Thermal Threat Detector

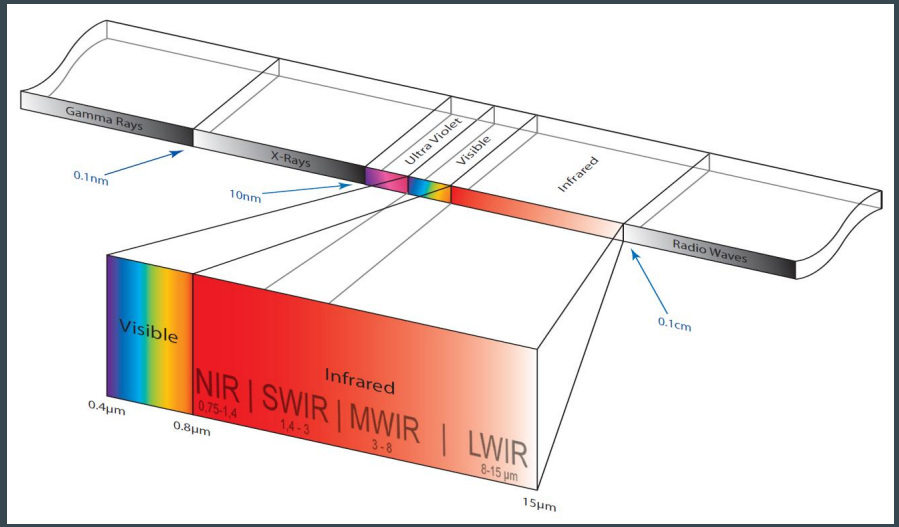
Photo Science Capstone 2023-24
November 16th, 2023

Overview

- Design and develop a thermal imaging system that can detect a suspected threat in a room with no lighting.
- The device must be able to enter a room and return images to the operator.

Thermal Cameras

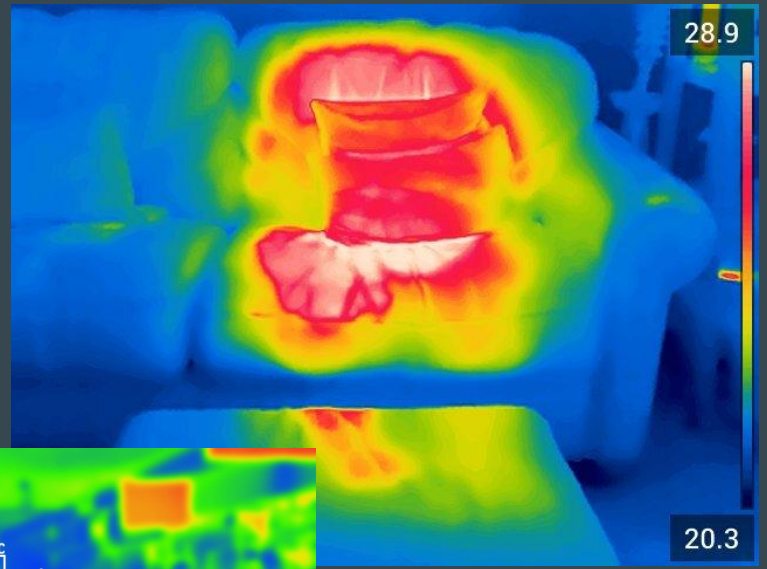
Thermal cameras allow us to view infrared radiation emitted from an object. Allowing the user to see past the “visual spectrum” by using applied colors through thermal images.

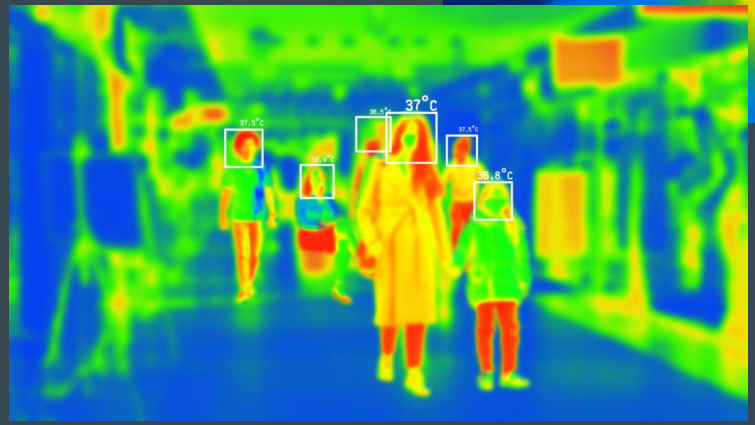


https://www.ametek-land.com/pressreleases/blog/2021/june/thermalinfraredrangeblog

Thermal Image

- Thermal color palette applied to image
- Color differences represent temperature differences
- Works in the dark and low light situation, because it detects invisible heat radiation





https://www.edge-ai-vision.com/2022/12/thermal-imaging-the-chinese-advantage/

On The Market Now

FLIR Elara™ DX-Series multispectral pan/tilt/zoom security camera

Pros

Thermal Imaging

Detection and Identification

Pan and Tilt Movement

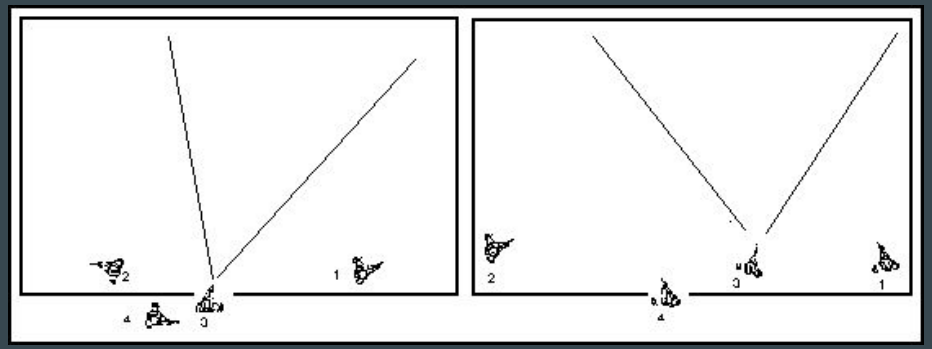
Cons

Limited User Control

Limited Field of View - 61* FOV

Unaffordable Price - $15,000

Dealing with Threats



- Robots can be used on-site to understand the scene while providing a safer option than a person having to enter the room with the known threat.

Requirements

Size: The device should be around 14 in (d) x 4 in (h).

Sound: The device must be able to operate with minimal sound output.

Mobility: The system must be on the ground.

Operation: The device must be operative in manual mode, but if possible, it should be able to switch between manual and autonomous modes.

Power: The device should last at least 1 hour on a single charge.

Camera: The imaging system should have multiple thermal cameras able to detect a range of human body temperatures.

Requirements

Field of View: The imaging system should achieve 180 degrees.

Users View: Wireless live view, from a safe distance.

GUI: The GUI must have a button to allow the user to capture a picture.

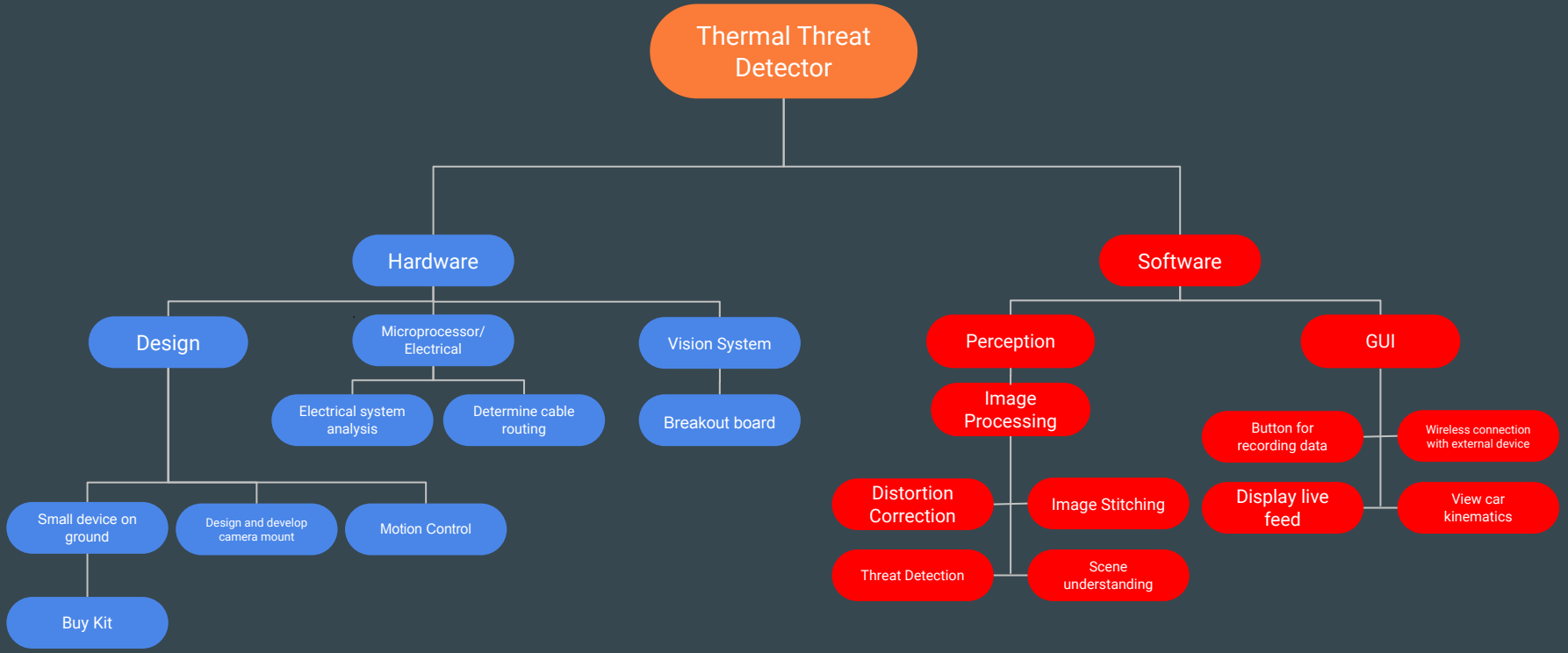
Resolution: The system should be able to resolve a human being.

Lens: The lens should be a fixed focus lens.

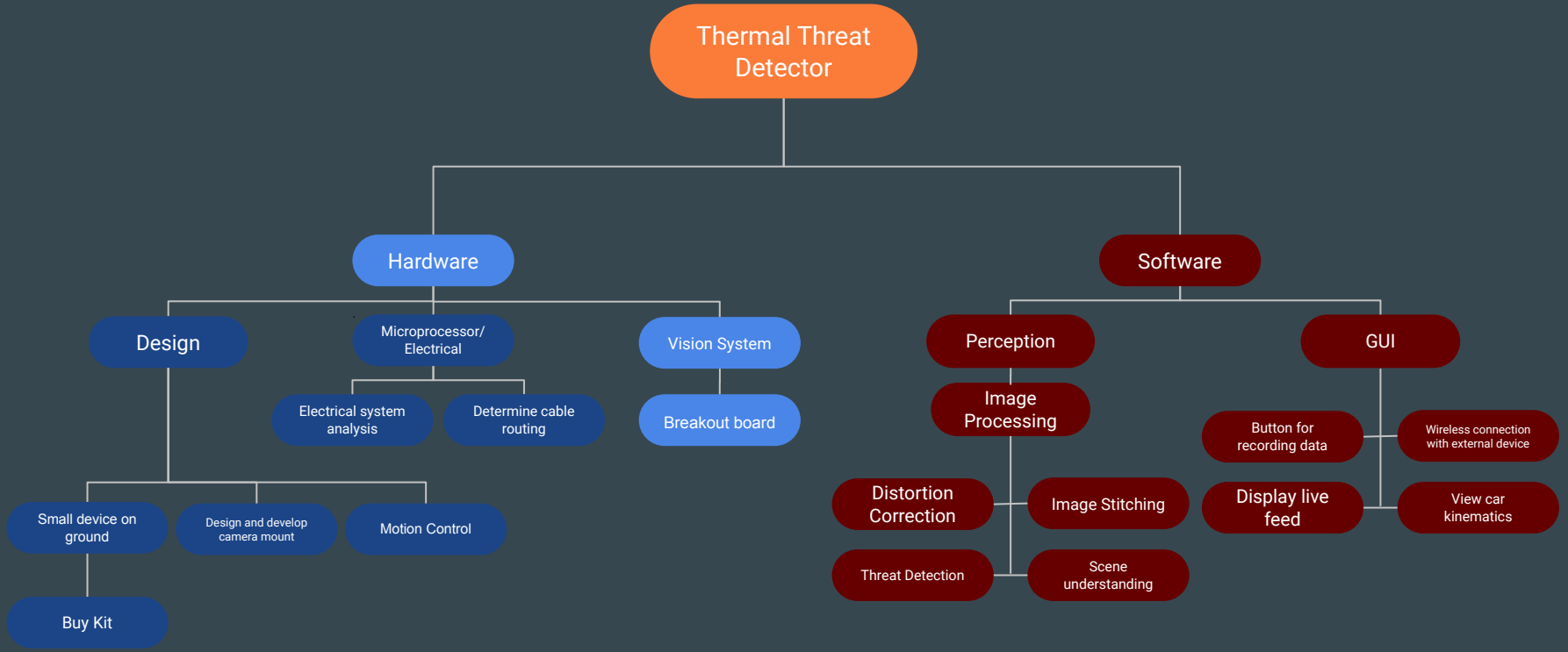
Budget: The budget is $3,000.

Completion date: The completion date is April 27, 2024 at Imagine RIT.

Work Breakdown Structure



Work Breakdown Structure - Vision System Design



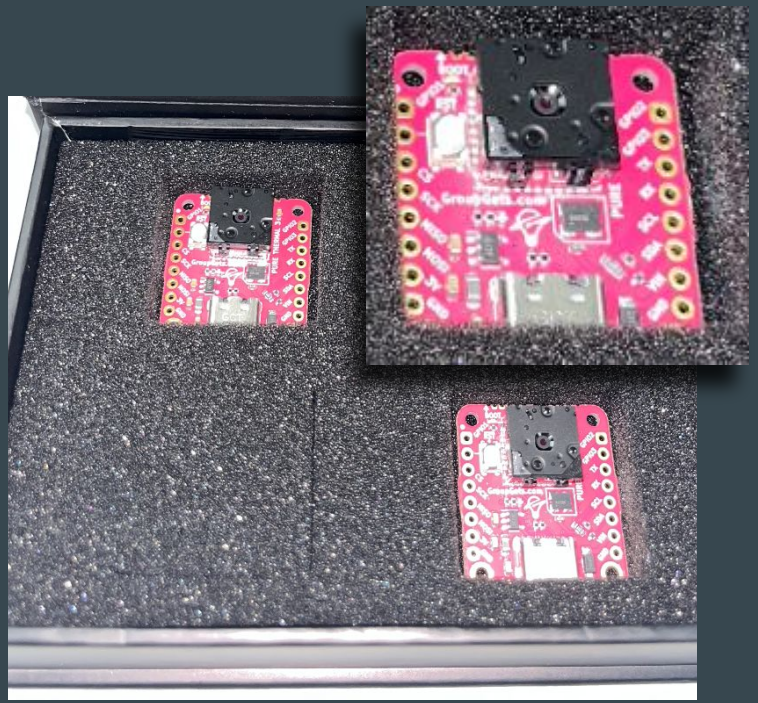
Pugh Analysis - Camera

Criteria	Weight	Lepton 3.1R	FLIR K1	FLIR C3-X	SN-TPC4201VT-F (III)	Klein Tools Pro	HIK Vision
Price	5	$142	$499	$589	N/A	$499	$480
Resolution	5	160x120	160x120	128x96	400x300	480x320	2688x1520
Temperature Range	5	High Gain Mode: -10°C to 140°C Low Gain Mode: -10°C to +450°C	High Gain Mode: -10°C to 140°C Low Gain Mode: -10°C to 400°C	-20°C to 300°C	-20°C ~ 150°C	-20°C to 400°C	-20°C to +150°C
Field of View	5	95°	57° x 44°	53.6°	46° x 35.3° (H x V)	55.6° +/- 2.8°	25° x 18.7° (H x V)
Power	3	Powered by microprossecer which is controlled by a batter said to last for 90 minutes	5.5 hours	4 hours	No time frame given of how long the camera can run	No time frame given; Rechargable lithium-ion battery with 5 year lifespan	No time frame given of how long the camera can run
Easy-to-Setup	1	Requires additional parts to operate	Appears to be easy to setup and operate	Might be some challenges in the setup process but appears to be achievable	User manual appears to be complicated/not giving enough information to allow us to know what we need to setup the camera for our project purposes	Might be some challenges in the setup process but appears to be achievable	Might be some challenges in the setup process but appears to be achievable
Rotate	2	Cannot Rotate on its Own	Cannot Rotate on its Own	Cannot Rotate on its Own	Cannot Rotate on its Own	Cannot Rotate on its Own	Can Rotate on its Own
Durability	1	Some durability however there are some concerns given the size of the camera	Marketed towards those who need thermal for high impact situations; very durable	Water and dust protection on camera; able to be taken to rugged enviornments	Some durability; more of a security system than a fully durable thermal camera	Comes with durable cover over the camera to help in certain situations	Some durability; more of a security system than a fully durable thermal camera
Resources/Online Information	2	Newer model; might have trouble finding additional resources	Released within the past few years; online information present to help with learning the camera	Released within the past few years; online information present to help with learning the camera	Released within the past few years; online information present to help with learning the camera	Released within the past few years; online information present to help with learning the camera	Released within the past few years; online information present to help with learning the camera
Camera Size/Shape	3	Very small in size but more of an ideal shape	Includes handle at the bottom which could pose a problem for mounting	Square shape which could make it easier to mount	More of a box shape with lens; could be relatively easy to mount	Square shape which could make it easier to mount	Dome-shaped; could pose some issues when attempting to mount
Stream on its Own	2	Cannot Stream on its Own	Cannot Stream on its Own	Cannot Stream on its Own	Can Stream on its Own	Cannot Steam on its Own	Cannot Stream on its Own

Pugh Analysis - Camera

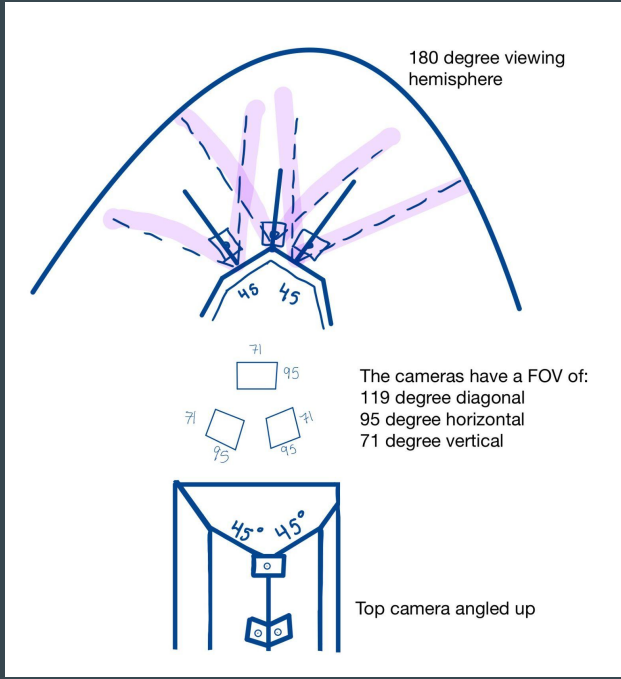
			Camera					
Baseline	**Criteria**	**Weight**	Lepton 3.1R	FLIR K1	FLIR C3-X	SN-TPC4201VT-F (III)	Klein Tools Pro	HIK Vision
$2000 total	**Price**	5	Better	Same	Worse	Worse	Same	Worse
160x120 px	**Resolution**	5	Same	Same	Worse	Better	Better	Same
97.6-99.6	**Temperature Range**	5	Better	Better	Better	Better	Better	Better
50-60	**Field of View**	5	Better	Same	Same	Worse	Same	Worse
1 hour	**Power**	3	Better	Better	Better	Worse	Worse	Worse
Per user manual	**Easy-to-setup**	1	Worse	Better	Same	Worse	Same	Same
Yes/No	**Rotate**	2	Worse	Worse	Worse	Worse	Worse	Better
Per website and description	**Durability**	1	Same	Better	Better	Same	Better	Same
Based on year released	**Reasources/online info**	2	Worse	Same	Same	Same	Same	Same
Would it be easy to create a mount	**Camera size/shape**	3	Same	Worse	Better	Better	Better	Same
Yes/No	**Stream on it's own**	2	Worse	Worse	Worse	Better	Worse	Worse
	Better		4	4	4	4	4	2
	Same		3	4	3	2	4	5
	Worse		4	3	4	5	3	4
	Weighted Better		18	10	12	15	14	7
	Weighted Same		0	0	0	0	0	0
	Weighted Worse		-7	-7	-14	-16	-7	-15
	Overall Score		11	3	-2	-1	7	-8
	Best Decision	**Lepton 3.1R**						

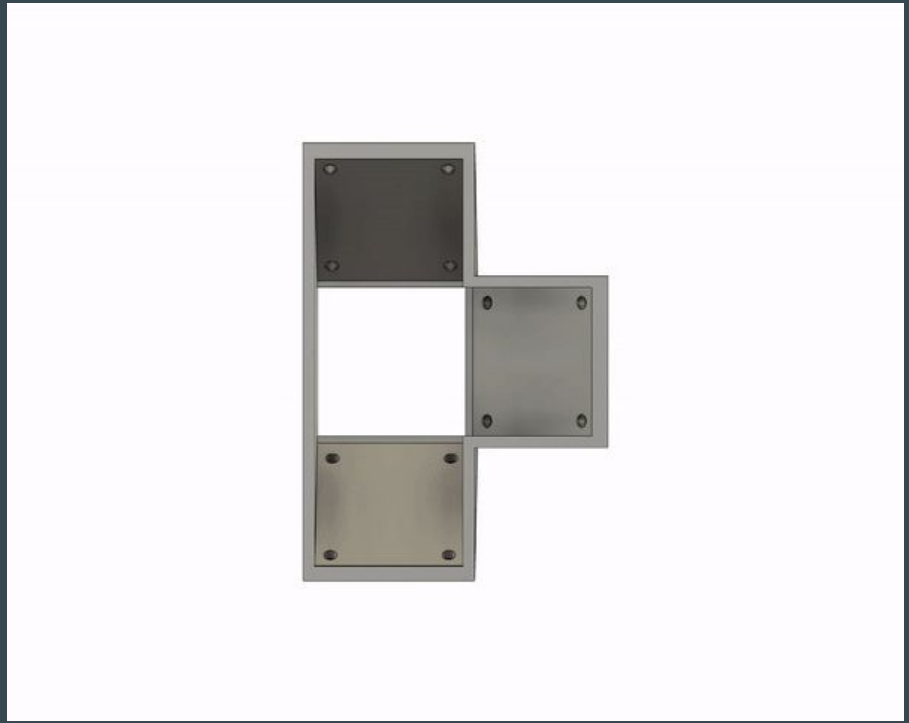
Thermal Cameras & Breakout Boards Arrived



Field of View (FOV):	95* HFOV, 71* VFOV
Thermal Imaging Detector :	Uncooled microbolometer
Frame Size :	160x120 px
Frame Rate Options :	8.6 Hz
Thermal Spectral Range :	Longwave infrared, 8 µm to 14 µm
Scene Temperature Range :	High Gain Mode : -10 ℃ to 140 ℃ Low Gain Mode : -10 ℃ to +450 ℃
Temperature Accuracy :	High Gain Mode : Greater of +/- 5 ℃ or 5% Low Gain Mode : Greater of +/- 10 ℃ or 10%

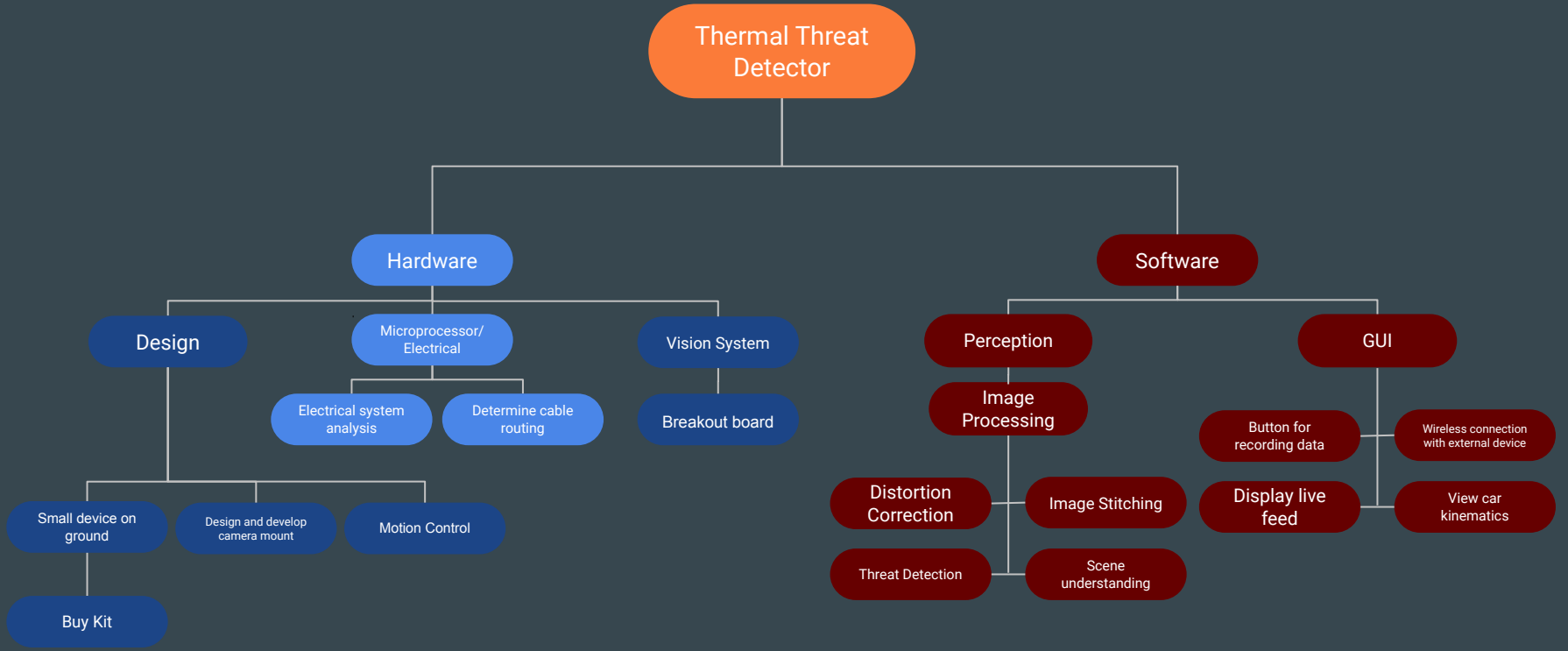
How Will We Mount The Camera





- Mount allows for 180* HFOV, 156* VFOV
- Image stitching will enable user to view entire scene seamlessly

Work Breakdown Structure - Microprocessor



Pugh Analysis - Microprocessor

Topics	Criteria	Weight	Raspberry Pi	Jetson Nano	Jetson Orin Nano	Coral
Processing	GPU	4	Broadcom VideoCore VI	128-core Maxwell	1024-core NVIDIA	GC7000 Lite Graphics
	CPU	1	Quad-core ARM A72	Quad-core ARM A57 @1.43 GHz	6-core ARM 1.5MB L2+4MB L3	NXP i.MX 8M SoC (quad Cortex-A53, Cortex-M4F)
	RAM	4	1GB, 2GB, 4GB, 8GB	4GB 64-bit	8GB. 128-bit	1GB, 4GB
Cost	Processor Cost	4	$75	$149	$499	$129
Software	SDK	5	N/A	JetPack, DeppStream	JetPack, DeppStream	N/A
Hardware	Power Efficiency	4	USB-C Power	Micro USB	bundled DC Power	USB-C Power
Expandability	USB 3.0 Ports	3	HDMI, 2 USB 3.0 ports, Gigabit Ethernet	HDMI, 4 USB 3.0 ports, Gigabit Ethernet	HDMI, 4 USB 3.1 ports, Gigabit Ethernet	HDMI, GIgabit Ethernet
	Storage	3	Micro SD card slot	Micro SD card slot	SD card slot & external NVME via M.2 Key	Micro SD card slot
Convenience	Vehicle Compatibility	5	Needs Adaptor	Vehicle Powered by Jetson Nano, Involved in Vehicle Kit	Needs Adaptor	Needs Adaptor

Pugh Analysis - Microprocessor

Topics	Criteria	Weight	Raspberry Pi	Jetson Nano	Jetson Orin Nano	Coral
Processing	GPU	4	Worse	Same	Better	Better
	CPU	1	Same	Same	Better	Same
	RAM	4	Better	Same	Better	Worse
Cost	Processor Cost	4	Better	Same	Worse	Same
Software	SDK	5	Worse	Better	Better	Worse
Hardware	Power Efficiency	4	Better	Worse	Worse	Better
Expandability	USB 3.0 Ports	3	Same	Better	Better	Worse
	Storage	3	Same	Same	Better	Same
Convenience	Vehicle Compatibility	5	Same	Better	Same	Same
	Better		3	3	6	2
	Same		4	5	1	4
	Worse		2	1	2	3
	Weighted Better		12	13	20	8
	Weighted Same		0	0	0	0
	Weighted Worse		-9	-4	-8	-12
	Overall Score		3	9	8	-4

Microprocessor - Jetson Nano

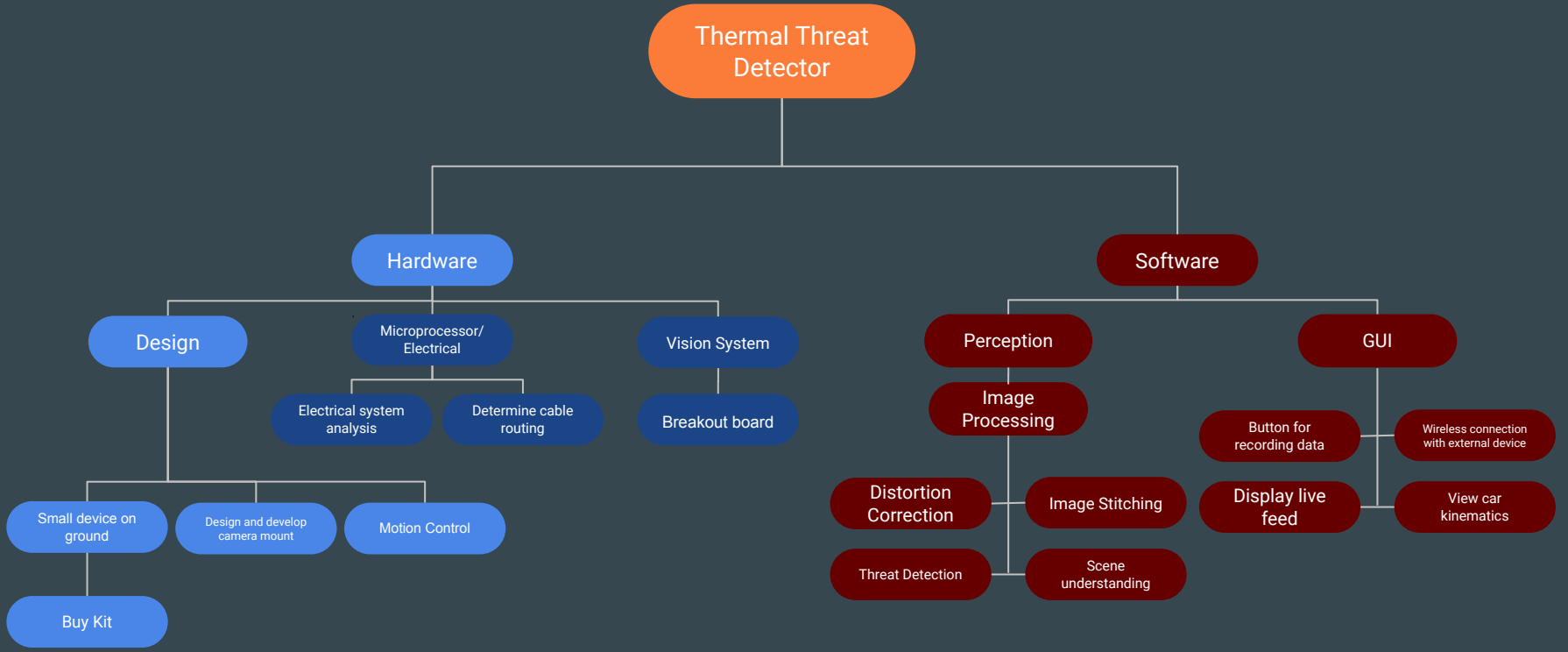
Complimentary SDK:

- JetPack
- CUDA Toolkit
- cuDNN

Seamlessly integrates with frameworks for computer vision and robotics development like OpenCV and ROS

Because of the processing power, it gives developers a lot of headroom to design and debug

Work Breakdown Structure - Hardware Design



Pugh Analysis - Vehicle

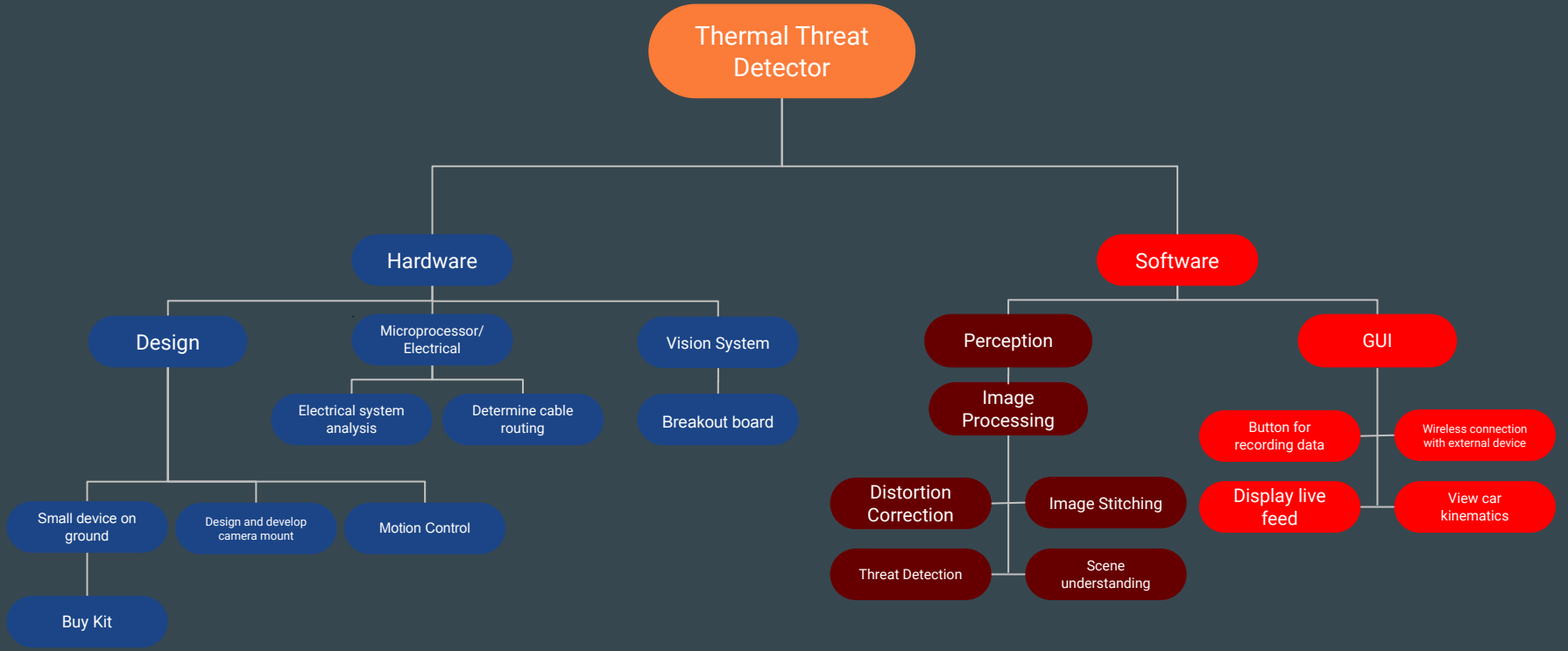
Criteria	Weight	JetRacer	JetRacer ROS AI kit	JetAcker	Jetbot
Price	4	Better	Better	Worse	Better
Size	5	Same	Worse	Better	Same
Jetson Nano	5	Same	Same	Same	Same
Platform to build on	5	Better	Same	Better	Worse
Power	4	Same	Same	Better	Better
wireless	5	Same	Same	Same	Same
Better		2	1	3	2
Same		9	9	7	8
Worse		0	1	1	1
Weighted Better		9	4	14	8
Weighted Same		0	0	0	0
Weighted Worse		0	-5	-4	-5
Overall Score		9	-1	10	3

JetAcker (Jetson Nano Included)

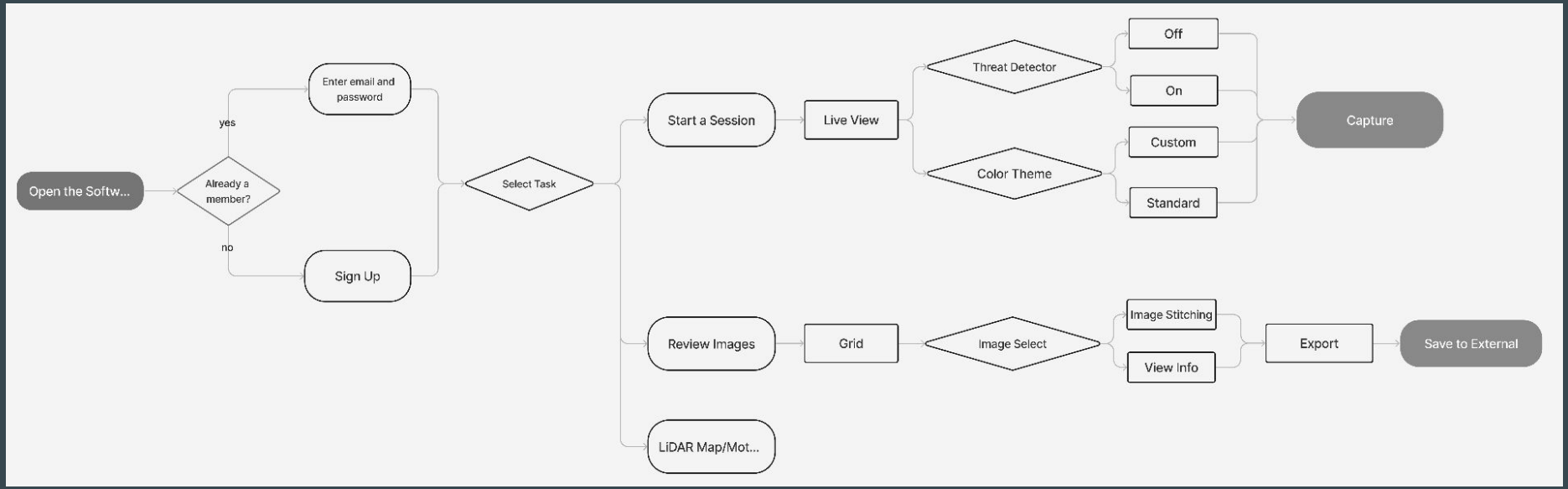
Features:

- LiDAR mapping
- Multiple communication methods (USB/ WiFi/ Ethernet)
- Multiple control methods (app/ wireless handle/ ROS)
- 90 min working life
- Compatible with Python programming language
- User programs all components

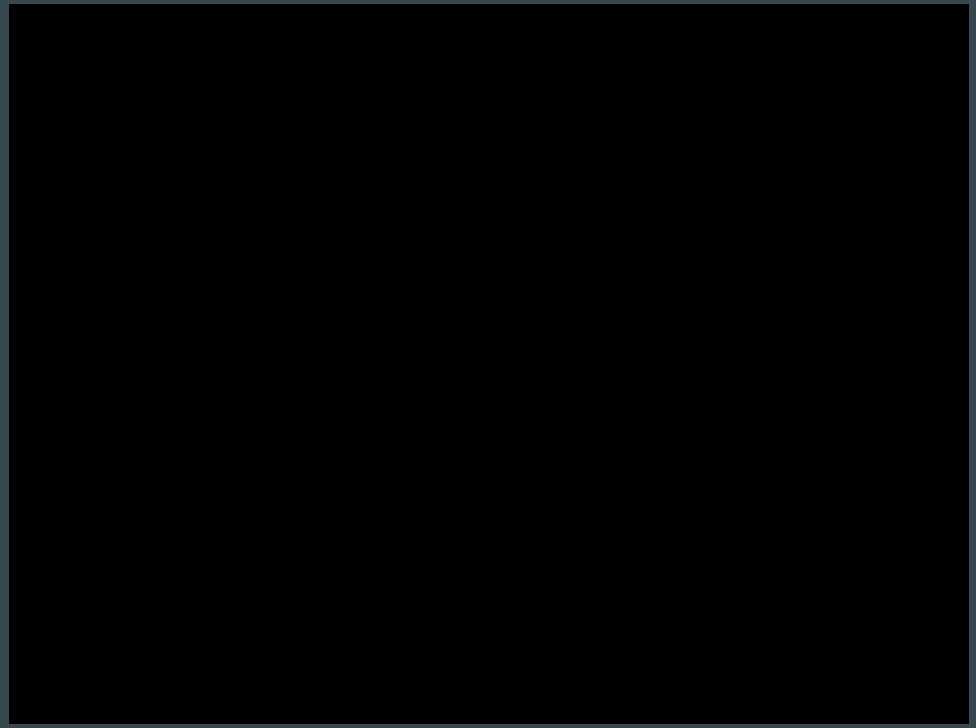
Work Breakdown Structure - GUI Design



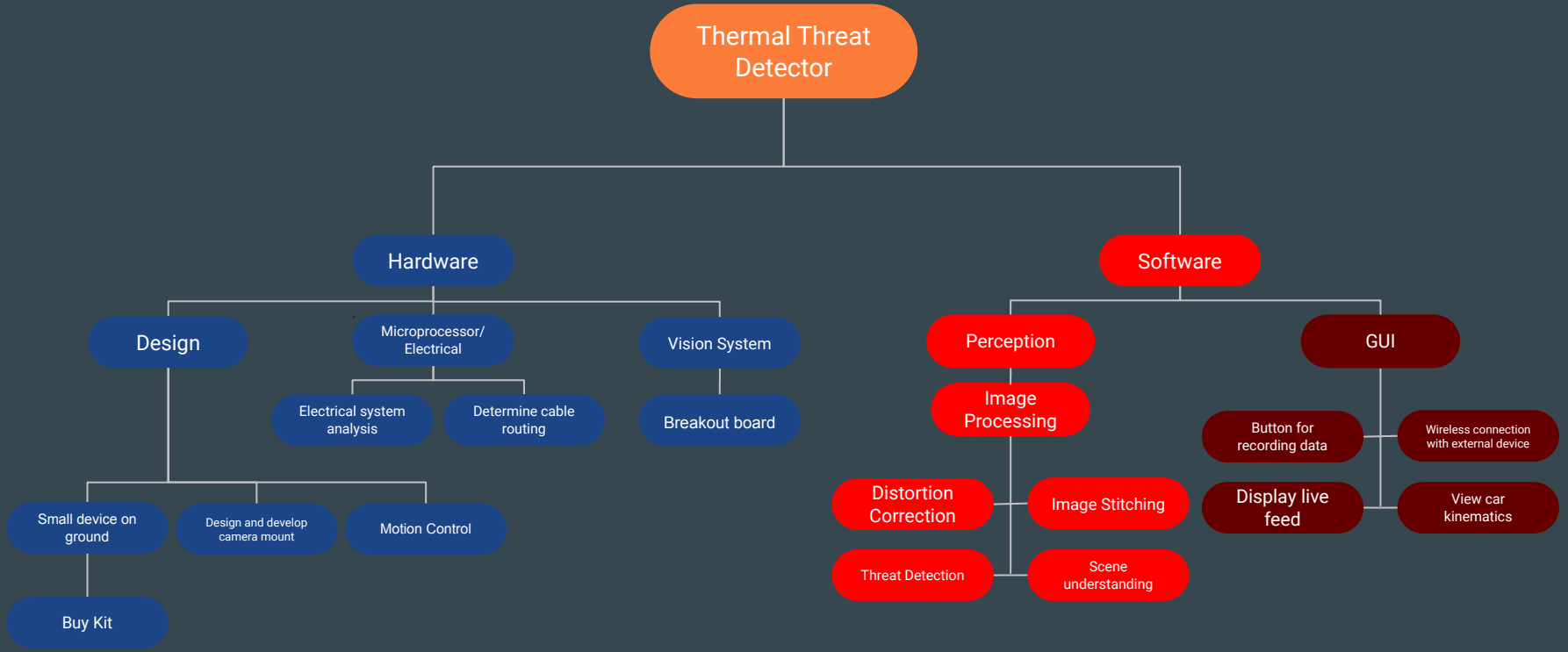
User Flow


Open the Softw...
Already a member?
yes
Enter email and password
no
Sign Up
Select Task
Start a Session
Live View
Threat Detector
Off
On
Color Theme
Custom
Standard
Capture
Review Images
Grid
Image Select
Image Stitching
View Info
Export
Save to External
LiDAR Map/Mot...

Interface Design - Lofi

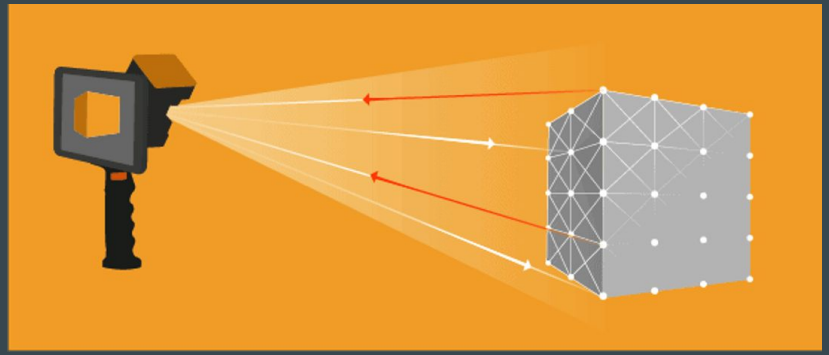


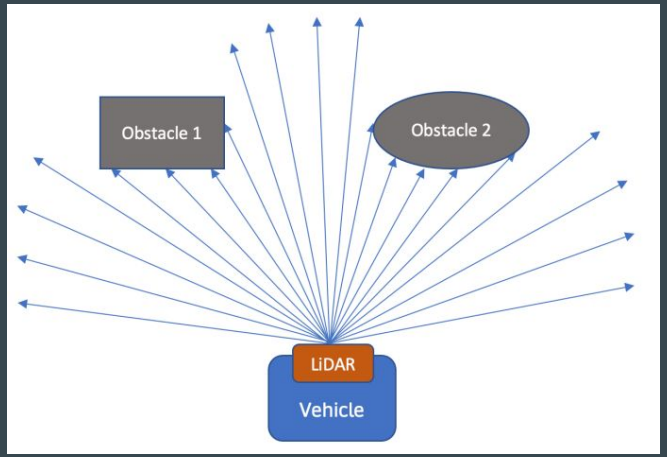
Work Breakdown Structure - Perception



LiDAR Sensors

- Predicts the surrounding environment, measuring the distance between the vehicle and an object's position.
- LiDAR systems use pulses of light to illuminate and reflect off objects in the field of vision.
- The LiDAR system we chose for our vehicle was Slamtec A1 which uses Precise 2D mapping navigation, TEB path planning and dynamic obstacle avoidance.

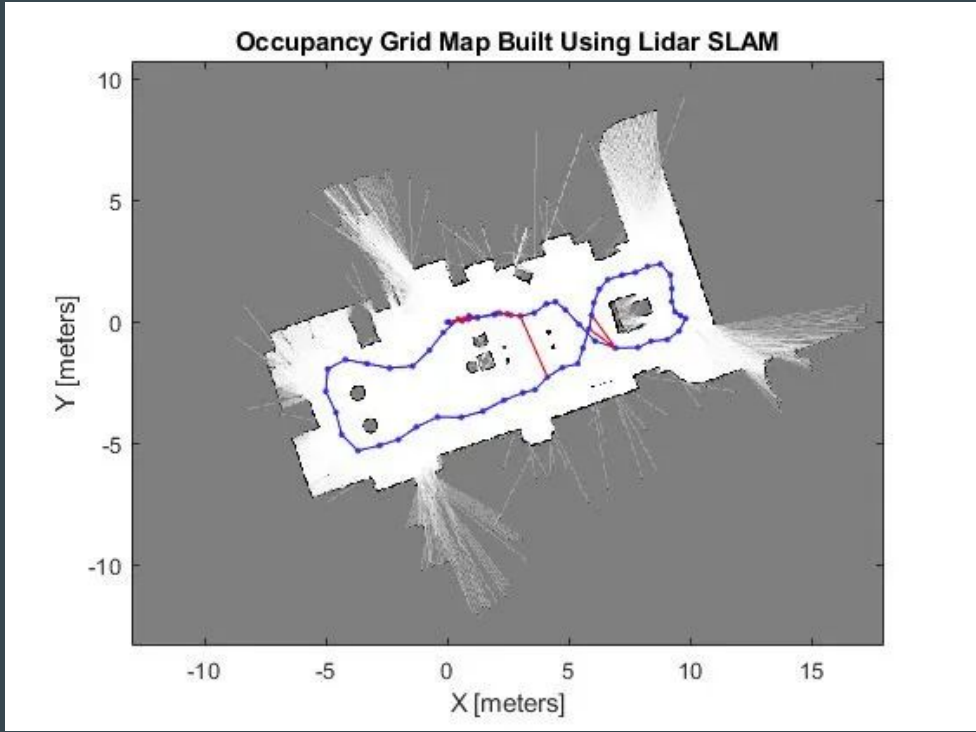




https://geoslam.com/us/what-is-lidar/

SLAM

- SLAM - Simultaneous Localization and Mapping
- Allows for real time localization and scene reconstruction
- Able to view ego trajectory
- Uses a laser sensor from LiDAR to generate a 3D map



https://geoslam.com/us/what-is-lidar/

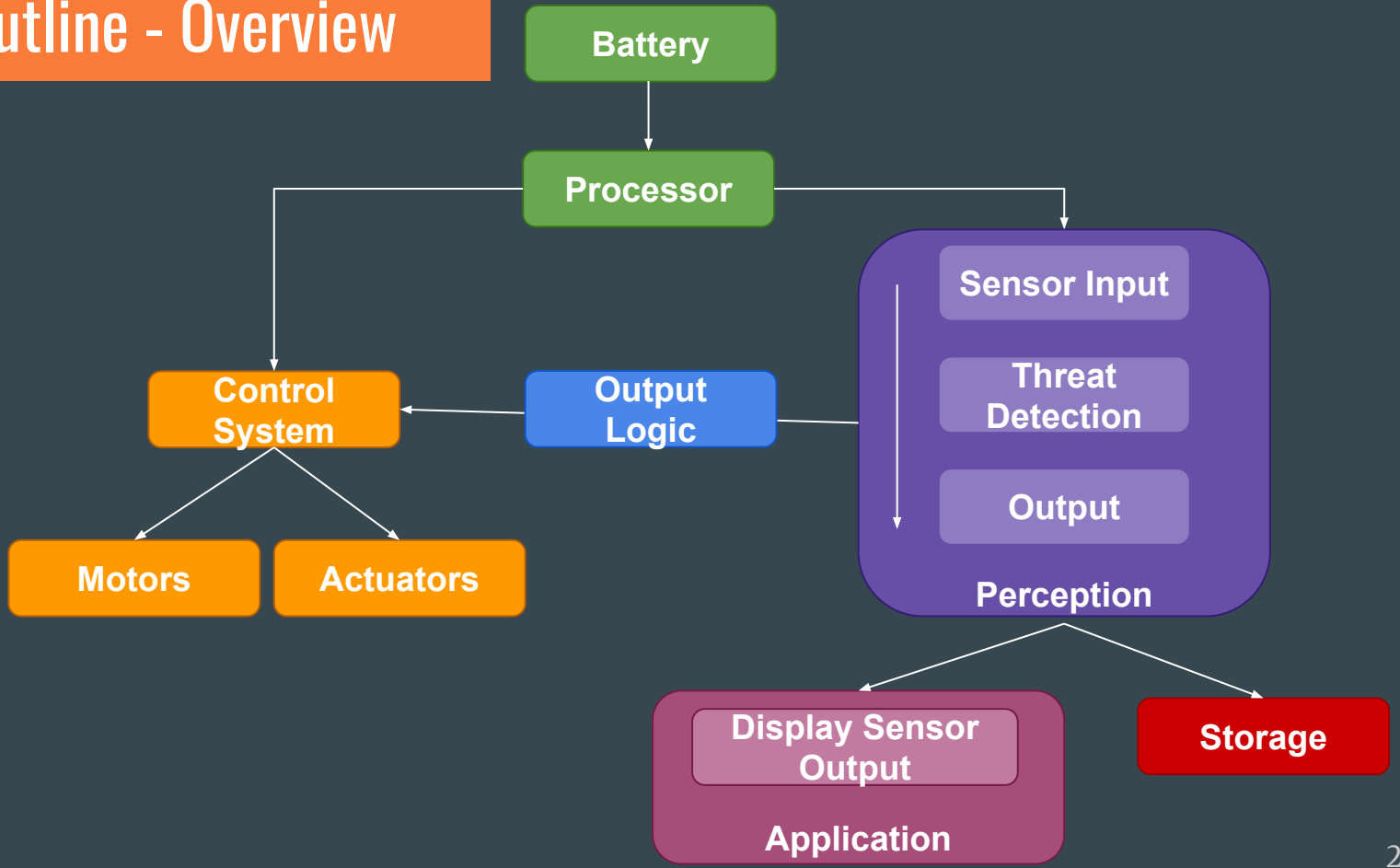
Neural Network

- FLIR ADASv2: pretrained model
- Use a pretrained model because other companies have spent a lot of money to train open source datasets
- Model had 80% accuracy, which is consistent with the current industry standard
- We can add our own data to increase robustness

Model	People	Bicycles	Cars	All*
Yolov3-spp-thermal(Small area excluded)	0.749	**0.879**	**0.865**	**0.831**
Yolov3-spp-thermal	0.590	0.756	0.795	0.714
FLIR	**0.794**	0.580	0.856	0.743

* mAP scores when all of three categories are included.

System Outline - Overview



System Architecture Information Flow

Perception
Detect/Track objects, events, conditions & predict short term evolution of these events

Localization
Find the location and pose of vehicle on map

Scene Understanding
Detect the current driving scene

Motion Control
Send control signals to vehicles actuators/motors to effect vehicle motion

Ego Motion
Measure/estimate how the vehicle is moving (wheels, steering, odometry, etc.)

Supervision
Ensure vehicle is operating within boundary conditions

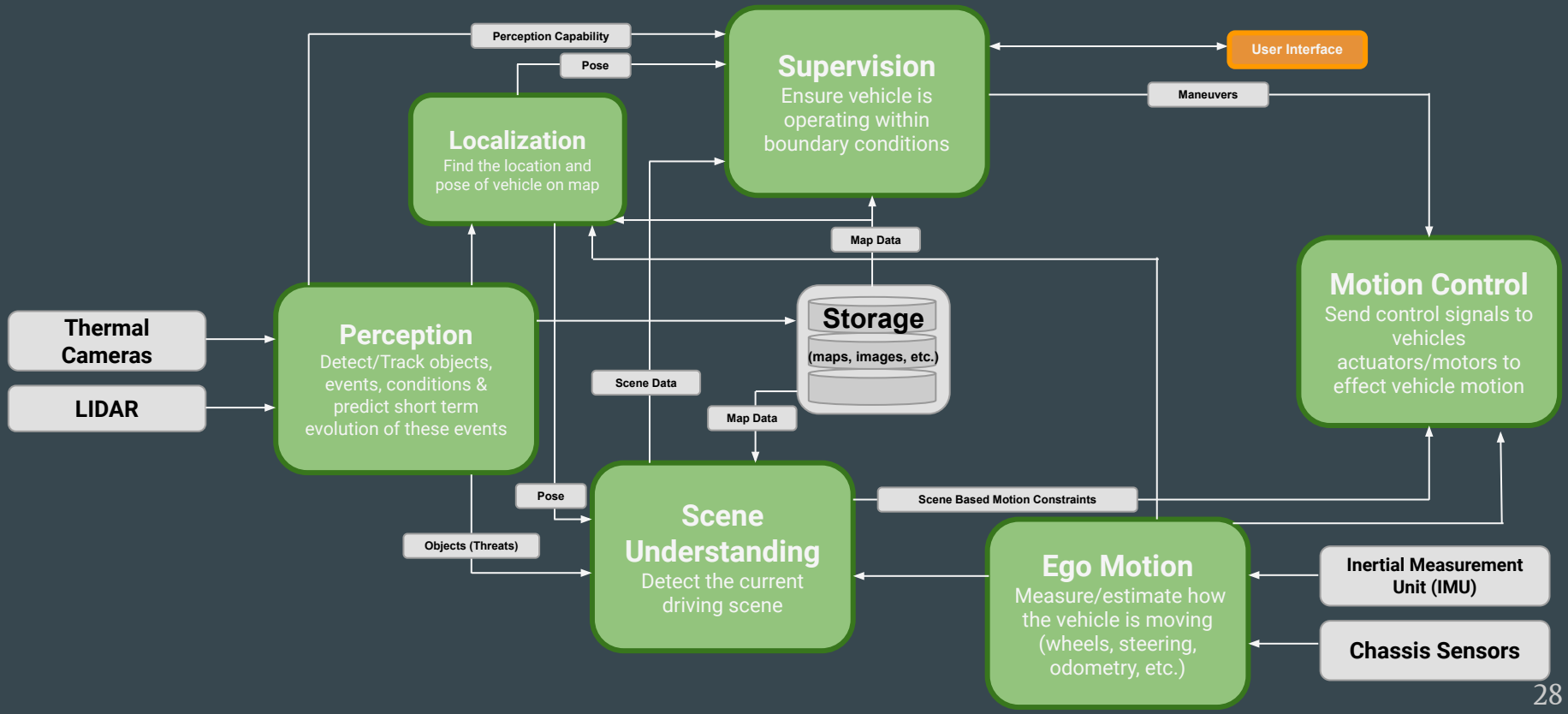
Connected Services
Handle communication with user

Event Recording
Enable user to record data from GUI

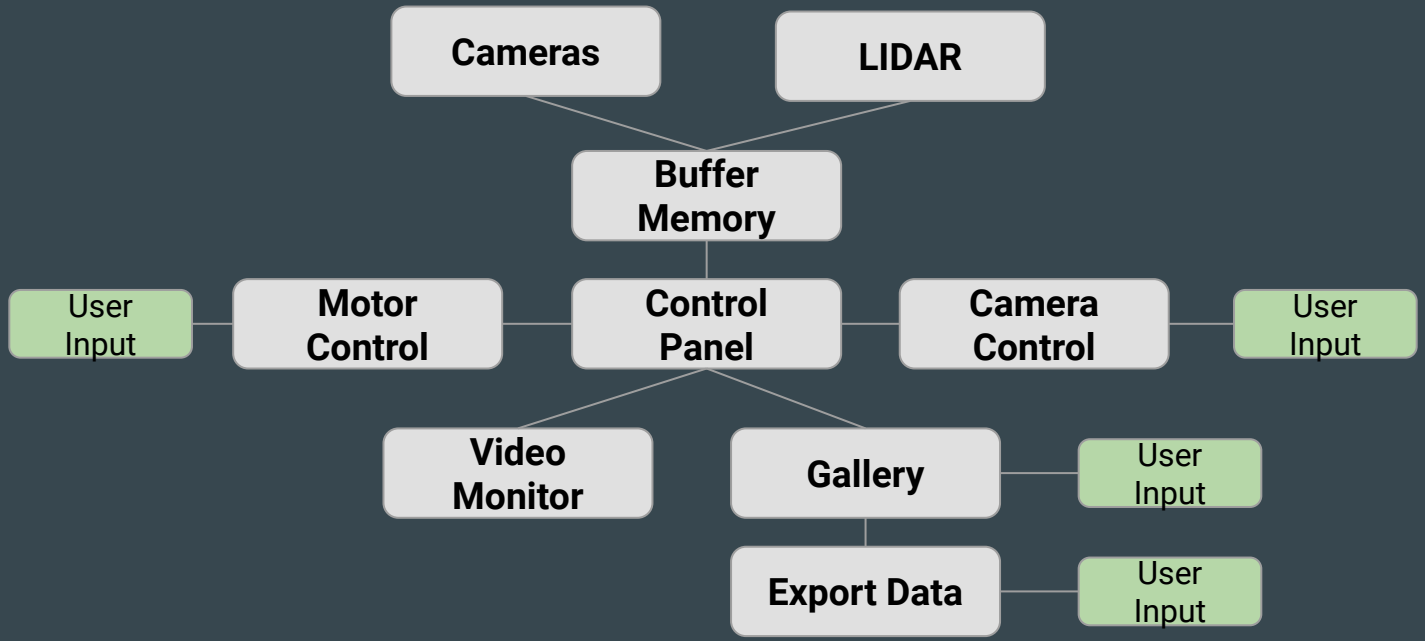
Development
Debug and Diagnostics
Access to sensor data and driving decisions. Enable real-time monitoring

Color Code | Autonomous Driving System (ADS)
- Core ADS Functions
- Non-ADS Functions
- Cross Functional Features

System Architecture Information Flow



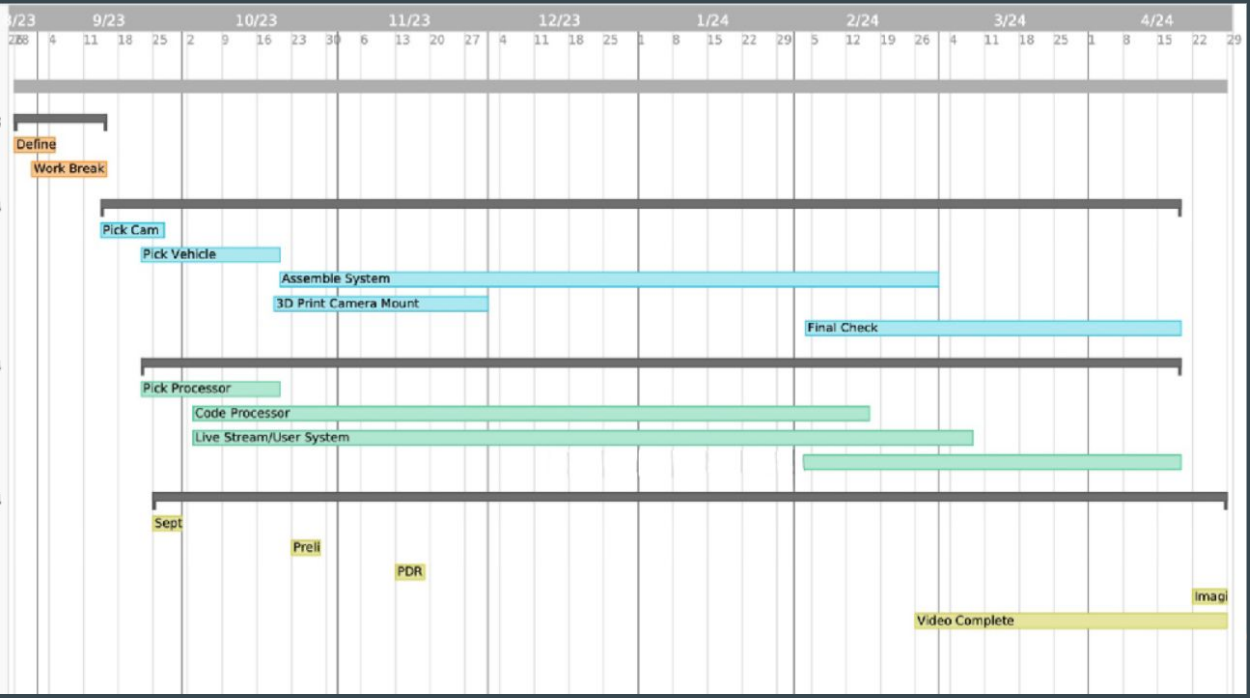
Software Specifications



- Programming Language: Python
- Libraries: OpenCV, PyQT 5

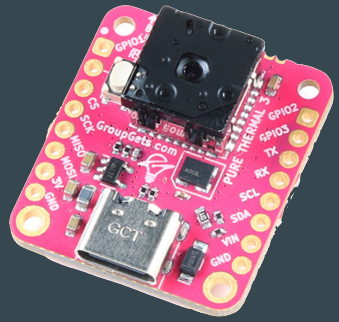
Schedule

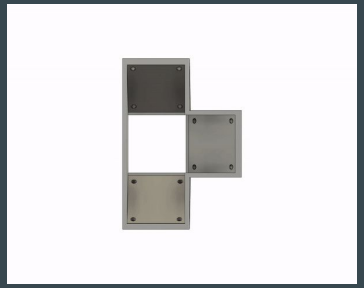
Thermal Threat Detector	start	end
General	**08/28/23**	**09/14/23**
Define Requirements	08/28	09/04
Work Breakdown Structure	08/31	09/14
Hardware	**09/14/23**	**04/18/24**
Pick Camera	09/14	09/26
Pick Vehicle	09/22	10/19
Assemble System	10/20	02/29
3D Print Camera Mount	10/19	11/30
Final Check	02/03	04/18
Software	**09/22/23**	**04/18/24**
Pick Processor	09/22	10/19
Code Processor	10/03	02/15
Live Stream/User System	10/03	03/07
Final Check	12/14	04/18
Presentations	**09/25/23**	**04/27/24**
September Faculty Meeting 9/28	09/25	09/29
Preliminary Design Review 10/27	10/23	10/27
PDR 11/16	11/13	11/17
Imagine RIT 4/27	04/22	04/27
Video Complete	02/26	04/27

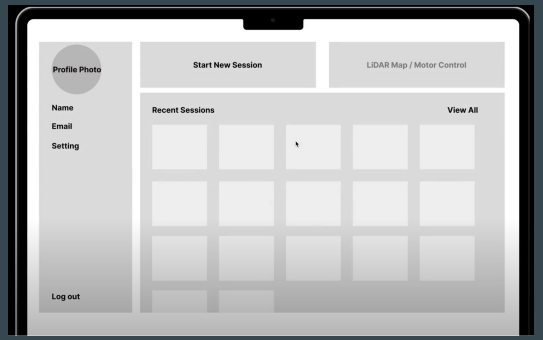


What we've done so far

- Purchased Cameras and breakout boards
- Purchased Vehicle
- Programmed GUI and Object Detection
- Designed Camera mount and Printed Prototype
- Designed User Application







What we are working on

- 3D Print Camera Mount
- Calculate Power Consumption
- Obtain Car Kinematics
- Communicate with external devices
- Software development

Questions?