FLIR Helios

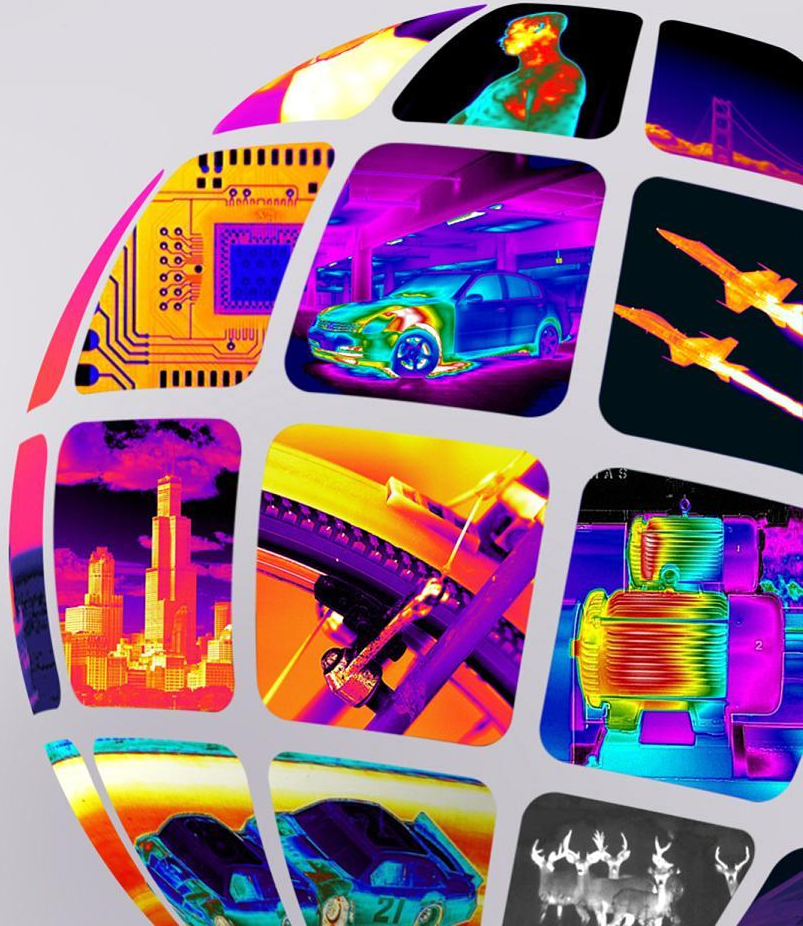
A wireless security camera, powered by the sun

2016-2017 Senior Capstone Engineering Design Project

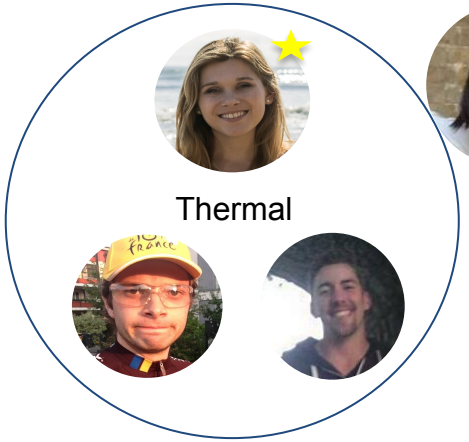
FLIR®

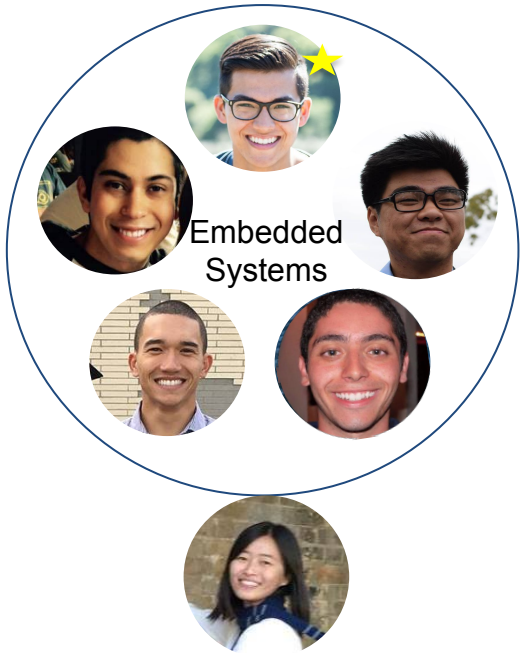
The World's Sixth Sense™

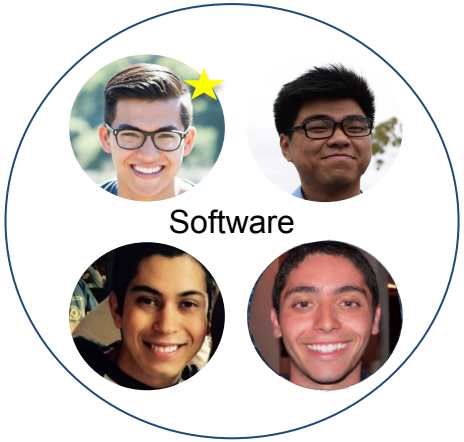
12/2/2016

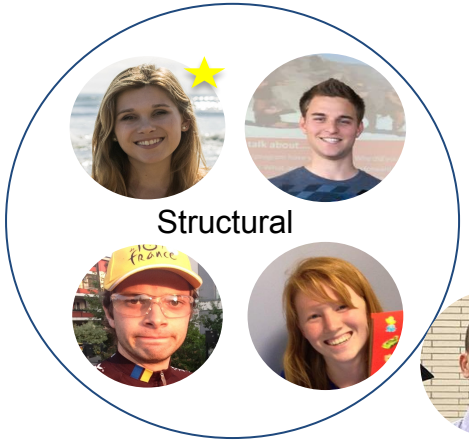


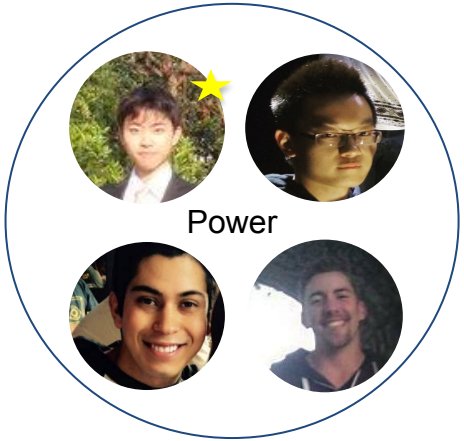
Introduction











Presentation Overview

- Product Capabilities
- Engineering Specifications and Customer Definition
- Embedded Systems
- Power Management
- Structural Design and Thermal Analysis
- Software
- Future Plans

FLIR Helios

Figure 1: FLIR Helios

Target Market

- People looking for an affordable camera
- Busy people who are away from home
- People looking for peace of mind

Figure 2: Busy People

Figure 3: Grandma

Market Research

- Isla Vista Foot Patrol (IVFP)
- SB SWAT

Figure 4: IV Foot Patrol

What are customers looking for?

- Extremely flexible camera placement
- Provide 24/7 surveillance
- Low energy consumption

Figure 5: Knotted Electrical Wires

Competing Products on the Market

We have identified two main competitors

- EyeTrax
- Videofied

Competing Products

Figure 6: EyeTrax

EyeTrax

- Strengths
  - Sturdy Metal Housing
  - Battery Life: 240 hours (10 days)
  - Solar Powered
- **Where we beat them**
  - Price: $2400 - 7000
  - Night Vision: IR LED lights
  - Subscription requirements

Competing Products

Videofied

Figure 7: Videofied

- Strengths
  - Replaceable Batteries
  - Variety of products and accessories
  - Quick Response to sensor trips
  - Full Security System
- **Where we beat them**
  - Price
  - Ease of Installation
  - Self Sustainability (No Solar)
  - Low Resolution/Pic Quality

Design Goals

Create a widely accessible security camera by utilizing solar power and wireless connectivity, advancing the following three areas:

- **Installation**: Eliminate expensive and intrusive installation process
- **24/7:** Provide 24/7 security surveillance capability
- **Durability**: Withstand adverse conditions

Design Benchmarks

- IP67 Rating
- Modular Solar Panel and adjustable antenna for any scenario
- Combined visible and thermal imaging
- 100% Duty Cycle

Design Risk Analysis

Risk	Severity	Probability	Rating
Temperature Mismanagement	4	4	16
Water leak into the housing	5	3	15
Vandalism	3	5	15
Signal Interference	5	2	10
Dirt on the solar panel	2	5	10
Damage in 70+ MPH wind	3	3	9
Ice/Snow on the lens	4	2	8
Attachment Failure	5	1	5
Battery life cycle	1	4	4

Engineering Specifications

Engineering Characteristic	Target Spec (Minimum requirement)	Target Spec (Ideal)
Submerged in 1m Water	30 min*	30 min
Dust tight	8 hours*	8 hours
Maximum Wind Speed	70 mph	80 mph
Minimum Solar levels	2.9 hours/day	2 hour/day
Temperature Range	-20 to +50 °C	-30 to +60 °C
Vibration Resistance	MIL-STD-810F Transportation	
Weight	15 pounds	10 pounds
Connectivity	WiFi	WiFi (large range)
Battery Life	2.5 hours**	10 hours**
Price (in bulk)	$700	$200

*As defined by IP67 standards set by the International Electrotechnical Commision.

** Continuous power on operations.

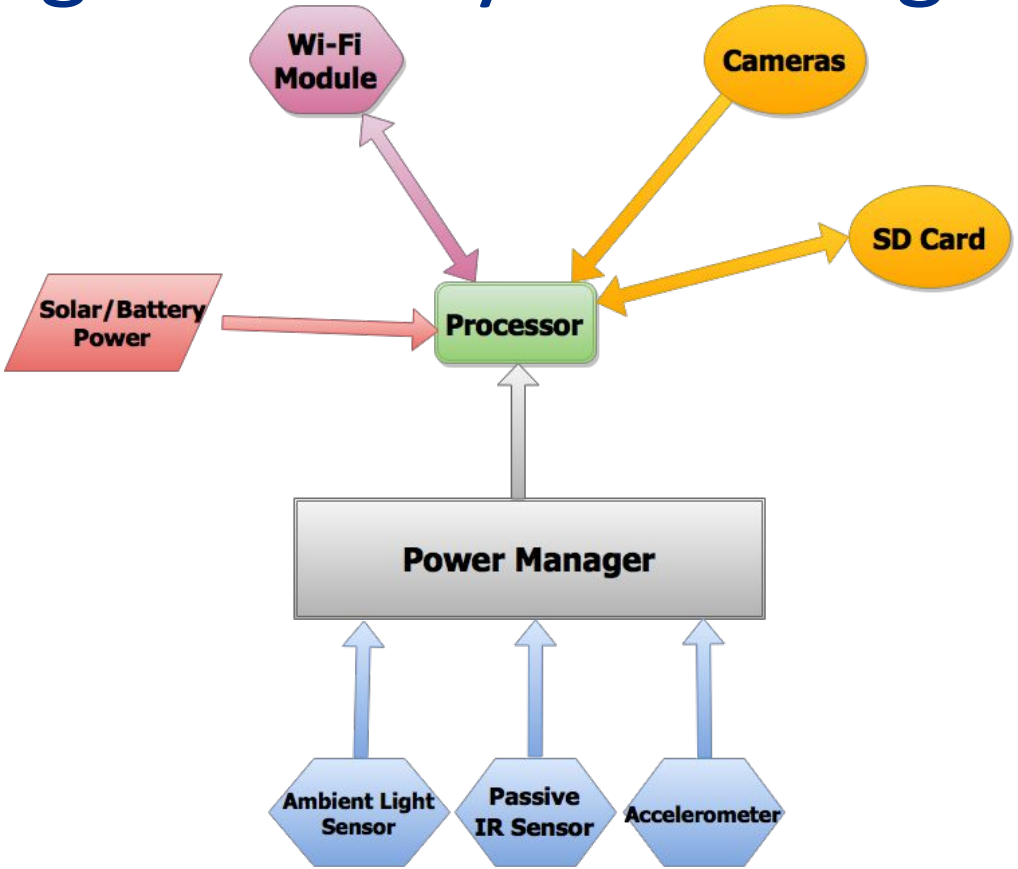
FLIR

Why is the FLIR Helios special?

- Solar Powered and WiFi Enabled
  - No cabling and low installation cost
- FLIR Lepton is the enabling technology
  - Actual IR imaging, not IR lighting
- THOR board
- Website and Android Interface

Figure 8: FLIR Helios

High Level System Diagram



Visible Camera

- Great for daytime use
- Full HD camera
- Capable of taking still images while recording video

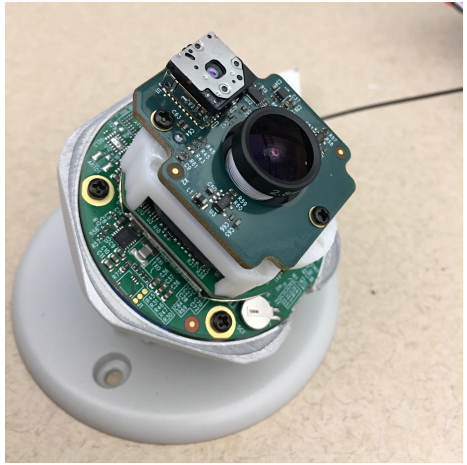


Figure 9: Visible Camera + Lepton

FLIR Lepton

- State-of-the-art Infrared camera
- Compliments visible camera
- Allows for 24/7 surveillance
- Extremely low power draw when on (150mW)

Figure 10: FLIR Lepton Size

Comparison

Visible Light

Thermal

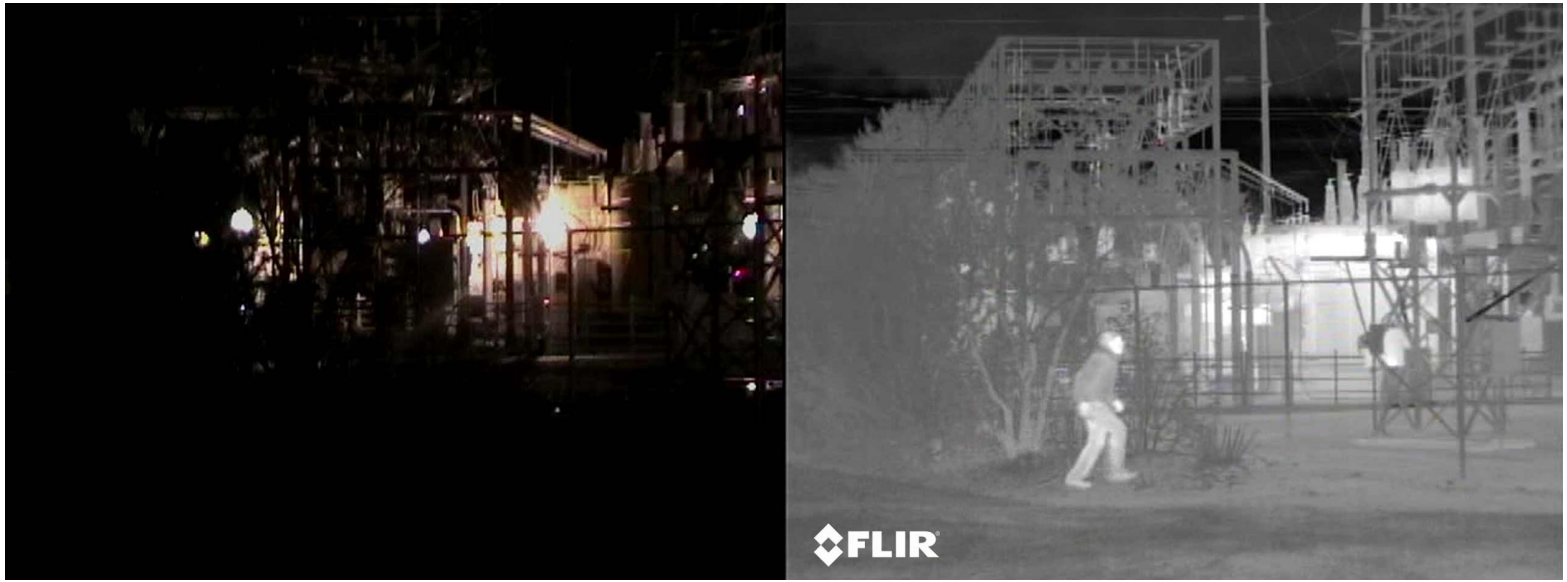


Figure 11: FLIR Visible vs. Thermal

THOR Board

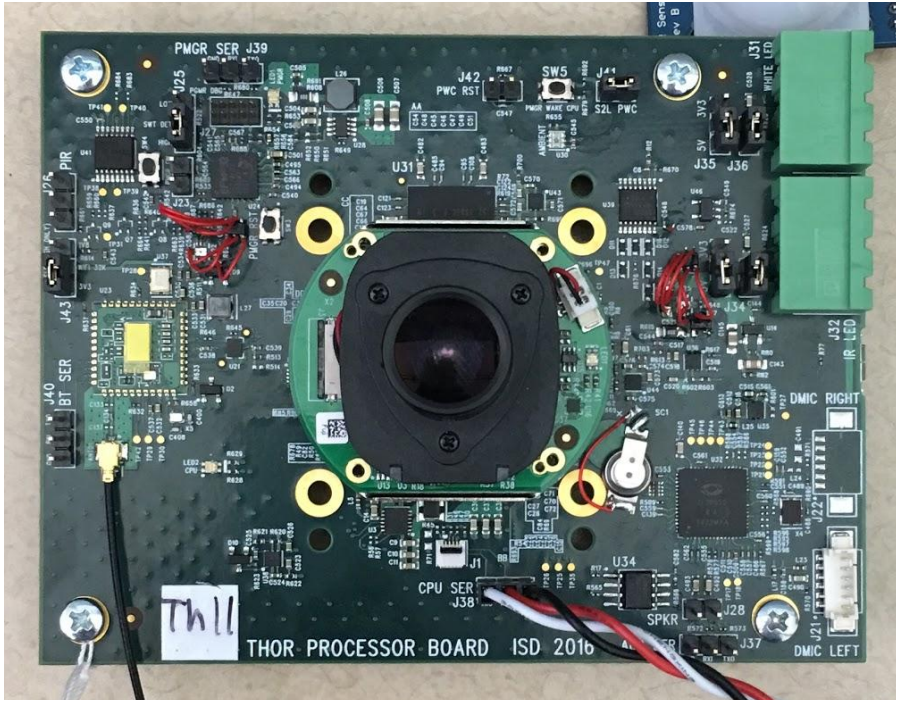


Figure 12: THOR Processor Board

Sensors

Passive IR Detector

- Threat detection

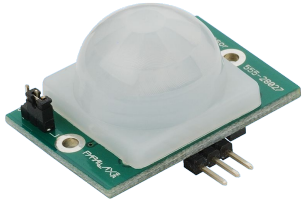


Figure 13: PIR Sensor

Lux Sensor

- Camera switching

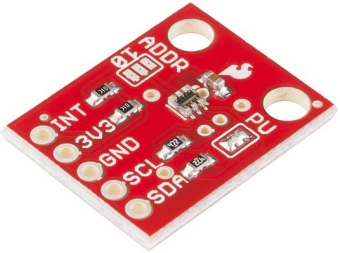


Figure 14: Lux Sensor

Accelerometer

- Sense Tampering

Figure 15: Accelerometer

Why we chose these sensors

- Cost effective
- Small footprint

Antenna

- Directional Antenna
  - Maximize wireless range
  - Offers more range than omnidirectional
- IP67 Rating
  - External to camera

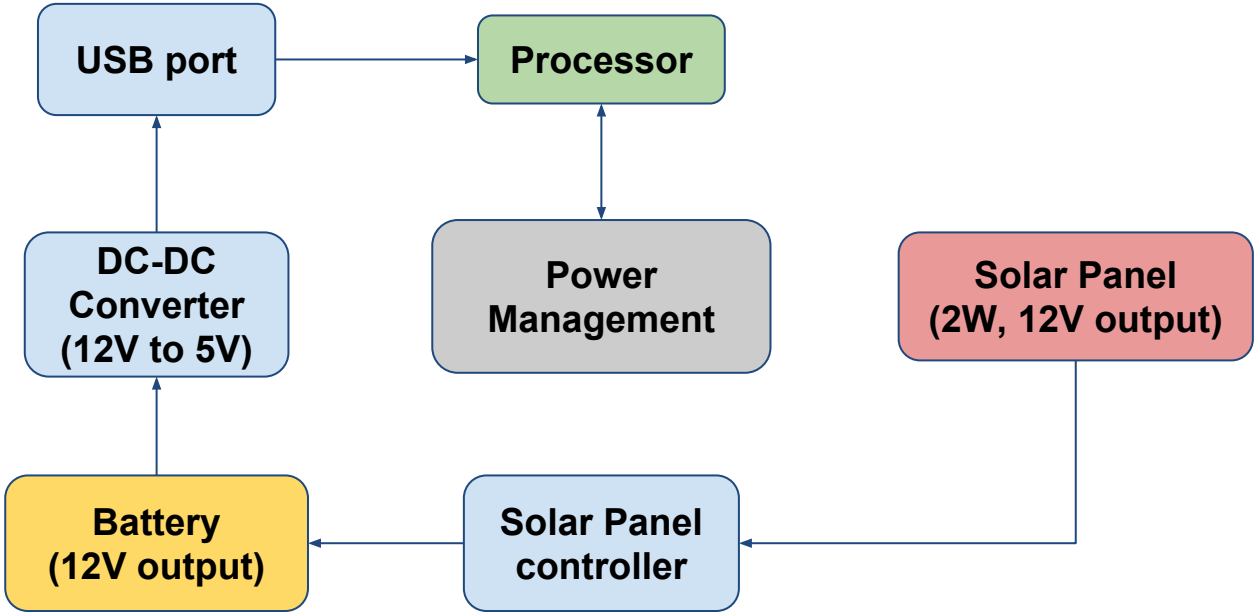
Figure 16: Directional Antenna

SD Card

- Write to SD Card if threat is detected
  - Conserve energy when live stream is not requested
- Maintain all video clips for future reference

Figure 17: SD Card

Power Block Diagram
(Current Design)



Solar Panel

Figure 18: Amorphous Solar Panel

- 2W 12V output
- Amorphous solar panel works in all daylight conditions, even on cloudy days
- Temperature range: -40°C to 80°C

Solar panel controller

Figure 19: Solar Panel Controller

- Auto charge and cut-off power when 11.1V Lipo battery pack is low or full
- Protect battery from overcharged and over-discharged to increase battery service life
- Built in fuse to protect short circuit and wrong polarity connection

LiPo Battery

- Rechargeable
- High energy density
- Flat discharge rate
- Low cost

Figure 20: LiPo Battery

DC-DC Converter

- USB port
- Light in weight
- Small in size
- Low power consumption
- Low cost

Figure 21: DC-DC Converter

Shape of Structure

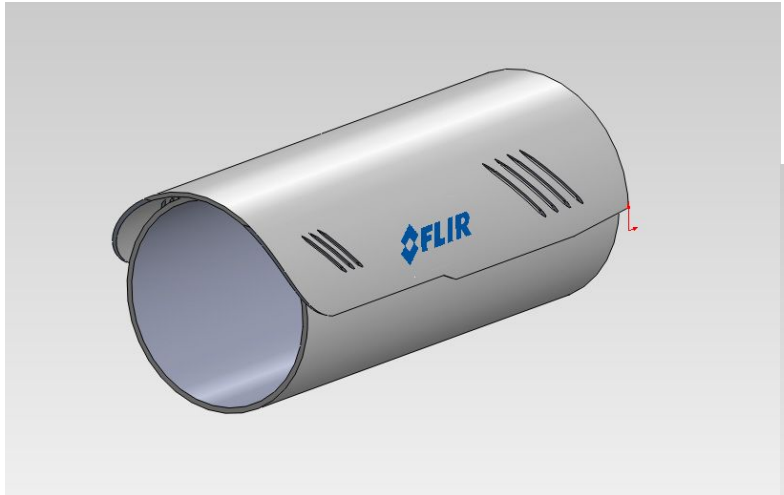


Figure 22: Cylindrical Design

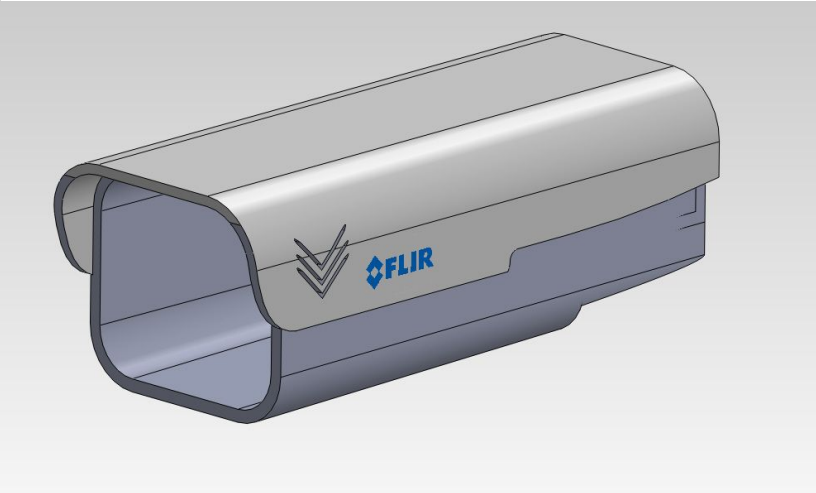


Figure 23: Rectangular Design

Preliminary Design

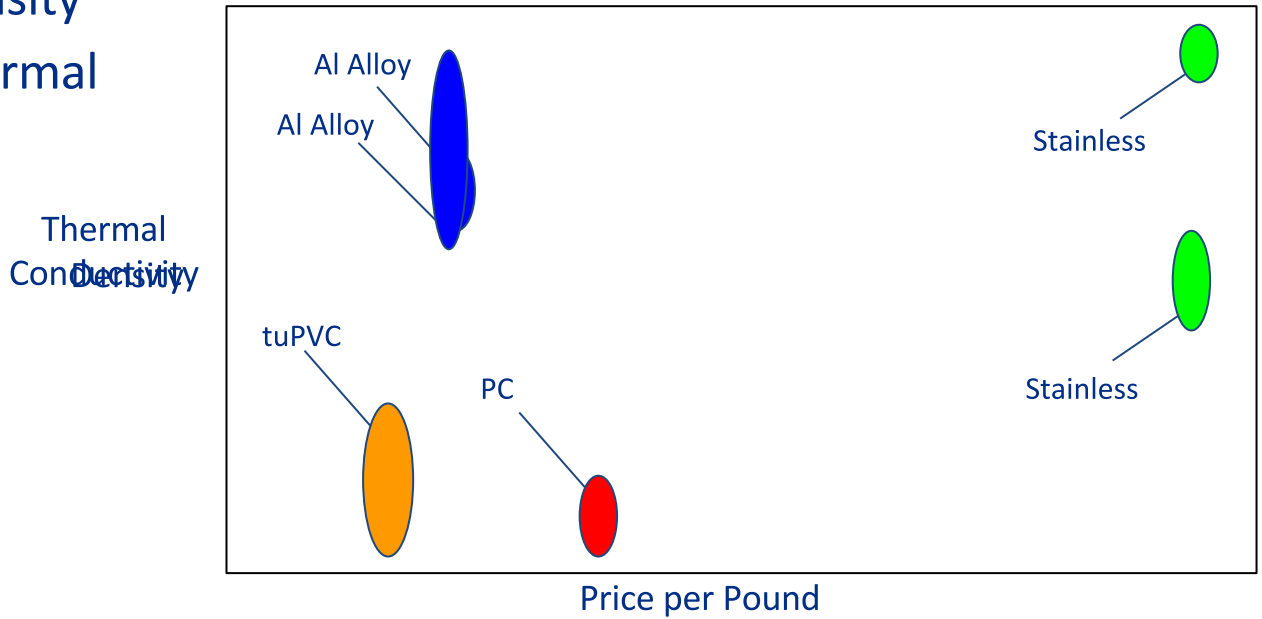
Installation
24/7
Durability

Figure 24: Preliminary Design

Material Selection

- Cost
- Corrosivity
- Density
- Thermal

Material Ashby Chart



Waterproofing

- Venting
  - Gore Vent XS
- Gaskets
  - Complex geometry
- To Do: Speak with L-3 Communications, MariPro Inc.

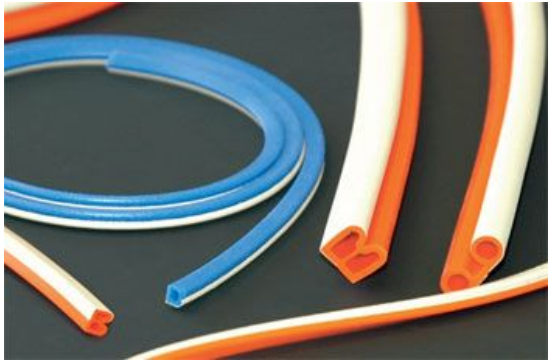


Figure 25: EMI Shielding Gaskets

Figure 26: Gore Vent

Mounting Solutions

- Mountable to poles and walls

Figure 27: Wall Mount

Figure 28: Tree Mount

Figure 29: Pole Mount

Thermal Testing
Hand Calculations

$$Q_{electric} = \frac{T_{max} - T_{inf}}{R_{net}}$$

$$T_{max} = T_{inf} + Q_{electric} R_{net}$$

$Q_{electric}$ = Heat dissipation from processor
T_{max} = Max temperature of processor
T_{inf} = Temperature of ambient
R_{net} = Net resistance of thermal circuit

1 dimensional thermal analysis

T_{max} = 56.3°C

2 dimensional thermal analysis

T_{max} = 49.9°C

Real World Test

4 AAA batteries

8 100Ω resistors

$$P = \frac{V^2}{R} = 2.26W$$

P = Power in Watts

V = Voltage

R = Resistance

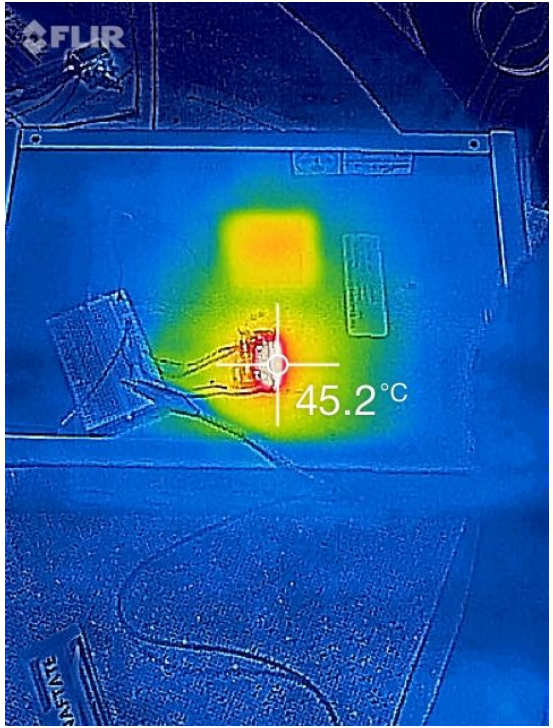


Figure 30: Real World Test

PC: FLIR ONE

Thermal Analysis with COMSOL

Installation 24/7 Durability

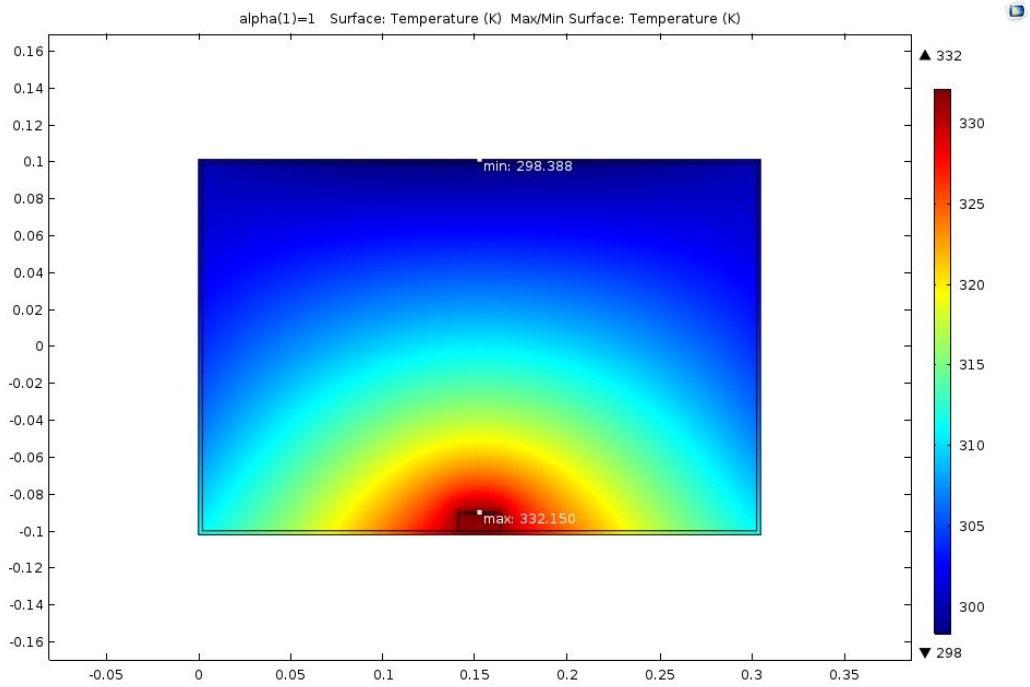


Figure 31: COMSOL Models

- Heat transfer in solids with advection in air
- Max Temp: 332.15K (59°C)

Thermal Analysis with COMSOL

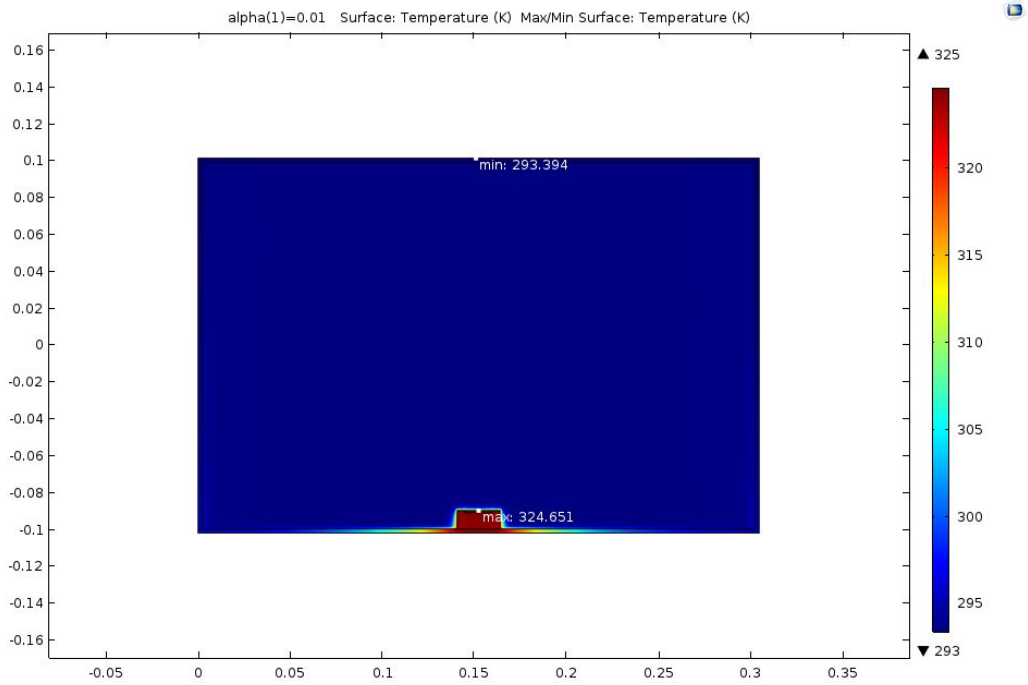


Figure 32: COMSOL Models

- Combined convective heat transfer with buoyancy effects.
- Max Temp: 324.651K (51.85°C)

Design Evolution

Installation
24/7
Durability

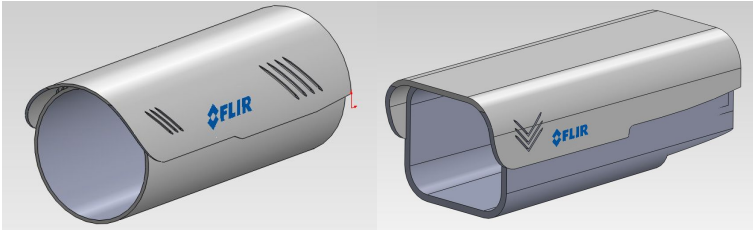


Figure 33: Cylindrical vs. Rectangular Design

Figure 34: First Preliminary Design

Figure 35: Preliminary Design

?

Installation
24/7
Durability

Website Support/Android App

Installation
24/7
Durability

- Live Stream available at any moment
- Allow user to interact directly with camera
  - Store Video
  - View multiple streams at once
  - Manually switch between infrared and visible camera
  - Set camera to “Do Not Disturb” mode
- Stretch Goal
  - Android App with same capabilities of website
  - Why an Android App?

Android Design

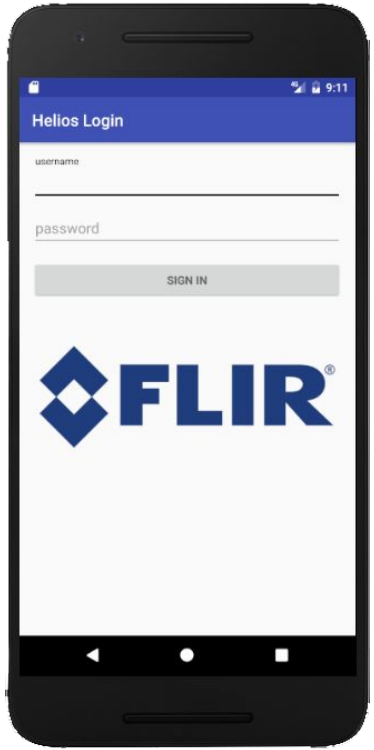


Figure 36: Login Screen

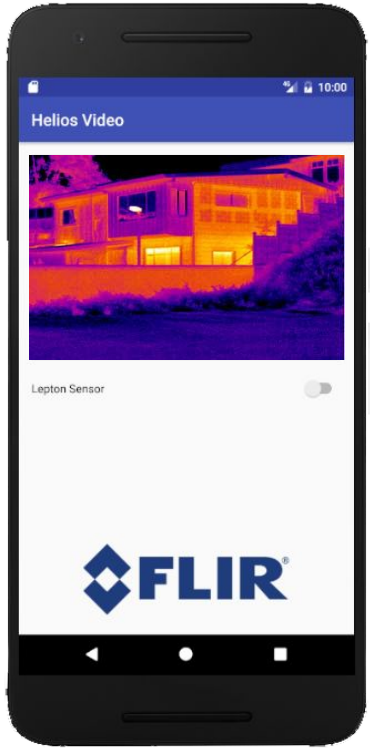


Figure 37: Video Screen

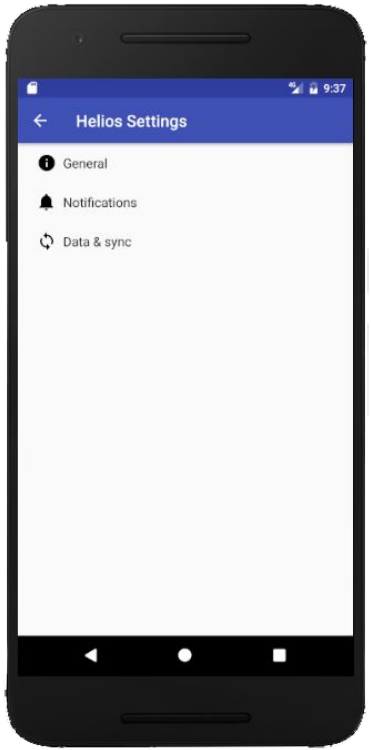


Figure 38: Settings

Android Design

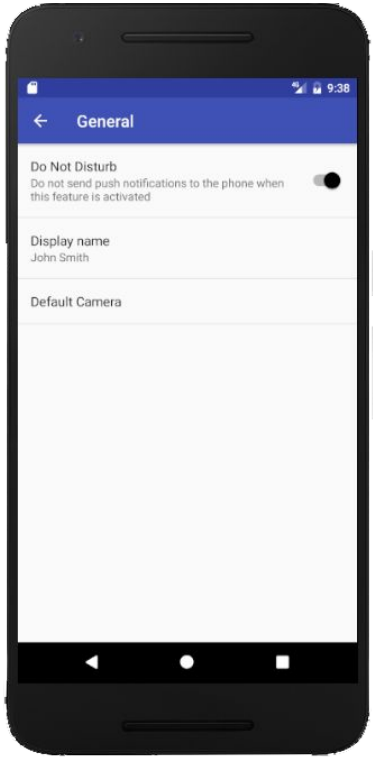


Figure 39: General Settings

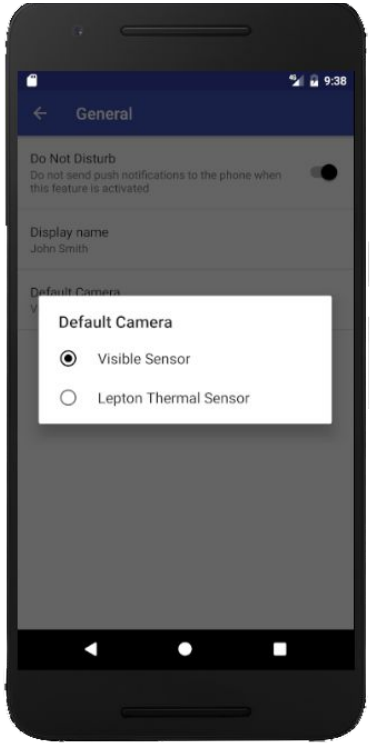


Figure 40: Camera Options

Future Plan

Current Layout

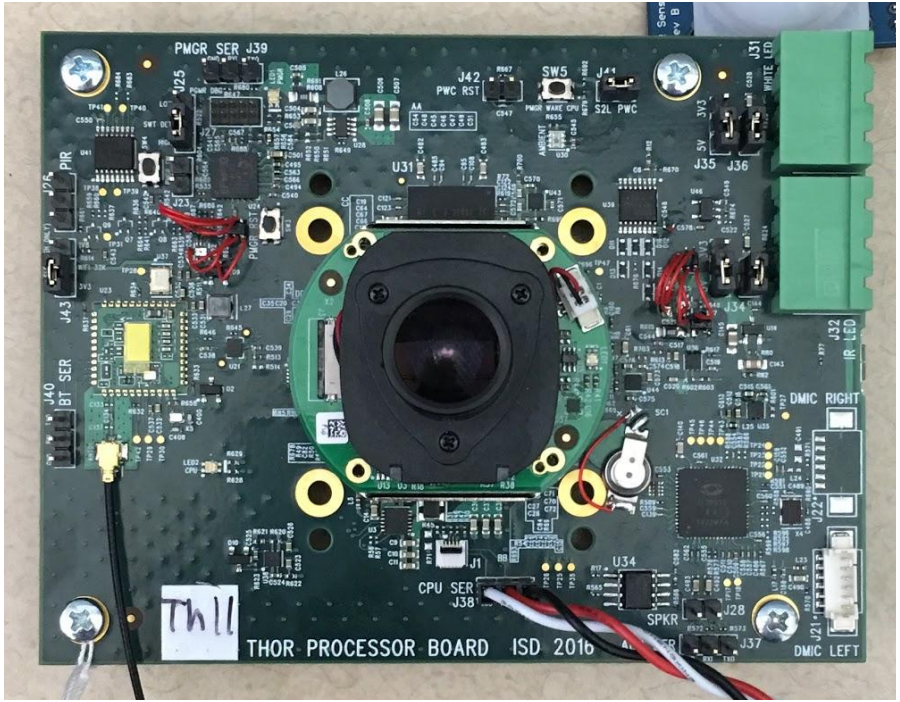


Figure 41: THOR Processor Board

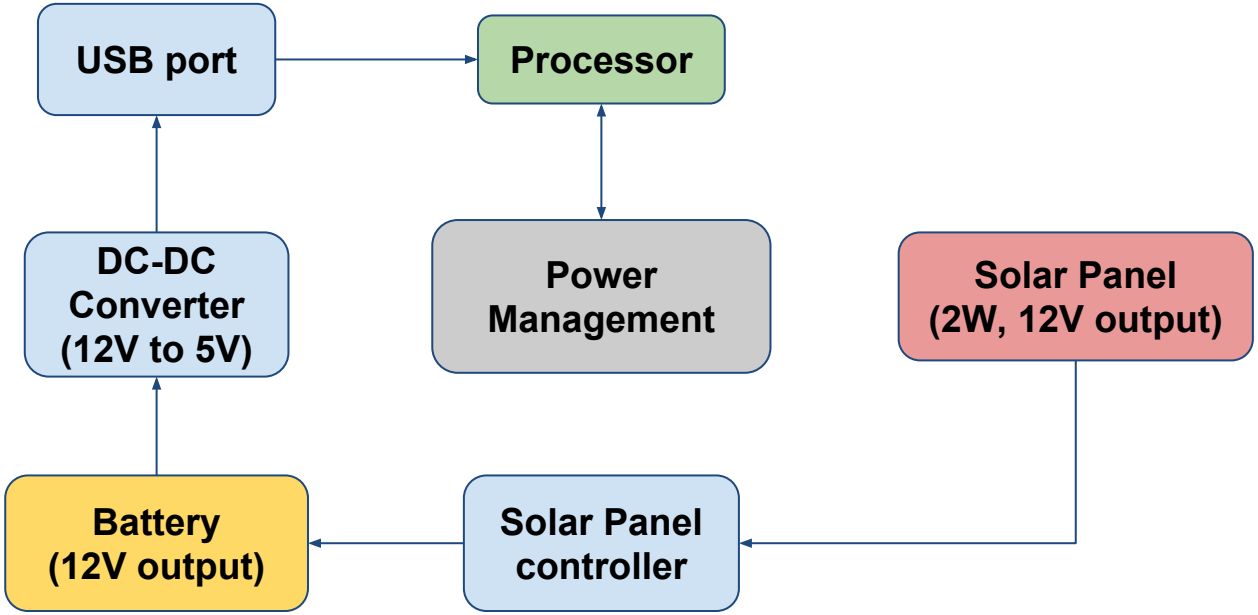
Desired Arrangement

- Extension cable bridging THOR board and camera
- Allows more freedom in the structural design of the camera

Figure 42: Flat-Flex Cable

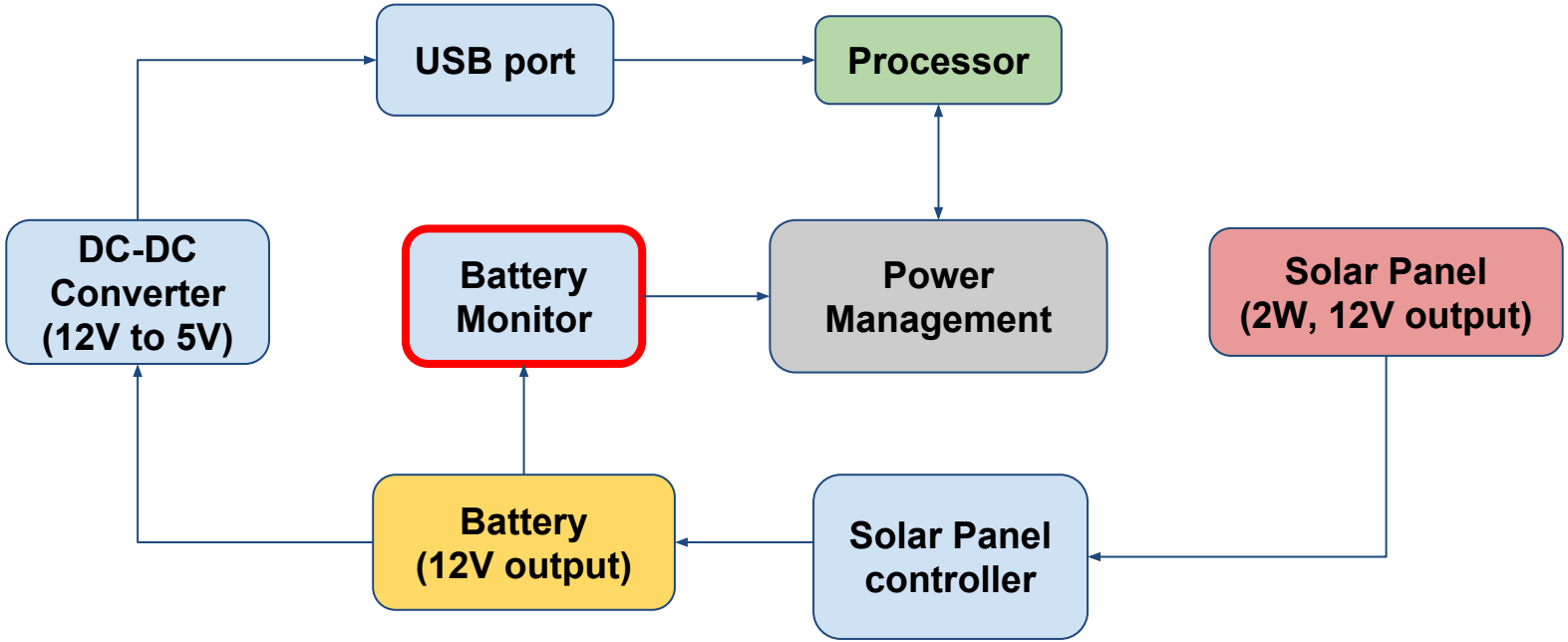
Power Block Diagram

(Current Design)



Power Block Diagram

(Future Improvement)



Housing Review

- Waterproofing
- Removable solar panel
- Wall thickness considerations & structural features
- Production
- FLIR design language

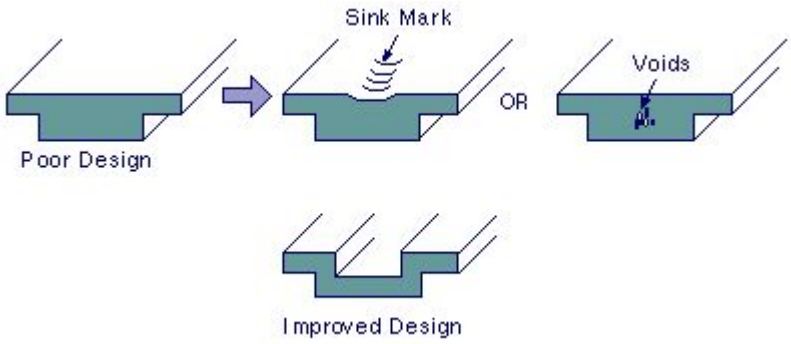
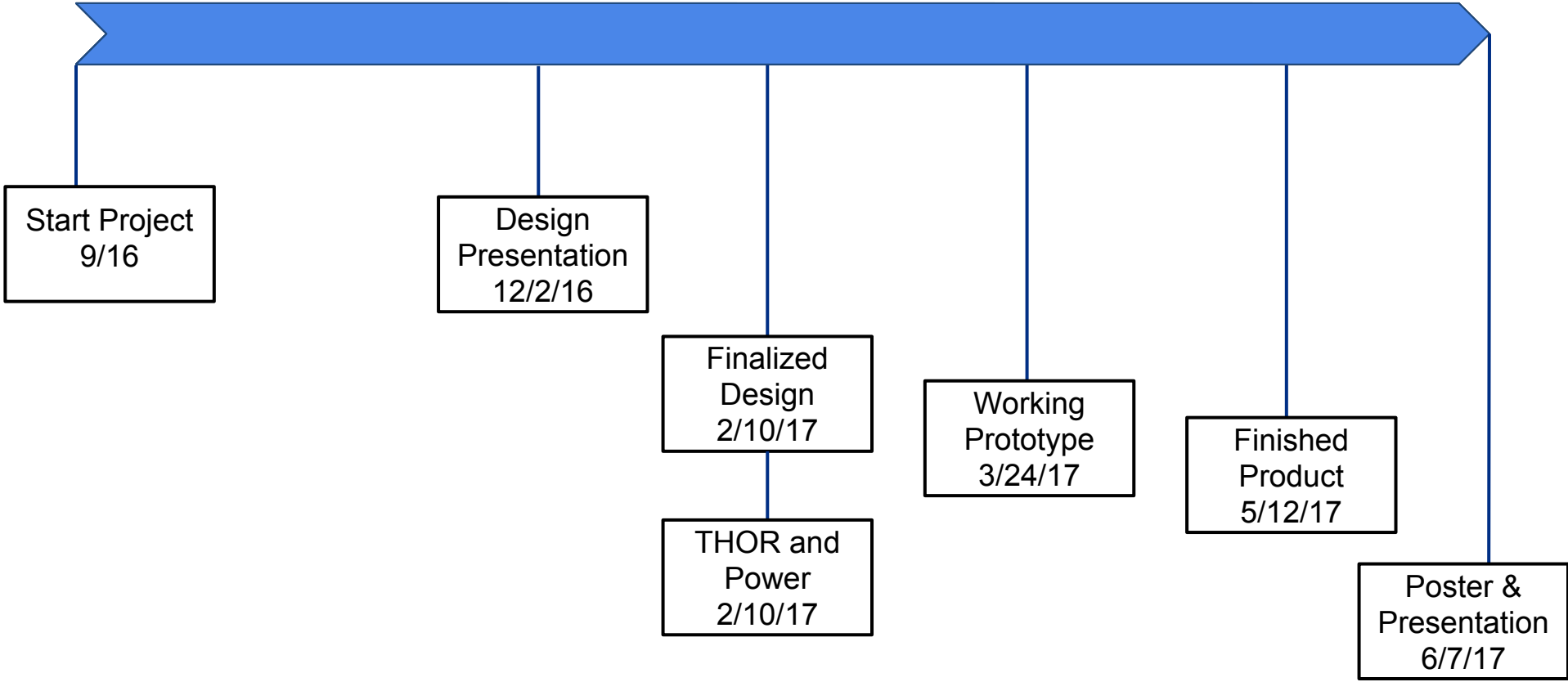


Figure 43: Wall thickness considerations

Future Timeline



Thank you!

PC: FLIR ONE

Additional Slides

Customer Needs & Characteristics

List of needs / Engineering Characteristics	Unit Production Cost ($)	Dust Tight (h)	Submerged in Water (m and min)	Weight (kg)	Wireless Range (m)	Power Required when On (W)	Battery Life (h)	Amount of Sunlight (h/day)	Camera Mobility (Degrees)	Corrosion Resistance (Testing hours NSS)
Low Cost	X									
High Volume Production	X									
Durability		X	X							X
Weather/Water Resistance		X	X							
Ease of Installation				X					X	
Wireless Communication					X	X				
Low Power Consumption					X	X	X	X		

Competing Products (EyeTrax)

	EyeTrax		
Model	Ranger	Mega	Predator
Price ($)	2,400	6500	6500
Communication	Cellular	Cellular	Cellular
Capture Media	Still images	Still Images	Video & Images
Power Supply	Solar w/ internal Battery	Solar w/ internal Battery	Solar w/ internal Battery
Resolution	1600x1200	4000x3000	2560x1920
Night Vision	IR (IR Lights)	N/A	IR (IR Lights)
Night Vision Range (m)	46	N/A	46
Motion Detect Range (m)	12	N/A	12
Camera Mount	Fixed	Pan & Tilt	Pan & Tilt
Battery Life (hours)	240	240	240
Weight (lbs)	6	15	15
Other		Windshield Wiper	Uses 2 Solar Panels
Pan & Tilt Weight (lbs)	N/A	15	15
	EyeTrax Solar Panel	Skyway Security	
Solar Panel			
Weight (lbs)	8	N/A	
Dimension	22"x16"x1"	N/A	
Power (W)	30	35	
Max SP Distance (ft)	115	N/A	

FLIR

Competing Products (Videofied)

- Full security system
  - Our product is a supplemental video system, not meant to compete with a full security system
- Price quotes only available signed in customers
  - Indicative of high price, and more exclusive and different customer market
- Difficulty of installation
  - Offers a variety of products including outdoor sensors, key/alarm pads, Control Panels, and accessors, nearly guaranteeing a more difficult installation process
- Reliant upon disposable and/or replaceable batteries
  - No solar powered products, requiring maintenance and/or replacement of batteries.

FLIR Lepton

- Captures infrared radiation input and outputs a uniform thermal image
  - Used during low-light situations or favorable weather conditions (for thermal imaging)
- MIPI/SPI Video Interface
  - Export compliant frame rate (< 9 Hz)
  - Field of View: 50 deg
  - Image size: 80x60px
- Uses standard cell-phone-compatible power supplies:
  - Low operating power, nominally 150 mW (< 160 mW over full temperature range)

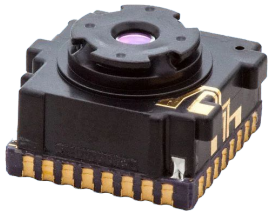


Figure 44: FLIR Lepton

Visible Camera

- 2.8mm
- 4MP Camera
- Full 1080p video recording capabilities
- Connection through MIPI interface

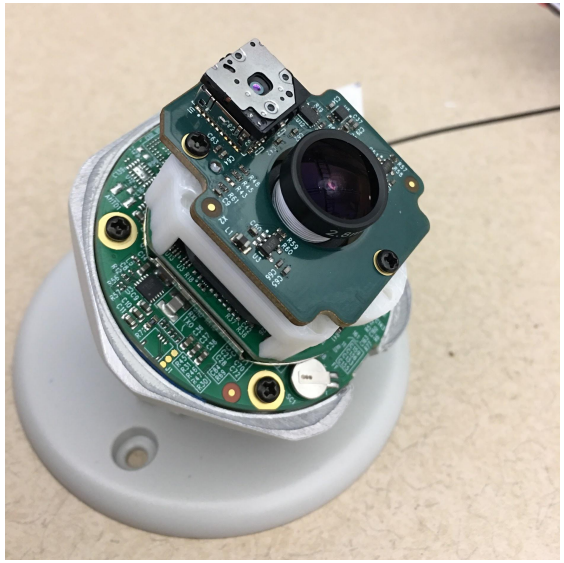


Figure 45: Visible Camera + Lepton

Full Block Diagram

Ambarella Camera Processor

- Small, powerful processor capable of streaming with low-power demands
  - Thermally contained
- Advanced image processing and video encoding for high resolution
  - 180˚ view
  - Multi-streaming capability
- Advanced video analysis capabilities
  - Intelligent motion detection
  - Face detection and tracking
  - Object detection

Figure 46: Ambarella Processor

Passive IR Detector

Part: Parallax #555-28027 Rev B

- 30 ft range, 90° FOV
- Price: $12
- Source: 3.3 V DC, 3mA active

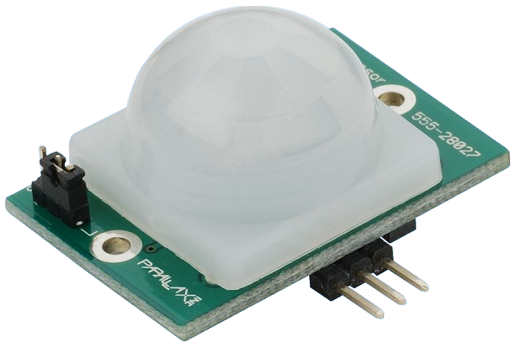


Figure 47: PIR Sensor

Lux Sensor

- TSL2561
  - I2C interface
  - able to conduct specific light ranges from 0.1 - 40k+
  - Source: 3V DC, 0.6mA max

- Lux Range
  - Sunlight (>100,000)
  - Full Moon (.108)

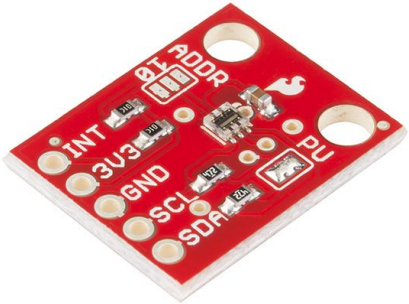


Figure 48: Lux Sensor

Antenna

- Directional Antenna (2.4GHz band)
  - Vertical Polarization
  - 5dB Gain
- IP67 Rating
  - Male RPSMA Header

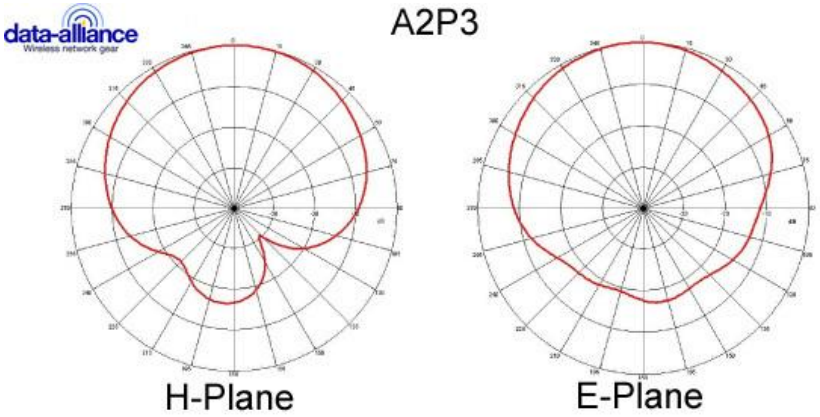


Figure 50: Magnetic and Electric Reference Planes

Figure 49: Directional Antenna

Pole Mounting Solutions

Figure 51: Eyetrax Pole Mount 4-16”

Mounts To:

- Aluminum Light Poles
- Fiberglass Poles
- Decorative Poles

Figure 52: Tree Mount

Like with Eyetrax version, this mount features steel straps to allow for flexible sizing

Figure 53: Pole Mount

On this design, the mount features a clamp. This provides more strength, but limits the versatility..

Wall Mounting Solutions

- Mounts will be set in common materials such as, wood, brick, steel, and drywall
- These mounts will require drilled holes for wall anchors

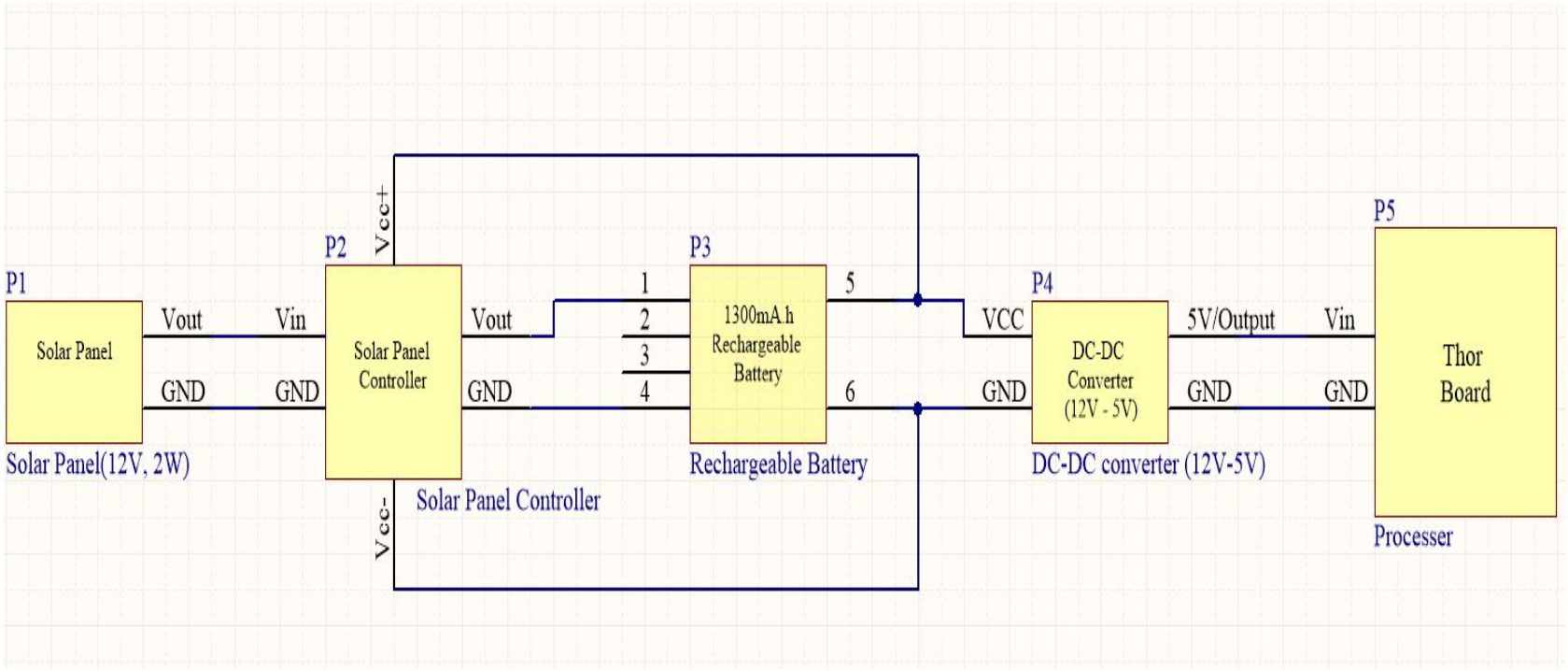
Figure 54: Wall Mount

Figure 55: Wall Mount

Figure 56: Wall Mount

Figure 57: Wall Mount

Schematic Circuit Diagram



Power Consumption

Component	Power consumption (max)	Efficiency
Solar panel controller	0.076W	>96.2%
DC-DC converter	0.08W	>96%
Thor Board	2W	

Output power required: 2W
Input voltage required: 5V
Operating time per day: 15 min
Sunshine time over 10 days: 2.9 hr
Total power consumption(max): 2.156W
Total energy needed for 10 days:

$$(2+0.08+0.076)*15*60*10\text{days}=19.4\text{kJ}$$

$$19.4\text{kJ}/(2.9*3600)=1.86\text{W}$$

Thus, we choose a 2W solar panel.

Solar Panel/Battery

Which ones we chose

Assumptions

	Length (inch)	Width (inch)	Height (inch)	Weight (lbs)
Lipo Battery	2.76	1.26	0.87	0.22
Solar Panel	13.75	5.00	0.50	1
DC-DC converter	1.77	1.30	0.91	0.066
Regulator	1.7	0.825	0.38	0.017
Solar panel controller	4.25	2.75	0.75	0.35

Power Usage

	theoretical value	practical value	efficiency
Solar Panel Output Power	2W	1.85W (High light intensity)	>92.5%
Solar Panel Controller power consumption	0W	0.076W	>96.2%
Rechargeable Battery output Voltage	12V	11.8V	
DC-DC converter power consumption	0W	0.08W	>96%
DC-DC converter output Voltage	5V	5.02V	

Real World Test

4: AA batteries to provide 6 volts (5.5 volts measured)

8: 100Ω resistors resulting in a net resistance of 14Ω

$$P = \frac{V^2}{R} = \frac{(5.5V)^2}{14\Omega} = 2.16 \text{ Watts}$$

P = Power in Watts

V = Voltage

R = Resistance

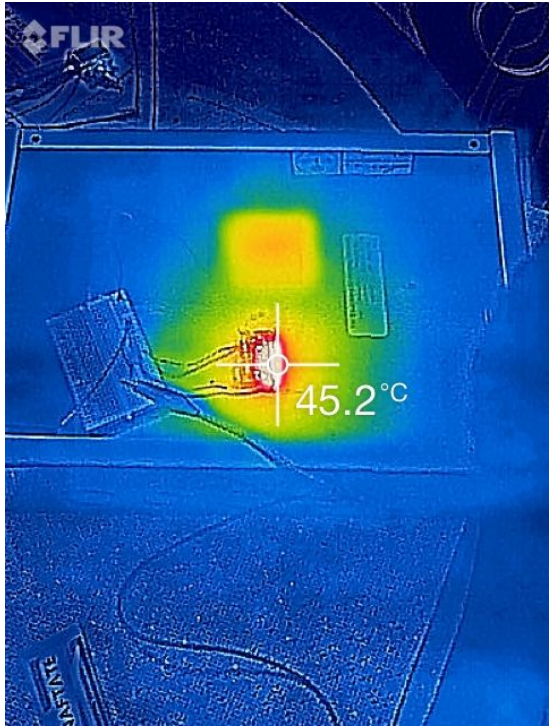


Figure 58: Real World Test
PC: FLIR ONE

Material Selection Criteria

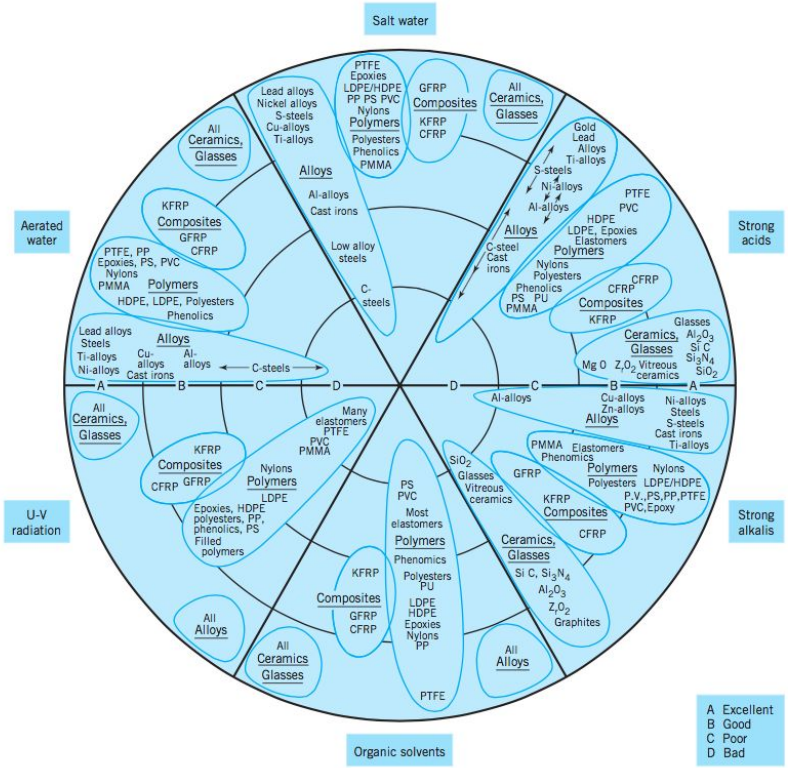


Figure 59: Corrosion Resistance Chart

- Manufacturing costs
- Corrosivity
- Wall thickness currently ~6mm

Material Selection Criteria

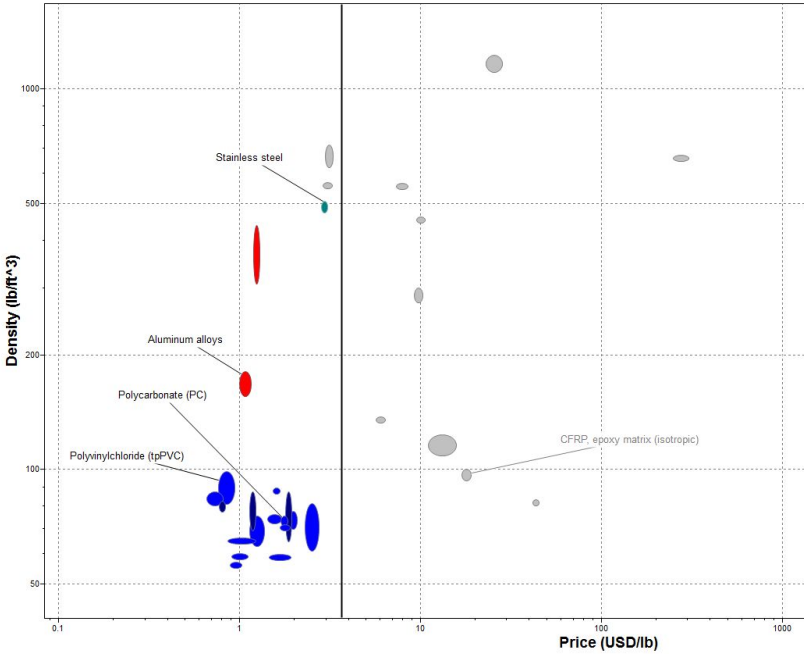


Figure 60: Density vs. Price Ashby Chart

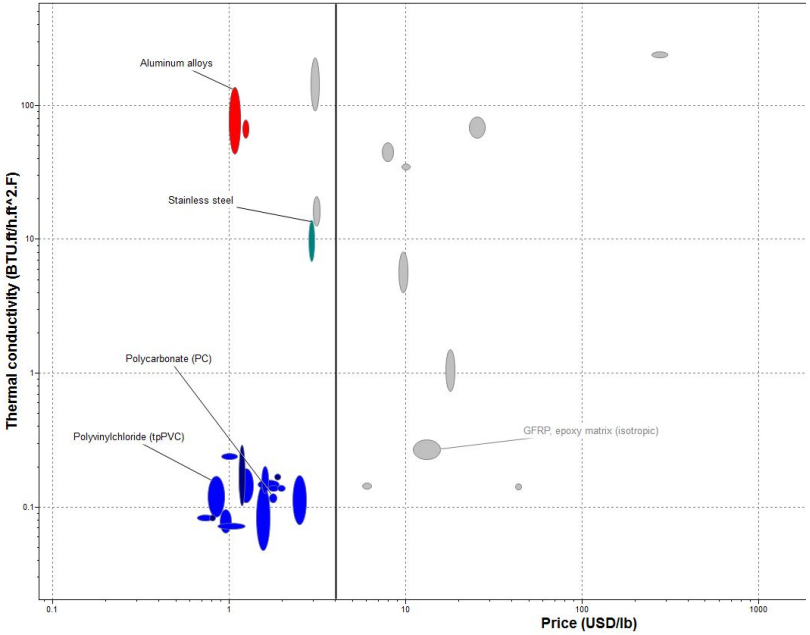


Figure 61: Thermal vs. Price Ashby Chart

Material Selection

- Weight of electronics= 2 lbs
- Weight of everything other than housing = 4lbs
- Weight of housing = 6 lbs
- Weight of 3D print = 1 lb
- Density of 3D print = 1.25 g/cm^3

$$\rho = \frac{W}{V} = \frac{6lb}{\frac{1lb}{.045\frac{lb}{in^3}}} \approx 500\frac{lb}{in^2}$$

Waterproofing

- L-3 Communications
  - 30 years of experience
  - 2000m depth sealing for 40 year life-span
  - Undersea cable routing

COMSOL Parameters

Name	Expression	Value	Description
L	12 [in]	0.3048 m	
H	8 [in]	0.2032 m	
L2	(12-1/6) [in]	0.30057 m	
H2	(8- 1/6) [in]	0.19897 m	
l_thor	23 [mm]	0.023 m	
h_thor	10 [mm]	0.01 m	
w_chip	15 [mm]	0.015 m	
h_chip	1.1 [mm]	0.0011 m	
l_chip	15 [mm]	0.015 m	
Q	2.223 [W]	2.223 W	
rho_0	1.225 [kg/m^3]	1.225 kg/m^3	
T_amb	20 [degC]	293.15 K	
alpha	1/100	0.01	

*convection coefficient, h, assumed to be 10 $W/(m^2K)$ based on common values for air

Flow Velocity

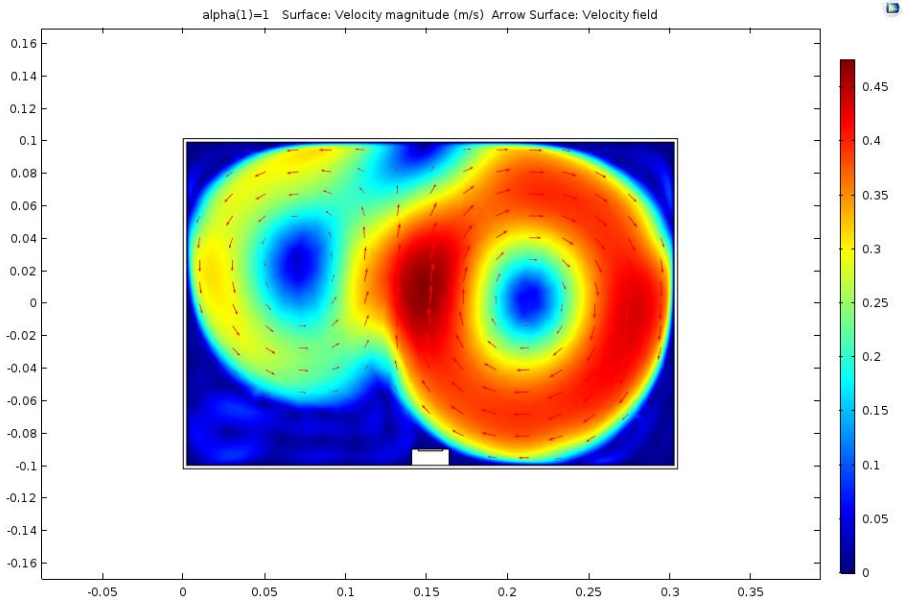


Figure 62: Heat Transfer: Turbulent Flow

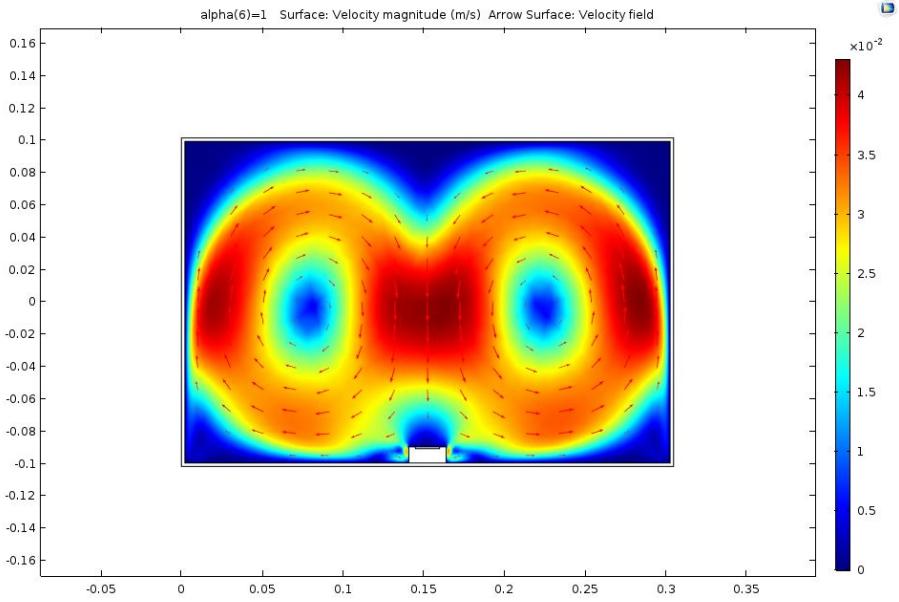
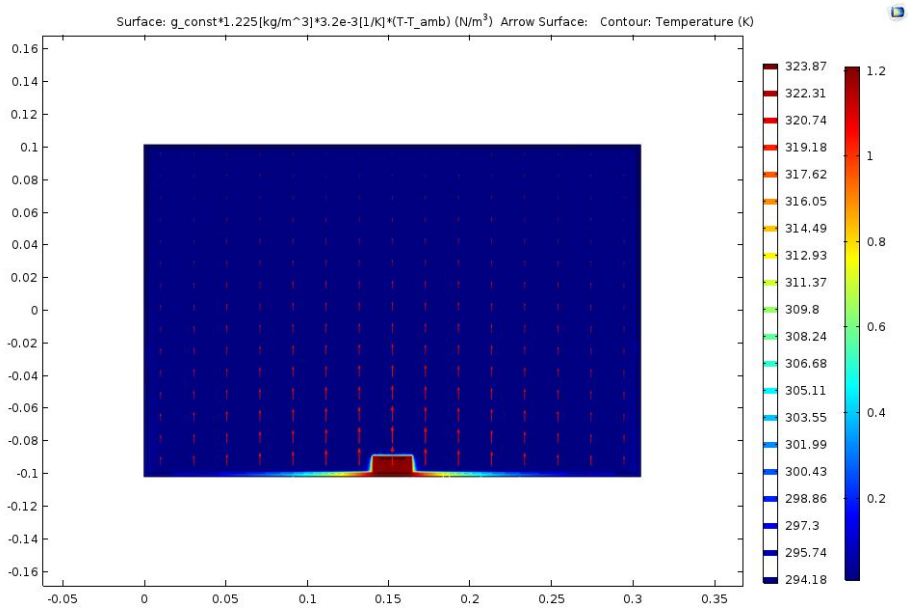


Figure 63: Buoyancy Included: Laminar Flow

Buoyancy Forces



Volume force: *

F: 0 (x); g_const*1.225[kg/m^3]*(T-T_amb)/T_amb*alpha (y) N/m³

Volume force:

F: 0 (x); g_const*1.225[kg/m^3]*(3.2e-3[1/K])*(T-T_amb)*alpha (y) N/m³

Figure 64: Buoyancy Forces

* https://www.comsol.com/blogs/using-the-boussinesq-approximation-for-natural-convection/

Desired Arrangement

How we will create the MIPI flat flex cable (FFC) extension:

- Design a schematic and layout for PCBs that will extend the connectors using a FFC.
- Each PCB will have a Hirose connector and an FFC.
  - 1-layer process
  - One connector corresponding to the camera module
  - Another connector to connect directly to the board

Design Risk Analysis

Risk	Severity	Probability	Rating	Comments
Temperature Mismanagement	4	4	16	High outside temperature and internal power output
Water leak into the housing	5	3	15	Little experience with waterproofing
Vandalism	3	5	15	Will happen regardless of measures taken
Signal Interference	5	2	10	Interruption in signal between camera and computer/recorder
Dirt on the solar panel	2	5	10	Inadequate power to the camera
Damage in 70+ MPH wind	3	3	9	Unknown force by wind and objects striking the camera
Ice/Snow on the lens	4	2	8	Obstruction of the lens
Attachment Failure	5	1	5	Customer may not attach the camera correctly
Battery life cycle	1	4	4	Battery will lose storage capacity

Approximate Locations

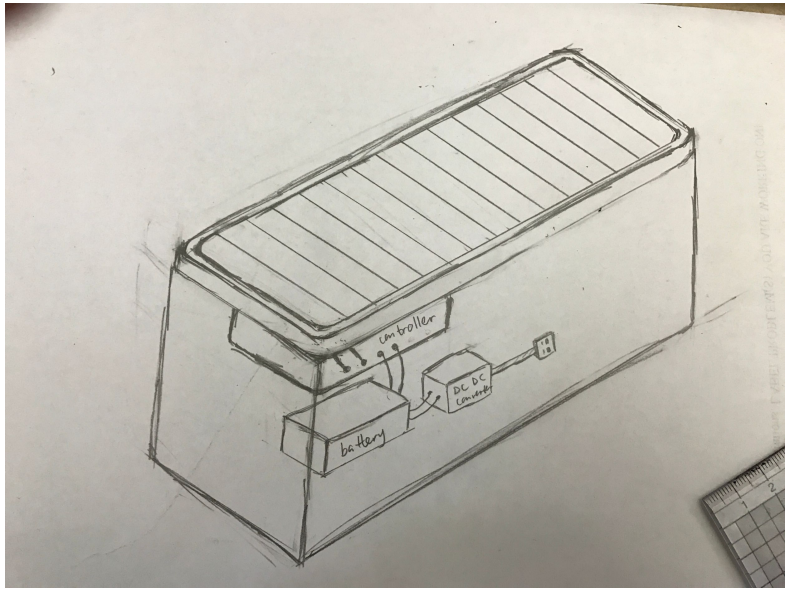


Figure 65: Approximate Locations

Figure 66: Approximate Locations (CAD)