NORTHROP GRUMMAN

Drone Disabling Device Design Review 6

Ryan Cziko
Quentin Lewis
Dylan Macaulay
Trevor Stade
Taylor Stamm

Team 518

Part 1: Introduction

Trevor Stade

Team Introductions

Trevor Stade

Project Manager

Mechanical Engineering

Quentin Lewis

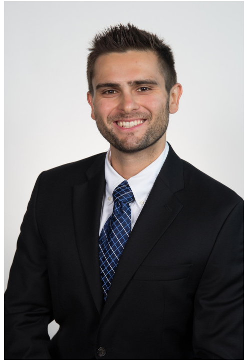
Sensor Interface Engineer

Computer Engineering

Ryan Cziko

Test Engineer

Mechanical Engineering



Taylor Stamm

Systems Integration Engineer

Electrical Engineering

Dylan Macaulay

Design Engineer

Mechanical Engineering

Sponsor and Advisor

Sponsor
Tameika Hollis
Executive at Northrop Grumman

Academic Advisor
Jonathan Clark, Ph.D.
Professor

Trevor Stade

Objective

Develop a device to secure specified air space from unmanned flight vehicles. There needs to be an improvement upon functionality, size, and overall use on last year's project.

Trevor Stade

[1]

Key Goals

- Improve speed and accuracy of drone-detecting functionality
- Reduce size of drone disabling apparatus to the size of a rifle
- Increase range of device functionality to a 50 ft dome
- Adhere to all safety, legal, and environmental regulations

Trevor Stade

Targets

Target Values						
Target No.	Need	Metric	Importance	Units	Marginal Value	Ideal Value
1	2, 10	Assembly & Disassembly Time	5	min	60	5
2	10	Weight of Device	5	lbs	30	10
3	4,5,10	Disabling Range	3	ft3	30	50
4	10	Target Acquisition Speed	4	s	20	5
5	10	Battery Life	3	h	2	3
6	3,5,10	Frequencies Jammed	3	GHz	2.4	2.4 and 5
7	2,10	Device reload speed	1	min	5	2
8	10	Target max drone wingspan	3	in	25	30
9	10	Target max drone Weight	3	lbs	4	6
10	1-9	Project Cost	5	$	5000	2500

Taylor Stamm

Highlighted Device Targets

Metric	Marginal Value	Ideal Value	Units
Assembly & Disassembly Time	60	5	Minutes
Weight of Device	30	10	Lbs
Project Cost	2000	1500	$
Target Acquisition Speed	20	5	Seconds

Taylor Stamm

Part 2: Project Design Process

Dylan Macaulay

Concept Generation and Selection

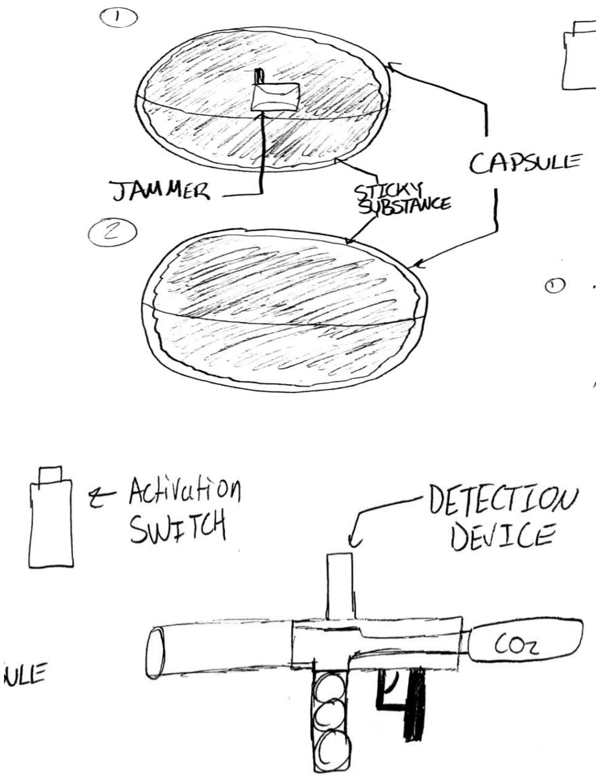
- Brainstormed a large list of terms and methods related to the project description
- Developed concepts from the list of terms and methods
  - Five drafted concepts to work with
  - Used design techniques to further evaluate concepts
- Focus narrowed down to a single concept
  - House of Quality (HOQ)
  - Pugh Matrix
  - Analytical Hierarchy Process (AHP)

Dylan Macaulay

Concept #1

- Modeled after classic paintball gun
- Activation switch for jamming
- CO2 tank allows for additional projectiles fired

- Small projectile fired
- Must hit target in order to disrupt frequencies

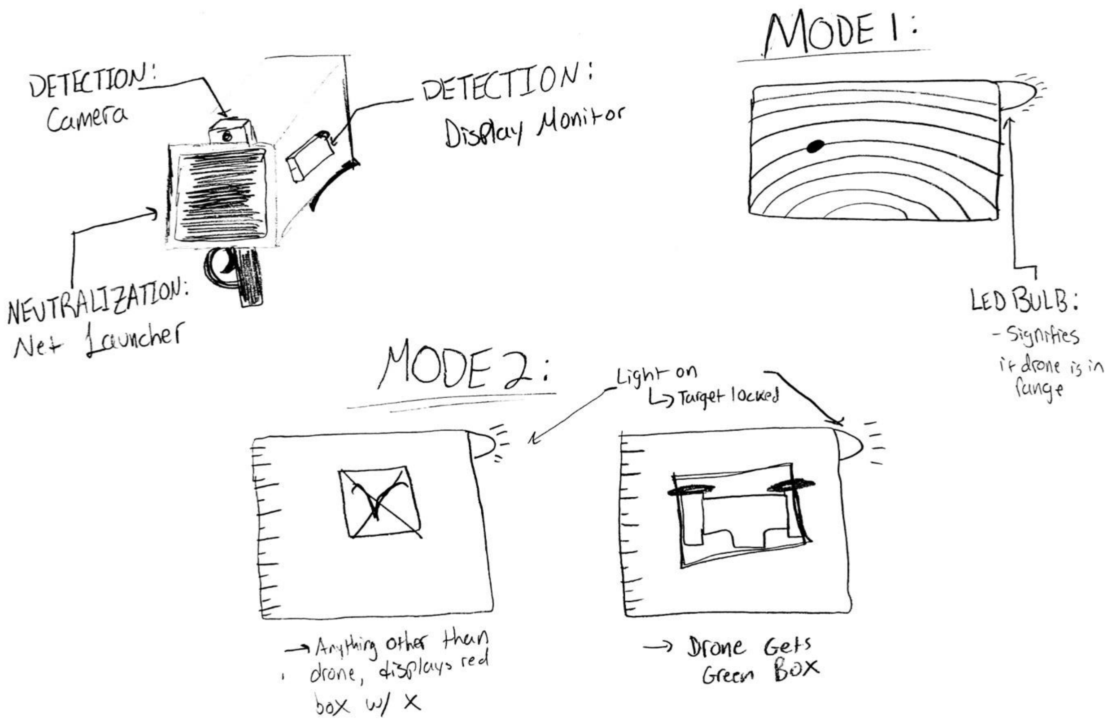


Dylan Macaulay

Concept #2

- Ideal use of detection system
- Single device system
- Mobile
- LED notification

- Integration of compressed air makes device large and bulky
- Computer systems exposed to elements

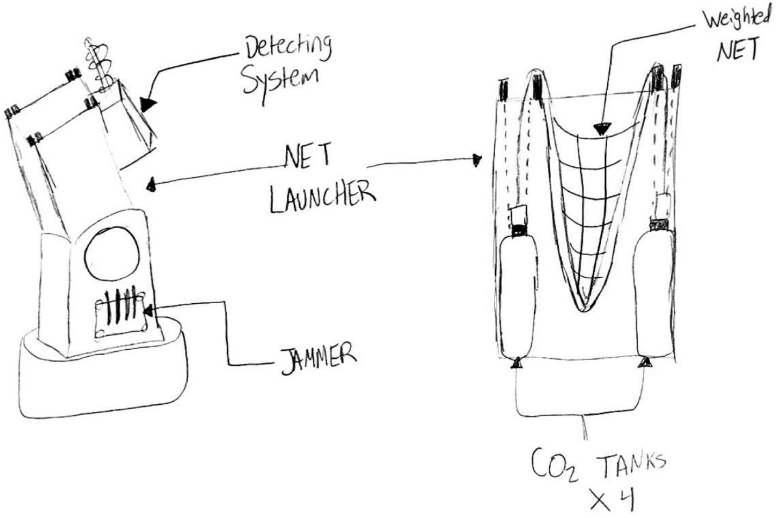


Dylan Macaulay

Concept #3

- High powered
- Wide range of Coverage
- All in one device

- Low mobility
- Uses four separate air systems
  - Increase chance of failed launches

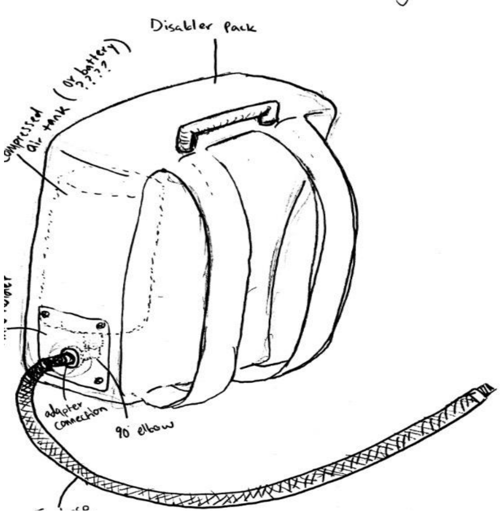


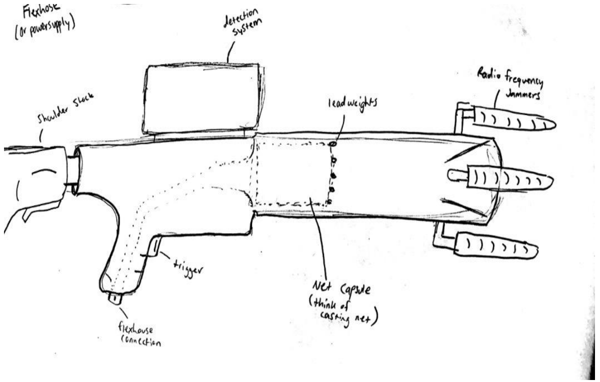
Dylan Macaulay

Concept #4

- High pressurized air/CO2
- Device modularity
- High mobility
- Focus on standard issue equipment

- Slow reload time
- Limited shots due to tank capacity
- Pack including tank/power sources can weigh



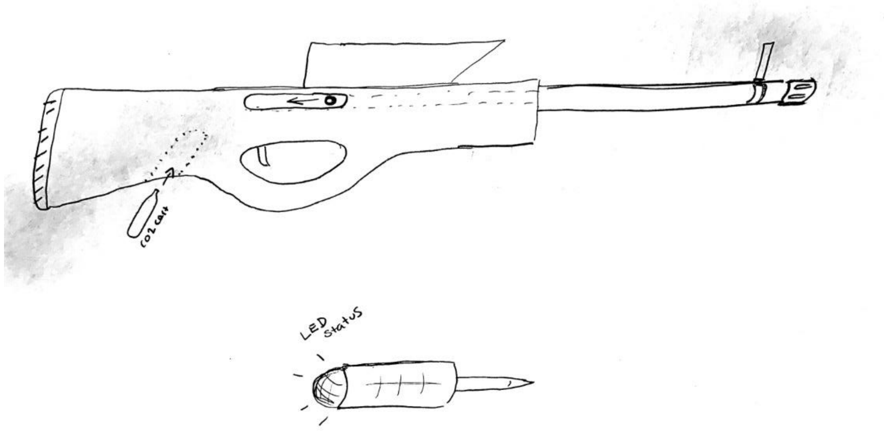


Dylan Macaulay

Concept #5

- CO2/High powered spring
- Quick assembly/disassembly process
- High mobility

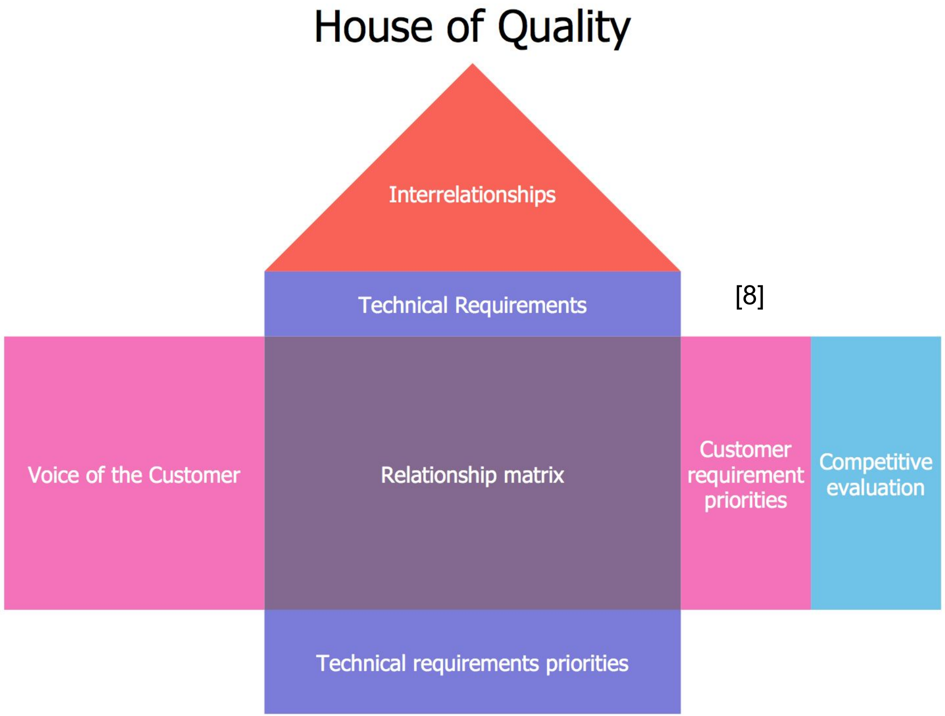
- Small projectile fired
- Complex projectile
- Low chance of drone neutralization



Dylan Macaulay

House of Quality

- Customer requirements determined through pairwise comparison
- Improvement direction of design evaluated for engineering characteristics
- From HOQ, top engineering characteristics selected



[8]

Quentin Lewis

HOQ

		Engineering Characteristics									
Improvement Direction		↓	↓	↑	↓	↑	↑	↓	↑	↑	↓
Units		Mins	lbs	Ft	Sec	Hr	Ghz	Sec	in	lbs	$
Customer Requirements	Importance	Assembly/Disassembly Time	Weight of Device	Disabling Range	Target Acquisition Speed	Battery Life	Frequencies Jammed	Device Reload Speed	Target Max Drone Wingspan	Target max drone weight	Project Cost
Automatic Detection System	**6**		3		9	9			9		9
Device reach	**4**		3	9		1		3	1		1
Neutralization of Drone (undamaged)	**5**			9	9	3	9		3	3	
Device Safety	**5**		3								1
Retrieval of Drone	**2**			1					3	9	
Device Mobility	**3**		9								
Length of Operation	**2**			1		9	9				3
Ease of use	**1**	9	3					9			
Raw Score		9	75	85	99	91	63	21	79	33	69
Relative Weight %		1%	12%	14%	16%	15%	10%	3%	13%	5%	11%
Rank Order		10	5	3	1	2	7	9	4	8	6

Quentin Lewis

Pugh Matrix

- DroneShield DroneGun used for Datum [3][4]
- New Pugh matrix made with Concept 5 as Datum
- Top selection criteria then used to further analyze Concepts 2, 4, and 5

Selection Criteria	DroneGun	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Target Acquisition Speed	Datum	S	-	-	S	-
Battery Life		+	+	S	+	+
Disabling Range		-	-	-	-	-
Target Max Drone Wingspan		S	S	S	S	S
Weight of Device		+	-	+	-	+
Frequencies Jammed		S	S	S	S	S
# pluses		2	1	1	1	2
# minuses		1	3	2	2	2

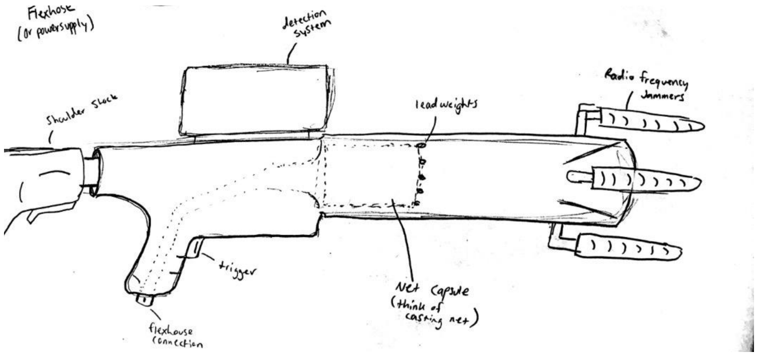
Selection Criteria	Concept 5	1	2	3	4
Target Acquisition Speed	Datum	S	+	-	+
Battery Life		-	-	-	+
Disabling Range		-	S	-	+
Target Max Drone Wingspan		S	S	S	S
Weight of Device		S	-	-	-
Frequencies Jammed		+	+	+	S
# pluses		1	2	1	3
# minuses		2	2	4	1

[5]

Quentin Lewis

AHP Summarized

- Through the Analytical Hierarchy Process (AHP) Concept 4 was selected
- AHP was done for each criteria and each concept
- Final rating matrix shows Concept 4 with highest Alternative Value



Developement of Candidate set of Criteria weights {W} for Drone Disabling Device			
Criteria Comparison Matrix [C]			
	Disabling Range	Weight of Device	Battery Life
Disabling Range	1	0.333	0.200
Weight of Device	3	1.000	0.333
Battery Life	5	3.000	1.000
Sum	9	4.333	1.533

Final Rating Matrix				
Selection Criteria	**Disabling Range**	**Weight of Device**	**Battery Life**	**Alternative Value**
Concept 2	0.607	0.751	0.259	0.332
Concept 4	0.090	0.168	0.065	0.347
Concept 5	0.303	0.081	0.675	0.308

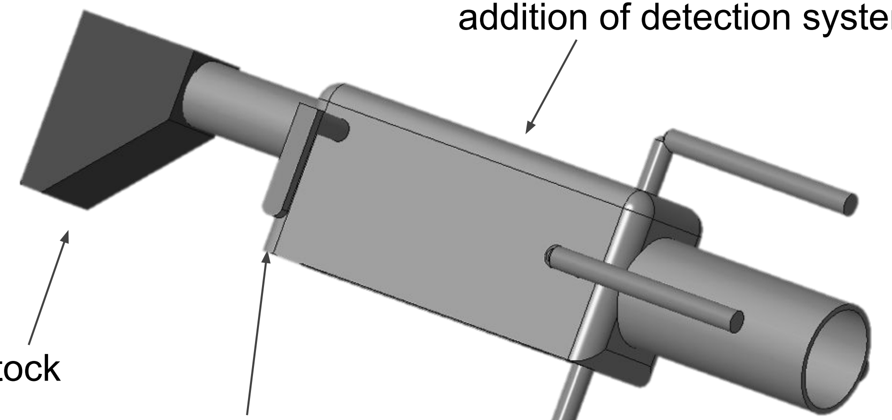
Quentin Lewis

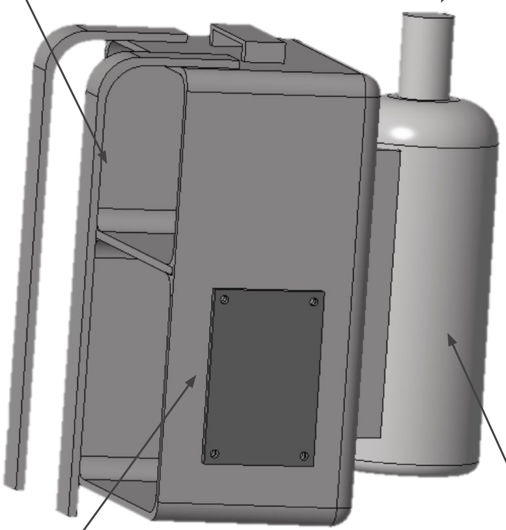
Concept Generation and Selection Summarized

- Five detailed concepts generated
  1. Paintball style marker that fires substance to disrupt communications between drone and operator.
  2. Bazooka style launcher that uses a sonar like detection system.
  3. Automated device that is floor mounted and fires net at detected drones.
  4. Mobile rifle with detection system and operator pack that fires a net powered by pressurized air or CO_2.
  5. Dart rifle that disrupts electronics on drone, uses high tech sight to manually scan airspace for drones.

Quentin Lewis

Original Proposed Design





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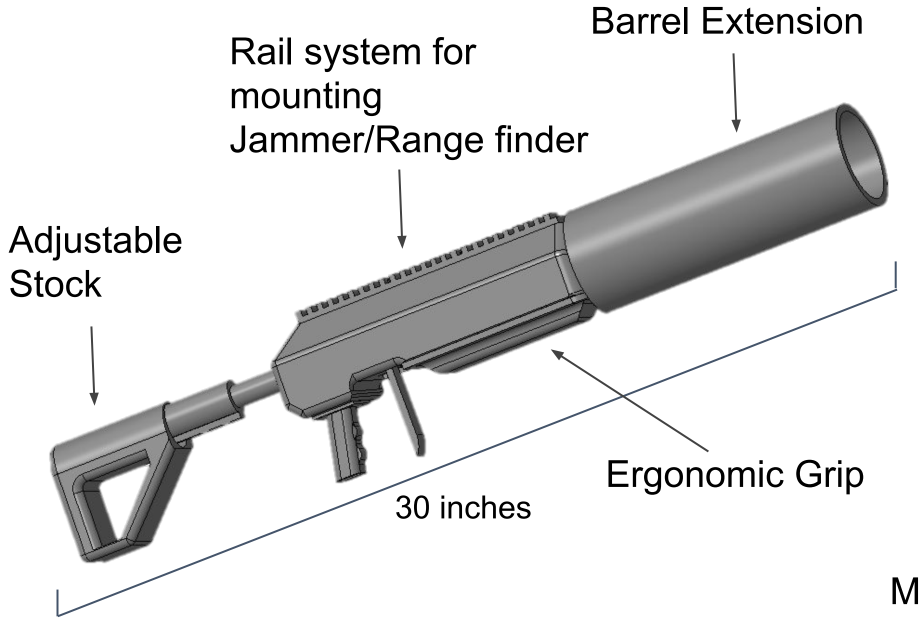
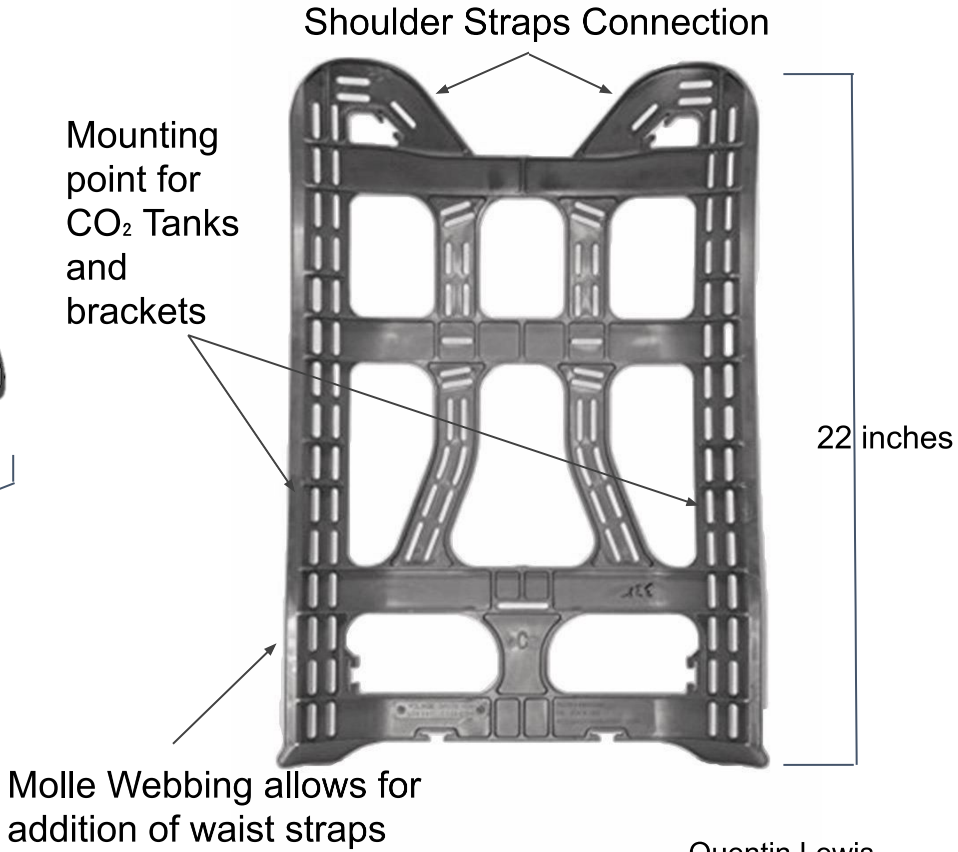
Reworked Design





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Part 3: Final Design

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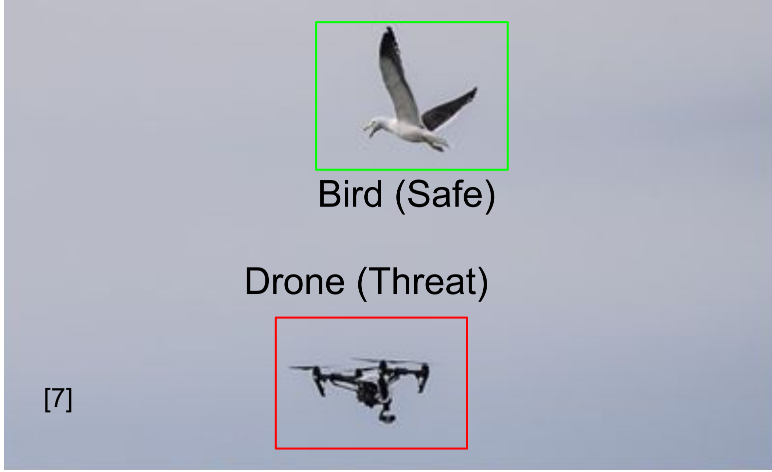
Detection System

- Raspberry Pi Model 3 B
  - Runs the detection algorithm
  - Powers the cameras
- Intel Neural Compute Stick 2
  - Dedicated processor designed for neural networks
  - Utilizes OpenVINO machine learning architecture
- SJCAM SJ4000 Cameras (3, mounted)
  - Provides 360° detection coverage
- 30,000 mAh USB Power Bank
  - Powers system for 11 hours minimum



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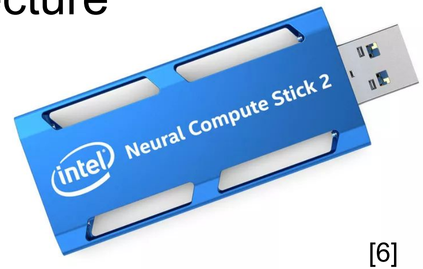

[6]

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Detection System - Demonstration

Taylor Stamm

Air System

- 48ci 3K Paintball Tank - Globally Certified
  - Seamless, high strength aluminum alloy 6061-T6
  - Service pressure- 3000 psi
- High Output Regulator
  - 4500 psi air tank
  - Regulator output pressure -850 psi
  - Displays amount of gas inside tank
  - Lightweight and easily rebuildable
- Heavy Duty Coiled remote line
  - Quick disconnect
  - Works with up to 3000 psi of CO_2 and 4500 of HPA
  - Allows for mobility when handling device

Ryan Cziko

Net Launcher and Backpack Overview

Net Launcher:

- Launches net to capture a stationary drone.
- Rails allow easy addition of attachments and a signal jammer.

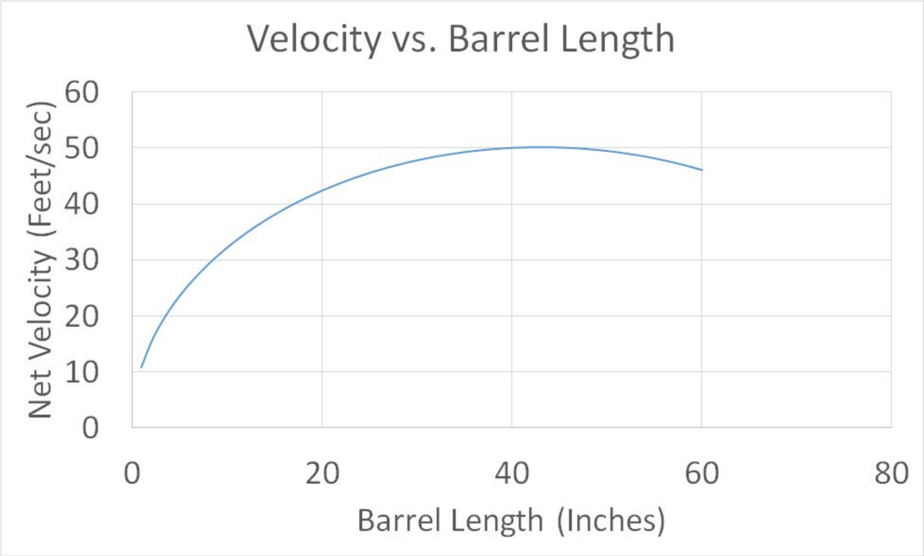
Backpack

- Support detection system and compressed air with minimal hindrance to wearer.

Ryan Cziko

Net Launcher

- Addition of extended barrel
  - Extension of 8 inches or greater to increase net velocity
  - Too long of a barrel becomes cumbersome



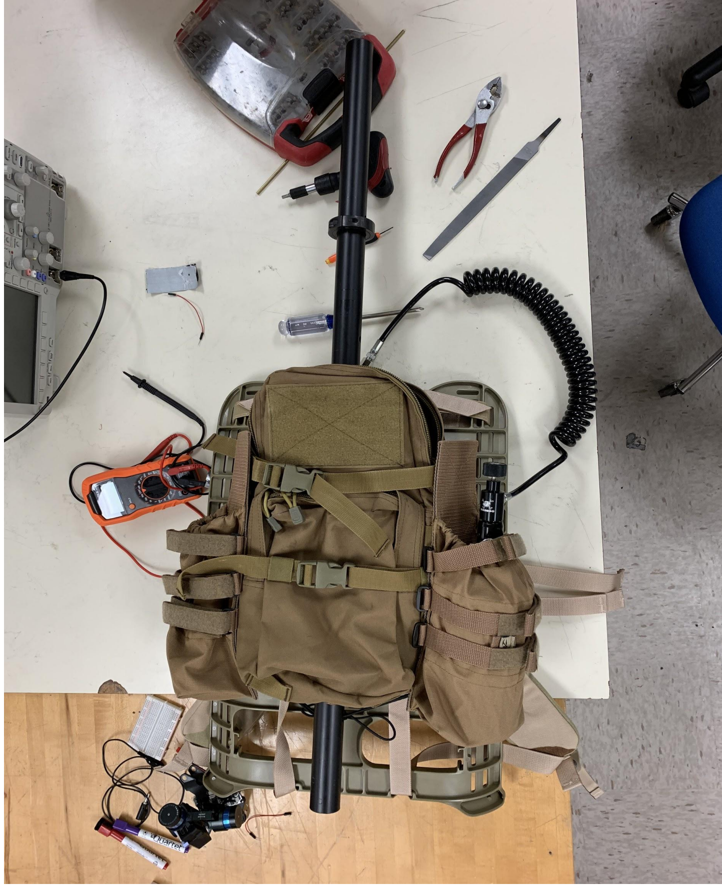
- Testing and designs for “net cap”
  - Net attached to cap that is used for launch
  - Modeled after horn of casting net

Holes for leader lines connecting weights to netting

Ryan Cziko

Backpack

- Molle II Rucksack Frame and Shoulder straps
  - Durable and built to last a lifetime
  - Frame is lightweight and molds to back for comfort
  - Shoulder straps add comfort and weight distribution
- Frame is modular and standard issue equipment



Ryan Cziko

Net Launcher - Dry-Fire Demonstration

Ryan Cziko

Part 4: Achieved Targets

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Project Targets vs. Achieved Targets

Metric	Marginal Value	Ideal Value	Achieved Value	Units
Assembly & Disassembly Time	60	5	5	Minutes
Weight of Device	30	10	10	Lbs
Net Launch Distance	30	50	~10	Feet
Project Cost	5000	2500	659.29	$
Target Acquisition Speed	20	5	0.2	Seconds
Detection Distance	30	50	150	Feet

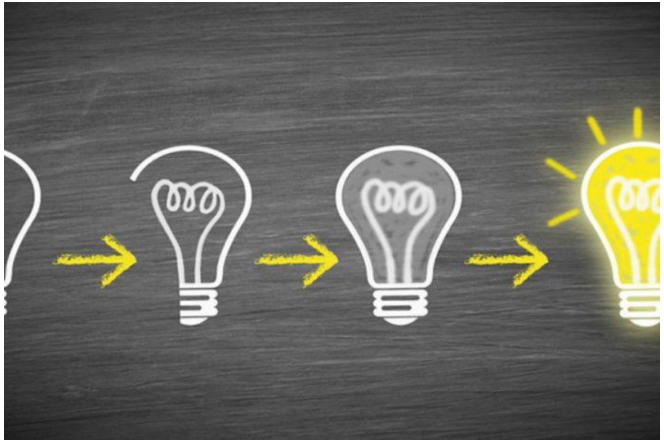
Taylor Stamm

Part 5: Conclusion

Taylor Stamm

Lessons Learned

- Be prepared for shipping delays/errors.
- Research until confident and then begin designing.
- Document the design process along the way.
- Sometimes the simplest approach is the best approach.



[9]

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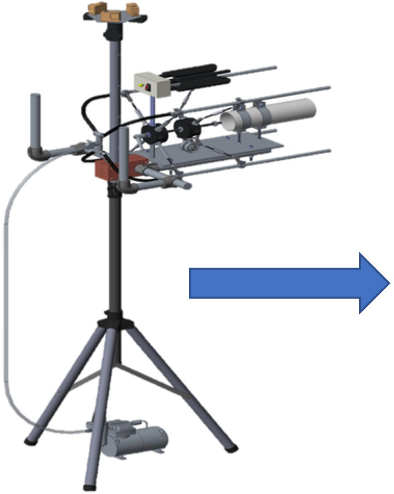
Most Important Points



- Improvements made on device functions and portability
- New device met or surpassed ideal set targets
  - Launch distance to improve with proper barrel seal
- Standard issue equipment compatibility

Taylor Stamm

References

[1] SDT13. (2018) - Senior Design Team 13 year 2018; Concept prototype of drone disabling device. [digital Image]. Retrieved from https://ww2.eng.famu.fsu.edu/me/senior_design/2018/team13/docs_pdfs/Design_Review2.pdf

[2] NA. (2018, January 23). - Mavic Air for limitless exploration. [digital Image]. Retrieved from https://forum.dji.com/thread-130833-1-1.html

[3] http://hyperphysics.phy-astr.gsu.edu/hbase/pber.html

[4] https://www.princeton.edu/~asmits/Bicycle_web/Bernoulli.html

[5] https://www.engineeringtoolbox.com/colebrook-equation-d_1031.html

[6] https://www.zdnet.com/article/intel-rolls-out-neural-compute-stick-2/

[7] https://becominghuman.ai/deep-learning-made-easy-with-deep-cognition-403fbe445351

[8]https://www.google.com/search?q=house+of+quality&rlz=1C1CHBF_enUS801US801&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjO2YKsnrDhAhUDTKwKHcH6DtUQ_AUIDigB&biw=1220&bih=528#imgrc=rBc_IgqimUYB0M:

[9]https://www.google.com/search?q=lesson+learned&rlz=1C1CHBF_enUS801US801&source=lnms&tbm=isch&sa=X&ved=0ahUKEwje6MvdprDhAhUCa60KHbqZD2MQ_AUIDigB&biw=1220&bih=473#imgrc=ziju5g2PoEqMCM:

Thank You!
Questions?

Backup Slides

Customer Needs Backup

Customer Needs

What is the size and type of drone to be neutralized?

- **Recreational drones that could be carrying IEDs or have cameras.**

How long does this device need to be operable for?

- **The device should be operable for the time necessary until the user powers it off.**

What is the outcome of the neutralized drone?

- **We are looking to just neutralize the drone given the time constraints, but if possible, recover the drone if it is not completely destroyed.**

Is the device expected to be autonomous?

- **No, due to time constraints it will most likely not be possible; but ideally that is what we would want.**

Is there a specific range that the device must function within?

- **100 feet in radius, 100 feet altitude. Constraints may need to be adjusted due to not being possible to meet.**

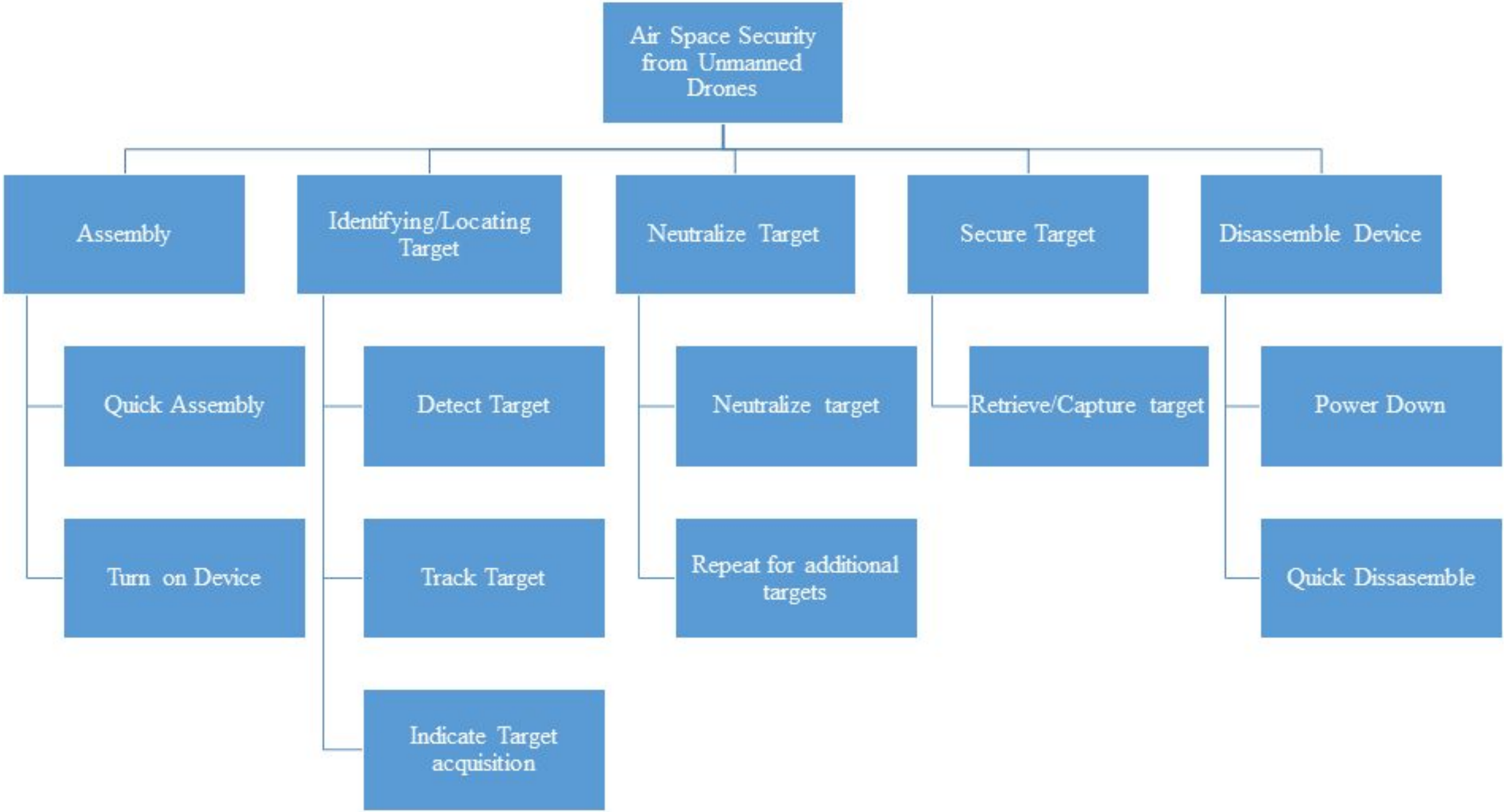
Does this device need to be portable?

- **Yes, must be able to assemble the device within 4 hours.**

What is the purpose of Northrop Grumman sponsoring this project?

- **To aid-to-hire and give students an understanding of the learning process. Northrop Grumman is not looking for a proof of concept to scale.**

Functional Decomp Backup


Air Space Security from Unmanned Drones
Assembly
Identifying/Locating Target
Neutralize Target
Secure Target
Disassemble Device
Quick Assembly
Turn on Device
Detect Target
Track Target
Indicate Target acquisition
Neutralize target
Repeat for additional targets
Retrieve/Capture target
Power Down
Quick Dissasemble

Targets Backup

Target Values

Target No.	Need	Metric	Importance	Units	Marginal Value	Ideal Value
1	2, 10	Assembly & Disassembly Time	5	min	60	5
2	10	Weight of Device	5	lbs	30	10
3	4,5,10	Disabling Range	3	ft3	30	50
4	10	Target Acquisition Speed	4	s	20	5
5	10	Battery Life	3	h	2	3
6	3,5,10	Frequencies Jammed	3	GHz	2.4	2.4 and 5
7	2,10	Device reload speed	1	min	5	2
8	10	Target max drone wingspan	3	in	25	30
9	10	Target max drone Weight	3	lbs	4	6
10	1-9	Project Cost	5	$	2000	1500

Detailed Math Backup

CO_2 Calculations

- Used Bernoulli's equation (1) twice to find the velocity of CO2 as it leaves the barrel of the gun.
  - First stage is from the tank to the nozzle
  - Second stage is from nozzle and through hose to rifle
- Problem then modeled as smooth pipe (Barrel) with turbulent flow
  - Re ≃ 151,721
  - Darcy friction factor (2) solved, *f* = 0.016569
- Velocity of net determined to be ≃ 30.414 feet/sec

$$P_1 + \frac{1}{2}\rho V_1{}^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho V_2{}^2 + \rho g h_2$$

(1) Bernoulli's equation

$$f = \frac{0.25}{\left[\log\left(\frac{\varepsilon/D}{3.7} + \frac{5.74}{\mathrm{Re}^{0.9}}\right)\right]^2}$$

(2) Colebrook-White's equation

Gas Velocity leaving Regulator

- V2 solved by subbing values into bernoulli and rearranging

$$V2 = \sqrt{2\left(\frac{P1}{\rho 1} - \frac{P2}{\rho 2}\right)}$$

- Velocity leaving nozzle of 12 OZ CO_2 tank and high output regulator at 70 deg. Fahrenheit was then found to be 34.108 ft/sec

P1	1800 psi
h1	0 inch
V1	0 ft/sec
Rho1	54.403 lb/ft^3
P2	850 psi
h2	0 inch
V2 (solved)	34.108 ft/sec
Rho2	10.422 lb/ft^3

Gas Velocity through hose to rifle

- V3 found by following previous method and substituting values for the gas to travel from tank to rifle

$$V3 = \sqrt{2(\frac{P2}{\rho 2} - \frac{P3}{\rho 3} + g * (h1 - h2) + \frac{V2}{2})}$$

- Using ¼" diameter hose line and ambient temperature and pressure
- Velocity reaching rifle from hoseline at 70 degrees Fahrenheit found to be 52.356 ft/sec

P2	850 psi
h2	0 inch
V2	34.108 ft/sec
Rho2	10.422 lb/ft³
P3	14.7 psi
h3	72 inch
V3 (solved)	52.356 ft/sec
Rho3	0.075 lb/ft³

Velocity of net through barrel

- Relation of barrel length to output velocity used

$$V_{net} = \sqrt{\left(\frac{2}{m} * (Po * Vo) * \ln\left(1 + \left(\frac{A_c * L}{Vo}\right)\right) - f * L\right)}$$

- Mass of 2 lbs, output pressure of 850 psi from nozzle, cross sectional area of 28.26 inch², and a fraction factor of 0.016569 were all used
- Desired barrel length determined to be anything over 8 inches

Length (inch)	Volume (inch³)	V of net (ft/sec)
2	56.52	15.207
4	113.04	21.506
6	169.56	26.339
8	226.08	30.414
10	282.60	34.004
12	339.12	37.249

Objectives					Major Tasks	Project Completed By: April 01, 2019												Owner / Priority				
0				1	Order and test CO2 tank on current device	~	~														A	
		0		2	Test hose line		~											A				
	0			3	Interface cameras alert system with raspberry pi		~												A			A
	0			4	Create initial drone detection algorithm		~														A	
0				5	Order casting nets and size specifications		~	~													A	
	0			6	Pressure chamber calculations and manufactoring		~	~												A		
	0			7	3D print CAD models				~											A		
		0		8	Pressure equipment safety test				~									A				
		0		9	Net launch distance test				~									A				
		0		10	3D imaging test of stationary drone				~										A			
		0		11	Test trigger assembly with low pressure				~									A				
	0			12	Optimize speed and accuracy of detection algorithm					~									A			
	0			13	Assemble trigger system, air tank, hose line, and 3D prints					~										A	B	
	0			14	Assemble Rifle components						~									A	B	
		0		15	Test pressure chamber for leaks and durability						~							A				
	0			16	Combine pressure chamber and designed trigger							~								A	B	
	0			17	Implement casting net to device							~								A	B	
	0			18	Full assembly of 3D prints								~							A	B	
		0		19	Test and optimize net launch									~	~			A				
		0		20	Test optimize detection system									~	~							A
				21	Spring Break											~						
	0		0	22	Final system testing												~	A				
	0	0		23	Refine Prototype												~	A	A	A	A	A
				A	Syllabus																	
				B	ABET																	
				C	Sponors																	
				D	Documentation																	
				E	Lessons Learned																	
				F																		
					# People working on the project: 5	1	2	3	4	5	6	7	8	9	10	11	12					
Parts Ordering	ale Development	Testing	Documentation		Major Tasks / Target Dates / Objectives	7-Jan-19	14-Jan-19	21-Jan-19	28-Jan-19	4-Feb-19	11-Feb-19	18-Feb-19	25-Feb-19	4-Mar-19	11-Mar-19	18-Mar-19	25-Mar-19	Ryan Cziko	Quentin Lewis	Dylan Macaulay	Trevor Stade	Taylor Stamm

Previous Project

Three-Camera Video Detection

- 360 degree field of view
- Drone visual recognition software
- Drone sound recognition

Radio Frequency Interference

- Disrupts signal from controller to drone
- Four signal jammers
- 2.4 GHz bandwidth interference

Weighted Net

- Backup to RF interference
- Launches projectiles attached to net
- Manual angle control to adjust distance

Trevor Stade

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Customer Needs

- Size of drone
    - Typical recreational or household drones
- Operable time
    - Device should operate until task is completed
- Device outcomes
    - Neutralize, not destroy, drone and if possible recover drone
- Size of device
    - Device should be portable and easily maneuverable
- Purpose of this project
    - Aid-to-hire and give better understanding of the design process

Trevor Stade