Drone Disabling Device

Design Review 4

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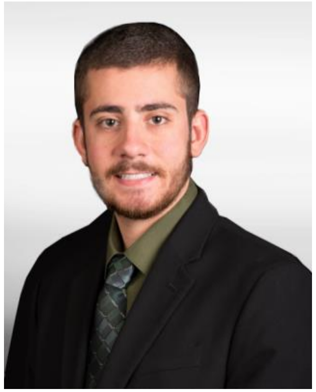
Team Introduction

Latarence Butts
Lead Electrical Engineer



Brandon Eiler
Lead Computer Engineer

Deshon Purvis
Mechanical Engineer and Scribe

Jordan Lane-Palmer
Lead Mechanical Engineer

Gregory Boldt
Webmaster

Natalie Villar
Financial Advisor and Scribe

Justin Wawrzyniak
Project Manager

Project Description

Project Scope

Objective

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

Problem

Drones with cameras and possible explosives (IEDs) pose a security threat to the public and military safety.

Customer Needs

Drone Specs

- Typical household drones

Effectiveness

- Minimum Requirement: disable
- Bonus: recovery

Range

- 30 feet radius hemisphere

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

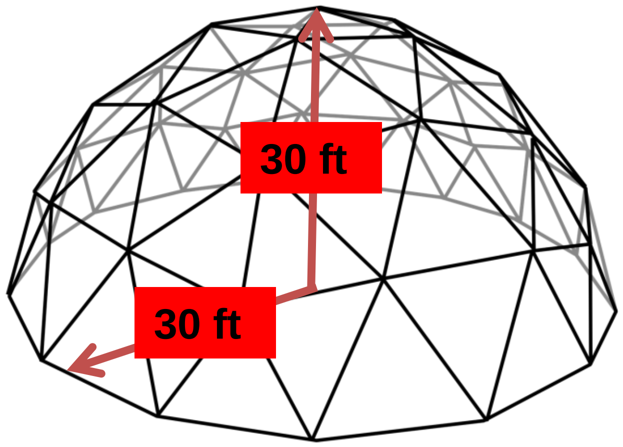


***Figure 2**: Visual representation of desired dome [2]*

Customer Needs

Operation

- Trained human operator

Power

- AC Power
- 120 Volts

Portability

- Portable
- 4 hour assembly time

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

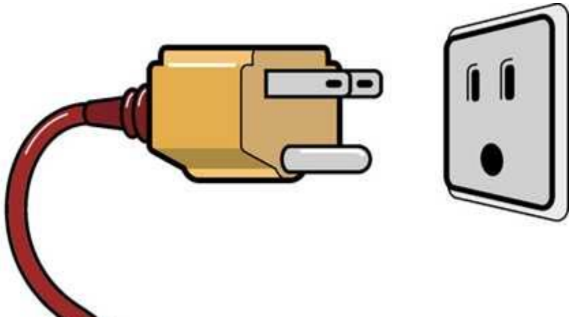


Figure 4: *Simple wall plug and outlet [4]*

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 takedown	90	%
Time to disassemble device	4	h
Project cost	5000	USD

Selected Design

Concept Selection

Detection

- Video
- Operator

Control

- Manual

Neutralization

- RF Interference
- Weighted Net

Detection System

Video

- An array of video cameras will be used to gain 360 field of view
- Open source object recognition application to process video
- Provides general location of detected drone to user

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

Update

- Awaiting arrival of purchased camera
- Testing open source software for drone recognition

Figure 6*: SJCAM SJ4000 Action Camera [6].*

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.

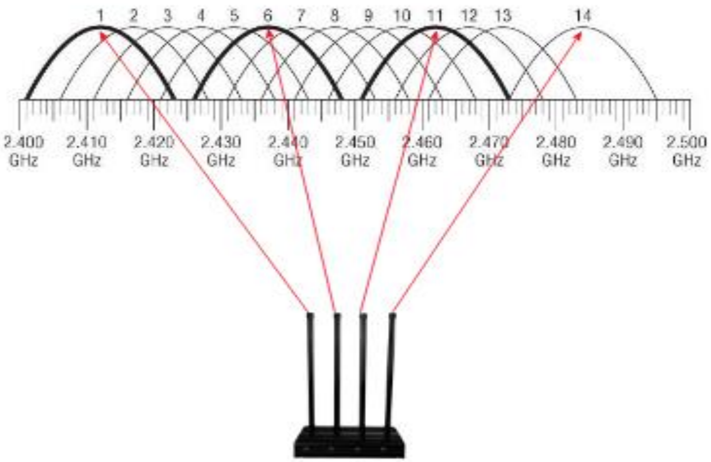


Figure 7*: four channels of 2.4GHz band [7].*

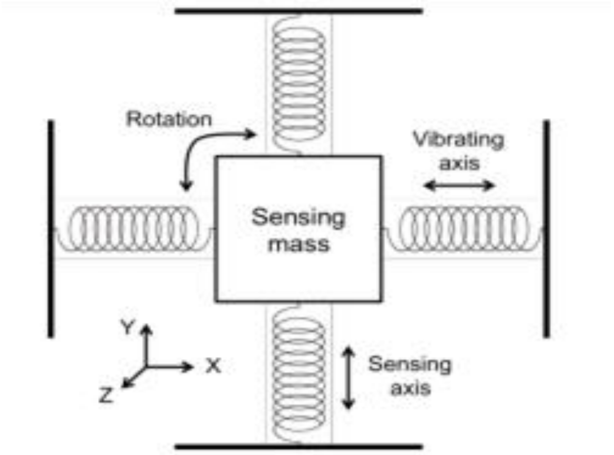


Figure 8*: gyroscope schematic [8].*

Update

Sound Update

- Solution was determined to be infeasible through testing
- Testing occurred at night due to ear irritation
- Brief testing will be conducted on future drones

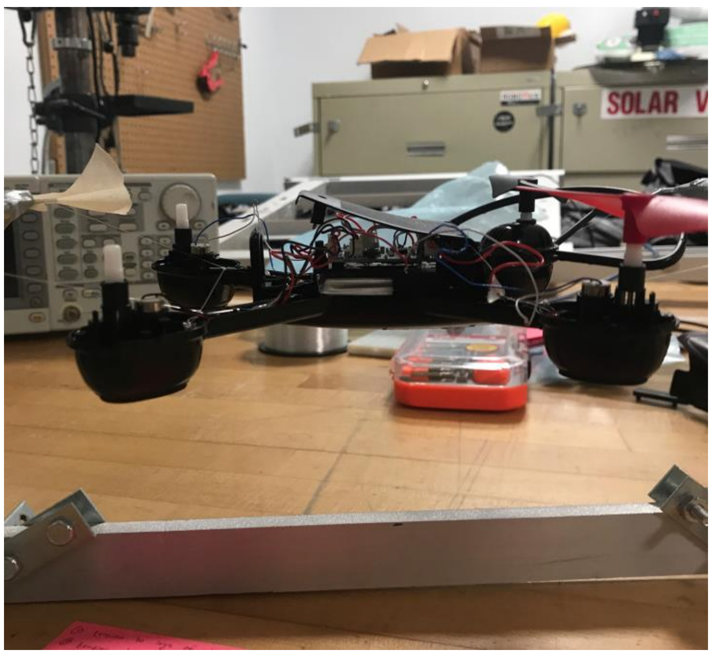


***Figure 9**: tethered drone for testing.*

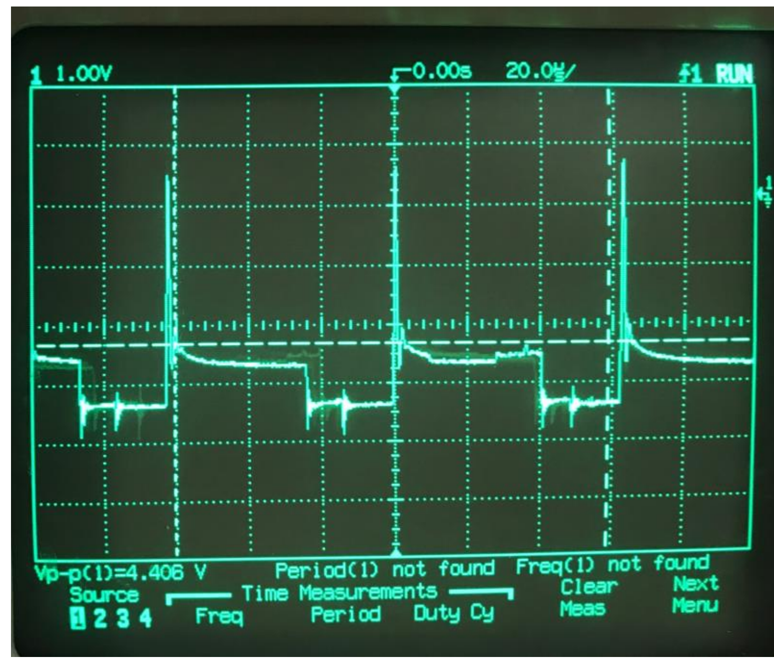
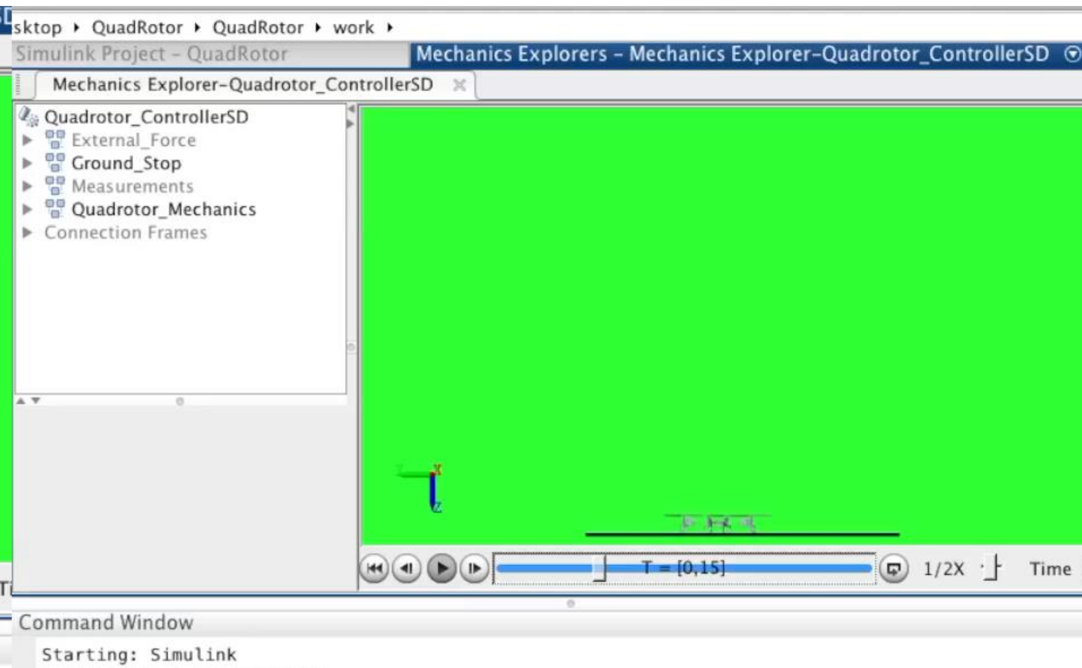


***Figure 10**: motor reading on oscilloscope.*

Update

Reality

Expected



Neutralization System

Weighted Net Attack

Use compressed air to launch a weighted net at drone.

1 **Launcher**
- Compressor
- Trigger valve
- Pipes and Fittings

2 **Net**
- 4 weighted projectiles
- Netting connected to projectiles

3 **Supports & Angle Control**
- Keep pipes in place
- Change pipe angle to vary net deployment distance

4 **Aiming**
- Side to side rotation
- Up and down rotation

Weighted Net Attack

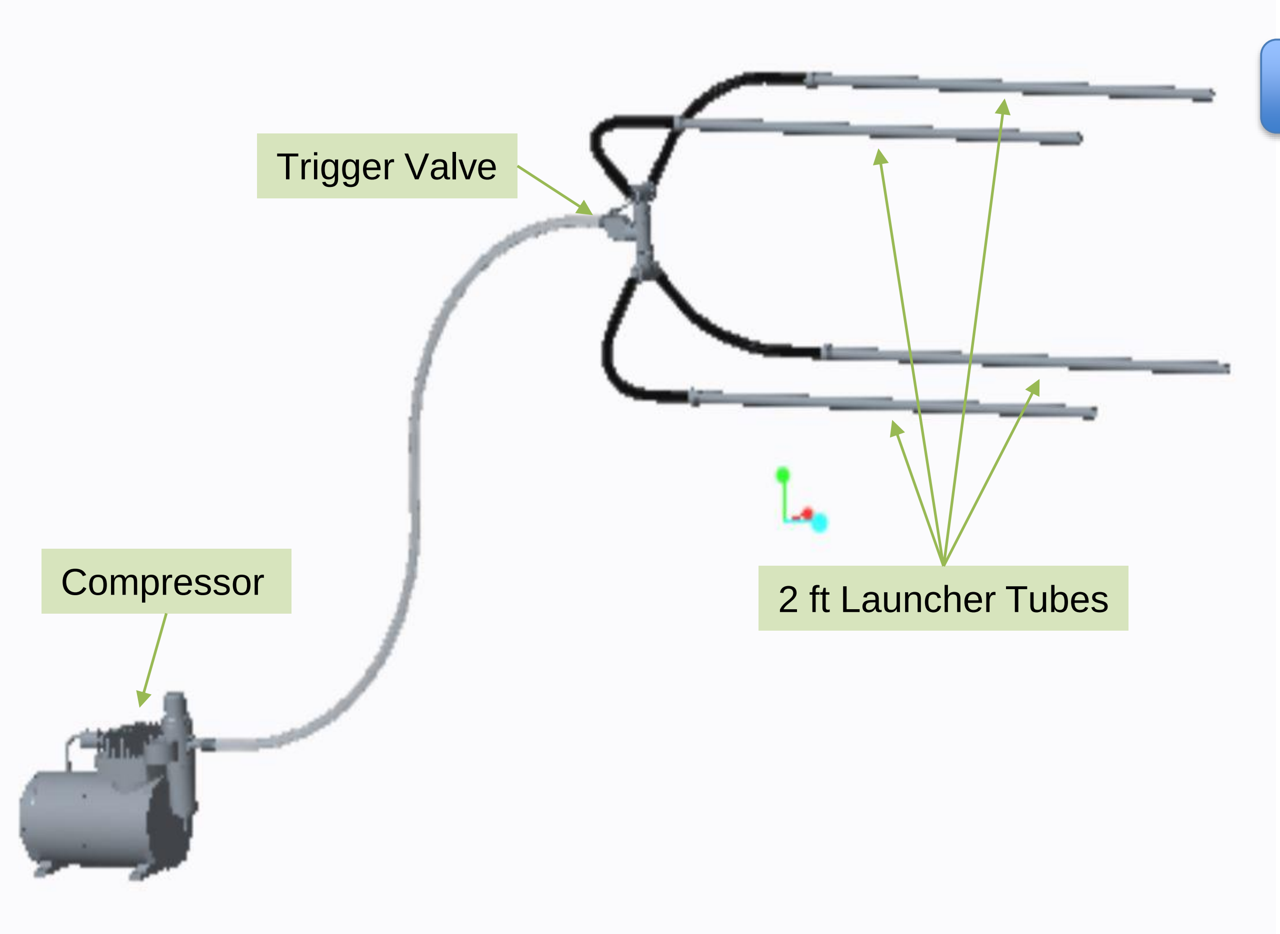


Figure 11*: illustration of weighted net attack.*

Launcher

- All parts purchased
- Stainless steel pipes and fittings
- ¼” nominal pipes and fittings
- 150 psi compressor

Weighted Net Attack

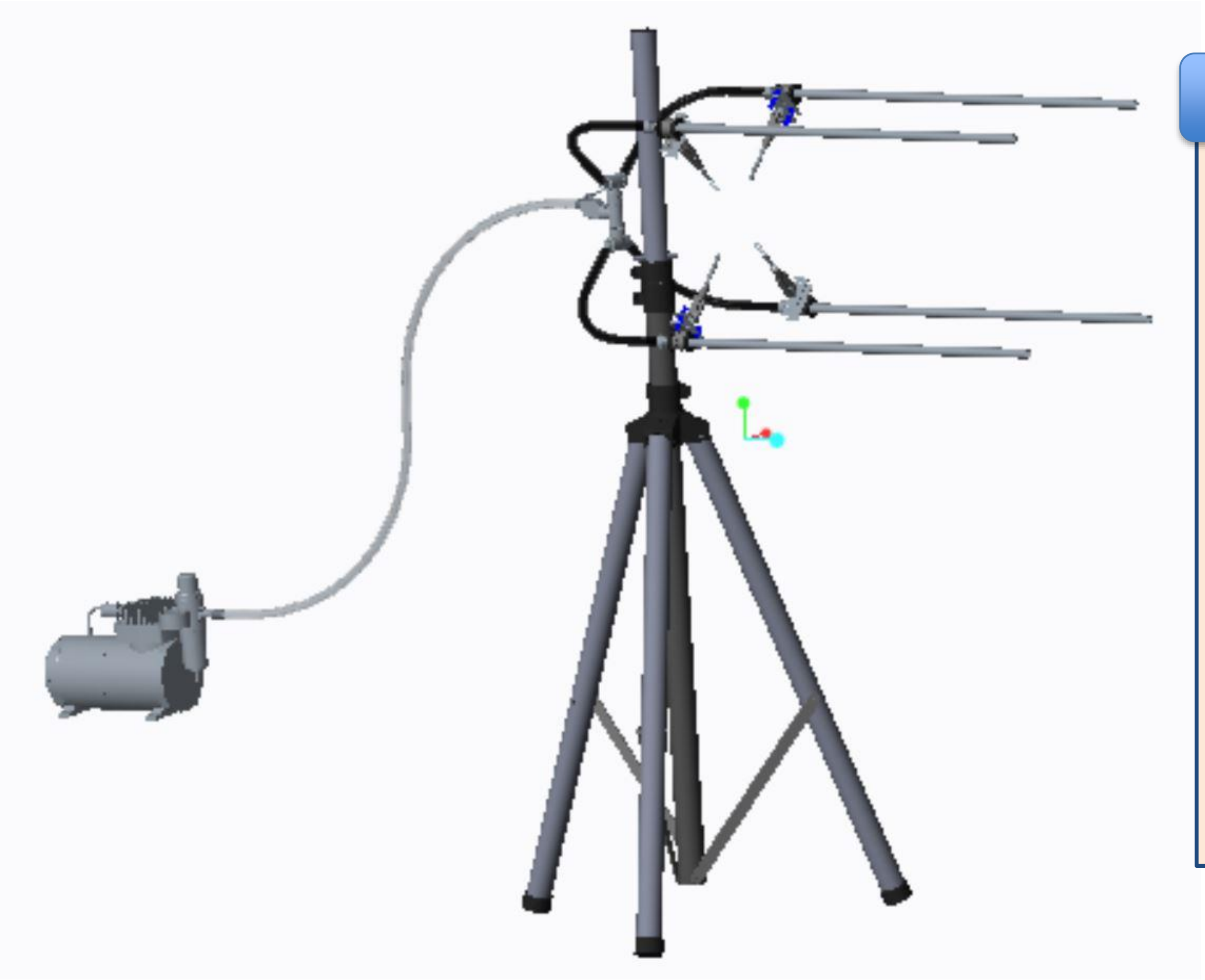


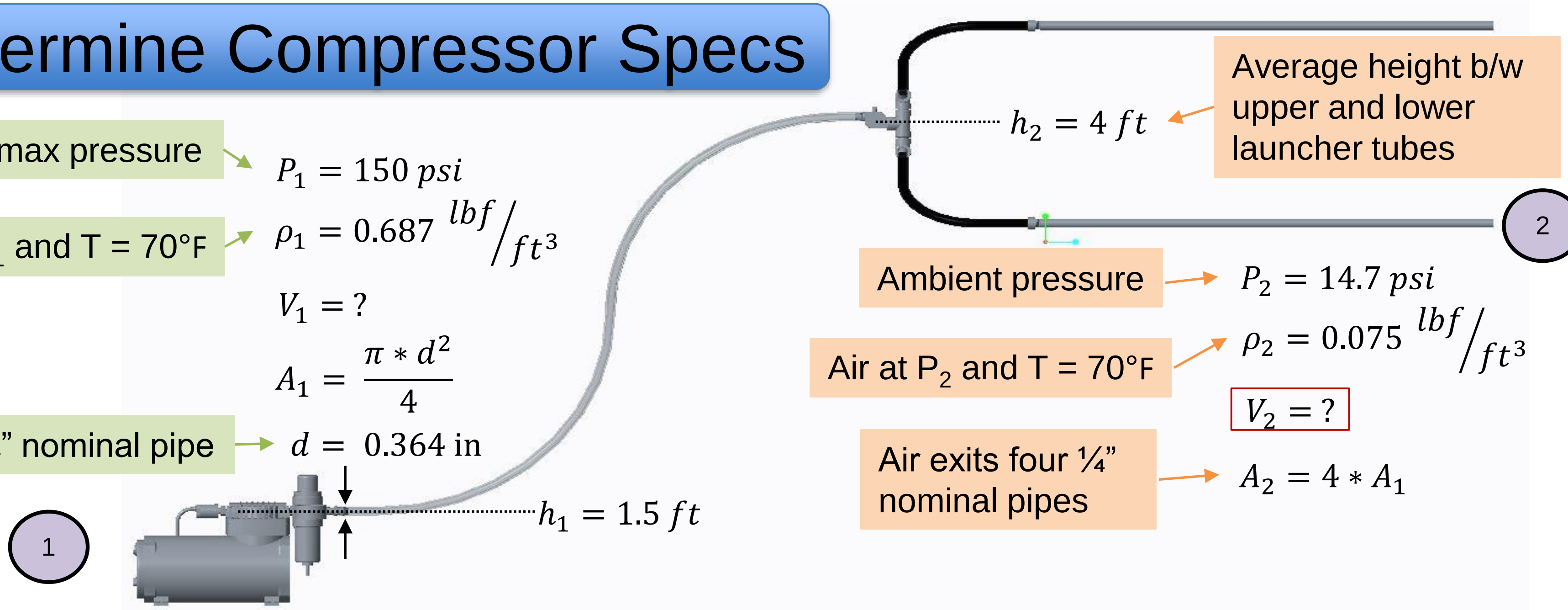
Figure 12: illustration of weighted net attack.

Up Next

- Test launcher
- Begin purchasing support and angle control parts
- Determine how to allow for manual aiming

Weighted Net Attack

Determine Compressor Specs



Piping max pressure → $P_1 = 150\ psi$

Air at P_1 and T = 70°F → $\rho_1 = 0.687\ {lbf}/{ft^3}$

$V_1 = ?$

$A_1 = \frac{\pi * d^2}{4}$

ID for ¼” nominal pipe → $d = 0.364$ in

$h_1 = 1.5\ ft$

$h_2 = 4\ ft$ ← Average height b/w upper and lower launcher tubes

Ambient pressure → $P_2 = 14.7\ psi$

Air at P_2 and T = 70°F → $\rho_2 = 0.075\ {lbf}/{ft^3}$

$V_2 = ?$

Air exits four ¼” nominal pipes → $A_2 = 4 * A_1$

***Figure 13**: illustration of weighted net attack.*

Bernoulli's Equation

$$\frac{P_1}{\rho_1} + \frac{V_1{}^2}{2} + gh_1 = \frac{P_2}{\rho_2} + \frac{V_2{}^2}{2} + gh_2$$

…solve for V_2

Mass Conservation

$$\dot{m}_1 = \dot{m}_2$$

$$\rho_1\ V_1\ A_1 = \rho_2\ V_2\ A_2$$

$$V_1 = \frac{\rho_2 V_2 A_2}{\rho_1 A_1}$$

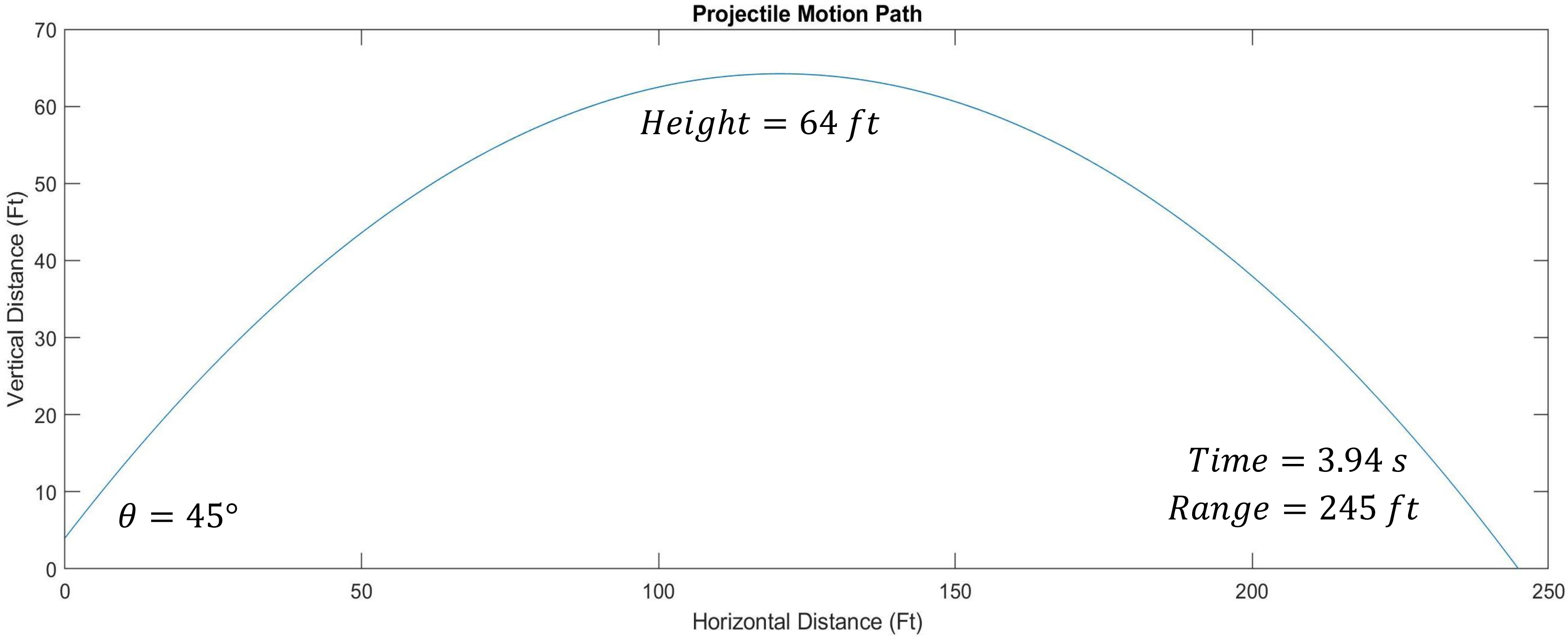
Weighted Net Attack

Determine Compressor Specs

No Air Resistance

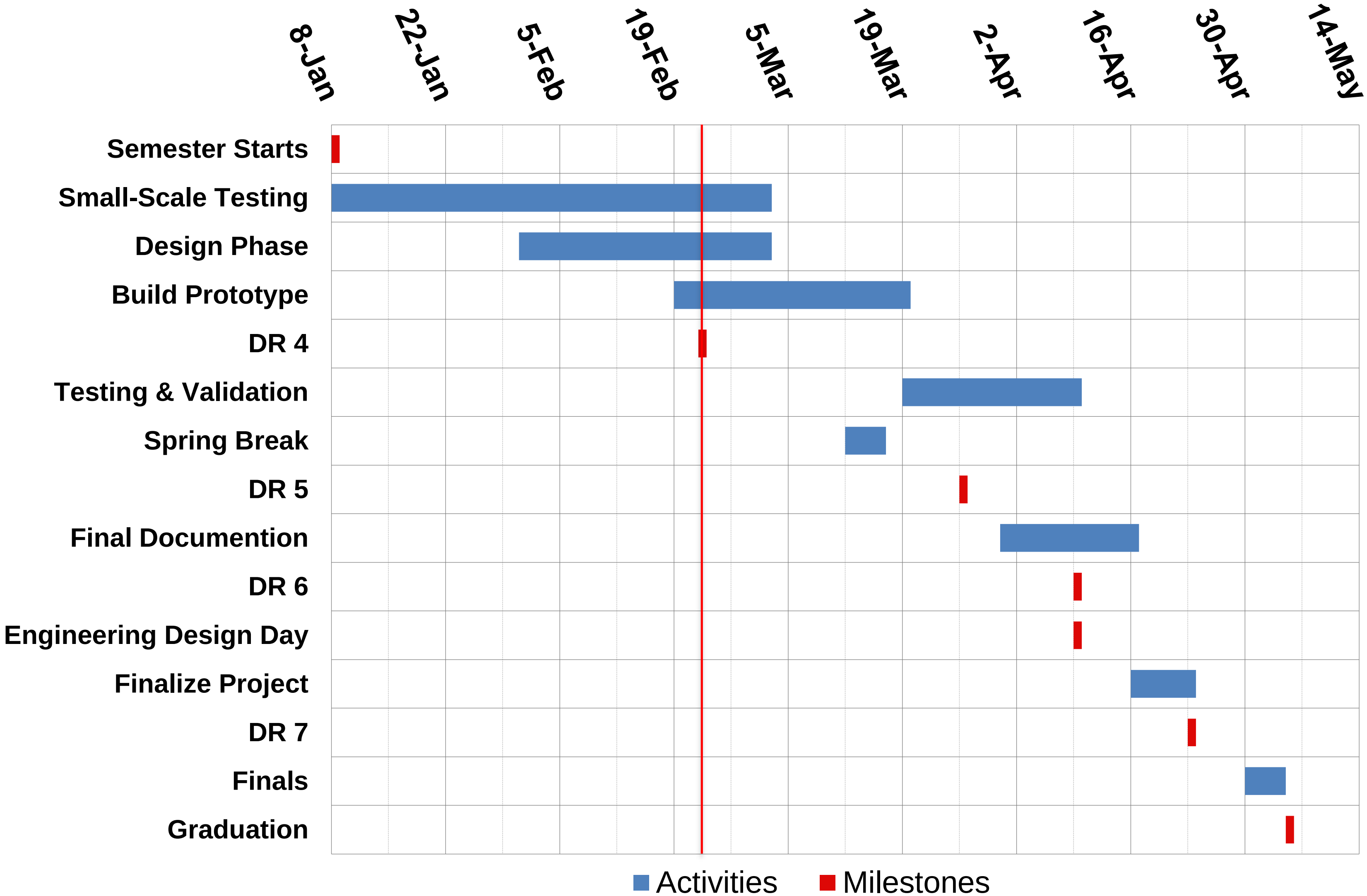
No Pressure Loss From Compressor

$V_2 = V_0 = 88\ {}^{ft}/_{s}$



Future Activities

Project Plan



Purchasing Update

Detection

- Camera

Control

- Tripod (i.e. speaker stand)

Neutralization

- Transmitters – RF attack
- Various parts – Weighted Net attack

Figure 14: *shows the camera purchased for testing [6].*

Figure 15: *shows a similar transmitter purchased for testing [9].*

Next Steps

Complete small scale testing for RF attack

Continue testing algorithm for drone detection

Begin building prototype

References

1. Argos (Photographer). (2017). *DJI Mavic Pro Quadcopter 4k Drone* [digital image]. Retrieved from http://www.argos.co.uk/product/6259381
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4. M. (2014, September 04). *Kerbal Attachment System (KAS) 0.4.7 –- Pipes as fuel lines and even fewer explosions!* [digital image] Retrieved October 13, 2017, fromhttps://forum.kerbalspaceprogram.com/index.php?/topic/48738-kerbal-attachment-system-kas-047-pipes-as-fuel-lines-and-even-fewer-explosions/&page=6
5. Akpan, N. (2015, August 13). The heart rates of black bears spike when drones fly overhead. Retrieved November 07, 2017.
6. A., R., B, R., Marv, M., P., C., . . . D. (2016, March 25). SJ4000 Action Camera (Black). Retrieved February 21, 2018, from https://www.bhphotovideo.com/c/product/1072775-REG/sj4000_sj4000_action_camera.html
7. MNS Laboratory. (2016, June 29). DronePD - Drone Police Department - project [System Overview]. Retrieved November 3, 2017.
8. S. (2017, May 21). Radar Principle. Retrieved November 07, 2017.
9. 2. (1970, February 01). 2.4 GHz Wireless FM Audio Video Transmitting Module A/V Transmitter For DVD DVB. Retrieved February 21, 2018.

Questions?

Matlab Code for Compressor Spec

```
%% Bernoulli's Equation
g = 32.174;                        % acceleration due to gravity in ft/s^2
% Entrance conditions
P1 = 150*144;                      % pressure in lbf/ft^2
rho1 = 0.687;                      % lbf/ft^3 air density @ P1 @ 70F
A1 = (pi*(0.364/2)^2)/144;         % cross section area at compressor in ft^2
h1 = 1.5;                          % height of compressor outlet
% Exit conditions
P2 = 14.7*144;                     % pressure in lbf/ft^2
rho2 = 0.075;                      % lbf/ft^3 air density @ P2 @ 70F
A2 = 4*A1;                         % cross section area at exit in in^2
h2 = 4;                            % average height of exit tubes
% Plug mass continuity eqn into Bernoulli's and rearrange to solve for V2
V2 = sqrt((2*(P2/rho2-P1/rho1+g*(h2-h1)))/((rho2*A2/(rho1*A1))^2-1))
```

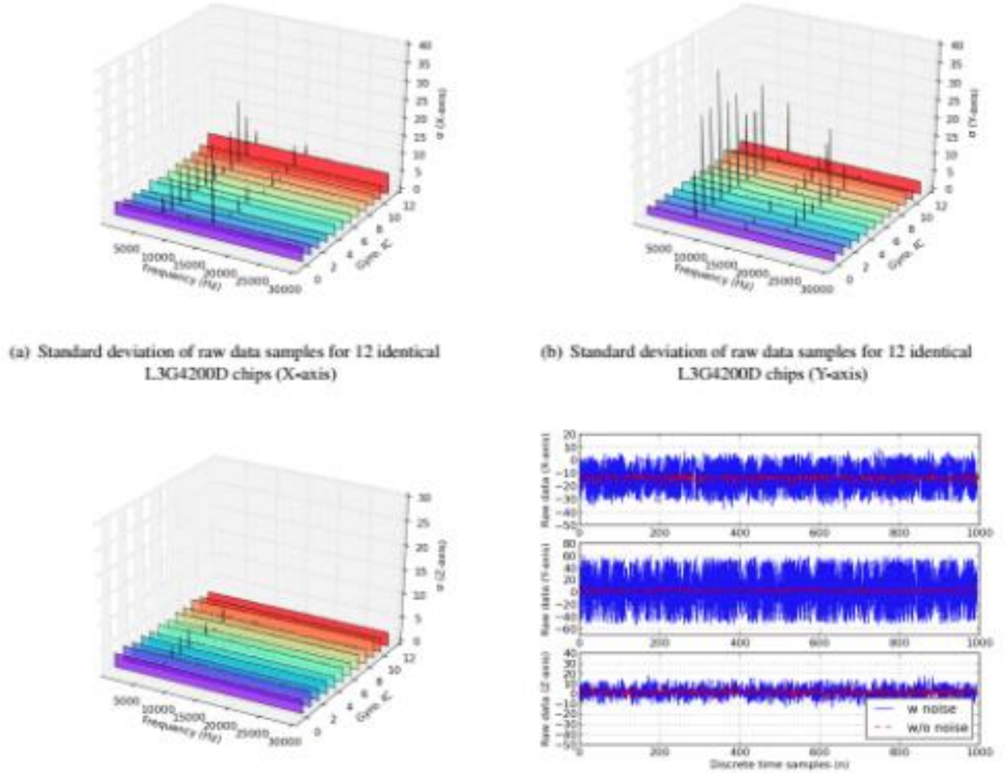
Matlab Code for Compressor Spec

```matlab
%% Projectile Motion
Theta = 10;                 % lanch angle of projectile in degrees
V0 = V2;                    % initial velocity in ft/s
V0x = V0*cosd(Theta);       % x component
V0y = V0*sind(Theta);       % y component
x(1) = 0;                   % initial horizontal position in ft
y(1) = 4;                   % initial vertical position in ft
% variables for while loop
t = 0;                      % time
i = 1;                      % counter variable
dt = 0.01;                  % change in time
% build array of x and y positions over time
while min(y)> -0.01;
    t = t+dt;
    i = i+1;
    % projectile motion equations for position
    x(i) = x(1) + V0x*t;
    y(i) = y(1) + V0y*t - 0.5*g*t^2;

end;
t                                % time to hit ground
R = V0x*t                        % max range
h = y(1) + V0y^2/(2*g)           % max height
% plots the Projectile Motion
plot(x,y);
axis([0 110 0 10]);
xlabel('Horizontal Distance (Ft)');
ylabel('Vertical Distance (Ft)');
title('Projectile Motion Path');
```

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)

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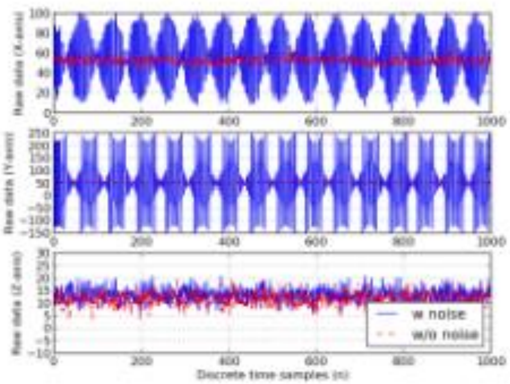
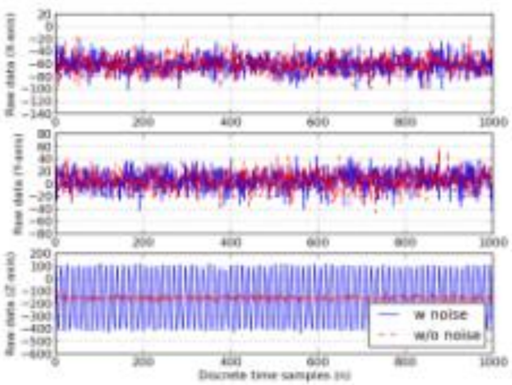
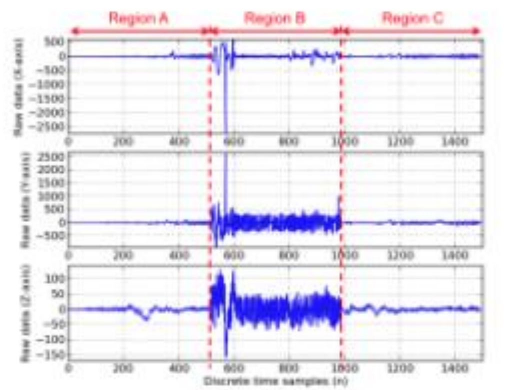


(a) Raw data samples of one L3GD20 chip with a single-tone sound noise at 20,100Hz

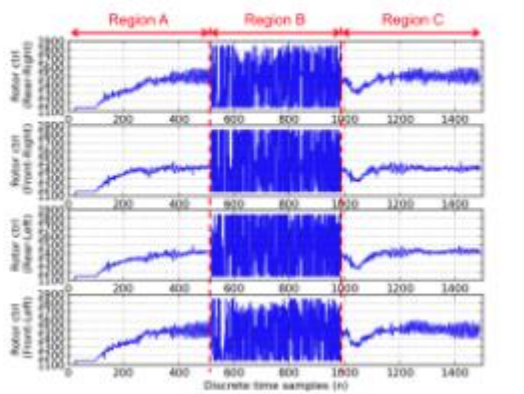


(b) Raw data samples of one MPU6000 chip with a single-tone sound noise at 26,800Hz

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