University of Idaho
College of Engineering

INFRASONIC WILDFIRE DETECTOR

- Technical Presentation 2021

PROJECT SPONSORED BY JOE STANLEY AND STANLEY SOLUTIONS

Special Thanks to: Dr. Herb Hess and Dr. Feng Li

TEAM FIREWATCH

- Meridian Haas – Mechanical Engineering
- Cory Holt – Electrical Engineering
- Drew Malinowski – Electrical Engineering
- Carlos Santos – Computer Engineering

OBJECTIVE

- Current fire detection is very primitive and involves seeing or smelling smoke. It is also difficult to locate the source of the fire.

- We want to modernize this process by creating a set of devices that use infrasonic detection and signal processing to detect wildfires.

- Our aim is to set up a mesh network of smart nodes and dumb nodes that can detect infrasound waves (0 – 20 Hz) and communicate this information wirelessly.

- This technology has the potential to drastically improve our ability to mitigate wildfires by allowing us to detect the fire and know its location.

- A robust network of affordable sensor devices has the potential to save lives and property by quickly identifying wildfires.

BACKGROUND

Figure 16

Surface fire.

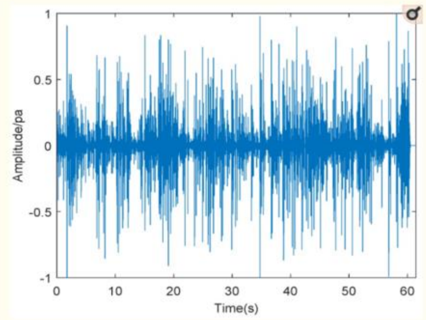


Figure 17

Time-domain sound signal.

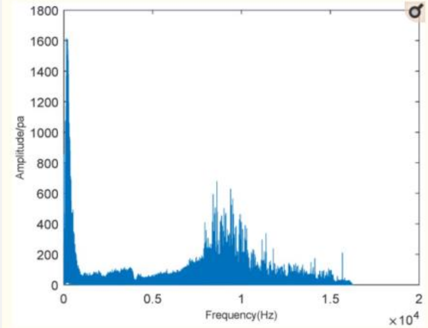


Figure 18

Frequency-domain sound signal.

- Surface Fires: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6929188/

Figure 10

Initial crown fire.

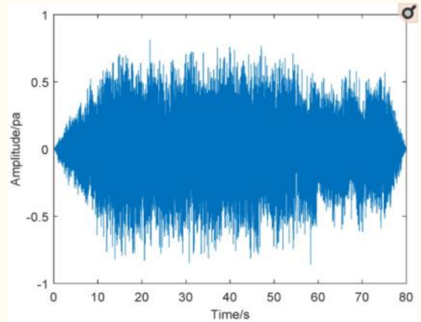


Figure 11

Time-domain sound signal.

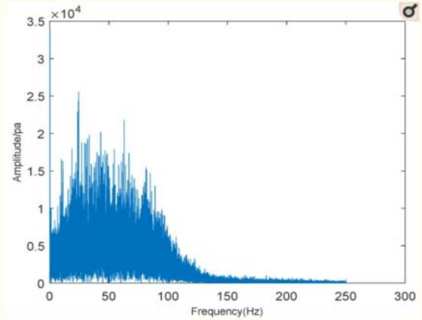


Figure 12

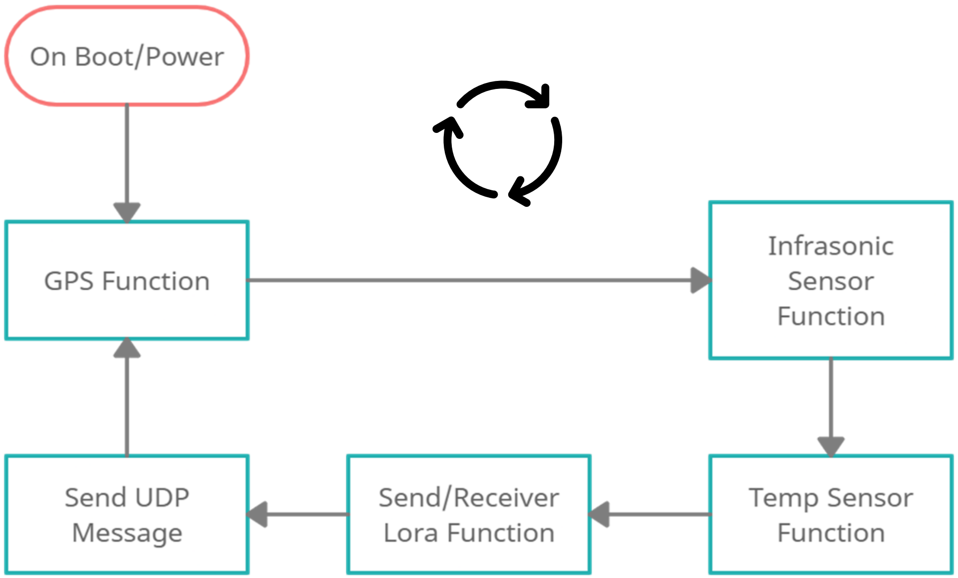
Frequency-domain sound signal.

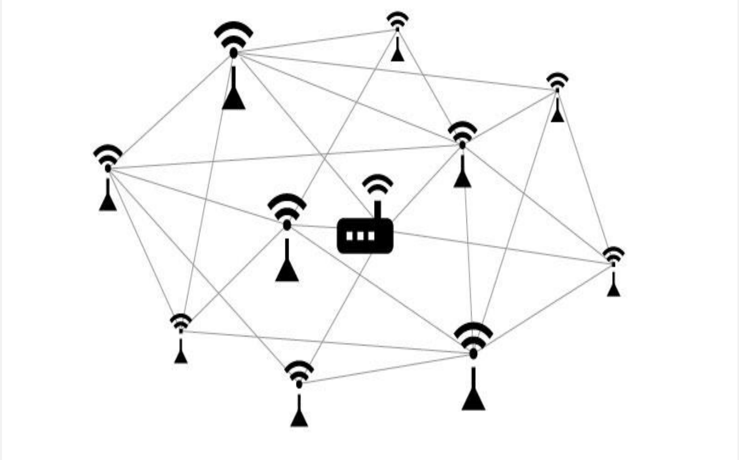
- Crown Fires: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6929188/

DEVELOPMENT BOARD

- TTGO T-Beam (T22_V1.1 20191212)
- ESP-32 Processor
- LORA-32 915 MHz Radio
- NEO-6M GPS
- AXP-192 Power Controller
- 18650 Battery Source
- UART, SPI I2C, Communication

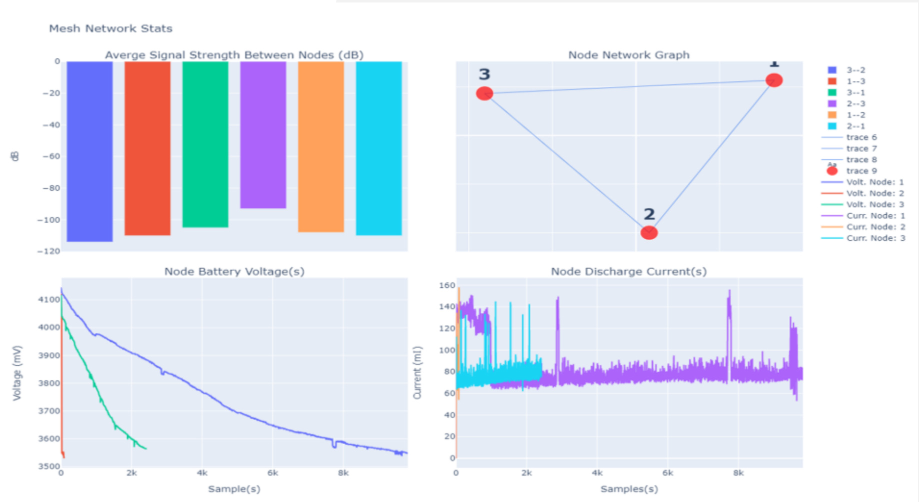
SOFTWARE DESIGN



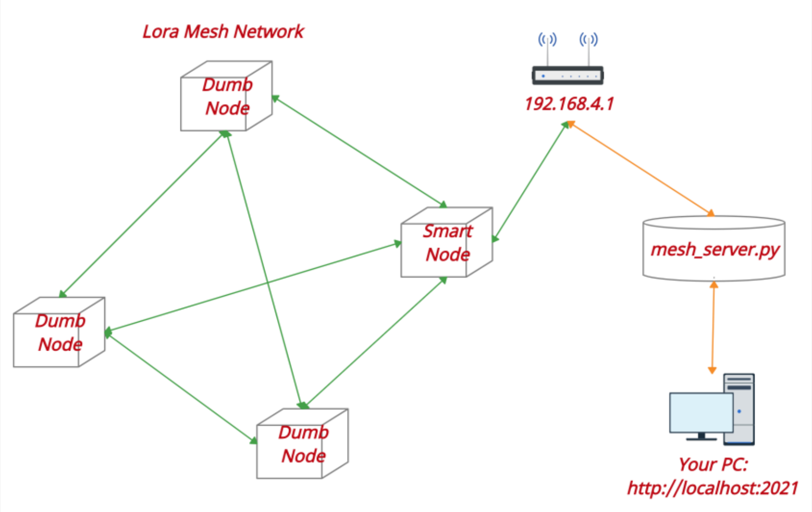


- A block diagram of the current software implementation for "smart nodes," as well as "dumb nodes" that don't send UDP messages.
- Currently structured to be a forever loop.
- PlatformIO for Visual Studio Code
- C/C++
- Usage of Radiohead Mesh Networking Library
- Node's relay JSON messages

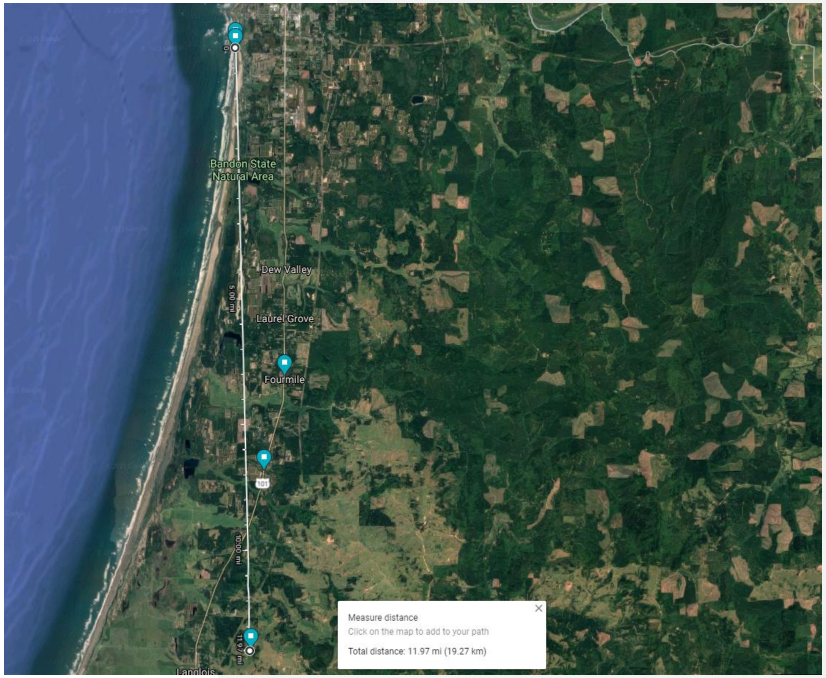
MESH NETWORK VALIDATION

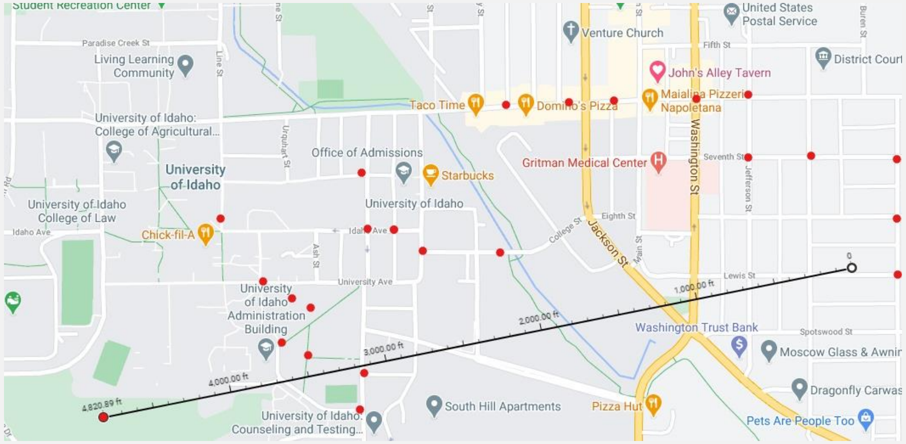


- Mesh Visualization tool created using python
- Listens for and parses UDP messages
- Plots the extracted information
- UDP messages contain JSON
- Example: 1:2:21 - node: { "3": [{ "n": 1, "r": -134 }, { "n": 2, "r": -116 }, { "n": 255, "r": 0, "lat": 48.727131, "lon": -119.996716, "temp": 29.299999, "VBat": 4104.100098, "DisCurr": 68.5 }]}



LORA RADIO VALIDATION

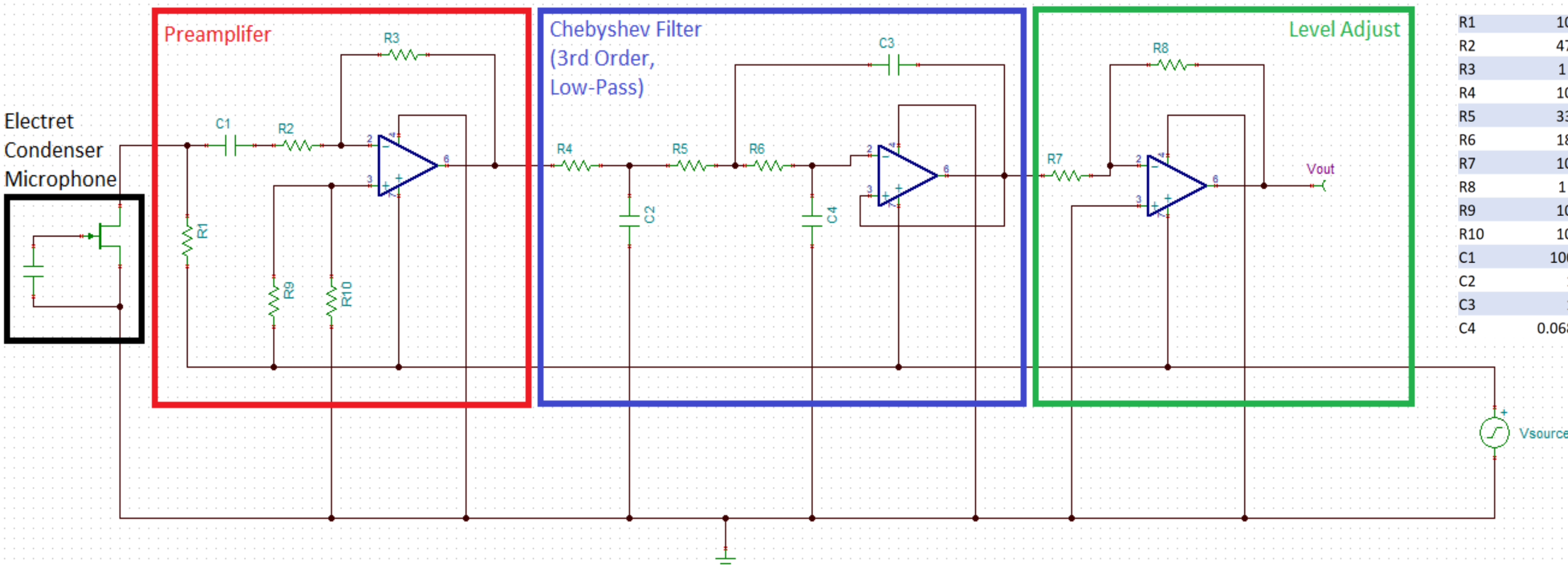




- Range testing was done in a forested, mountainous area.
- Devices could reliably communicate over 12 miles Line-of-Sight
- Without Line-of-Sight, devices communicate reliably within ½ mile.

LoRa™

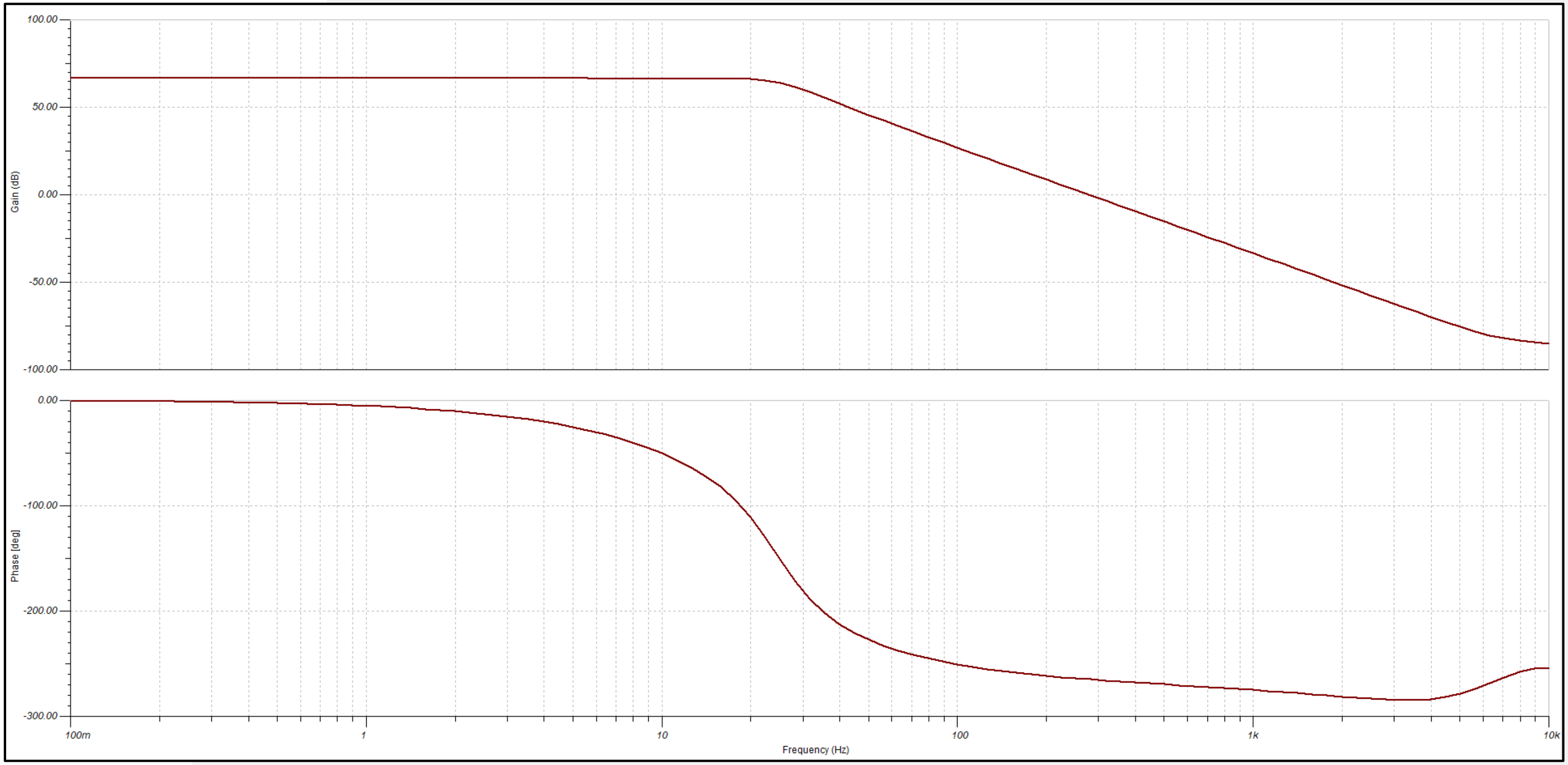
ELECTRICAL DESIGN – INFRASONIC SENSOR



R1	10 kΩ
R2	47 kΩ
R3	1 MΩ
R4	10 kΩ
R5	33 kΩ
R6	18 kΩ
R7	10 kΩ
R8	1 MΩ
R9	10 kΩ
R10	10 kΩ
C1	100 µF
C2	1 µF
C3	1 µF
C4	0.068 µF

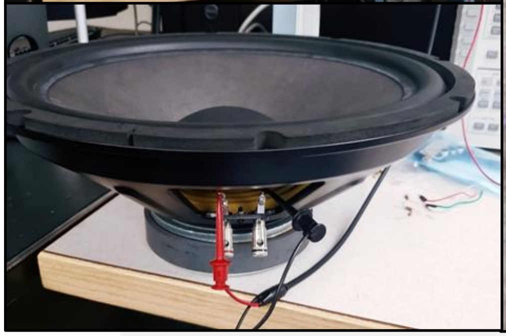
ELECTRICAL DESIGN – INFRASONIC SENSOR

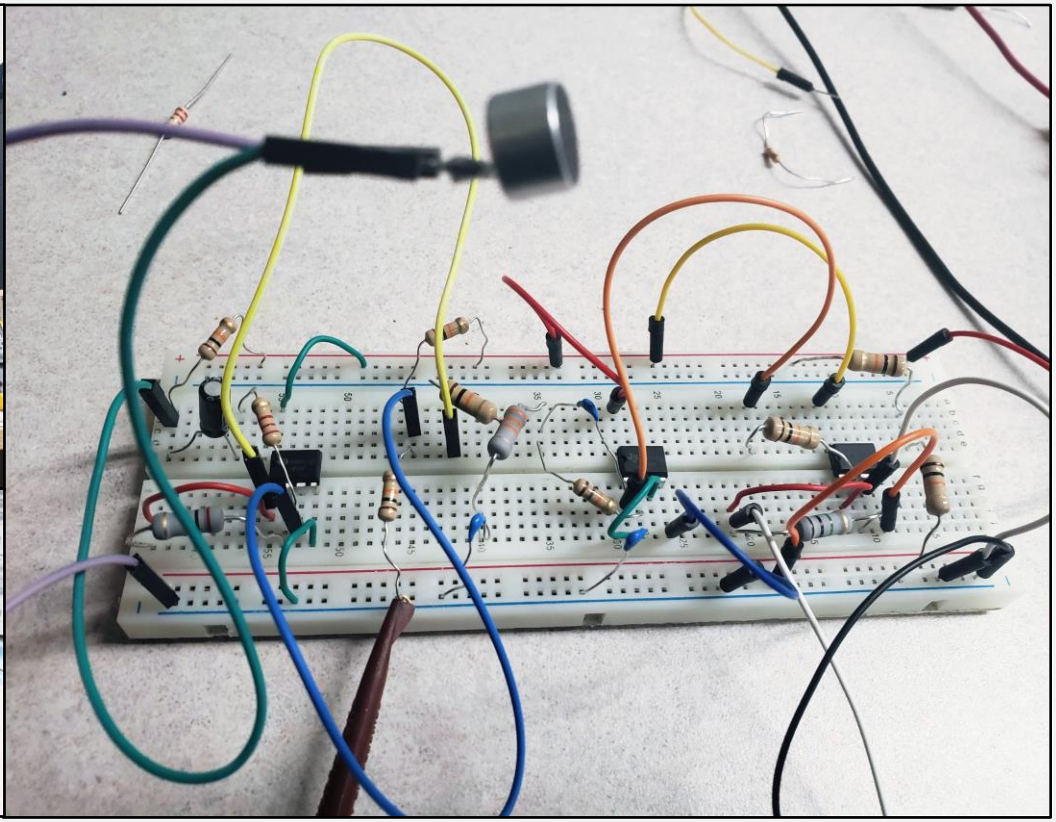
Simulated AC transfer characteristic:



INFRASONIC SENSOR VALIDATION

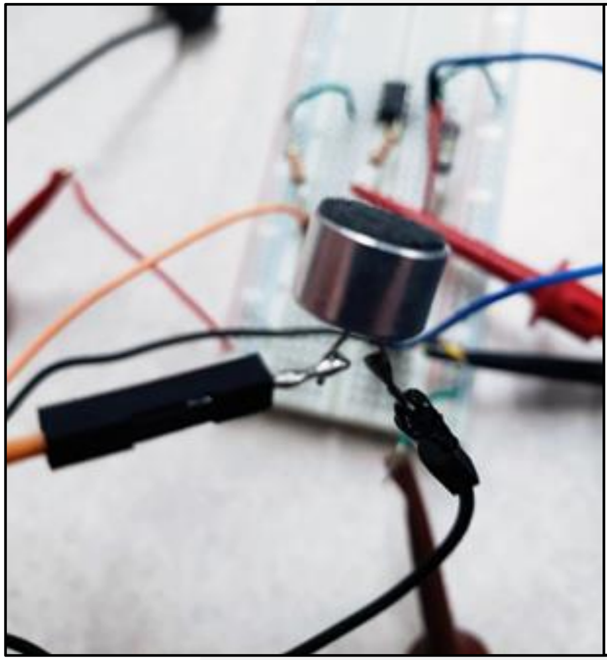
Testing Procedure:

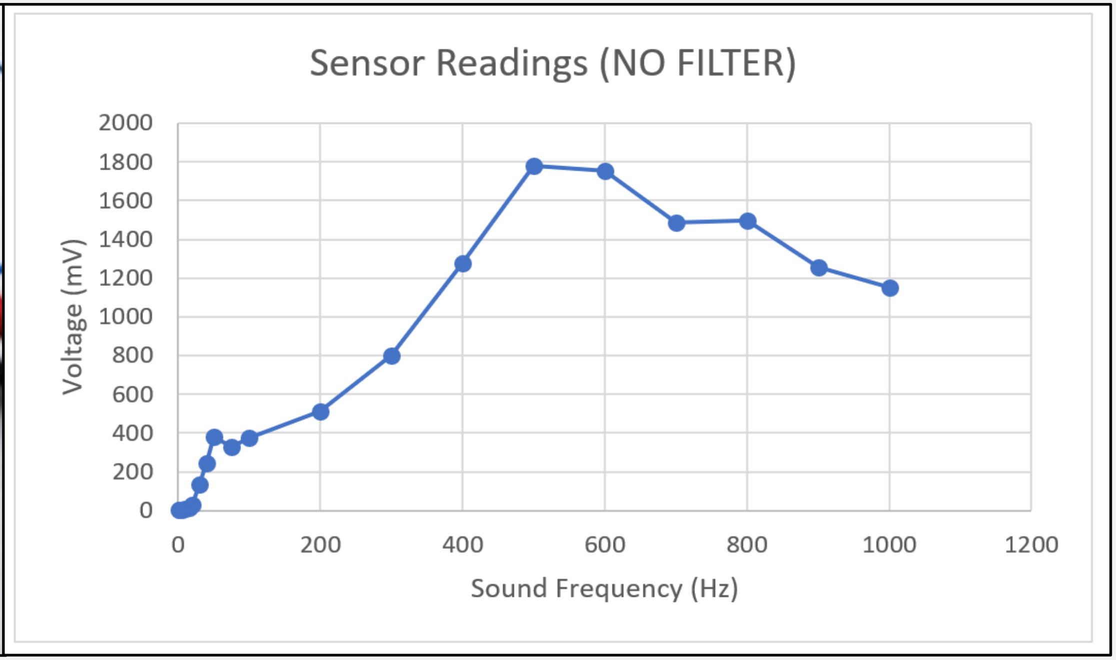




INFRASONIC SENSOR VALIDATION

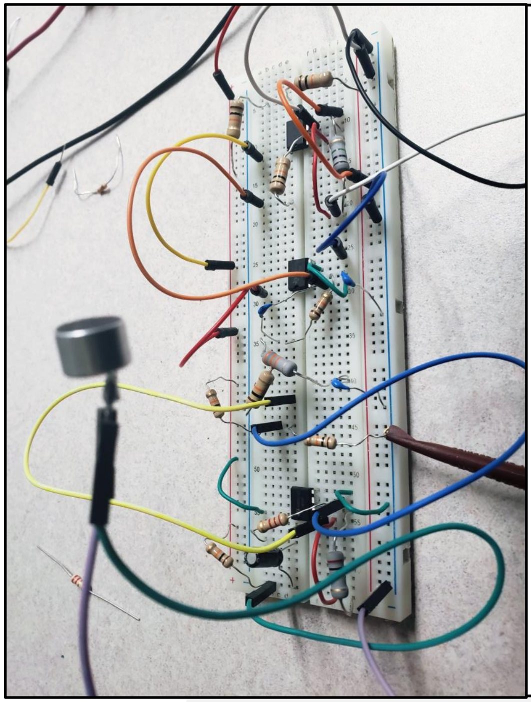
Test Results (Microphone and Preamplifier) :

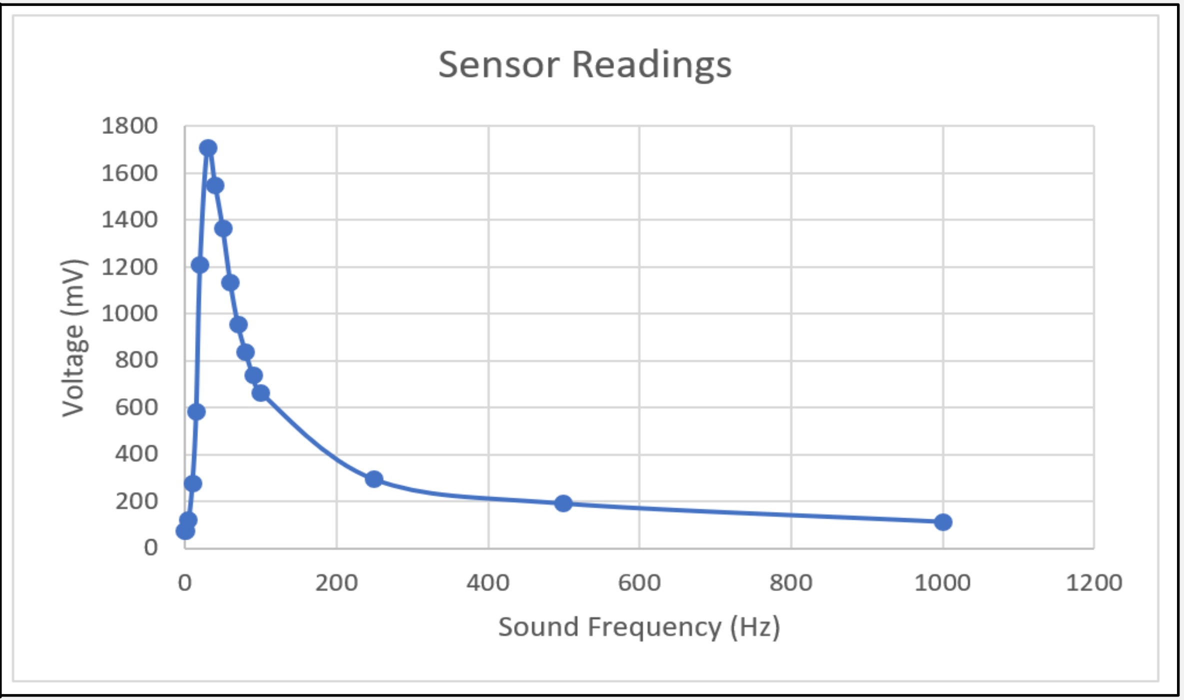




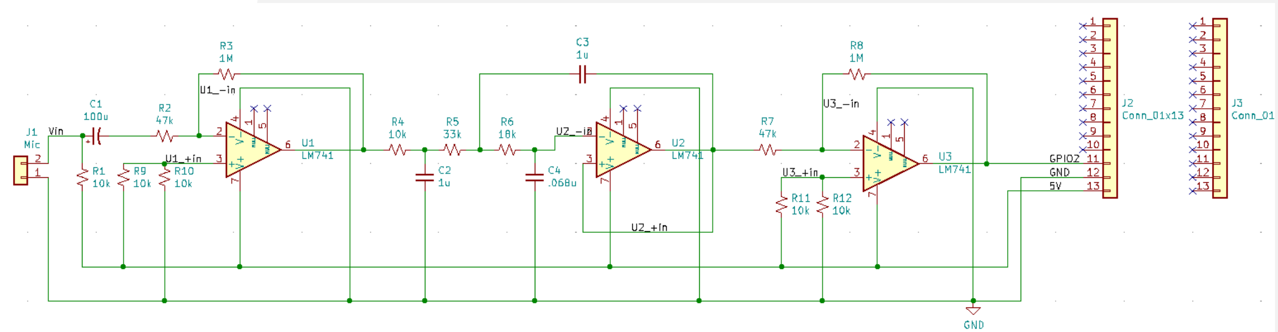
INFRASONIC SENSOR VALIDATION

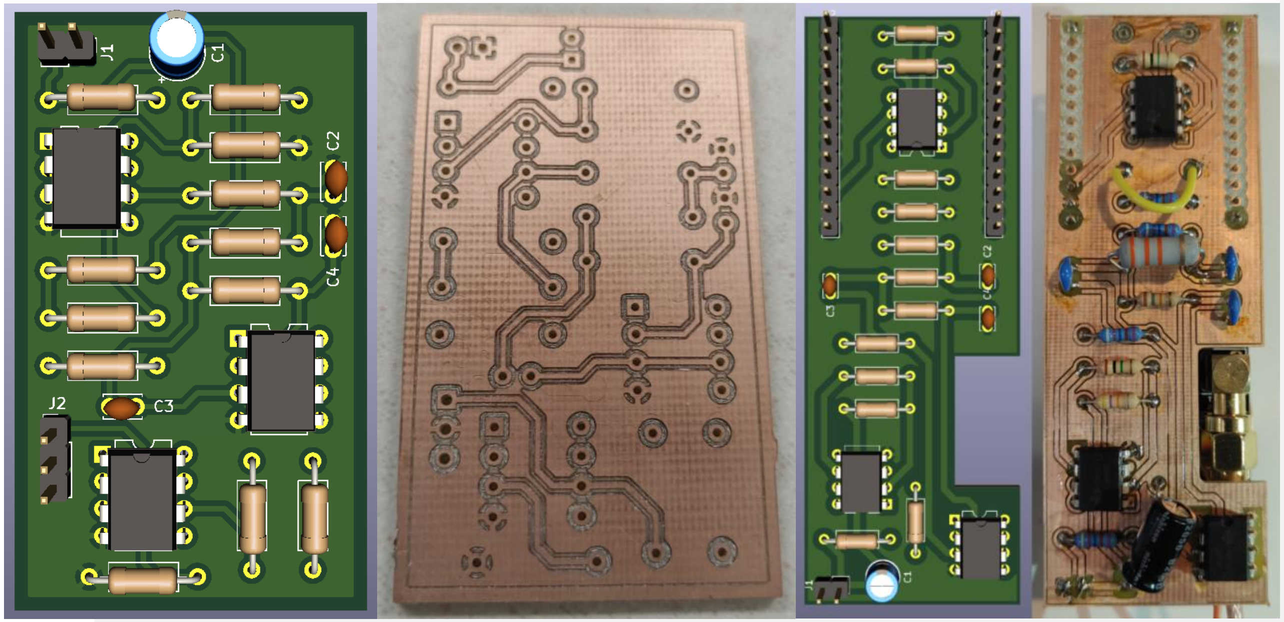
Test Results (Microphone, Preamplifier, Chebyshev Filter, and Level Adjust) :





ELECTRICAL DESIGN - PCB



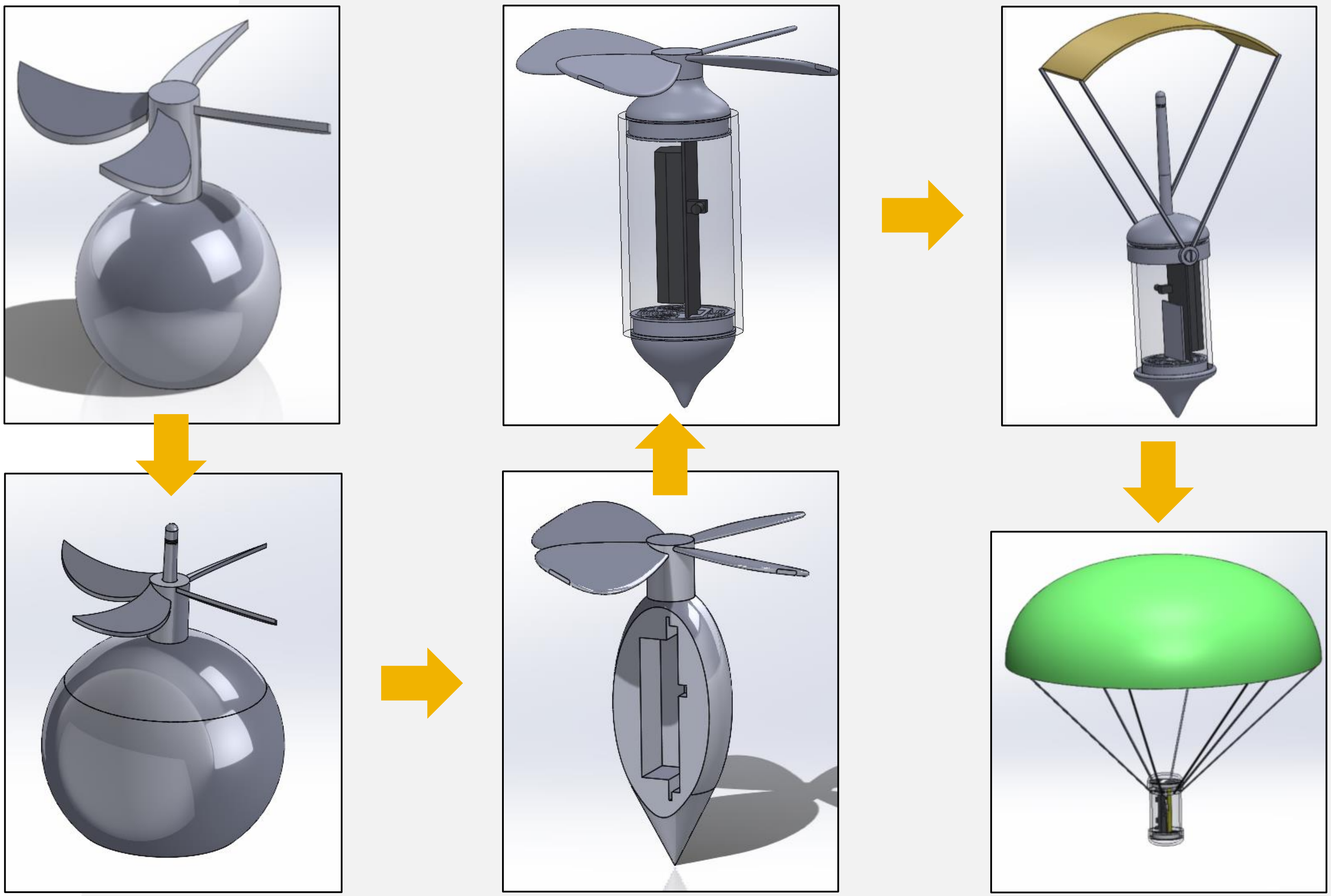


V1

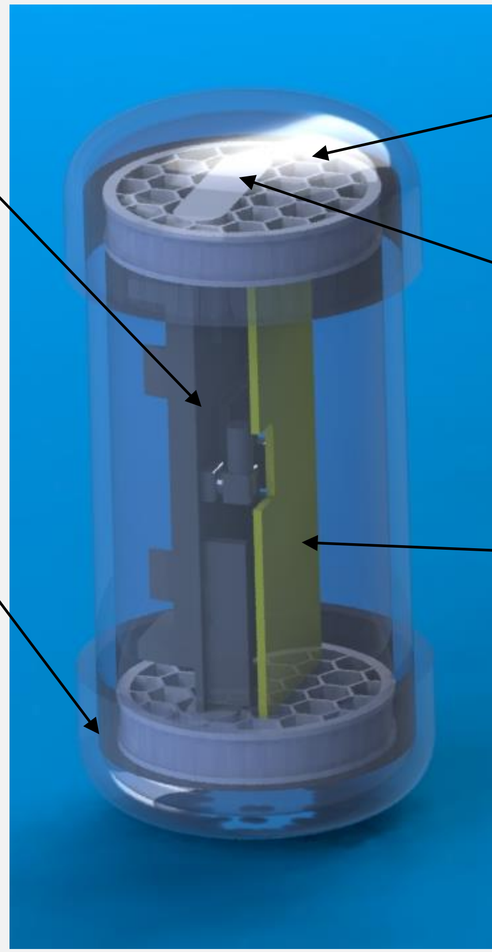
V2

Final

CONCEPT DEVELOPMENT



ENCLOSURE DESIGN



TTGO T-BEAM

- Fits into the slots of the Shock Absorber.
- Turned the antenna port 90 degrees to fit.

PVC HOUSING

- Already widely manufactured and cheap material.
- Designed around the size of 2in SCH 40 pipe and end caps.

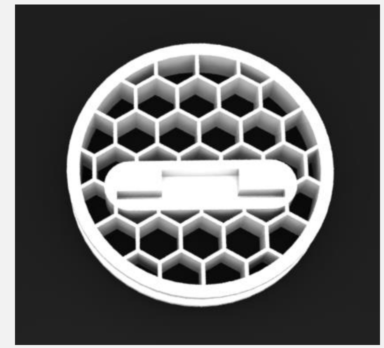
ATTACHMENTS

- Holes for Antenna and Microphone

PCB

- Supported by empty pin connections to development board.
- Fits in the space between the shock absorbers.

SHOCK ABSORBER



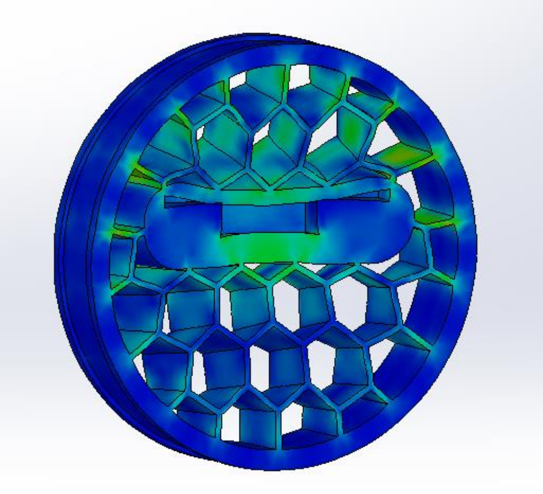
- Inspired by a similar design by Naomi Wu.
- Has a honeycomb design for durability and dampening.
- 3D printed using flexible TPU filament.

FINAL PROTOTYPE

ENCLOSURE VALIDATION

IRIC 3 STORY DROP TEST

- After test dropping the parachute and enclosure from 2 stories, we were able to go inside the IRIC to drop 3 stories.
- We were able to get slow motion video to be able to see the velocity change as it dropped.
- The prototype reached a terminal velocity before it hit the ground.
- This proved it could be dropped from any height and survive.



SHOCK ABSORBER LOAD SIMULATION

- Simulated a load acting on the center of the Shock Absorber, where the chip will be sitting.
- Showed that we would get deflection and dampening effects.

BILL OF MATERIALS

Infrasonic Wildfire Detector

Part Count : 14

Total Cost : $62.01

Part #	Part Name	Description	Qty	Units	Picture	Unit Cost	Cost
	TTGO T-Beam	Development Board	1			$ 27.03	$ 27.03
	LM741	Operational Amplifiers	3			$ 0.83	$ 2.48
	Misc. Electrical Components	Resistors + Capacitors	1			$ 3.64	$ 3.64
	Antenna Extension		1			$ 5.00	$ 5.00
	18650 Battery	Rechargable Li-Ion Battery	1			$ 2.37	$ 2.37
	Microphone	Electret Condenser Mic	1			$ 0.99	$ 0.99
	PCB	Printed Circuit Board for Amp + Filter	1			$ 11.22	$ 11.22
	Plastic Filament	TPU Filament	1			$ 0.48	$ 0.48
	PVC End Caps		2			$ 2.49	$ 4.98
	PVC Tubing		1			$ 0.62	$ 0.62
	Fabric + String	Parachute Materials	1			$ 3.20	$ 3.20
	Total		**14**				**$ 62.01**

CONCLUSION

ACCOMPLISHMENTS

- Simple Mesh network communication
- Network Monitoring and visualization tools
- Prototype of an infrasonic sensor
- Sensor PCB design
- Robust enclosure with shock absorption

QUESTIONS?

FUTURE GOALS

- Improve network speed
- Develop power management
- Switch to an RTOS for task management
- Digital Signal Processing for fire detection
- Weatherproofing