Hack-a-Thon:BB-RC Jammer

MAE 4344 Final Report

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Introduction and Problem Statement

Drones, also known as unmanned aerial vehicles, are aircrafts that fly autonomously through programmed software or are controlled by a person through remote control. These drones now pose a threat to the United States' national security, as enemy drones are used to scout enemy positions, film propaganda videos, and drop dangerous objects below. For example, in recent years ISIS has been caught attaching explosives to the drones and then flying them into US held cities. However, on a domestic level, drones have also become a growing issue in the state of Oklahoma's jail system. A growing number of criminals have been using drones to fly drugs into state penitentiaries. In an attempt to combat this security risk, we will create a system to defeat the target drone by disabling or hacking. There are a few current defeat systems available on the market ranging from drone based nets to using combat trained hawks.

Figure 1: Drone based net

Figure 2: Guard hawk

These current methods have seen limited success, and in order to improve upon their success our group has created a new system that utilizes EM waves to disrupt communication between the drone and the controller. Our system will consist of a ground operator holding an electromagnetic jammer. The electromagnetic jammer will flood the 2.4 GHz bandwidth, preventing the enemy pilot from communicating with his drone. For testing purposes we will be attempting to stop a standard 3DR IRIS+ Solo Quadcopter, which is a very prototypical drone that criminals use.

Figure 3:: 2.4 GHz spectrum channels.

Project Requirements and Deliverables

This project requires us to build an electrical or mechanical system to hack, disable and or track an enemy controlled drone. The effectiveness of the system will be tested in the Hack-A-Thon competition as outlined by Dr Jacob.

Testing of the system will take place in The Colvin Annex or the Sherman Smith Training Center and two scenarios will take place.

Figure 4: Colvin Annex

Figure 5: Sherman Smith Training Center

First, the enemy drone will travel at a moderate speed and will keep a constant path towards the target. Next, the enemy drone will actively avoid the defense system we created. Points will be awarded based on where the enemy drone is disabled, relative to the red zone. Additionally, bonus points will be given based on level of damage to enemy drone. A scoring matrix is shown below.

Distance	Score
<10'	0
10'	10
25'	25
50'	50

Statement	Bonus
No damage	50
Broken prop	25
Unflyable	0

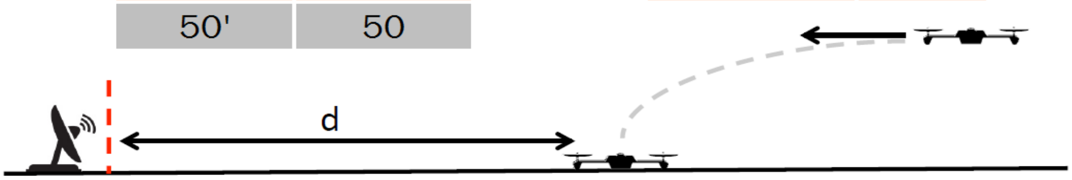


Figure 6: Scoring Matrix

Plan of Attack

When given this problem our team began debating between a number of designs. After talking with Dr. Jacob it became clear that our group should lean towards a design that is focused around more the electrical side of things by utilizing EM waves. After reviewing our options our group elected to begin work on a design that was focused around an Electromagnetic Pulse (EMP) generating device. Our idea was to attach the EMP generator to a relatively cheap drone and then fly our disposable drone towards the enemy drone. Shortly before collision occurs we planned to set the EMP off, which then would destroy all electrical systems within a short range.

Figure 7: Initial Concept of Drone
with EMP generator

Unfortunately, after more research we found two main issues with our EMP idea. The first issue we encountered is that EMP's require a large amount of electrical energy in order to be generated. In order to generate a reasonably sized EMP from our drone we would have to increase the carrying capacity of our drone, which requires a larger drone, thus our plan was no longer financially feasible. The second major issue with the EMP based plans was that EMP generation is actually a felony according to the U.S. government. Generating EMP's can lead to jail time and fines.

Due to the negative findings we encountered with the EMP plan our group decided against using EM waves via EMP, but yet we still wanted to find a method that utilized EM to disable the enemy drone. Our team began to evaluate how the drone and controller communicated. After research we saw there was a potential weakness with the drone's built in fail safes that could be exploited. The 3DR IRIS+ has a few built failsafe's that dictate that when the drone and controller lose connection one of the following options must occur: 1) the drone hovers in place until either the battery is exhausted, or the connection is reestablished. 2) the drone makes an emergency landing and lands directly below where it is currently positioned. 3) the drone will return to "home", which is the same location the drone took off from.

Moving forward with this plan to disrupt the communication between the drone and controller our team began to investigate the best way to achieve our goal. We discovered that the best method appeared to be flooding the 2.4 Ghz band in order to block all communication attempts.

Detailed Description of Work and Key Decisions Made

Our group initially intended to utilize small, relatively cheap drone with a small EMP (electromagnetic pulse) generator attached. These drones were going to be manually flown at the target drone and briefly before impact we planned to initiate the EMP device. Once the EMP was generated, all electronic devices in a small radius around our drone, such as the target drone, would have been forced off.

Further research into the legality of generating EMPs led to the discovery that EMP generators are both illegal and very easily tracked by the authorities. Detonating an EMP is punishable with a $16,000 fine and the possibility of jail time. Additionally, it would be very difficult to shield our drone from the EMP and the risk of potentially damaging unintended targets in a destructive manner was too high. In an effort to mitigate these issues, we decided to pursue an EM Jammer instead of the EMP.

An EM jammer will disrupt communication with the controller, but will not necessarily take down the drone. In order to take down the drone, a physical takedown method is also needed.

In addition to a jammer, we considered designing a ground based system to launch a net at the drone, however a shotgun shell is already on the market that will be much more practical. We decided to mount our system on a shotgun, and equip the wielder with said shotgun shells.

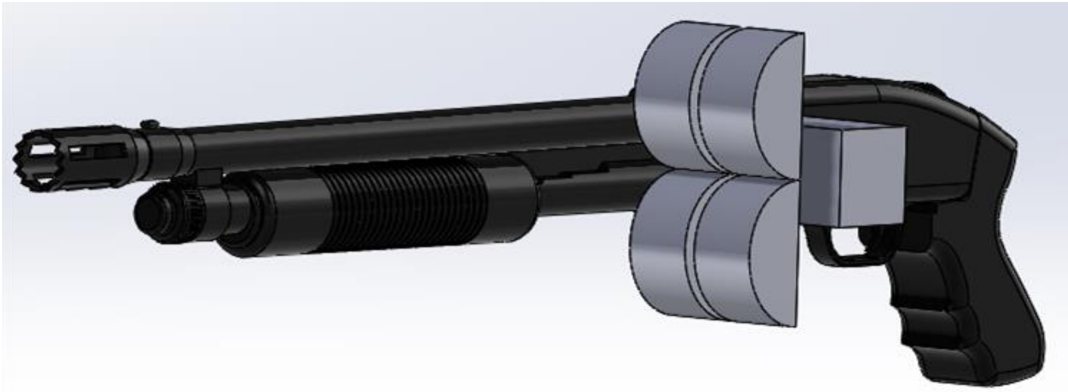


Figure 8: Rendering of our attachable
jammer concept

The decision to mount our system on a shotgun was made for several reasons. Currently, warfighters often carry more than 90 lbs of equipment. Most fire teams already have at least one shotgun. Our system would simply be a lightweight attachment to this shotgun instead of two additional systems (jammer and net launcher). Furthermore, by mounting the jammer on the takedown weapon, both steps of the takedown can be simultaneously accomplished by one person.

Detailed Description of the Final Design

We decided that an EMP was not the best option to accomplish our task. The size an EMP would need to be in order to reliably take down a drone would also likely damage other nearby electrical equipment. This, coupled with the fact that large EMPs are not legal to detonate, we decided to go in a different direction.

After ruling out an EMP we decided to go with an EM jammer. A jammer with a directional antenna will be much more reliable than a one shot EMP and also much simpler than a mechanical defeat system. According to the manufacturer's data, a 3DR IRIS+ Solo Quadcopter transmits signals from its controller to the drone over the 2.4 GHz wifi spectrum. The 2.4 GHz spectrum has 11 channels over which data can be transmitted. The drone and controllers are built so that if they lose connection on one wifi channel they will begin bouncing from channel to channel until they are able to re-establish a link.

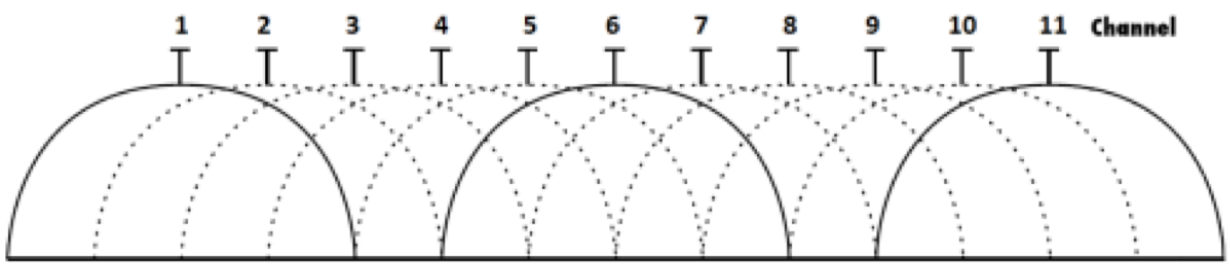


Figure 9: 2.4 GHz spectrum channels.

All 3DR IRIS+ Solo Quadcopters have a series of built in default commands when the controller and the drone lose contract. The reason these safeguards exist is to help prevent the drone from crashing simply because the controller runs out of battery or some interference occurs. The three built in commands for the Solo are hover in place, land, and return to take-off point.

The key components to the jammer are four 2.4 GHz radio transmitters and 2.4 GHZ 8dB patch antennas. The jammer will work by flooding specific channels with noise. The radio transmitters selected are able to flood the specified channel, as well as the channels above and below said channel. After all four radio transmitters are activated, the entire 2.4 GHz spectrum will be flooded to the point where no other signals can be transmitted within range of the jammer's transmitters. Thus, once the drone enters the transmitters' range it will lose contact with the controller and begin channel hopping in an effort to reconnect with its controller. The drone will be unable to re-establish connection with the controller and the target drone will be forced into one of its failsafe mechanisms.

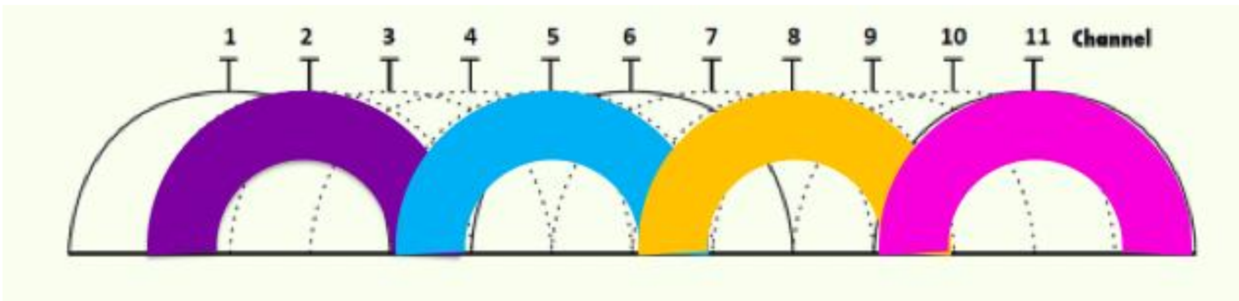


Figure 10: 2.4 GHz spectrum channels flooded by four transmitters.

We chose to use patch antennas because their power drop off is much lower than an omni directional antenna. Also, the conical gain pattern of patch antennas will allow us to 'aim' the jammer at the target. aiming will help us avoid accidentally interfering with nearby Wi-Fi communications.

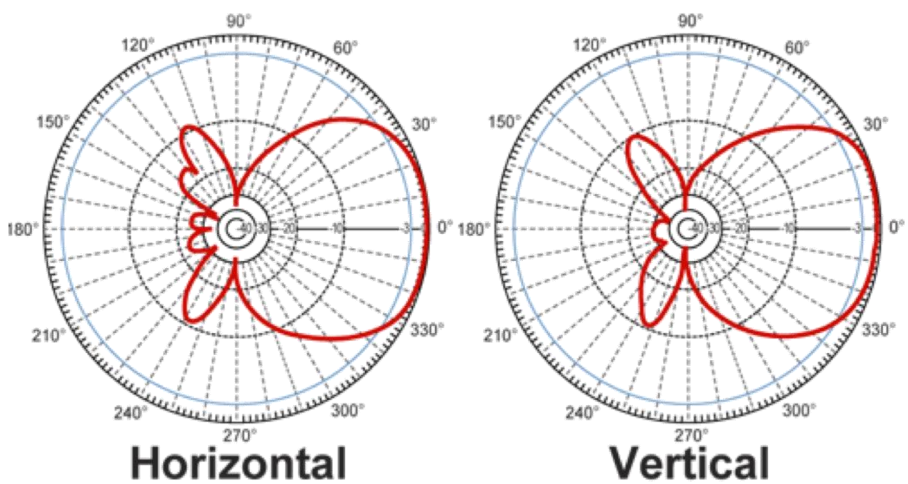


Figure 11: Gain pattern of 8 dB patch antenna.

Evaluation of Final Design

On April 7th, 2017 we tested the BBRC Jammer on a IRIS SOLO Quadcopter and the device did not work due to the type of radio transmitters we ordered. We tested the radio transmitters prior to testing and confirmed that they did flood one channel with signal, but not the channels above and below its set channel like we anticipated. That is to say, there was very little signal spilling into adjacent channels. This meant that we would either need many more radios, or radios with looser tuning. We decided to use four 500 mW radios with looser tuning. We also compared the signal strength of the transmitters with a patch antenna and an omnidirectional antenna and could not tell a significant difference. We decided to test anyway to confirm that these 2 radio transmitters were not enough to flood the entire 2.4 GHz spectrum. When we turned on the BBRC Jammer the test drone did not lose communication with the controller and was still able to proceed to the target.

The new radios we ordered have not yet arrived. Based on the tests and observations from UAS 1--who have a similar design--our new design should work. By mounting our system on a shotgun, we allow for both jamming and takedown to be performed by a single operator. The operator first jams the enemy, making it a much easier target, and then shoots it down.

Overall, this is a good step in the right direction. Although still and early prototype, this hybrid of electrical and mechanical techniques allows for a reliable and compact drone defense package.

Recommendations for Future Work

This project is a good step in the right direction, but it is far from perfect. Future improvements must be made for this to be a truly viable system. Currently, our system is only equipped to counter targets operating on the 2.4 GHz bands. In order to increase the effectiveness of our system, we implement the ability to also jam the 5.8 GHz bands. These are by far the most popular channels for commercial drones.

This could be accomplished fairly easily by adding more transmitters to the system, or by replacing the current transmitters with signal generators capable of producing a much wider range of frequencies. The antennas currently in place on our system are dual band antennas and are capable of effectively transmitting both 2.4 and 5.8 GHz signals. If more signals than these are desired, new antennas should be selected.

Material, Equipment, and Facilities Requirements

The key components of our jammer are radio transmitters, Wi-Fi antennas and a power source. The radios we selected are 500mW, 16 channel 2.4GHz transmitters, purchased from “hobby king”. The antennas we selected are ALFA networks APA-M25 Dual band patch antennas. The power source has yet to be selected, a multitude are available at the USRI and will be selected once we receive our radios.

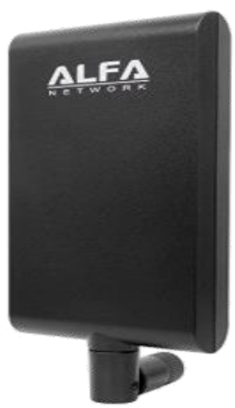


Figure 12: Alfa APA-M25 dual band 2.4GHz/5GHz 10dBi high gain directional indoor panel antenna

Figure 13: TBS Unify 2.4GHz 500mV Wireless Radio Transmitter

These components will be mounted on a shotgun using a system of our own design. THe body of this mount is primarily comprised of PVC pipes. Two concentric pipes--one connected to the shotgun and one connected to the jammer--are connected to one another by a springs and damping pads. This spring/damper system vastly lessens the acceleration felt by the antennas when the gun is fired.

The third key piece of our system is the physical projectile we plan to use to take down the jammed drones. These are commercially available, we selected SkyNet Drone Defense shells.

Revised Budget

Our maximum budget for this project is 1000 USD. We are currently on track to be well within this budget. Specific costs are shown below.

4-2.4 GHz Transmitters	$200
4-Dual band patch antennas	$80
Power source	Provided
Construction Components (mount)	$50
Excess	~$670

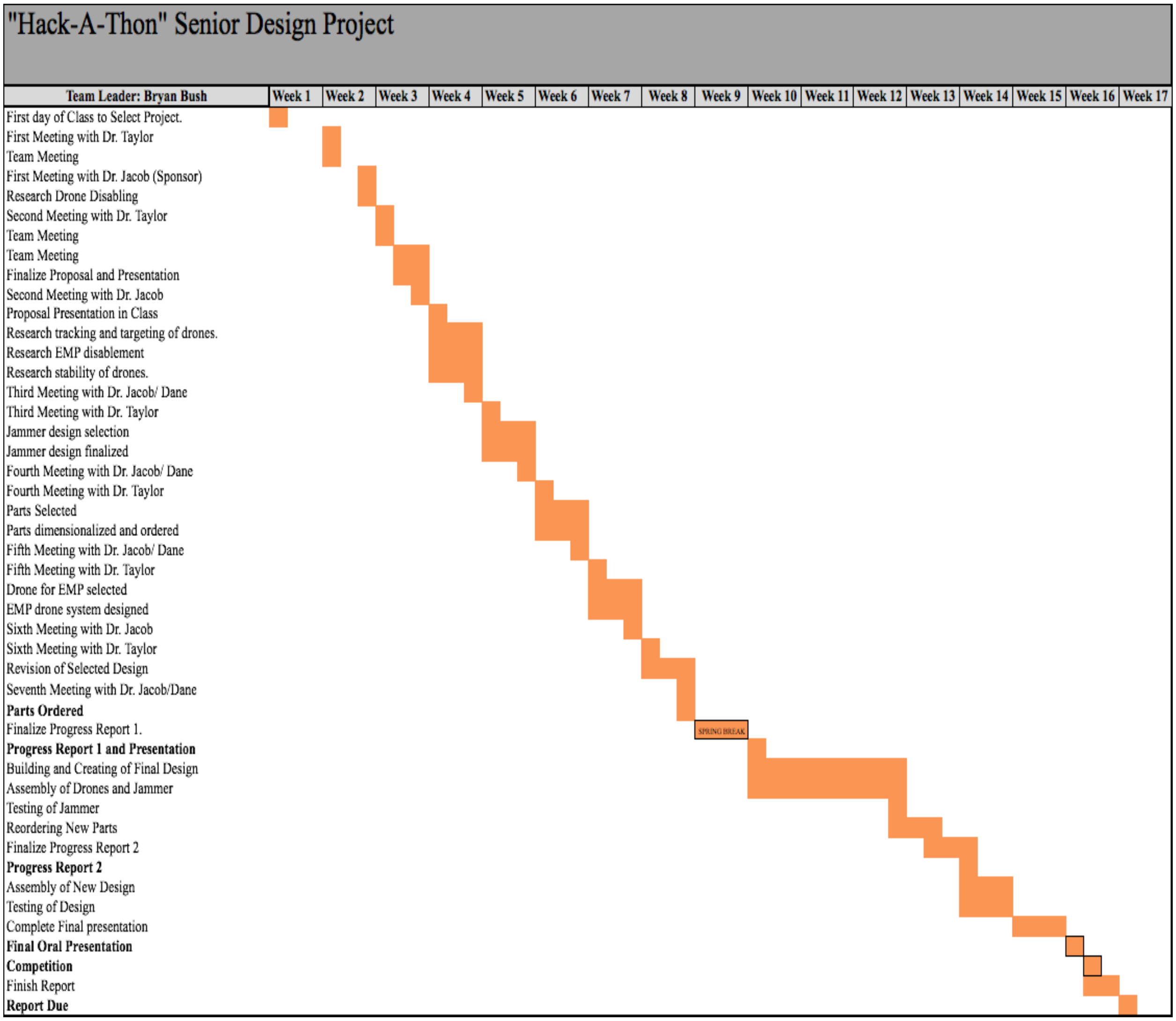
Figure 14:Finalized Budget

Revised Gantt Chart

Hack-A-Thon Senior Design Project

Team Leader: Bryan Bush	Start	End Date	%	Note	Deliverables	Assigned To:
First day of Class to Select Project.	23-Jan	23-Jan	100%			
First Meeting with Dr. Taylor	30-Jan	30-Jan	100%	Discussed assigned problem and brainstormed potential ideas.	Notes and key advice from the meeting.	Team
Team Meeting	30-Jan	30-Jan	100%	Brainstormed ideas and decided on 5 possible ideas.	Notes in log book.	
First Meeting with Dr. Jacob (Sponsor)	3-Feb	3-Feb	100%	Learned about the conditions and tasks and identified requirements	Rules and guidelines for the project.	
Research Drone Disabling	3-Feb	3-Feb	100%	The team seperately came up with further ideas to bring to meeting with Dr. Jacob.	Research to present to the team.	Team
Second Meeting with Dr. Taylor	6-Feb	6-Feb	100%			
Team Meeting	6-Feb	6-Feb	100%	Finalized the potential ideas.	All brainstorming and notes.	
Team Meeting	9-Feb	10-Feb	100%	Met to prepare our ideas to present to Dr. Jacob.	All brainstorming and notes.	
Finalize Proposal and Presentation	9-Feb	10-Feb	100%	Practiced for presentation and made our proposal for the class.	Problem statement and outlines of current plan	Team
Second Meeting with Dr. Jacob	10-Feb	10-Feb	100%	Presented our final idea to Dr. Jacob and discussed ways to accomplish the design.		
Proposal Presentation in Class	13-Feb	13-Feb	100%		Final Proposal Document and presentation.	
Research tracking and targeting of drones.	13-Feb	17-Feb	100%	Researched ways to track in order to start the actual design process. Will meet with grad student to discuss coding.	Log book notes including all research done and sources.	Christy/ Gracie
Research EMP disablement	13-Feb	17-Feb	100%	Researched ways to create EMP's and use them to disable the drone without also hurting personal drone.	Log book notes including all research done and sources.	Bryan
Research stability of drones.	13-Feb	17-Feb	100%	Researched other possiblities of disabling and bringing down the drone.	Log book notes including all research done and sources.	Price
Third Meeting with Dr. Jacob	17-Feb	17-Feb	100%	Will ask questions and report our current status with the research and design.	Current ideas this far with all research done to date.	
Third Meeting with Dr. Taylor	20-Feb	20-Feb	100%	Will update Dr. Taylor on current status and will ask any questions that may have arrised so far.	Log book and current ideas this far with all research done to date.	
Jammer design selection	20-Feb	24-Feb	100%	The group will narrow down which design we have decided to move forward with after looking into all aspects.	All notes and research to compare and contrast.	Team
Jammer design	20-Feb	24-Feb	100%	The group will begin designing the Jammer and gathering materials needed to complete the design process.	Log book notes.	Team
Meet with Dane to test for frequencies	23-Feb	23-Feb	100%	We will meet with Dane and test the Drone we are competing against's frequency to know what to jam.	Frequency of which to create jammer.	Team
Fourth Meeting with Dr. Jacob	24-Feb	24-Feb	100%	We will update Dr. Jacob on the Jammer selection and current progress of the project.	Log book notes including all research done and sources.	
Fourth Meeting with Dr. Taylor	27-Feb	27-Feb	100%	We will update Dr. Taylor on the selection and ask any possible questions. We will also keep Dr. Taylor informed of what Dr. Jacob says.	Log book notes including all research done and sources.	
Parts Selected	27-Feb	3-Mar	100%	The parts used to complete the Hacking of the drone will be finalized so we know exactly what needs to be done or bought.	Log book notes and final outline of the parts of the system.	Team
Parts dimensionalized	27-Feb	3-Mar	100%	After the parts are selected we will go more in depth and dimensionalize them and design them.	Log book notes and final outline of the parts of the system.	Team
Parts Ordered	3-Mar	3-Mar	100%	We will communicate the parts needed to Dane and will have them ordered and delivered in time to start building after Spring Break	List of Final Parts	Bryan
Fifth Meeting with Dr. Jacob/Dane	3-Mar	3-Mar	100%	We will update Dr. Jacob on the part selection and dimensioning and make sure everything is feasible to move forward with the design.	We will provide Dr. Jacob with all research this far and why we selected this method.	
Fifth Meeting with Dr. Taylor	6-Mar	6-Mar	100%	We will update Dr. Taylor on where we are currently and ask questions.	Discuss progress and relay information from Dr. Jacob this far	
Jammer drone system designed	6-Mar	10-Mar	100%	We will finalize the system we plan to use to complete the task and will have the design finished.	Rough sketches of the system we wish to use.	Team
Sixth Meeting with Dr. Jacob/Dane	10-Mar	10-Mar	100%	We will present our entire designed system to Dr. Jacob.	Log book notes, sketches of current system with all math and notes.	
Revision of Selected Design	13-Mar	17-Mar	100%	After talking with Dr. Taylor and Dr. Jacob we will take their advice and finalize our design while still improving it.	Sketches of system will be refined and assembled.	Team
Finalize Progress Report 1.	13-Mar	17-Mar	100%	We will prepare for the progress report one and finish the paper.	Final design sketches and Log book.	
Progress Report 1 and Presentation	20-Mar	20-Mar	100%	Presentation to the class	Progress Report 1 presentation and paper.	
Building and Creating of Final Design	27-Mar	7-Apr	100%	The final design will be created and assembled and any issues that arise will be handled as we go. This is a very long process and will take multiple weeks.	Day to day log in log book of how assembly is going and any issues that arose to bring to Dr. Taylor for help.	Team
Assembly of Jammer	27-Mar	7-Apr	100%	We will officially put everything together and ensure everything works accordingly and together.	Attempted to completed the system.	Team
Testing of Jammer	7-Apr	7-Apr	100%	We went and tested the current design to ensure it works and realized our radios did not work well enough.	Tested with Dane at the USRI to realize radios weren't good enough.	Price/Christy
Reordering New Parts	10-Apr	14-Apr	100%	We will order new transmitters and test again.	Dane will have ordered our new parts for testing the follow week.	Team
Finalize Progress Report 2	10-Apr	14-Apr	100%	Practice for presentation and prepared the report to be turned into Dr. Taylor	Written progress report and presentation	Team
Progress Report 2	17-Apr	17-Apr	100%	Presentation to the class	Progress Report 2	
Assembly of new Design	17-Apr	21-Apr	100%	We will have our new parts in and will test them at the USRI with Dane before the competition.	New design will be completed and built for testing.	Team
Testing of Design	17-Apr	21-Apr	100%	Testing of design will be done in the Colvin or Training Facility to ensure everything works, if there are any issues that arrise we will deal accordingly.	Multiple trials with our system to analyze what is wrong and how to fix it.	Team
Complete Final presentation	24-Apr	5-May	100%	Practiced for the final presentation in front of peers multiple times to ensure we were prepared and tried to prepare for possible questions.		Team
Final Oral Presentation	1-May	1-May	100%	Final presentation	Written Formal report and presentation	
Competition	2-May	2-May	100%	Hack-A-Thon Competition against other teams	Will take place on May 2nd	Team
Finish Final Report	3-May	10-May	100%	Final report will be written and turned in.	Due May 10th	Team
Report Due	10-May	10-May	100%	Report and log books will be turned in to Dr. Taylor.	Log books and Final senior design report will be turned in.	

Work Plan


"Hack-A-Thon" Senior Design Project
Team Leader: Bryan Bush
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
Week 12
Week 13
Week 14
Week 15
Week 16
Week 17
First day of Class to Select Project.
First Meeting with Dr. Taylor
Team Meeting
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Jammer design selection
Jammer design finalized
Fourth Meeting with Dr. Jacob/ Dane
Fourth Meeting with Dr. Taylor
Parts Selected
Parts dimensionalized and ordered
Fifth Meeting with Dr. Jacob/ Dane
Fifth Meeting with Dr. Taylor
Drone for EMP selected
EMP drone system designed
Sixth Meeting with Dr. Jacob
Sixth Meeting with Dr. Taylor
Revision of Selected Design
Seventh Meeting with Dr. Jacob/Dane
Parts Ordered
Finalize Progress Report 1.
Progress Report 1 and Presentation
Building and Creating of Final Design
Assembly of Drones and Jammer
Testing of Jammer
Reordering New Parts
Finalize Progress Report 2
Progress Report 2
Assembly of New Design
Testing of Design
Complete Final presentation
Final Oral Presentation
Competition
Finish Report
Report Due
SPRING BREAK