Drone Disabling Device

Virtual Design Review 2

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Team Introduction

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Project Scope

Objective

- Develop a device to secure specified air space from unmanned flight vehicles.

Key Goals

- <u>Neutralize</u> unmanned flight vehicles within a specified air space
- Ensure the device is <u>portable</u>
- Maintain <u>environmental safety</u>
- <u>Function properly</u> over necessary time period
- Comply with safety and legal <u>regulations</u>

Customer Needs

Drone Specs

- Typical household drones

Effectiveness

- Minimum Requirement: disable
- Bonus: recovery

Range

- 30 feet radius dome

***Figure 1**: DJI Mavic Pro Quadcopter 4k Drone [14]*

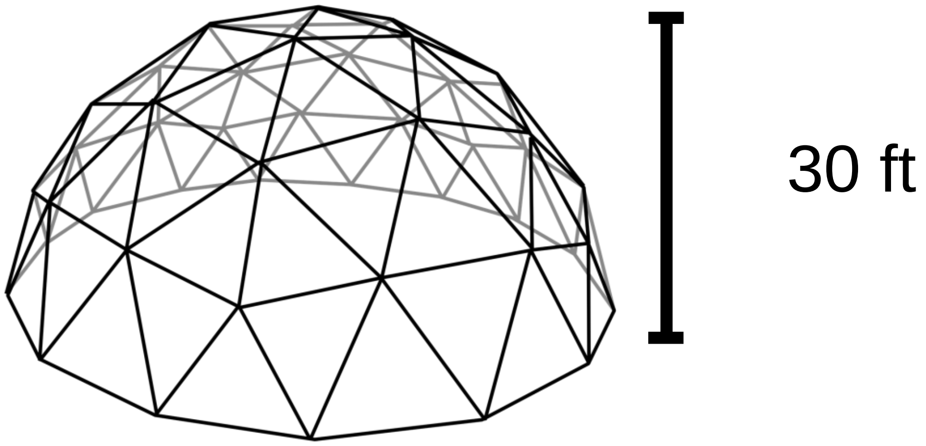


***Figure 2**: Visual representation of desired dome [15]*

Customer Needs

Operation

- Trained human operator

Power

- AC Power
- 15-20 amps

Portability

- Portable
- 4 hour assembly time

Purpose

- Focus on development process

Figure 3*: Visual representation of sample user operation [16]*

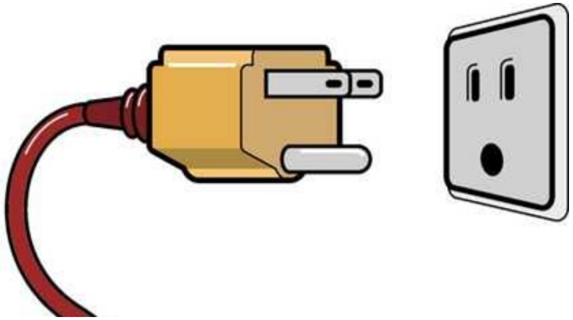


Figure 4*: Simple wall plug and outlet [17]*

Target Catalog

Target Catalog

Quantitative Target Values

METRIC	TARGET	UNITS
Time to assemble device	4	h
Device current	15-20	A
Device voltage	120	V
Range of device (dome)	30	ft
Time to find/lock on to target	30	s
Time to neutralize drone	5	s
Probability of hit	90	%
Probability of takedown	90	%
Time to disassemble device	4	h
Project cost	5000	USD

Yes/No Targets

METRIC	YES	NO
Power up device	✓	
Identify drone	✓	
Lock on to drone	✓	
Neutralize drone	✓	
Repeatable	✓	
Power down device	✓	
Portable	✓	
Minimal damage to drone	✓	
Safe for environment	✓	

Concept Generation

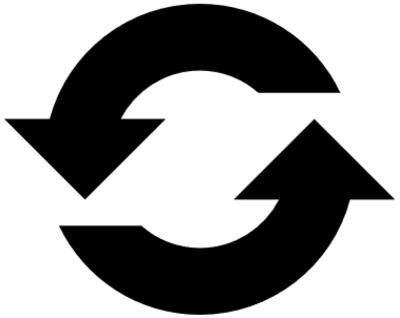
Concept Generation

Detection

- Audio
- Video
- Thermal
- Radio Frequency (RF)
- Radar
- Operator

Control

- Manual
- Remote
- Automated



Neutralization

- RF Interference
- Sound Attack
- EMP
- Hacking Attack
- Weighted Net
- Projectile Attack

Concept Generation

Detection System

Detection System

Video

- Video camera with software to identify moving objects on the feed.
- Low-Medium cost.
- Range depends on camera resolution.
- Video camera can also be used for aiming the neutralizing solution.

Figure 5*: video detection of a drone and bird [1].*

Thermal

- Similar to video detection.
- Smaller drone with camera may not give off large heat signature.
- Drone carrying payload (IED) would easily be detected.
- Medium cost.

Figure 6*: drone detected on thermal imaging [2].*

Detection System

Radio Frequency (RF)

- Transmitter and receiver to detect drone not sending out RF signals.
- Receiver can identify location of controller and drones that send signals to controller (video feed).
- High range.
- High cost.

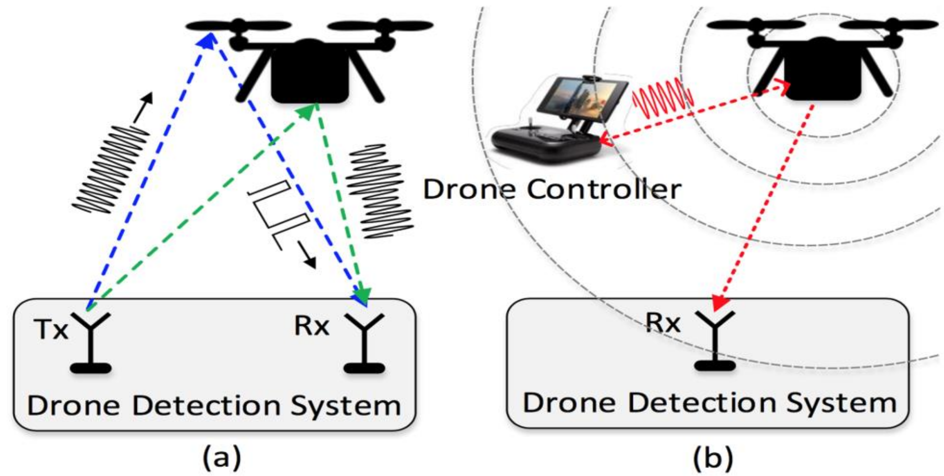


Figure 7: *potential RF detection approaches [3].*

Radar

- Possible to alter an existing radar product to detect smaller devices.
- Medium range.
- High cost.

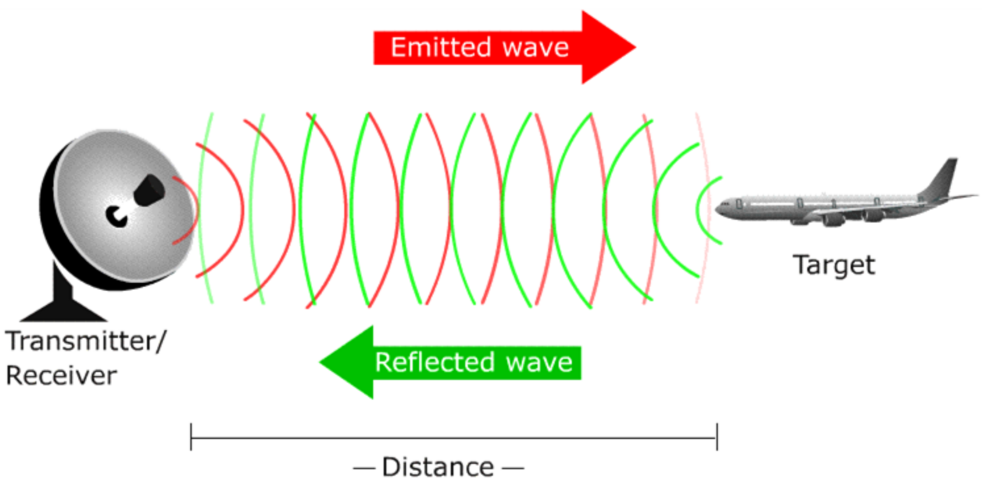


Figure 8: *basic principles of a radar system [4].*

Detection System

Audio

- Requires use of machine learning to distinguish drone sounds.
- Low cost.
- Low range.
- Not effective in busy urban areas.

Operator

- Depend on eyesight and hearing of device operator to detect drone.
- Range depends on operator.
- Eliminates cost of a detection product.
- Eliminates complexity of developing a detection system.

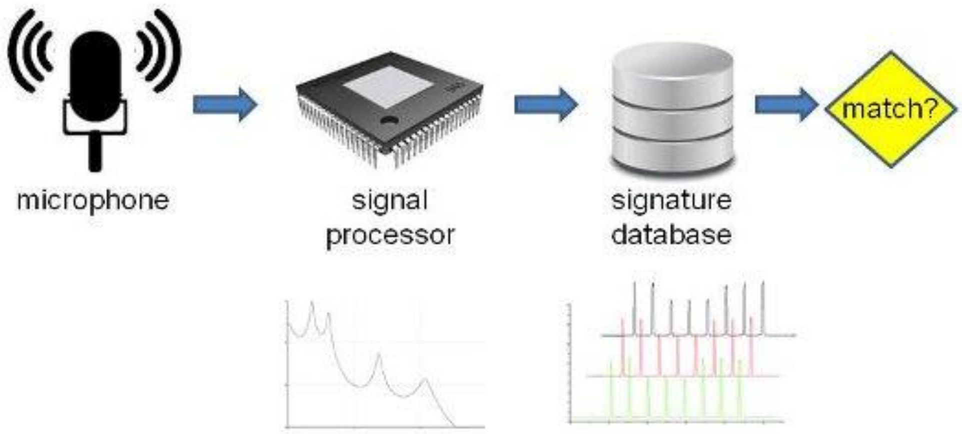


Figure 9: *audio detection system basic principles [5].*

Figure 10: *device operator detecting drone [6].*

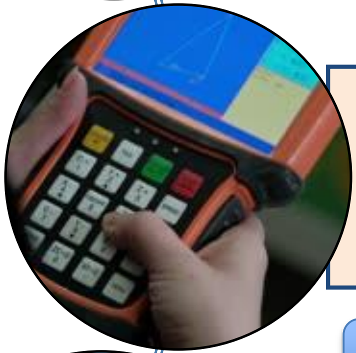
Concept Generation

Control System

Control System

Manual Control

- Rotated and aimed by operator
- Device could operate similar to a gun
- Device could be placed on a tripod or stand



Remote Control

- Device equipped with a video camera
- Operator uses video feed to aim device
- Remote will control all functions of the device

Automated Control

- Device detects and tracts drone
- Device has both automated and operator controlled attack protocols

Concept Generation

Neutralization System

Neutralization System

Weighted Net Attack

- 2 DOF mechanism with mounted CO_2 cannon
- CO_2 cannon houses projectile [11].
- Projectile houses weighted net.
- Net deploys from projectile at a specific time due to proximity of target.

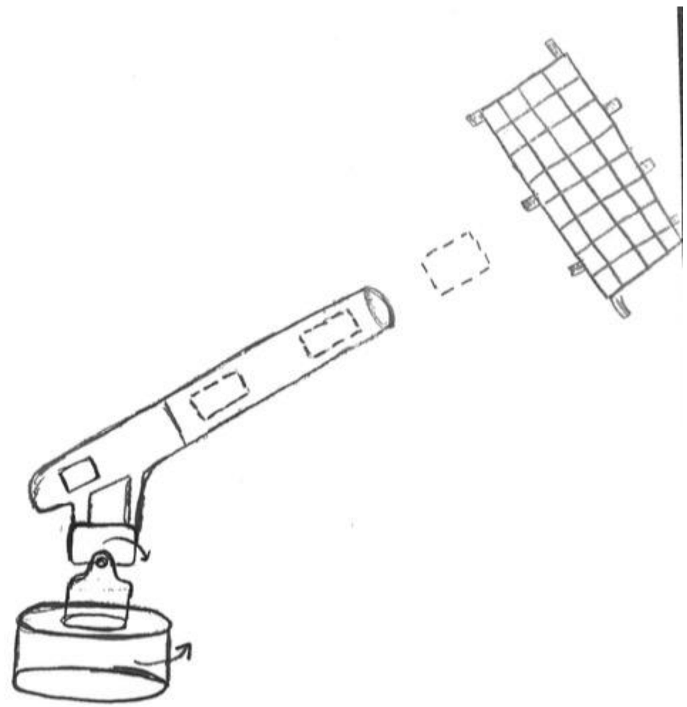


Figure 11*: illustration of weighted net attack.*

Neutralization System

Weighted Net Attack

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- Large surface area covered
- Accuracy considering a stationary target

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- Neutralization of multiple drones
- Complex timing net deployment
- High speed drones

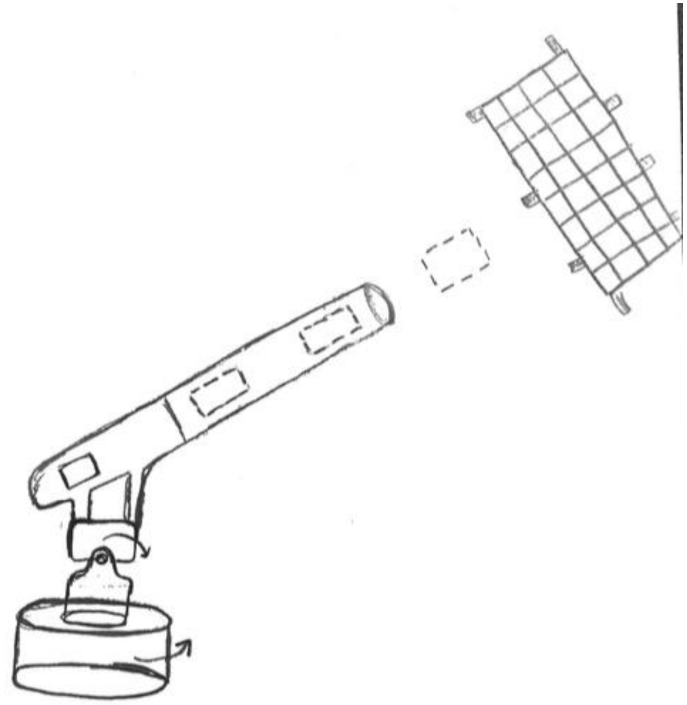


Figure 11*: illustration of weighted net attack.*

Neutralization System

Projectile Attack with Epoxy Ammo

- Soft-shelled capsules [12].
- Contains epoxy foam mixture [13].
  - Free radical peroxide initiator.
  - Polymethyl methacrylate.
  - Epoxy vinyl.
- Foam expansion inhibits drone functionality.

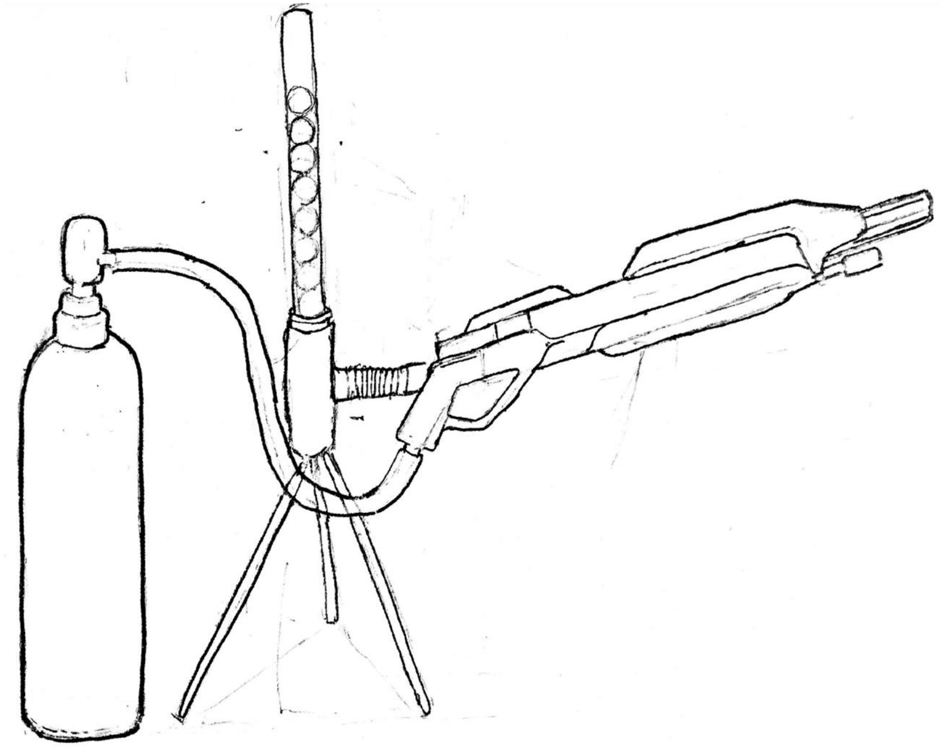


Figure 12*: illustration of epoxy based ammo attack.*

Neutralization System

Projectile Attack with Epoxy Ammo

- Simplicity of operation
- Complete neutralization of drone

- Complexity of ammunition development
- Environmental hazard
- Tracking drone would be difficult to implement

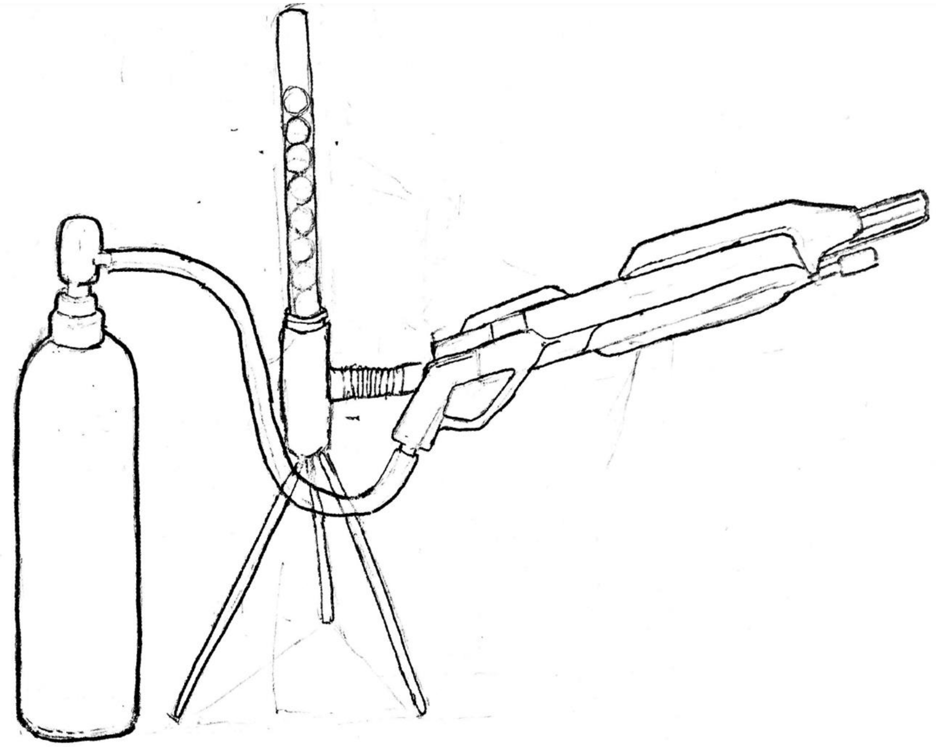


Figure 12*: illustration of epoxy based ammo attack.*

Neutralization System

Radio Frequency Interference

- Jam 2.4GHz radio frequency band.
- Four channels needed.
- Disrupt controller ↔ drone communication.

Sound (Pressure) Wave Attack

- Sound emitted from long range acoustic device (LRAD) at resonant frequency of the gyroscope or accelerometer.
- Multiplying effect.
- Causing false orientation readings being sent to flight controller.

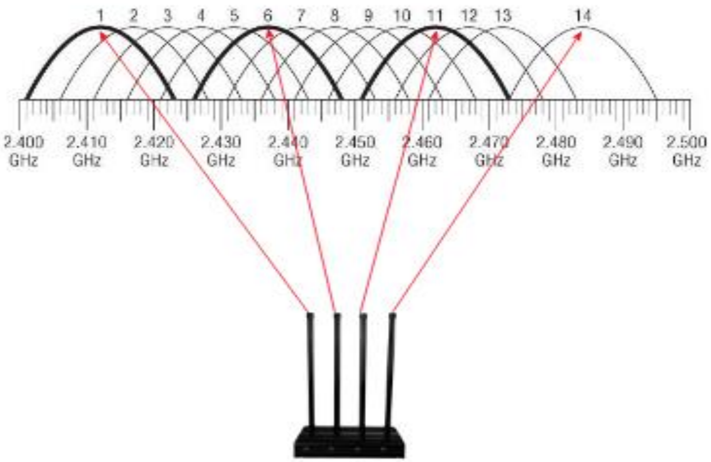


***Figure 13**: four channels of 2.4GHz band [7].*

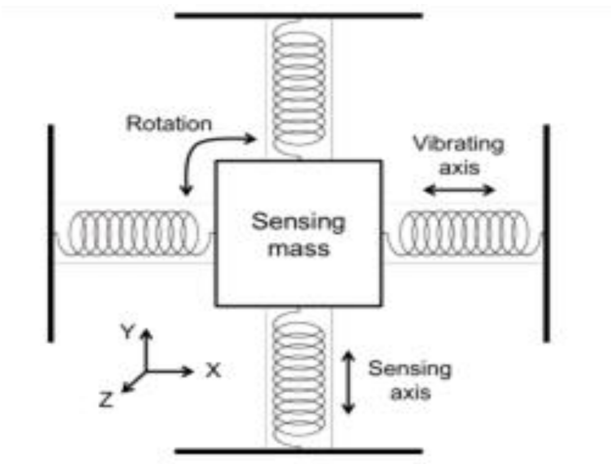


***Figure 14**: gyroscope schematic [8].*

Neutralization System

Radio Frequency + Sound Wave Attack

- Limited precision needed
- Quickly effective
- No ammunition needed
- Effective against pre-programmed flight

Sound:

- May take a while to find resonant frequency
- May not be able to find resonant frequency
- Pricy (LRAD)

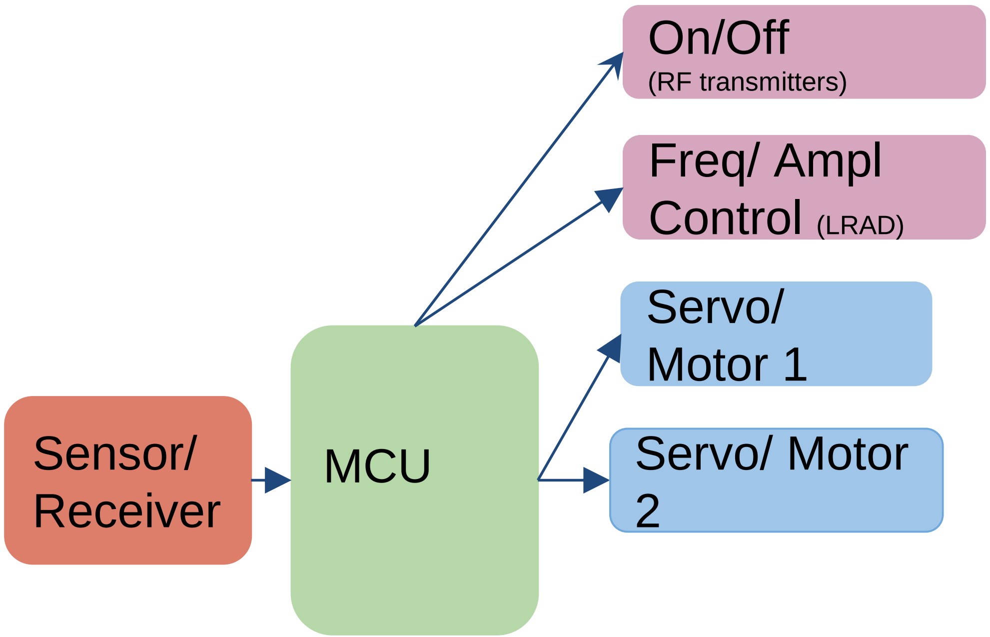


***Figure 15**: functional schematic of RF + sound attack.*

Neutralization System

Electromagnetic Pulse (EMP) Attack

- EMP causes current-surge in flight critical component.
- Generate a high power burst of electrons focused by an antenna.
- Possible affected components:
  1) MCU
  2) Integrated circuit chips
  3) RF module
  4) Power circuit

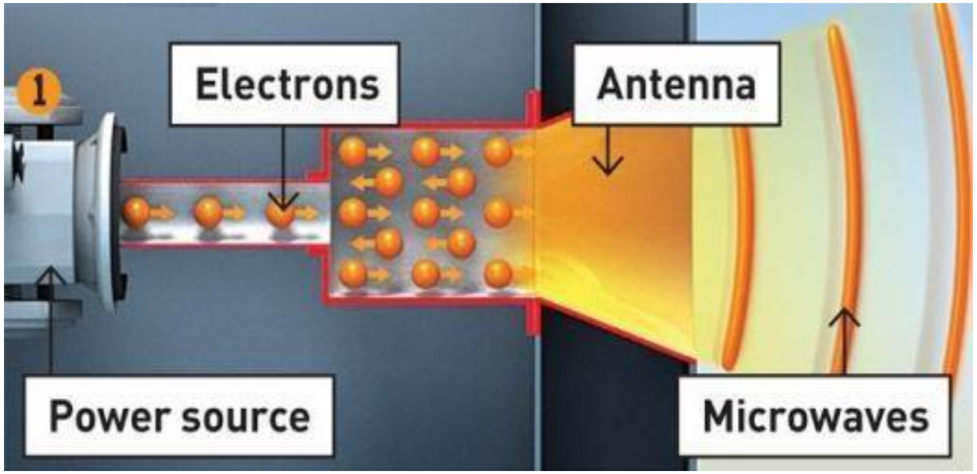


Figure 16: *EMP schematic [9].*

Neutralization System

Electromagnetic Pulse (EMP) Attack

+

- Effective against pre-programmed flight
- High probability of hitting target
- Permanent disabling solution

−

- Must adhere to FCC regulations
- High power requirement
- Expensive
- Unlikely to generate strong enough pulse

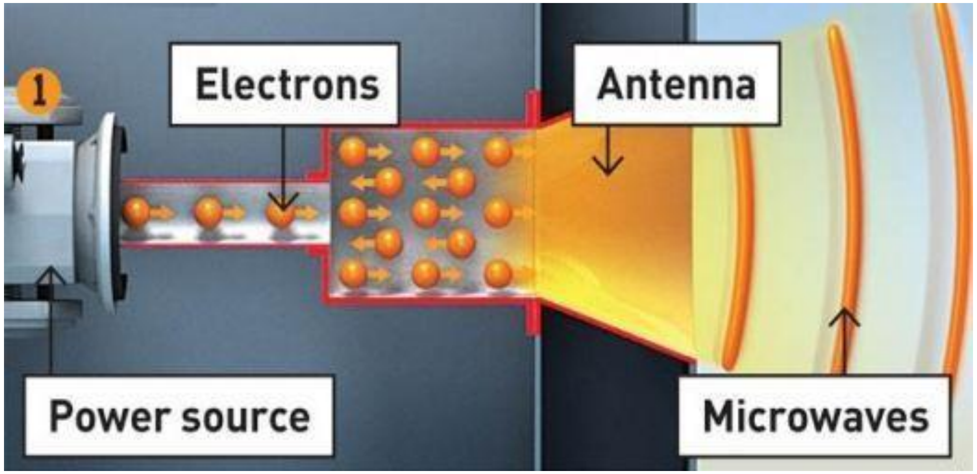


Figure 16: *EMP schematic [9].*

Neutralization System

Hacking Attack

- Exploit vulnerabilities in:
  1. Software
  2. Microcontrollers
  3. Communication protocols
- Methods:
  1. Communication interception [10]
  2. Distributed Denial of Service (DDoS) [10]
  3. Buffer overloading [10]

+

- Design cost low
- Possibility for control of drone
- Limited collateral damage

−

- Expense of drones for testing to find vulnerabilities
- May take too long to hack
- Hack may be specific to drone model

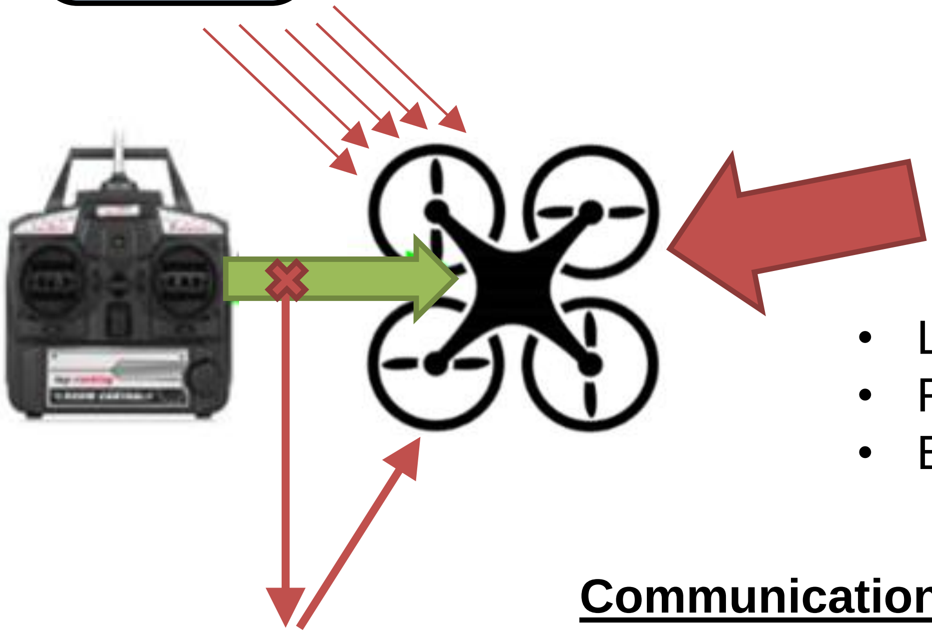
Neutralization System

Hacking Attack

Hacker's sending unit

Distributed Denial of Service (DDoS)

- Many transmission requests cause MCU to shut down.
- Results in termination of flight.
- Few methods for defending DDoS attack.



Hacker's sending unit

Buffer Overloading

- Large data packet overloads MCU buffer.
- Results in termination of flight.
- Buffer size of MCU will differ for drones.

Communication intercepted

Communication Interception

- Intercept commands/flight path and replace.
- Instruct the drone to shut down or gain full control over drone.
- Control of drone may not be permanent.

Sample Selection Criteria

Neutralization System

RANK	CATEGORY	NET	EPOXY	RF	SOUND	EMP	HACKING
	Effectiveness						
	Range						
	Public Safety						
	Environmental Safety						
	Cost						
	Ease of Operation						
	Complexity						
	Portability						

Next Steps

Produce similar selection criteria for detection and control systems

Explore combination of neutralization systems

Small scale testing

References

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Back Up Slides

TOPICS OF SLIDES

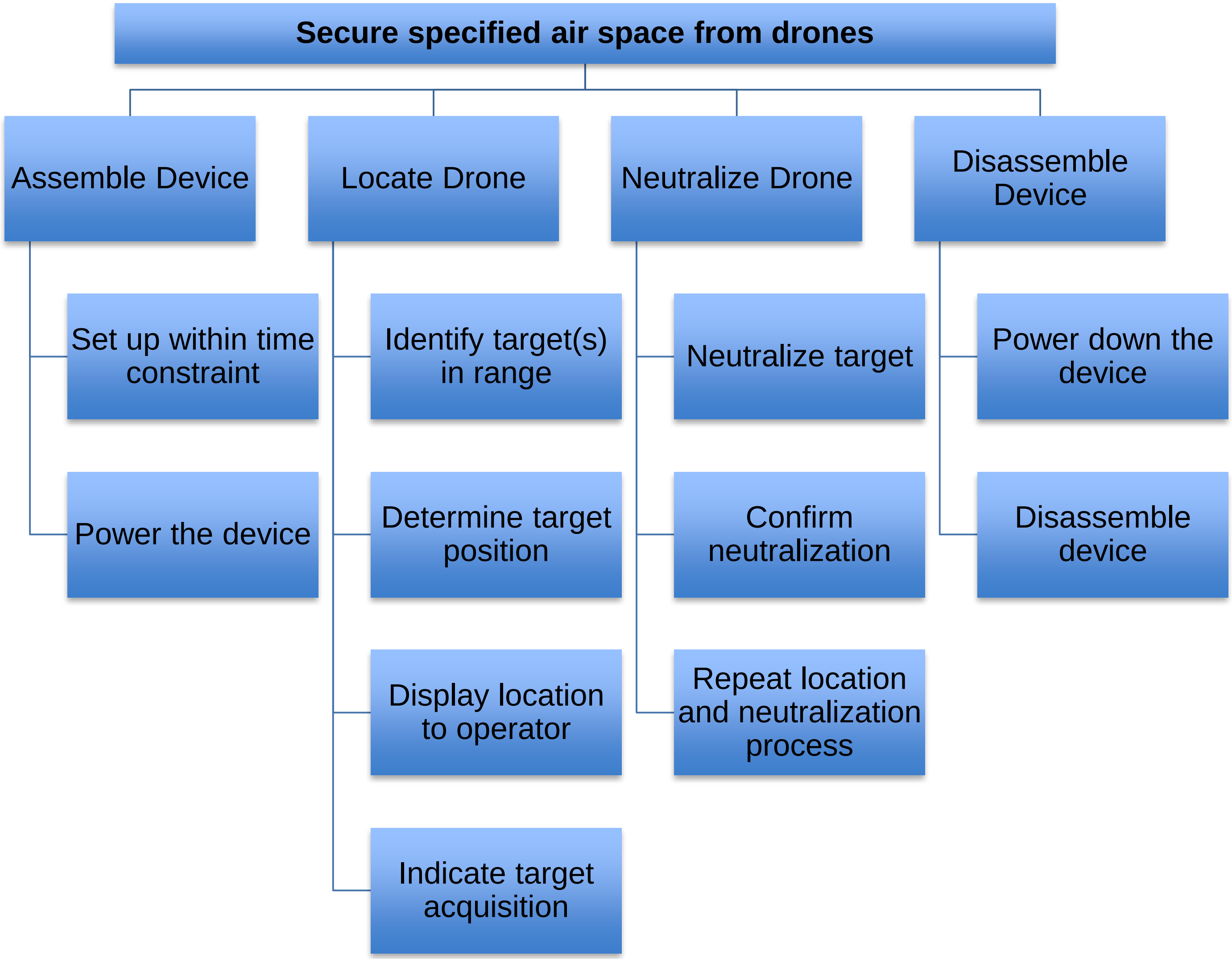
Customer Needs

Question?	Customer Statement	Interpreted Need
What is the size and type of drone to be neutralized?	Recreational drones that could be carrying IED's or have cameras.	Disable non-military, typical household drones.
How long does this device need to be operable for?	The device should work as long as possible. It can be plugged into a car, building, generator, etc.	AC power with 15-20 amp power consumption (typical outlet)
What is the outcome of the neutralized drone?	Looking to just neutralize the drone given the time constraints, but if possible recover the drone if it is not completely destroyed.	The threshold or minimum requirement would be to disable the drone. Recovering the drone would exceed expectations.

Customer Needs

Question?	Customer Statement	Interpreted Need
Is the device expected to be autonomous?	No, due to time constraints it will most likely not be possible but ideally that's what we would want.	The threshold or minimum requirement is that the device provides user operation.
Is there a specific range that the device must function within?	30ft radius dome around device; may realize this is not possible and constraints may need to be adjusted.	30ft radius dome minimum but operate at longer range if possible.
Does the device need to be portable?	Yes, be able to assemble device within 4 hours.	Portable device with a quick set-up time.
What is the purpose of Northrop Grumman sponsoring this project?	Aid-to-hire and give students an understanding of the learning process. Northrop Grumman is not looking for a proof of concept to scale.	Our team should focus on the development process over delivering the final product.

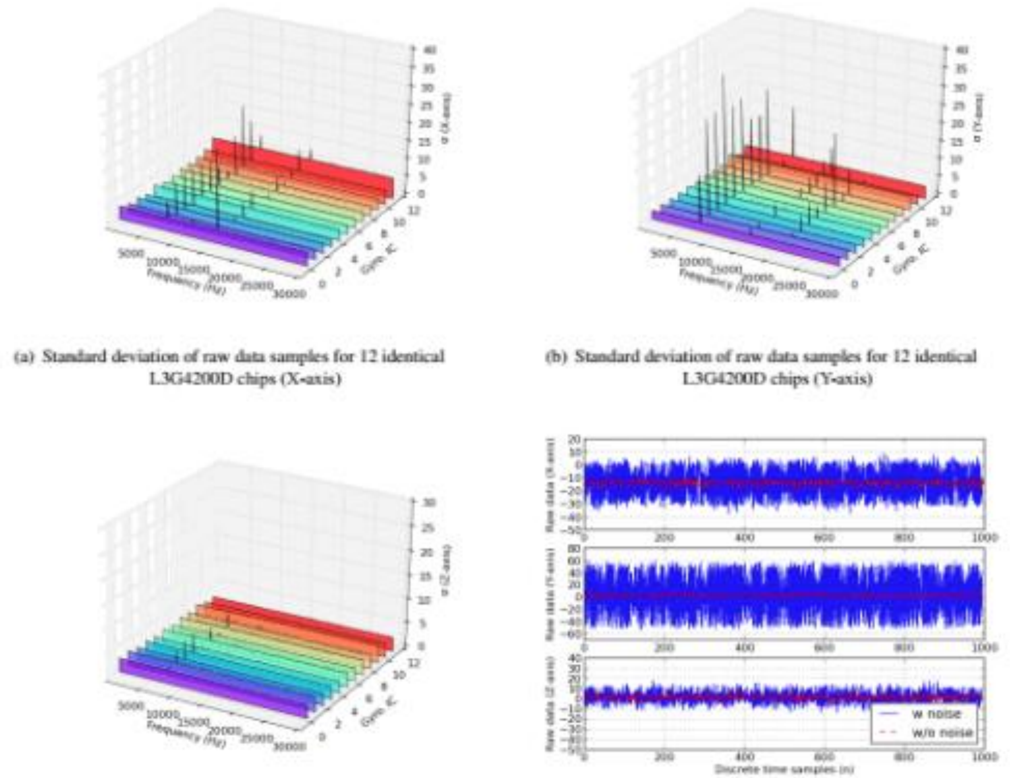
Functional Decomposition



Supporting Data

Rocking Drones with Intentional Sound Noise on Gyroscopic Sensors

Korea Advanced Institute of Science and Technology



(a) Standard deviation of raw data samples for 12 identical L3G4200D chips (X-axis)

(b) Standard deviation of raw data samples for 12 identical L3G4200D chips (Y-axis)

(c) Standard deviation of raw data samples for 12 identical L3G4200D chips (Z-axis)

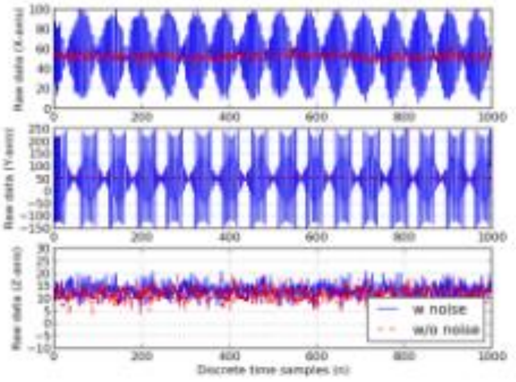
(d) Raw data samples of one L3G4200D chip with the single tone sound noise at 8,000Hz

Figure 6: Sound noise effect on L3G4200D gyroscopes (all samples were collected as raw data stored in the gyroscope's register)

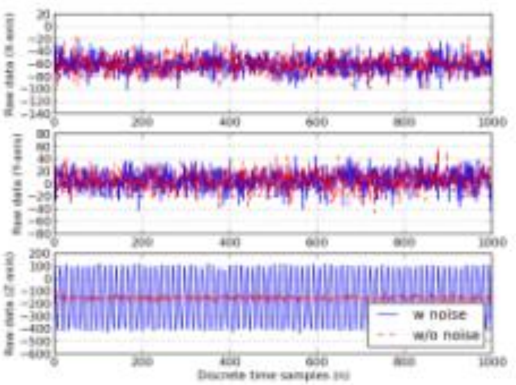
Supporting Data

Rocking Drones with Intentional Sound Noise on Gyroscopic Sensors

Korea Advanced Institute of Science and Technology

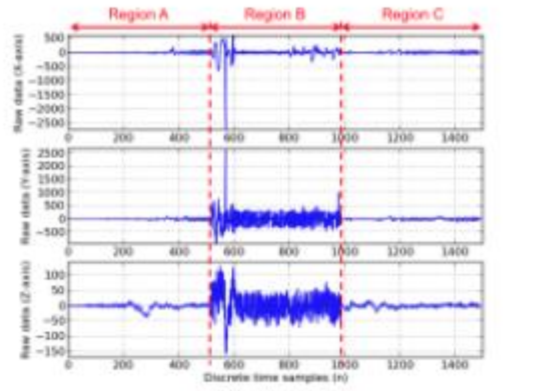


(a) Raw data samples of one L3GD20 chip with a single-tone sound noise at 20,100Hz

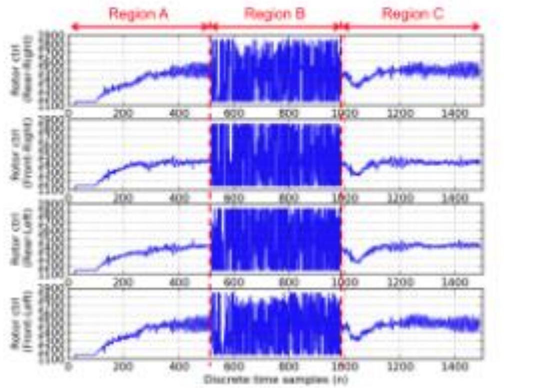


(b) Raw data samples of one MPU6000 chip with a single-tone sound noise at 26,800Hz

Item	Target Drone A
Resonant Freq. (Gyroscope)	8,200 Hz (L3G4200D
SPL at Resonant Freq.	97 dB
Affected Axes	X, Y, Z
Attack Result	Fall down



(a) Raw data samples of the gyroscope



(c) Rotor control data samples (from the flight control software)

Supporting Data

Waging Doubt on the Integrity of MEMS Accelerometers with Acoustic Injection Attacks

University of Michigan

TABLE 1. ACCELEROMETER RESONANT FREQUENCIES: UNDER RESONANT ACOUSTIC INTERFERENCE, AN OUTPUT BIASING ATTACK CLASS INDICATES A SENSOR'S FALSIFIED MEASUREMENTS FLUCTUATE (INSECURE LPF) WHILE AN OUTPUT CONTROL ATTACK CLASS INDICATES CONSTANT FALSIFIED MEASUREMENTS ARE OBSERVED (INSECURE AMPLIFIER). TWO INSTANCES OF EACH SENSOR WERE TESTED.

Model	Type	Typical Usage	Resonant Frequency (kHz)			Amplitude (g)*	Attack Class‡		
			X	Y	Z		X	Y	Z
Bosch - BMA222E	Digital	Mobile devices, Fitness	5.1–5.35	–	9.4–9.7	1	B	–	BC
STM - MIS2DH	Digital	Pacemakers, Neurostims	–	–	8.7–10.7	1	–	–	BC
STM - IIS2DH	Digital	Anti-theft, Industrial	–	–	8.4–10.8, ...	1.2	–	–	BC
STM - LIS3DSH	Digital	Gaming, Fitness	4.4–5.2	4.4–5.6	9.8–10.2	1.6	BC	BC	BC
STM - LIS344ALH	Analog	Antitheft, Gaming	2.2–6.6	2.2–5.7	2.2–5.6	0.6	B	B	B
STM - H3LIS331DL	Digital	Shock detection	–	–	11–13, ...	5.2	–	–	BC
INVN - MPU6050	Digital	Mobile devices, Fitness	5.35	–	–	0.75	BC	–	–
INVN - MPU6500	Digital	Mobile devices, Fitness	5.1, 20.3	5.1–5.3	–	1.9	BC	C	–
INVN - ICM20601	Digital	Mobile devices, Fitness	3.8, ...	3.3, ...	3.6, ...	1.1	BC	BC	BC
ADI - ADXL312	Digital	Car Alarm, Hill Start Aid	3.2–5.4	2.95–4.75	9.5–10.1	1.3	B	B	BC
ADI - ADXL337	Analog	Fitness, HDDs	2.85–3.1	3.8–4.4	–	0.8	B	B	–
ADI - ADXL345	Digital	Defense, Aerospace	4.4–5.4	3.1–6.8	4.4–4.7	7.9	BC	BC	B
ADI - ADXL346	Digital	Medical, HDDs	4.3–5.1	6.1	4.95, ...	1.75	B	B	B
ADI - ADXL350	Digital	Mobile devices, Medical	2.5–6.3	2.5–4	2.5–6.8	1.8	B	B	B
ADI - ADXL362	Digital	Hearing Aids	4.2–6.5, ...	4.3–6.5, ...	4.5–6.5	1.4	BC	BC	BC
Murata - SCA610	Analog	Automotive	–	–	–	–	–	–	–
Murata - SCA820	Digital	Automotive	24.3	–	–	0.13	C	–	–
Murata - SCA1000	Digital	Automotive	–	–	–	–	–	–	–
Murata - SCA2100	Digital	Automotive	–	–	–	–	–	–	–
Murata - SCA3100	Digital	Automotive	7.95	–	8	0.15	C	–	C

* Amplitude is taken as the maximum false output measurement observed.
‡ B = Output Biasing Attack; C = Output Control Attack (Red Highlight)
STM = ST Microelectronics; ADI = Analog Devices; INVN = InvenSense

– Experiments found no resonance
... Additional ranges of resonance elided