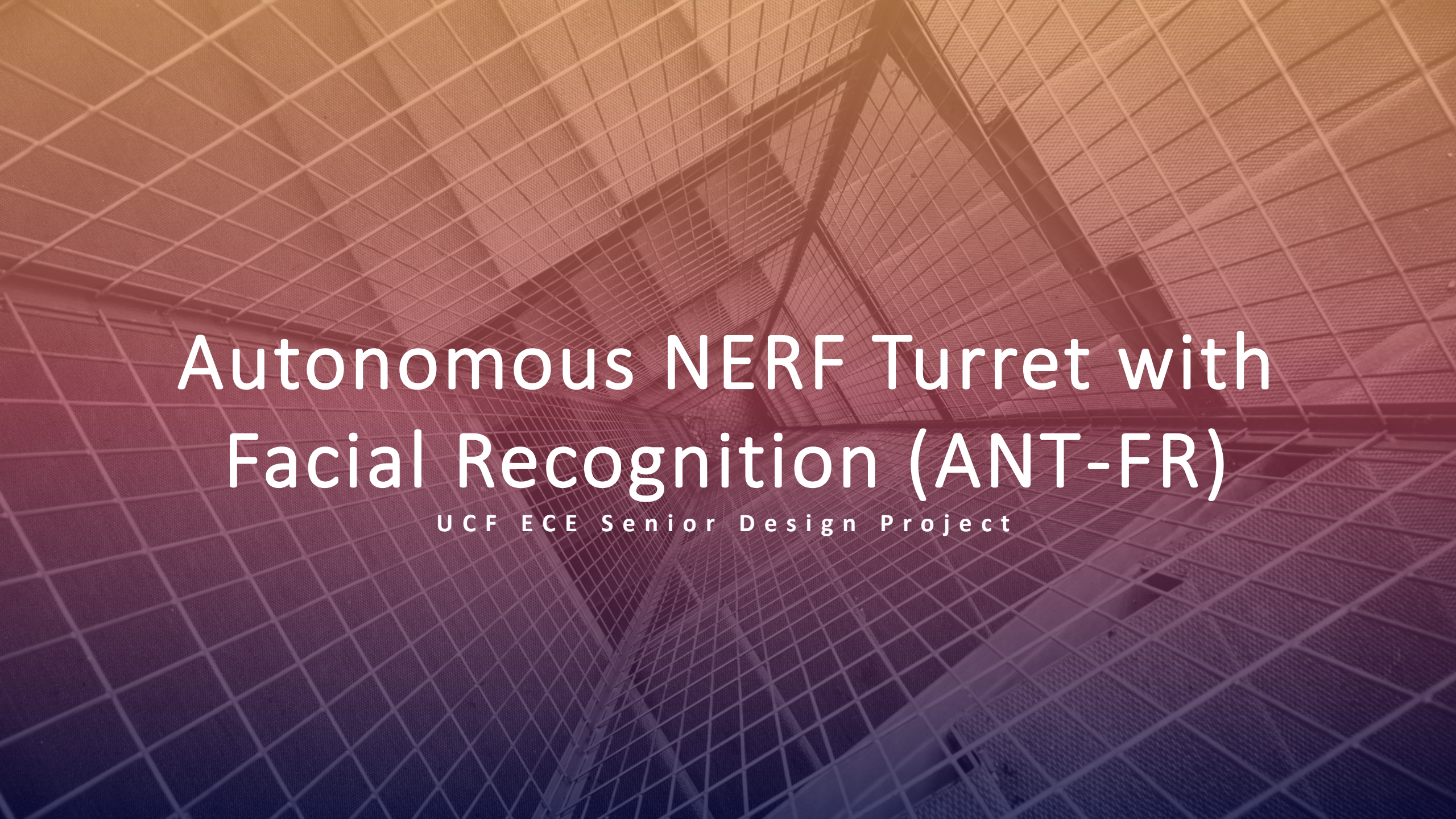


Autonomous NERF Turret with Facial Recognition (ANT-FR)

UCF ECE Senior Design Project

Meet the Team

Steffen J. Camarato

Computer Engineer

- Machine Learning
- Artificial Intelligence

Nicolas Jaramillo

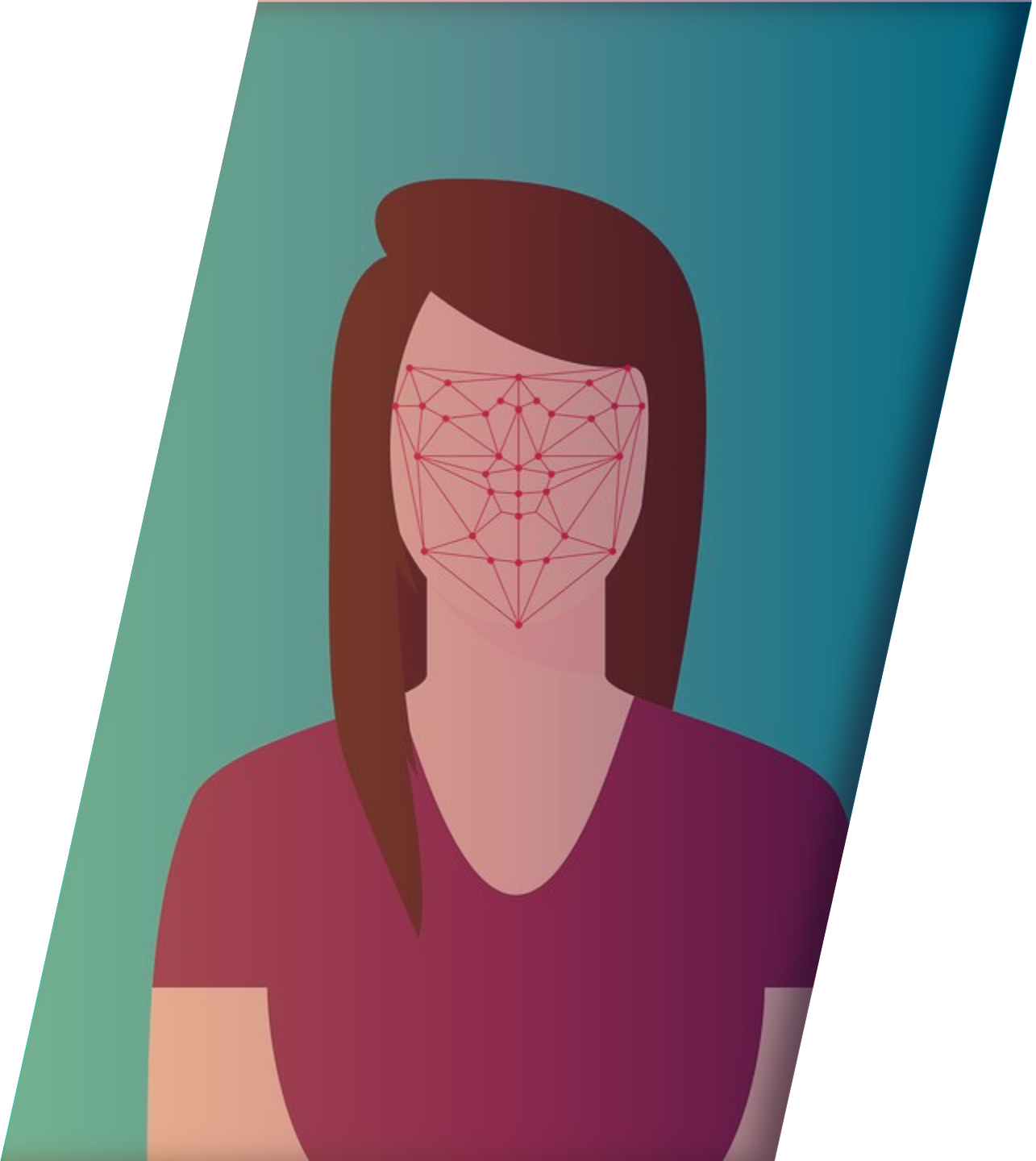
Computer Engineer

- Front End Development
- Back End Development
- Embedded Systems

Michael A. Young

Electrical Engineer

- Power System
- Printed Circuit Board (PCB) Design

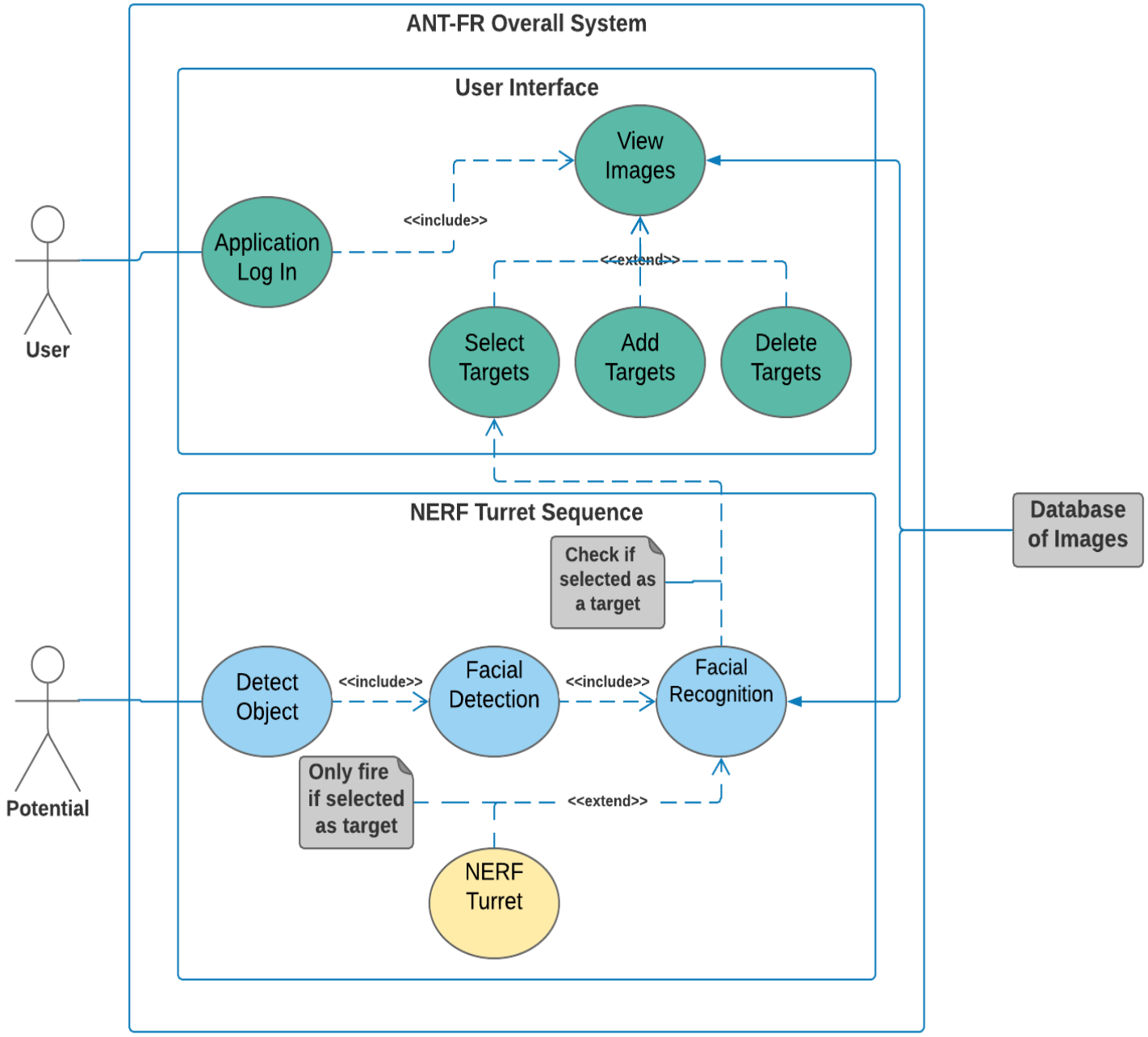


What is ANT-FR?

- Overall Goal
  - Our project goal will be to design and build a functioning alpha prototype of an Autonomous NERF Turret that utilizes facial recognition software to lock onto targets.
- Desired Outcomes
  - A database of faces is collected as potential targets.
  - An application (Mobile desired) allows you to select a target of interest
  - If an individual matching that face comes into the field of vision, the NERF gun should autonomously track the individual and fire at center of mass.
  - Gun should try to minimize false positives and not aim at faces directly.

Motivation for Project

N o s t a l g i a



Use Case Diagram

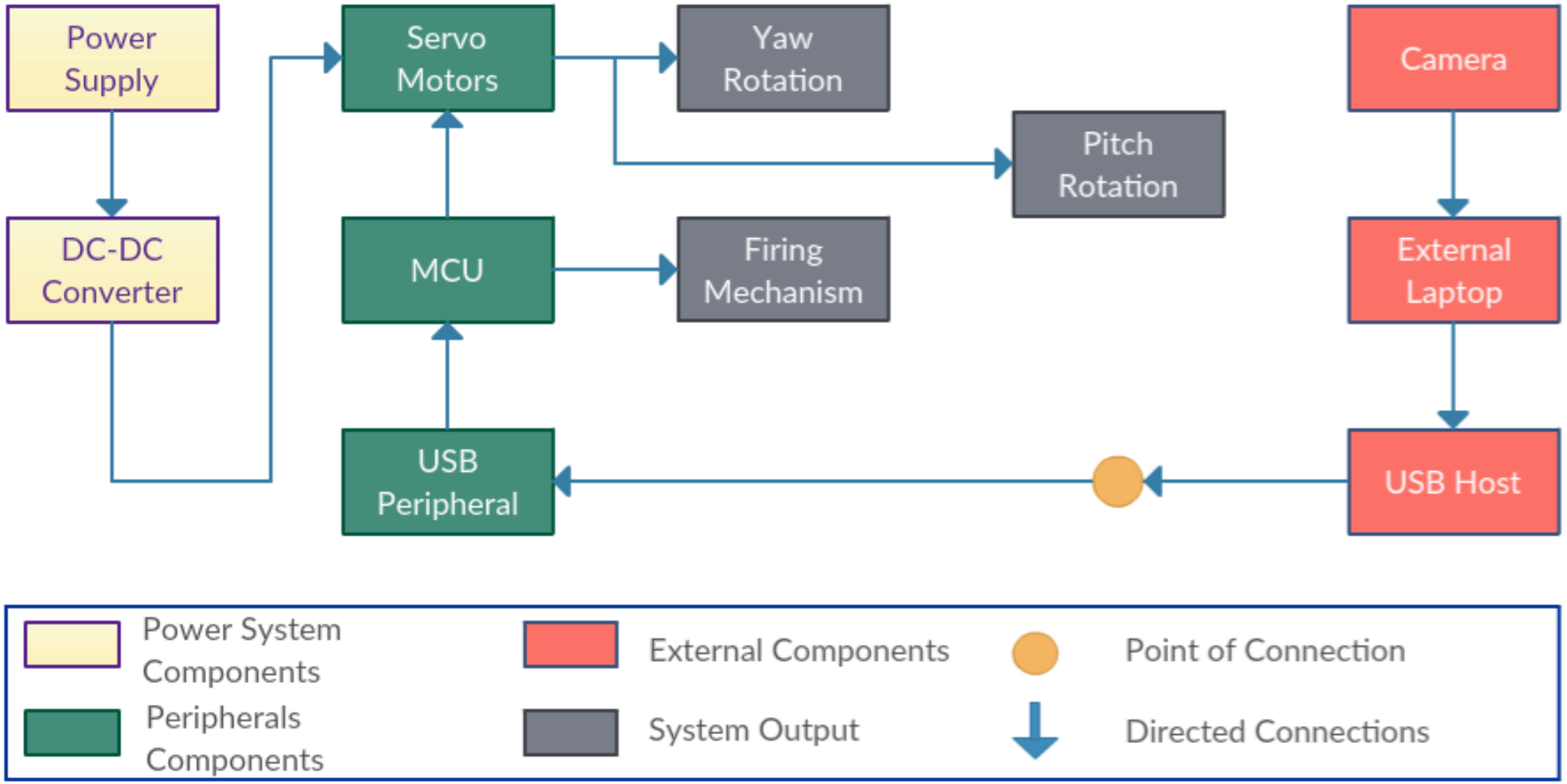
An Overall View

- User can view images in the database
  - Select image as a target
  - Add new images
  - Delete images
- As the target walks into the field of vision of the NERF turret
  - Software follows target on camera
  - Search for and detect a face
  - Run facial recognition algorithms to determine if face is in database
  - Turret fires at a person if they are selected as a target

Project Specifications

Marketing Requirements	Engineering Requirements
Low Cost (USD)	< 1500
Software False Positives (Percent)	< 30
Operation Time (Hours)	> 2
Response Time (Seconds)	< 10
Range of Motion (Degrees)	> 120 Yaw
Hit Rate (Percent)	> 20

Hardware Block Diagram



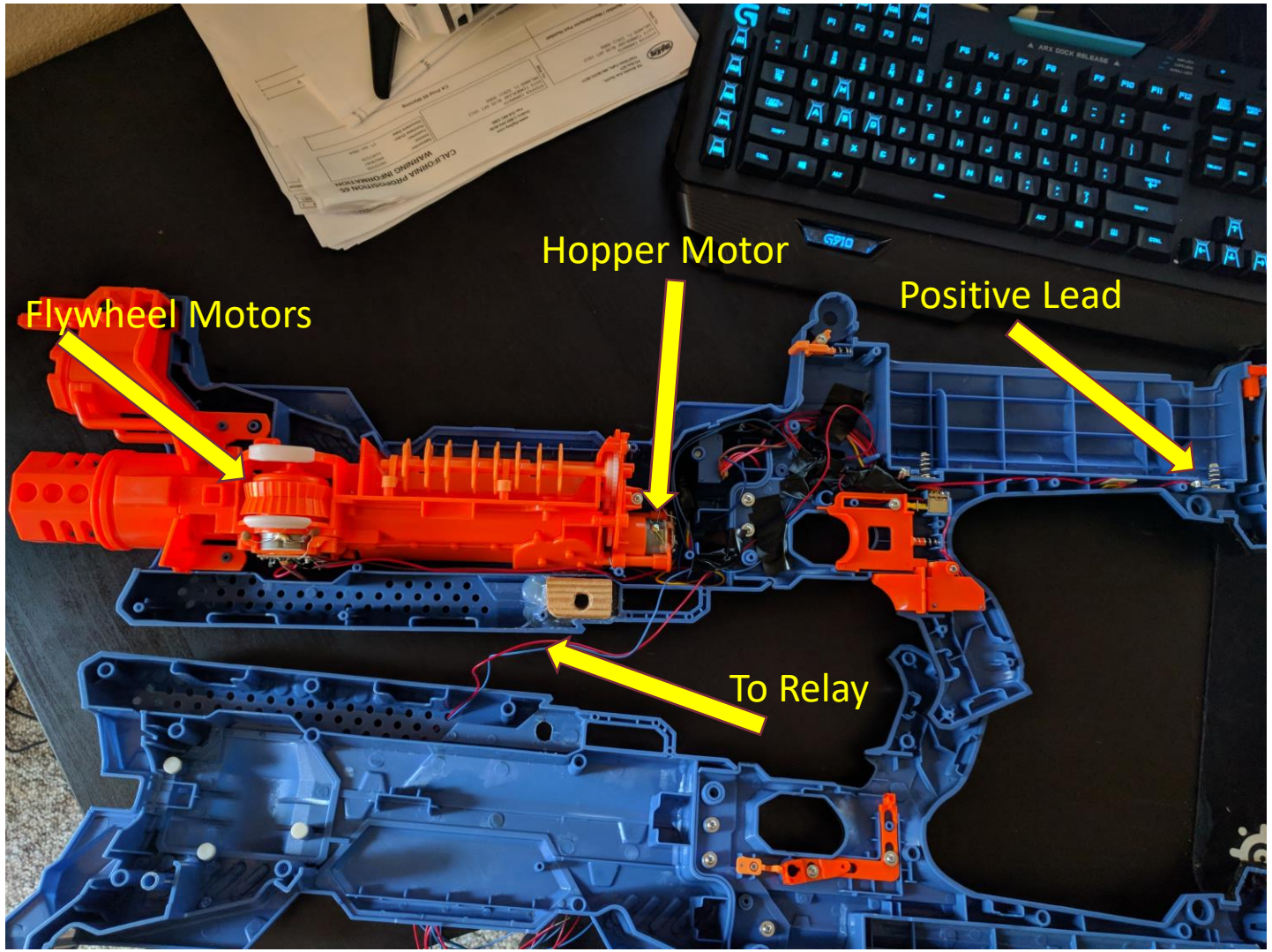
Camera Selection

Type	Logitech Pro/Brio	Logitech C930e
Resolution	4K UHD 2160p	Full HD 1080p
Field of View	90	90
Frames Per Second	60	30
Digital Zoom	5x	4x
Autofocus	Yes	Yes
Auto-light Correction	Yes	Yes
Lens	Glass	Glass
Weight	4.7oz	5.7oz
Dimension	2.5in x 1.4in x .73in	1.14in x 3.7in x .95in
Price	$159.99	$129.99

NERF Rival Nemesis

- NERF Rival Nemesis chosen as the onboard NERF gun
  - High Capacity Hopper holds 100 Rounds
  - High-Impact Spherical NERF Rounds
  - Fully Automatic Operation
  - Ease of Modification

NERF Rival Nemesis Cont.



- NERF gun is actuated with two separate triggers; one for bringing two fly-wheel motors up to speed, the other for actuating the hopper agitator motor.
- Triggers have been bypassed and all three motors' positive lead wires have been rerouted to a relay.
- Positive lead wire for NERF gun battery has been rerouted to the same relay.

Relay for Trigger Assembly

Type	Vellman Relay	SunFounder 2 Channel Relay
Operating Voltage for Actuation	5V	5V
Current Ratings	10A at 250VAC, 10A at 30VDC	10A at 250VAC, 10A at 30VDC
Line Side Contacts	Common, Normally Closed, Normally Open	Common, Normally Closed, Normally Open (x2)
Control Side Inputs	Ground, +5VDC, Control Signal	Ground, +5VDC, Control Signal
Dimensions	1.6” x 1.06” x 0.71”	1.99” x 1.54” x 0.73”
Price	$3.19	$6.79

- Relay receives control signal from a digital output pin of the ATmega328P-PU, giving full firing control of the NERF gun to the primary PCB.

Battery Packs- NERF Gun Battery

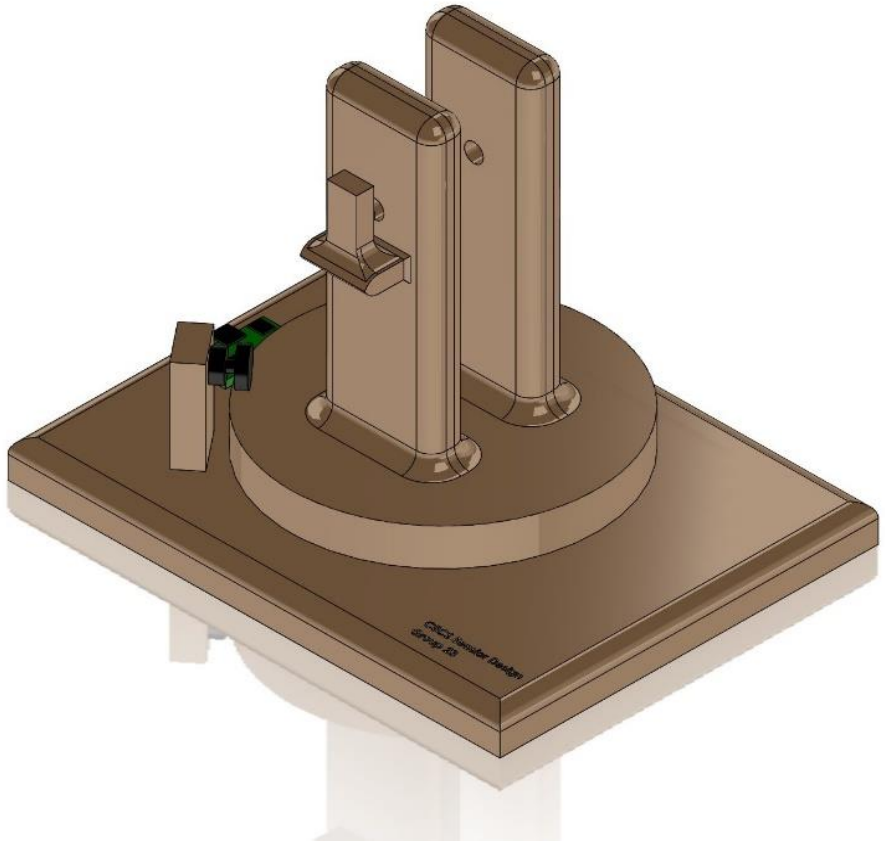
- NERF NiMH rechargeable battery pack will be used to increase modularity surrounding the NERF gun.
    - Chassis of the battery pack is designed to fit accurately within the stock of the NERF gun without movement/vibration.
- Nominal operating voltage of 7.2V at 1.5Ah capacity, powers the NERF gun without voltage regulation.

Battery Packs - Servo Battery

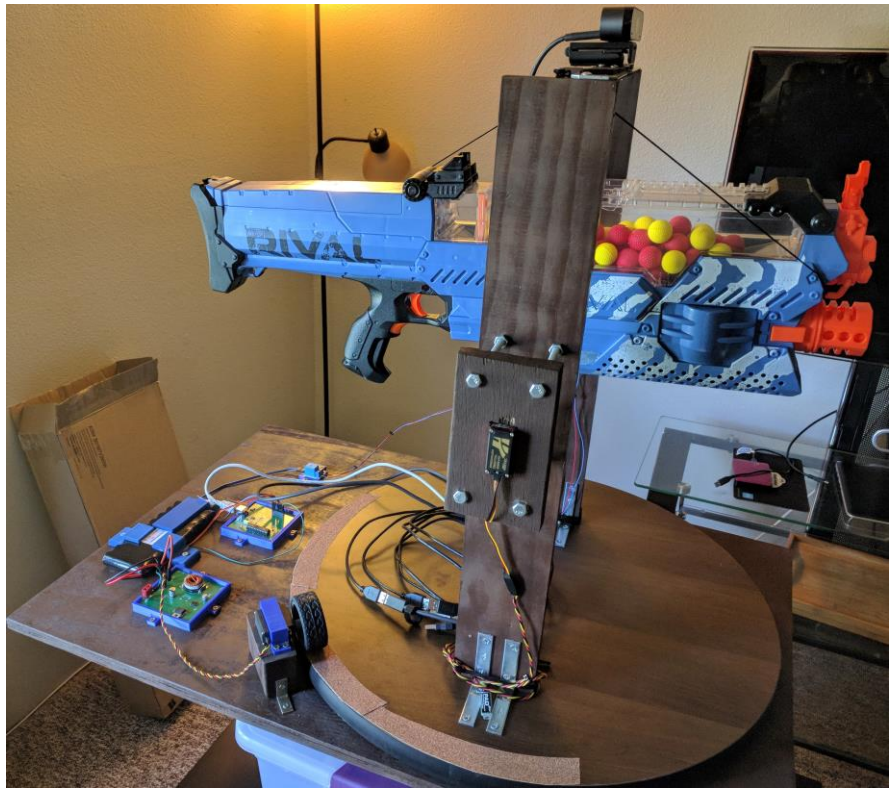
Type	Tenergy All-Battery	Tenergy Battery Junction
Li-Ion Nominal Voltage	11.1V	11.1V
Capacity	6.6Ah	5.2aH
Maximum Discharge Current	5.7A	5.2A
Overcharge Protection	>12.6V	>12.0V
Over-Discharge Protection	<9.0V	<8.8V
Price	$74.99	$47.95

- Battery pack comes with a built in protection circuit board to shield it from over-discharge and overcharge.
- High maximum discharge current will accommodate in-rush current from servos and allow the switching regulator to run at its maximum rated current of 3 amps.

Turret Framing



Initial Framing Design in SolidWorks



Final Framing

Yaw Servo Specifications

Model	HSR-2645CRH	HSR-2648CR
Voltage Range	4.8V - 7.4V	4.8V – 7.4V
Speed (6.0V)	58 RPM	58 RPM
Torque (6.0V)	138.87 oz-in	138.87 oz-in
Rotation	Continuous	Continuous
Price	$31.99	$32.99

- Yaw Rotation - HSR-2645CRH
  - Continuous Rotation along the turn table is controlled with Pulse Width Modulation which is time dependent for relative position.

Pitch Servo Specifications

Model	HSB-9380TH	HS-5645MG	HS-7955TG
Voltage Range	6.0V – 7.4V	4.8V - 6.0V	4.8V - 6.0V
Speed (@6.0V)	0.17sec/60deg	0.18sec/60deg	0.15sec/60deg
Torque (@6.0V)	472 oz/in	168 oz/in	250 oz/in
PWM Increase	Clockwise	Clockwise	Clockwise
Price	$152.99	$64.00	$129.00

- Pitch Rotation - HSB-9380TH
  - Encoded Rotation along the horizontal rod is controlled with Pulse Width Modulation with values mapped to absolute position.

Motor Control

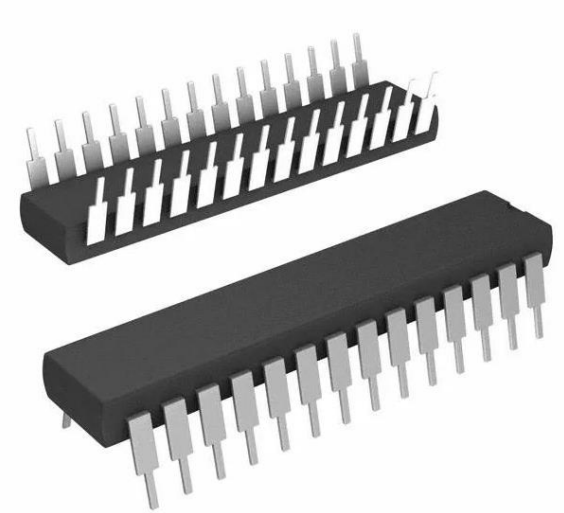
Encoded Directions

Value	Yaw Rotation	Pitch Rotation	Firing
0	Clockwise	Previous - 1	Low
1	Stationary	Previous	High
2	Counter-Clockwise	Previous + 1	N/A

- Encoded instructions with the target's relative position is sent from ATmega16U2-MU.
- Instruction set decoded by ATmega328P-PU, arithmetic and logical processes are used to determine pulse width modulation and delay times.
- Instructions are in the form of three integers, which indicate the direction of motion or firing state.

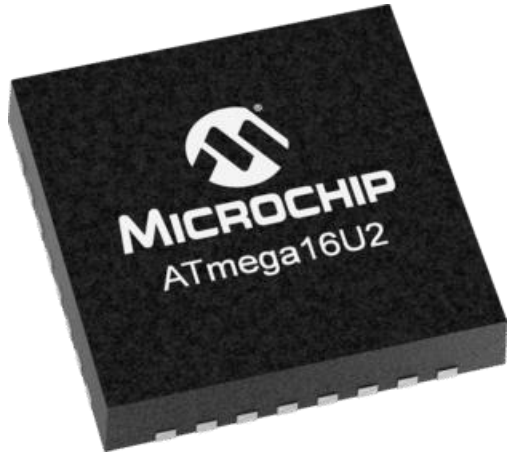
Main Microcontroller Specifications

Model	ATmega328P-PU	AT89C51RC
Architecture	28-pin AVR	40-pin 8051
I/O Pins	23	32
Timers	2-8bit, 1-16bit	3-16bit
Memory	32kB	32kB
Internal RAM	2k SRAM bytes	512bytes
Oscillator	20MHz	24MHz
A/D Converter	10-bit 6 channel	None Specified
Price	$2.20	$2.50



Secondary Microcontroller Specifications

Model	ATmega16U2-MU	FT232HQ-REEL
Description	AVR microcontroller	Single Channel USB to Serial
Number of Pins	32	48
Interface	SPI, USB, UART, USART	UART/FIFO IC
Memory Size	16 kB Flash	None Specified
Min. Supply Voltage	2.7 V	2.97 V
Max. Supply Voltage	5.5 V	3.63 V
Watchdog Timer	Yes	No
Price	$2.52	$4.25



Embedded Systems

ATmega16U2-MU

- USB-Serial Interface.
- Receives the 5V, GND, D+ and D- lines from the USB 2.0 Type B connector and converts the serial information into USART format, which is then sent to ATmega328P-PU.

ATmega328P-PU

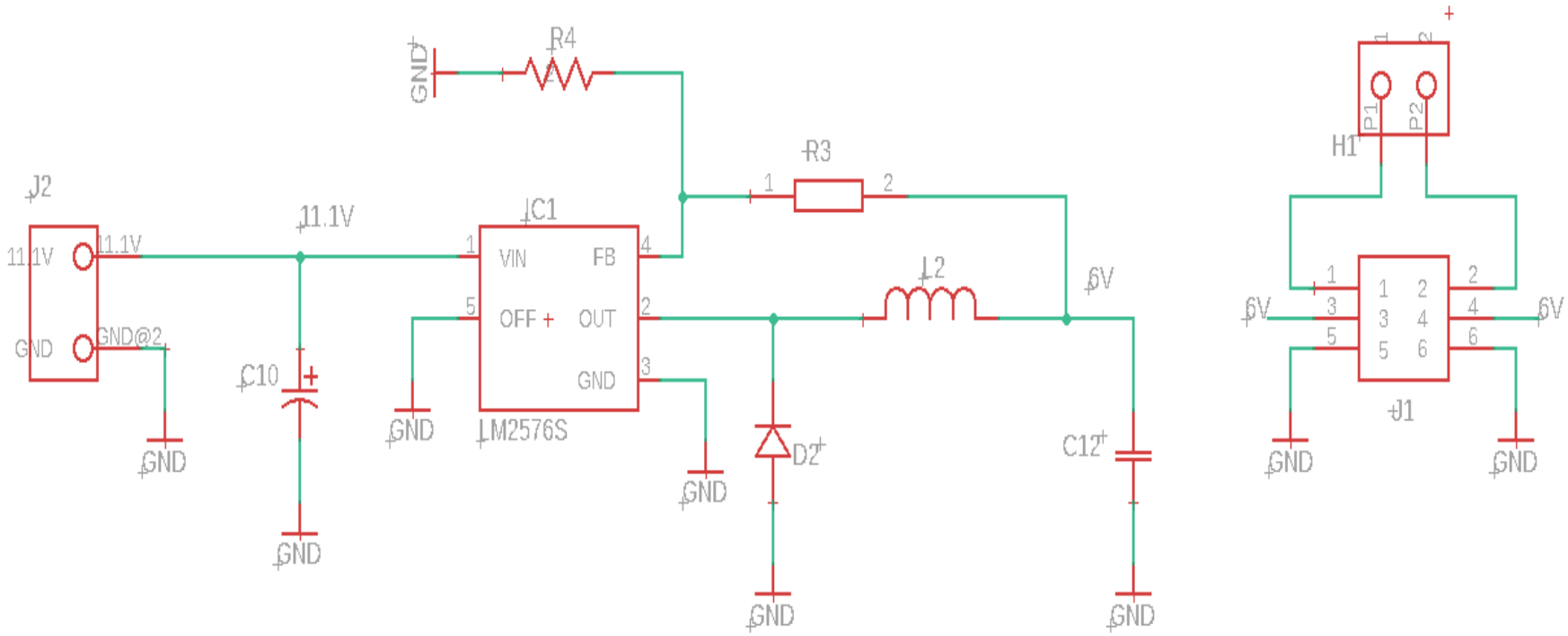
- Serves as the central processing unit, providing digital and analog I/O control, Pulse Width Modulation signals, and arithmetic and logical calculations.
- Also decodes system inputs and interrupts, giving the appropriate response.

Power PCB Voltage Regulator

Model	LM2576	LMR14050
V_{IN} Range	4V-40V	4V-40V
V_{OUT} Range	3.3V-37V	1V-36V
I_{OUT} Max	3A	5A
I_Q	5mA	0.04mA
Price	$3.03	$3.37

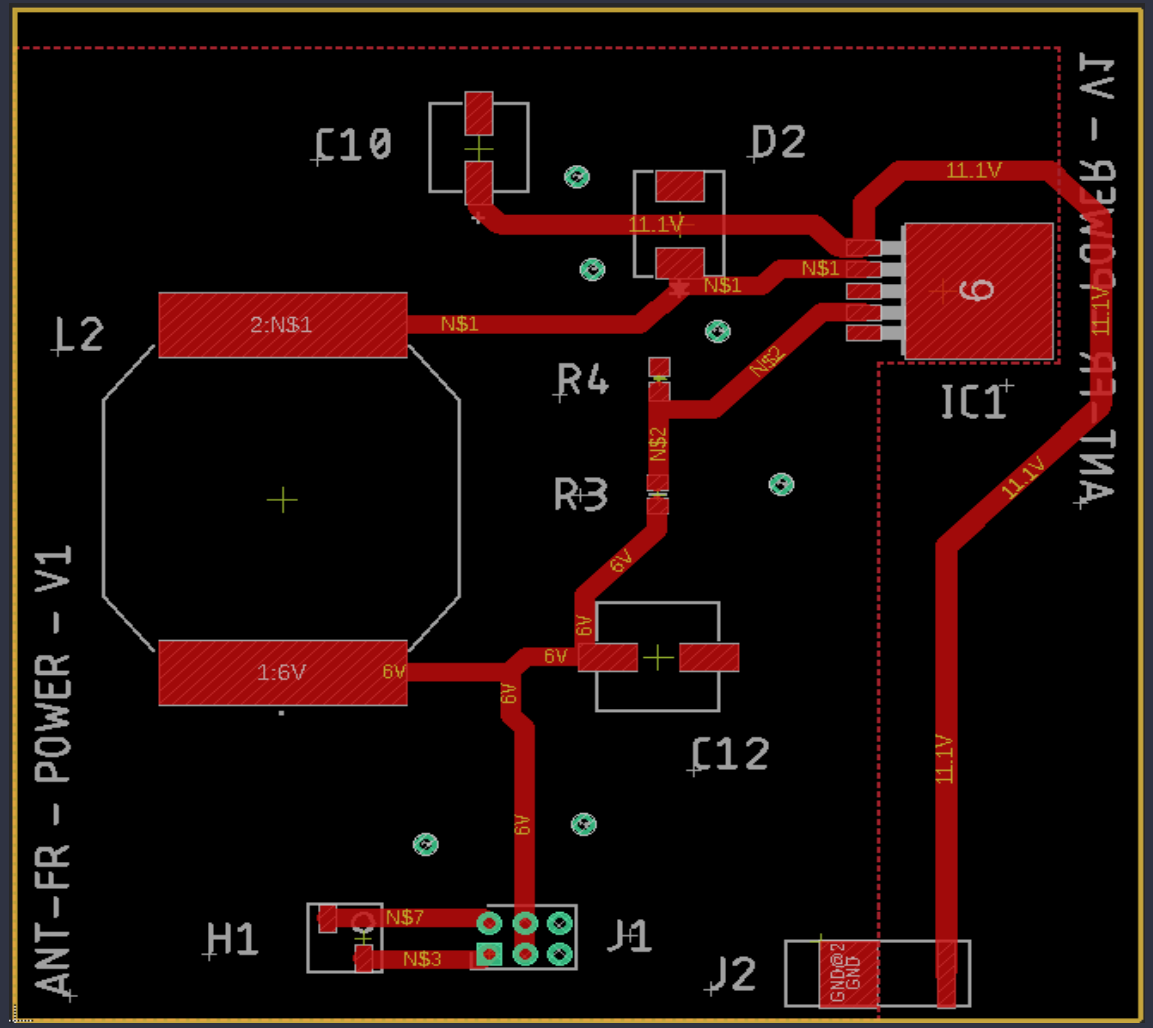
- The adjustable version of the LM2576 was chosen to produce a final output voltage of 6 volts, which is the nominal operating voltage of the servos.

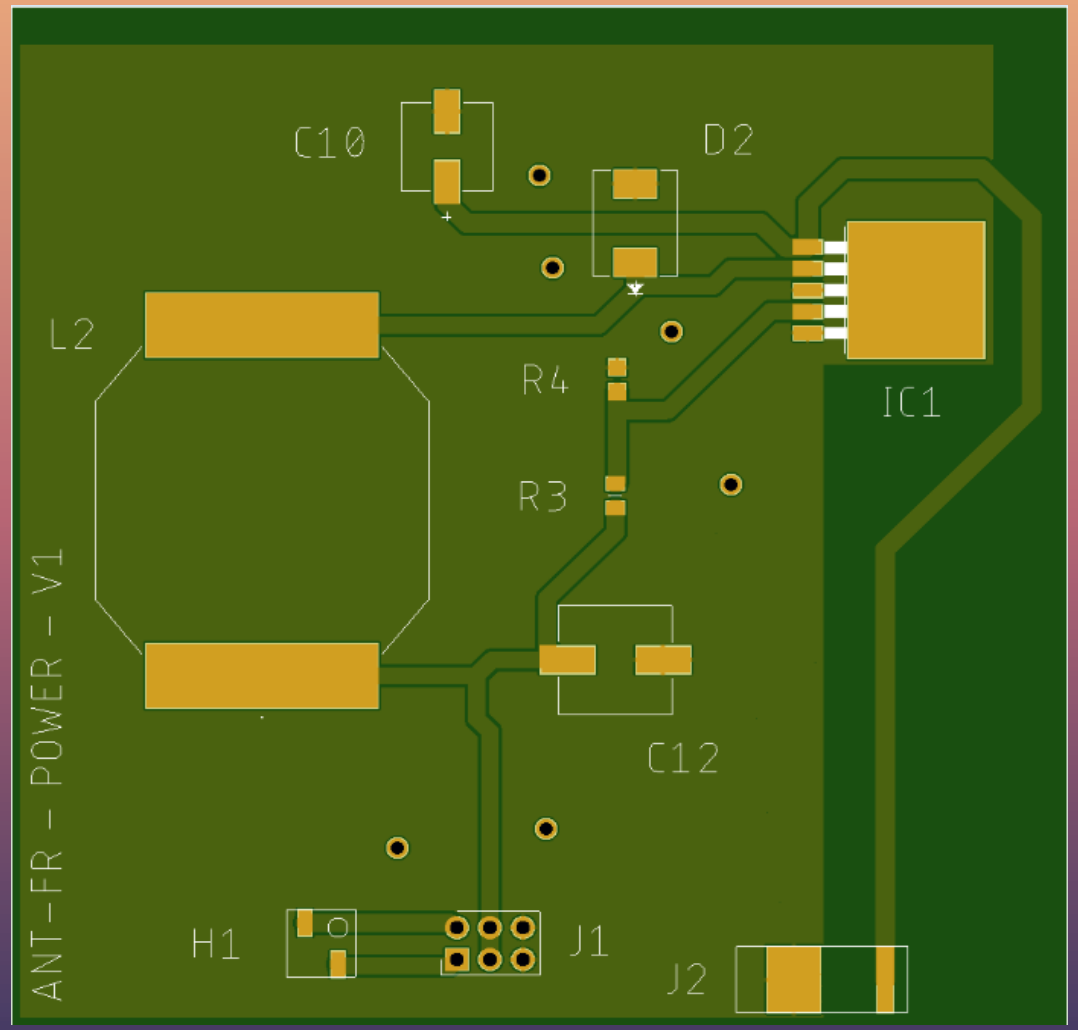
Power PCB Schematic



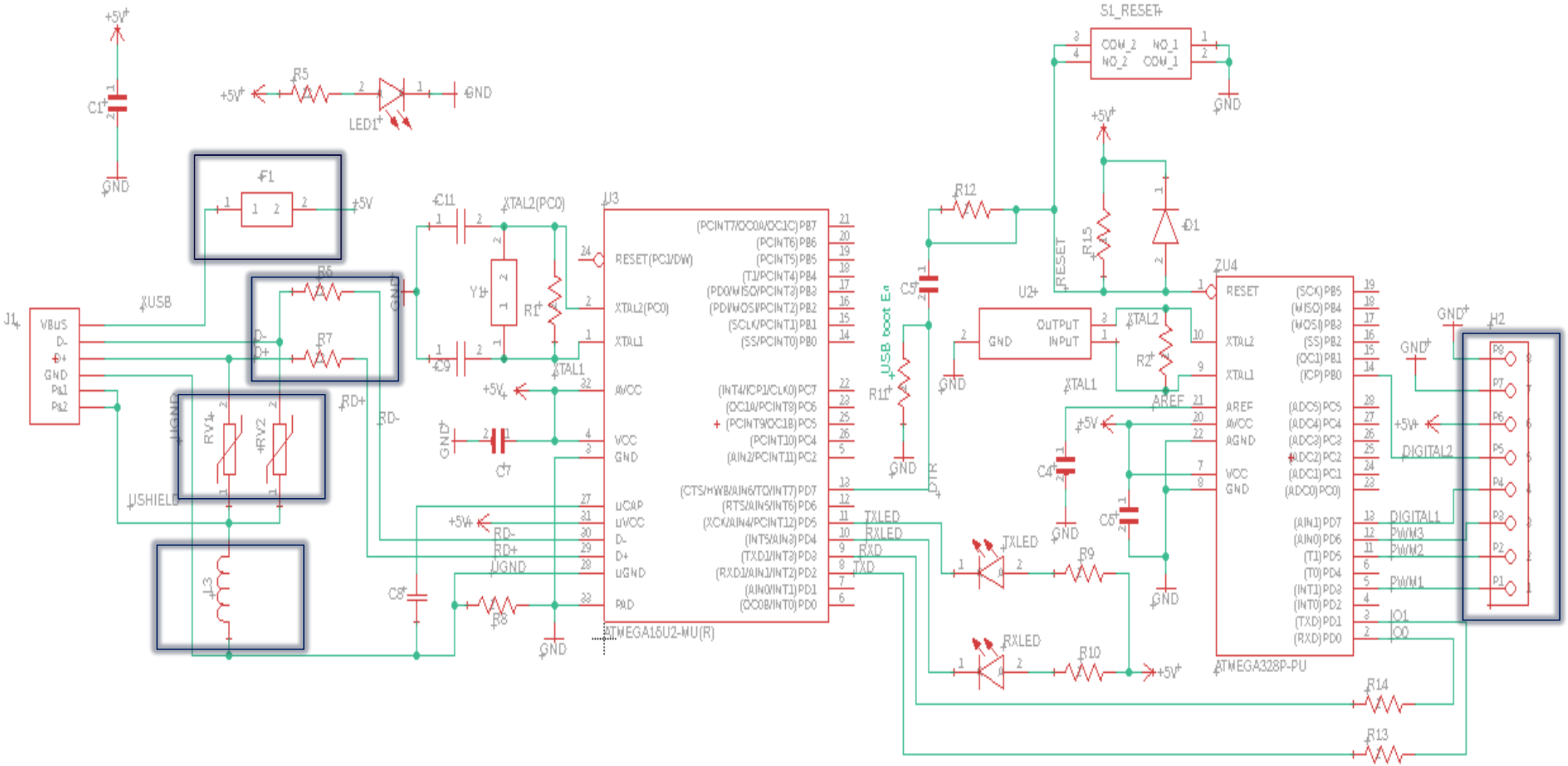
- Power PCB regulates 11.1V down to 6V to allow for optimal servo operation.

Power PCB Layout

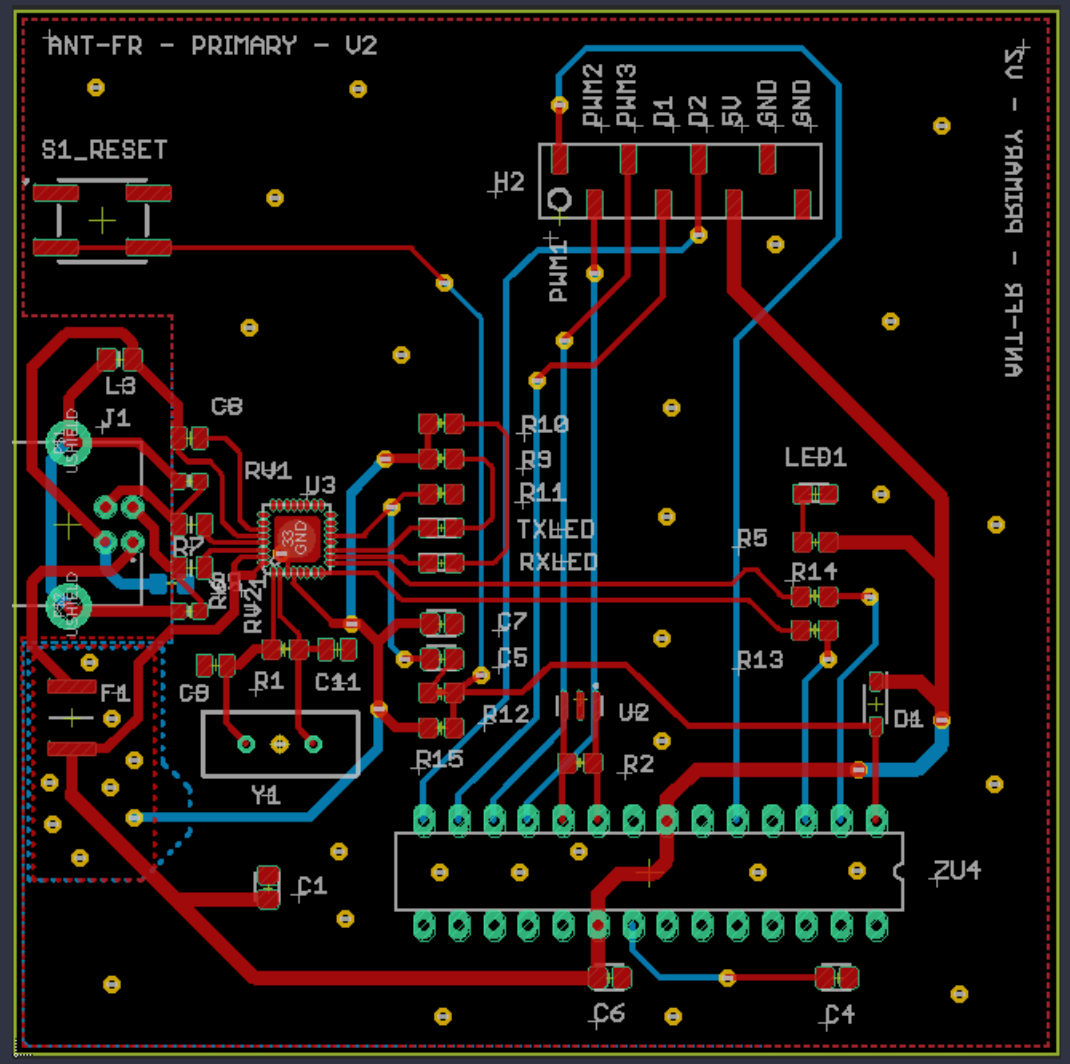


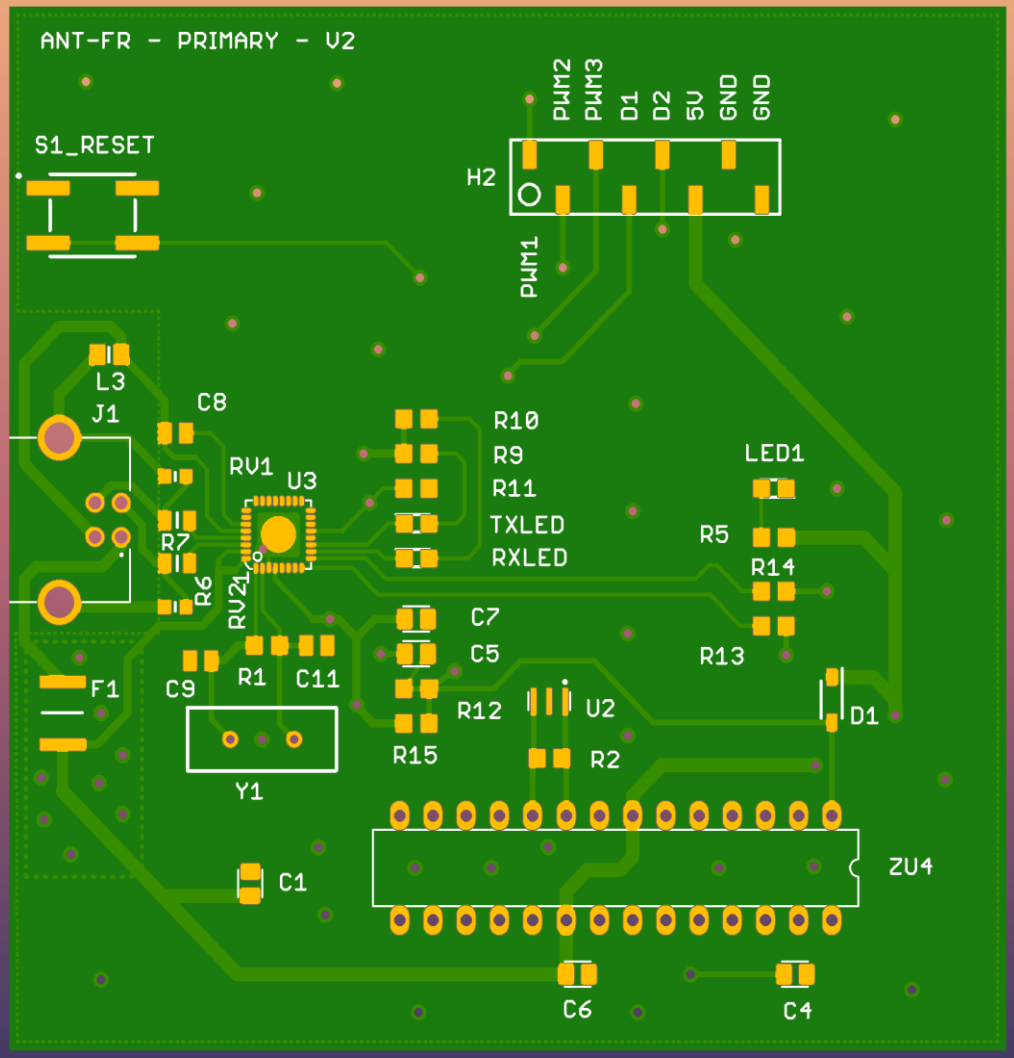


Primary PCB Schematic

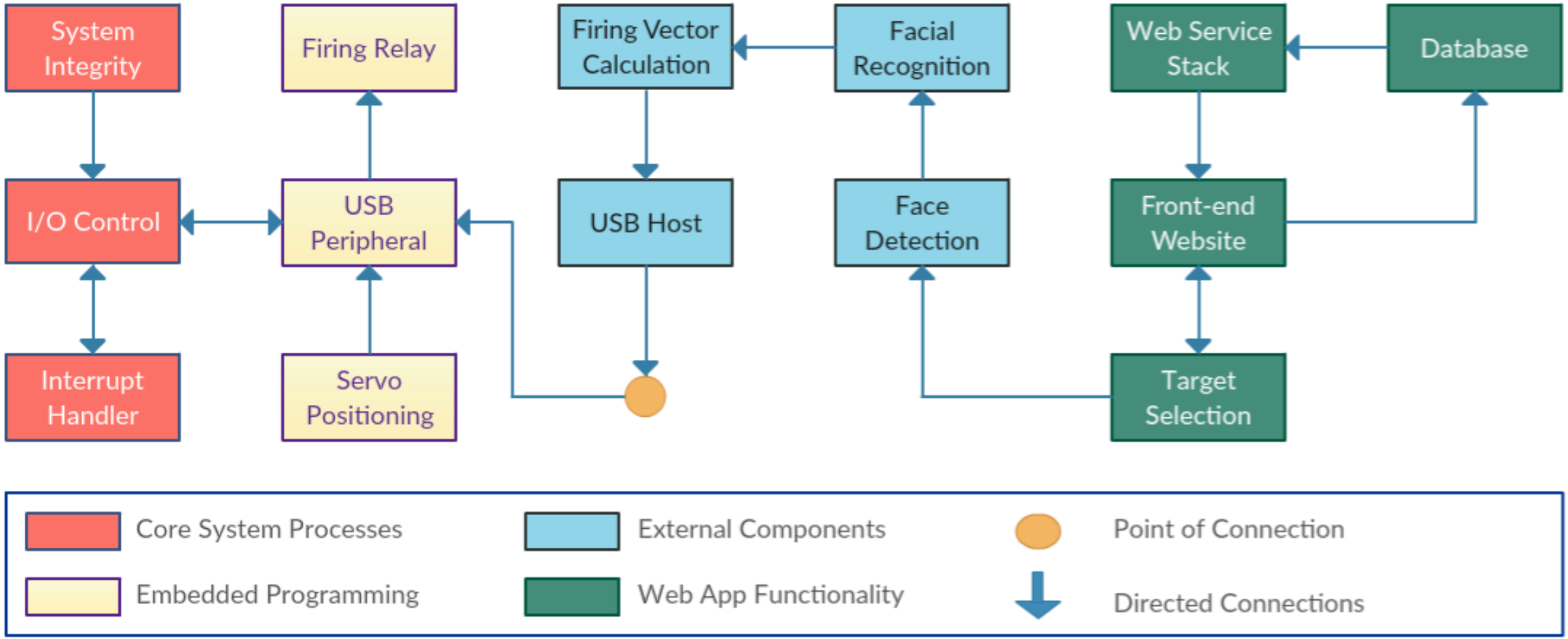


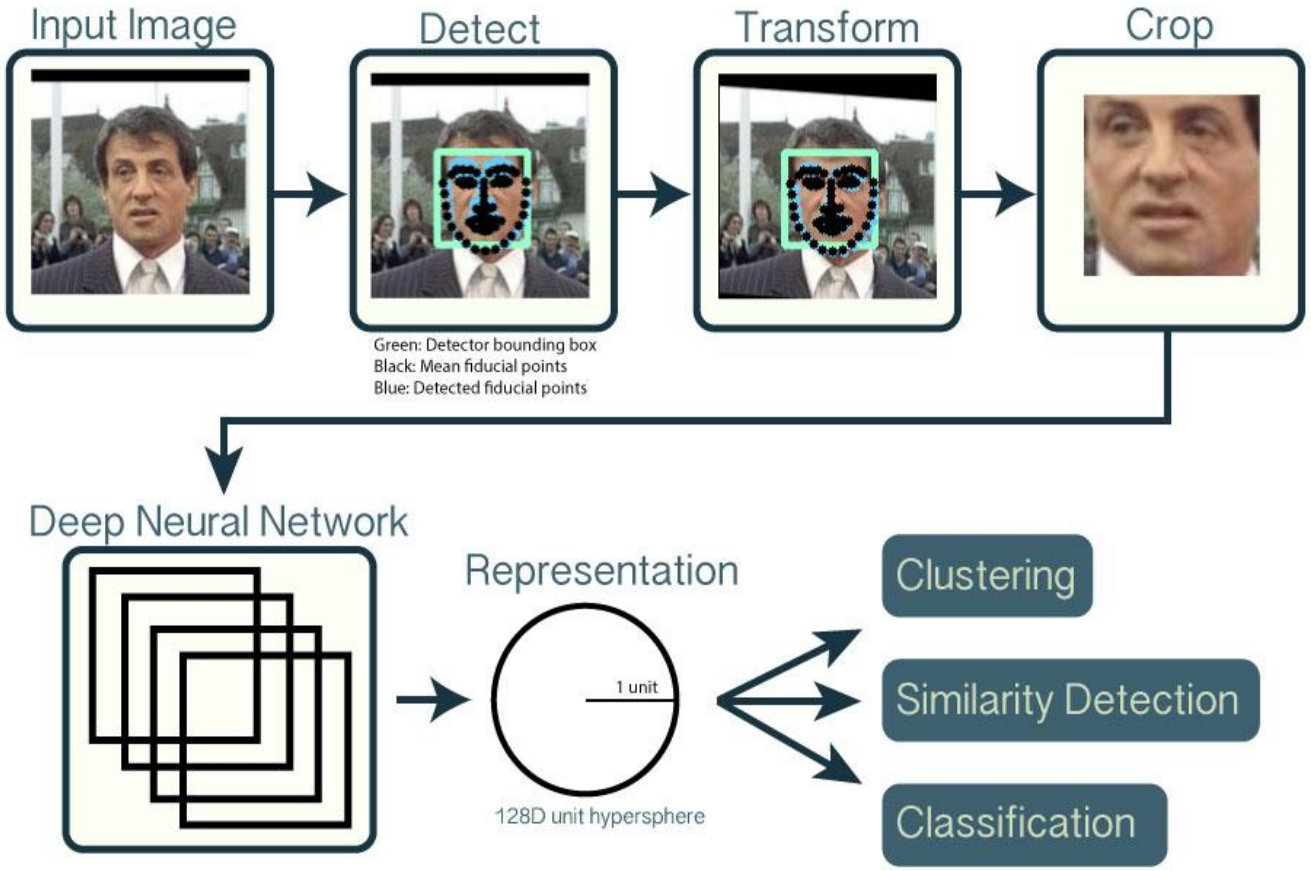
Primary PCB Layout





Software Block Diagram





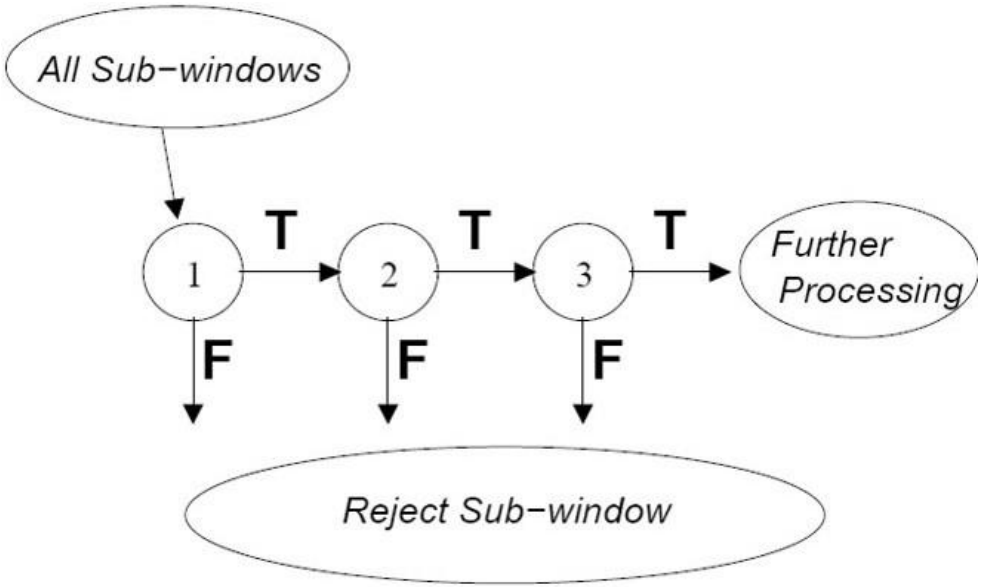
OpenFace

Project Overview

- The facial recognition software is one of the main components of this project which will be used to identify the targets in the field of vision of the turret.
- OpenFace, which is a free and open source face recognition with deep neural networks, will be used for implementation of the facial recognition portion of this project.

Face Detection

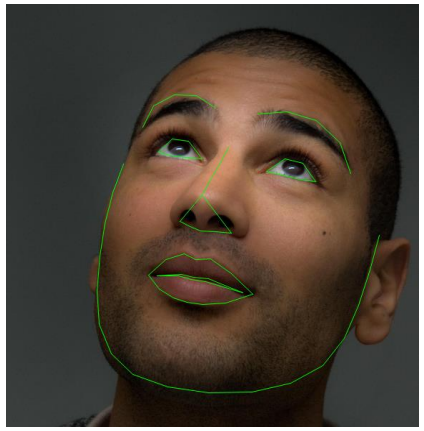
Cascade Method



- With adaptive boosting, we can exploit the fact that faces are rare. The cascade method can be used, which uses a cascade system to speed up the process greatly.
- More classifiers are added to a team until a desired missed detection and false positive rate, approximately 30%, is achieved, which is generally 15-30 classifiers.
- With this design, each team will pass 99.9% faces and 30% non-faces.
- This means that approximately 91% of “failure” are rejected with only 50 experts used.

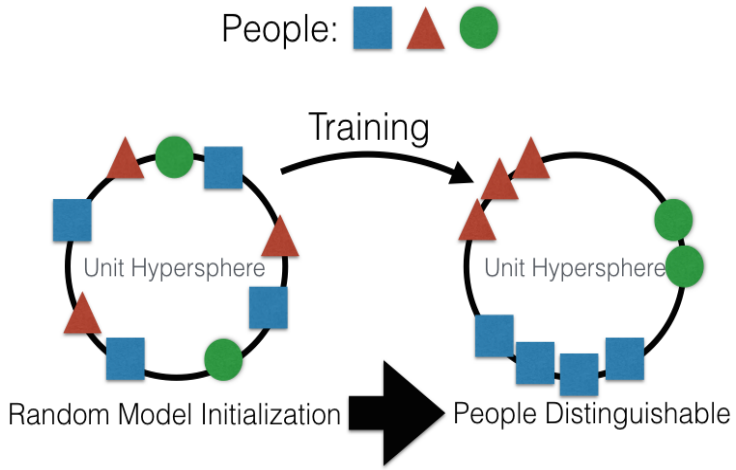
OpenFace Classifications

Face Landmark Estimation



- Adds an annotation around the key features of a face with 68 points of reference.
- Performing these techniques will make the eyes and bottom lip appear in the same location for each image after cropping.

Hypersphere / Support Vector Machine



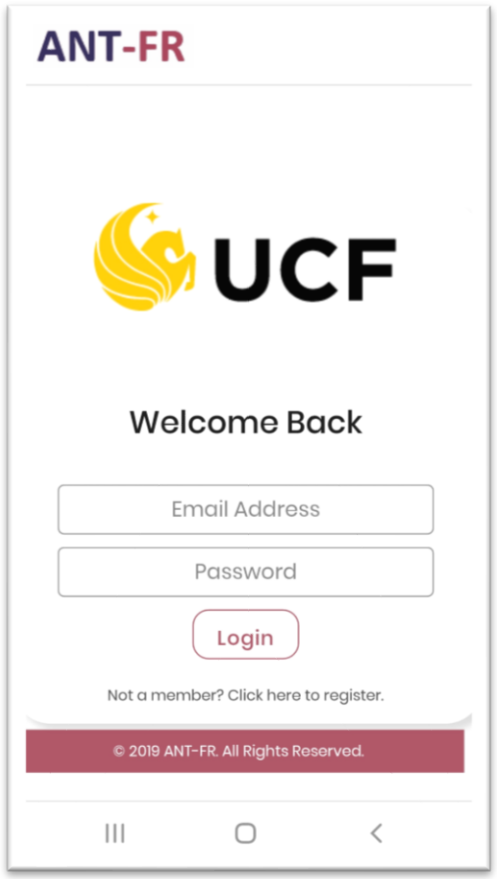
- Through iterations of the network, the images are grouped together and will be fully optimized.
- Finally, support vector machines is used for classification which will allow us to determine who someone is.

Web Stack

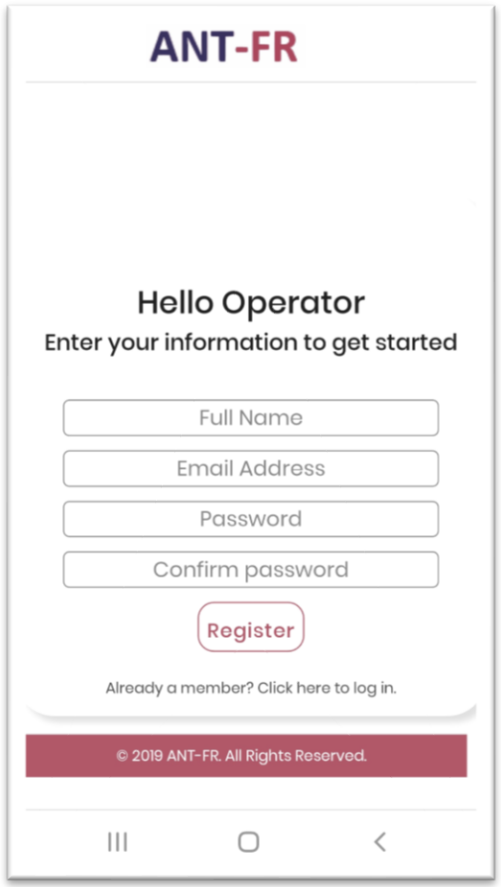
Web Development

- Allow users to interface with the turret by enabling communications between the web application and the host computer running the facial recognition software.
  - Hosted service, server write privileges
  - LAMP web service stack
  - SFTP (SSH File Transfer Protocol)
- Users will be able to retrieve, display, and manipulate database information from a web app designed for desktop and mobile devices.

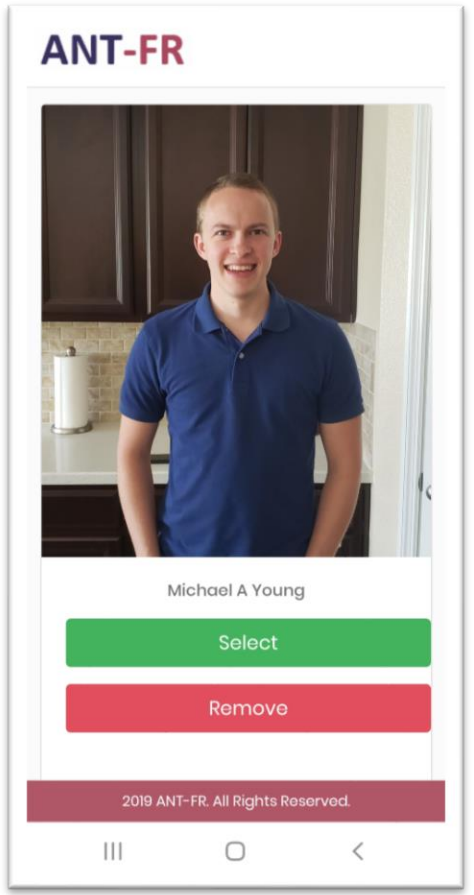
Mobile Application



Login



Profile Creation



Target Selection

Encountered Issues

- Trying to connect different software modules together
  - Using OpenFace to output a similarity score and sending a signal to the PCB to activate the NERF gun.
- Optimization of video stream and frames because there are too many faces on the screen, which slows down the processes.
- Training the classifiers for facial recognition
  - Not accurate, 5 hour training time.
- Connecting mobile application target selection to the facial recognition.
- Tracking selected targets and having the turret follow a target.
- Android application debugging issues
  - Application constantly crashes due to website instability.

Budget

- Sponsorships are provided by
  - Soar Technology, Inc. (SoarTech)
  - Valencia College Division of Engineering and Built Environments

Company	Part	Price
Digikey	PCB Components	$109.50
All-Battery	PCB Power Supply	$89.98
ServoCity	Servos	$283.73
Jameco	Relay	$15.40
Logitech	Camera	$159.74
Amazon	NERF Gun	$133.87
JLCPCB	PCB Manufacturing	$53.09
Hardware Store	Robot Frame	$98.45
Miscellaneous	Miscellaneous	$126.94
Available: $1500	Total Spent:	$1070.70

Copyright

Slide 27. OpenFace Workflow.
(Reprinted with permission from OpenFace 2015).

Slide 28. Viola-Jones Cascade Method.
(Reprinted with permission from Robot Vision 2018).

Slide 29. Landmarked Face.
(Reprinted with permission from Dlib C++ Library 2014).

Slide 29. Optimization Sphere.
(Reprinted with permission from OpenFace 2016).


Questions?