Project F.I.R.E: Fire Intelligent Response Equipment

Group 4
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- **Senior Design 2: Critical Design Review**

Meet the Engineers:

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Jonathan Kessluk
Computer Engineering

Focus:

- Wireless Communication
- Software Design
- PCB Design

Arisa Kitagishi
Computer Engineering

Focus:

- Machine Learning
- Computer Vision
- Programming

Nicholas Hainline
Electrical Engineering

Focus:

- Power System Design
- Device Enclosure
- PCB Design

Noora Dawood
Electrical Engineering

Focus:

- Sensor Technology & Data Collection
- PCB Design
- Sponsor Liaison

Goals, Objectives, Specifications, and Requirements

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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 within 100m
- The system shall communicate wirelessly to nearby nodes
- The system shall be able to withstand normal weather conditions
- The system shall charge a battery with solar panel
- The system battery shall last 36 hours without charging

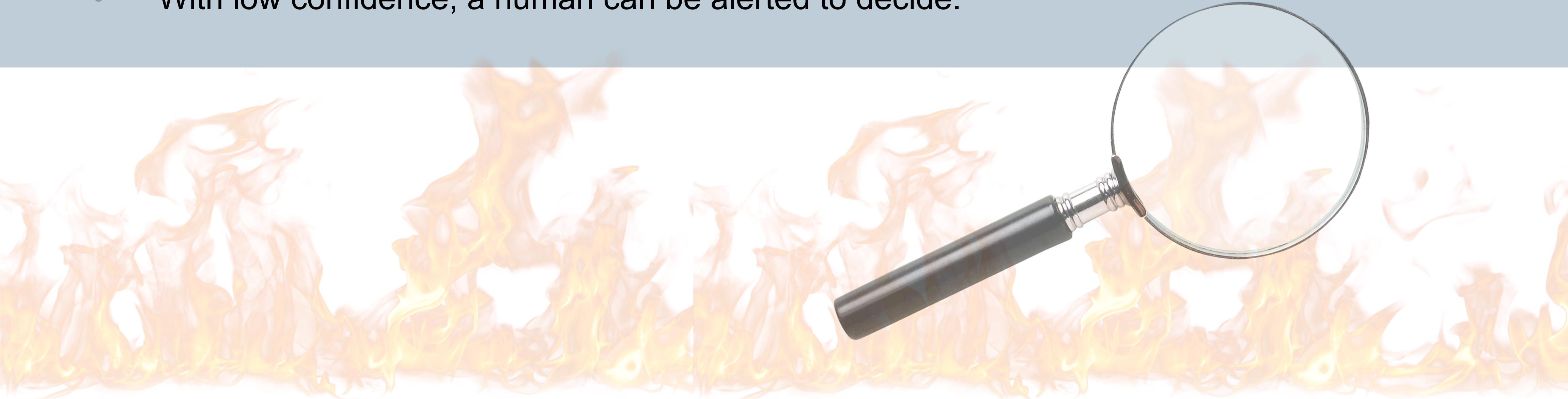
Specifications

- The system reads Temperature, Gas, and IR sensors 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

Detecting a Fire

- Standalone sensors
- Camera + Human Interaction
- Camera + Machine Learning

- Solution: All of them!
  - Machine Learning to decide if a fire is likely.
  - Sensors to add confidence to the decision.
  - With low confidence, a human can be alerted to decide.



The Entire System

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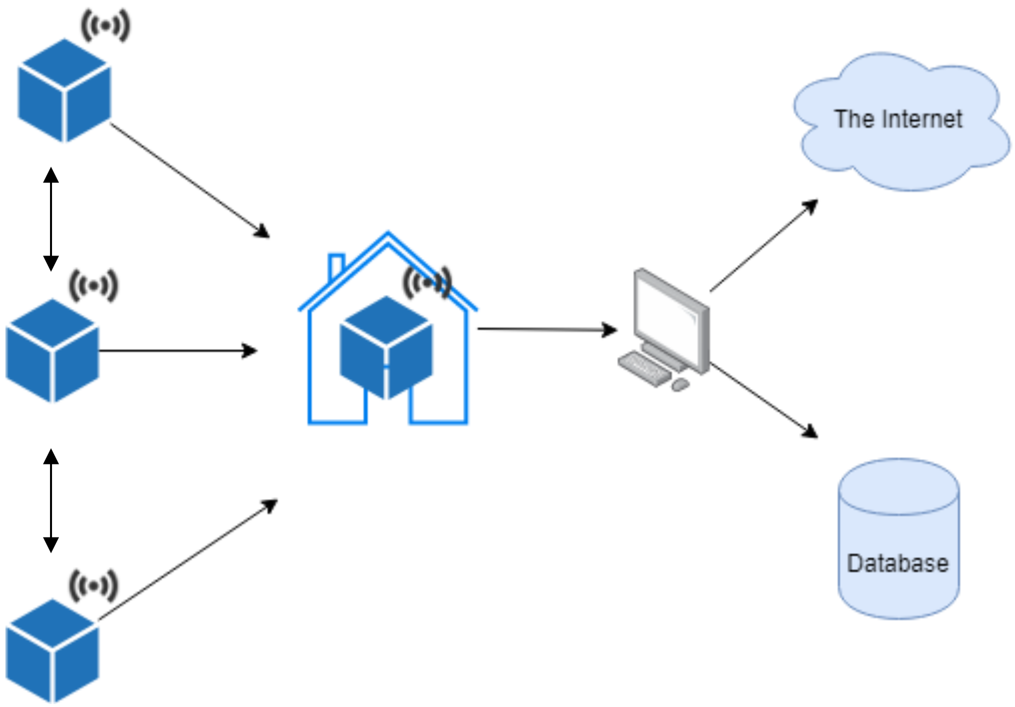
- Multiple Nodes that can sense fire within their local area
- Each node can send data to other nodes
- Endpoint acquires data and determines what to do with that data
- Every node must communicate with the Endpoint



Block Diagram of a Single Node

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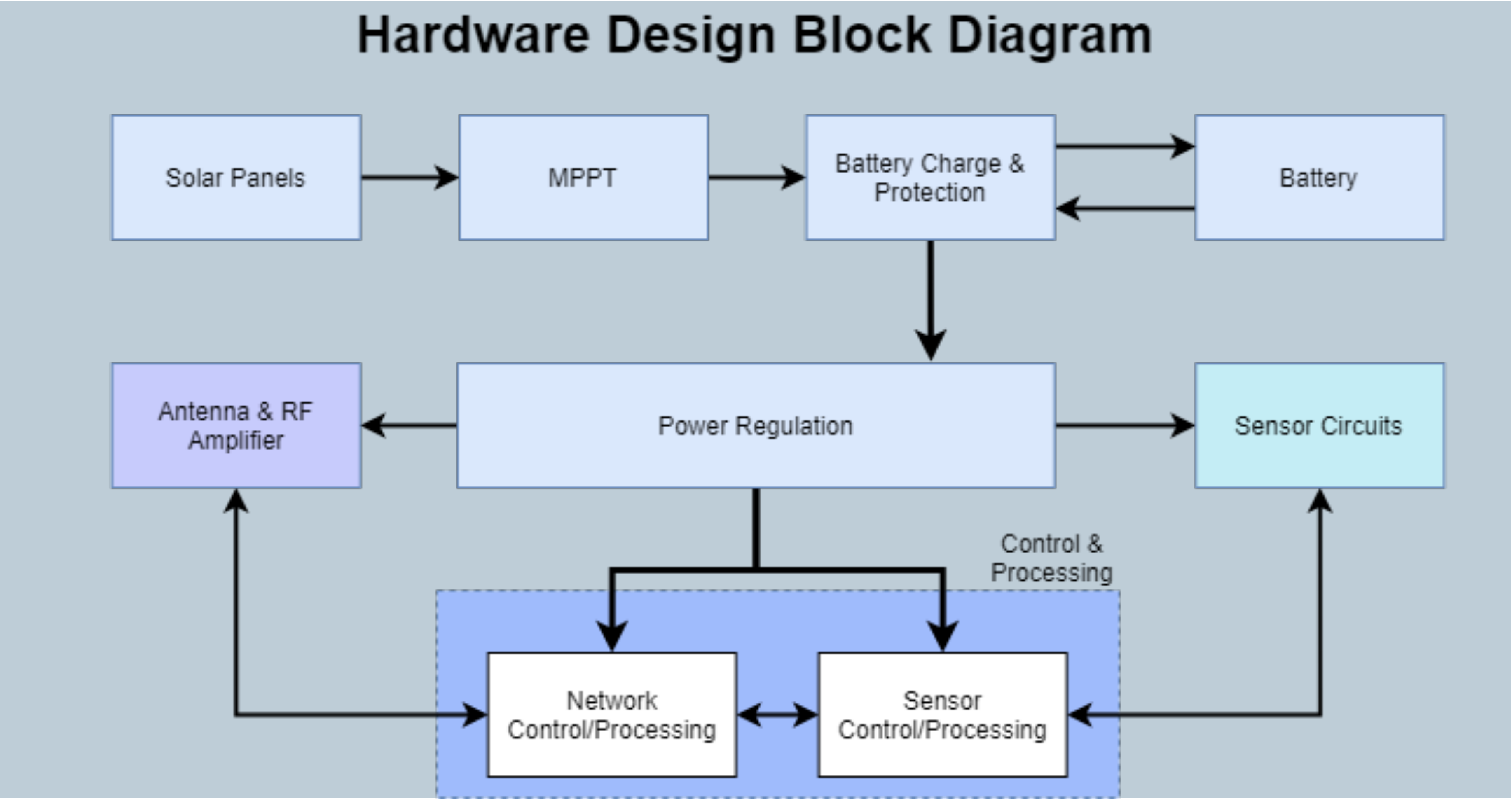

Wireless Communication

Jonathan Kessluk
Computer Engineering

Mesh VS Star Topologies

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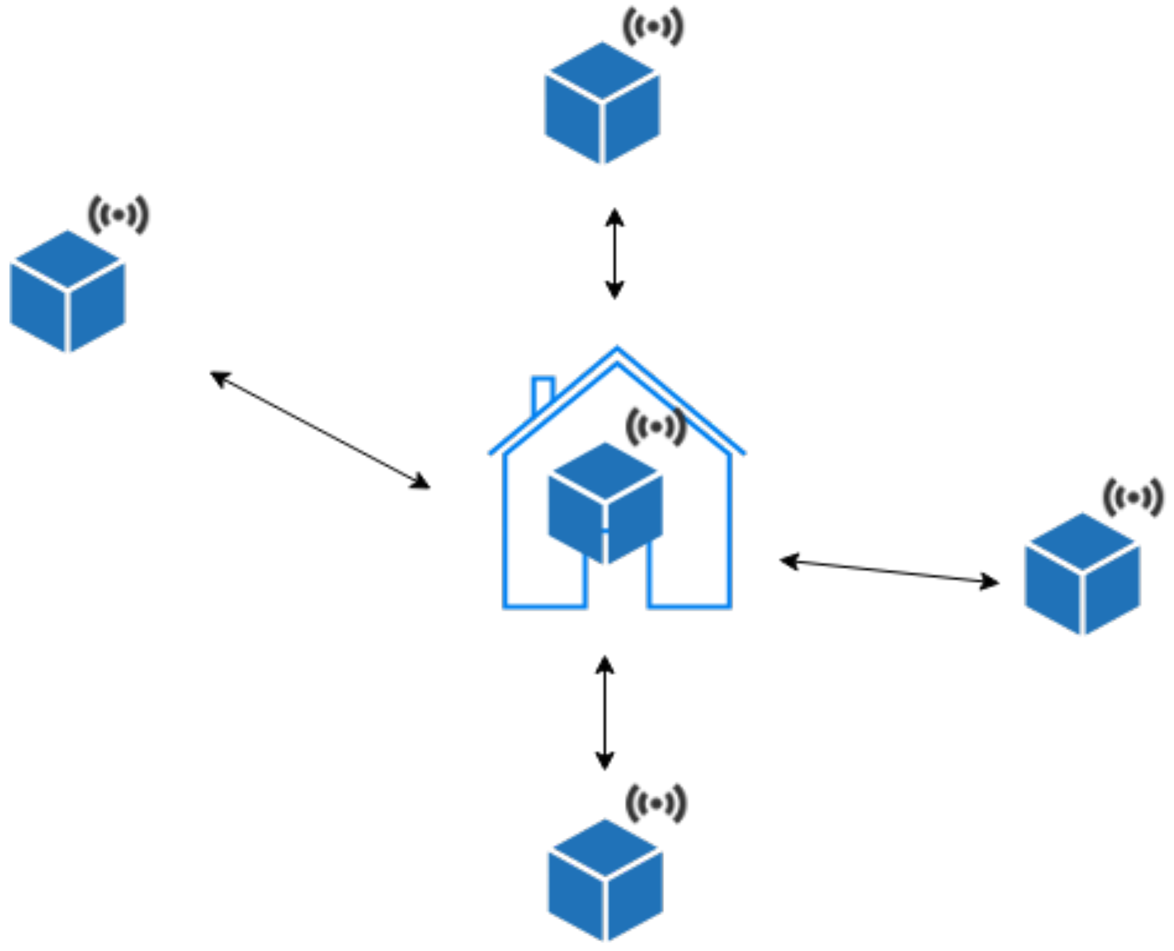
Star Topology

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



Mesh VS Star Topologies

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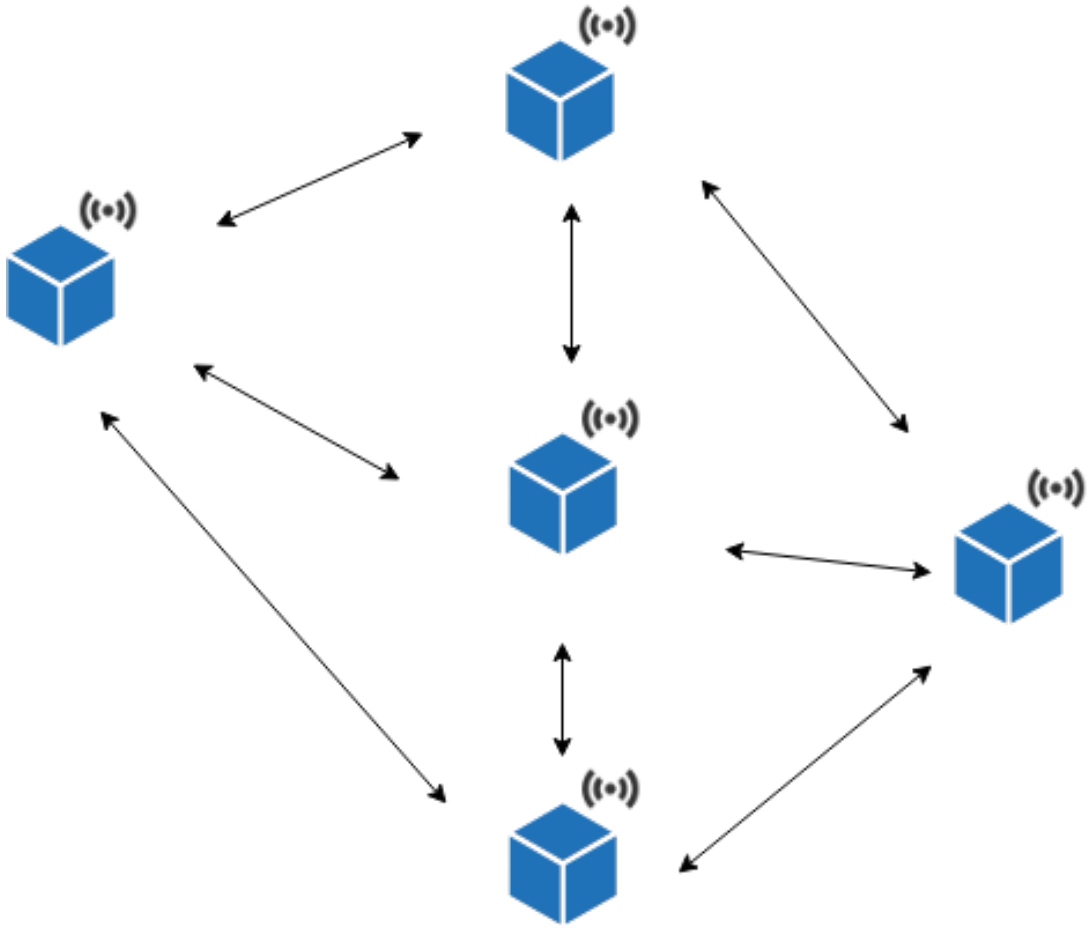
Mesh Topology

- 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

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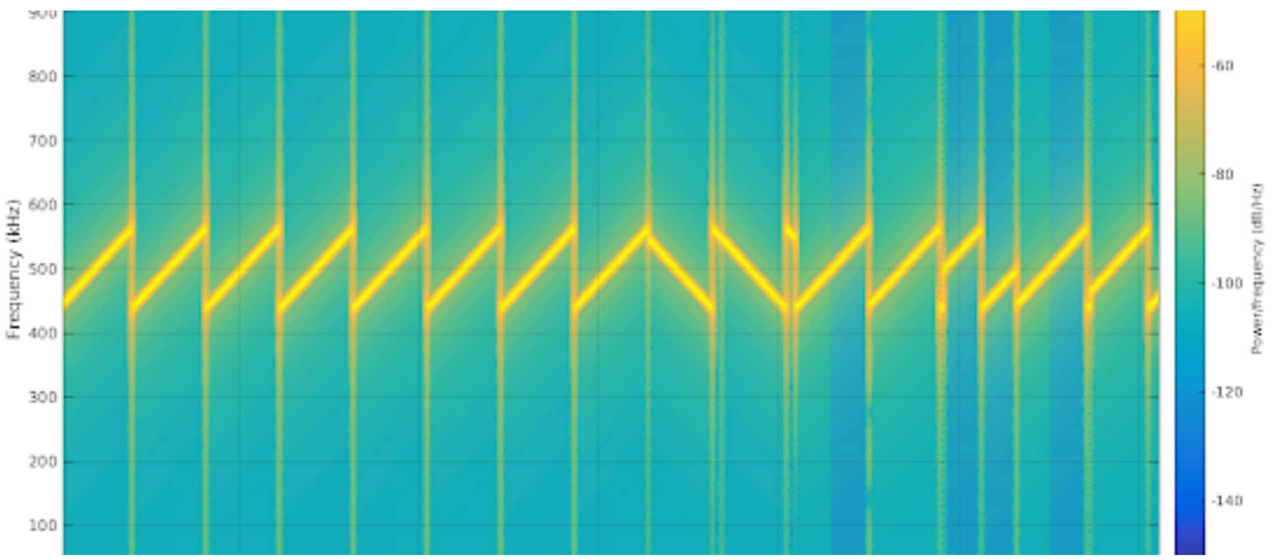
- Uses a derivative of Chirp Spread Spectrum Modulation (CSS)
- Can use the 400MHz and 900MHz bands
- Link budget of 155-170dB
- In ideal conditions, can reach >10km



Controllers

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Computer Engineering

Processing Subsystem

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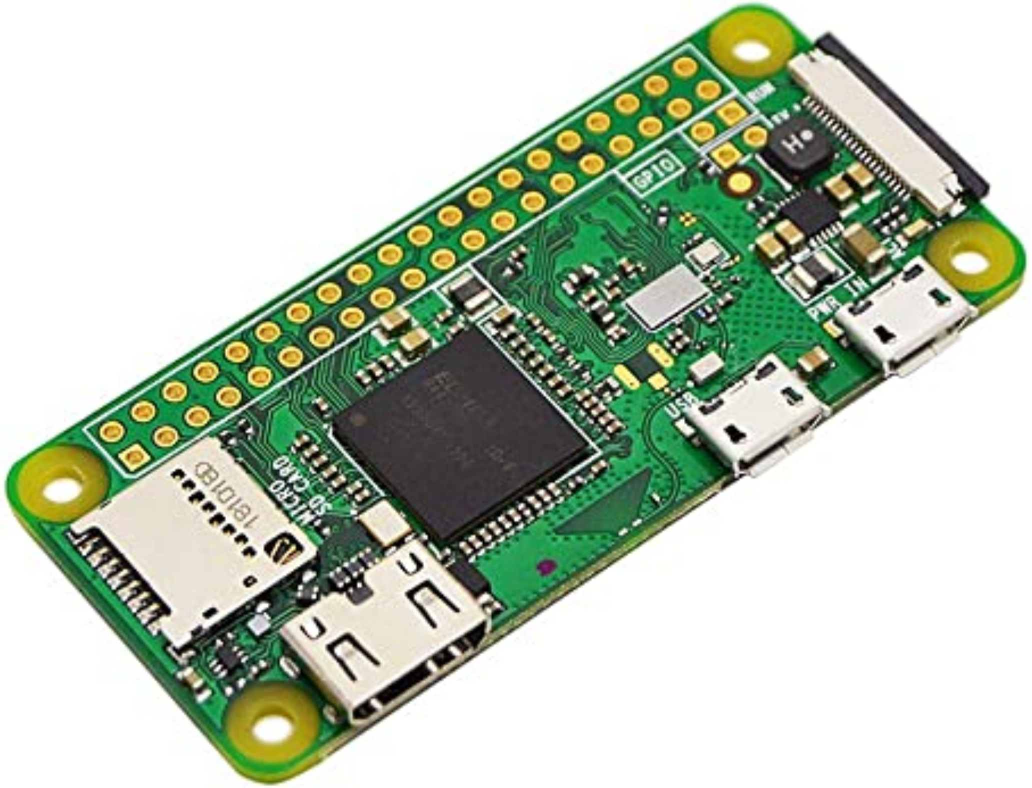
Raspberry Pi

- Easy to program with Linux OS
  - Python, C, C++, Bash, many packages
- Provides many communication interfaces
  - I2C, SPI, UART, 26 GPIO, USB
- Many resources available
- Higher than desired power usage



Network Subsystem

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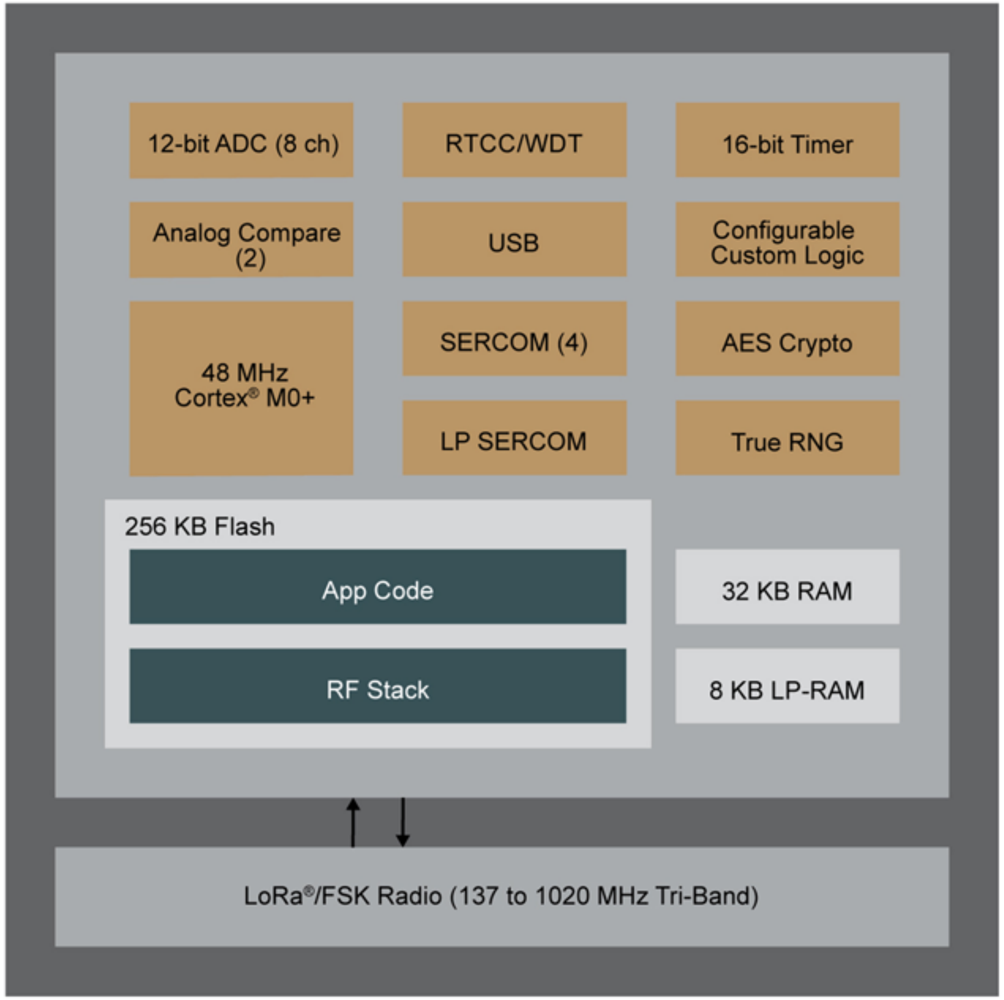
SAMR34/5

- C or C++ embedded system
- Internal 32-bit Arm Cortex M0+
- Up to 256KB Flash and 40KB RAM
- Sleep current is 790nA
- Built in LoRa UHF transceiver communication interface



Software Design

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Software Design

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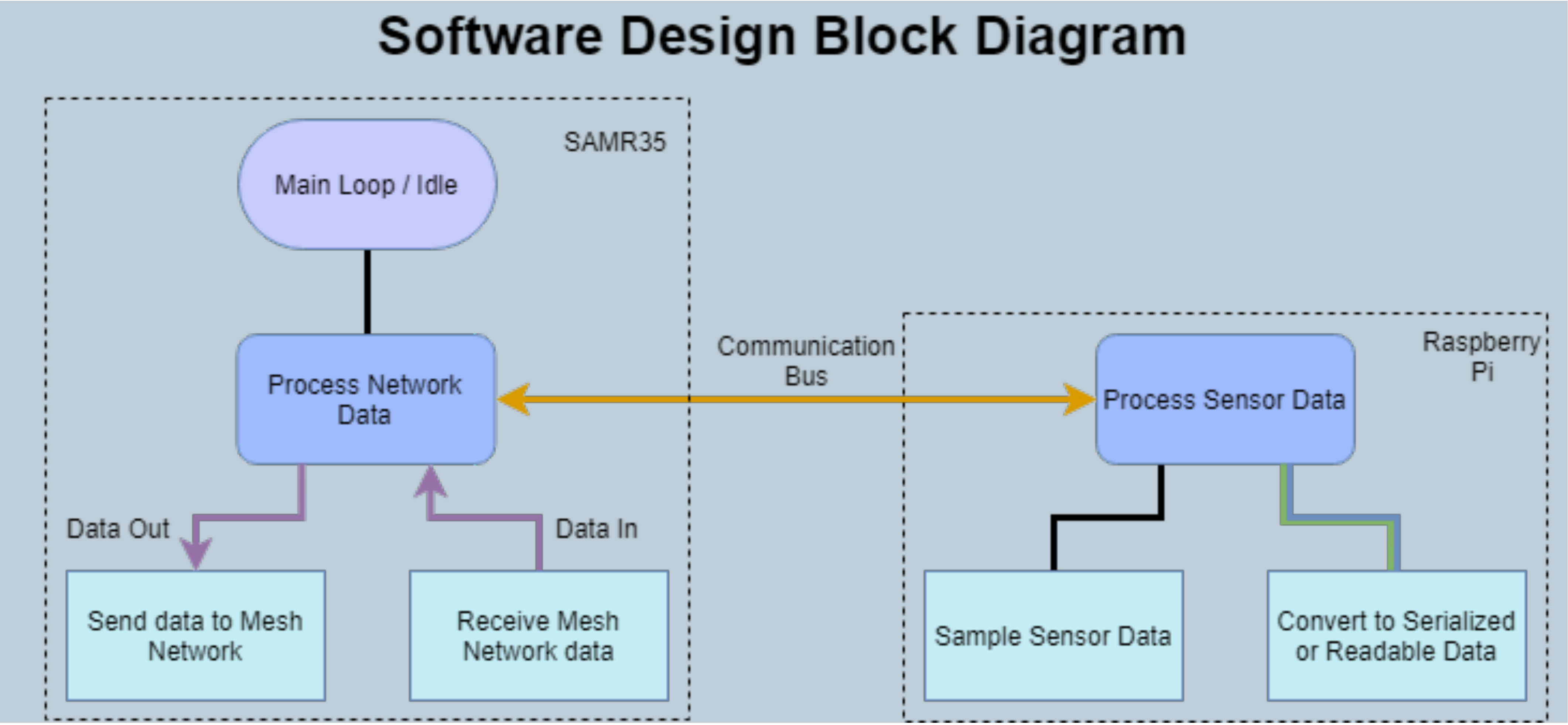
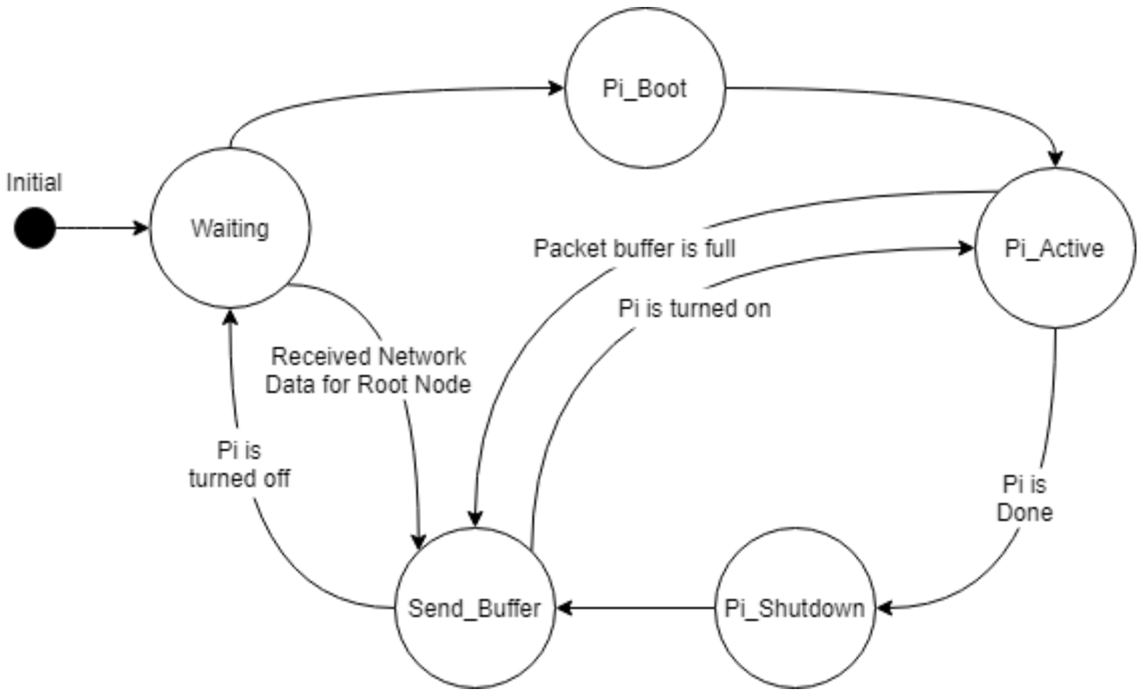


Simplified State Diagram

Order of operations:

1. Wait for timer to finish
2. Boot Raspberry Pi
3. Get data from Raspberry Pi & Transmit the data
4. Shutdown the Raspberry Pi
5. Wait

If there is a received packet when waiting/idle, forward that packet to the network



Computer Vision

Arisa Kitagishi
Computer Engineering

Design/ Objective

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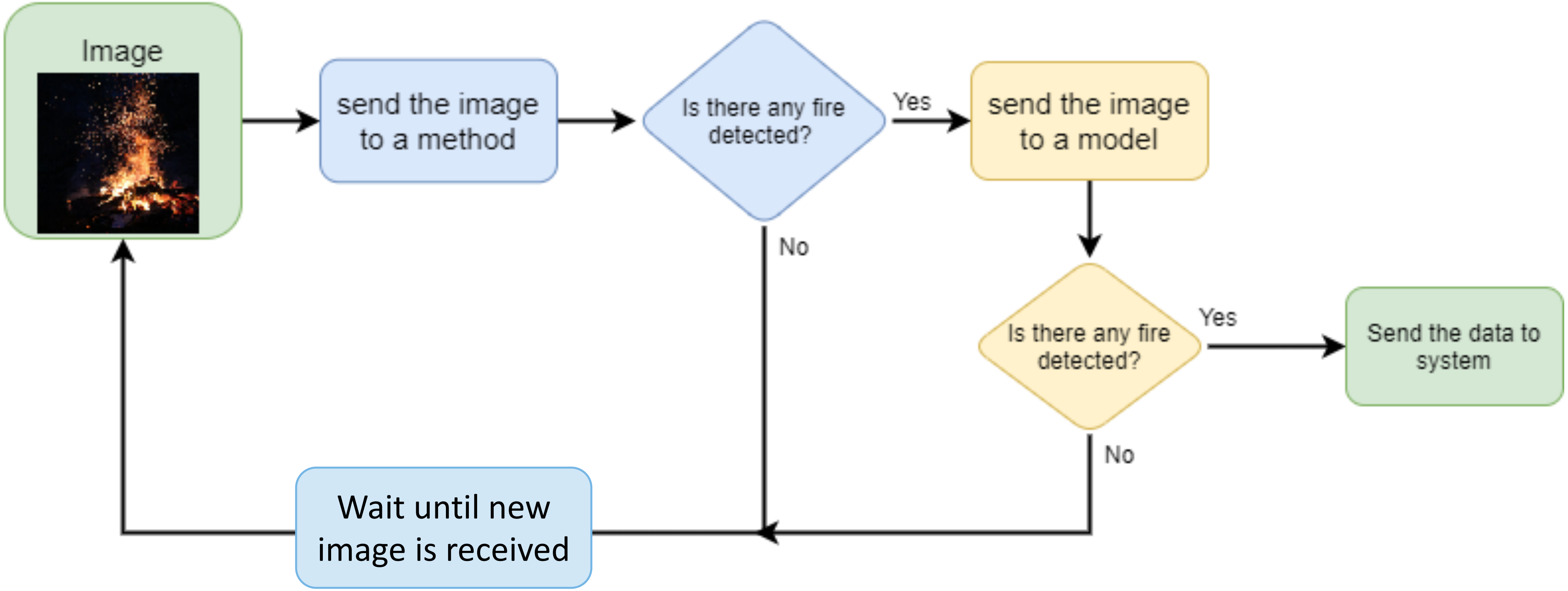

Significant Component Decisions

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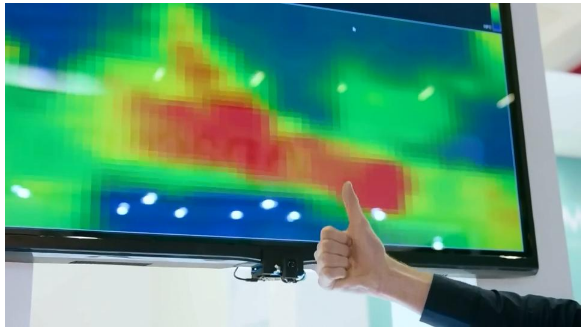
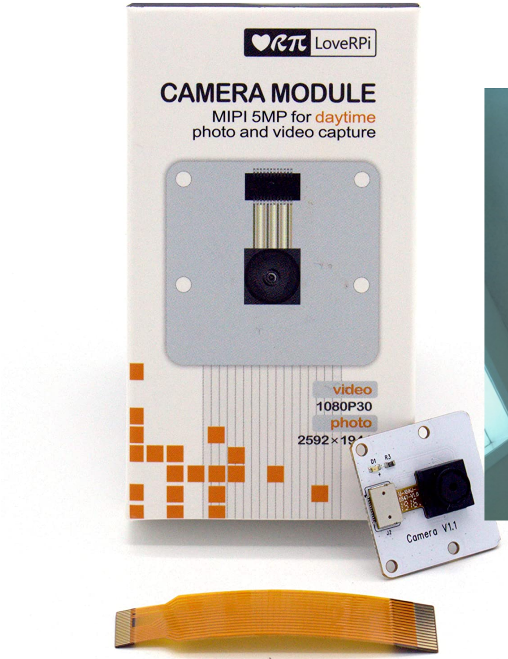
Which camera to use?

- **Thermal Camera:** MLX90640 thermal camera by Melexis Technologies
  - Price: ~$60

- **PiCamera:** LoveRPi 5MP Camera Module
  - Price: ~$10





Successes: Color Classification

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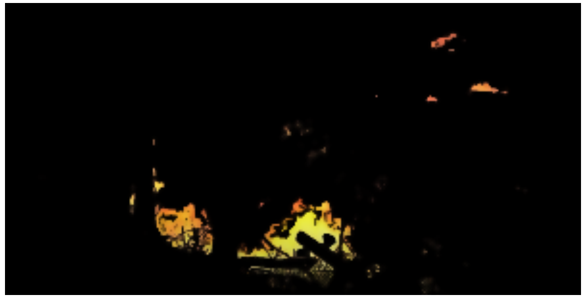
Frame 1

Mask

Contour

Frame 2



Mask

Contour

Successes: Optical Flow

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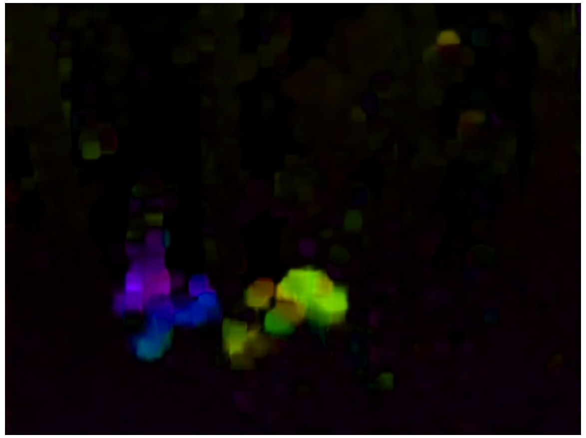
Frame 1

Frame 2



Optical Flow

Difficulties: Color Classification

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(1)

Higher value of epsilon

(2)

Lower value of epsilon

(3)

Different Filter

(4)

Lower Threshold of Area size

Difficulties: Color Classification

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Difficulties: Machine Learning

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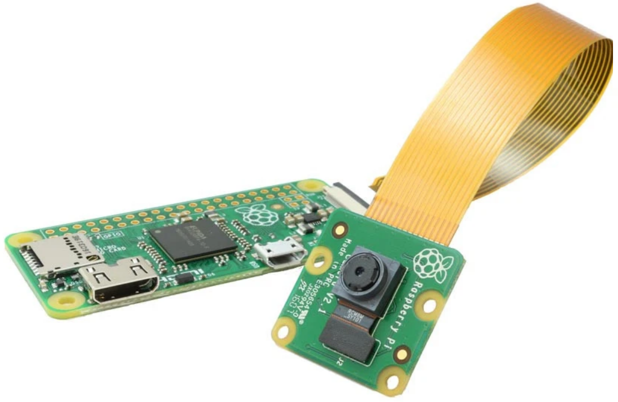
- Limited RAM, slower processor
- Unfamiliarity
- Limited Dataset
- Difficult acquiring the picture from desirable environment
- Time Consuming:
  - training, adjusting hyperparameters, obtaining appropriate pre-trained model

TensorFlow

python



Power System & Enclosure

Nicholas Hainline
Electrical Engineering

Power System Design

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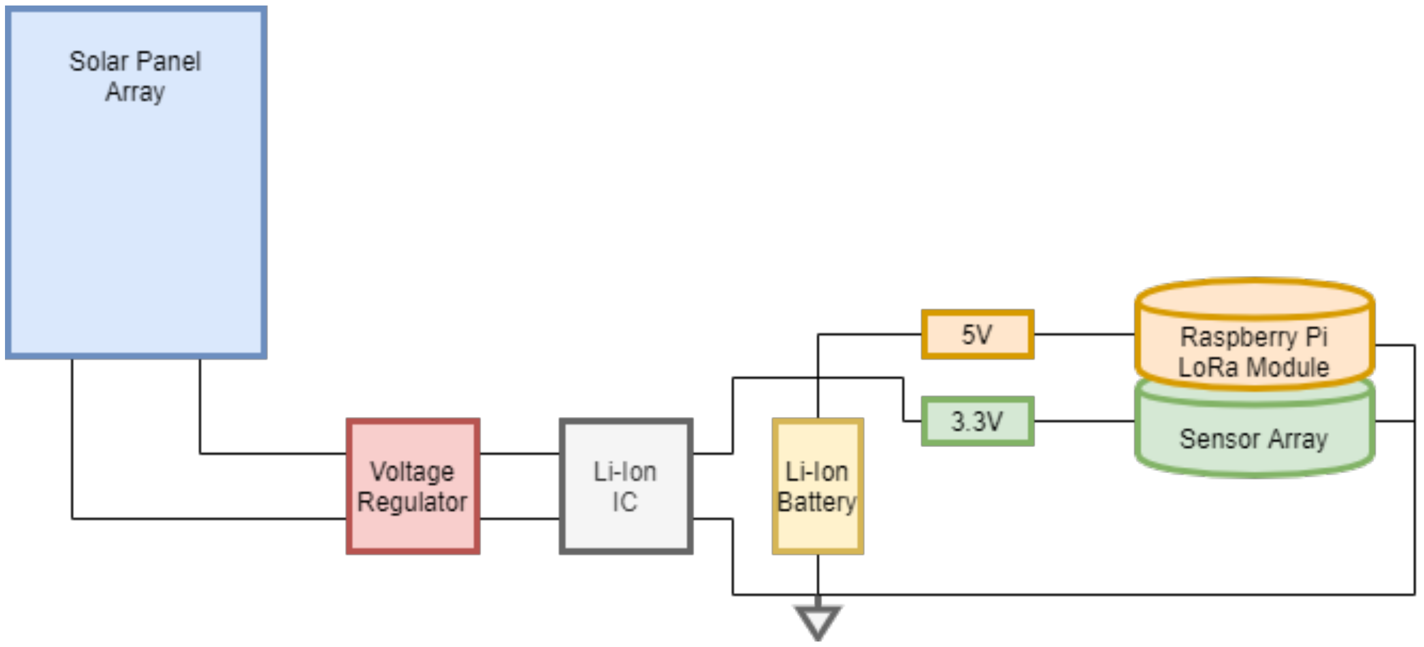
Requirements:

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

If possible, under perfect solar conditions have the system run completely off solar and the battery would be a backup.



Choosing The Right Battery

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- 18650 Lithium Ion Cells were chosen for the power storage.
- Will include battery protection IC on them and will be charged with a li-ion IC.
- Battery protection is a major point as Li-ion cells are volatile if mishandled
- Provide the best discharge curve and size to storage ratio.

Integration of Solar Array

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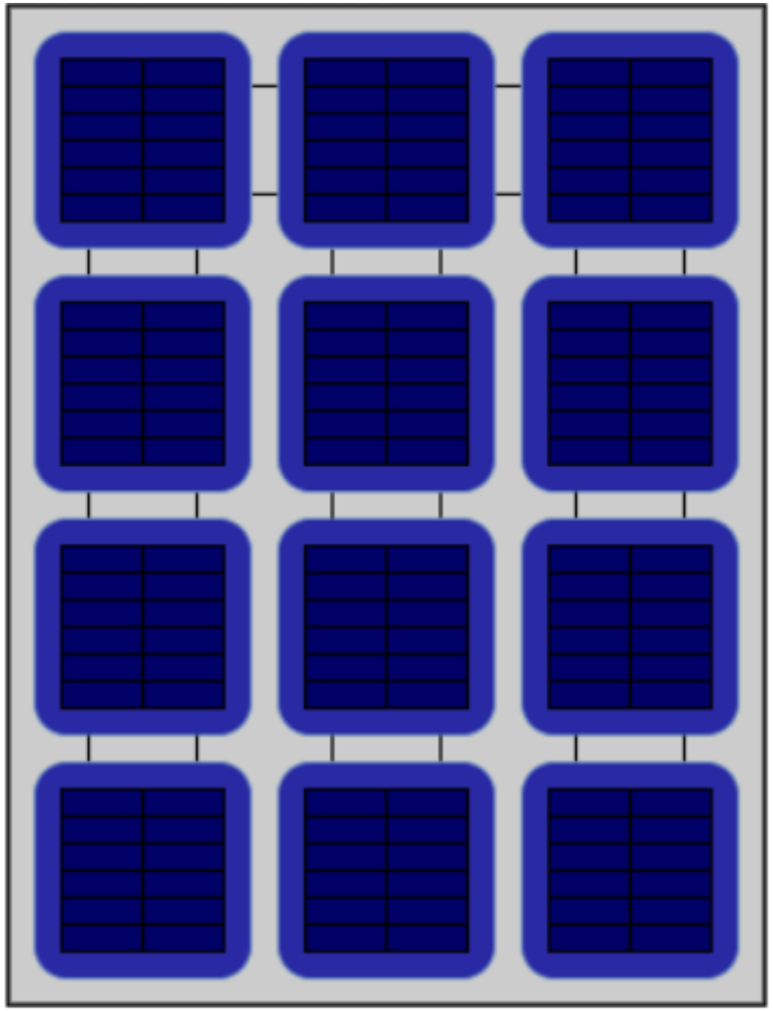
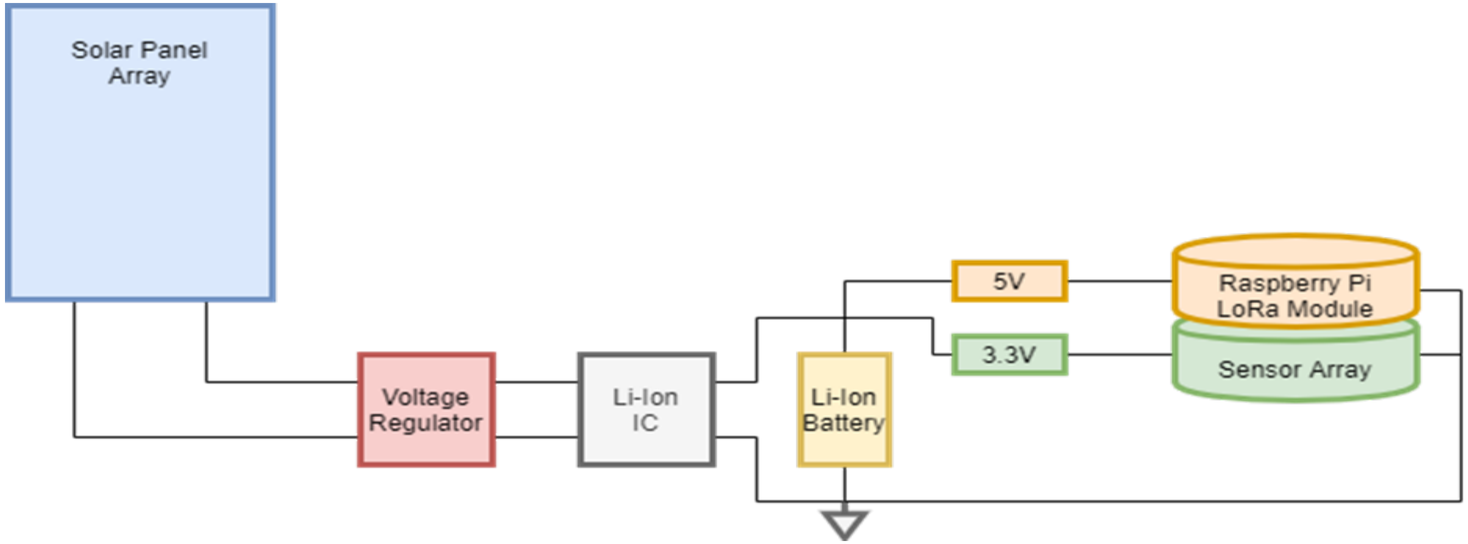
The goal is to have it keep the batteries charged during the day.

- Nighttime will use the batteries
- Daytime will use the solar panel as much as possible.
- This set up minimizes the load on the batteries extending the life cycle of them.



Power System Implementation

1. **Voltage Regulator:** output a constant 5 volts.
2. **Li-ion IC:** takes this and charges the battery or bypasses it to run the system.
3. **Two Buck-Boost converters:** output 5 volts and 3.3-volts to run the Raspberry Pi and the sensor array.



Fire Resistant Enclosure

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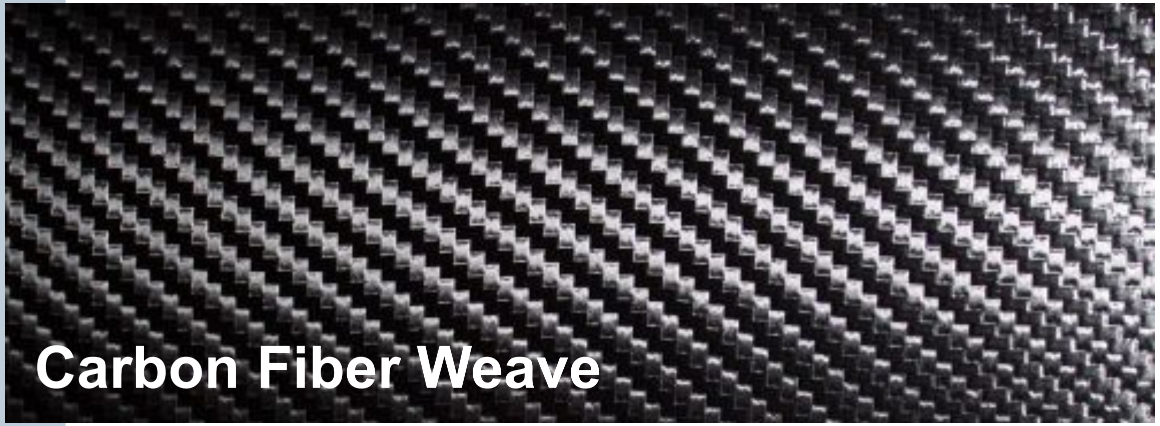
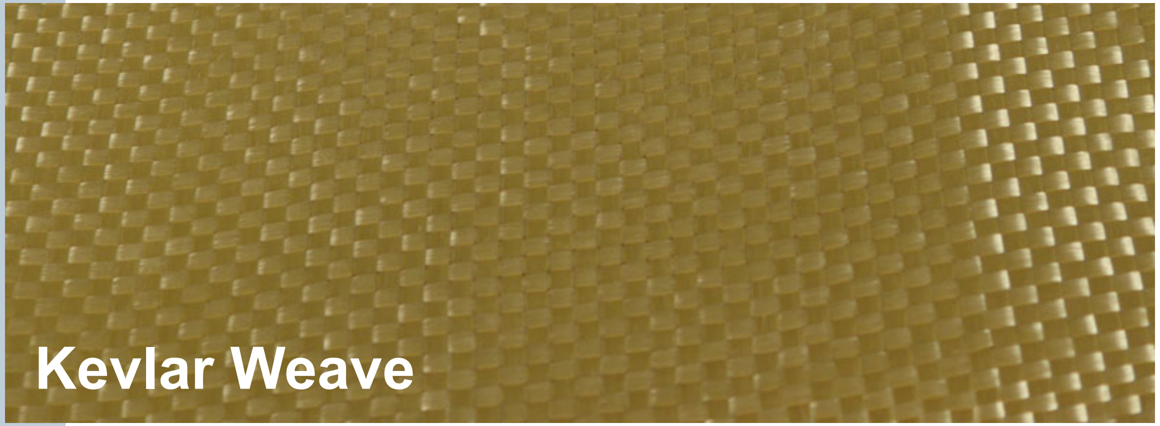
- For the enclosure for the system it will need to be able to deal with intense heat and two easy to handle materials exist to deal with fires.
- Kevlar and carbon fiber are both fire retardant and make very strong composite materials.
- For the prototype phase of this project the encloser will be 3D printed.





Sensors

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Electrical Engineering

Fire Detection Sensors

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Flame:

- Detect pulsation of flames: flicker
- Detect image of fire using a camera

Smoke:

- Detect presence of smoke in a smoke chamber

Gas:

- Detect gas particles in the atmosphere

Fire Detection Sensors

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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

Operating temperature

Cost:

$10 - $30

Average Current

Average active current of the system: 100mA

Sensors should use lowest possible current

Potential Flame Sensors:

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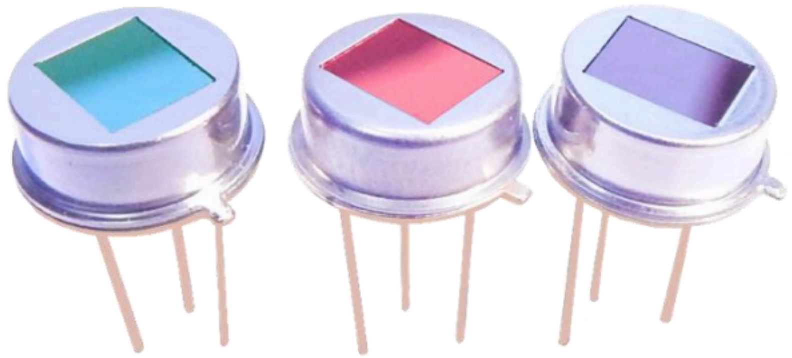
Pyreos PY0573

- 2.7 – 8V input
- TO-39
- 1 (only) for $56.92
- Analog signal
- Flame flicker 8-10 Hz
- 1 for $56.92



Pyreos EPY12241

- 1.75 - 3.6 V input
- SMD/BO board option with header pins
- $34.13/$41.54
- I2C signal
- Flame flicker 3-30 Hz
- 1 for $34.13/$41.54

Gas Sensor

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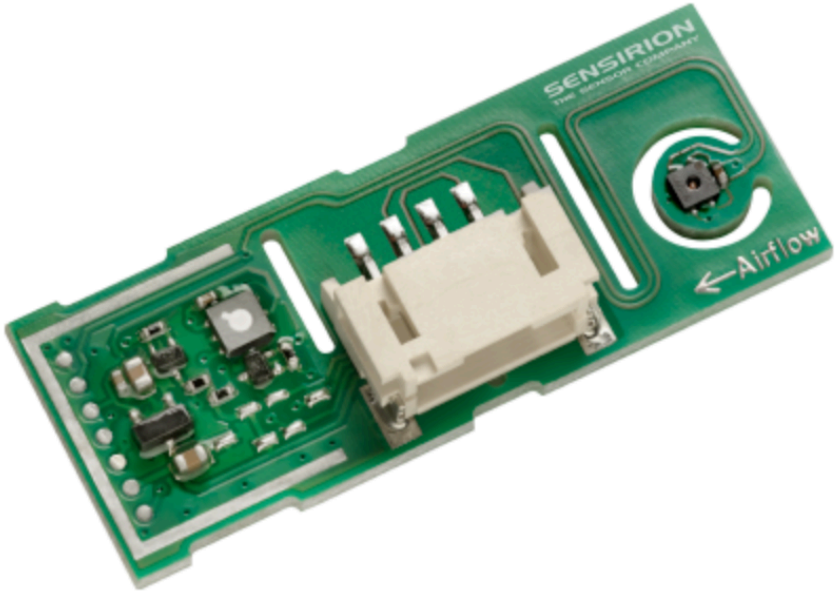
- Sensirion SVM30
  - Output:
    - Total VOC (60,000 ppb)
    - H2-based CO2eq (60,000 ppm)
    - Relative humidity
    - Temperature
  - Input: 4.5 - 5.5 V
  - I2C signal
  - SMD, mounted with screw and connector
  - 1 for $24.26



Smoke Sensor

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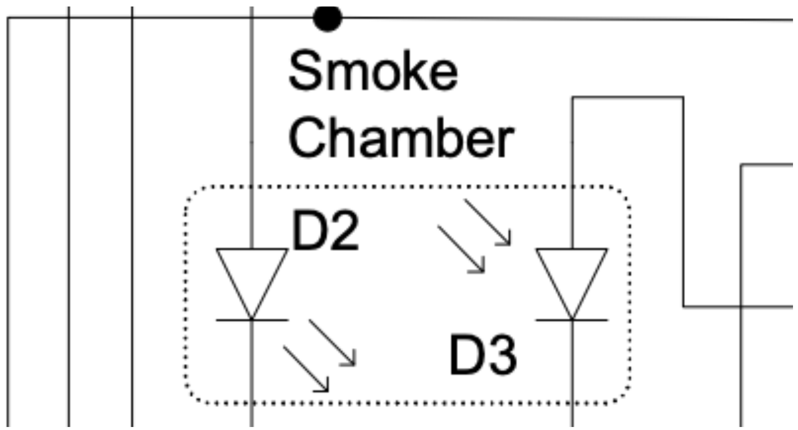
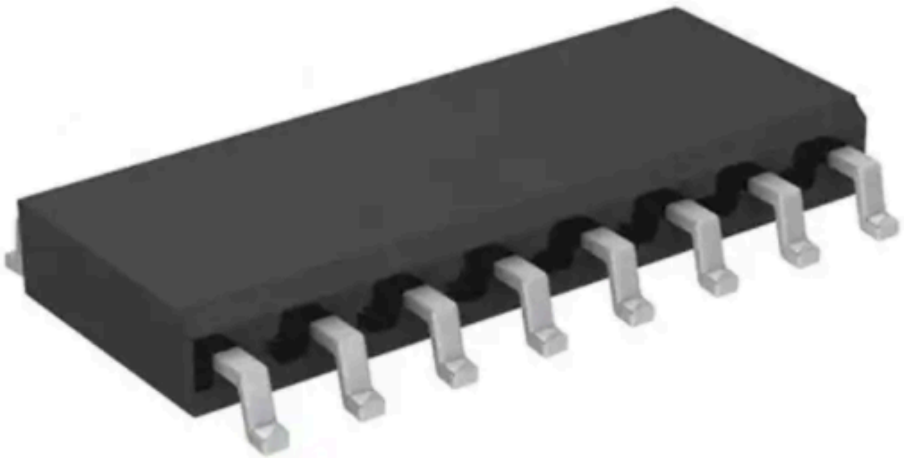
- Microchip Technology RE46C190S16TF
  - CMOS Low Voltage Photoelectric Smoke Detector
  - SOIC package –> SOIC to DIP adapter
  - Smoke chamber (comparator)
  - Voltage output
  - 2 – 5V input
  - 1 for $1.30





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Administrative

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Electrical Engineering

Project Budget

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- **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	50
Infrared sensors (flame detection)	50
Particle sensors (smoke detection)	20
Thermal Camera / Sensor Array	200
Temperature	1
Humidity	1
Electronics*^	
Controller	20
General components (resistor, capacitors, inductors, connectors) ^	30
Specialized components (voltage regulation, MPPT, radio frequency) ^	30
PCB Manufacturing*^	60
Prototype (machine shop labor if applicable)	80
Development kit (for software)^	30
Miscellaneous (solder and jumper wires)	40
Total Cost**	≈ $500.00***

SOAR Analysis

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

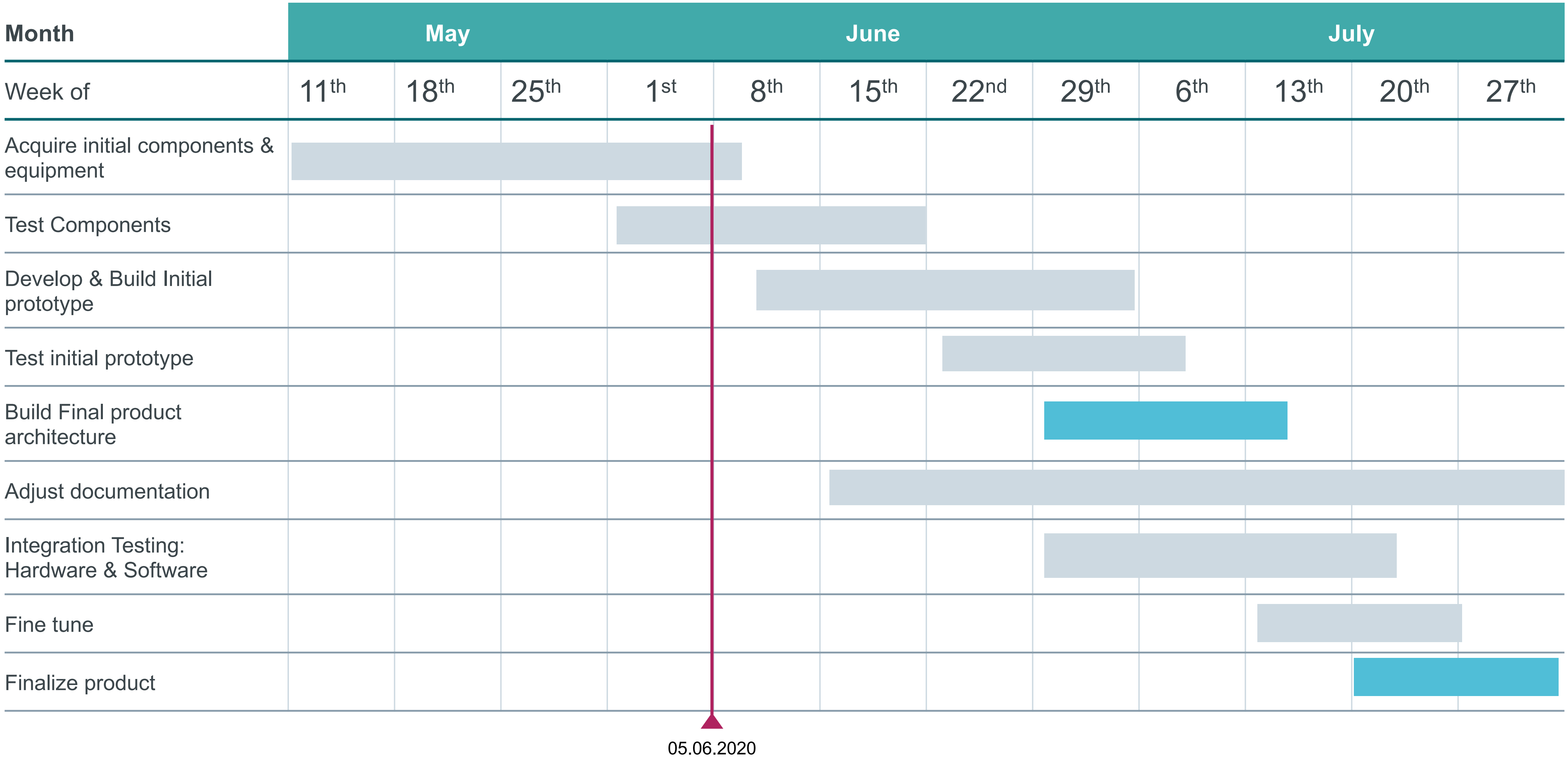
Opportunities
- To overcome challenge of limited time and resources
- Making use of existing parts and equipment
- Lowering cost of forest fire detection systems

SOAR

Aspirations
- Mesh communication
- Explore sensor components
- Develop and tune machine learning algorithm
- Mechanical design and 3D printing

Results
- Following project timeline
- Regular communication and progress updates
- Assemble subsystems to create final system

Project timeline



Success Checklist

1	Finish network and software tests and interpret results	✓
2	Perform long term battery testing to prove efficacy	✓
3	Ensure proper functionality of smoke, flame, and gas sensors	✓
4	Tune machine learning algorithm to detect a fire	✓
5	Test various mechanical designs to determine suitable design enclosure	✓
6	Ensure system behaves as intended	✓
7	Continue maintaining communication between our sections	✓
8	Keep professor and sponsor informed on major updates	✓

Thank you

Questions?

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