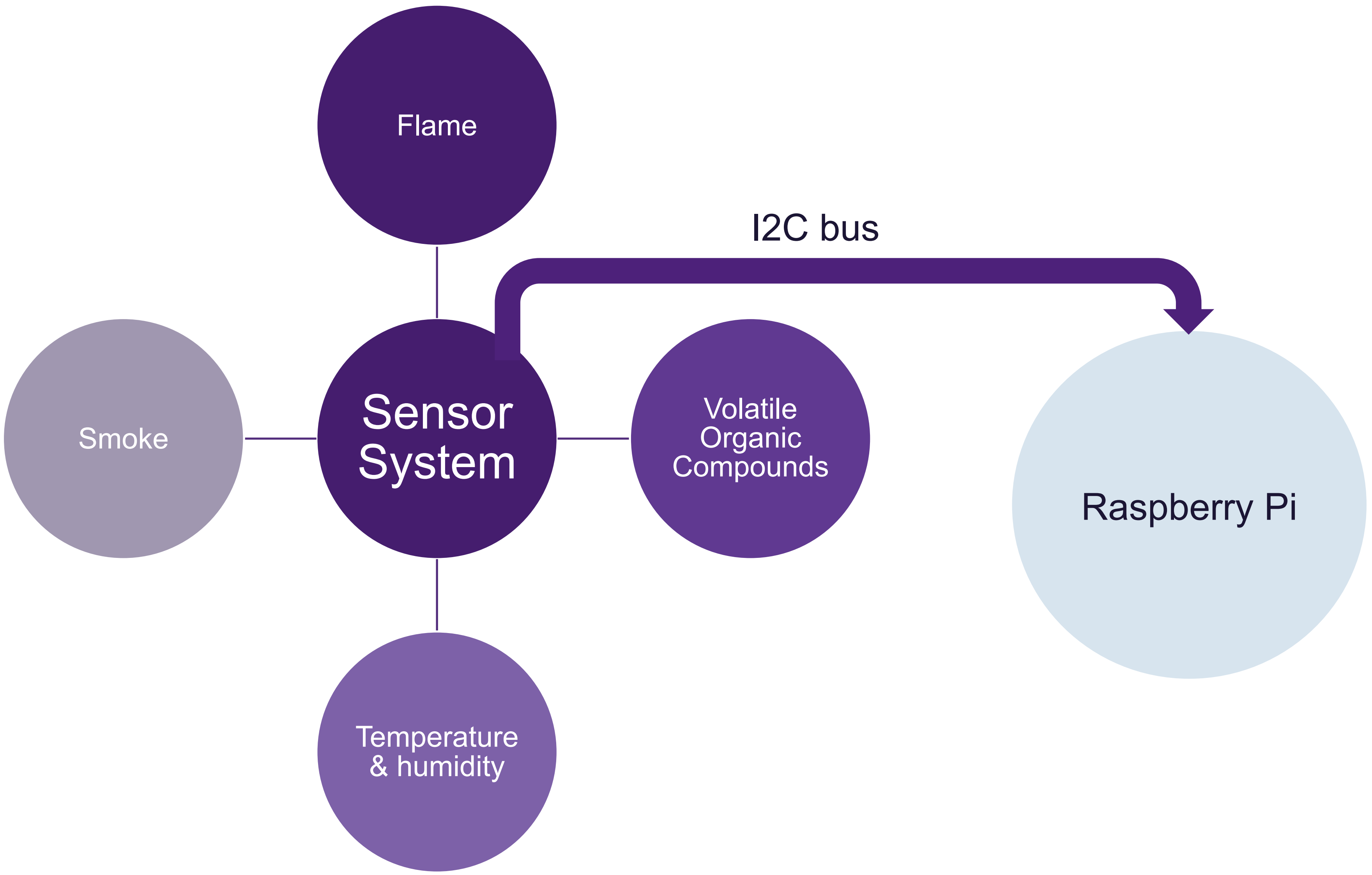
MAX30105 module from Maxim Integrated:

- LEDs (Red, Infra-Red (IR), Green)
- Photo diode
- Analog front end
- Works in high ambient light, complete darkness, or artificial light.
- External Sampling Photoelectric (ESP) smoke detection technology.

Data processing:

Mean of a data in a data window N → Delta: Compared current value to a value X readings ago → If Delta > Threshold Change = True → Count the maximum number of consecutive Trues → If # of consecutive Trues > Y A flame is detected

Sensor system summarized



- ✓ I2C protocol
- ✓ Linux environment
- ✓ Python 3
- ✓ Data processing

Project Budget

Sponsor: Siemens STEM Initiative

- Allocated $500 budget
- Educational EE kit for future STEM events
- Project's connection to SIEMENS industry:
  - Gas Turbine Fire and Gas sensor system
  - Wind Turbine fire detection and extinguishing system
  - Digitalization/Internet of Things

Item	Estimated Cost ($)
Solar Panel System	100
Sensors	
Gas sensors + Temperature + Humidity sensor	22
Flame sensor	41
Smoke sensor	16
Raspberry pi camera	10
Communication system (RF and controllers)	68
Electronics	
General components (resistor, capacitors, inductors, connectors, jumper wires)	30
PCB manufacturing	75
Shipping costs	40
Backup parts	70
Total Cost	≈ $472

SOAR Analysis

Strengths

- Fire detection strategies
- Sponsorship
- Balanced individual strengths
- STEM outreach

Opportunities

- To overcome challenge of limited time and resources
- Maximize existing parts and equipment
- Lowering cost of forest fire detection systems

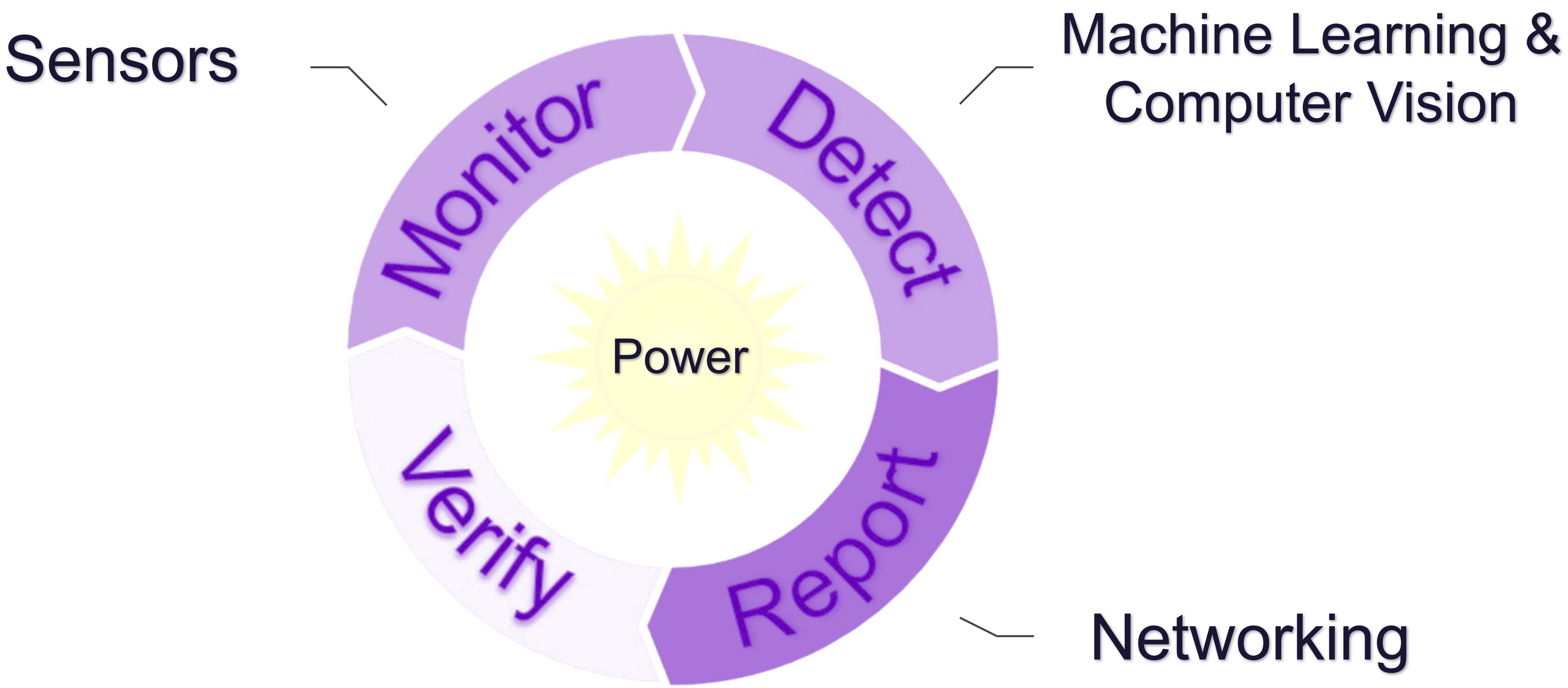
Aspirations

- Apply theoretical knowledge in a practical situation
- Challenge ourselves in each of our subsystems to learn new skills

Results

- Fulfilling the requirements of our subsystems
- Functioning PCB

Project F.I.R.E.



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Thank you

Questions?