Battlebot

Sponsored by Lockheed Martin MFC: Applied Research

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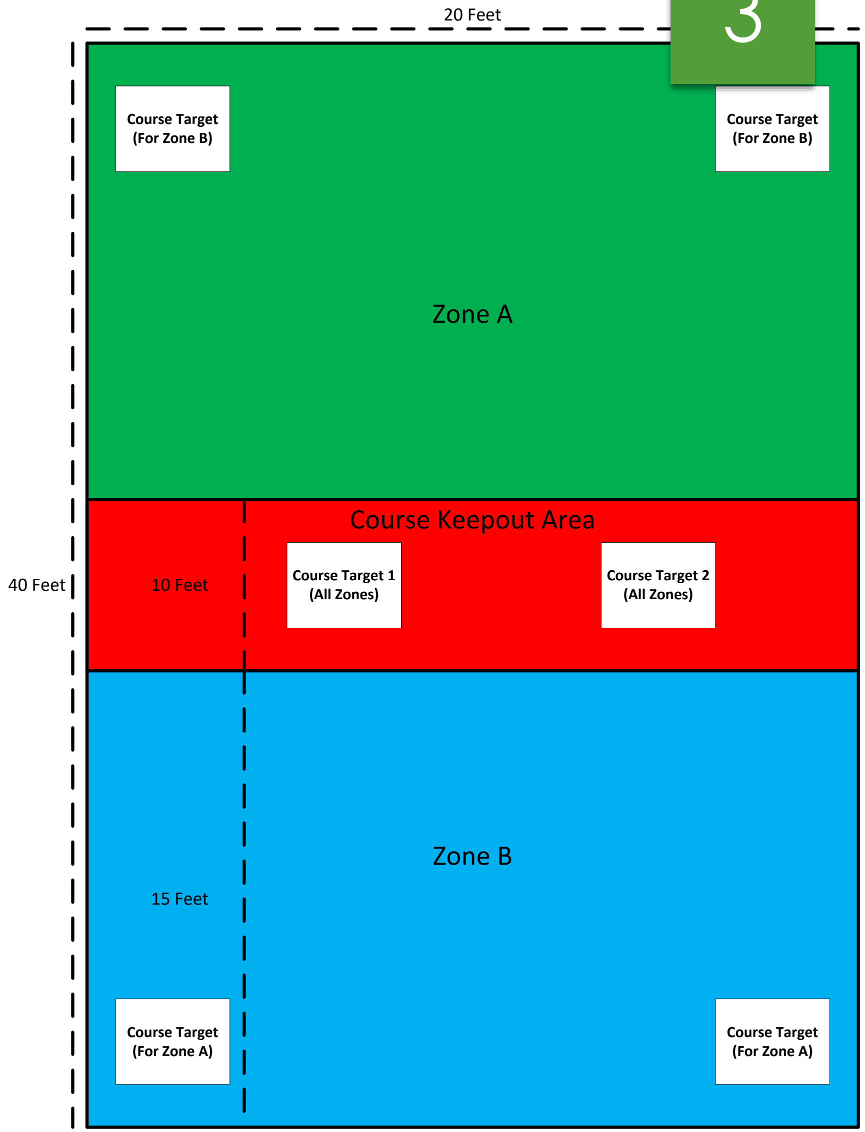
Project Overview / Statement of Work

- Design, build, test, and deliver a manually-remote-controlled ground robot that utilizes several sensing technologies to:
  - Autonomously detect, track, and fire at enemy robots, medics, and other targets
- Compete in NERF-enabled Battlebot competition
  - Comprised of 3, 10-minute rounds

Course Description

- 40 ft. x 20 ft.
- 2 primary zones
- 1 keep-out area (10 ft. x 20 ft.)
- 2 course obstacles
- Multiple stationary course targets



Lockheed Robot Requirements

- **Physical Platform**
  - Maximum size of 3ft. x 3ft. x3ft.
- **Budget**
  - Maximum budget of $2k
  - Maximum as-demonstrated cost of $1k
- **Sensors**
  - Minimally use 1 sensor modality
- **Weapon Systems Allowed on Robot**
  - 1 NERF Ball and/or Dart Gun
  - Maximum of 50 shots per weapon
- **Target Detection Automation**
  - Provide video overlays that highlight detected targets
  - Provide wireless video feed

Work Distribution

Mechanical		Computer Science		Computer & Electrical	
Name	Responsibilities	Name	Responsibilities	Name	Responsibilities
Tyler Coughlin	• Drivetrain	**Daniel Healy**	• Prioritization • Object Detection • User-Application	**Clayton Cuteri**	• Software Integration (primary) • Sensor Detection (secondary)
Austin Moore	• Chassis	**Nick Ho Lung**	• Facial Detection • Movement Detection	**Corey Nelson**	• Firmware Integration (primary) • Fire Control (secondary)
Jared Weber	• Turret	**Sayeed Tahseen**	• Visual Feed • Object Detection • User-Application	**Kyle Nelson**	• Fire Control (primary) • Firmware Integration (secondary)
Corbin Rowe	• Power • Drive Control			**Alexander Perez**	• Sensor Detection (primary) • Software Integration (secondary)
Nathan Herald	• NERF Weapon				

Group 2: Goals and Motivation

The project goals:

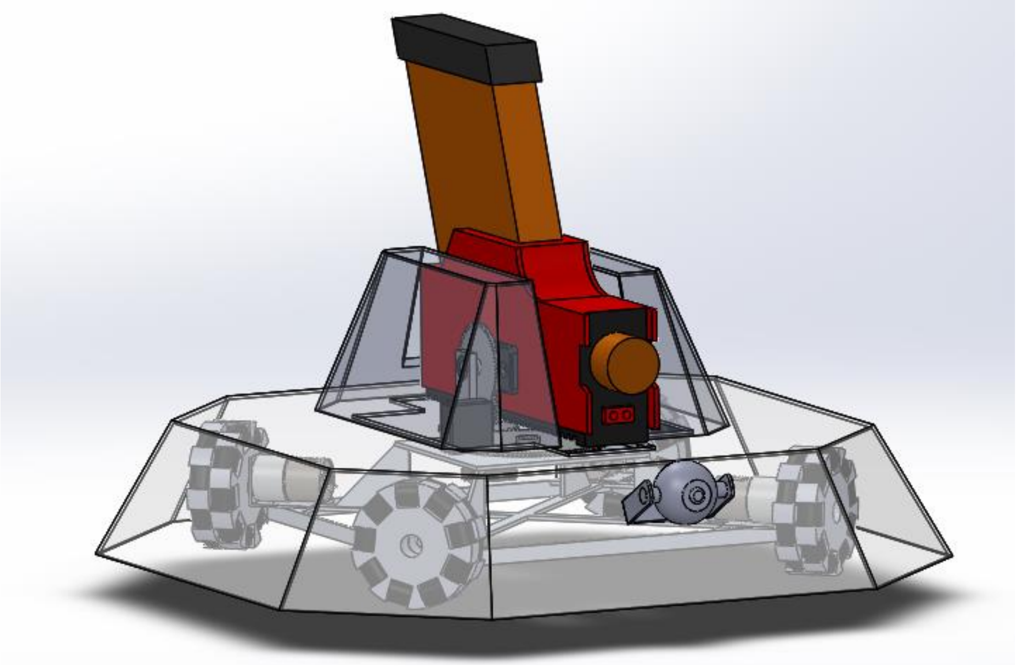
- Cost-effective
- 100% in compliance with Lockheed's required specifications

The cumulative motivation:

- Experience coordinating with multiple engineering disciplines
- Working together with Lockheed Martin Applied Research

Battlebot Design Goals

- Modular
  - Easy to assemble and perform maintenance
- Responsive
  - Low latency reaction to user-commands
- Accurate Target Discrimination
  - Facial, Robot, Human Profile (medic)

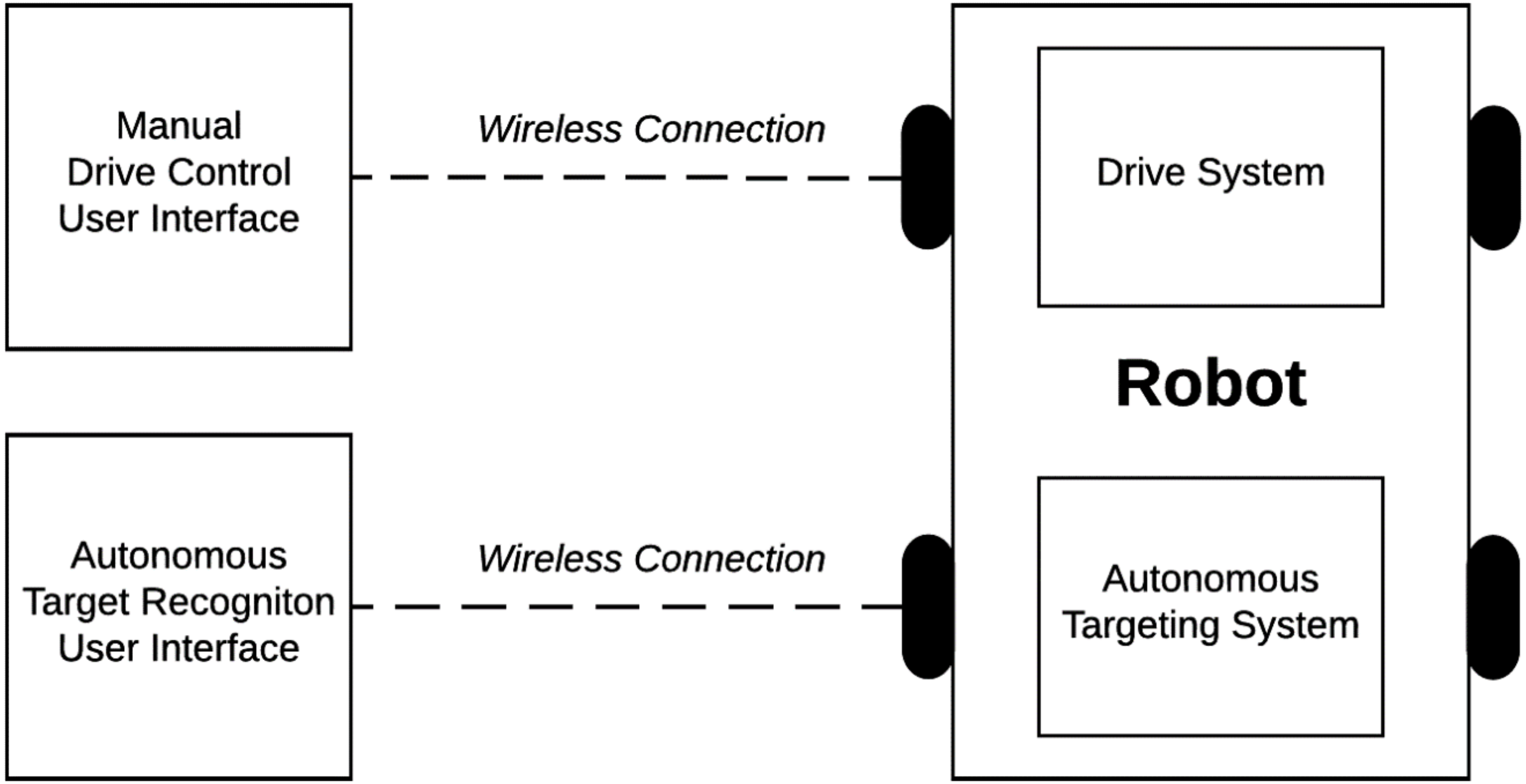


Green Team Battlebot design as of 12-13
(Subassembly discussions to follow)

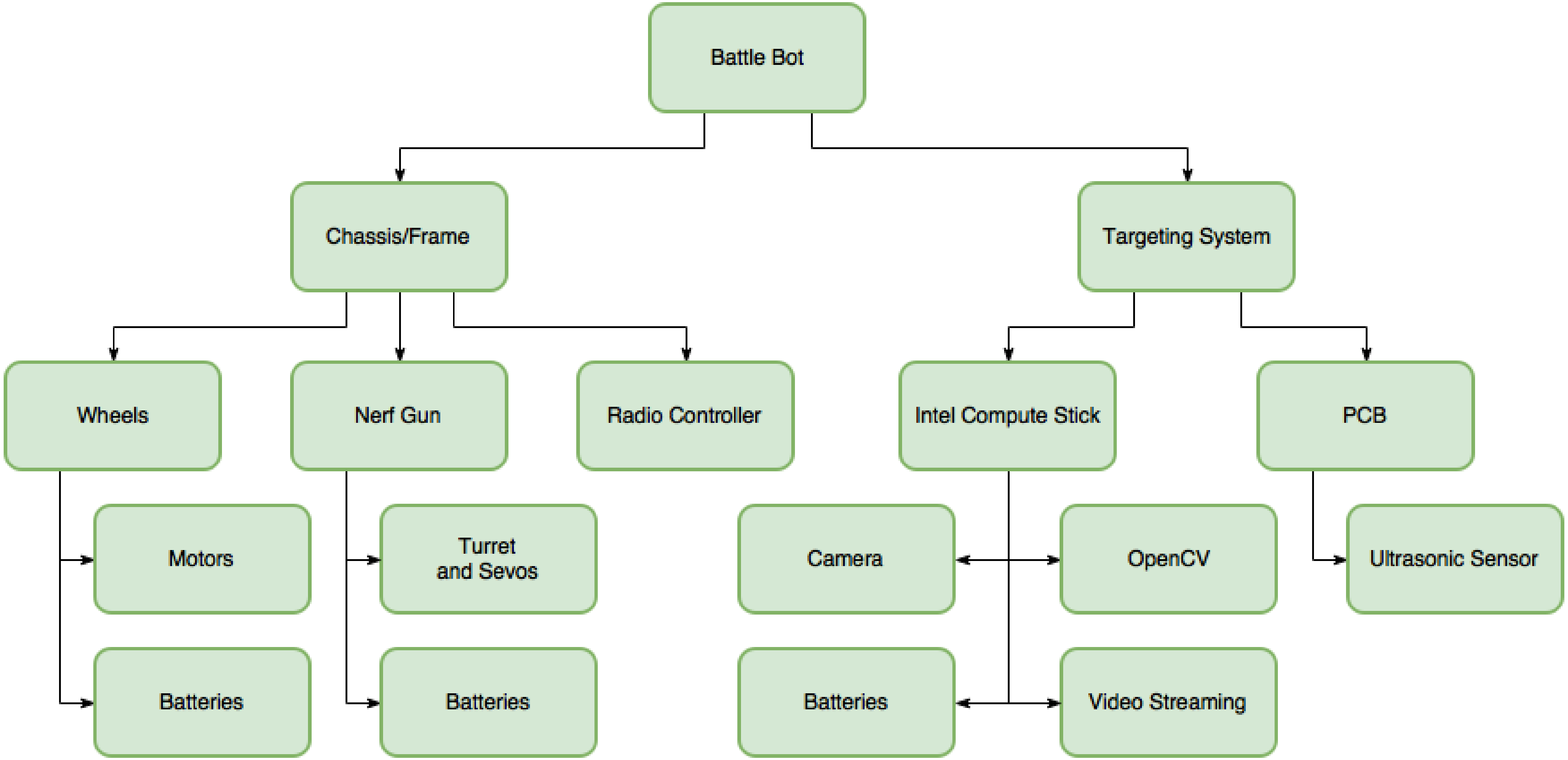
Engineering Requirements

- Small Footprint:
  - Less than 2 feet in length, width, and height (2’ x 2’ x 2’)
- Maximum Engagement Range
  - 40 feet
- Ammo Capacity
  - 40 rounds unmodified
- Duel Sensor Integration
  - Camera
  - Range Sensor

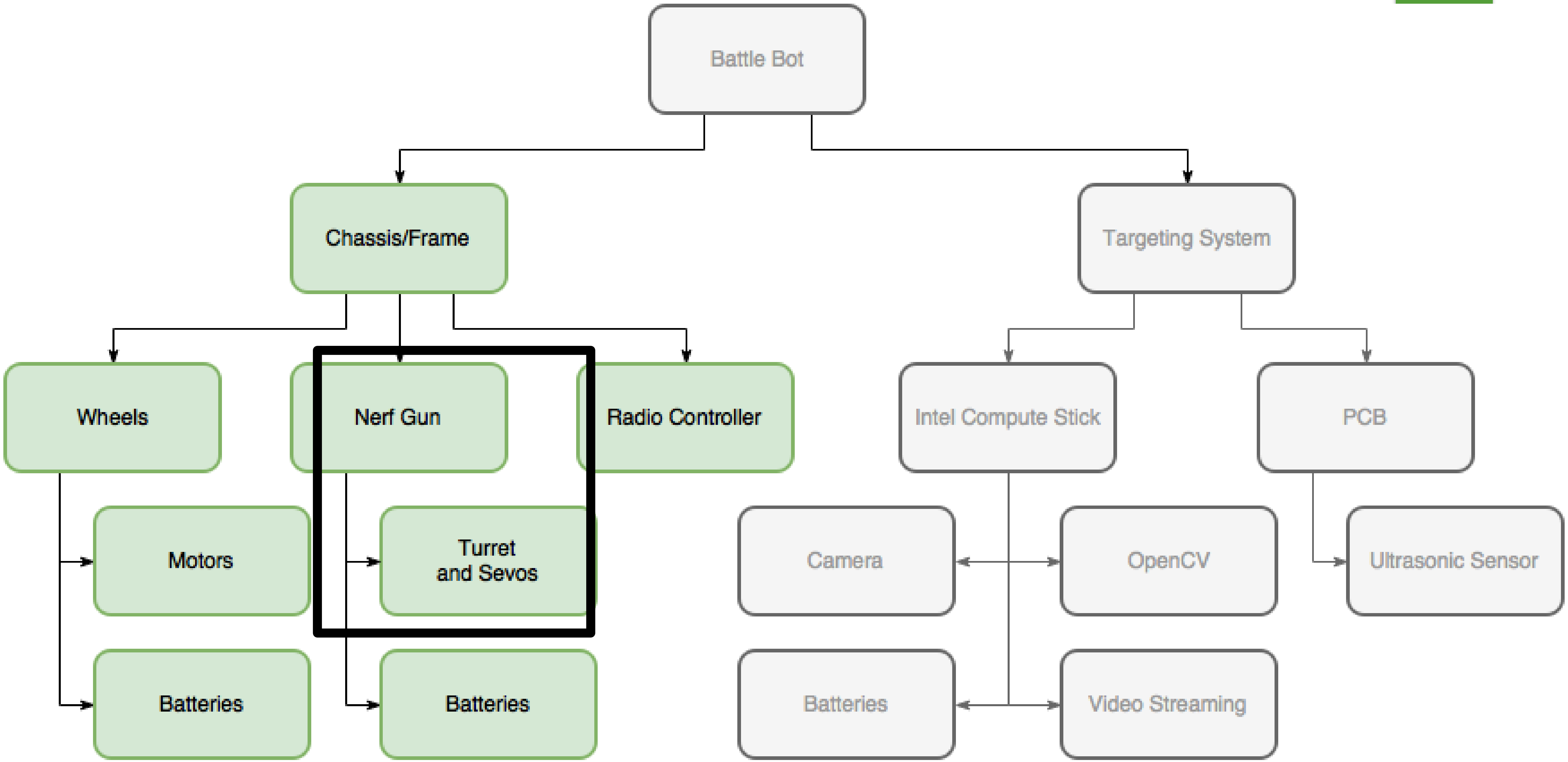
Project Top-Level Overview



Battlebot Subassemblies



Battlebot Subassemblies: Chassis/Frame



Weapon Choice: NERF RIVAL KHAOS

- Cost: $65.00
- Holds 40 rounds
- Electric Trigger
  - Test fire completed with software
- Trading weight for power
- Issues
  - Heavy
  - Jam probability
  - Upward spin

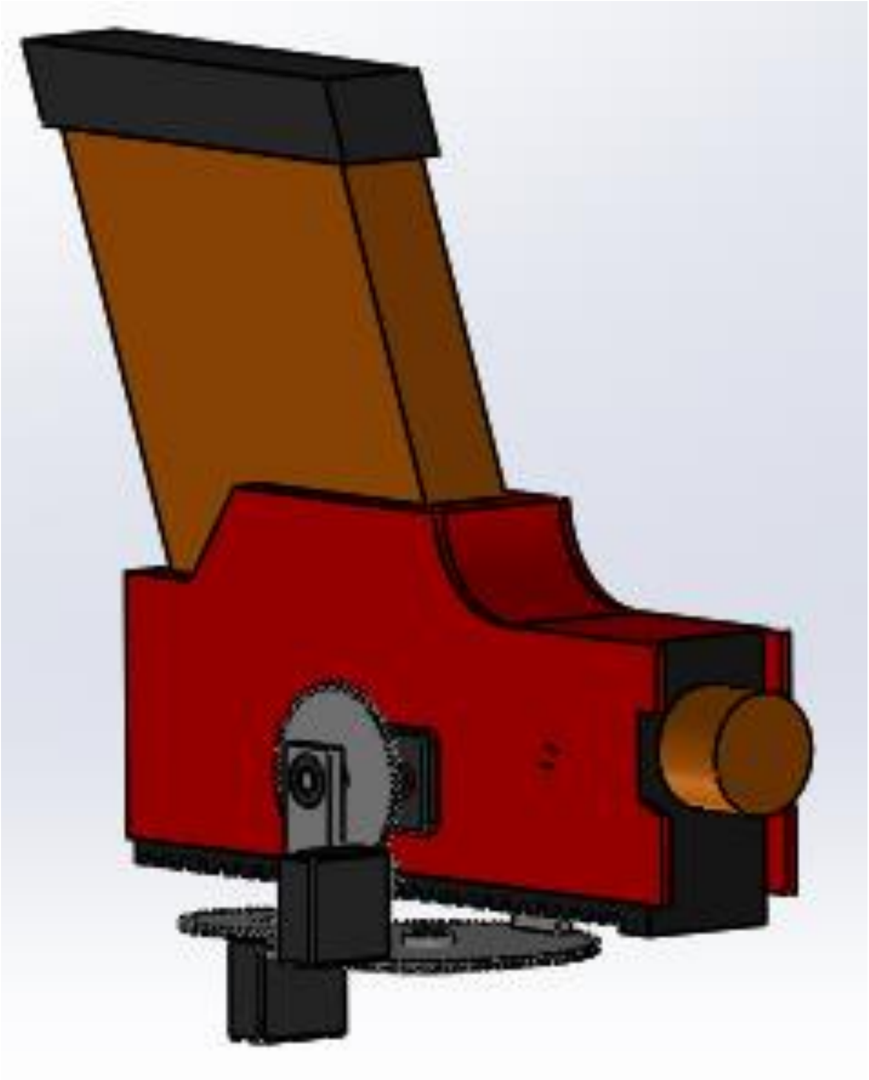
Servo Part Analysis

COMPONENT	HS-805BB	HS-645MG
Bearing Type	Dual Ball Bearing	Dual Ball Bearing
Speed (4.8V)	0.19sec/60°	0.24/sec/60°
Speed (6.0V)	0.14sec/60°	0.20sec/60°
Torque (4.8V)	19.8 kg/cm	7.7 kg/cm
Torque (6.0V)	24.7 kg/cm	9.6 kg/cm
Size	2.59 x 1.18 x 2.26 in	1.59 x 0.77 x 1.48 in
Price	$38.99	$49.99

One of two chosen servos

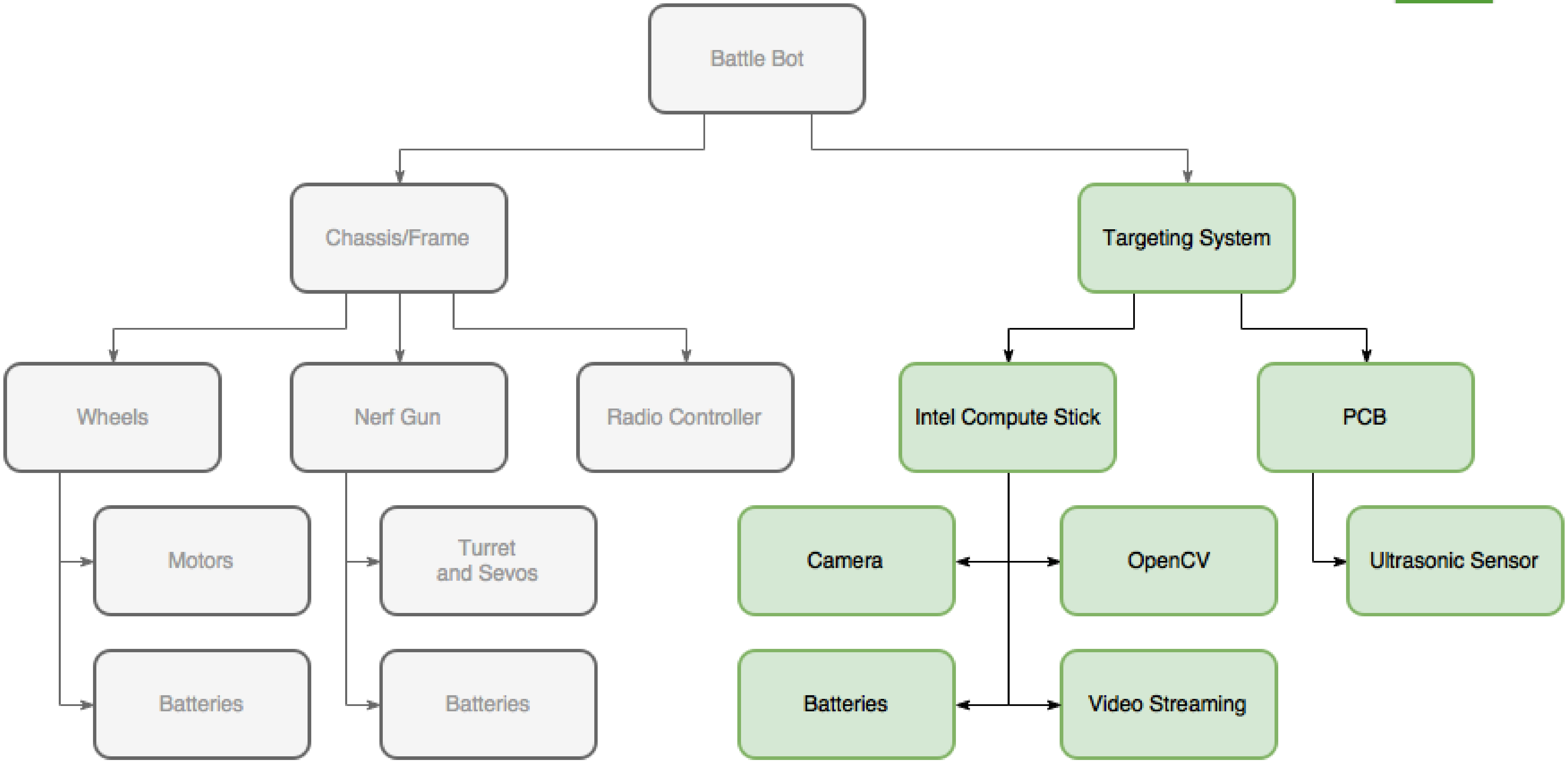
Turret System

- Pan and Tilt system for 2 degrees of motion
  - Metal Gear Pan Servo
  - Giant-scale Tilt Servo



NERF Pan & Tilt system as designed by the M.E. team

Battlebot Subassemblies: Targeting System



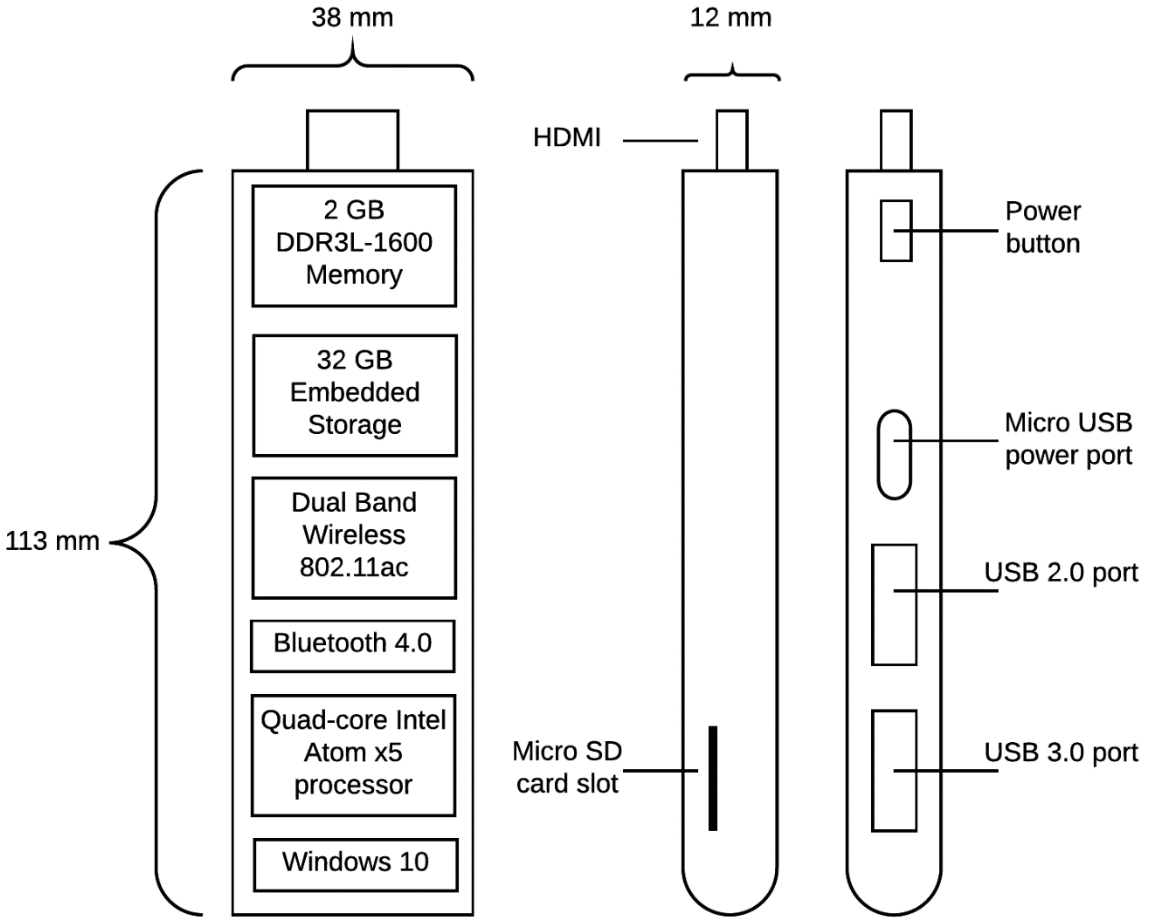
Intel Stick Advantages

- Twice the memory
- Provides Internal Flash Storage
- Over 3X faster CPU

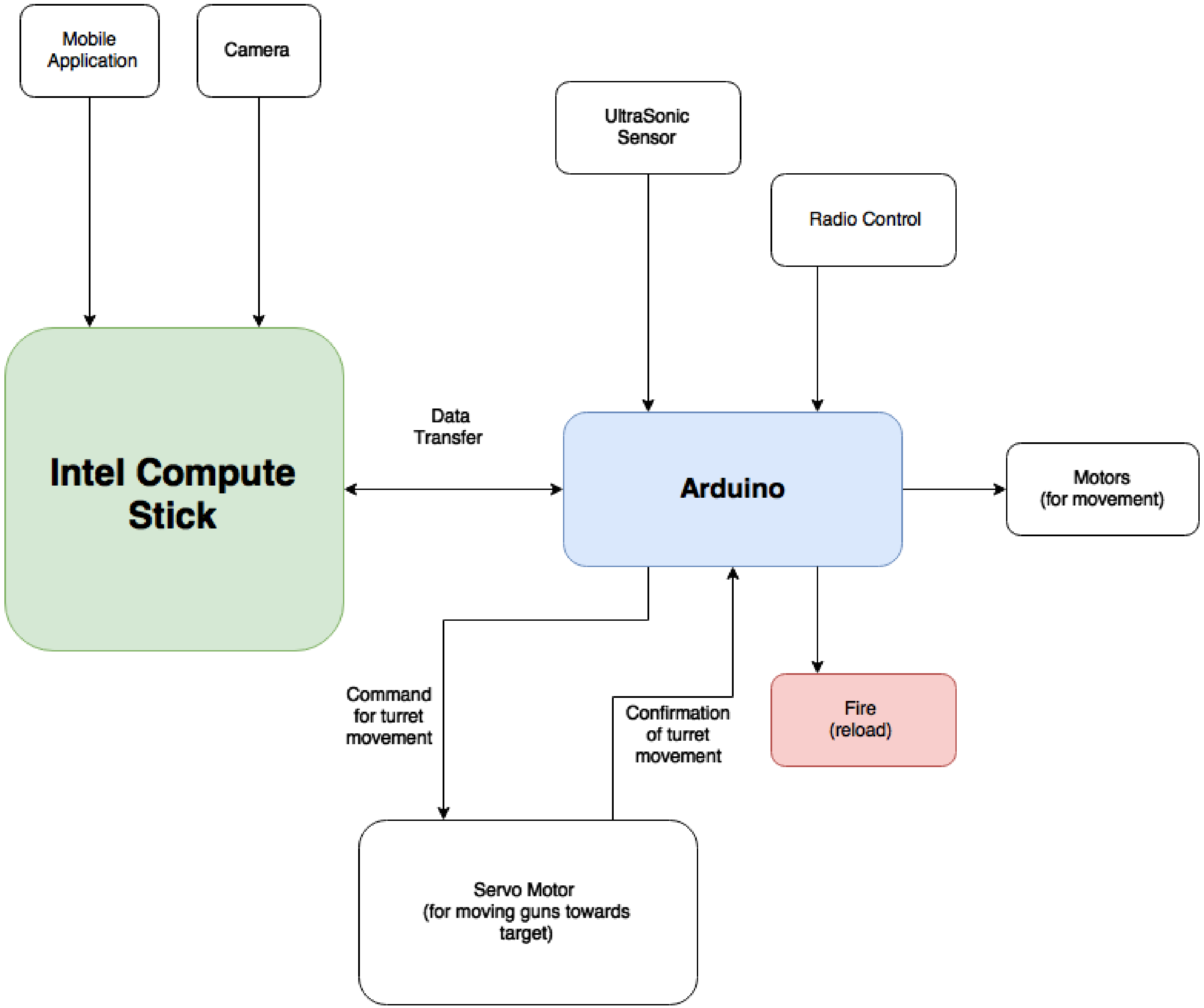
	Intel Stick	Raspberry Pi 3
Clock Speed	1.44 GHz	1.2 GHz
Memory	2 GB	1 GB
Internal Storage	32 GB	N/A
USB Ports	2	4
Power Consumption	10 Watts	4 Watts
Average CPU Benchmark	1697	482
OS	Windows	Raspbian
Dimensions:	113 x 38 x 12 mm	3.4 x 2.3 x 0.8 in
Cost	$130.00	$35

Intel Compute Stick: Computer Processing

- Full computer in palm-sized package
  - 32-bit Windows 10 OS
  - x86-based 14 nm processor
- USB to PCB
- USB to Camera
- Expandable Storage

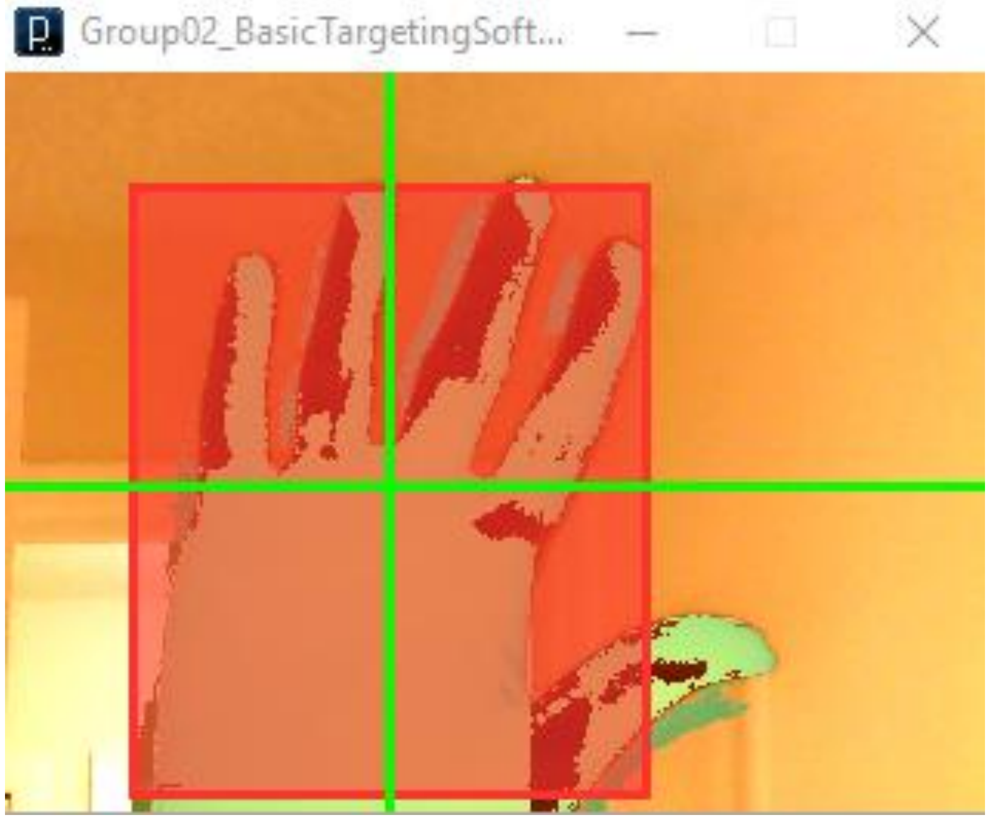


Autonomous Targeting System: Overview



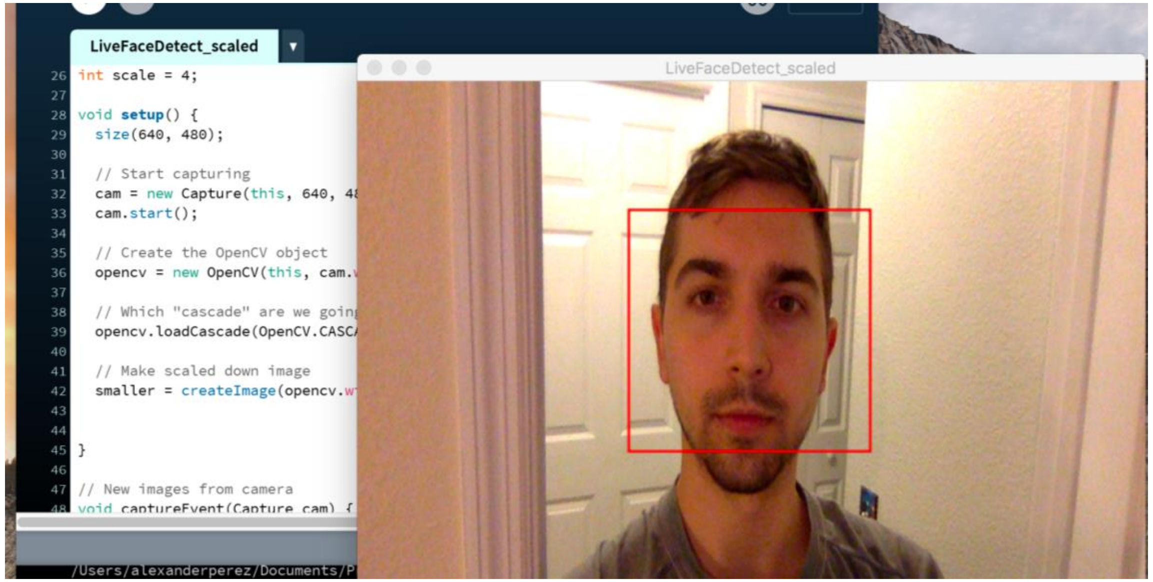
OpenCV Blob Detection

- Useful for detecting colors and movement
- CS team will be implementing facial recognition algorithms



Example using Blob Detection to track motion

Processing and GUI



Example of using imported library to detect faces

- Processing is an object-oriented environment
  - Compatible with Computer Vision libraries
  - Provides means of implementing:
    - 1) Graphical User Interface
    - 2) Video streaming overlays
    - 3) Communication with hardware

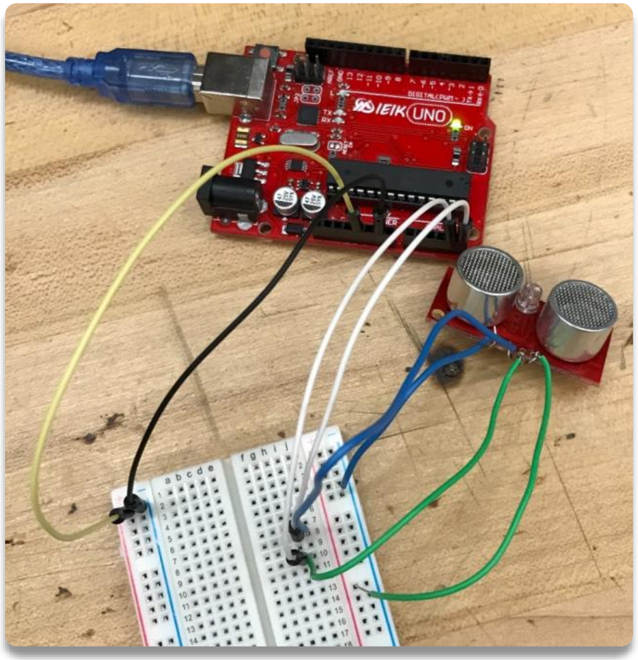
Logitech Camera Analysis: C270 vs C615

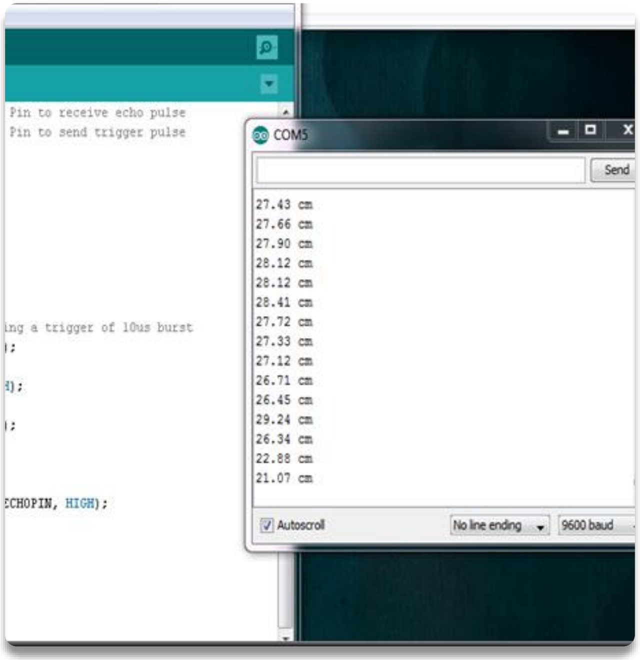
	Logitech C270 ($20)	Logitech C615 ($40)
Photo Quality	3 Megapixels	8 Megapixels
Field of View (FOV)	60°	74°
Optical Resolution (True)	1280 x 960 1.2 MP	True = 2MP, Interpolated = 8MP
Video Capture (16:9 W)	720p	1080p
Frame Rate (max)	30fps @ 640x480	30fps @ 640x480
Focus Type	Fixed Focus	Auto Focus

- Logitech C270 was selected: More affordable and less demanding on the computer due to lower resolution

Ultrasonic Sensor: Fall Analysis

- The sensor was tested to verify functionality
- Results revealed greater difficulty with long range detection than specified in the product documentation





Solution: LIDAR Range Sensor Upgrade

Features	LIDAR Lite V3	SRF08 Ultrasonic
Range	0 – 40 meters	3cm – 11m
Power	5V	5V
Current	130ma	20ma
Optimal Range	>5 meters, <45 meters	6m
Cost	$150	$50

- LIDAR Lite V3 was selected due to increased range

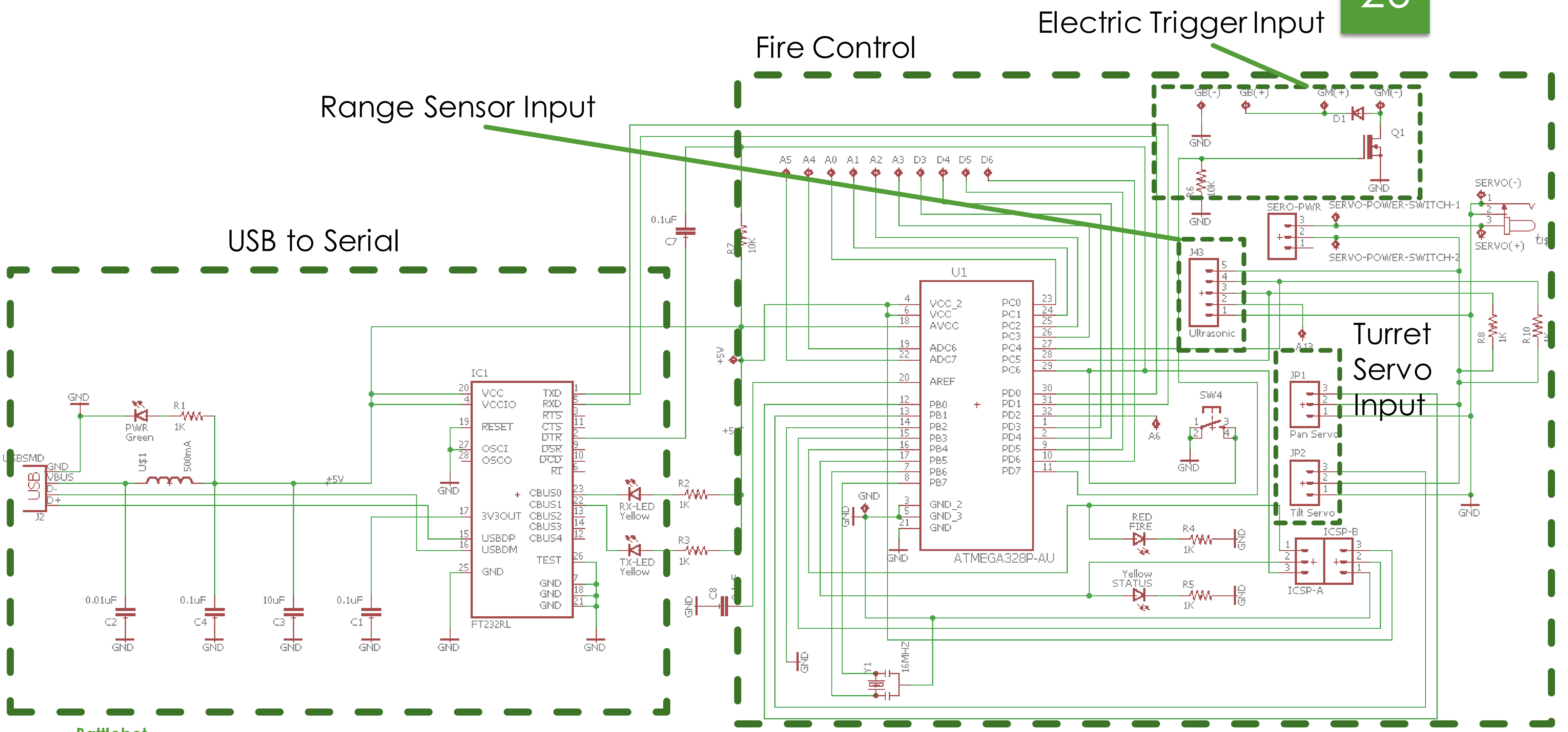
Targeting System Battery Technologies

- Rechargeable Lithium Ion Battery
  - Will be utilized to power the on-board computer
- 6V Battery Holder
  - Provides 6V of power to peripherals

ATmega328/P Microcontroller

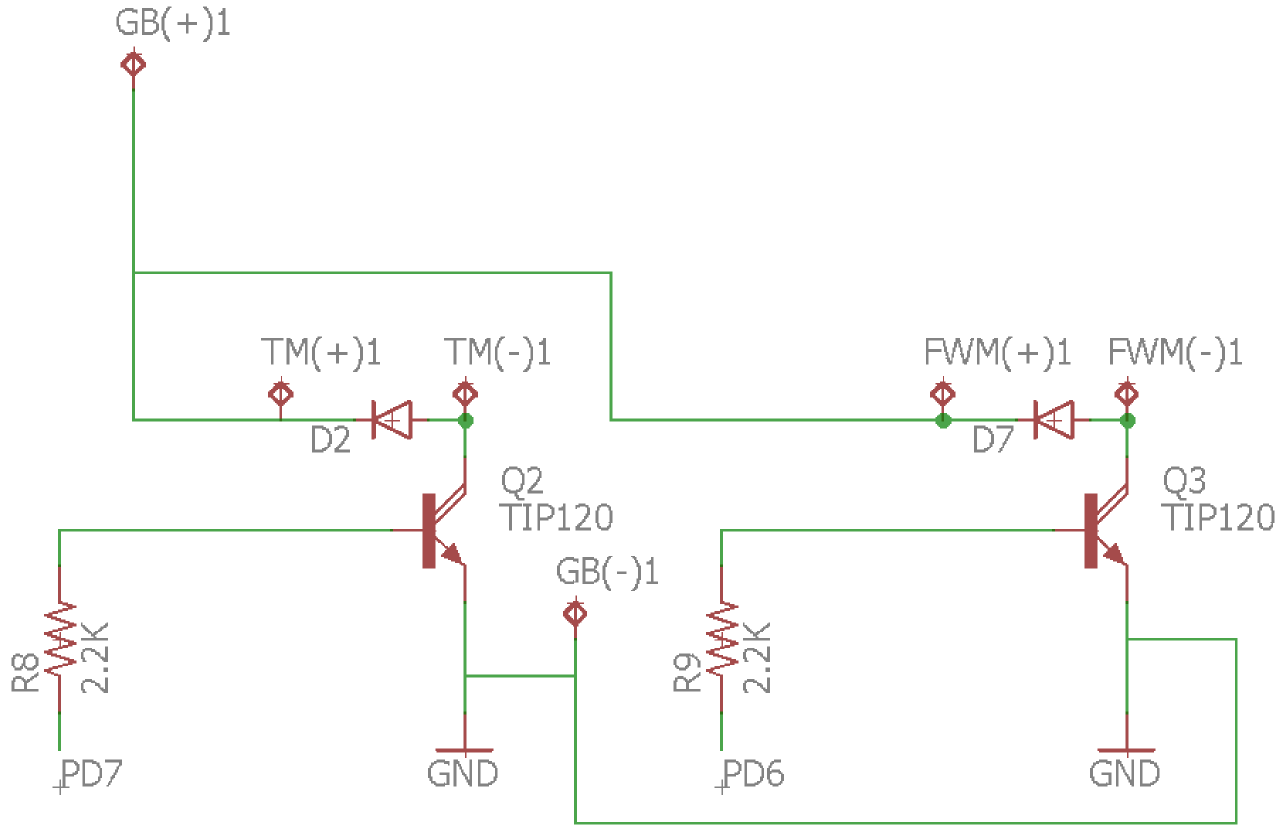
- 32K Flash Storage
- 23 GPIO pins
- Low cost development board available
  - Arduino Uno (IEIK) $10

Custom Targeting Schematic



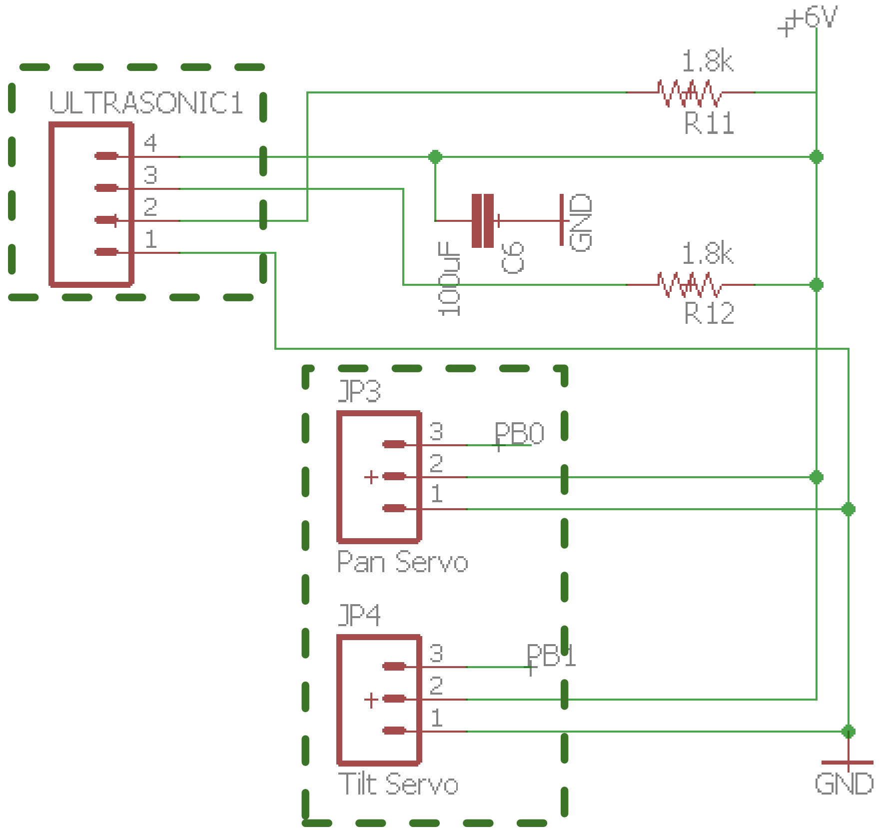
Flywheel and Trigger Motor Control

- Two transistors individually control the NERF flywheel and trigger motor



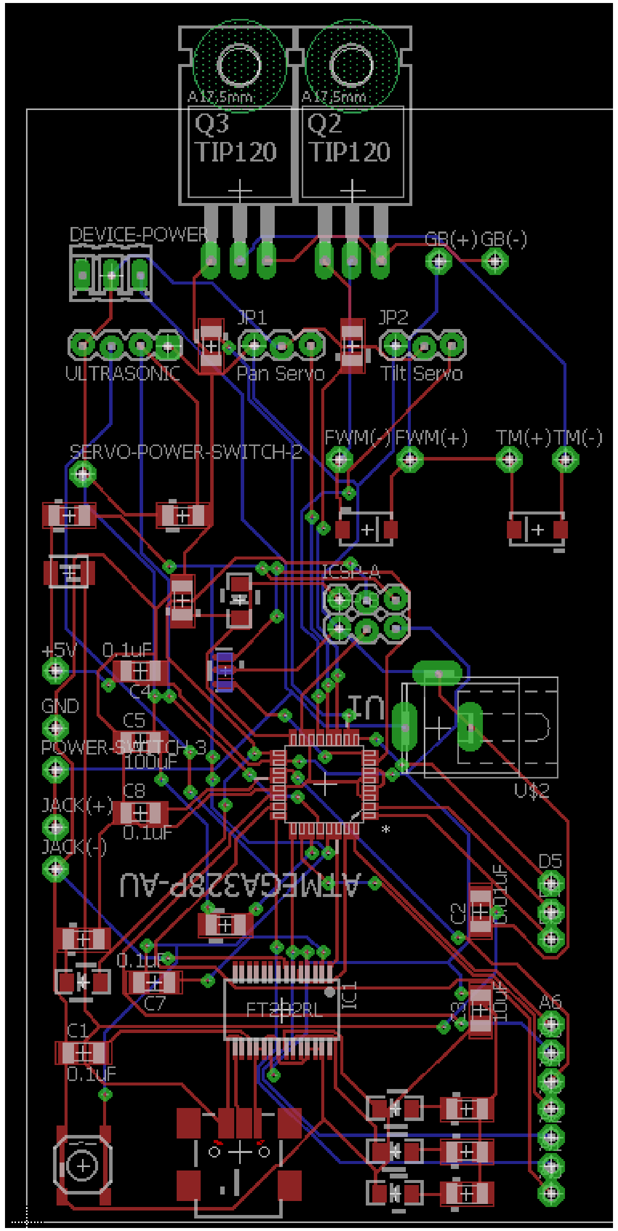
Servo and Sensor Control

- The data outputs of the *pan servo*, *tilt servo*, and *range sensor* are connected to various inputs of the microcontroller
- The microcontroller sends and receives data from these peripherals



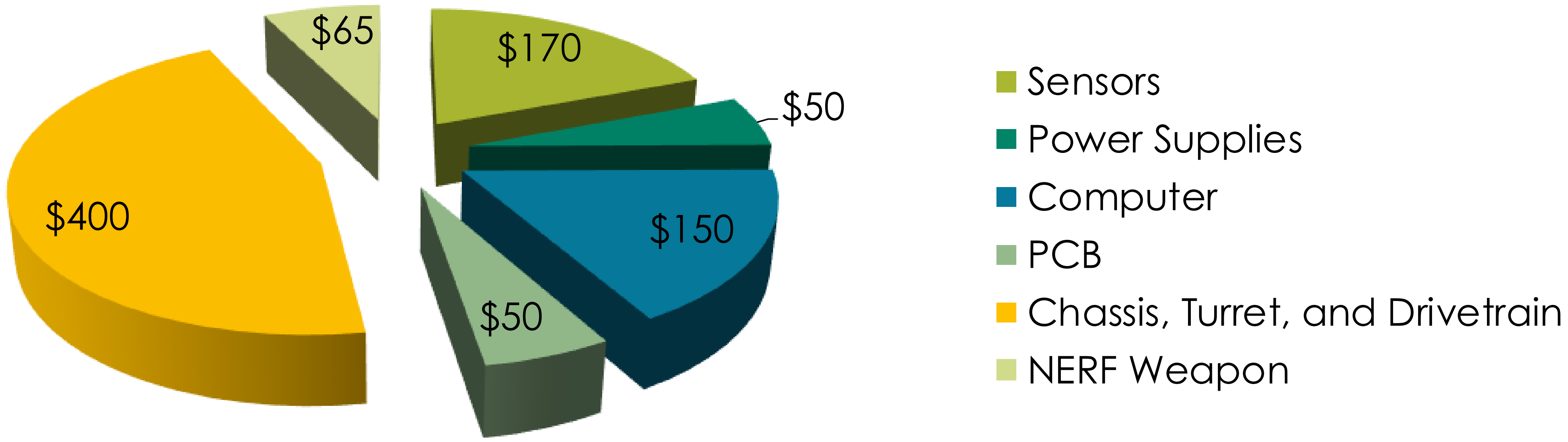
PCB Generation from Custom Schematic

- Two layer design
  - Surface mounted
- Final board to measure ~ 6" x 4"
  - Smaller size to reduce cost
- Final vendor selection TBD
  - 4PCB offers $33 per board
    - No minimum order requirement
  - Additional component costs



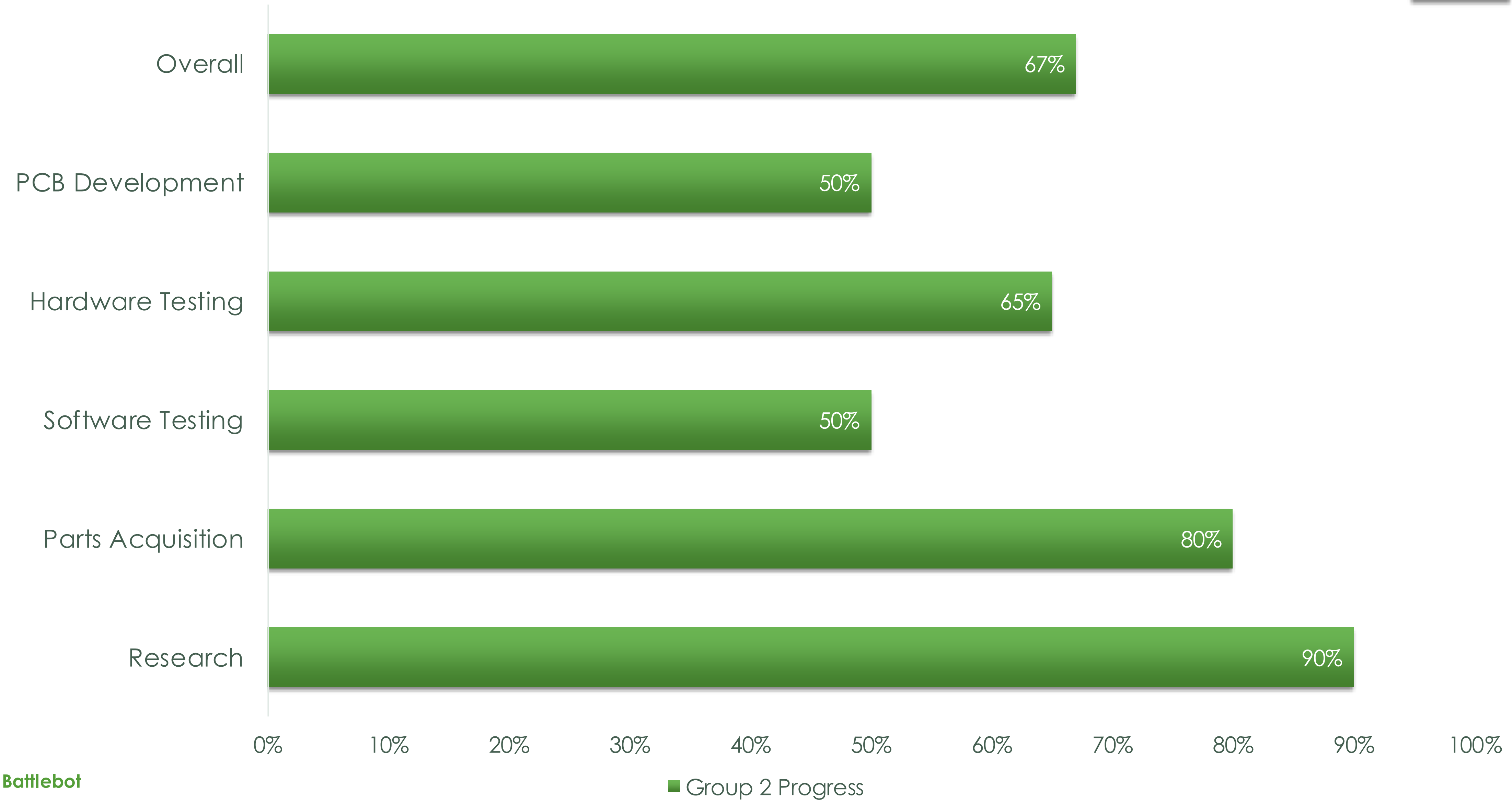
Preliminary Design

Budget & Finance



Total: $885

Current Progress



Issues

- Chassis Stability and Performance
- NERF Gun accuracy
- Open CV – microcontroller integration
- Range Detection Consistency
- Cost

Path Forward

- Integrate Autonomous Targeting Software and Hardware
- Optimize software for ideal objective fulfillment
- Finalize and order PCB
- Construct prototype Battlebot
  - Conduct practice battle scenarios & longevity tests
  - Iron-out issues

Have any questions, do you?

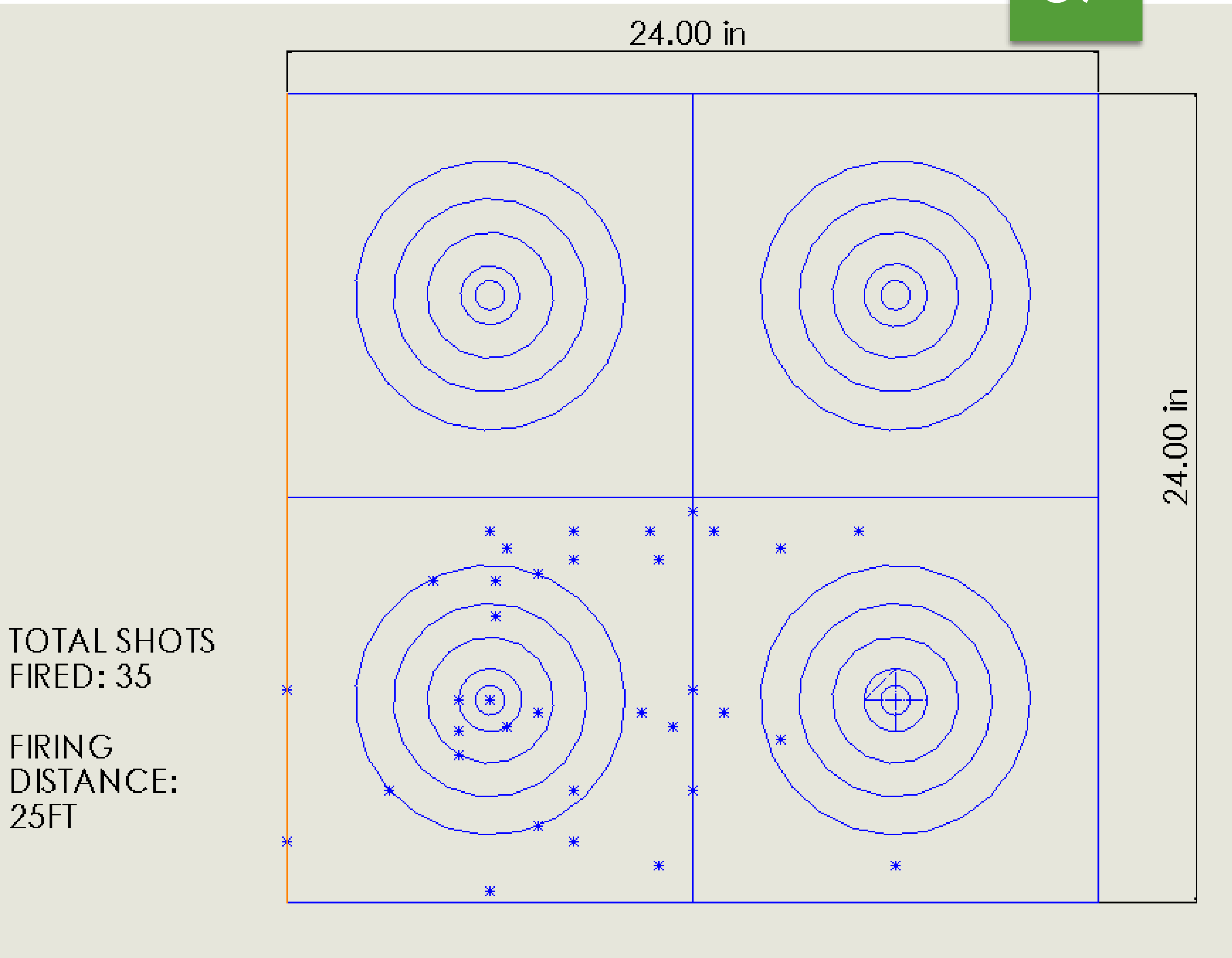
Appendix

Remote Manual Drive Selection: Radio Control

- GoolRC FS-T6 2.4ghz Digital Proportional 6 Channel RC Transmitter and Receiver Model 2
- Comes with receiver that wires into Arduino
- Arduino Motor Shield attachment:
  The Arduino Motor Shield allows your Arduino to drive DC and stepper motors, relays and solenoids.
- Motors and receiver plug into Arduino; code will be written with assistance from EECS team.

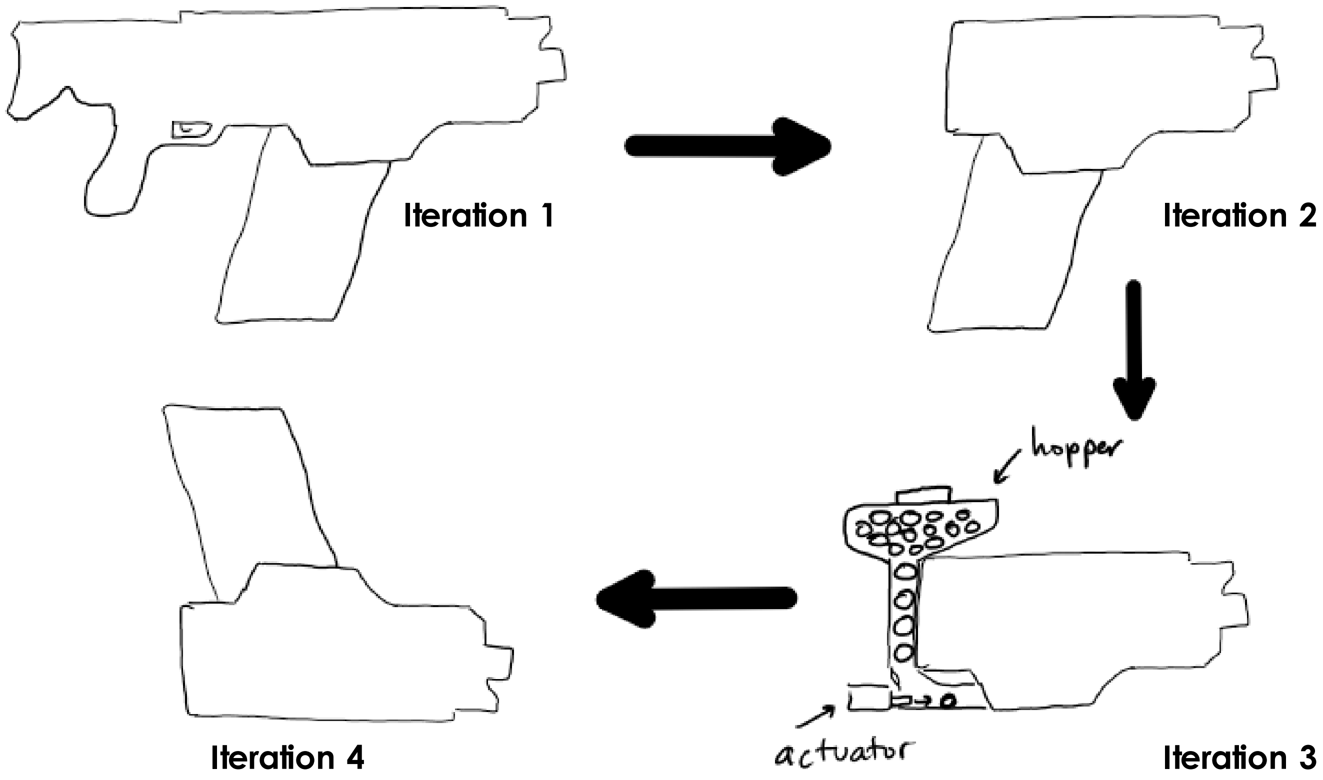
Nerf Gun Accuracy

- 35 shots were fired
  - Aiming at bottom right target
- Figure (right) shows the distribution from 25 feet away



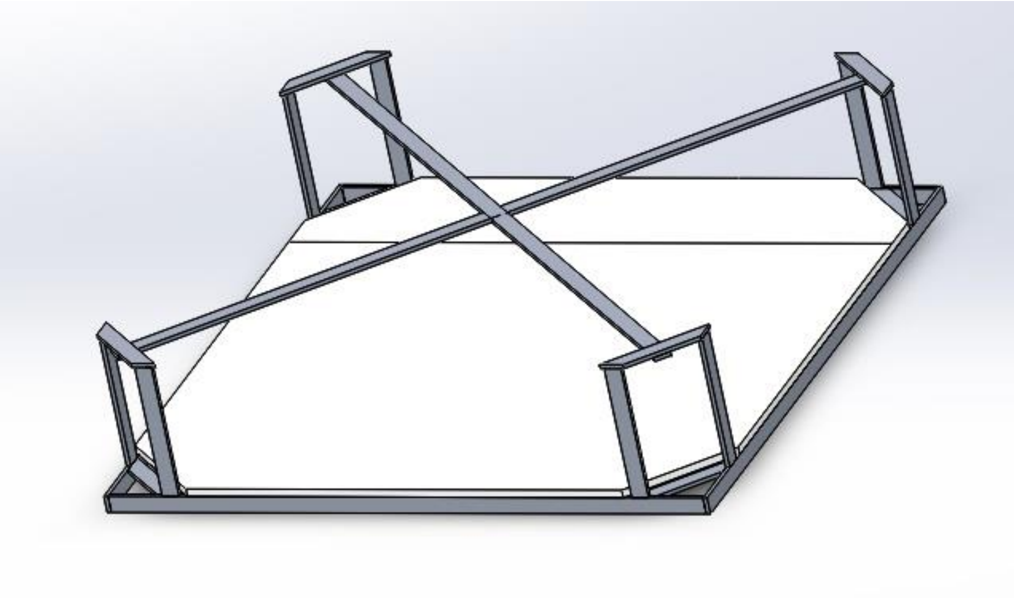
Concept Generation

- Final Concept:
  - Lower Center of Gravity
  - 50% reduction in weight
  - Smaller target
  - Allows for future modification of magazine



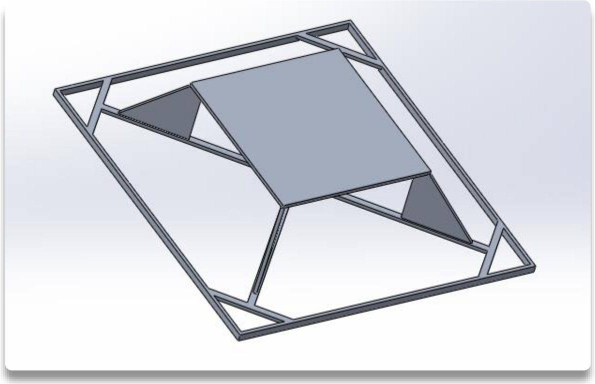
Initial Frame

- Constructed of ⅛" x ½" 6061 aluminum beams for weight reduction and strength
  - ⅛" x ½" standard
  - Available at Alro metals
- Upper bracing to mount turret and additional space for CS/CE components
- Gussets and diagonal beams to increase rigidity. Gussets also act as mounting surface for electric motors
- 2ft x 2ft x .42 ft

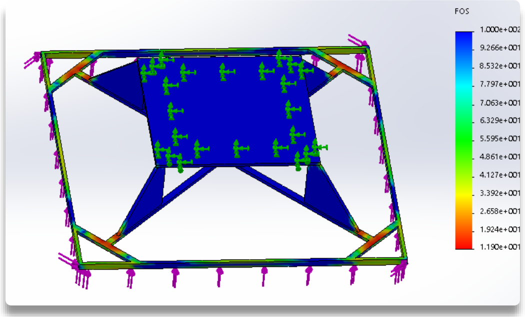


Final Frame Revision

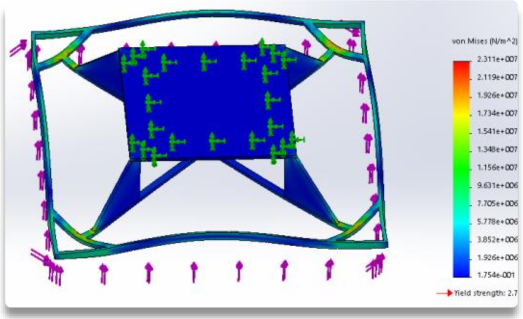
- Reducing width of beams to a ¼" reduced the weight of the frame to 0.85 lbs, but resulted in a higher displacement.
- Thickened to original ½ in width for reduced displacement from 0.22mm to 0.08mm from weight and drivetrain forces (FEA)
- Weight: 1.1lbs
- Dimensions: 12" x 12"
- Manufacturing:
  - Welding with use of tig welder and jig fixtures



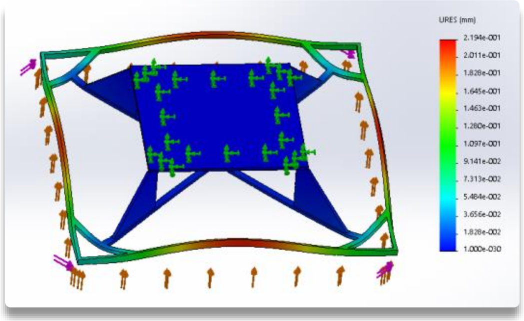
Factor of Safety Plot



Stress Plot



Displacement Plot

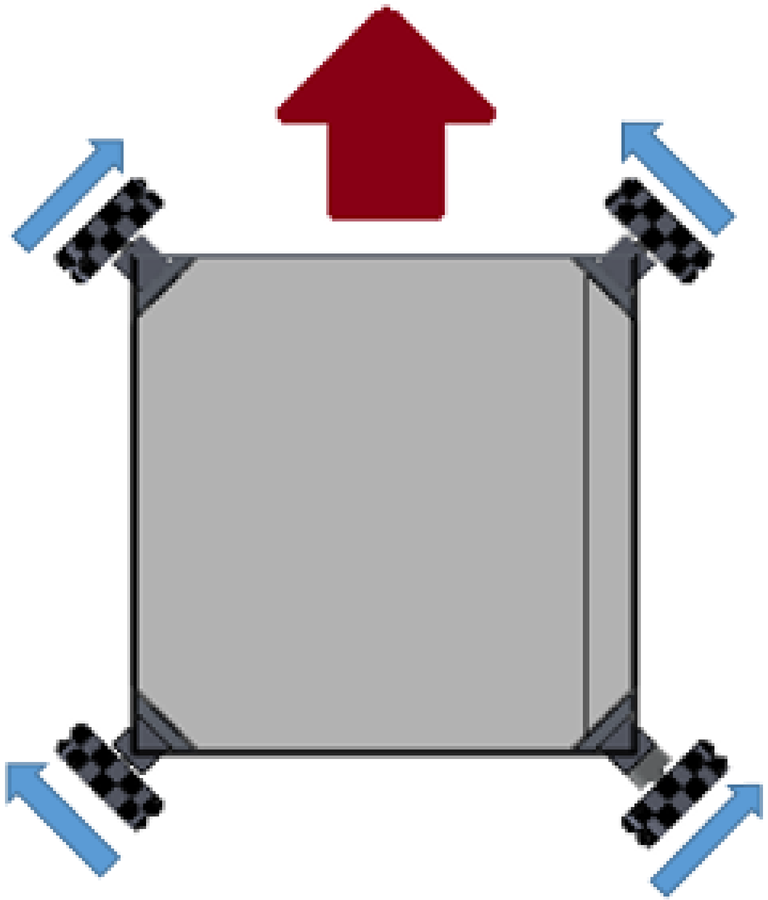


Wheel/Drivetrain Generation and Selection

- Originally selected tank drivetrain.
- Researched the slide, mecanum, and swerve drivetrains for their perpendicular movement to "juke" the opponent.

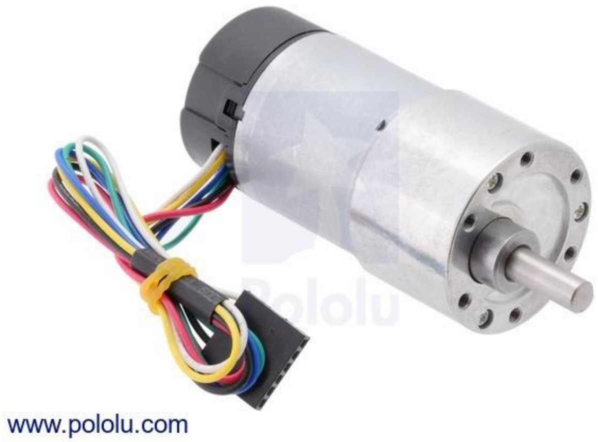
	High push force	Agility	Inexpensive	Simple Software	# of motors
Tank	x		x	x	1-2
Slide		x	x	x	2-4
Crab	x	x			6-8
Mecanum		x			4

- Slide Drivetrain was chosen for its simple design and inexpensive cost



Drivetrain and Wheel Explanation

- Four part assembly of motor, omni-directional wheels, mount, and screw hub
- Pololu 131:1 Metal Gearmotor 37Dx73L mm with 64 CPR Encoder.
  - Inexpensive at 39.95 per motor
  - Versatile motors
- 100 mm Omni-directional wheels selected



	Price	Motor ready
100 mm RobotShop	19.99	Yes
4" Vex Robotics	17.99	No
55 mm Robotshop	12.49	No
152 mm Robotshop	72.51	Yes

Motor Stall Torque Explanation

- Stall Torque = W x μ x r
- Where W is weight on wheel, μ is coefficient of friction, and r is radius of wheel.
- This robot achieves maximum power at about 18.6 lbs.
  - Goal of final design
  - Good starting point; variety allows for easy changes in the future

Dimensions

Size:	37D x 72.5L mm[1]
Weight:	235 g
Shaft diameter:	6 mm

General specifications

Gear ratio:	131:1
Free-run speed @ 6V:	40 rpm[2]
Free-run current @ 6V:	250 mA[2]
Stall current @ 6V:	2500 mA[2]
Stall torque @ 6V:	125 oz·in[2]
Free-run speed @ 12V:	80 rpm
Free-run current @ 12V:	300 mA
Stall current @ 12V:	5000 mA
Stall torque @ 12V:	250 oz·in
Lead length:	11 in

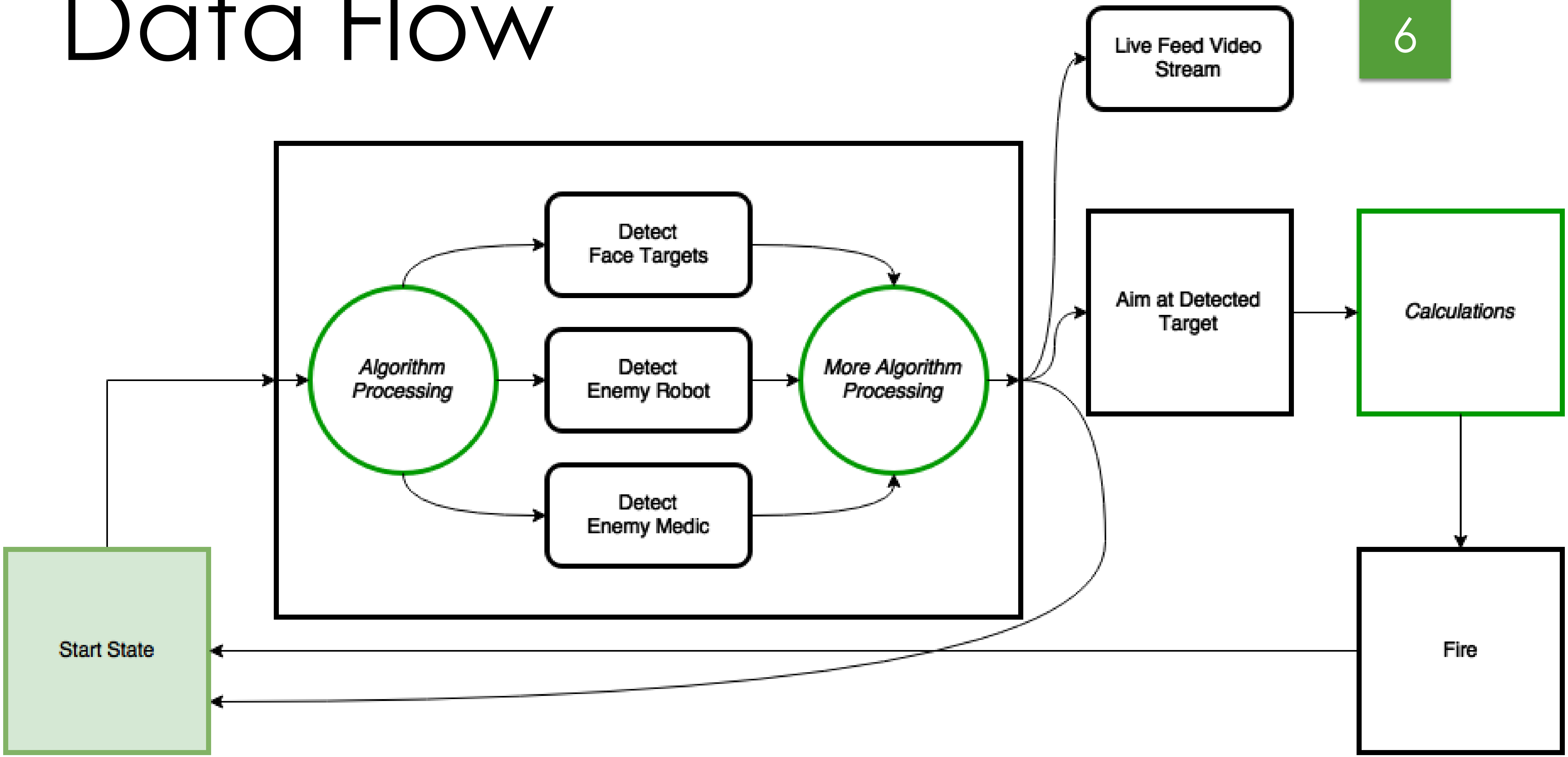
Drivetrain Battery

- Duel Universal Smart Charger:
  - 7.2v - 12v (#01005) + 2 pcs Tenergy 7.2V NiMH 3800mAh Battery Packs
- Comes with two batteries and charging unit
  - Will be able to replace battery mid-battle if needed

Battery Calculations

- At 6V, the motor's stall current is 2500mA. To calculate maximum conditions, we assume all four motors are going to remain in stall the entire round. Provided that this is the case, the total current draw is 2500mA x 4 = 10,000mA
- The battery chosen has a capacity of 3800mAH
- 3800mAH/10000mA = 0.38 hours
- Theoretical run time under full load= 0.38 hours
- Realistic run time=20 minutes = .33 hours

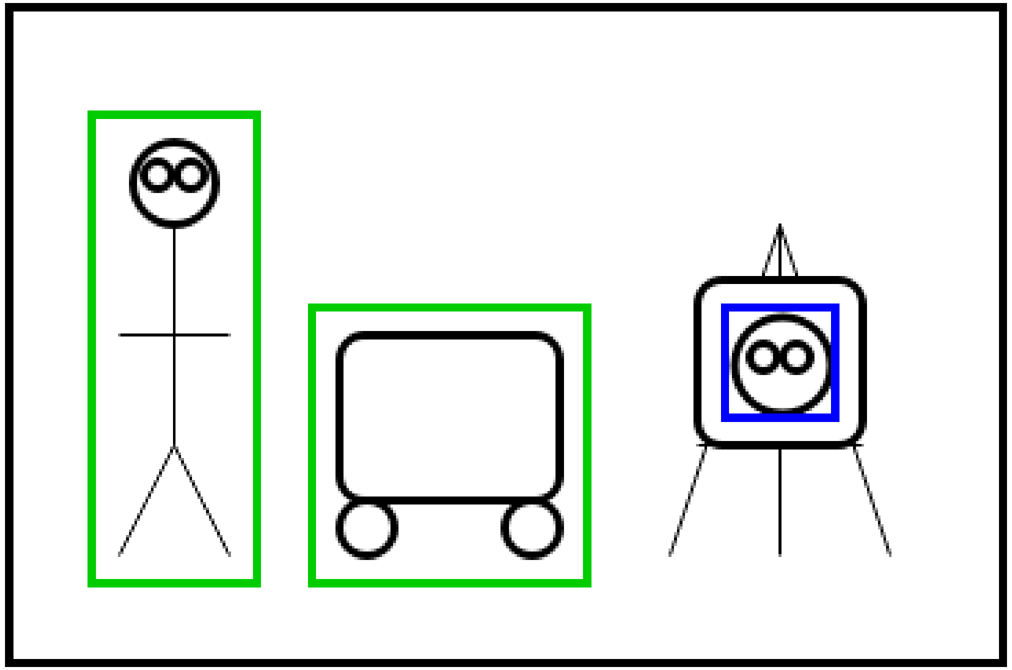
Data Flow



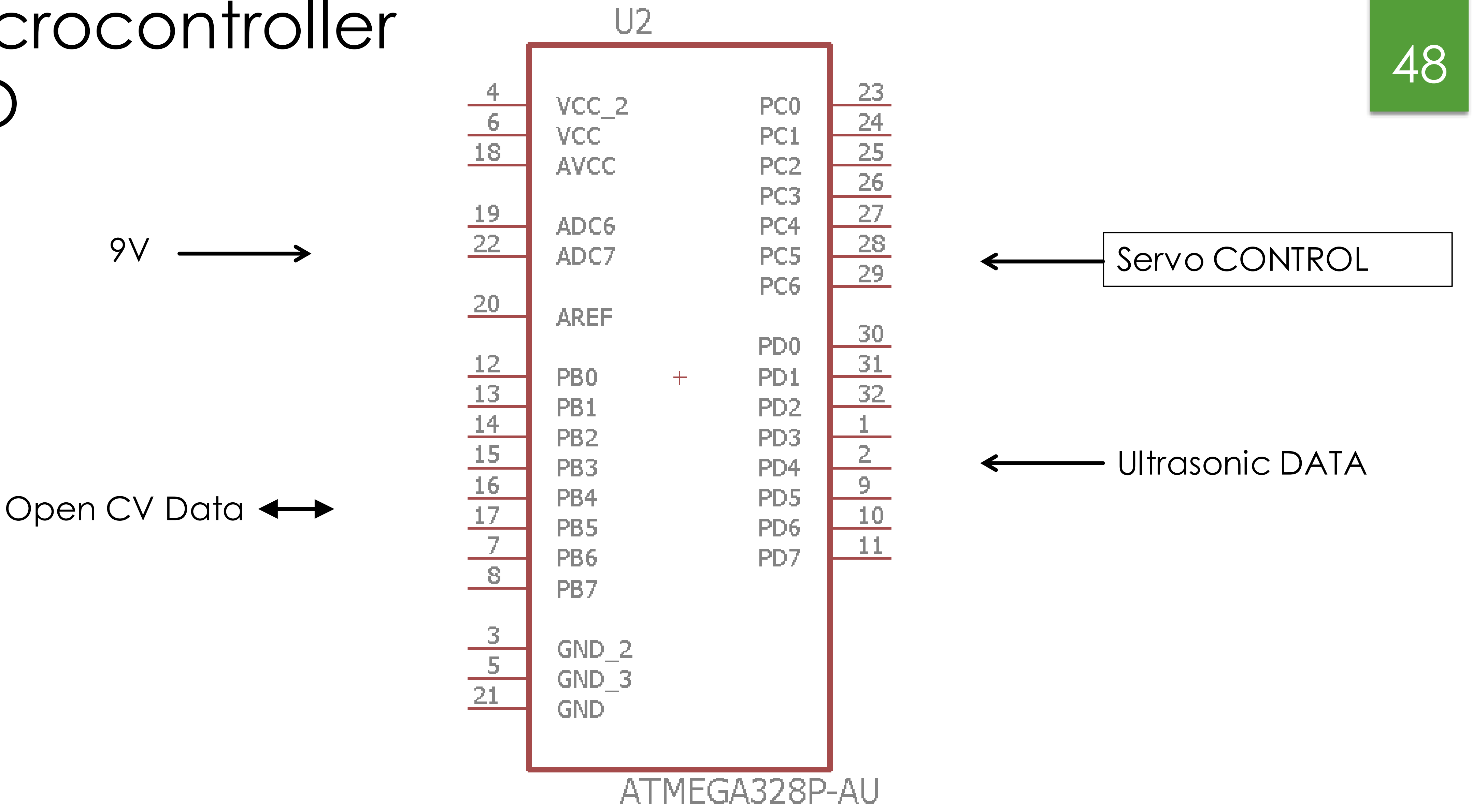
Live Feed Video Stream
Detect Face Targets
Algorithm Processing
Detect Enemy Robot
More Algorithm Processing
Aim at Detected Target
Calculations
Detect Enemy Medic
Start State
Fire

Video Steaming

- Multimedia Frameworks
  - GStreamer
    - Pipeline-based multimedia framework
    - Compatible with Windows OS
  - FFMPEG
    - Streaming
  - To show boxes around the detected targets
  - The video feed will display:
    - Range to target
    - Current algorithm running



Microcontroller I/O



ATmega328P microcontroller schematic

Alternative Scenarios: A Case Study

- Options if provided with extra $500:
  - Faster processor & advanced optics
  - More RAM
    - Pushing 70% RAM usage with current software trials
  - Additional NERF gun
  - Greater quantity of high quality sensor modalities