FLIR Helios

A wireless security camera, powered by the sun

2016-2017 Senior Capstone Engineering Design Project

The World’s Sixth Sense™

12/2/2016
Presentation Overview

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

● 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

*Figure 7: Videofied*
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

<table>
<thead>
<tr>
<th>Risk</th>
<th>Severity</th>
<th>Probability</th>
<th>Rating</th>
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<tbody>
<tr>
<td>Temperature Mismanagement</td>
<td>4</td>
<td>4</td>
<td>16</td>
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<tr>
<td>Water leak into the housing</td>
<td>5</td>
<td>3</td>
<td>15</td>
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<tr>
<td>Vandalism</td>
<td>3</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Signal Interference</td>
<td>5</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Dirt on the solar panel</td>
<td>2</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Damage in 70+ MPH wind</td>
<td>3</td>
<td>3</td>
<td>9</td>
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<tr>
<td>Ice/Snow on the lens</td>
<td>4</td>
<td>2</td>
<td>8</td>
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<tr>
<td>Attachment Failure</td>
<td>5</td>
<td>1</td>
<td>5</td>
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<tr>
<td>Battery life cycle</td>
<td>1</td>
<td>4</td>
<td>4</td>
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</table>
# Engineering Specifications

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

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

** Continuous power on operations.
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*
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

Lux Sensor
- Camera switching

Accelerometer
- Sense Tampering

*Figure 13: PIR Sensor*
*Figure 14: Lux Sensor*
*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
Power Block Diagram
(Current Design)

USB port → Processor

DC-DC Converter (12V to 5V) → Power Management

Battery (12V output) → Solar Panel controller

Solar Panel (2W, 12V output)
Solar Panel

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

Figure 18: Amorphous Solar Panel
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

*Figure 19: Solar Panel Controller*
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

Figure 24: Preliminary Design
Material Selection

- Cost
- Corrosivity
- Density
- Thermal

Material Ashby Chart

- Al Alloy
- tuPVC
- PC
- Stainless

Price per Pound
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

\[ Q_{\text{electric}} = \frac{T_{\text{max}} - T_{\text{inf}}}{R_{\text{net}}} \]

\[ T_{\text{max}} = T_{\text{inf}} + Q_{\text{electric}} R_{\text{net}} \]

\[ Q_{\text{electric}} \] = Heat dissipation from processor

\[ T_{\text{max}} \] = Max temperature of processor

\[ T_{\text{inf}} \] = Temperature of ambient

\[ R_{\text{net}} \] = Net resistance of thermal circuit

1 dimensional thermal analysis

\[ T_{\text{max}} = 56.3^\circ\text{C} \]

2 dimensional thermal analysis

\[ T_{\text{max}} = 49.9^\circ\text{C} \]
Real World Test

4 AAA batteries
8 100Ω resistors

\[ P = \frac{V^2}{R} = 2.26\text{W} \]

P = Power in Watts
V = Voltage
R = Resistance

Figure 30: Real World Test
PC: FLIR ONE
Thermal Analysis with COMSOL

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

*Figure 31: COMSOL Models*
Thermal Analysis with COMSOL

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

*Figure 32: COMSOL Models*
Design Evolution

Figure 33: Cylindrical vs. Rectangular Design

Figure 34: First Preliminary Design

Figure 35: Preliminary Design
Website Support/Android App

- 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)

- USB port
- Processor
- DC-DC Converter (12V to 5V)
- Power Management
- Solar Panel controller
- Solar Panel (2W, 12V output)
- Battery (12V output)
Power Block Diagram
(Future Improvement)

- **Solar Panel** (2W, 12V output)
- **Solar Panel controller**
- **Battery Monitor**
- **Battery (12V output)**
- **DC-DC Converter (12V to 5V)**
- **USB port**
- **Processor**
- **Power Management**
Housing Review

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

*Figure 43: Wall thickness considerations*
Future Timeline

- Start Project: 9/16
- Design Presentation: 12/2/16
  - Finalized Design: 2/10/17
  - THOR and Power: 2/10/17
  - Working Prototype: 3/24/17
- Finished Product: 5/12/17
- Poster & Presentation: 6/7/17
Thank you!

PC: FLIR ONE
Additional Slides
# Customer Needs & Characteristics

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

<table>
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<th>Model</th>
<th>Ranger</th>
<th>Mega</th>
<th>Predator</th>
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<tbody>
<tr>
<td>Price ($)</td>
<td>2,400</td>
<td>6,500</td>
<td>6,500</td>
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<tr>
<td>Communication</td>
<td>Cellular</td>
<td>Cellular</td>
<td>Cellular</td>
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<tr>
<td>Capture Media</td>
<td>Still images</td>
<td>Still Images</td>
<td>Video &amp; Images</td>
</tr>
<tr>
<td>Power Supply</td>
<td>Solar w/ internal Battery</td>
<td>Solar w/ internal Battery</td>
<td>Solar w/ internal Battery</td>
</tr>
<tr>
<td>Resolution</td>
<td>1600x1200</td>
<td>4000x3000</td>
<td>2560x1920</td>
</tr>
<tr>
<td>Night Vision</td>
<td>IR (IR Lights)</td>
<td>N/A</td>
<td>IR (IR Lights)</td>
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<tr>
<td>Night Vision Range (m)</td>
<td>46</td>
<td>N/A</td>
<td>46</td>
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<tr>
<td>Motion Detect Range (m)</td>
<td>12</td>
<td>N/A</td>
<td>12</td>
</tr>
<tr>
<td>Camera Mount</td>
<td>Fixed</td>
<td>Pan &amp; Tilt</td>
<td>Pan &amp; Tilt</td>
</tr>
<tr>
<td>Battery Life (hours)</td>
<td>240</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>6</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Other</td>
<td>Windshield Wiper</td>
<td>Uses 2 Solar Panels</td>
<td></td>
</tr>
<tr>
<td>Pan &amp; Tilt Weight (lbs)</td>
<td>N/A</td>
<td>15</td>
<td>15</td>
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</table>

<table>
<thead>
<tr>
<th>Solar Panel</th>
<th>EyeTrax Solar Panel</th>
<th>Skyway Security</th>
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</thead>
<tbody>
<tr>
<td>Weight (lbs)</td>
<td>8</td>
<td>N/A</td>
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<tr>
<td>Dimension</td>
<td>22&quot;x16&quot;x1&quot;</td>
<td>N/A</td>
</tr>
<tr>
<td>Power (W)</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>Max SP Distance (ft)</td>
<td>115</td>
<td>N/A</td>
</tr>
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</table>
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 accessories, 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)
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 49: Directional Antenna

Figure 50: Magnetic and Electric Reference Planes
Pole Mounting Solutions

Mounts To:
- Aluminum Light Poles
- Fiberglass Poles
- Decorative Poles

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

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
### Power Consumption

<table>
<thead>
<tr>
<th>Component</th>
<th>Power consumption (max)</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar panel controller</td>
<td>0.076W</td>
<td>&gt;96.2%</td>
</tr>
<tr>
<td>DC-DC converter</td>
<td>0.08W</td>
<td>&gt;96%</td>
</tr>
<tr>
<td>Thor Board</td>
<td>2W</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Length (inch)</th>
<th>Width (inch)</th>
<th>Height (inch)</th>
<th>Weight (lbs)</th>
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</thead>
<tbody>
<tr>
<td>Lipo Battery</td>
<td>2.76</td>
<td>1.26</td>
<td>0.87</td>
<td>0.22</td>
</tr>
<tr>
<td>Solar Panel</td>
<td>13.75</td>
<td>5.00</td>
<td>0.50</td>
<td>1</td>
</tr>
<tr>
<td>DC-DC converter</td>
<td>1.77</td>
<td>1.30</td>
<td>0.91</td>
<td>0.066</td>
</tr>
<tr>
<td>Regulator</td>
<td>1.7</td>
<td>0.825</td>
<td>0.38</td>
<td>0.017</td>
</tr>
<tr>
<td>Solar panel controller</td>
<td>4.25</td>
<td>2.75</td>
<td>0.75</td>
<td>0.35</td>
</tr>
</tbody>
</table>
## Power Usage

<table>
<thead>
<tr>
<th>Component</th>
<th>Theoretical Value</th>
<th>Practical Value</th>
<th>Efficiency</th>
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<tbody>
<tr>
<td>Solar Panel Output Power</td>
<td>2W</td>
<td>1.85W (High light intensity)</td>
<td>&gt;92.5%</td>
</tr>
<tr>
<td>Solar Panel Controller power consumption</td>
<td>0W</td>
<td>0.076W</td>
<td>&gt;96.2%</td>
</tr>
<tr>
<td>Rechargeable Battery output Voltage</td>
<td>12V</td>
<td>11.8V</td>
<td></td>
</tr>
<tr>
<td>DC-DC converter power consumption</td>
<td>0W</td>
<td>0.08W</td>
<td>&gt;96%</td>
</tr>
<tr>
<td>DC-DC converter output Voltage</td>
<td>5V</td>
<td>5.02V</td>
<td></td>
</tr>
</tbody>
</table>
Real World Test

4: AA batteries to provide 6 volts (5.5 volts measured)
8: 100Ω resistors resulting in a net resistance of 14Ω

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

\begin{align*}
P &= \text{Power in Watts} \\
V &= \text{Voltage} \\
R &= \text{Resistance}
\end{align*}
Material Selection Criteria

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

Figure 59: Corrosion Resistance Chart
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 = 4 lbs
- Weight of housing = 6 lbs
- Weight of 3D print = 1 lb
- Density of 3D print = 1.25 g/cm^3

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

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

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

*convection coefficient, h, assumed to be 10 W/(m^2K) based on common values for air*
Figure 62: Heat Transfer: Turbulent Flow

Figure 63: Buoyancy Included: Laminar Flow
Figure 64: Buoyancy Forces

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

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

Figure 65: Approximate Locations

Figure 66: Approximate Locations (CAD)