THE SKYWALKER

Precision Pesticide Application

FY15 RWDC National Aviation Challenge

Submitted by

AERONAUTICAL DOLPHINS

Name	Age	Grade	E-mail	Phone Numbers (670)
Norcio, Ann	16	10	annmargaret.dn@gmail.com	234-1937
Nisola, Edna	17	11	nisolaedna@yahoo.com	785-8557
Alam, Masrur	17	11	masruralam@live.com	783-2345
Kim, Jun Young	18	11	junkim319@gmail.com	989-3535
Cao, Matthew	17	11	caomatthew0@gmail.com	989-0009
Malate, Robert	15	10	robert.jomarm@yahoo.com	783-7932

OBJECTIVE FUNCTION: 0.7048

Marianas High School
CNMI Public School System
PO Box 501370
Saipan, MP 96950
(670) 664-3800

October 2, 2015

Advisor: John Raulerson
Team Leader: Ann Margaret Norcio
Marianas High School Mathematics Department and Aviation Department Chair
237-3258 / 235-2568
raulerson28@hotmail.com

Table of Contents

List of Figures

List of Tables

ABSTRACT

Introduction: The importance of agriculture being a primary source of food production has always been at an all-time high around the world. In the near future, there will be a necessity to sustain the availability of crop produce due to the increasing population. However, the negative economic impacts of invasive and indigenous species are evident to cause yield losses, furthermore, the practical method of pesticide application risks environmental hazards. This dilemma sets a drawback from the amount of crops obtained and requiring costly expenditures to control the issue. This is no less true in the Northern Marianas Islands, where sweet potato crops are grown in an abundant quantity, however, the island's Division of Agriculture estimates that 33% of those crops are either dominated by pest infestations or wilted by excess pesticide. The commercial uses of unmanned aircraft systems (UAS) authorized by the Federal Aviation Administration (FAA) can help assess this problem as they gradually become more involved in private and public sectors. In purpose of creating a reliable solution, the team has designed an unmanned aircraft system in regards to the issued mission scenario. Our design solution comprises of reducing the SOLVITAL application volume, improvement in aircraft productivity, reducing the application cost, and maximizing business profitability as opposed to conventional operations in order to achieve the mission objective. **Conceptual Design:** In the efforts of maintaining pest management and reducing the adverse effects of pesticide application, the Aeronautical Dolphins have developed an unmanned aircraft system prototype solution. During the conceptual design phase, members of the team initiated to review the mission and define constraints that we were to adjust to. Once we were familiar with the challenge, we then identified several design candidates through concurrent engineering. It was necessary to consider all options available throughout the first design phase. Our selection of components was viewed from the provided catalog and outside resources. Cost played an important factor to our marketing analysis as feasibility coincided. In addition, we identified baseline requirements that were essentially important according to the selection of candidate systems. **Preliminary Design:** In our preliminary design phase, we began to form a general basis of our prototype. We down selected options based on cost, time, reliability, and efficiency in regards to a preliminary performance analysis. This included specifying our air vehicle element, power plant system, airfoil selection, aerial equipment, and aircraft combination design. We considered a specified range of aircrafts and conducted research on existing crop dusters. Approaching a design that would ensure precision agriculture application, while complying with the FAA Regulations, narrowed the team's approach towards our UAS combination. We designed search patterns and structures for the following: five small sprayer aircrafts, two large sprayer combinations, and one large sprayer aircraft. Heavily considering factors such as application time, cost, and area of coverage of the specified mission established the team's selection of using two large sprayer UAS. Furthermore, we decided to modify an existing and aerodynamic light sports aircraft as the base of our sprayer. The Aeroprakt A-22L Foxbat served as our best candidate as it has a high payload capacity and a component selection that fit the team's prerequisites. **Detailed Design:** The team considered different types of wing designs and airfoils that would accommodate the ratio, taper, wing sweep, angle of attack, twist, and angle of incidence aspects of the plane. An aluminum airfoil and gasoline engine was selected in regards to our payload capacity and flight time. The final approach to our design phase carried on with a 31.4-feet wingspan modified light sports aircraft. We achieved a total objective function of 0.7048 while cruising at 100 mph with a turning speed of 55 mph flying while executing finesse over infected areas. Instead of a pilot area, the cockpit load will contain SOLVITAL tanks and major components of the metal air-framed high wing strut-braced monoplane.

1. Team Engagement

1.1 Team Formation and Project Operation

The Aeronautical Dolphins is comprised of six STEM-impacted members who carry skills needed to specialize in different aspects of the challenge. To promote the importance of science, technology, engineering, and mathematics, an Aviation Club was established that would accentuate these areas of the challenge. Members of the club were educated and well aware of the challenge in anticipation that they may take on positions of future teams. Upon advertisement of the club and formation of the team, many potential students were attracted. However, only a few dedicated students were prompted to stay. The finalization of the team required that each member specialize in a profound role most acquainted by their interest.

These prospective roles included as follows:

Table 1. **THE TEAM**

Name	Title	Responsibility
Ann Margaret Norcio	Project Manager/ Communicator	Organize team schedules, distribute jobs, communicate with mentors, and piece together the design notebook.
Robert Malate	Design Engineer	Document all designs considered, research materials and innovative concepts, and configure as well as organize aircraft details.
Masrur Alam	Mathematician	Solve mathematical problems, verify and support excel worksheet calculations, and provide measurements for aircraft and search area.
Jun Young Kim	Simulation Engineer	Work with 3D models to create the aircraft and conduct analysis on MathCAD.
Edna Nisola	Marketing Specialist	Identify targeted commercial applications, calculate costs, assess the competitiveness of the system, and conduct cost/benefits analysis and justification.
Matthew Cao	Mission Planner	Creates possible mission plans with effective outcomes as well as specializing in the chosen search pattern.

Relaying effective collaboration and communication among the members was especially important for the team's success. As each team member was distributed certain tasks to complete, it was clear that cooperation was essential for the skillsets that the challenge demanded.

Additionally, our coach, Mr. Raulerson is currently teaching a STEM class, welcoming and engaging students with the advancements of today's high-tech savvy world. With the resources and knowledge provided through the STEM class, students are able to develop an interest within these career fields and possibly become a team member of the Aeronautical Dolphins.

Challenges

On the evening of August 2, 2015, our island, Saipan, was struck and devastated by the strongest typhoon the year has ever encountered, namely Typhoon Soudelor. A few of our team members were on island and experienced the havoc and outright devastation Soudelor brought with it. Hundreds of homes, cars, belongings, businesses, and even electric poles were totally destroyed. Because of the damaged electric poles, our entire island was without electricity and portable water for several weeks. However, we must give thanks to the people of Saipan as well as the countless number of other agencies that came here to help rebuild our devastated community. President Obama declared our island as a “State of Disaster”. Unfortunately, even with the president’s declaration, our school and most of our team members still are without basic electricity and portable water. This whole catastrophe has of course, affected our work flow significantly; furthermore, due to the fact that our school has no access to electricity, we were unable to complete any work at all on our high school campus. Thus, we found other ways to access power and the Internet; consequently, we were forced to work in various cafes during after school hours. Though it requires sacrifice from all of our team members, we firmly believe in the saying that if there is a will, there is a way. It seems so that the restoration of power in our school will still take a bit more time, but we refuse to wait, therefore we got together as a group and found ways to do our work and stay positive as well. As it was mentioned in the movie “The Great Debaters,” we also believe that we have to do what we got to do in order to do what we want to do.

The team worked on the challenge every day after school, but as soon as the submission date drew in closer, we prioritized meetings to extend into the weekends as well. It was important that each member recognize the roles of everyone as the challenge required the fundamentals of teamwork. Research and information was conveyed amongst the team which allowed us to evolve our design approach from time to time. Progressively, as the team adapted to the issued scenario, we were able to grasp on a better understanding of the complexity of the challenge. As according to the mission scenario, we were able to depend on resources found here on the island. This was an advantageous feat for the team as informational access came by relatively easy, however it was also essential to attain research from outside sources which spanned from the team’s mentors as well as companies online.

Time management was an important factor that affected the team’s design process. The team ensured that organization was a primacy, therefore, we also worked contingent to the national challenge dates.

Table 2. National Challenge Dates	
National Challenge Issued	April 23, 2015
Solution/Notebook Submission Deadline	October 2, 2015
State Challenge Digital Submissions Scored by Judges	October 26, 2015
Eagle Vision Training	November 2-13, 2015
National Challenge Results	November 15, 2015

As a novice to the challenge, Masrur Alam took on the position of being the team’s mathematician. His ability to accustom to the rigorous mission scenario proved that he would be a reliable member to the team. He was responsible for ensuring precise measurements and calculations who also worked hand-in-hand with the mission planner. Masrur has taken an AP Statistics class and is currently taking AP Calculus. He excels in math court competitions and tutors math at a local school. The evidence of his mastery in arithmetic helped solve all the mathematical problems that the team faced.

Entering his second year of RWDC, Jun Young maintained his position as the team's simulations engineer. As he was formerly introduced to the software from the last challenge, it was easily comprehensible for him to work with. He worked jointly with the engineers of the team as we innovated our design gradually. As simulations engineer, he worked on the creation of the system's 3D CAD models and performed analyses on MathCAD. Along with the Project Manager, Jun Young maintains the team's Winchill project updates. His title includes part researcher, designer, tester, analyst, and troubleshooter.

Edna Grace, being her first year in joining RWDC, represented as the team's marketing specialist. She has shown competent skills in being able to analyze and justify the selections that the team considered. As she conducted research on the competitiveness of the system, she was able to propose effective strategies in efforts of increasing customer satisfaction and attraction. The team revolved around a centralized plan, and as the marketing lead, she coordinated the basic business principles. With the elite skills that she possessed, we were ensured that our prototype was commercially acceptable.

The team's mission planner, Matthew, was responsible for the documentation of mission plans. He had the agility in conducting research when given the task, consequently being able to assimilate the challenge as he entered his first year. As he was mindful to comply with the limitations and constraints that the challenge posed, he worked around them to conduct appropriate aircraft dispatching and created practicable search patterns. His ability to work at a fast yet accurate pace according to the responsibilities given was an essential characteristic that helped strengthen the team.

Robert Malate, the team's design engineer, expressed exceptional qualities in assessing the aerodynamic components the team considered for the aircraft design. His ability to reason using detailed analysis and research proved essential to the overall strength of the team. Robert was mindful of the limitations and capabilities of each design candidate made by the team, which he has exemplified throughout each design phase.

As the team's project manager, Ann Margaret Norcio expressed excellent leadership characteristics that kept the team's workflow organized and on schedule. She was able to organize team schedules that, under circumstances, took place in and outside of the school environment. Her ability to effectively communicate with the team's mentors was a viable aspect in gaining information throughout the challenge.

1.2 Acquiring and Engaging Mentors

Consulting with mentors was a requirement the team sought to obtain. We needed mentorship from experts in areas we needed assistance on, such as the engineering and mechanical aspects in creating our project. The team selected mentors with the right competencies that responded within a reasonable amount of time, willing to negotiate ideas with feedback.

Moreover, the Mentor List in the RWDC webpage was not issued for a prolonged period, lacking the team to push forward. However, with the mentors from the past being proven to fit the team's criteria, we renewed mentorship from those available and necessary to our design approach. The team also recognized that the RWDC Social Community site was a valuable tool in submitting technical support questions. However, a response would often be protracted by time, disallowing the team to articulate new notions and supportive ideas.

With the help of webinars from the past, we also waited and were constantly on check for the publishing of webinar dates. Consequently, these dates were never published. Despite the adverse circumstances the team faced, we took the initiative to work around these problems to convey an operative mission with the help of the mentors.

The mentors that we reestablished communication with were some of those who from the past have worked with the Aeronautical Dolphins for consecutive years. This included Manoj Rahematpura from Pratt and Whitney. Mr. Rahematpura who specializes in aero-structures has deemed to be a reliable mentor over the previous years, advising the team to the best of his knowledge while providing logical suggestions. The team was able to retain Emory Frink, a retired pilot, as another one of our trusted mentors.

Douglass Brennan, general manager of Atkins Kroll Toyota based in Saipan, was a new mentor that helped us with our engineering ideas. Moreover, the team was able to schedule an educational tour last year in Guam's Andersen Air Force Base where we met Captain Christina Hart Mastracchio. She was a former mentor, and because she posed such expertise prior to aerodynamics, there was no doubt that the team had to request for her guidance and support once again.

We established a working engagement with our mentors through email. We initially introduced a brief summary of the challenge and then provided them with our goals and objectives in order to give us the most effective insight of our design. Needless to say, although they had busy schedules, it was in the team's courteous desire to respect their obligations. However, they did provide us with beneficial information from time to time that aided in the progress and development of our project.

Table 3. Mentors

Name	Company	Specialty	E-mail
Manoj Rahematpura	Pratt & Whitney	Aero-structures	Manoj.rahematpura@pw.utc.com
Cpt. Christina Hart Mastracchio	Andersen Airforce Base	Aerodynamics	cm.cchio@gmail.com
Douglass Brennan	Atkins Kroll Toyota	Mechanical Engineering	Doug.brennan@aksaipan.com
Emory Frink	Self-Employed	Professional Pilot	Em.frink@gmail.com

1.3 State the Project Goal

The Project goal is to design an unmanned aircraft system that may have the following: fixed wing, rotorcraft, or hybrid design. The overall mission scenario states that, although the use of pesticide has contributed greatly in the increase of agricultural production, it also presented issues concerning loss of wildlife, the deterioration of water quality, and ultimately, human illness. Thus, this is also affecting tropical vegetation throughout the entire Northern Marianas Islands Chain. Because of the tropical weather conditions that we have, crops such as sweet potatoes are capable of being grown year round.

Furthermore, for this challenge, the sweet potato crop that is indigenous to the island of Saipan has been the team's identified targeted crop. Sweet potatoes are a universal crop that is widely used for both human and animal consumption. The sweet potato plant is generally known as a low growing crop that requires care when pesticides are applied, due to the fact that it takes three months to harvest. Therefore, it is very critical that the crop is treated with the right amount of pesticide. In our given mission scenario, the fictional pesticide SOLVITAL, will be applied on our targeted crop. With crop detection already completed at a previous time, the given infestation levels of high, medium, and low, have been systematically, pre-programmed into the aircraft's auto-pilot. Thereby, the team approached the use of an unmanned aircraft system to spray the field while considering the following: acres per minute (APM), application cost, application volume, and business profitability. This all fell under the business plan that will then be developed for the team's commercial operations of the system. Although the conventional APM for the challenge is 18.1823, this assumes that an aircraft or aircrafts will be cruising while spraying indiscriminately above the entire two by one-mile field. To ensure precision agriculture and careful application, the team would achieve our goal by spraying *only* the infected areas. The team developed a search pattern while identifying the optimal altitude for collections based on the sensor and platform performance. Although detection has been conducted beforehand, our selection of a sensor payload allows the operational system to conduct additional scientific research on the crop area. Thus, we acknowledged the following goals for the overall design that included: accurate distributions of SOLVITAL, a plan to remain within a prescribed operational and development budget and a business case that will outline and justify the selections made.

$$Maximize\left\{mean\left\{\begin{matrix}\left(\frac{AV_{conv}-AV_{RWDC}}{AV_{conv}}\right),\\ \left(1-\left(\frac{APM_{conv}-APM_{RWDC}}{APM_{conv}}\right)\right),\\ \left(\frac{AC_{conv}-AC_{RWDC}}{AC_{conv}}\right),\\ \left(\frac{TR_{Year5}-OE_{Year5}}{TR_{Year5}}\right)\end{matrix}\right\}\right\}$$

Finally, we were given an objective function for the FY15 national challenge. It constituted four core elements listed as followed: application volume, acres per minute, application cost, and business profitability. The team had to make reductions in application cost and volume compared to conventional, manned application. We had to show improvement of the APM compared to the conventional method. However, during a recent webinar, professionals have mentioned that the aircraft did not have to exceed the conventional acres per minute. This is due to the fact that our UAS is conducting precision application, instead of spraying over the entire field indiscriminately. Additionally, we have to show that we are able to make a profit from our UAV system.

The objective function represents an enormous part of our efforts toward completing the challenge as it is derived from our unique ideas and designs. We noted that if the number outcome is too low, it would indicate that either the crop yield does not prove substantial or the life cycle cost is too high. Furthermore, our design variables created a strong relationship with the project goal as we worked to produce an optimal design in respect to cost. Furthermore, we wanted to minimize the cost of our air vehicle system and ground support station. Application volume (AV) and Aircraft productivity or acres per minute (APM) plays a big role in achieving our objective function as it constitutes the improvement compared to the conventional application.

$$((AV_{Conv} - AV_{RWDC})/ AV_{Conv})$$

The equation above demonstrates the reduction from the total amount of pesticide/water mixture sprayed in a conventional application using the RWDC solution. Because our UAV will be spraying at specific areas where there is infestation rather than spraying the whole field, there will be a great decline in application volume. We can reduce the amount of pesticide/water mixture that needs to be sprayed instead of spraying over unnecessary locations.

$$1 - ((APM_{Conv} - APM_{RWDC})/ APM_{Conv})$$

This demonstrates the improvement of aircraft productivity from conventional application using the RWDC solution. The aircraft productivity is measured by the number of acres an aircraft can apply pesticide to in one minute. The APM depends on the swath width and speed of an aircraft. If the aircraft takes longer to finish the overall application, this will be more costly.

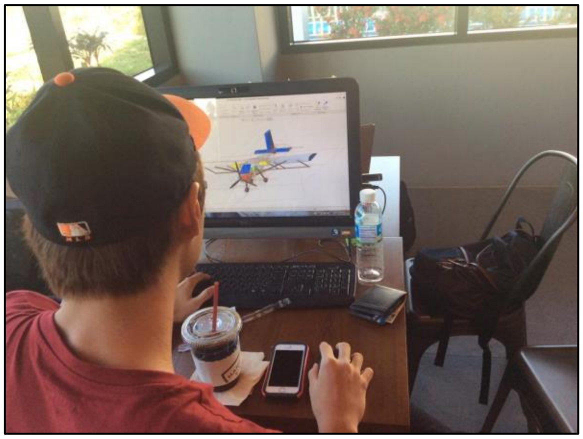
$$((AC_{Conv} - AC_{RWDC})/ AC_{Conv})$$

Shown above is the reduction of application cost from conventional application using the provided RWDC solution. The application cost depicts the cost to treat a subject area. It is important to reduce the costs in order to make more profits.

$$((TR_{Year\ 5} - OE_{Year\ 5})/ TR_{Year\ 5})$$

This demonstrates the profitability achieved using the RWDC solution. It is the profit our business would receive at the end of a five-year period. It is important to demonstrate profitability in order to show that our business operations are feasible and that we can invest more in the future.

1.4 Tool Set-up/Learning/Validation



The installation of Creo 2.0 and MathCAD 2.0 were relatively straightforward. There were obstacles that we faced, but tutorial videos and insight from the team's experienced simulation engineer helped us overcome such difficulties. Working with MathCAD was relatively easy, and it proved an extreme help when the team utilized the software in regards to our objective function, mission time calculations, and aircraft anaylysis. On the other hand, Creo Parametric was the main program that we had to adapt to. This program deemed more than just a sketchpad as it allowed us to visualize our models step by step. We started out by following tutorials, modeling easy concepts such as cubes and spheres. Our team's simulation engineer played a big role in educating those who were new to the software from the basis to view of our final model. When we started to integrate our plans into the model, we started with the very basic parts, fuselage and wing. We shared our ideas of various types of wings that could work well and also "look" well. Adding the spray boom to the aircraft proved challenging when dealing with placements, but this proved successful with several trial and errors. Lots of designs were discussed and created. As we pushed forward with our design phases, we decided to modify a light sports aircraft in which we integrated changes towards the inside of the plane. We tried to share these ideas by visualizing them with Creo Paremetric. Next, we started to design the major components, including stabilizers, nozzles, and more. To perform a more precise and professional design, we asked help from PTC forum and as well as the design community. We learned how to design more complicated models until we were comfortable designing basically anything. Finally, we brought all our model components to build our own airplane. We considered aerodynamic measurements such as center of gravity and carefully placed each component in its most ideal place where its performance could be maximized. Calculations within our center of gravity (CG) were an important factor within measurements. The integration of Windchill in our design process helped significantly in documenting our work and sharing them with our mentors. Additionally, we implemented the Javafoil software, which allowed us to perform wing analyses.

1.5 Impact on STEM

ANN MARGARET: "Marianas High School was not always known for our integration in STEM. Before we were introduced to RWDC, the farthest we would go is join the STEM fair. Since the introduction to the Real World Design Challenge, opportunities and interest in the field of Science, Technology, Engineering and Math have greatly diversified. The impossible dream of pursuing a career in aviation was now possible in the island of Saipan. This is my first year to take on the challenge, and although there is a handful of knowledge and information being presented, I am constantly left with the urge to learn more. Every bit of information I take in brings the team and I a step closer to completing the challenge. The idea of completing the challenge was one thing, but embracing the opportunity to be able to solve real world problems for the betterment of the future is what fuels my passion for aviation. The idea of designing an aircraft seemed simple at first, but the innovative process and its details required endless work and left us with endless possibilities. It made me realize that even Saipan's limited resources and simple approach on life can lead to innovative success. I soon realized that the greater challenge lay within the members and our ability to work as a team. Major sacrifices are made by both coach and students. Every day of the week, the classroom is inhabited by members and our coach working to ensure that our mission is successful. It opened my eyes to see the major sacrifices people in the STEM industry have made. I want to become a scientist, an engineer, and like those who have sacrificed their lives to make ours better, I am determined to make a change in which no lives will be the cost. My life was full of taking challenges, but I've never encountered one that matched this. The impact of STEM is changing my life, and it's continuing to change the world around us."
JUN YOUNG: "This year is my second year joining the Real World Design Challenge. Every year when the challenge is released, my team and I gather around in excitement to face the rigorous challenge. STEM played and still plays a huge role in our challenge. In a real design challenge like this one, real methods and real skills are required to guide our way through. With each part of the STEM implemented, we see ourselves not just solving a mere math problem but a complex and real life challenge. Our STEM class taught by our coach is getting more and more people interested each year. I encounter students of diverse grade levels who would love to join in, constantly reminding me the important impact STEM has on future engineers. STEM also affected my career path to become a Computer Programmer. As I work with models in Creo and MathCAD, I'm excited to see our thoughts evolving into a solution to a problem. STEM will always impact our daily lives in many ways and it will continue to do so."
MATTHEW: "This is my first year joining the Real world design challenge and yet I have learned so much. The many days I've spent throughout working on the challenge with my team members increased my knowledge regarding aeronautical aspects. I've learned that Real World Design is not just a yearly challenge, but an

opportunity to gain something better for ourselves. It is no doubt a helpful system to prime skills on interacting with different people, as well as developing the skill of teamwork. Real World Design plays a huge role on people who are interested in aeronautics with the sole fact that one can benefit so much from this program. Furthermore, I have gained interest in aeronautical engineering and hope that this would open doors of opportunity for me in the future."

MASRUR: "I decided to participate in the Real World Design Challenge after watching my brother join the team last year. He would always talk about what he learned and the adversity he faced during the challenge. I thought he was just exaggerating over designing an airplane, but after participating in this year's challenge, I realized that there was more to just merely designing an airplane. We had to start from scratch, consider all options, and be mindful of the costs not only for our project, but also the impacts to the environment. This challenge changed my perspective of STEM because it made me realize the importance of this field in solving contemporary real-world issues that we face. I realized that the field of STEM will lead to a better future for this world. This challenge has influenced my choice to become a chemical engineer in the future. RWDC has also influenced my school to introduce a STEM class last year. In our island, there are only a scarce amount of STEM programs, so this STEM class will be beneficial for all students. This year, our school also introduced its first aviation class. STEM will not only bring out the best for us, but also for our peers."

EDNA: "Many people do not realize that STEM has a huge role in every person's daily life, and I cannot say that I myself have not taken it for granted. I decided to join the Aviation program in my school quite reluctantly at first, not realizing that I would be interested in knowing more about the field of aviation. As the course started, we were asked by our instructor to write a short paper on why we decided to take the class. That put me in a very reflective state, and I asked myself, why am I here? I wasn't quite sure, but I know that I would keep a very open mind and take in all the lessons seriously. I said that STEM has never been considered as being part of my strengths, and of course, no one enjoys dwelling in their weaknesses. Little did I know that this Aviation Class would lead me to a defining opportunity in my life? I was requested by Mr. Raulerson, the RWDC coach, to join their team. Again, I was reluctant, but he said that he believed that I was capable of handling the challenge. Sometimes, we just need someone to believe in us, and I am quite grateful for that. Therefore, I decided to join the team and provide all the help that I could give, and though I have only been a part of it recently, I can say that it has been one of the best decisions I've made in my high school career. RWDC is greatly increasing my knowledge and interest in STEM, and I am enjoying the process. It gave me an awareness of my environment; which enabled me to appreciate STEM even more. Furthermore, it gave me an opportunity to experience the field of business, as I am contemplating of pursuing a career in marketing. It isn't easy, as there are many components that are crucial that has to be done correctly, but it is nice to know that our work and ideas have a purpose and can be easily translated into the real world."

ROBERT: "The world is in need of people in the STEM field. However, at our school, STEM is not highly advertised. Only few people eventually decide to take on the challenge to create or improve upon a product and system. This year, during my sophomore year, my interest in engineering sparked. I started to have a hunger for knowledge; a desire that wants to know the world's problems. Every day, I would watch videos and read research papers on current technology, and improvements being made. I would think about possible inventions or improvements on technology that could be made. To aid in my efforts, I decided to take our STEM class offered. Mainly, it focuses on the field of aviation. It greatly expanded my knowledge on aeronautics; the language, the math, the history. I learned about challenges with aviation and what people did to overcome it. I wanted to be a part of those people who decided to take the challenge. Later on, I learned about the Real World Design Challenge. I heard about the project problem, and that ideas made can be put forth to create a potential solution. I decided to take up the challenge to create a solution. Becoming a part of this challenge has expanded both my knowledge and interest in the field of STEM. It's great to know that a program like the Real World Design Challenge allows your ideas to become part of the solution to the world's problem."

There are a growing number of students in Marianas High School who signs up for Aviation class, an elective that students are willing to take as an extra period during the morning. The RWDC team members also run an Aviation Club at our school, sharing and training students to their greatest potential in the field of STEM.

2. Document the System Design

2.1 Conceptual, Preliminary, and Detailed Design

2.1.1 Engineering Design Process

Specific Work Method: Concurrent Engineering

As the team propelled forward with the challenge, we recognized the need to incorporate a design strategy in order to hasten the pace of our engineering development. We assimilated a system of practice that enabled us to advance efficiently, proficiently, and sufficiently in a simultaneous flow, a method widely known as **concurrent engineering.** Of the aspects in working in concurrency, we operated in parallel to each member's job functions. Most aircraft manufacturing industries integrate this strategy into its system reasonably for processing shortens design cycles and the need to reduce schedule risks. It also enables engineers to work on the same database at the same time, allowing effective cooperation and teamwork in order to identify constraints and the need for improvements.

Our Product Lifecycle Management (PLM) in regards to concurrent engineering overviewed the aspects of our initial concept to finalized design. The team was also organized in dissemination according to each member's role responsible for managing certain tasks, defining our Operation Process Management (OPM). This was essentially important as this factor of design would follow-up to quality assurance, pertinent to a leading marketing strategy, process of production would deem commercially acceptable.

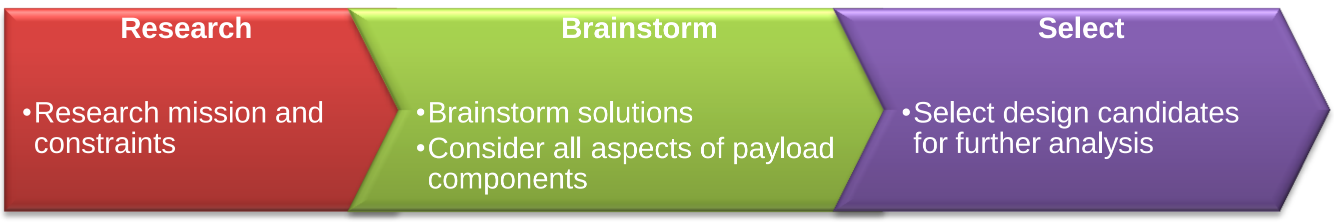
The Design Process

In the **Conceptual Design**, the problem is addressed and limitations provided in the challenge are acknowledged. Furthermore, assessment of the objective function is highly considered as our system must provide exceptional and surpassing values that of expressed in conventional purposes. Regulating to these details, the design engineer takes on the lead among the rest of the engineers of the team to select a broad range of components, equipment, and systems to form a basic outline of the UAS. During this phase, research is highly complementary as understanding the specifications that each item poses in the intentions of determining the pros and cons that claims significance to the project. The marketing analyst also works in proximity to gather in consumer based demands in the aviation industry towards suggesting resourceful ideas.

In the **Preliminary Design,** as these options are passed on to the system's and test engineer for validation of feasible function, they are coincidentally dispensed to the simulations engineer so they may initiate a general visual of the aircraft archetype. This is where the parallelism of concurrent engineering will take place, where if the preliminary performance analysis declares that an element is insufficient, modification of the design would update. The range of options are narrowed down and furthered analyzed in a selection of beneficial output. The items are specified through the requirements of the challenge, which are then rendered to the baseline requirements of the team. As opposed to the linear method of engineering, time is reduced and the ability to work collaboratively is present.

Finally approaching the **Detailed Design,** major milestones have been achieved. By the means of entering this phase, inferior ideas are disregarded in which the team's attention is now gripped on the more favorable concepts that will be integrated into the project goal. The last and final step requires confirmation that the system is operative and a business case will calculate cost analysis. It is also in the team's interest to prescribe a plan to raise financial resources for covering these initial costs.

2.1.2 Conceptual Design



After the National Challenge was issued, we looked over the new requirements given. Majority of the requirements and limitations included in the National Challenge were similar to those set in the State Challenge. The only differences were listed as followed: the increase of the field size, weather conditions, the "NO FLY ZONE", and the $100,000 grant.

Once we were familiar with the challenge, the team looked for ways to improve our UAS system design. We examined, researched, and debated on how the UAS system could be improved, from our SOLVITAL capacity to our on-ground operations. To add on, the team even examined how our productivity would increase by adding another aircraft- one with a new type of air vehicle.

We wanted an aircraft that would be aerodynamically capable of flying. This aircraft would also have to be capable of carrying a sufficient amount of payload and SOLVITAL, the given pesticide. This aircraft would have to be efficient as well as cost effective, which would prove greatly beneficial for our team. The conceptual design would list down all our candidates for this solution.

Figure 1: Foxbat A22-LS

The Foxbat A22-LS is a light-sport aircraft that was modified to be part of our UAS system in the State Challenge. It is capable of a high useful (payload) capacity, weighing at about 649 lbs. Furthermore, the aircraft is mainly composed of aluminum, with 6031 aluminum forming the frames and 2024-T3 aluminum for the fuselage and wing skins. Several factions of the aircraft are made of supplementary materials, such as the composites that form the engine cowling and DIATEX fabric that covers the flight controls along with parts of the wing. The aircraft is driven by the Rotax-912 ULS 100 horsepower, which allows the aircraft to reach a maximum speed of 136 mph. Thus, with a cost of only $70,000, the Foxbat proved its value through its design in the State Challenge and is now a major candidate for the FY 15 National Challenge.

Figure 2: Savannah S

While looking for different aircrafts, the team came across the Savannah S, another light-sport aircraft. Upon further examination, the Savannah S' design was a possible candidate for our updated UAS system. Furthermore, like the Foxbat A22-LS, this aircraft runs on the Rotax 912-ULS 100 horsepower engine, enabling it to reach speeds of 115 mph. It also has a useful (payload) capacity of 572 pounds. The entire aircraft is composed of all-metal, making it strong and durable. Costing at about $71,950 with a 110-hour construction time, the Savannah S was listed as a potential aircraft for our UAS.

Figure 3: Rotorcraft CAD Model

The team pondered as to how our aircraft would deal with real-life situations, one of which is the situation of trees surrounding a field area. With this particular obstacle in mind, the team put into consideration the utilization of rotorcraft as part of our UAS. Unlike the fixed-wing designs of the aforementioned aircrafts, a rotorcraft is able to hover and pivot on its vertical axis. Compared to an aircraft banking out to execute a turn, the rotorcraft is able to fly backwards and make turns with ease. Additionally, rotorcrafts have a higher payload to empty weight ratio. In regards to our mission scenario, the role of the rotorcraft would be limited to spraying the perimeter of the field where, in a real-world setting, trees would surround. The team used the existing RMax chopper as a research basis during our conceptual design phase.

Figure 4: M-2 Scout LSA

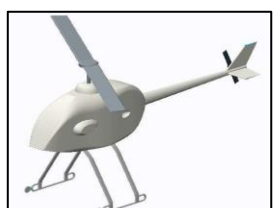
The team longed for an aircraft that was aerodynamically faster than our existing UAV, the Skywalker. By utilizing a faster aircraft, our mission time would significantly reduce, which will in turn increase our profits. We found the M-2 Scout LSA, a low-wing, monoplane aircraft. It has a cruise speed of 136 mph and a high payload capacity of 605 pounds. The fuselage and wing is composed mainly of aluminum. After modifying the aircraft to meet our needs, it seems that the M-2 Scout LSA would prove to be an exceptional aircraft in terms of its speed and payload capacity.

Not only did the team examine at new aircraft that is modifiable, we also looked at aspects that would improve the Skywalker. Composites, specifically carbon fiber-epoxy, were a great choice for our aircraft. It had a higher tensile strength and lower specific density when compared to aluminum. Additionally, it had numerous proven advantages in the aerospace industry. This comes in the likes of the Boeing-787 and Airbus 380, which are composed of half composites, and half other materials such as aluminum and titanium. This steered the team to further research on the use of carbon fiber on our UAV.

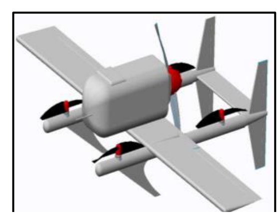
In heeding with the issued scenario, the application pattern for the UAS had to be modified to ensure accurate pesticide application while airborne. Furthermore, the area of interest covering a total amount of one square mile contained different levels of infestation on specific areas, requiring the team to strategize for viable search patterns. In order to control the dispersal of pesticide and secure that the infested areas are accurately sprayed, we designed multiple application patterns. The team assured that we eliminated options that contained too many turns because this would increase flight time. Furthermore, we excluded patterns that overlapped tracks because we were aware that excessive amounts of SOLVITAL pesticide applied to the same location would further damage the health of the crops. These requirements were taken into consideration in which the lawn mower pattern deemed appropriate; however, we would have to configure such a pattern to fit the criteria of each strategy. Starting with one large sprayer, the team formulated several search patterns.

The selection of the proper air vehicle element would be able to determine the operational flight mission. Offered in the catalog were three baseline air vehicle element options: Fixed-wing Tractor Propeller, Rotary-wing/helicopter, and Hybrid (Fixed-wing/Quadrotor). Each option presented differing characteristics and it was up to the team's accountability to examine all trade-offs that outweighed each other as we were to choose a complementing air vehicle element that would best conduct the mission. Specifically, we wanted to form a vehicle that submitted to maneuverability and efficiency both in time and cost.

Option A: Fixed-Wing Design

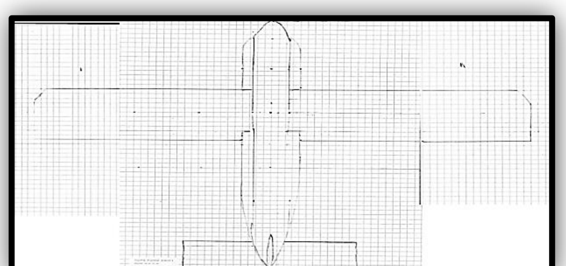


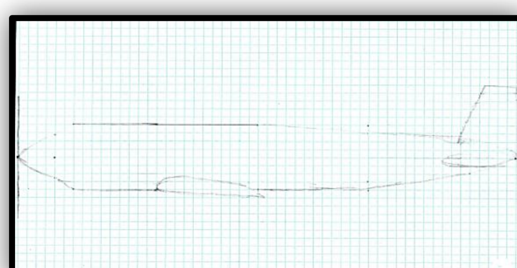
Option B: Rotary Wing Design



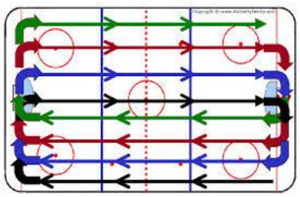
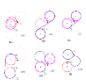
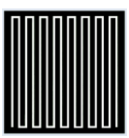
Option C: Hybrid (Fixed-Wing Quadrotor) Design

As time narrowed down, we looked through the options for the air vehicle element. We realized that none of the options provided seemed to meet our requirements as they limited our proposed solution. Therefore, we proceeded to create our own design of our aircraft system based on the existing UAVs we initially researched on in the conceptual design phase.





Possible Application Search Patterns

Spiral Pattern 	The spiral pattern seemed possible for our mission, for it had little turns and the potential to cover all infested locations of the field. However, the aircraft will be required to travel around the whole field from the outer lane towards the inner lane. This would result in the aircraft having to fly over uninfected locations, which deemed useless and a waste of time furthermore this would also require the aircraft to possibly refuel during the mission, hence we have decided not to use this pattern.
Zamboni Pattern 	The Zamboni pattern is a complicated pattern with many repetitions of strides within a circular motion turn. Hence, this pattern did not fit for our mission due to our field only having specific areas that were infested. If we were to use the Zamboni pattern, it would require the aircraft to fly over pointless locations. Furthermore, the overall pattern will leave several parts of the area overlapped, which is inaccurate. This would decrease our time efficiency and productivity towards the mission because the aircraft would be required to make unnecessary turns. This will result in a decrease in the mission rate. The team has decided not to use this pattern.
Dubin's Path 	Dubin's path is a continuous circular motion which proved ineffective towards our requirements. The circular pattern does not have precision and will not cover the field promptly. Therefore, we did not choose to utilize this search pattern.
Lawnmower Pattern 	Depicted on the left is the lawn mower pattern, similar to that of a lawnmower's. This pattern has long lanes with 180° turns. It can have a straight, forward, up and down, or a back and forth motion that is easy to apprehend. The pattern's efficiency depends on the number of turns; the more turns, the more precise. Furthermore, the sweep of the pattern results the number of turns in a same area, the sweep can be erected up and down or side to side.

After several application pattern attempts, the team formulated that the lawnmower pattern serves as the best candidate in regards to the sprayer's flight path. During the conceptual design phase, we placed mandatory requirements for each search pattern to have full coverage of the infected areas. This would allow the aircraft to cover specified ranges in respect to the compatibility of our system. Methods such as the Zamboni, Dubin's path, spiral, and lawnmower path were carefully considered. Consequentially, we avoided options that included too many turns due to our UAV having to slow down, increasing the mission time. The team would have to consider turn radius, angle of bank, elevation, and speed upon implementing these ideas into the scope of our pattern.

The team's mission planner monitored all search pattern possibilities. Utilizing the lawnmower method the most, our team started off by experimenting with several search patterns utilizing the Skywalker. Below are the team's constructed search pattern candidates. As we moved on further with the challenge, we decided to eliminate all single sprayer patterns, as it would consume too much time, turns, and refueling.

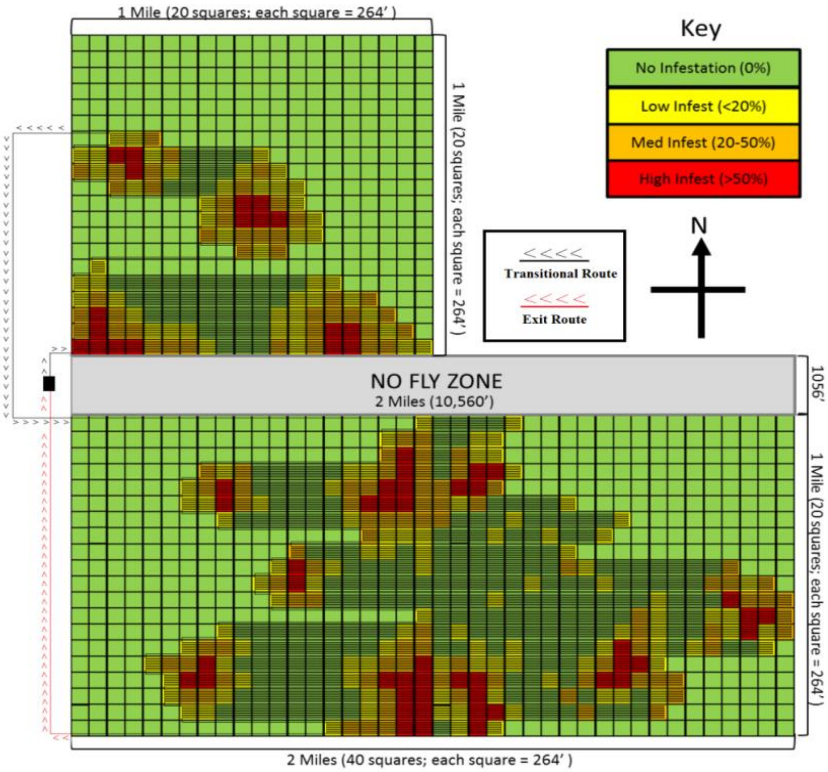


Figure 5. Application Pattern 1: One large UAS spraying over the 1 x 1 field first, then transitions into the 2 x 1 field.

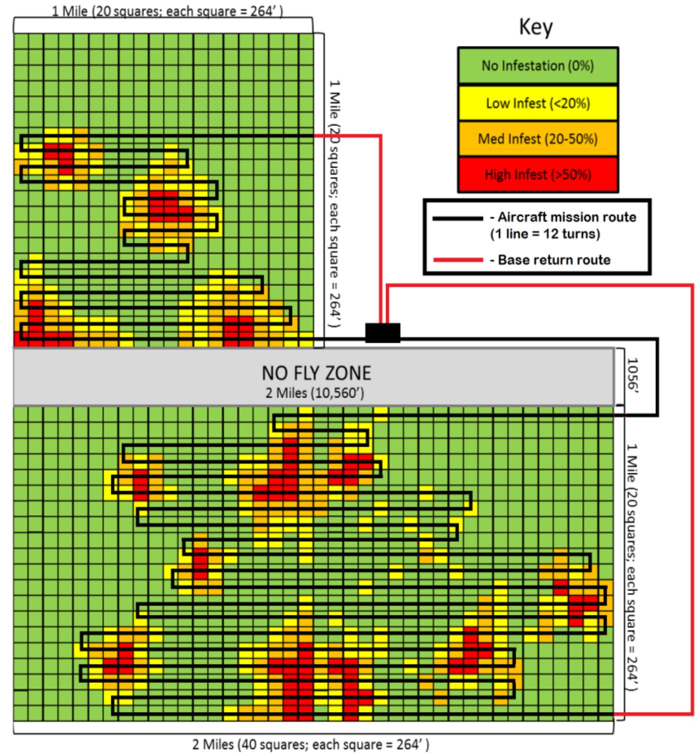


Figure 6. Application Pattern 2: Two large UAS with base located in the center of the mission scenario, directly above the No Fly Zone.

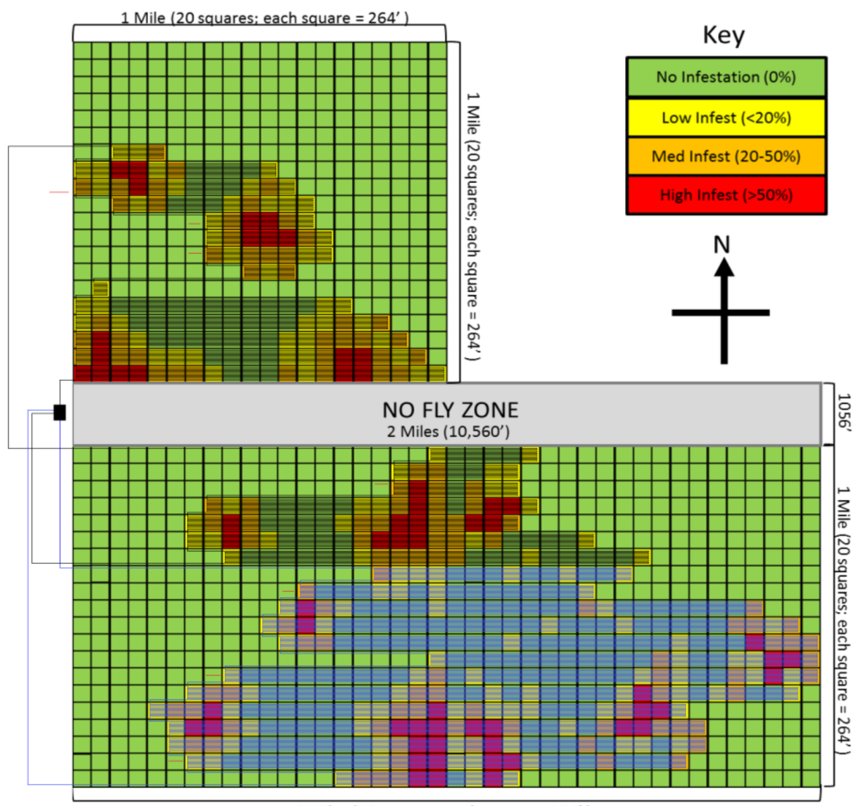


Figure 7. Application Pattern 3: Two large UAS with base located at the left of the No Fly Zone

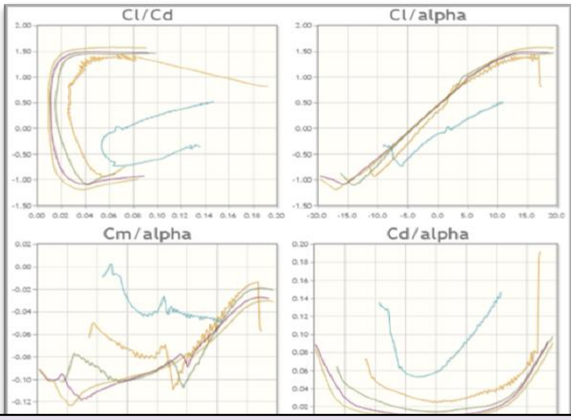
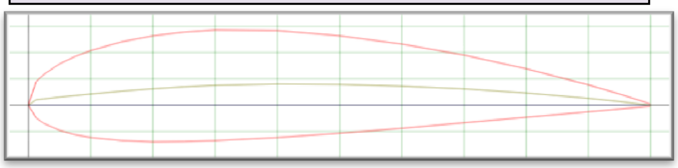


Figure 8. NACA 4421 airfoil results (Javafoil)



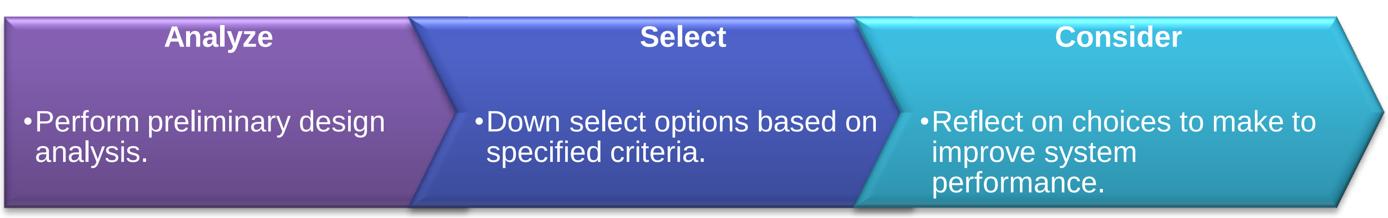
In the efforts of updating our initial state challenge design, the team carefully considered options that would further improve our UAS for the national challenge.

In contribution to the wing characteristics of our UAV, we speculated on selections of our airfoil type. *Bernoulli's principle* applies to how the airfoil works because the increase of a moving fluid works in conjunction that decreases the pressure within the fluid. Furthermore, air is moving at a faster speed on the top of the airfoil as compared to the bottom. This allows it to be lifted by the higher pressure created beneath the wing; thus, creating lift. The candidates for the air foil selection are the NACA 4421 from our state challenge design and the TsAGI P-III.

In regards to the ground system selection, we had to select components that would be necessary for our aircraft. The team decided that our command, control, and communications selection from the state challenge would remain the same as their capabilities and frequencies are suitable for use in the national challenge. Major components (see 2.2.1) such as the engine remain the same, while spraying components have been greatly modified. This goes the same for the next aspect of our design- the support equipment. Due to its large size, there is no need for a catapult to launch the aircraft. Rather, the team decided to utilize the truck we purchased from the state challenge to carry and transport the refueling tank. The team considered on a material selection composed of either aluminum (state challenge selection) or composites.

The nozzle selection is one of the most important factors of our design solution. The team knew the need for nozzles that can produce higher concentrations of droplets. Our new selection consisted of the Guardian Air GA 110-025AZ (state challenge nozzles), and the Guardian Air 110 – 03.

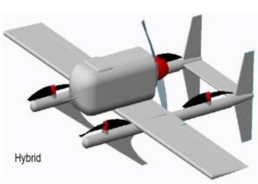
Since the Skywalker will be used for several application purposes other than precision agriculture, the team decided that a sensor payload with more sufficient imaging capabilities was needed. The team considered between the Boscam Cm 210 and the M1-D-19-16.



2.1.3 Preliminary Design

The preliminary design phase was the next step in finalizing our design concept. As the team entered this phase, we recognized the need to narrow down the options based on each candidate's merit. Moreover, we conducted an aircraft combination analysis for each proposed design options as mentioned previously in the conceptual phase to compare and contrast each system's viability.

TABLE 4. Air Vehicle Elements

Option	Airframe	Flight Controls	Propulsion	Metrics
C. Fixed-wing Pusher Propeller 	• Composite airframe • V-tail • High-mounted with w/ ailerons • Tricycle landing gear	• Push-pull connectors • (2) ailerons, (2) mixed-elevator/rudder (v-tail), (1) steerable nose gear • Electronic speed control • BEC	• Electric Brushless Propeller (pusher) • Battery (640 Wh 44.4V, Lithium Polymer)	• $15,000 • Empty weight: 32.85 lbs. • Max payload: 14.55 lbs. • Endurance: 110 mins. • Cruise speed: 42.76 knots (49.21 mph)
B. Rotary-wing Design 	• Plastic and aluminum	• Single main rotor • Tail rotor • (1) engine throttle • (1) rotor pitch • (1) rotor roll • (1) rotor collective • (1) yaw(tail rotor) • (1) Gyroscope mode selection	• 52CC two-stroke, two-cylinder, internal combustion engine • Engine cooling fan • Rotor • Fuel : gasoline mixed with two-cycle engine oil • Fuel tank • Battery(3000 mAh 6.0V)	• $8,000 • Empty Weight: 20 lbs. • Max payload: 25lbs • Endurance: 30 mins. • Cruise speed: 21.6 knots (24.85 mph)
C. Hybrid (Fixed-wing/Quadrotor) 	• Composite materials	• Quadrotor: multirotor flight controller w/ autopilot functionality, ESC • Fixed-wing: (2) ailerons, (1) rudder, (1) elevator, push-pull connectors, (1) ESC	• Fixed-wing: Electric Brushless Motor; Propeller (pusher); Li-Po battery • Secondary (quadrotor): Electric Brushless Motor; (4) propellers (carbon fiber)	• $25,000 • Empty Weight: 25 lbs. • Max payload: 5 lbs. • Endurance (forward flight): 60 mins. • Endurance (hover): 5 mins. • Cruise speed: 35 knots (40.28 mph)

After putting together a list of several aircraft choices, the team compared each of the aircrafts' technical specifications against each other, mainly focusing on the Foxbat A22-LS. This is because the Foxbat A22-LS was utilized during the State Challenge. We wanted to ensure that it would prove proficient enough to meet our requirements in order to fulfill the more complex National challenge. Upon further analysis, the Foxbat A22-LS emerged victorious after the scrutiny of comparison. Compared to the other aircraft, its abilities and design proved the best for our mission requirements. Below are the main technical specs of the aircraft:

Take-off Dstance
- Normal: Maximum 250 metres to height of 50 feet
- Short field: Maximum 100 metres at MTOW to height of 50 feet

Rate of Climb
- 600-1,200 feet per minute on full power at 57kts

Cruise Speeds
- 90kts/5,200 rpm at 14 litres per hour
- 70kts/4,400 rpm at 11 litres per hour
- 60kts/4,000 rpm at 10 litres per hour
- 55kts/3,800 rpm at 8 litres per hour

Rates of Descent
- 400 feet per minute at 52kts and "clean" (flaps up)
- 750 feet per minute at 48kts and "full flap" (20 degrees)

Landing
- Normal: Maximum 350 metres at MTOW from a height of 50 feet
- Short field: Maximum 150 metres at MTOW from a height of 50 feet

- **Short takeoff and landing roll.**
- **Useful load capacity of 649 lbs.**
- **High-wing design**

Compared to the other aircraft in the conceptual design phase, the Foxbat's abilities was the most suitable for our mission.

Table 5. Aircraft Comparison

Savannah S

The Savannah S design was very similar to that of the Foxbat. However, upon further Research and comparison, its abilities were proven to be inferior. Not only does it have a smaller payload capacity, it also flies at a much lower speed. Furthermore, its wingspan was two feet narrower than the Foxbat, which would in turn reduce our spray boom size, thus decreasing our productivity.

M-2 Scout LSA

The M-2 Scout LSA was a highly viable option. It had a high payload capacity and a faster cruise speed than the Foxbat. However, despite its attributes, its low-wing displacement design and high take off/landing roll were its major shortcomings. We even reached out to several mentors to find out which one of the aircrafts would prove more efficient, and the majority responded that the Foxbat was the best choice. This is due to its high-wing displacement design. It was further proven that an aircraft with a low-wing displacement was highly prone to (FOD: Foreign Object Damage) damage which would structurally compromise the wings as well as the spray boom. Additionally, a longer takeoff-and-landing roll is needed, which isn't preferred, because our aircraft will be taking off and landing on short flat fields, not an airport. Safety was another concern, and the M-2's shortcoming was in its stability and stall-speed. Unlike a high-wing displacement, the low-wing design did not provide as much lateral stability. Furthermore, having a low-wing design required a higher stall speed, which is not preferred, because our aircraft will be flying close to the ground.

	Foxbat	Savannah S
Weight		
Empty Weight	638 lbs	660 lbs
Useful Mass	682 lbs	572 lbs
MTOW (Max Takeoff Weight)	1320 lbs	1232 lbs
Plane Specs		
Wingspan/Swath-Width	31.324 ft/ 23.493 ft	29.52 ft/ 22.14 ft
Max Speed	126 mph	115 mph
Cruise Speed	99 mph	105 mph
Stall Speed	36 mph	30 mph
Take-off/Landing roll	328 ft/ 328 ft	114.8 ft/ 164 ft
Costs		
Price	$79,999	$71,950
Build time	500 hrs.	110 hrs.
Taildragger Modification Cost	-Pay for modification	-Can order it

Foxbat A22-L		Savannah S	
PROS	CONS	PROS	CONS
+Greater weight-carrying capacity +Greater swath-width +Greater maximum speed	-More initial costs: *Longer build time *Greater Price *Expensive to turn into a tail dragger -Lower cruise and stall speed	+Cheaper: *Lower price *Less build time *No additional costs to turn into a taildragger -Smaller stall speed -Greater cruise speed	-Less weight-carrying capacity -Smaller swath-width -Flies slower

Table 6. Foxbat & Savannah Comparison

The calculations on the right are the lift and drag calculations of the following airfoils: NACA 4421 and TsAGI P-III 15%. In order to decide which airfoil to utilize, the team compared the lift and drag performances of both subjects. We used JavaFoil to plot the airfoils and calculate their unique and complex aerodynamic performances. After analyzing the data given, we inputted them into the lift and drag equations. The equations were retrieved from the NASA website.

Drag Calculation

NACA 4421

$Cd_{NACA} := 0.01120$
$A := 8.306$
$p := 1.2754$
$V := 44.704$

$$D := Cd_{NACA} \cdot \frac{p \cdot V^2}{2} \cdot A$$

$D = 118.555$
$drag := D \cdot 0.2248$
$drag = 26.651$

TsAGI P-III 15%

$Cd_{TSAGI} := 0.00803$
$A := 8.306$
$p := 1.2754$
$V := 44.704$

$$D := Cd_{TSAGI} \cdot \frac{p \cdot V^2}{2} \cdot A$$

$D = 85$
$drag := D \cdot 0.2248$
$drag = 19.108$

Lift Calculation

NACA 4421

$Cl_{NACA} := 1.247$
$A := 8.306$
$p := 1.2754$
$V := 44.704$

$$L := Cl_{NACA} \cdot \frac{p \cdot V^2}{2} \cdot A$$

$L = 13199.807$
$lift := L \cdot 0.2248$
$lift = 2967.317$

TsAGI P-III 15%

$Cl_{TSAGI} := 0.963$
$A := 8.306$
$p := 1.2754$
$V := 44.704$

$$L := Cl_{TSAGI} \cdot \frac{p \cdot V^2}{2} \cdot A$$

$L = 10193.596$
$lift := L \cdot 0.2248$
$lift = 2291.52$

In order to properly calculate the drag and lift, we needed five factors: the coefficient of lift and drag, the area of the wings (square meters), the atmospheric density at sea level (kilograms per cubic meter), and velocity of the aircraft (meters per second). These coefficients were determined from JavaFoil. The area of the wings was given in the Aeroprakt Manual. The velocity is the cruise speed of our aircraft. The atmospheric density was found by online resources.

The results were as expected after we executed the calculations. Just by looking at the airfoil, we could tell that the drag of the NACA 4421 would be greater, but so is its lift. The drag of the TsAGI P-III 15% would be smaller, but will not have as much lift as the NACA 4421. The TsAGI P-III 15% has 39.47% less drag than the NACA, but has 29.49% less lift. The NACA 4421 has 28.3% more pounds of drag, but has 22.77% greater lift.

Ultimately, the team decided to keep the NACA 4421 as our airfoil. For this particular mission, our UAV will be flying 10 ft. above the ground. The higher lift capabilities an airfoil has, the less chances of our aircraft stalling or losing altitude. An airfoil that gives us high lift capabilities is one we need for our mission.

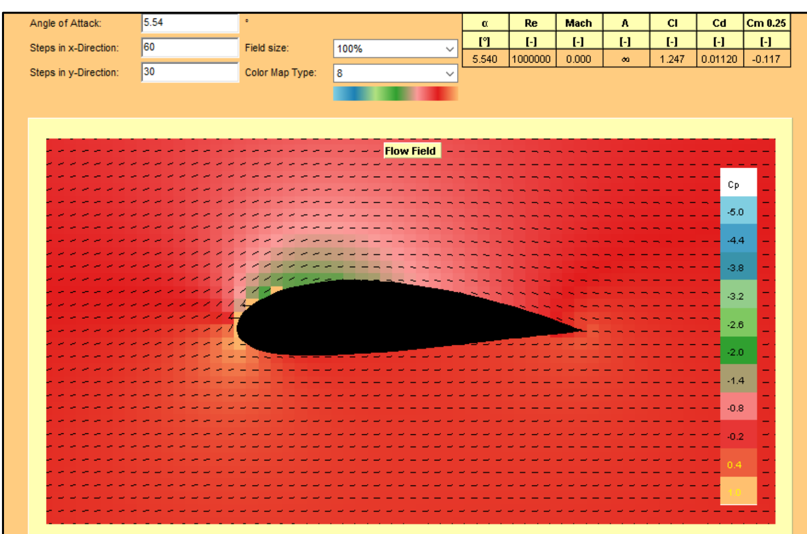


Figure 9. **NACA 4421 (Javafoil)**

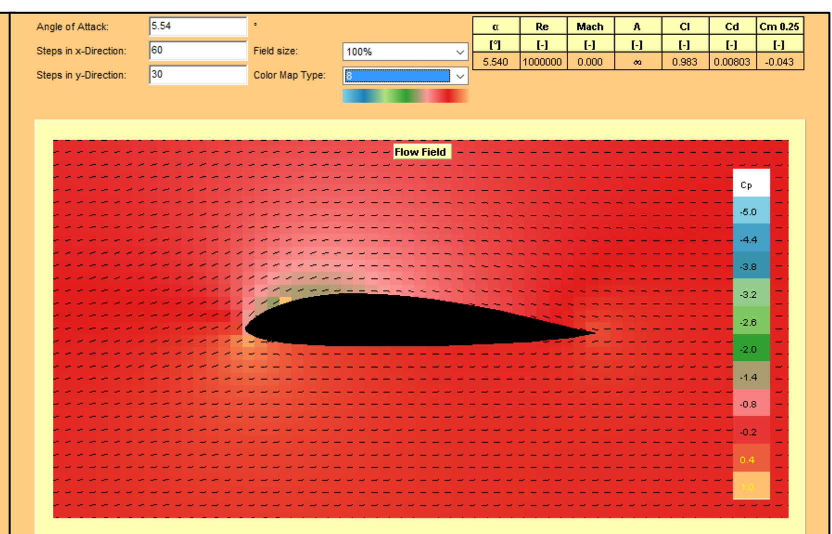
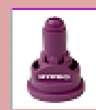


Figure 10. **TsAGI P-III (Javafoil)**

Nozzle Selection:

After carefully analyzing the Guardian Air 110-03 and the Guardian Air GA 110-025AZ, the team has come up with supporting rationale that proves the Guardian Air 110-03 is the best selection for the national challenge mission scenario. While the specifications of both nozzles seem similar, the ability of the GA 110-03 to produce extremely course and ultra-course droplets made it the most suitable in terms of our nozzle selection.

Table 7. **Nozzle Comparison**

Guardian Air 110 – 03 	• 75% spray drift reduction at low pressures • High quality spray distribution (lower spraying pressures) • Material: high resistance plastic • Produces extremely coarse droplets
Guardian Air GA 110-025AZ 	• 75% spray drift reduction at low pressures • Available in seven sizes • Spray: inclined 10-13 degrees backwards for more coverage • Capable of wide range of applications • Material: plastic

Sensor Payload

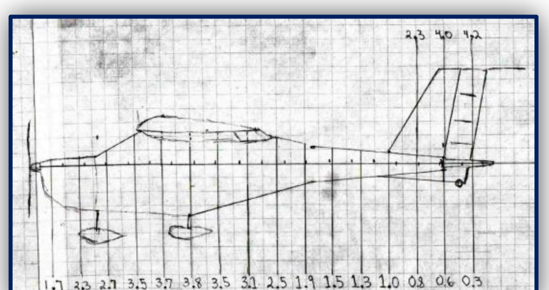
Precision agriculture sprayer aircrafts should be equipped with high quality cameras that can aid in additional applications. With an advanced sensor payload selection, the aircraft becomes more than just a sprayer. The camera, for example, can aid in scientific research by providing detailed images of the pests and damage caused by them. In this case, the M1-D is equipped with both CCTV and thermal imaging lenses that will result in additional precision properties of our UAS. The pros outweigh its cost of $3,990.

Table 8. **Sensor Payload Comparison**

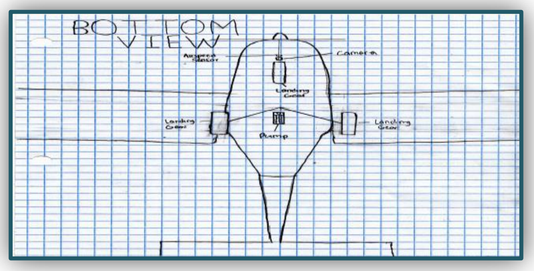
Sensor	Merits	Faults
Boscam CM210 	• Costs only $41.06 • Weighs 14g (camera only) • View Angle of 90° • 480 TV Line level of sharpness • Tilt rotation range: 160 deg. • Tilt rotation speed: 100 • deg./s • Excellent Stabilization	• Working humidity is 0-50%
SPI M1-D Micro 160x120 19mm Thermal FLIR PTZ Camera - M1-D-19-16 	• Equipped with thermal and CCTV imaging • Weighs ~2 lbs. • Tilt rotation range: 160 deg. • Pan: 360 degrees continuous • Multi Axis stabilization module, Hard mount vibration stabilization	• Costs $3,990

The application patterns were carefully examined as well. The team decided on choosing a pattern that consisted of two large UAS. The team came to a conclusion that one large sprayer would not prove efficient in terms of aircraft productivity and mission time.

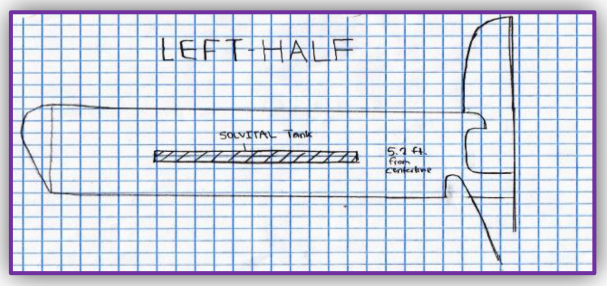
Preliminary Design Drawings:



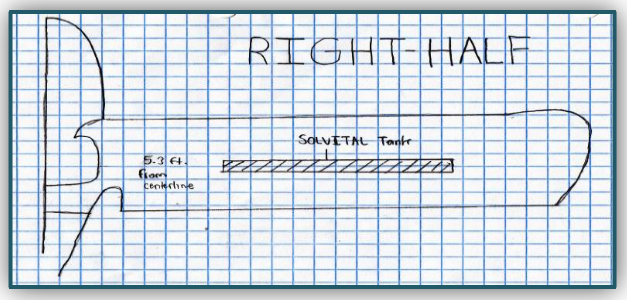
Drawing 1: Modified Large Sprayer
Drawing 1 illustrates the team's large sprayer modified from the A-22 Foxbat. The numbers above represent the diameter (in feet) at the specified fuselage station. The insecticide tanks will be placed with the 3.5, 3.7, 3.8, and 3.5 diameter placements. Furthermore, this area represents the modification that was installed replacing the pilots and installing the insecticide tanks.



Drawing 2: Bottom View (Large Sprayer)
Drawing 2 illustrates the bottom view of the 31.4-foot wingspan sprayer aircraft. The aircraft will be equipped with three landing gears, making the sprayer capable of landing on any flat, even rugged surface. Our sensor payload will be attached towards the front of our aircraft. Additionally, an airspeed sensor will be located towards the front of the aircraft as well.



Drawing 3: Left Wing (Large Sprayer)
Drawing 3 illustrates the left-half of the wing of the aircraft. 5.2 feet from the centerline, both left and right wings will contain pesticide tanks in which amounts of SOLVITAL mixture will be stored while connected to the spray pump.



Drawing 4: Right Wing (Large Sprayer)
Drawing 4 illustrates the right-half of the wing of our aircraft. Equivalent to the left-half wing, the right wing will contain a pesticide tank in which the SOLVITAL mixture will be contained. The overall wingspan of the aircraft is 31.4 feet.

2.1.4 Detailed Design

Detailed Design
- One Solution Candidate Refined

Analyze candidates to improve aircraft
- Integrate Innovations

Conduct high-order analysis
- Refine overall solution candidate

The team approached the last step of the engineering design process to further refine the UAS. After choosing the Foxbat as the final aircraft for the UAV, the team worked on modifying it to our mission requirements. Extensive calculations were done to ensure that the aircraft would perform optimally. Using the Java Foil software, we analyzed the NACA 4421 to ensure that it would provide a high-lift capacity. Additionally, we also used it to test the performance of our aircraft when the flaps and spoilers were extended. Furthermore, not only were we able to analyze it's pressure and velocity performances, but we were also able to calculate its coefficient of lift and drag, which was detrimental to fully calculating our airfoil's possibilities.

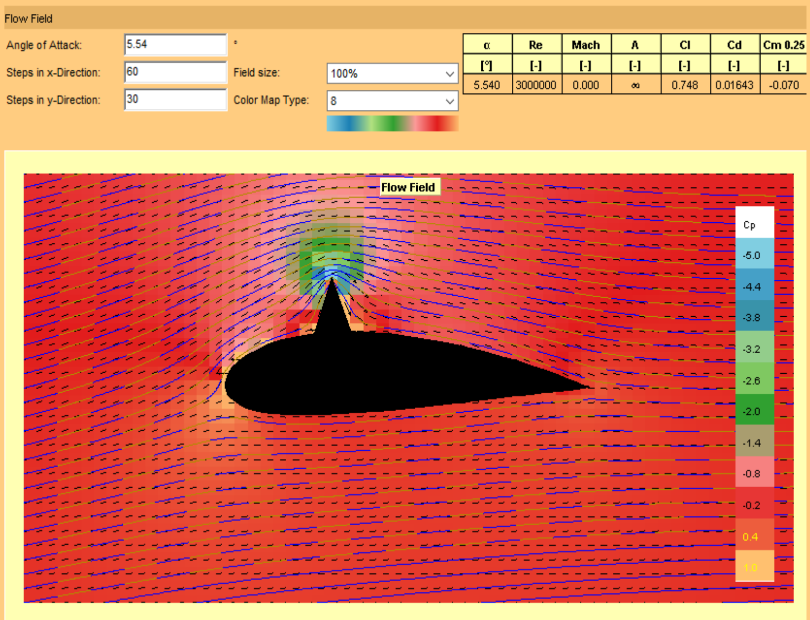


Figure 11. **NACA 4421 (Spoilers)**

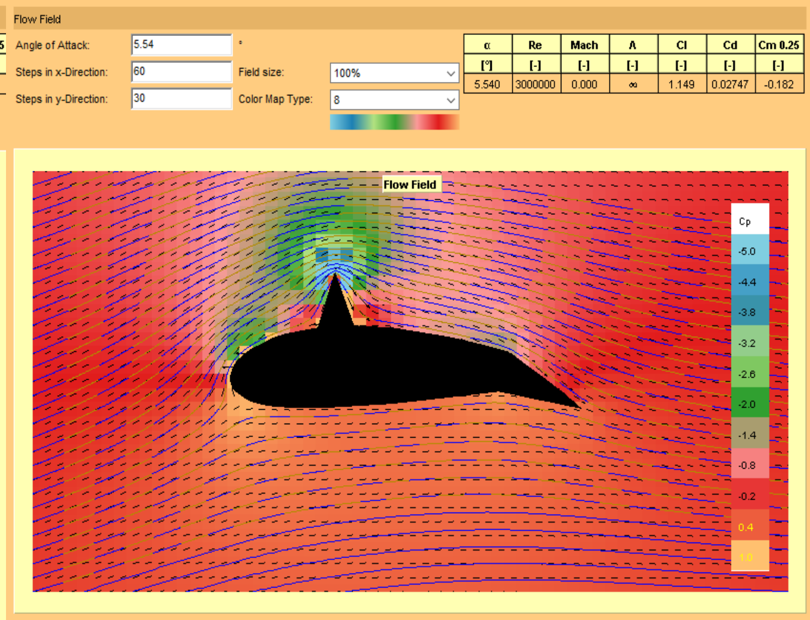


Figure 12. **NACA 4421 (Flaps & Spoilers)**

The spray equipment was further refined. Our design and simulation engineers collaborated to design a unique, extending spray boom. We decided we needed this because it was necessary to control the spray drift. Thus, it was able to extend an extra 2.24 feet during flight, parallel to the level of the wheels.

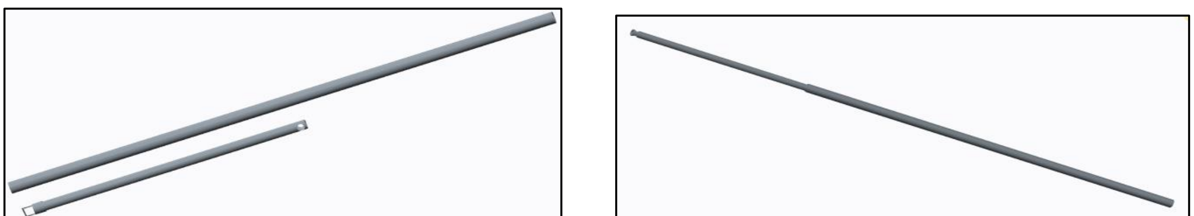


Figure 13. **Extending Spray Boom (Original Design)**

Upon the selection of the Guardian Air 110-03, the team was followed by the decision to have a total of 24 nozzles with 12-inch spacing in between, resulting in an efficient percentage of coverage and an effective swatch width of 24 feet. This positively affects our APM as our aircraft flies at 100mph. The Guardian Air 110-03 was capable of spraying bigger droplets, which significantly helped in reducing the spray drift.

Infestation Level	Gallons per minute	Pounds per square inch
Low	0.21	27.5
Medium	0.23	33.3
High 0.25	40	

Table 9. **Infestation Levels**

Figure 14. Infestation Levels

	160x120	320x240	640x480
Thermal Performance			
Detector	Microbolometer Long Wave InfraRed		
Resolution	160x120	320x240	640x480
Spectral Response	8-12 microns (LWIR)		
Thermal Optics	19mm or 25mm	19mm or 25mm	19mm or 25mm
19mm FOV	12° HFOV	24° HFOV	32° HFOV
25mm FOV	9° HFOV	18° HFOV	25° HFOV
Visual Performance			
Sensor	1/3" CMOS		
Resolution	520 TV Lines		
FOV	20° HFOV		
Pan Tilt			
Pan Range	360° Continuous Rotation		
Tilt Range	90° Tilt Range		
P/T Speed	PAN:0.05o~240o/sec;TILT:0.03o~160o/sec		
Auto Cruise	1-39 preset positions scan in sequential order		
Pattern Scans	4 programable routes.		
Presets	Up to 100		
Interface			
Video	Single channel NTSC		
Communication	RS/485 2400bps Pelco-D protocol		
Environmental			
Size	4.5" Gimbal (130mm x 116mm x 163mm)		
Weight	2lbs. (19mm system)		
Operating Temp.	-25°C to +60°C		

Sensor Payload Selection:

Unlike the Boscam CM210, the M1-D is capable of zooming in clearly to examine the infected crop. With this, we are highly capable of conducting scientific research in terms of the types of insects located on the crop. The M1-D's low power requirements and light weight, along with a combined pan/tilt mechanism with digital servos that it will be mounted on. Because of its numerous capabilities and excellent stabilization ability, the M1-D offers features that is unmatched against our carefully narrowed range of sensor payload options.

Material Selection:

The 2024-grade Aluminum is a strong, lightweight material capable of handling the weight of our aircraft. The use of aluminum, along with other materials such as DIATEX fabric and components within the aircraft design, results in a total weight of 1,242.65 lbs which fits the criteria of not exceeding 1,320lbs.

Table 10. Coverings

Coverings	
Type	Advantages
2024-grade Aluminum (Main)	• High strength • Lightweight • Low maintenance • Easily assembled • Corrosion Resistance
DIATEX fabric	• High strength • Lightweight • High quality • High pressure resistance • High compressive strength

Landing Gear:

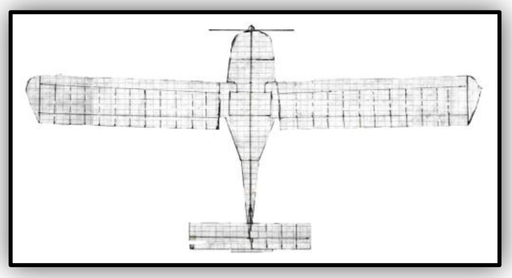
As for our landing gear, the aircraft will be equipped with a tricycle landing gear, with a tail wheel to protect the empennage from pitching off during takeoff. Such flight controls regarding instruction to maneuver the aircraft will be controlled by the autopilot. The plane will be able to fly autonomously along with a detector aircraft that will detect the level of infestation in the field beforehand. For reasons concerning safety, contingency, and additional sources of control, the aircraft will be equipped with a control switch that enables either the operational or safety pilot to switch between manual and autonomous control of the aircraft even while airborne.

The final major upgrade was to increase our SOLVITAL capacity. Earlier during the State Challenge, our aircraft's capacity was 48 gallons. Our current capacity now is 61 gallons, 13 more gallons than the UAV could carry in the State Challenge.

Because of the new components and upgrades, we had to redo our weight and balance configurations of our aircraft. Components such as the SOLVITAL and fuel tanks were shifted forward to ensure that the CG of the aircraft was in optimal range. Based on the "Weight and Balance" worksheet, the aircraft's CG range was determined to be 74.22 inches from the datum line, or about 25% of the MAC. According to the Aeroprakt

Pilot's Manual, the optimal CG range is 19-37% of the MAC, and our aircraft's CG lies safely within that zone.

Detailed Design Drawings:



Drawing 5: Top Center (Large Sprayer)

Drawing 5 illustrates the entire top center view of the large sprayer. The spray boom, depicted in the previous drawings, will be attached to the CG of the wings, facing outwards towards the rear of the aircraft with precise spacing behind the landing gear. To reduce compression load in the fuselage during the flight, additional SOLVITAL tanks will be kept in the left and right wing area. Major components are evenly spaced out to avoid an unnecessary wetted area, in addition to leaving space for extra support equipment upon installment of the pesticide tanks and C3 components.

2.1.5 Lessons Learned

LESSONS LEARNED	
Conceptual **Design**	• We learned that farmers will usually start planting the crop during the spring time then harvest just before fall because the growth quits in cooler temperatures. The most accurate time to apply the pesticide to the crop is during the month of July because that's when the temperature's rises and it is the hottest time of year. • We learned that the UAS extends human potential and will allow us to execute dangerous or difficult tasks safely and efficiently, saving time, money and most importantly lives. There are also several advantages of a UAS, one being that there will be no pilot on board thus contributing to weight saving and cost saving. UAVs are also environmentally friendly because it requires less materials to build, creates less pollution, uses less fuel per kilometer flown and is easier to dispose of at the end of its' task. • We learned that our communications, control and telemetry are activated by the data transceiver set that allows us to activate the servo receiver. This allowed data from our sensor payload and servos to be transmitted to our ground station. • We recognize that a high wing attachment provided more lateral stability as well as extra protection from FOD (foreign object damage). Less FOD means less structural damage to the wings, which in better for the overall life cycle of the aircraft.
Preliminary **Design**	• We recognized the very importance of dihedral and upper wing placement in reference to the lateral stability of the aircraft. Through the use of Javafoil, we were able to recognize that the NACA 4421 airfoil provided sufficient lift to our aircraft as well as providing enough space inside for the placement of major • We are now aware of the additional FAA regulations that have to be complied with requiring experience, special certification, inspection and approval of the aircraft, and specific qualifications to be able to legally fly the aircraft for agricultural use components. • We recognized efficient methods towards our business case as we learned that there is a two-week approximate time gap once a crop has been sprayed with a pesticide mixture. We learned that the more missions accomplished per day will result in continuous missions as two weeks follows by. • We learned that the aspect ratio is the square of the wing span divided by the wing area, in addition to recognizing that tapered ratio is the length of the tip chord divided by the length of the root chord. • We recognized the positive effects of placing antennas near the outboard wings. These antennas, when placed parallel and attached to the spar, serves as anti-torque that devises structural reinforcement for the spar, as well as improving communication. • We were able to recognize that neither landing gears nor a catapult would be needed as our aircraft contains a large, 31.4-feet 12 • while maintaining a light weight. No takeoff aid is needed as the aircraft has a short landing and takeoff roll. We gained knowledge that our landing gear was strong and flexible, the aircraft is capable of landing on any flat, hard, even rugged surface. Therefore, no airport runway is needed. • We learned the further development and capabilities of the Creo Parametric 2 software as it allowed us to create various complex designs that included the propeller and attached spray boom. • We learned that composites had greater tension strength than aluminum, but it is very expensive. We also learned that composites have a poor compression load capability. We considered composites as a possible material of the future, once the price is more feasible. • We recognize a need for the pilots to be strategically located in the 2x1 field in reference to line of sight and signal interference. These locations had to be carefully calculated to maintain the one- mile line of sight while

	maintaining a one-mile signal separation. • We learned to use the space inside the wings to install our SOVITAL Tanks. Furthermore, this placement maintained aerodynamics, and reduced our compression load, thereby, preventing the wings for possibly snapping off.
Detailed Design	• We recognized that flapperons acted as both flaps and ailerons. Therefore it allowed us to multi-function both flight controls into one system. • We recognize the need to decelerate our UAV's at a speed of 12 mph/second by extending the spoilers and slightly lowering our flaps before entering the turning phase. • We learned that fine droplets produced by nozzles are more likely to drift away from targets, while coarse droplets are less likely to drift away. As a result, extremely course droplets are recommended for broadleaved plants such as the sweet potato crop. • We recognized the importance of making our trailer multifunctional, utilizing it for the following: a storage area for components, work space for personnel and area for data analyst, and a mobile tower. We recognized the need of a truck in order efficiently move equipment and carry the refueling system while acquiring an efficient mission time. • We recognized that, as per our communications and control, our video system allowed live information from our sensor payload to be received by our ground control system. We learned that an added GPS and autopilot allows view waypoint that pinpointed direct locations, thus increasing precision within the system. • The team learned that investing part of our salary to reinvest and improve our system would reduce cost, and portray the commitment that is present towards the project. • We recognized the possible communication interferences between UAVs if we selected the option to utilize more than two large sprayers flying over the infested crop area simultaneously. • We recognized, by moving the door and the windscreen, saved valuable weight. This weight-saving increases our useful load.
Throughout Entire Design Phase	• The team learned the importance of communication, teamwork, and patience throughout the challenge. Despite the lack of resources and inability to directly print or copy material, along with extended times of wait for responses, we learned how to maintain our goal of completing the mission scenario no matter what our limitations were. • We learned that every team member has to pull their own load. Unfortunately, we had to let one of our members go because she didn't produce. We learned that hard choices must be made for the betterment of the entire team. • We learn that the strongest Typhoon of the year wasn't quite strong enough to stop the Aeronautical Dolphins from completing their RWDC challenge. We learned that we will do whatever it takes to succeed. We learned that if our school is unsupportive, then we will go to locale cafes and even the airport. We learned that we are a proud and determined group.

2.1.6 Project Plan Updates and Modifications

Project plan updates and modifications were made with careful consideration throughout the conceptual, preliminary, and detailed design phases. Several modifications were acted upon after the team attended a webinar sponsored by the RWDC.

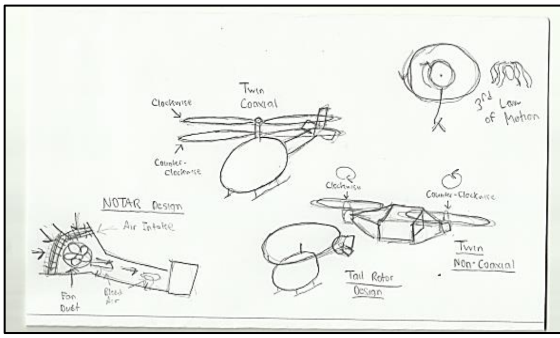
The A-22 Foxbat, our selected base design aircraft, is a light sports aircraft that will be modified by the team to fit the needs of precision agricultural spraying of pesticide. The A-22 aircraft is modified specifically to be controlled either autonomously or manually with an autopilot. While keeping the base and structure of the aircraft, the team removed the pilot area in the cockpit load and removed the manned flight controls and avionics due to the fact that there will be no human pilots on board the aircraft.

During the preliminary design phase, the team decided to fabricate the tanks that will contain fuel and the SOLVITAL pesticide mixture, later to be distributed and refueled throughout the mission application. We have increased our SOLVITAL capacity from 48 gallons to 61 gallons. Due to the 100hp

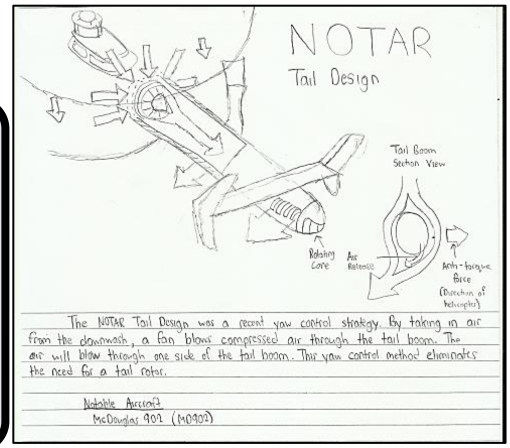
Rotax 912 engine's low fuel consumption, the team recognized that decreasing the size of the fuel tanks will allow a larger area for the SOLVITAL mixture to be stored, thus increasing our acres per minute and coverage area before maneuvering back to our three refueling points. However, we had to add an extra 3 ½ gallons to comply with the FAA regulation on fuel.

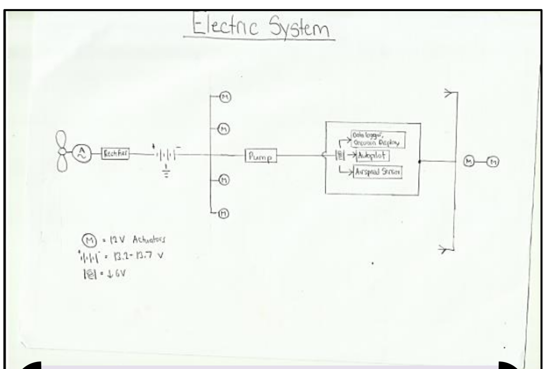
The original airfoil of the A-22 Foxbat has been modified by the team. We are using the NACA 4421 for its thickness provided efficient space to hold the pesticide tanks in the wings. Not only does it also provide more lift, having SOLVITAL tanks in the wings prevents the Foxbat's wings from snapping off due to compression load differences.

Aircraft Modifications Drawings:

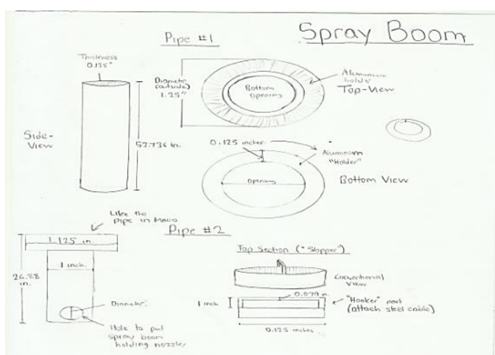


Drawing 6: These are the various rotor-craft airframes the team was considering. We wanted to experiment with different airframes to see which one would be optimal to use as part of our UAS. The four designs are: twin coaxial, NOTAR Design, tail rotor design, and twin non-coaxial.

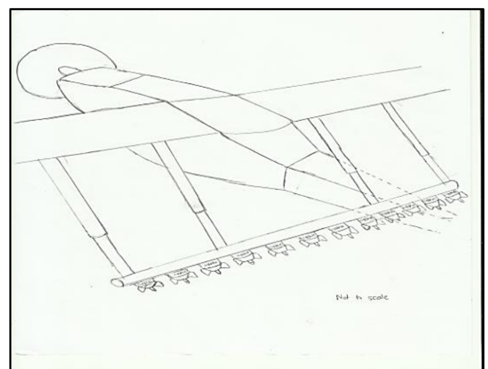




Drawing 7: The team redesigned the electric system. The picture depicts a simplified version of it, in which the components will be powered by the battery. The battery will in turn be charged by the alternator.



Drawing 8: We needed a way to reduce the spray drift of our aircraft, and extending the spray boom was a viable option. The team helped the design and simulation engineers to design a spray boom that would be able to extend up to the level of the landing gears. However, it will only extend when in flight.



Drawing 9: This is the rear 1/4 view of the aircraft. This was drawn to help our simulations engineer model the aircraft. The booms are fully extended, with their nozzles attached to them.

2.2 Selection of System Components

2.2.1 Payload Selection

Sensor Payload Selection

The data that is captured by the M1-D-19-16 will be transmitted back to our ground control station (GCS) where our data analyst can record data and observe the infested crop areas. Unlike the Boscam CM210 (state challenge camera), X250 and X500 cameras provided in the RWDC catalog, our selected payload is capable of zooming in clearly to examine the infected crop. With this, we are highly capable of conducting scientific research in terms of the types of insects located on the crop. The M1-D's low power requirements and light weight, along with a combined pan/tilt mechanism with digital servos that it will be mounted on. Because of its numerous capabilities and excellent stabilization ability, the M1-D offers features that is unmatched against our carefully narrowed range of sensor payload options.

Nozzle Selection

The team selected the Guardian Air 110 – 03 as our final nozzle. We will use 24 nozzles with a 12-inch spacing in between, which in turn produces a swath width of 24 feet. It is light, weighing only 0.8 ounces. It is feasible, costing only $4.86. Compared to the Guardian Air 110 – 025, the Guardian Air 110-03 produces extremely coarse droplets when spraying 0.215 to 0.253 gallons per minute, which is required in order to meet the dosage volume for each specific infested area. This allows the droplets to be heavier and fall faster to the ground, thus reducing the spray drift significantly.

The Guardian Air 110 – 03 delivers faster work rates which result in coarser droplets and drift reduction. Its incline allows more uniform coverage on the front and back of foliage for a wide range of speeds. It is suitable for wind speeds ranging from 3 to 20 miles per hour, which is suitable for our mission scenario since the wind speed is 11 knots (12.6586 mph). Due to the extremely coarse droplet that it produces and the suitability of spraying in speeds ranging from 3 to 20 mph, the Guardian Air 110 – 03 is the best nozzle to be used for the mission scenario since it reduced the spray drift significantly.

Majority of the payload is located in the forward fuselage, which has been carefully placed to maximize aerodynamics and reduce parasitic drag within the aircraft. We calculated the aspect ratio and planform of the wings to variably predict a high aerodynamic performance of our wings. This was of particular significance due to concerns from the recent RWDC webinar about the size of our aircraft. The performance ability of our aircraft, however, has been greatly proven as we worked the aspect ratio and the fact that the original Foxbat and crop dusters which contain a larger wingspan are highly capable of precision application. The aircraft's components have been aligned in a small and efficient manner, minding the location of the pesticide and fuel tanks which will be located in the mid-rear fuselage. The sensor payload is located at the bottom of the nose of the aircraft, while the major C3 components such as the Data Transceiver, Video System, Servo Receiver, and Autopilot will be located aft of the main fuselage, towards the rear of the aircraft. Antennas and actuators that transmit and receive data are located near the elevators, rudder, and stabilizers.

Table 11. Unchanged Components List (from State Challenge)

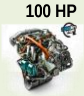
COMPONENTS				COMPONENT			
Component	Dimensions (L x W x H) *Inches*	Weight	Cost	Component	Dimensions (L x W x H) *Inches*	Weight	Cost
Rotax 912 ULS 100 HP 	2.8346 x 22.6772 x 16.259	125 lbs.	$19,377	**Onscreen Display (OSD) and Datalogger with Limited Telemetry Reporting** 	(OSD) .5 x 1 x .25 (Data Logger) .75 x 1 x .25 (GPS) .5 x .5 x .25	(OSD) .03125 lbs. (Data Logger) 0.05 lbs. (GPS) 0.025 lbs.	$250
Propeller 	(Blade) 65-68" (Spinner) 9-12"	10 lbs.	$2,225	**Airspeed Sensor** 	1.1 x .62 x .4	0.009375 lbs.	$45
Super B 7800 Battery 	4.7 x 3.7 x 3.23	2.86 lbs.	$566	**Autopilot** 	2.63 x 1.6 x .26	0.050625 lbs.	$250
Alternator 	Diameter: 4.2126 Length: 4.82	8 lbs.	$1,340	**Data Reciever Set(900 Mhz)- High Range Set** 	1.3 x 1 x .25	0.025 lbs.	$135
900 Mhz Video System-High Power (1500 mW) 	2.83 x 1.71 x 0.48	0.1875 lbs.	$125				

Table 12. Removed Components (National Challenge)

REMOVED COMPONENTS (from State Challenge)	
Components	Weight (Lbs.)
Seats(a set)	7.92
Harness Belts (a set)	3.08
Cockpit Heating System	1.65
Rudder Cables	1.32
Yokes with control column (a set)	7.7
Fuel Level indicator	0.308
Landing Light, BOSH (a set)	0.77
Flight Control Mechanism (ailero	4.6346
Elevator Rods**	4.18
Elevator Cables	0.66
Door 1 & Door 2 (with sliding wir	7.3706
Windscreen glass	4.12229
Windscreen glass edging	0.99208
Rear glass edging	0.61729
Avionics	15
Total:	**60.32486**

Figure 15. Weight (Airframe)

Main Fuselage	Cost	Weight
Frame1	51.3	4.191522
Skin (Frame 1-2)		
1.9 x 5.3 (4 sheets)	754.04	4.640256
3.8 x 4.2 (2 sheets)	551.52	3.677184
Frame 2 (5 square ba	140.85	20.58
Frame 2-3 skin		
3.8 x 5.8 (2 sheets)	761.7	5.078016
1.9 x 4.2 (4 sheets)	643.52	3.677184
Tail Boom		
Frame 3	12.18	10.1958
Frame 3-4 skin (2 shee	96.46	8.2944
Frame 4	6.24	8.09194
Frame 4-5 skin (2 shee	108.86	4.97664
Frame 5	7.45	5.72
Chromaly Tubing (2)	9.6	0.282
1/2 diameter 0.444 id		
Main LG (2)	13.46	0.46854
Struts (Wing) (2)	45.24	2.290646
Nose LG	2.99	0.10412
Total	3205.41	82.268248

Wing	Cost	Weight
Ribs	234	14.677
Spar	59.05	3.7024
Spar Skin	261.04	11.933
Wing Skin		
Part 1	257.17	9.1845
Part 2	34.68	0.8664
Total	845.94	40.363
2 wings total	1691.9	80.726

Flapperons (2)	Cost	Weight
Spar	50.1	3.1427
Ribs		
6061 ribs (9)	27.81	0.7798
2024 ribs (4)	15.92	0.0998
Total	93.83	4.0223

Verticle Stabilizer	Cost	Weight
Spar	41.15	2.5811
Ribs		
Rib 1	0.65	0.0411
Rib 2	1.06	0.0668
Rib 3	1.31	0.0821
Rib 4	1.8	0.113
Rib 5	1.96	0.1232
Skin	36.89	1.0504
Total	84.82	4.0576

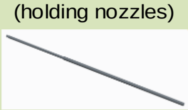
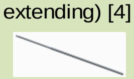
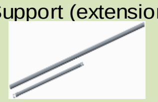
Rudder	Cost	Weight
Spar	6.94	0.435
Ribs (5)	16.05	0.449
Total	22.99	0.884

Horizontal Stabilizer	Cost	Weight
Spar	20.2	1.2671
Ribs (9)	18.63	1.1708
Skin (2 sheets)	116.16	3.3186
Total	154.99	5.7565

Elevator	Cost	Weight
Spar	1.81	1.366
Ribs (9)	26.82	1.2016
Total	28.63	2.5676

TOTAL COST	5282.55
TOTAL WEIGHT	

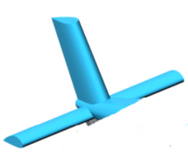
Table 13. Added/Updated Components List (National Challenge)

Updated Components (National Challenge)			
Component	Dimensions	Weight	Cost
PA-16-6-330 Mini Medium Force Linear Actuator (5)	Length: 6 in.	9.75 lbs.	$694.95
C3 Components	N/A	0.37875 lbs.	$805
4001XL-E2H Pump w/ Motor 	Diameter: 5 in. Length: 12 in.	18 lbs.	$495
SOLVITAL TANK (Fuselage) (30.5 gallons) [0.04 in. thick]	(2) 3.45 x 1.2 ft. (2) 1.2 x1 ft. (2) 3.45 x 1 ft.	9.822 lbs.	$102.72
SOLVITAL TANK (Wings) (15.25 gallons) [2] [0.04 in. thick]	(2) 2.489 x 2.331 ft. (2)2.331 x 0.356 ft. (2)2.489 x 0.356 ft	16.8024 lbs	$149.64
Fuel Tank (7.48 gallons) 	11.75^3 in.	3.2824 lbs.	$21.78
Spray Boom (holding nozzles) 	Outside Diameter: 1.25 in. Wall: 0.125 in. Inside Diameter: 1 in.	12.2106 lbs.	$231.24
Spray Boom Support (not extending) [4] 	Outside Diameter: 1.25 in. Wall: 0.125 in. Inside Diameter: 1 in.	9.308 lbs.	$199.88
Spray Boom Support (extension) 	Outside Diameter: 1.125 in. Wall: 0.125 in. Inside Diameter: 0.875	4.137728 lbs.	$140.84

Updated Components (National Challenge)			
Component	Dimensions	Weight	Cost
Boom Tubing (Catalog)	Diameter: 0.25 in.	Not given	$59.40
PA-14-4-35 Mini Actuator (4 in. stroke, 35 lbs force) [2 pieces]	Stroke: 4 inches	3.5 lbs.	$217.98
Campbell Commercial Weldless Galvanized Steel Cable	Length: 14 ft. Thickness: 0.0625 (1/16) in.	Not given	$3.64
Nozzles (24 pieces) 	N/A	1.2 lbs.	$116.64
Camera (M1-D) 	6" X 4.5"	2 lbs.	$3,990.00
Windshield (aluminum Sheet)	3.0765 x 0.9323 ft.	2.9325 lbs.	$66.08
Doors (aluminum sheet) (2)	4.12 x 2.473 ft.	12.471 lbs.	$322.78
		90.392 lbs.	$4,776.52

2.2.2 Air Vehicle Element Selection

Tail Configuration:

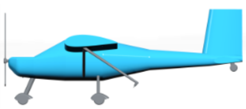


A conventional set up for the tail boom proved the best solution candidate towards our tail configuration. With a conventional tail boom, our aircraft will consist of efficient aerodynamics than the V-tail of T-tail design. The aircraft's conventional tail configuration allowed maximum pitch and yaw control. With that said, additional movement along the lateral and longitudinal axis allows the tail to have more stability. The tail boom will be made out of 0.8mm aluminum sheet with an essential monocoque structure. Our stabilizer structure consists of ribs, a spar and 0.5 mm aluminum sheet skin, in which attachments to the fuselage are present as well as elevator attachments. Our elevator and rudder structures are similar to that of flapperons.

Wing Configuration:

For the National Challenge, we had to consider between reverting back to the Foxbat's original airfoil, the TsAGI P-III 15%, or remain with the airfoil we used in the State Challenge, the NACA 4421. Thanks to JavaFoil, we were able to accurately test, experiment, and analyze the airfoils. Ultimately, we remained with the NACA 4421. Although it produces 28.3% more drag than the TsAGI P-III, however, it produced 22.7% more lift than the latter. Therefore, we decided that having more lift minimized our stall risk at an extremely low altitude. In any event, it is almost impossible to recover an aircraft at an altitude of 10 feet. Another benefit of using the NACA 4421 is its increase in inner wing space, which allows us to install more components without increasing parasitic drag.

Fuselage Configuration:



The fuselage of our aircraft has been modified from the original A-22 Foxbat, which had enough space to accommodate our fuselage components. The fuselage contains the following components: the Kievprop 263 series propeller, the Rotax 912 ULS 100 HP engine, an external alternator, the M1-D, an airspeed sensor with a pitot tube, the Super B 7800 battery, a fabricated 24 gallon tank, the Hypro 4001-XL pump, a fabricated six gallon fuel tank, the autopilot, the onscreen display, data logger, GPS sensor, and the video sensor. Organizing these components as efficiently as possible was of our best interest while facilitating in the reduction of unneeded space within our aircraft greatly affected its center of gravity.

Power plant Configuration:

The aircraft's power plant configuration consists of a single-engine, propeller driven aircraft. The team has selected the Rotax 912 ULS 100hp as the main engine. This engine rotates a crankshaft, which in turn rotates the propeller. The team selected the Kievprop three-bladed propeller which, compared to several Rotax engine propellers, is less in cost and more reliable. It additionally has ground-adjustable pitch, enabling us to set the proper pitch within the aircraft. Upon mentioning the Rotax 912 ULS 100hp engine to our mentors, they commented positively on the engine's reliability. The engine will be placed in the nose of the aircraft, mounted on an engine mount and will be covered with a composite engine cowling. The Rotax 912 engine produces 100 horsepower maximum at 5,800 RPM and consumes approximately seven gallons per hour at maximum RPM.

Sensor Payload Configuration:

The M1-D-19-16 had been chosen by the team as its sensor payload. It is both light weight and small in dimension. Compared to other candidates selected from outside research, the M1-D proved to have high zooming capabilities while sold at a reasonable price. This sensor payload's excellent stabilization and added mounting equipment makes it highly capable of transmitting HD visuals to our ground control system. The information provided by the M1-D will aid in research regarding the types of pest infestations as well as providing information on the quality of our pesticide application and its effects on crops. This proves highly helpful due to the fact that the aircraft will only be flying at 10 feet above the sweet potato crop.

Flight Controls Configuration:

The primary flight controls for the UAV will be flapperons, elevators and rudders. The only secondary flight controls that will be used are the spoilers. Flapperons are proven more useful than ailerons because they have the dual function of flaps and ailerons. Additionally, the flapperons will be used in takeoff/landing, while assisting the spoilers in the deceleration and turning phase. The rudder will control the aircraft's yaw movement. Consequently, in order to compensate for the engine torque, when the rudder is placed in its neutral position, it will have a 3-degree angle to the right. The elevators will be controlling the aircraft's pitch movement.

The spoilers were the new flight controls added for this challenge. In order to help our aircraft slow down before making its turns, we decided to install spoilers. The spoilers have been tested in JavaFoil to ensure that not only will it withstand the relative air stream, but also provide enough drag to assist in the deceleration of the aircraft during the turning phase.

Airframe:

- 6061-grade Aluminum (frames)
- 2024-grade Aluminum (Main) and DIATEX fabric covering
- Conventional tail
- High-wing with flapperons

Flight Controls:

- Flapperons
- Rudder
- Elevator
- Spoilers

Powerplant (Propulsion):

- Rotax 912 ULS 100hp
  - 4-cylinder
  - 4-stroke liquid/air-cooled engine with opposed cylinders
  - 2 carburetors
  - Electric starter
  - Dual-electric ignition
  - Air intake system
  - Mechanical fuel pump
  - Electric starter
- Performance:
  - kW: 73.5
  - ft. lb.: 100
  - 1/min: 5800
  - Max RPM: 1/min 5,800
- Weight
  - Engine with propeller speed reduction: 56.6 kg
  - Overload clutch: 1.7 kg
  - Exhaust system: 4.0 kg
  - External alternator: 3.0 kg
- Cost: $ 19,377

Required Equipment/Components:

- Onboard Sensors (All provided in the RWDC catalog; best candidates for selection)
  - GPS sensor
  - Video sensor
  - Onscreen Display and Datalogger
  - Airspeed sensor
- Autopilot
- Ground control and communications
- M1-D-19-16
- Antennas

2.2.3 Command, Control, and Communications (C3) Selection

After thoroughly analyzing the challenge scenario in relation to our theory of operation, the team identified that data transmission plays a vital role in communications. When dealing with precision pesticide application, variables such as maintaining quality visual line of sight, amount of (SOLVITAL) pesticide applied, detection signal, and flight operations along with safety procedures are carefully considered. We considered all candidates for components of the C3 selection- command, control, and communications. Careful observations and additional research were made in order to select which components best fit the requirements of our theory of operation. The team considered various components using the provided RWDC C3 selection catalog and outside research.

The command, control, and communications equipment provided in the catalog fit the team's criteria of maintaining data during our operation. Our C3 selection was vital towards calculating our overall weight and balance as we placed these components in the most appropriate areas of the aircraft.

Our aircraft's system will comply for the FAA technical readiness criteria for airworthiness. We are able to satisfy the primary and secondary needs of the system regarding the control data link, navigation and orientation, control station/pilot interface, and a contingency response. The team included in our cost and considerations the need for a redundant secondary control, multiplexer, as well as a primary and secondary source of power.

Our control commands and telemetry equipment will consist of using a Hobby-grade Remote Control (R/C) radio to associate both autonomous and control switching operations (semi-autonomous), which will purposefully deviate a pre-established flight when planning to move to specific areas. The handheld R/C radio and switch will also be used to utilize secondary controls to improve the system's safety precautions. We will obtain visual sight of the sprayer using the M1-D to transmit visuals of the crop from the plane. To maintain the information from the M1-D, we will display it for the pilot and on a secondary LCD screen for further observations by the data analysts.

To maintain communication, we will use a set of Data Transceivers (900Mhz) that come with antennas, capable of maintaining an outdoor line of sight range of up to 6.3 miles while airborne.

CONTROL/DATA PROCESSING & DISPLAY OPTIONS			
Component	Quantity	Cost Per Item	Subtotal
Hobby-grade Remote Control (R/C) Radio	2	$ 750.00	$ 1,500.00
Post Processor PC (Laptop)	2	$ 3,500.00	$ 7,000.00
YAGI-Directional Antenna 900MHz) - Ground Based	2	$ 60.00	$ 120.00
Total Ctl/Data Process/Display Cost	6	N/A	$8,620.00

Control/Data Processing & Display: $8,620.00

COMM EQUIPMENT OPTIONS			
Component	Quantity	Cost Per Item	Subtotal
Data Transceiver Set (900Mhz) - High Range	2	$ 135.00	$ 270.00
900MHz Video System - High Power (1500mW)	2	$ 120.00	$ 240.00
Global Positioning System (GPS) Sensor	2	$ 50.00	$ 100.00
Total Comm Equip Cost	6	N/A	$610.00

Communications Equipment: $610.00

ADDITIONAL C3 EQUIPMENT OPTIONS			
Component	Quantity	Cost Per Item	Subtotal
Additional LCD Display	2	$ 200.00	$ 400.00
Total Additional C3 Equip Cost	2	N/A	$400.00

Additional C3 Equipment: $400.00

Total C3 Cost: $6,085.00

Total C3 Cost		
Component	**Quantity**	**Total**
Total Ctl/Data Process/Display Cost	6	$8,640
Total Comm Equip Cost	6	$620.00
Total Additional C3 Equip Cost	2	$400.00
Total C3 Cost	**14**	**$9,660.00**

2.2.4 Support Equipment Selection

Provided that the Skywalker's large size is too big to be accommodated by a shelter, the team decided on using 7 ft x 16 ft trailer with a cost of $3,150 and the ability to accommodate our workstations (laptops and equipment), tools, fuel, and generators. This will provide a portable work area for the crew, computers, and other support gear. Furthermore, we were able to identify handling and storage equipment that is vital to the operational personnel.

SUPPORT EQUIPMENT/HANDING AND STORAGE			
Component	Quantity	Cost Per Item	Subtotal
400-Gallon Refueling Tank	1	$ 5,979.00	$ 5,979.00
2015 Nissan Frontier	1	$17,990.00	$ 17,990.00
7 ft x 16 ft Trailer	1	$ 3,150.00	$ 3,150.00
Chemical-Resistant Coveralls over (included) short-sleeved shirt and short pants	2	$ 33.60	$ 67.20
Chemical-Resistant Gloves	2	$ 4.99	$ 9.98
Chemical-Resistant Shoes plus Socks	2	$ 43.13	$ 86.26
Protective Eyewear	2	$ 2.80	$ 5.60
Chemical-Resistant Headgear (for overhead exposure)	2	$ 34.85	$ 69.70
Chemical-Resistant Apron (when cleaning equipment and mixing or loading)	2	$ 3.91	$ 7.82
Total Support Equipment Cost	15	N/A	$27,365.56

Pesticide storage and application can be very hazardous to both humans and domestic animals. To ensure safety within the personnel, we have added in our cost the necessary equipment the workers should wear: chemical-resistant coveralls, short-sleeved shirts, short pants, chemical-resistant gloves, chemical-resistant shoes, socks, protective eyewear, chemical-resistant headgear for overhead exposure, and chemical resistant aprons.

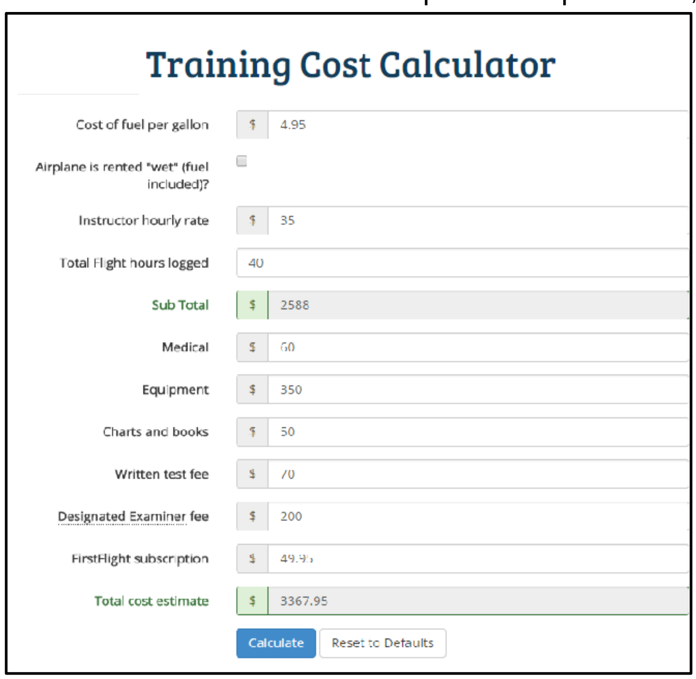
The team recognized that, upon choosing two large sprayer aircraft, there is no need to design a catapult that would aid in the aircraft's launching system. We will, however, have a means of transportation using the 2015 Nissan Frontier to carry and transport our refueling system tank. It will transport our refueling tank to the aircraft's designated refueling points. Compared to the trailers provided in the catalog, the 2015 Nissan Frontier and trailer support equipment combined prices proved cost-efficient as well as guaranteed quality and reliability.

2.2.5 Human Resource Selection

Initial Engineering Role	Dual Responsibility (Operational & Support Personnel)	Approved FAA Certification/Training License	Specifications
Marketing	Safety Pilot	FAA Private Pilot's License	Monitors the aircraft's telemetry and safety operations
Systems & Test Engineer	Operational Pilot	FAA Private Pilot's License with a Visual Flight Rule Rating, Agricultural Aircraft Operator Certificate	Operates and adjusts the aircraft's programming
Design Coordinator	Range Safety/ Aircraft Launch & Recovery/ Maintenance	FAA certified with A&P ratings	Coordinates air traffic management and ensures safety operations
Simulations Engineer	Range Safety/ Aircraft Launch & Recovery/ Maintenance	FAA certified with A&P ratings	Coordinates air traffic management and ensures safety operations
Project Mathematician	Data Analyst	Special Airworthiness Certificate – Restricted Category (SAC-RC)	Analyzes data collected from the mission
Mission Planner	Payload Operator	Special Airworthiness Certificate – Restricted Category (SAC-RC)	Monitors sensor payload and scopes the area
Project Manager	On-watch Personnel	FAA Pilot's License	Observes overall mission and operation

When selecting the crew members of our design system, it was crucial for each team member to identify their strengths, experience, and observations for the overall engineering design effort. We noted that the variety of skills each member possess plays an important role when considering cost, time, and the number of people needed for a specified mission. In our efforts to reduce the total number of man hours, the team decided on a rationale consisting of each member being multi-qualified in order to support the tangibles of the challenge. Furthermore, each team member has two professional jobs in order to coordinate and assist in the efficient operations of the aircraft and ground systems. The team members made up of the project manager ($75.00/hr), mathematician ($50.00/hr), mission planner ($50.00/hr), and design engineer ($50.00/hr), and simulations engineer ($50.00/hr) will have dual responsibilities as the operational personnel crew. The crew consists of two payload operators ($35.00/hr), two operational pilots ($35.00/hr), two safety pilots ($35.00/hr), two range safety maintenance ($35.00/hr), and two data analysts ($50.00/hr). The purpose of this selection is to minimize man hours as well as practicing cost reduction and efficiency towards our business case. The team took in consideration the personnel needed for the detector aircraft. There will be a total of 12 operational personnel;

Initial Engineering Role	Engineering Specifications	Career Qualifications
Marketing	Documents business costs and conducts cost/benefit analysis	B.S. in Marketing
Systems & Test Engineer	Tests design prototypes and pre-production products	B.S. in Engineering
Design Coordinator	Integrates new or modified design data into the overall product design	B.S. in Engineering
Simulations Engineer	Develops simulations and models for project designs	B.S. in Engineering
Project Mathematician	Translates and applies mathematical principles into the project designs and plans	B.S. in Engineering
Mission Planner	Develops and coordinates overall mission plan	B.S. in Engineering
Project Manager	Manages the project plan and deliverables	B.S. in Engineering



each needed to fulfill their specified jobs in to complete the mission. In addition, our company hired an assembly technician ($25/hr), electronics technician ($25/hr), and aircraft maintenance technician ($25/hr) to assemble and add the modifications to our UAVs. It will take approximately 160 hours for these personnel to build the Skywalker.

As stated in the RWDC Detailed Background document, the team members must input a most accurate estimation of the total time it would take real, professional engineers to design, build, and advertise this plane model. Modifying our existing state UAV would take approximately six months: one month for planning and designing, one month to implement changes on the aircraft, and four months to test and advertise the aircraft on the market. It would take approximately seven months to build a second aircraft; one month to build the aircraft and six months to test and market the product. The additional two months used for designing the aircraft will not be included because the aircraft contains the same features as the modified Skywalker. The idea of combining our roles and responsibilities branched from the Wright Brothers, who were able to conquer control sustainable flight by maximizing their ability to multi-task. The Wright Brothers worked as their own mechanics, engineers, and pilots. With this, the Wrights had no need to outsource labor and in turn facilitated lower cost and higher efficiency. Furthermore, UAS operators seek FAA-approved special airworthiness-restricted (SAC-RC) license that will allow us to perform specific tasks within our private institution.

Using the FirstFlight Training Cost Calculator above, the team was able to calculate the company's private pilot license cost requirements.

2.3 System and Operational Considerations

Throughout the project development, the team has come across many choices that required a mindset that our decisions would impact the final design of our system. We recognized that, from a business perspective, balance between costs and quality of our product performance had to be carefully weighed. We also recognized various tradeoffs we had to make in order to increase and maximize our objective function. The major tradeoff the team encountered was that of our objective function. The RWDC detailed background and calculator states a conventional APM of 18.1823, along with striving for an objective function that equaled or was greater than the value of one. When asking the concern of providing a higher APM, the team gained a response from the RWDC webinar that this conventional application would fall in a scenario of spraying the entire field area. As a team, we decided that, although an APM of 18.1823 or higher will greatly reduce time, it will also reduce the idea of precision pesticide application, which is what the challenge is all about. Since the field and future missions will have pre-determined infestation levels due to a detector aircraft, the team recognized that the green areas where there are no infestation levels do not have to be sprayed, and do not have to be flown over. The aircraft, instead, will only be flying over the percentage of the 1 x 1 and 2 x 1 mile area that is infected, thus lowering our objective function with a 9.6970 APM. This resulted in an overall objective function of 0.7048.This tradeoff, however, has nonetheless increased our business profitability, mission time, and will guarantee precision within every acre of land.

As time progressed, we made several considerations to our UAS design. We had to ensure that our aircraft was in compliance with FAA regulations while maintaining high productivity. Our aircraft will fall under the private (civil) operator category, as our private company is not considered public operators. Our company will have to apply for numerous certifications such as the Section 333 exemption. Because our aircraft is over 55 pounds, both the Skywalker and our pilots need to fit the criteria and go through processes required by the FAA in order to acquire specific certifications.

One of the biggest considerations we had to make was in regards to the amount of SOLVITAL the aircraft will carry. Early in the challenge, our SOLVITAL mixture capacity was found to go up to 65 gallons, nearing the weight limit of 1,320 lbs. Furthermore, we recognized that 65 gallons went over the maximum cockpit load of the original A-22 Foxbat. In order to comply with our business and FAA regulations, we decided to cut the SOLVITAL tanks down to 61 gallons. This will allow improvement to our UAV system over the five-year period and prevents us from approaching too close to the limit of 1,320 lbs. In regards to our powerplant, the team stuck to a single-engine, propeller-driven aircraft using the Rotax 912 ULS 100hp engine. We learned that gasoline provides a higher power to weight ratio than current battery technology, proving a better option for our system.

In regards to our mission plan, we considered time and efficiency of the system as well as cost. The team had to perform several modifications regarding our spray application pattern. From “evolving” to one large UAV to two large sprayer aircraft, we as a team had to change our spray application pattern in order maximize efficiency of the mission. We turned out with an outcome of varying lengths to our spray boom selections, all of which greatly affected our swath width. We later chose to place the nozzles with 12 inches of spacing, accommodating a 9.6 spacing between two middle nozzles to maintain our swath width. Our flight pattern and nozzle placements are designed to accommodate any wind occurrence, such as the 11-knot wind coming from the west. Additionally, we had to redesign our application pattern due to the amount of turns. We made numerous calculations, later shown in our example mission, until we found the right amount of turns and turn times of the overall operation.

Moving on to our business case, the team had to consider the rationale of maximizing our initial system cost during our first year of operation, or choose the option of showing improvement between a span of five years. Ultimately, we decided to show improvement over time. Several trial and errors were made to our business case using the provided RWDC cost calculator. When considering both options, the team recognized that maximizing our cost in the first year would result in an interesting break-even point in year one, whereas our loans and expenses would be paid by the end of that same year. This is due to the 5-day work schedule, along with completing two missions each work day. Although this goes to show the company’s confidence towards our UAS system, we recognized that it would result to either major or no changes in the following years. Our revenue would max out by year one and result in a flat line graph until year five, showing no improvement over time. We, as a company, expect to improve our system over the five-year span. We took into consideration the workers' hours/overtime, holidays, breaks, and vacation time. Our decision to group the total system initial cost within a five-year time period results in a breakeven point by our first year, while in turn allowing room to upgrade the aircraft such as increasing its pesticide tank capacity and lowering mission times.

Material Selection (Future Considerations)

The team closely studied composites as it was the strongest candidate against our state challenge aircraft covering, which was 2024-T3 aluminum. Weighing about 121 lbs. per cubic foot, it weighs 35% less than aluminum. The tensile strength of carbon-epoxy composite is 1240 MPa, which, by the way, measures more than double the tensile strength of aluminum. Right now, composites are being used in large-scale commercial aircraft such as the Boeing 787 and the Airbus 350.

2024-T3 Aluminum	Carbon Fiber-Epoxy (Composite)
• $0.72 per pound	• $12.00 per pound

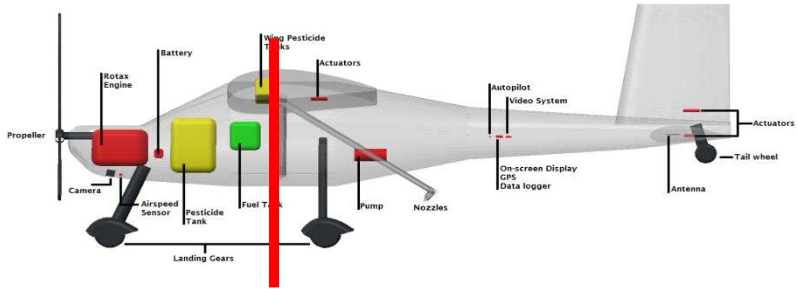
However, composites do have a disadvantage. It doesn't handle compression loads as good as aluminum. Despite its high material costs, the team decided to look into replacing the fuselage skin with composite materials, namely carbon fiber-epoxy. We hypothesized that by changing our fuselage skin material from 2024-T3 aluminum to carbon fiber-epoxy, the aircraft would have significant weight savings, allowing us to carry more SOLVITAL, thus increasing our UAS productivity. Cost was not a major issue in this research because we were provided with the $100,000 grant at the beginning of the national challenge. Unfortunately, the calculations and results weren't as impressive as we anticipated. By changing the fuselage skin, the aircraft will only lose about 13.48 lbs., only enough to add an additional 1 1/3 gallons of SOLVITAL. Speaking of SOLVITAL, composites are not recommended when working with chemicals. Although it only costs about $679.68 to purchase a roll of carbon fiber, the added cost of engineering, application, and additional materials proved not to be feasible. Ultimately, the team decided against the idea of changing the fuselage skin from 2024 aluminum to carbon fiber-epoxy. Although there were weight saving and maintenance benefits, it wasn't significant enough to convince the team to make said change. Eventually, we decided that using the $100,000 was more beneficial in purchasing another aircraft, which will, consequently, double the productivity of our UAS operational system.

The application patterns were carefully examined as well. The team decided on choosing a pattern that consisted of two large UAS. The team came to a conclusion that one large sprayer would not prove efficient in terms of aircraft productivity and mission time.

2.4 Component and Complete Flight Vehicle Weight and Balance

Weight and Balance/ Components/ Fuselage Configuration

Red line indicates the CG



The team focused on selecting materials that had a low density in addition to containing high strength characteristics for continuity and reliability for the later years. We chose varying grades and sheets of aluminum for the frame as well as DIATEX fabric for coverings. Both materials proved to be feasible, strong, and light weight thus making it perfect candidates for our aircraft design. These decisions, however, were made after careful considerations.

Making the plane as aerodynamic as possible meant that there required a need to reduce the weight of the aircraft. We chose materials that have a high strength to weight ratio. The team wanted to ensure that the UAV would comply with the FAA weight limit of 1,320 lbs., so we searched and chose components and materials that would make our aircraft lightweight but strong.

The fuselage is comprised of mainly aluminum, with the exception of the engine cowling, which is made of composite material. It is a semi-monocoque structure made of 6061-T3 aluminum frames. In addition, the skin is comprised of 2024-T3 aluminum which is the basic building material for more than 59% of the fuselage. Equally important, the aircraft is powered by a reliable Rotax 912 ULS 100 HP engine. As a matter of fact, the engine is complimented with a Kiev-Prop propeller, an alternator and a battery. By the same token, our aircraft holds the following components which are listed as followed: a camera, airspeed sensor, C3 components, Onscreen Display and Data-logger, Autopilot, and the 900MHz Video System-High Power. In addition, our aircraft will also be equipped with a modified spray system, which includes the pump and various spray regulators. Not to mention, the spray boom will have an extendable function, which greatly enhances our ability to control spray drift.

The wings are also structurally made of aluminum, mainly 6061-T3 frames forming the ribs and the spars. However, the bottom half of the wing will be covered in DIATEX Fabric, a strong, durable fabric that the Foxbat comes with. On the other hand, the upper half of the wing will be covered in 2024-T3 aluminum. In addition, the wings

No.	Weight Category	Component	Sub-Category	Weight (lbs)	Fuselage Station (inches)	Moment (lbs-inches)
1	Power Plant					
		Rotax Engine		125.00	20.64	2580.00
		Fuel Tank		66.28	67.00	4440.76
		Alternator		8.00	9.00	72.00
		Batteries		3.00	33.84	101.52
		Propeller		10.00	4.92	49.20
2	Tail Section	Elevator		5.28	243.00	1283.04
		Rudder		2.70	240.00	648.00
		Horizontal Stabilizer		14.15	232.56	3290.72
		Vertical Stabilizer		10.56	240.00	2534.40
3	Landing Gears			10.00	60.00	600.00
4	Wing & Components	Wing		160.50	86.40	13867.20
		Wing Actuators (4)		7.80	99.60	776.88
		2 Antennas		0.80	208.00	166.40
		Rudder Actuator		1.95	220.80	430.56
		2 Horizontal Actuator		3.90	231.60	903.24
		Push Rods		1.95	96.00	187.20
		Spoilers		15.70	68.00	1067.60
5	Fuselage & Components	Fuselage		160.50	123.00	19741.50
		Camera		2.00	15.00	30.00
		C3 Components		0.34	163.20	55.49
		Airspeed Sensor		0.01	16.00	0.16
6	Spray Equipment					
		Pump		18.00	95.40	1717.20
		SOLVITAL Tank (Body)		296.52	54.00	16012.08
		SOLVITAL Tank (Wing)		303.50	65.00	19727.50
		Spray Boom (Nozzles)		14.21	136.80	1943.93
Total Weight (lbs)				1242.65	2829.76	92226.58
C.G Location from the nose of the aircraft (inches)						74.22

will contain the following components, the SOLVITAL wing tanks, and two linear actuators on each wing to move the flapperons and spoilers. The SOLVITAL wing tanks have a capacity of 15.25 gallons each. In as much, our SOVLITAL tanks have been modified from the original fuel tanks to ensure our aircraft stay within the CG limit.

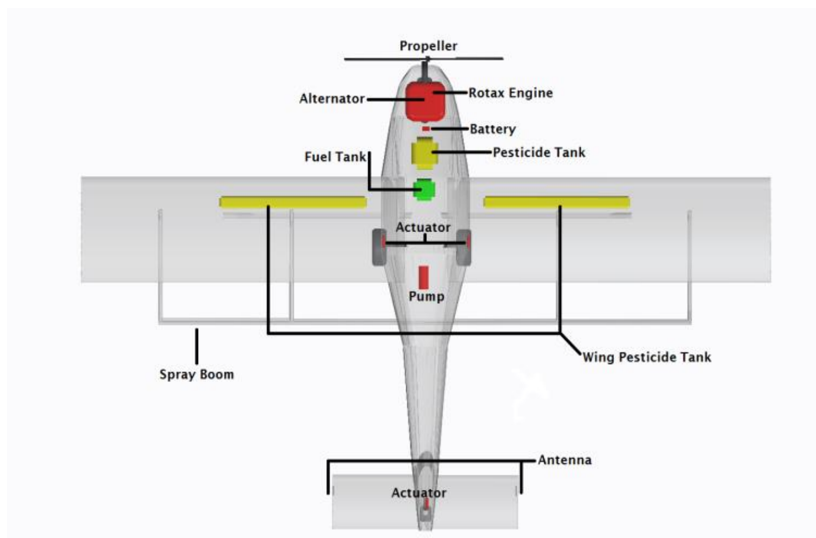
The empennage has a similar composition to the wings. All of the components in the empennage are structurally made of 6061-T3 Aluminum. The skin of the flight controls (the elevator and rudder) are covered by DIATEX Fabric. Likewise, the horizontal and vertical stabilizers are covered by 2024-T3 aluminum.

Thus, based on the calculations made by the team and the "Weight and Balance" worksheet, the final weight of the aircraft is 1,242.65 lbs.

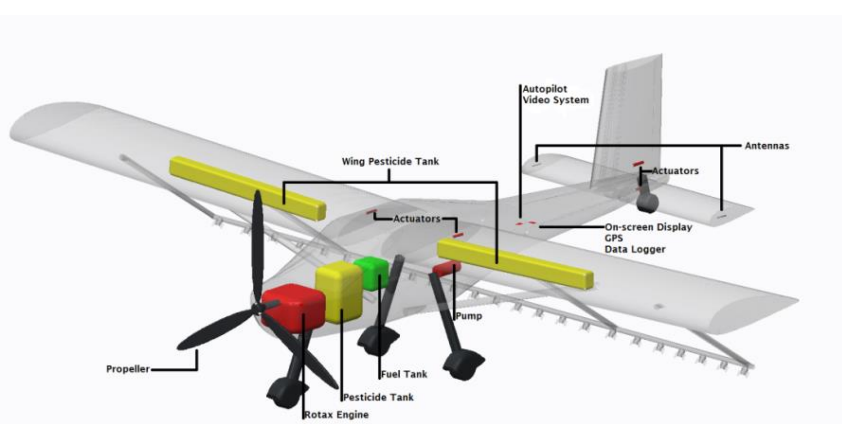
Additionally, the "Weight and Balance" worksheet also greatly assisted in determining our center of gravity (CG). According to the Aeroprakt Manual, the optimal CG range 19-37% of the mean aerodynamic chord (MAC), or 68.64-79.4 inches from the datum line. As a result, the worksheet determined our CG to be at 74.22 inches from the datum line or about 25% of the MAC.

2.5 Design Analysis

Figure 16: Plane Components



Based on the team's thorough analysis, our final UAS system complies with the design requirements listed in design variables, UAS constraints, and assumptions in the background information. The team thoroughly analyzed the UAS system to ensure that it complies with the restrictions given in the National Challenge. The Foxbat A22-LS was the optimal choice for this mission due to its exceptional abilities. The following are its characteristics: a high-wing displacement, high payload capacity, and a semi-monocoque aluminum structure. It is constructed out of aluminum, making it lightweight and durable. Our trailer will be multifunctional, allowing a workspace for the crew and our equipment as well as housing extra pesticide mixture tanks. The flight controls and the lower surface of the wing are covered with DIATEX fabric, which makes it lighter and easy to repair. Because of the large size and weight of our aircraft, the UAV will be equipped with tricycle landing gears sand must take off from a flat surface. However, because of the Foxbat's design, it will have a low take-off and landing roll



of about 250 feet. Additionally, to protect the empennage from pitching off during the plane's takeoff, the plane is equipped with a tail wheel.

The flight controls will be controlled with the autopilot, by which the mission will be ultimately carried out. The autopilot is programmed with waypoints and data on the level of infestation. The aircraft will be controlled by flapperons, a rudder, elevators, and spoilers. The first three flight controls are necessary to control our aircraft during flight. The spoilers were added in order to help our aircraft slow down before it executes its turns in mid-flight. Additional control equipment that will be used are the following: PC (laptop), hobby-grade remote control (R/C) radio, data transceiver set (900 Mhz)-high range, YAGI Directional Antenna (900hz)- Ground Based, Additional LCD Display, Data Transciever Set (900 Mhz)- High range, 900 Video System- High Power (1500mW), and a Global Positioning System (GPS) sensor. Our antenna, processor, controllers, and displays cover all system's needs in order to complete the mission. Inside the horizontal wing is the linear electric actuator. In the vertical wing is one linear electric actuator.

The team designed a unique spray system for this mission. The pump was selected after consulting our mentors and discussing the specific spray configurations we will need. The spray boom was designed by our own design and simulation engineers. It is designed it to extend, which will be the solution to our spray drift situation. Additionally, it will have four support beams to attach the boom to the wings of the aircraft. It will be holding 24 nozzles, which will be used to spray the SOLVITAL pesticide. Our total SOLVITAL capacity is 61 gallons. Half of it will be placed inside the fuselage, and the remaining half will be evenly distributed in the wings.

Attached to the spray boom will be the Guardian Air 110-03 nozzles, each evenly spaced out by 12 inches with 9.6 inches of spacing between two middle nozzles. Along with the pump and main electrical system, the nozzles will be spraying specific amounts of pesticide depending on the infestation level of the crop, further explained in the example mission. The plane will be spraying pesticide at 100 miles per hour in a lawnmower pattern.

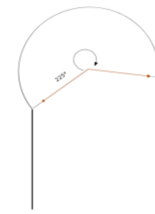
By utilizing the camera footprint calculator provided in the FY14 challenge, the team was successful in calculating our camera capabilities during the execution of our lawnmower application pattern. The use of two large sprayer aircraft was the most efficient choice in terms of cost and coverage. Our innovative UAS will be equipped with the M1-D thermal and CCTV imaging camera, which will be used while the aircraft is airborne at 100 mph.

Having sweet potatoes as our selected crop, the ground-control personnel are able to maintain a visual line-of-sight on the UAV. The antennas will be placed on the horizontal wing, one on each edge. They will be separated at about 96 inches, which is over the minimal requirement of 18 inches separation. This will prevent any destructive interference.

The team has created a contingency response in the possibility of problems within the UAV system might occur. In the event of such happenings, spraying will automatically be stopped. Flight control wills be shifted to manual mode, in which the ground-control pilot will fly the UAV back to base. Once at the base, the on-sight dual-qualified technicians will troubleshoot any problems within the UAV.

2.6 Operational Maneuver Analysis

The UAS is controlled by a computer in which the flight path is inputted. During the flight, the UAS will distribute the pesticide using 24 spray nozzles according to the amount that is needed for the infested crop area. Aerial pesticide spraying is accomplished by applying the amount that is needed at a specific point in a field, which is a process known as precision agriculture. This, in turn, contributes to saving money from unnecessarily overusing resources while at the same time reducing the amount of runoff that could flow into nearby rivers and streams.

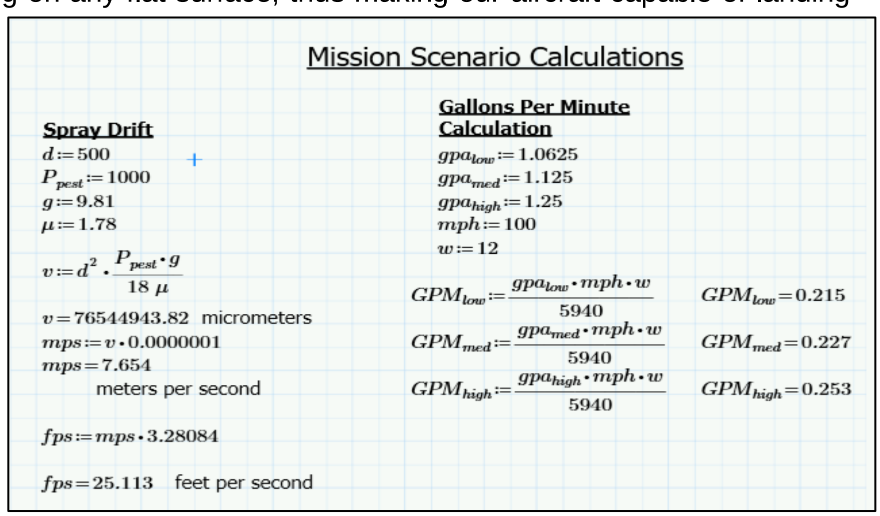


The Skywalker will be applying pesticide on the infested crop areas following a lawnmower pattern. When the point comes in which the aircraft has to make a turn, its airspeed will decelerate to 12 miles per second, and so on until the aircraft reaches to a speed of 55 miles per hour. The aircraft will then perform a 225 degree turn, along with a turn radius of 167.9 feet. Upon performing the turn, the aircraft will accelerate back to its original speed of 100 miles per hour.

The aircraft's takeoff and initial climb will be followed by a straight and level flight 10 feet above the sweet potato crop canopy. Maintaining straight and level flight over the crop canopy is one of the major factors of precision agriculture spraying. The team will utilize the forces of weight, lift, drag, and thrust as they cancel out to some degree in order to maintain straight and level flight, with the compensation for horizontal stabilizers. During flight, several operations within the aircraft will be made as the weight of the aircraft will change due to the spraying of pesticide and the use of fuel. The aircraft will be re-trimmed during flight as it changes its thrust and lift to maintain balance. While the aircraft disperses pesticide, its constant direction, altitude, constant speed, wings level, and balance of the aircraft will be carefully monitored.

The original A-22 Foxbat is capable of landing on any flat surface, thus making our aircraft capable of landing outside the field area during precision spraying applications. Similar to the field shown above with the A-22 Foxbat, our aircraft will be performing short take-off and landings on the high-lift wing, providing big safety margins on short air-strips.

In regards to the overall mission scenario, the team calculated the anticipated spray drift and gallons per minute using MathCad.



Mission Scenario Calculations

Spray Drift

$d := 500$
$P_{pest} := 1000$
$g := 9.81$
$\mu := 1.78$

$v := d^2 \cdot \frac{P_{pest} \cdot g}{18\ \mu}$

$v = 76544943.82$ micrometers
$mps := v \cdot 0.0000001$
$mps = 7.654$
meters per second

$fps := mps \cdot 3.28084$

$fps = 25.113$ feet per second

Gallons Per Minute Calculation

$gpa_{low} := 1.0625$
$gpa_{med} := 1.125$
$gpa_{high} := 1.25$
$mph := 100$
$w := 12$

$GPM_{low} := \frac{gpa_{low} \cdot mph \cdot w}{5940}$ $\quad GPM_{low} = 0.215$

$GPM_{med} := \frac{gpa_{med} \cdot mph \cdot w}{5940}$ $\quad GPM_{med} = 0.227$

$GPM_{high} := \frac{gpa_{high} \cdot mph \cdot w}{5940}$ $\quad GPM_{high} = 0.253$

Our flight operations will be determined by these two important factors.

The following are Mathcad calculations on the aircrafts' deceleration rate, wing deceleration, and take off speed.

Deceleration Rate

$v_f := 55$

$v_i := 100$

$t := 5$

$$d := \frac{v_f - v_i}{t}$$

$d = -9$ miles per second

Wing Deceleration Calculation

With spoilers and flaps (drag)

$Cd_{NACA} := 0.02615$

$A := 8.306$

$p := 1.2754$

$V := 44.704$

$$D := Cd_{NACA} \cdot \frac{p \cdot V^2}{2} \cdot A$$

$D = 276.804$

$drag := D \cdot 0.2248$

$drag = 62.226$ pounds-force

With spoilers and flaps (lift)

$Cl_{NACA} := 1.258$

$A := 8.306$

$p := 1.2754$

$V := 44.704$

$$L := Cl_{NACA} \cdot \frac{p \cdot V^2}{2} \cdot A$$

$L = 13316.244$

$lift := L \cdot 0.2248$

$lift = 2993.492$ pounds-force

Take Off Speed Calculations

Without flaps down

$L := 1320$

$Cl := 0.554$

$P := 1.2754$

$A := 8.306$

$$V := \sqrt{\frac{2\,L}{Cl \cdot P \cdot A}}$$

$V = 21.209$

$V_{mph} := V \cdot 2.23694$

$V_{mph} = 47.444$

With flaps down

$L := 1320$

$Cl := 0.554$

$P := 1.2754$

$A := 9.43071$

$$V := \sqrt{\frac{2\,L}{Cl \cdot P \cdot A}}$$

$V = 19.905$

$V_{mph} := V \cdot 2.23694$

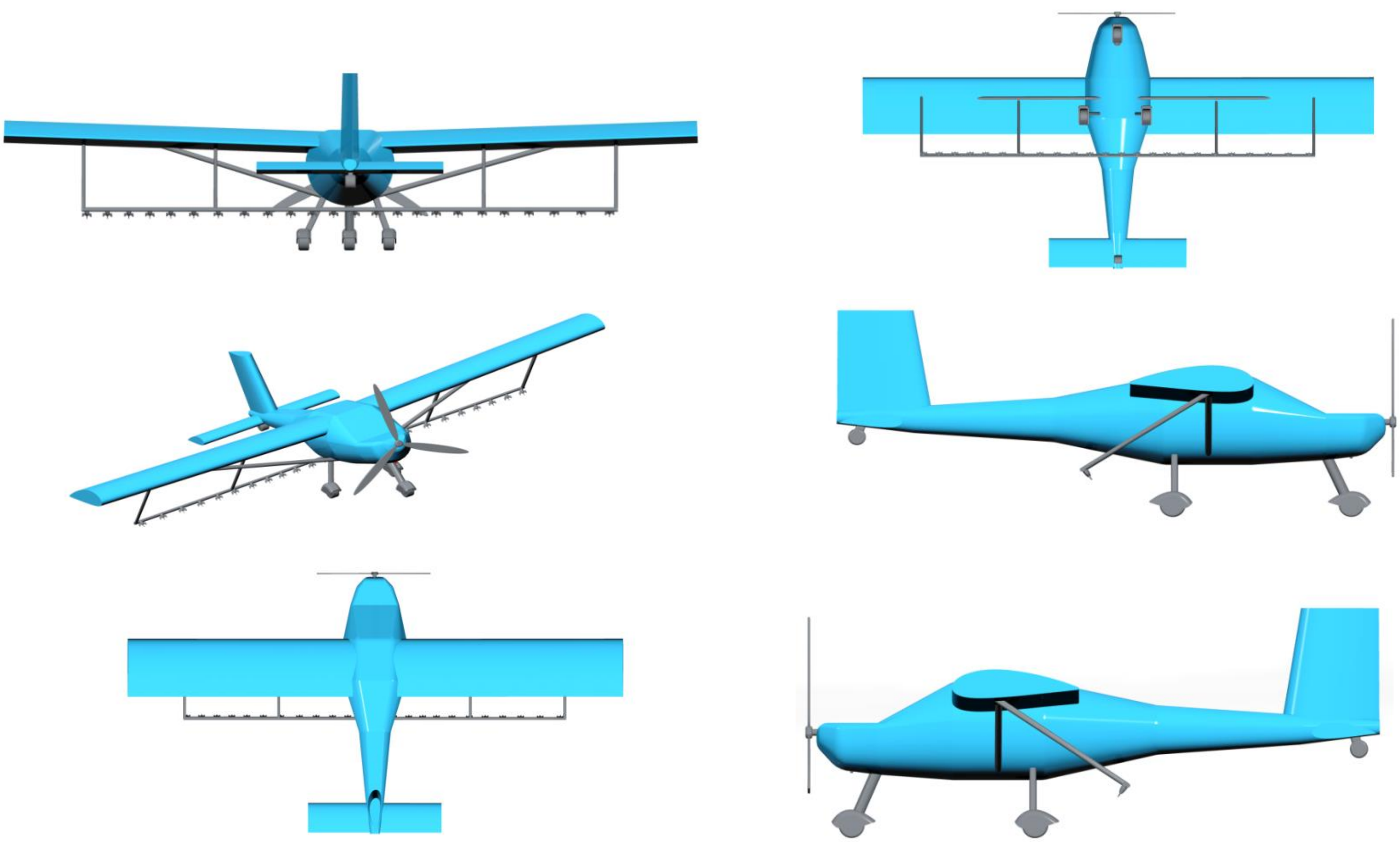
$V_{mph} = 44.525$

V=velocity
L=lift
Cl=Coefficient of lift
P=Air density
A=Area (wings)

Formula

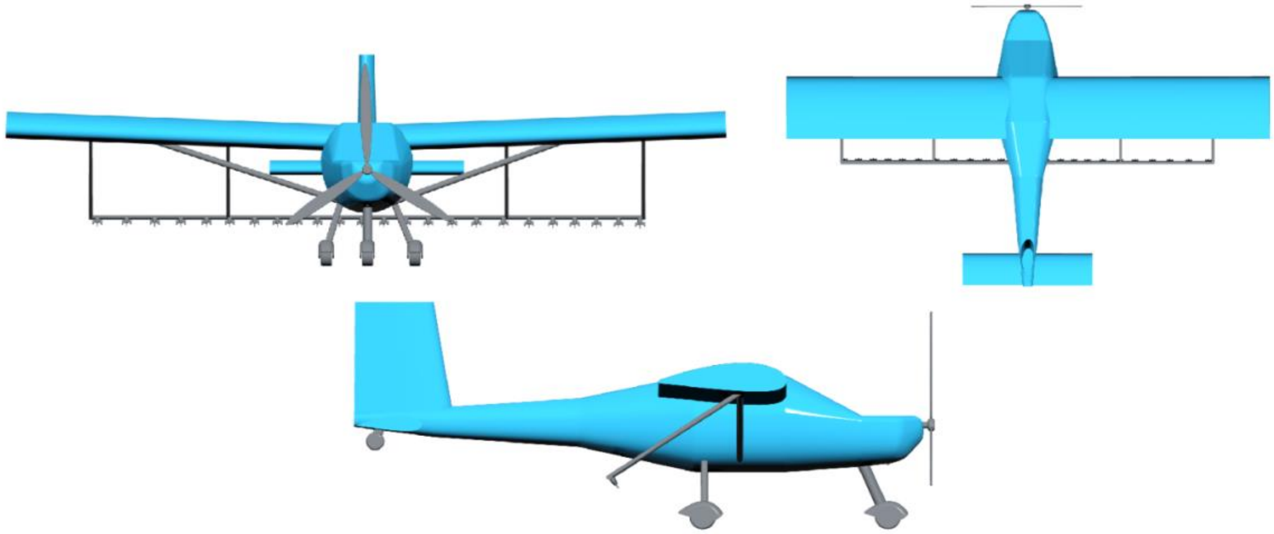
$$V := \sqrt{\frac{2\,L}{Cl \cdot P \cdot A}}$$

2.7 CAD models



2.8 Three View of Final Design

The following, Figure 7, depicts the three view of the final unmanned system design.



.

Figure 17. Three View of Final Unmanned System Design

Full Aircraft Dimensions:

Fuselage:

- Length: 20.5 feet
- Greatest Height: 7.87 feet
- Greatest Width: 3.8 feet
- Least Height: 0 feet
- Least Width: 0.3 feet
- Wetted Area: 142.17 sq. feet
- Weight: 235 lbs.

Wing:

- Planform Area: 151.536 sq. feet
- Aspect Ratio: 23.5774~
- Taper Ratio: 1
- Sweep: 3% forward sweep
- Dihedral: 5 degrees
- Wing Incidence: 6 degrees
- Wing-Root leading edge location: 5.256 feet
- Wing Span: 31.4 feet
- Semi Span: 15.7 feet
- Root chord including LE and TE/ Flapperons: 4.952 feet
- Tip chord including LE and TE/ Flapperons: 4.592 feet
- Mean Aerodynamic Chord: 4.592 feet
- Wing thickness/ chord: 0.96432 feet

Tail Type: Conventional

Horizontal Tail Wing:

- Planform Area: 21.915 sq. feet
- Aspect Ratio: 3.0581~
- Taper Ratio: 1
- Horizontal stabilizer area: 21.915 sq. feet
- Horizontal tail thickness/chord: 0.5621 feet

Vertical Tail Wing:

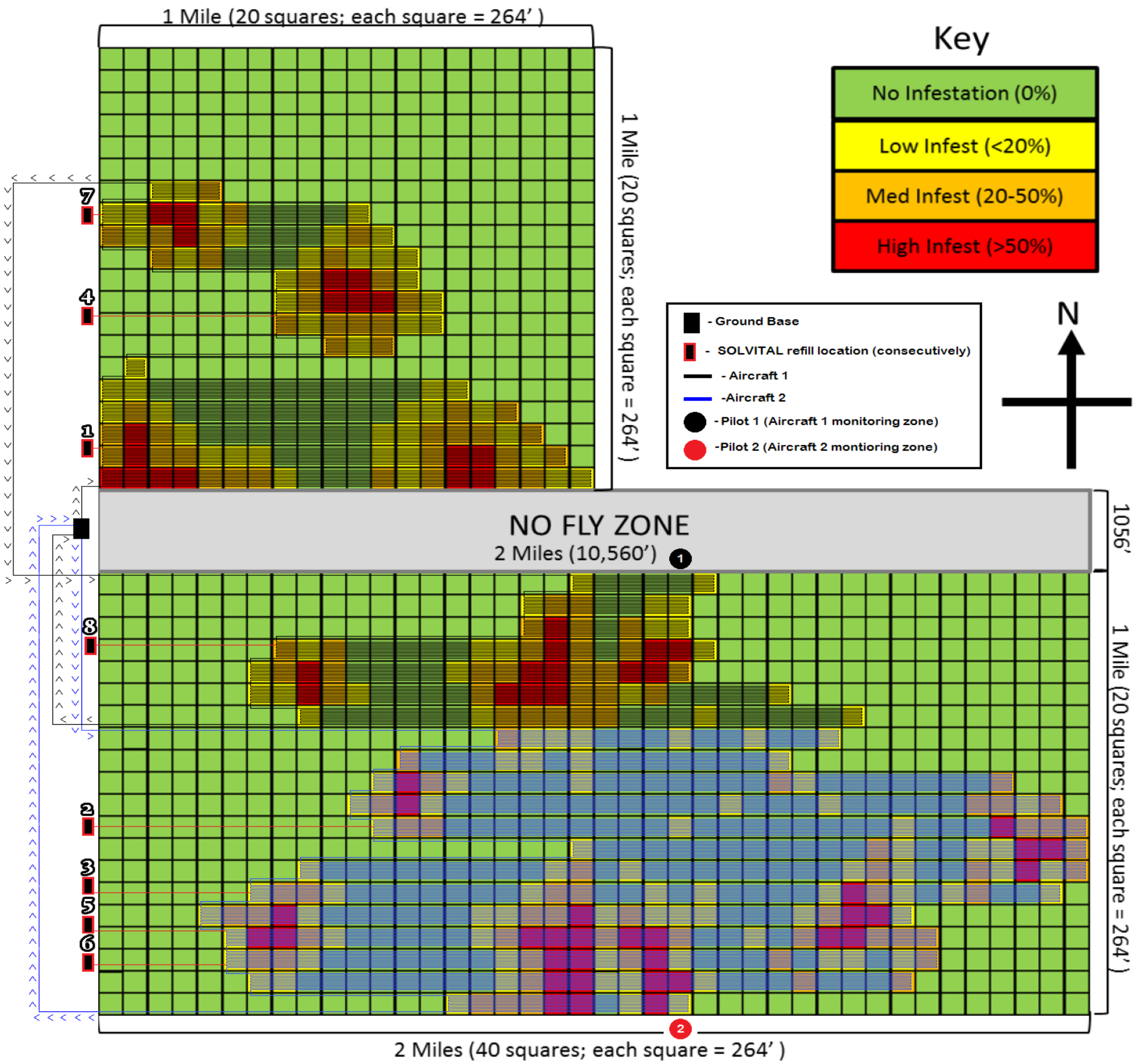
- Planform Area: 7.1310 square feet
- Sweep: 0
- Tip chord length: 2.336 feet
- Aspect Ratio: 2.7753~
- Taper Ratio: 0.579~
- Water line: 5.84

Airfoil: NACA 4421

- Thickness of LE: 0.3769 feet
- Thickness of TE: 0 feet
- Tip root of LE: 0.0565 feet
- Tip root of TE: 0 feet
- Constant Chord: 4.592 feet
- Sheeting: 0.03 in.
- Thickness (Highest): 0.9643 feet
- Angle of attack: 5.54 degrees

3. Document the Application Plan

3.1 Crop Application Pattern



MAIN APPLICATION PATTERN

In addition to it being a traditional crop, sweet potatoes are of regional importance in the Northern Mariana Islands as it is the main source of income for numerous farmers. Being a tropical island, sweet potatoes are grown year-round in the CNMI. Farmers' products are distinctly disturbed by common pests such as sweet potato weevils, potato aphids, and wire worms. As Saipan is relatively smaller than areas in the United States, the team has manipulated its largest sweet potato crop field into that of the 1 x 1 and 2 x 1 mile fields depicted above. Later specified in the example mission, the aircraft will spray specific amounts for the following levels of infested areas per acre: low infestation (20% or less), medium infestation (20-50%), high infestation (greater that 50%), and no pesticide on the non-infected areas. Sweet potatoes grow best in warm temperatures, making the most accurate time to carry out operations during the month of July when island temperatures rise. With the input of farmers from the Department of Natural Land Resources, our system will be conducting applications during the daytime and late afternoon. This is the time when insects are most active. Applying pesticides on hot, sunny days lead to rapid drying and reduced pest control.

Unmanned aircraft systems extend human potential and will allow us to execute dangerous or difficult tasks safely and efficiently, saving time, money and most importantly lives. There are also several advantages of a UAS, one being that there will be no pilot on board thus contributing to weight and cost saving. We can determine the right amount of pesticide that is being distributed rather than a farmer manually spraying the pesticide. How will one know if it is enough? With the use of UAS, we control the system so we are able to know the sufficient amount that is needed for the infected area.

Our main application pattern will consist of our two large sprayer aircrafts spraying the infected areas of the field following a lawnmower pattern. By managing the amount of pesticide dispersed in each infected area, we are able to achieve a significant reduction in the volume of pesticide and application cost, as well as improving productivity towards the conventional approach. This, in turn, will demonstrate drastic improvement towards the end profitability of our business case.

This application pattern is the most tenable pattern amongst the previous patterns the team generated. Furthermore, this pattern has proven to show that it is time efficient as well as productive when it comes to executing the allotted mission. In terms of efficiency, our plane is equipped with detachable nozzles which allow the SOLVITAL to be applied in hard to reach areas. Thus, our planes will apply SOLVITAL to both fields (1x1 & 2x1) simultaneously which will decrease our mission time in addition to providing the opportunity to complete more missions during the process. In essence, productivity in the field of marketing will significantly increase.

Unlike the previous patterns, our ground base is located in the most practical area. This area allows both planes to have an equal start off point, which minimizes the thru-flight time needed to replenish on SOLVITAL and fuel. Using a two plane system has proven to be the most feasible and time efficient strategy. Utilizing only one UAS resulted in a longer mission time and underutilization of human and operational resources.

The “No Fly Zone” was the driving factor that led the team to add another large sprayer to our system. The use of two aircraft allows a better utilization of personnel. With the base being located in the middle of both fields (outside the No Fly Zone), our personnel will have easy access throughout the mission phase.

The starting point is placed in the middle of the area between the 1x1 field and the 2x1 field. This is a crucial factor that affects not only the productivity of the mission but the overall mission outcome. Because the ground base/starting point is located in the middle area, both planes will have a uniformed take off along with an effective thru-flight.

The total time it takes to complete a turn is 10 seconds; the first aircraft will complete 252 turns and the second aircraft will complete 156 turns. This equals a total of only 408 turns for the entire mission.

Because our plane is equipped with detachable spray nozzles, the configuration can be adjusted to allow the SOLVITAL to be sprayed in different areas with precision. Due to the imposed 11-knot wind that blows from the west side of the mission scenario, our plane was designed to fly into (headwind) and away from (tailwind) the wind, hence we calculated the spray drift and adjusted our nozzles to a specific angle so that the spray drift will accurately bring the SOLVITAL within the targeted location.

SOLVITAL Refilling Scenario

In the case wherein one of the planes requires a SOLVITAL refill, that plane will directly fly over the field and land in our designated landing zones. It will rendezvous with the mobile thru-flight station. After the service is completed, the planes will again take off and fly directly over the field back to the position it left off, resuming the mission.

Mission Complete Scenario

Upon completion of applying SOLVITAL to the infested areas, the aircraft will exit the field by directly flying over it. Once it reaches its designated landing area, the planes will land and be taxied to the ground base. Due to the signal interference that could occur between the two planes, there will be a separate finishing point in the mission that will allow the planes to separately exit the field. However, in the event that the one-mile separation is compromised, the planes can be towed together safely back to ground base as a viable alternative method.

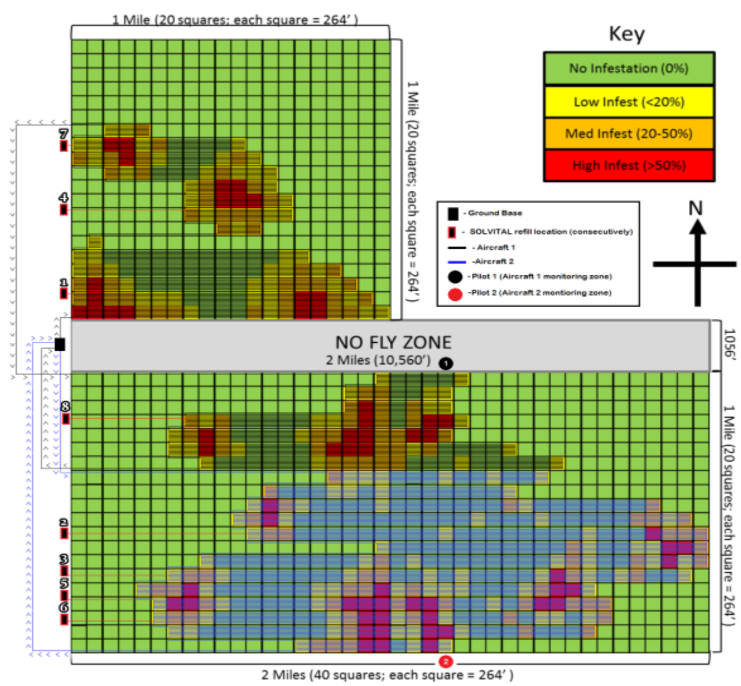
Taxi Scenario

This scenario only applies to the first aircraft when it is finished applying SOLVITAL to the 1x1 field. When the first aircraft finishes the 1x1 field, the second plane will still be applying pesticide on the 2x1 field. The first plane will leave the 1x1 field and taxi into the 2x1 field, where it will join the second plane in completing the application of SOLVITAL to the remaining infested areas.

3.2 Theory of Operation (Example Application)

Main Application Pattern

Depicted on the right is the main application pattern for the mission. The legend shows that the black box represents the ground base, the black and red boxes illustrate the SOLVITAL refill locations, and the black and blue lines represent aircraft 1 and aircraft 2. The ground base is located in the middle

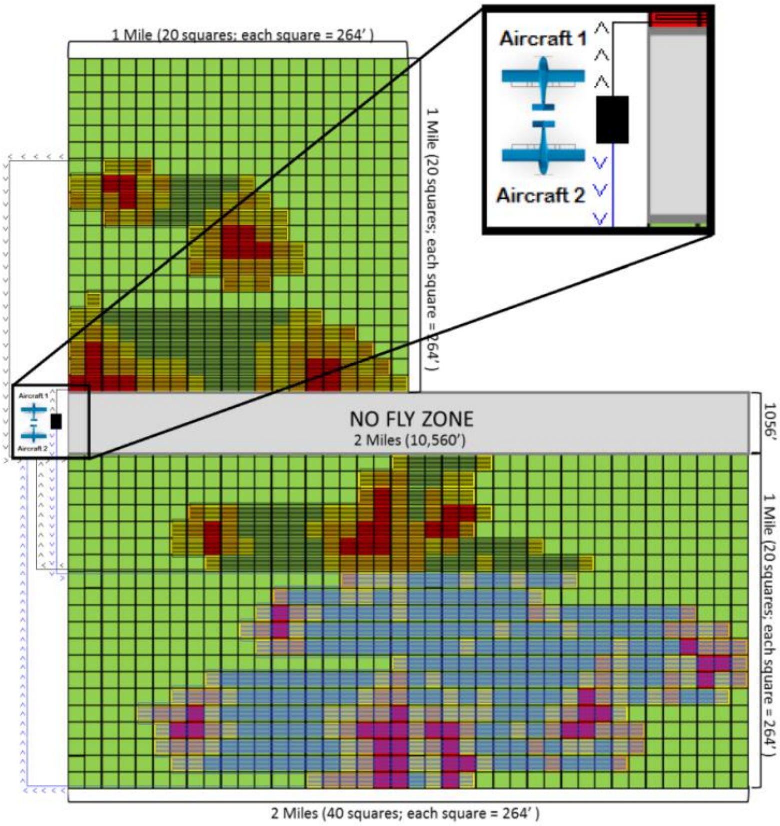


MAIN APPLICATION PATTERN

section of the scenario between the 1x1 and 2x1 field, alongside the no fly zone. Hence, the planes will have a separate take-off direction. The first plane will attend to the 1x1 field while the second plane attends to the 2x1 field, each starting from the point indicated in the application pattern. Both planes will take off simultaneously and enter their targeted field. Upon arrival on the mission area, the planes will fly at an altitude of 10 feet and accelerate to a maximum speed of 100 mph, which is 146.6667 feet per second. Furthermore, the planes will fly and spray SOLVITAL following a lawnmower pattern. The planes will spray a high concentration of SOLVITAL on the high level infested areas, medium concentration on medium level infestations, low concentration on the low level infestations, and no SOLVITAL on the no-infestation zones. For further clarification, the planes will take off at 60 meters (197 feet) at a speed of 45.6 mph. It will take approximately 7 seconds for the aircraft to take off and climb to its altitude level of 10 feet, where it will maintain its altitude and accelerate to a speed of 100 mph. When the aircraft takes off, it will first fly at an altitude of 15 feet where it will slowly lower its altitude to the mission height of 10 feet. Due to the 11-knot wind from the west side of the mission scenario, there will be an inevitable drift occurrence for the SOLVITAL. As a result, we changed our nozzle to the Guardian Air 110-03 which sprays at a range of 500-600 VMD (microns) to further reduce the spray drift. Thus, we were able to calculate the spray drift and adjusted the nozzles to accommodate the accurate spraying of SOLVITAL. The black and red rectangles represent the SOLVITAL refill location. In order to increase the aircraft's productivity, the team decided to make the SOLVITAL refill tanks mobile and drive to our projected landing areas. The aircraft will land and refill with SOLVITAL, which will take approximately 6 minutes. After refueling is completed, the aircraft will again take off and return to its previous location, resuming the mission. This strategy was developed to decrease time and increase productivity of the aircraft, unlike our state challenge strategy in which the plane flew all the way back to a stationary ground base for a thru-flight, wasting time and money. Finally, when the first plane completes its application of SOLVITAL to the 1x1 field, it will exit the field, land, and then taxi down to the 2x1 field where it will assist the second plane in applying SOLVITAL. However, due to the possible 1-mile signal interference restriction, we had to make the second plane started at a pre-determined point alongside the 2x1 field to prevent possible signal interference. Furthermore, the total time for the first plane to finish the 1x1 field is 2 hours and 54 minutes (174 minutes), and the interval time for the first plane to taxi down from the 1x1 to the 2x1 field is 2 minutes and 36 seconds. The total time to complete the application is 2 hours and 58 minutes (178 minutes), including all thru-flights.

Takeoff

Upon arriving at the mission field, the personnel will unload the trailer and prepare the aircraft for the mission. The set-up time will take approximately one hour. The challenge, however, assumes that we are already at the mission site. Once the equipment and personnel are in place and ready, the data collected by a detector aircraft regarding the waypoints of infestation on the field will be transferred to the sprayer aircraft's autopilot system. After all preparations are complete, the aircraft will remotely take off.

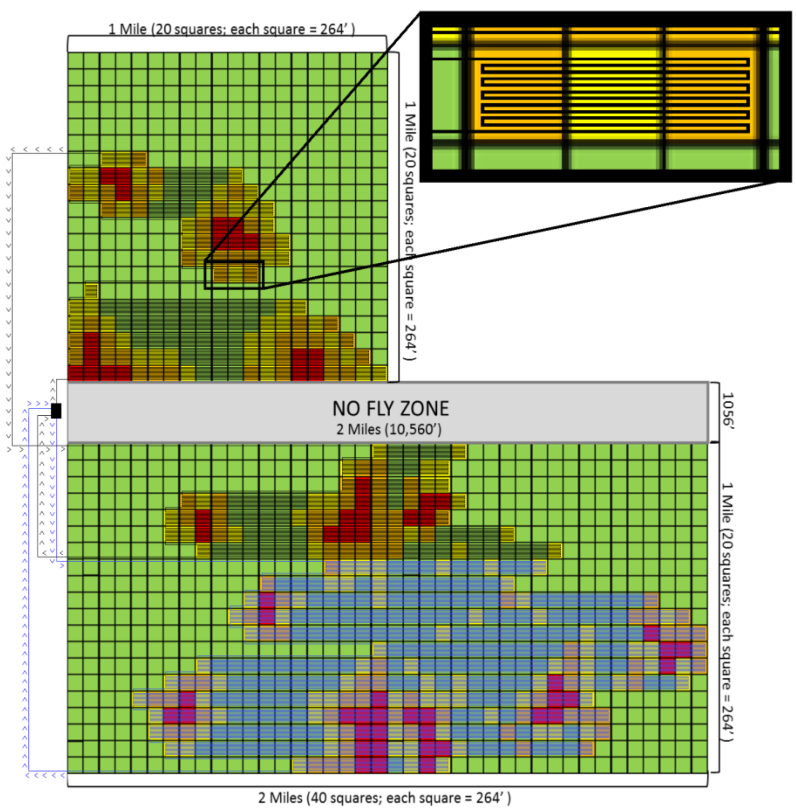


THIS PATTERN HAS BEEN MODIFIED FOR THIS SCENARIO ONLY

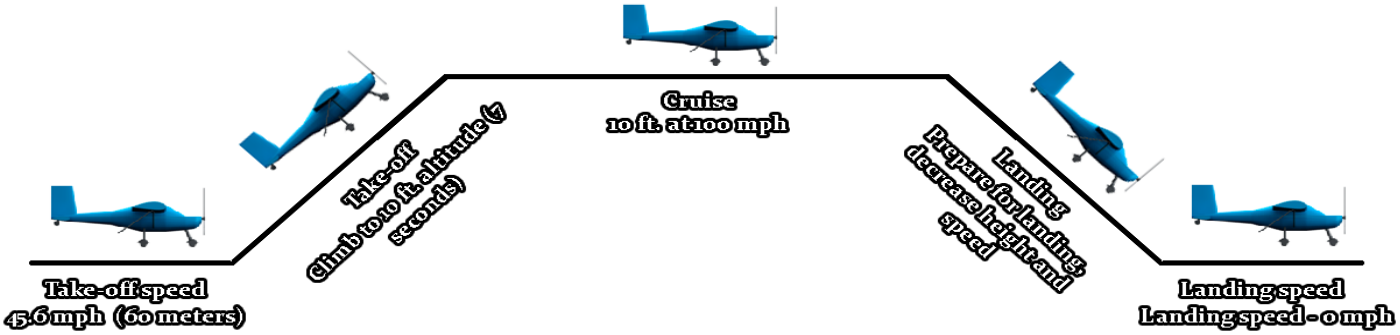
Depicted on the left is a detailed image of the take-off procedure for both aircraft 1 and aircraft 2. The ground base is located along the side of the mission fields, in the center next to the no fly zone. The 1st aircraft will take off at the top, indicated by the black route. Furthermore, the first aircraft will take off and proceed to the starting point of the field. Likewise, the second plane will take off from the bottom (indicated by blue lines) and will head towards its starting point on the field. Both planes will take off at 60 meters (197 feet) at 45.6 mph. Once each aircraft reaches its mission altitude level of 10ft while accelerating to 100 mph, it will begin spraying SOLVITAL pesticide on the targeted areas. The planes will take approximately seven seconds to climb to their respective spraying altitude of 10 ft. while accelerating to a maximum speed of 100 mph. After the aircraft takes off, it will switch to autopilot mode to commence with autonomous spraying of SOLVITAL.

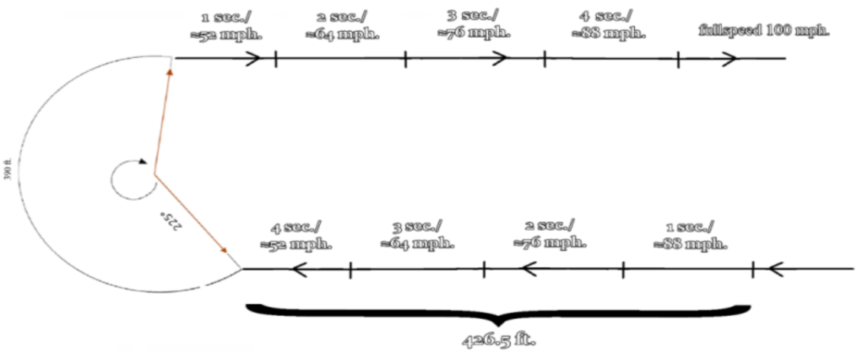
Turning

Depending on the level of infestation, the aircraft will spray more SOLVITAL in the high infestation areas, less on the low infestation areas and none on the uninfected areas. The aircraft needs to take at least 12 turns in each square to precisely cover the infested areas. Our aircraft will have a boom that contains 24 nozzles attached to it. The aircraft can accurately spray up to a swath width of 24 feet. In order to avoid as much turns as possible, the pattern was designed to allow the planes to fly in a long, straight forward horizontal motion. This is to ensure that the aircraft can systematically manage the precision application of SOLVITAL. Depicted on the right is a sample of the many turns that are to be executed in the mission scenario. The aircraft will fly and spray in a long side to side

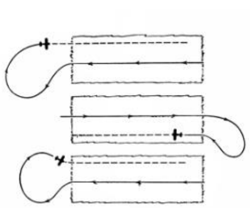


THIS PATTERN HAS BEEN MODIFIED FOR THIS SCENARIO ONLY motion with 12 turns in each square. This method ensures precision.

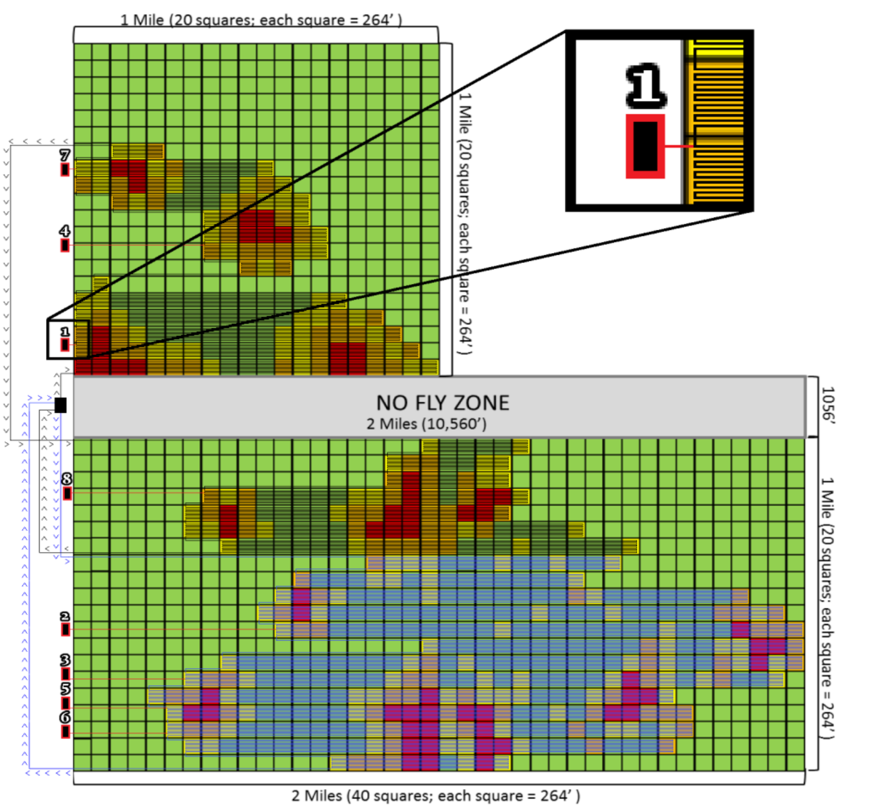




When the aircraft is required to make a turn, it will perform a 225° turn which will take approximately 10 seconds to complete. When it approaches 426.5 feet from the turning point, the speed of the aircraft will begin to decrease by 12 mph/second until it reaches the turning speed of 55 mph. Furthermore, it will take approximately four seconds for the aircraft



to fully decelerate from 100mph to 55mph. While doing so, the plane will maintain an angle of bank of 45° and a turn radius of 167.9 feet, while covering a total of 390 feet during the turn.

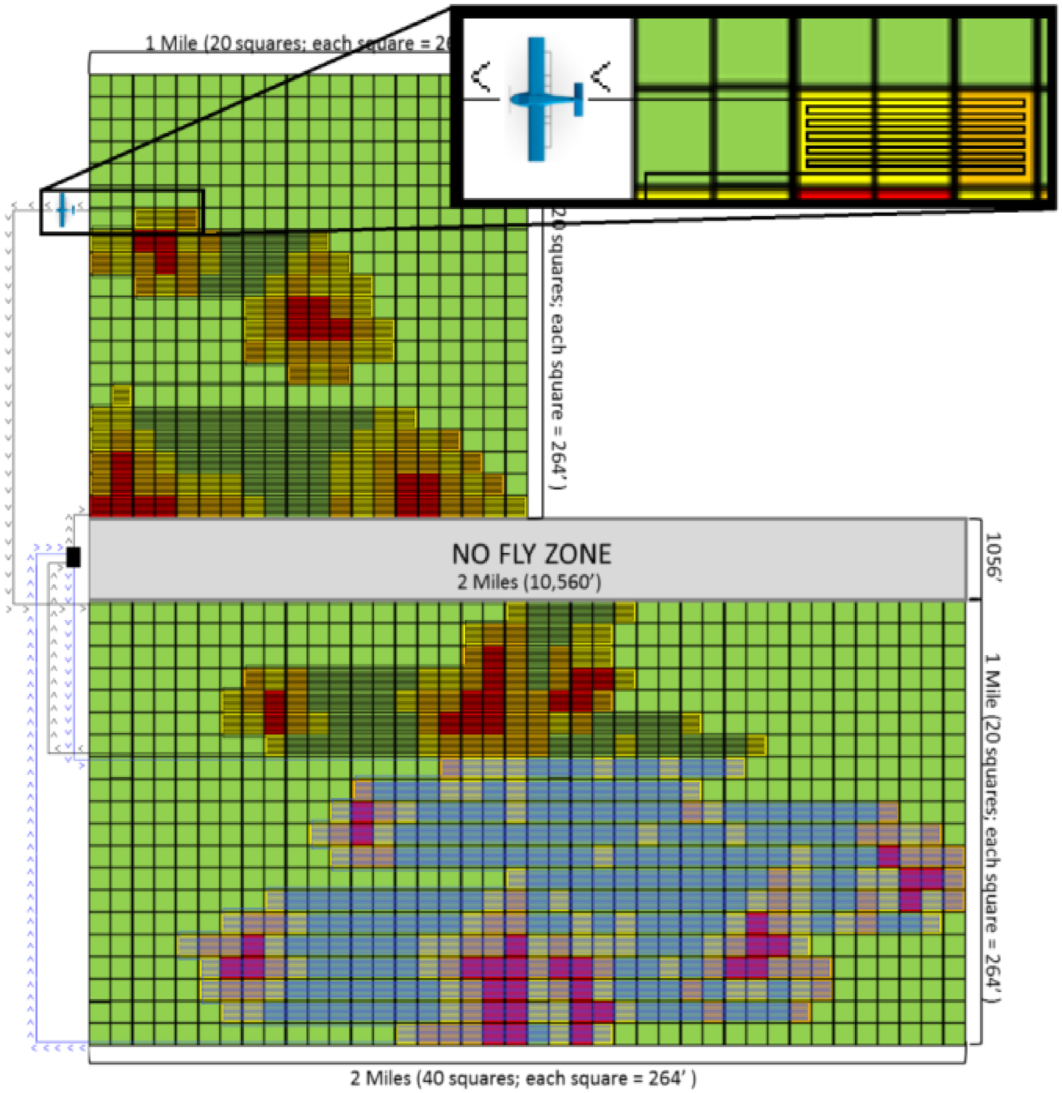


THIS PATTERN HAS BEEN MODIFIED FOR THIS SCENARIO ONLY

The first aircraft will complete 252 turns and the second aircraft will complete 156 turns, making a total of 408 turns for one complete mission.

Refueling

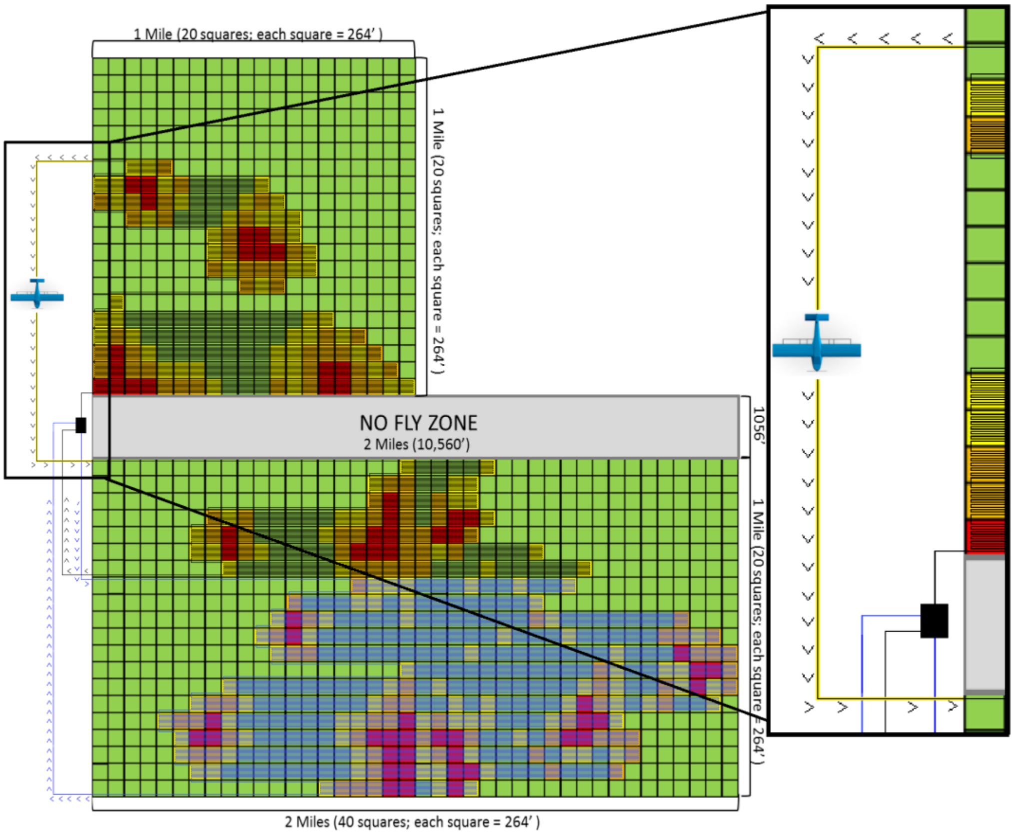
Illustrated on the left is one example of a SOLVITAL refuel location. Due to our limited SOLVITAL capacity of 61 gallons, the aircraft is required to return to its refuel location to replenish. A vehicle loaded with the SOLVITAL refueling tank will be waiting at projected landing locations. When the aircraft requires a SOLVITAL refill, the plane will directly fly over the field to the refuel location. Upon completion of the refill, the plane will once again fly directly over the field back to the location where it left off and resume its mission. The areas have been calculated by the team's mathematician and the SOLVITAL tank will systematically be at the projected location. The total turn-around time will be six minutes. As a result, once the aircraft is near the landing location, the pilot will switch to manual mode and will control the aircraft through the landing process. The plane will lower its speed and altitude until it arrives at its destination. The landing process will strictly be controlled by the pilot, which will take approximately seven seconds. Both aircraft 1 and aircraft 2 will have a total of four SOLVITAL thru-flights.



THIS PATTERN HAS BEEN MODIFIED FOR THIS SCENARIO ONLY

1 x 1 Mile Field Completion

To balance the area covered by both aircraft, the team decided to make the first aircraft assist the second aircraft in the 2x1 field after it completes its targeted application on the 1x1 field. When the first aircraft completes spraying SOLVITAL over the 1x1 field, it will exit the field as shown above. Furthermore, the plane will exit the field and land. Afterwards, it will taxi down to the 2x1 field where it will start assisting the second plane in applying SOLVITAL.



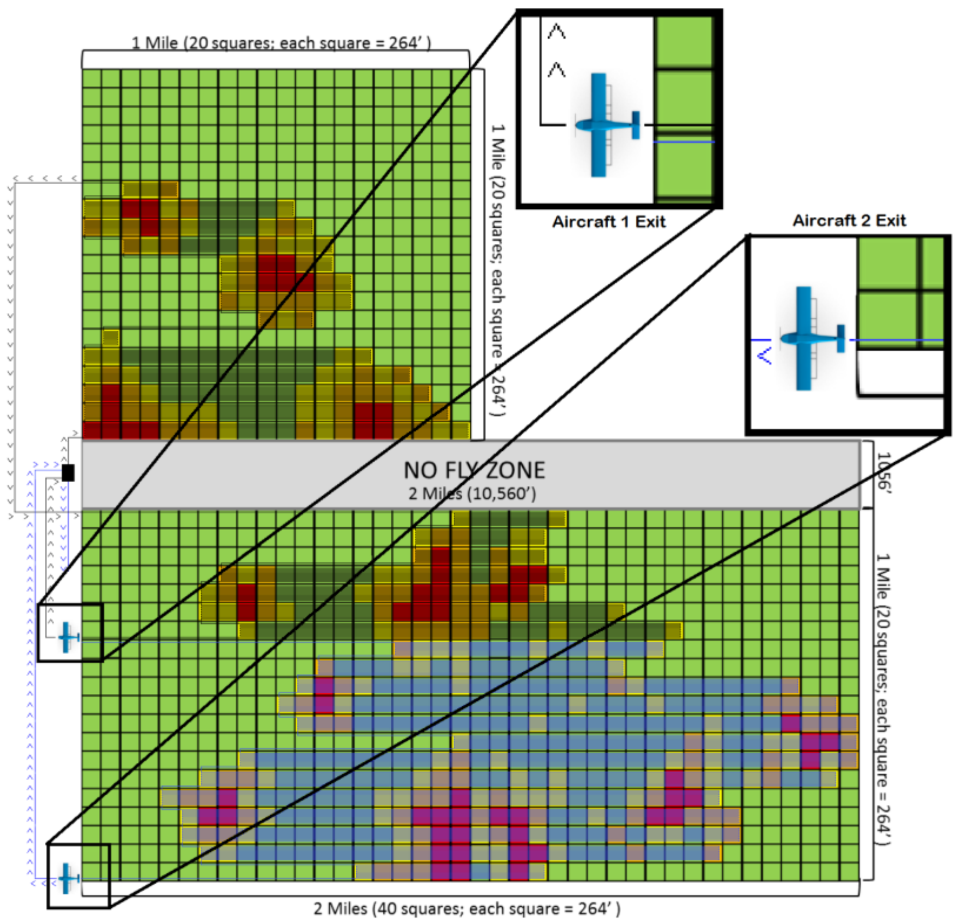
THIS PATTERN HAS BEEN MODIFIED FOR THIS SCENARIO ONLY

Taxi

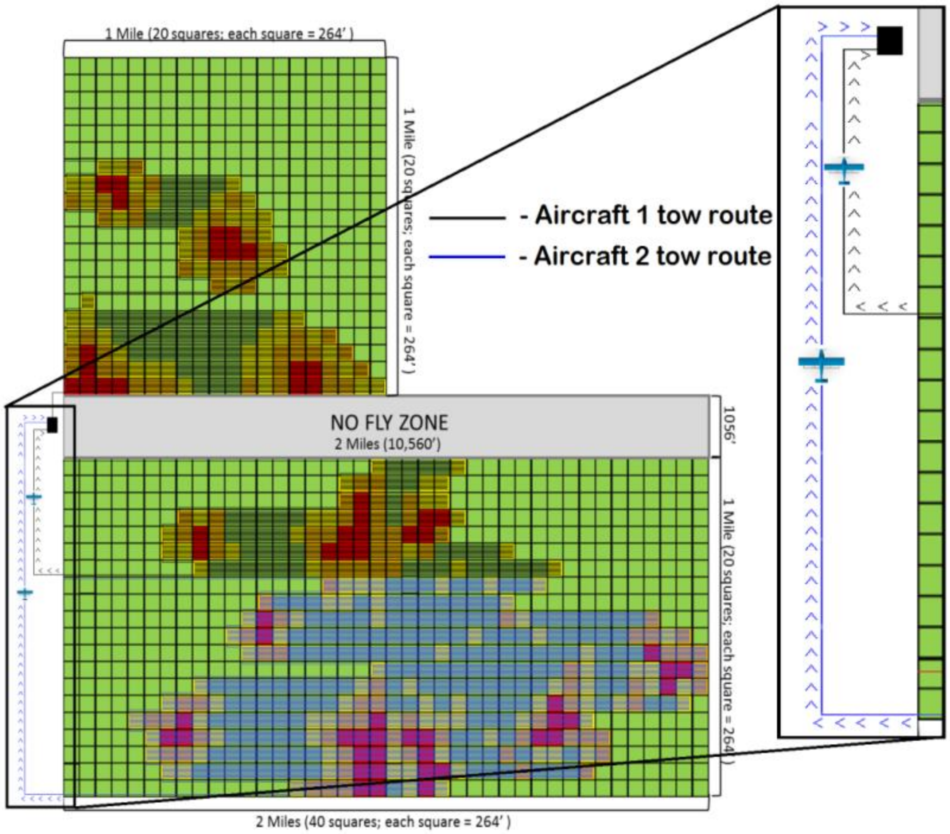
When the first aircraft exits the 1x1 field, it will land and taxi down to the 2x1 field as depicted on the left. Marked in yellow is the route that the first plane will take to arrive at the 2x1 field. When the first aircraft arrives at the 2x1 field, it will take off and assist the second plane in applying SOLVITAL to the 2x1 field. The total time it will take for the first aircraft to taxi down to the 2x1 field will be approximately one minute.

Separate exit

When the mission is complete, the planes will exit in separate locations to prevent signal interference. As demonstrated above, the first plane will exit the field and will be towed back to ground base. Likewise, the second plane will exit the field on the bottom of the 2x1 field as illustrated on the right. It will then be towed back to ground base. Aircraft 1 will complete its section of the mission before the second aircraft due to the time and coverage distance



THIS PATTERN HAS BEEN MODIFIED FOR THIS SCENARIO ONLY



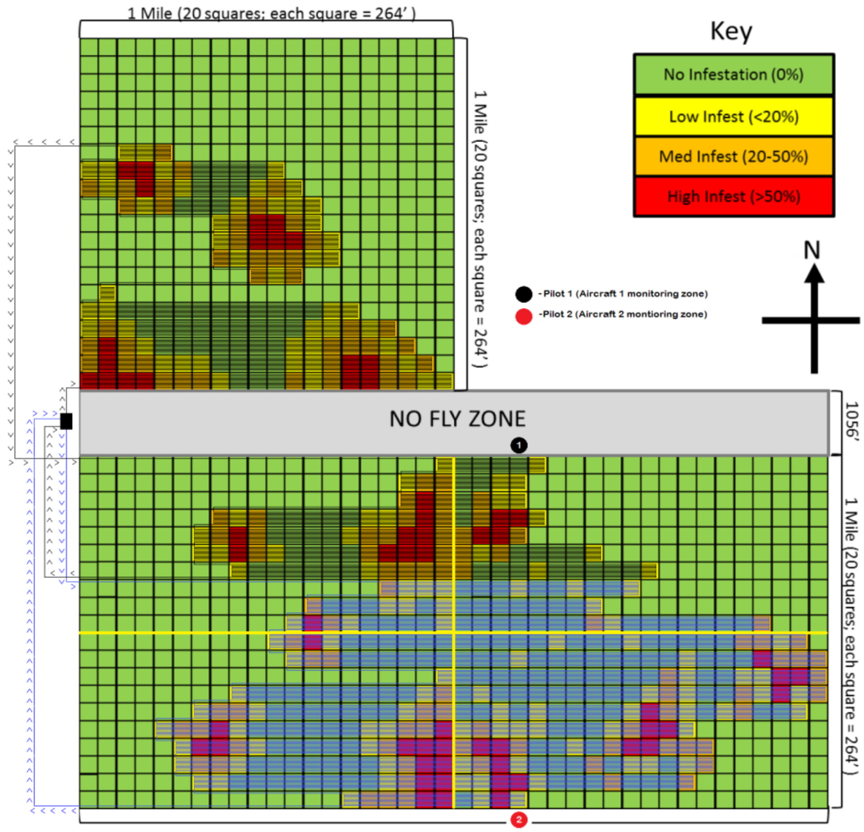
THIS PATTERN HAS BEEN MODIFIED FOR THIS SCENARIO ONLY

Tow

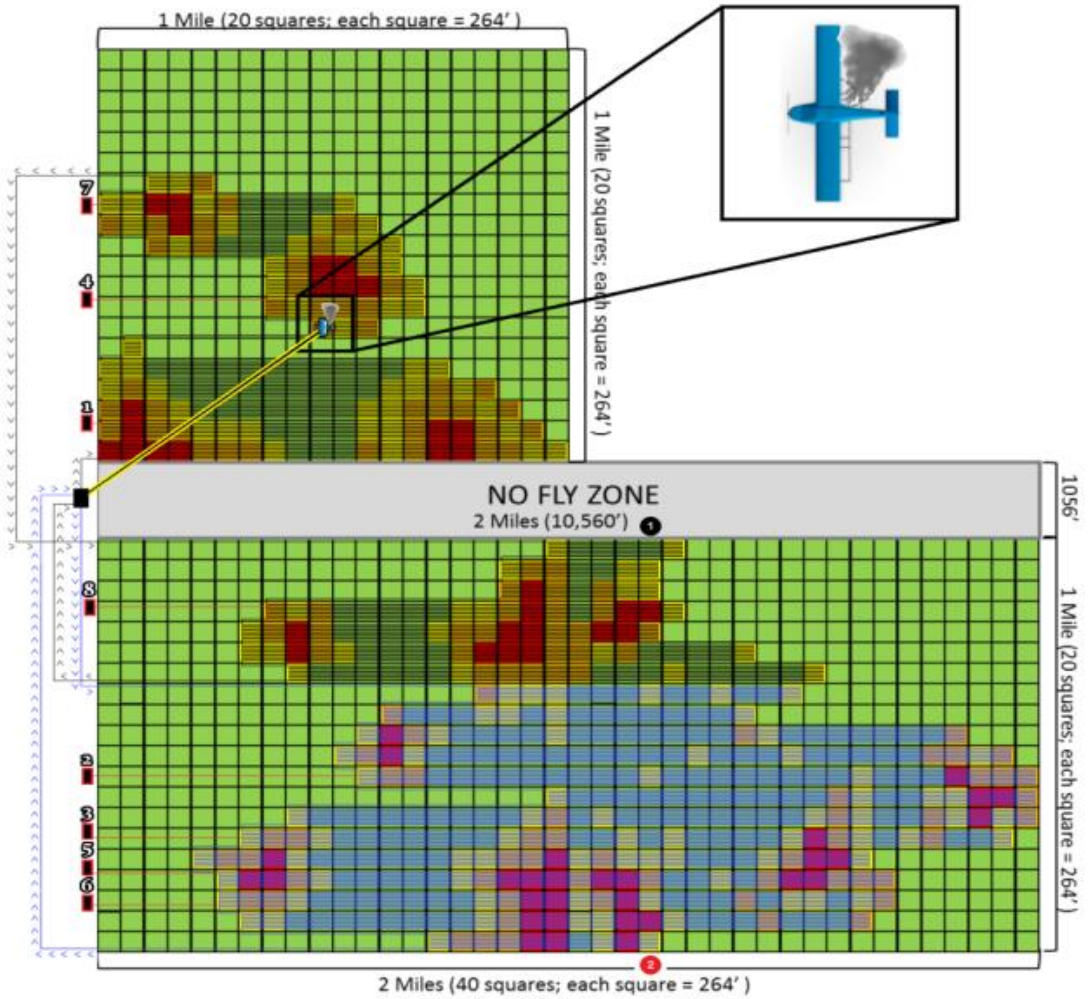
Illustrated on the left are the routes in which the aircraft will be towed back to base. Upon leaving the field after completing the mission, the planes will be towed back to base. Aircraft 1 will take approximately one minute to be towed to base while aircraft 2 will take approximately three minutes to do so. Since the aircrafts will be powered off, there will not be any signal interference. Hence, the planes can be towed together without any separation. The black line indicates the tow route of the first aircraft and the blue line indicates the tow route of the second aircraft.

Visual Line of Sight (1 mile)

Due to the required one mile visual line of sight that pilots have to maintain of the aircraft, the team decided to designate the pilots to an aircraft monitoring zone. Depicted above in black and red circles are representations of the aircraft monitoring zones. As you can see above, the 2x1 field was divided equally into four sections. This is a representation of a 1x1 mile visual line of sight. We placed our aircraft monitoring zone in the middle of the flight pattern for the purpose of pilots being able to maintain a one-mile visual line of sight from left to right and top to bottom. This only applies to the 2x1 field do to the fact that it is two miles long.



THIS PATTERN HAS BEEN MODIFIED FOR THIS SCENARIO ONLY



THIS PATTERN HAS BEEN MODIFIED FOR THIS SCENARIO ONLY

Contingency Plan

In case the aircraft experience a type of malfunction, the pre-programmed emergency plan in our system will activate. It will initiate to manual mode for the pilot to take control and land it, in which it will be troubleshoot and repaired. Depicted above is an example of the contingency plan. In the event of a malfunction, the aircraft will be initiated into manual mode wherein the pilot will manually control the aircraft back to base indicated by the black and yellow line. If the aircrafts were to lose its track and go off course or crash, the GPS system that is pre-pro0grammed into the aircraft will allow it to be recovered or returned to its rightful track. Additionally, components of the Minimum Equipment List (MEL) will be supplied with spare parts. They will act as backup components to replace the damaged ones, allowing the aircrafts to be repaired time efficiently with assurance that the mission can be resumed. The spare components consist of the fundamental components of the aircraft that are required to complete the mission, including: spare FPV, auto pilot, batteries, GPS, nozzles, landing gear (tires), airspeed sensors, RPM sensors, electric adjustable linear actuators, on screen display (OSD) and data loggers. Larger components such as the engine, transmitter/alternators, boom tubes, spray tanks and pumps are not included in the spare components due to the extensive size and weight, proposing that they are to be fixed manually if they were to malfunction.

3.3 Application Considerations

Major considerations

In regards to the national challenge, the team had to consider major changes to our aircraft and mission plan in order to work in accordance with the national challenge requirements. Some of the major changes in the national challenge that we had to consider are listed as follows: a new mission scenario of a 1x1 field in conjunction with a 2x1 field, the 11-knot wind coming from the west, and the no-fly zone separating the 1x1 field and 2x1 field.

RWDC Application Costs			
$Acreage_{Low}$		227.2000	acres
$Acreage_{Medium}$		192.0000	acres
$Acreage_{Heavy}$		97.6000	acres
Low $SOLVITAL_{Dosage}$		0.0625	gallons per acre
Medium $SOLVITAL_{Dosage}$		0.125	gallons per acre
Heavy $SOLVITAL_{Dosage}$		0.25	gallons per acre
SOLVITAL $Required_{RWDC}$		62.6	gallons
SOLVITAL $Cost_{RWDC}$	$	2,817.00	
T_{RWDC}		3	hours
$FCPH_{RWDC}$	$	506.88	per hour
$FCPA_{RWDC}$	$	2.94	per acre
AC_{RWDC}	**$**	***4,337.63***	per crop
Total to charge to perform application	**$**	***10,000.00***	
Dcost	**$**	***(17,362.37)***	per crop
$(AC_{Conv} - AC_{RWDC})/AC_{Conv})$	**$**	***0.80***	per crop
Objective Function Calculation			
Application Volume (reduction desired)			
AV_{Conv}		2400.0000	gallons
AV_{RWDC}		579.4000	gallons
$(AV_{Conv} - AV_{RWDC})/AV_{Conv})$		**0.7586**	
Aircraft Productivity (improvement desired)			
APM_{Conv}		18.1823	acres per minute
APM_{RWDC}		9.6970	acres per minute
$1 - ((APM_{Conv} - APM_{RWDC})/APM_{Conv})$		**0.5333**	
Application Costs (reduction desired)			
AC_{Conv}	$	21,700.00	per equivalent crop
AC_{RWDC}	$	4,337.63	per equivalent crop
$(AC_{Conv} - AC_{RWDC})/AC_{Conv})$		**0.8001**	
Business Profitability			
Operating Expense ($OE_{Year\ 5}$)	$	3,359,955.42	
Total Revenue ($TR_{Year\ 5}$)		############	
$(TR_{Year\ 5} - OE_{Year\ 5})/TR_{Year\ 5})$		**0.7273**	
Objective Function		***0.7048***	

Application volume

Due to the 11-knot wind that blows from the west side of the mission area, we had to make a few major changes to our plane in order to accommodate the mission plan. For the state challenge, our aircraft was equipped with the Guardian Air GA 110-025AZ nozzle which had a PSI range of 14.5-87 and a spray angle of 45° along with a VMD range (microns) of 400-450. However, due to the implementation of an 11-knot wind, there was a spray drift occurrence. The occurring spray drift is due to the produce of small VMD (microns) of our state challenge nozzles. Thus, we decided to upgrade our nozzle selection to the Guardian Air 110-03, because it created a greater drift reduction by increasing the spray discharge to 500-600 VMD (microns). Furthermore, we maximized our SOLVITAL capacity, thereby, decreasing the number of thru-flights. Likewise, our thru-flight time changed from eight minutes to six minutes because we acquired a better SOVITAL servicing cart. This allowed us to increase the servicing rate by three gallons per minute.

Aircraft Productivity

Working towards our aircraft productivity, the team debated on numerous changes as compared to our mission in the state challenge. For the most part, our aircraft was modified to accommodate the national challenge by increasing it's the productivity and efficiency. The conventional APM suggests the following: airspeed of 150mph, a total of 36 nozzles with 10-inch spacing, and an overall APM of 18.1823 all to be applied in a two-hour period. After rigorous research and communication with our mentors, the team has identified flaws within the conventional that opposed the definition of precision agricultural spraying. We chose to use two identical large sprayers as opposed to numerous small UAVs to minimize communication interference, cost, and number of logistics and personnel. Our aircraft will be flying at airspeed of 100mph instead of 150mph to ensure full coverage of the appropriate amount of SOLVITAL mixture. To improve precision within the operation, the team decided on a pattern in which the aircraft will maneuver only above the infected areas, with the exception of flying over the non-infected areas to get to its destination. This decreased our overall APM to a 9.6970 but increases our application volume, cost, and productivity. The team decided on utilizing 24 nozzles with 12 inch spacing, maximizing our spraying capabilities resulting in a swath width of 24, the same amount provided in the conventional. Time was a major tradeoff, but this was compromised in regards to our business case in which our aircraft will show improvement each year (years 1 to 5). With a rounded off application time of three hours as opposed to two, the team is able to compromise precise coverage within each infected lane while accomplishing two missions or more per day for year one.

Furthermore, to increase the productivity of our business, we decided to use the $100,000 grant to update our plane components and purchase a second aircraft. This aircraft will contain the updated features we implemented on our state challenge UAV. With this, we are increasing productivity in all four elements of the objective function.

To reduce the number of times the aircraft has to thru-flight, the tesm decided to maximize the payload capacity with SOLVITAL tanks. Our state UAV had a maximum capacity of 48 gallons of SOLVITAL per flight. For the national challenge, we decided to add and reshape additional tanks which increased the SOLVITAL capacity to 61 gallons. In addition to the increased capacity of SOLVITAL, our refueling rate has increased from 15 gallons per minute to 18 gallons per minute due to a new refueling tank.

To accommodate the 11-knot wind, we designed and upgraded our boom tube into an adjustable boom tube that can extend down to 5 ft. from the ground. To accomplish this extension, we acquired a new actuator and our nozzles have been changed to produce a higher VMD (microns) output. Our camera has been upgraded from the Boscam CM 210 to the M1-D due to the dual function of visual and thermal imagery.

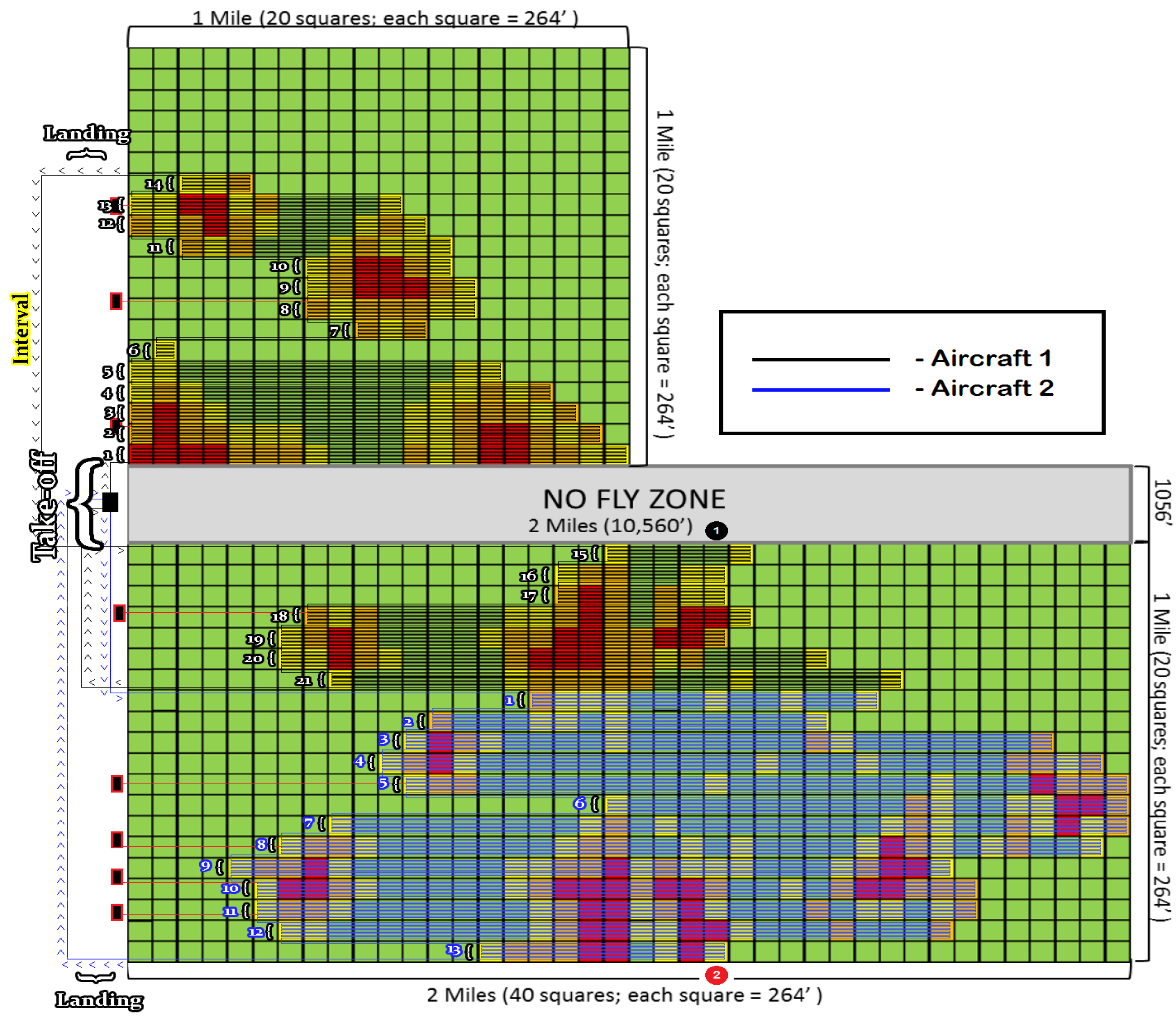
Application Cost

With the $100,000 grant, the team decided to improve the components of our state plane while using the remaining money plus additional loans to build a second aircraft. Aside from making exceptional profits over the years, the team considered the importance of our competitiveness in the market. The conventional aircraft's total application cost is $21,700 per equivalent crop. The team's application cost shows a significant range at only $4,337.63 per equivalent crop. This will positively affect our business profitability as well as competitiveness against crop dusters and other UAS in the market.

Business Profitability

With an updated aircraft design and additional aircraft, our mission productivity has significantly increased from that of the state. An increase in our mission productivity results in a decrease of mission time, more possible missions per day, and improved business profitability. The team carefully assessed its expenses upon designating price for each mission. In regards to our application cost, the team decided to charge $10,000 to perform one precision application, which is a highly exceptional deal as compared to conventional sprayers.

3.4 Application Time and Resource Requirements



MAIN APPLICATION PATTERN

Manpower Requirements:

- 2 x Payload Operator
- 2 x Data Analyst
- 2 x Range Safety/ Aircraft Launch & Recovery/Maintenance
- 2 x Launch and Recover Assistants
- 2 x Safety Pilot
- 2 x Operational Pilot

Aircraft 1

Rows	Distance Travelled	Time	Cumulative Time	Solvital Sprayed	Cumulative Solvital Sprayed		
Take-off		37	37				
1	68040	602.2	639.2	31.4	31.4		
2	64872	940.6	1579.8	27	58.4	Refuel #1	12th Lane
3	61704	559	2138.8	19.6	78		
4	58536	537.4	2676.2	13.9	91.9		
5	52200	494.2	3170.4	6.8	98.7		
6	7848	155.9	3326.3	1.7	100.4		
7	14184	222.2	3548.5	5.3	105.7		
8	26856	681.4	4229.9	12.3	118	Refuel #2	12th Lane
9	26856	321.4	4551.3	13	131		
10	23688	299.8	4851.1	11	142		
11	39528	407.8	5258.9	13.9	155.9		
12	42696	429.4	5688.3	16	171.9		
13	39528	767.8	6456.1	12.6	184.5	Refuel #3	6th Lane
14	14184	222.2	6678.3	5.2	189.7		
Taxi Time		156	6834.3		189.7		
15	23688	299.8	7134.1	3.4	193.1		
16	26856	321.4	7455.5	8.7	201.8		
17	26856	321.4	7776.9	10.8	212.6		
18	61704	559	8335.9	21.8	234.4	Refuel#4	3rd Lane
19	61704	919	9254.9	26	260.4		
20	74376	645.4	9900.3	25.5	285.9		
21	77544	667	10567.3	15.8	301.7		
Landing		37	10604.3				
	893448	10604		301.7			

Aircraft 2

Rows	Distance Travelled (ft)	Times	Cumulative Time	Solvital Sprayed	Cumulative Solvital Sprayed		
Take-off		37	37				
1	49032	472.6	509.6	12	12		
2	55368	515.8	1025.4	8.6	20.6		
3	92508	731.8	1757.2	14.2	34.8		
4	103182	796.6	2553.8	17.7	52.5		
5	103182	1157	3710.4	16.1	68.6	Refuel #1	6th Lane
6	96552	796.6	4507	14.4	83		
7	74718	623.8	5130.8	21.1	104.1		
8	106056	1221	6352.2	28.1	132.2	Refuel #2	6th Lane
9	109224	883	7235.2	35.8	168		
10	96522	1157	8391.8	39.2	207.2	Refuel #3	2nd Lane
11	96552	796.6	9188.4	30.4	237.6	Refuel #4	10th Lane
12	90216	1113	10301.8	23.6	261.2		
13	36360	386.2	10688	16.5	277.7		
Landing		37	10725				
Sum	1109472	10725		277.7			

Table 14. Detailed Flight Sequence Chart:

Aircraft # 1					Aircraft #2				
Line	Solvital Sprayed (gal)	Cumulative Solvital Sprayed	Time (seconds)	Cumulative Time	Line	Solvital Sprayed (gal)	Cumulative Solvital Sprayed	Time (seconds)	Cumulative Time
Take-off			37	37	Take-off			37	37
1	2.616666667	2.616666667	50.18333333	87.18333333	1	1	1	39.38333333	76.38333333
2	2.616666667	5.233333333	50.18333333	137.3666667	2	1	2	39.38333333	115.7666667
3	2.616666667	7.85	50.18333333	187.55	3	1	3	39.38333333	155.15
4	2.616666667	10.46666667	50.18333333	237.7333333	4	1	4	39.38333333	194.5333333
5	2.616666667	13.08333333	50.18333333	287.9166667	5	1	5	39.38333333	233.9166667
6	2.616666667	15.7	50.18333333	338.1	6	1	6	39.38333333	273.3
7	2.616666667	18.31666667	50.18333333	388.2833333	7	1	7	39.38333333	312.6833333
8	2.616666667	20.93333333	50.18333333	438.4666667	8	1	8	39.38333333	352.0666667
9	2.616666667	23.55	50.18333333	488.65	9	1	9	39.38333333	391.45
10	2.616666667	26.16666667	50.18333333	538.8333333	10	1	10	39.38333333	430.8333333
11	2.616666667	28.78333333	50.18333333	589.0166667	11	1	11	39.38333333	470.2166667
12	2.616666667	31.4	50.18333333	639.2	12	1	12	39.38333333	509.6
13	2.25	33.65	48.38333333	687.5833333	13	0.716666667	12.71666667	42.98333333	552.5833333
14	2.25	35.9	48.38333333	735.9666667	14	0.716666667	13.43333333	42.98333333	595.5666667
15	2.25	38.15	48.38333333	784.35	15	0.716666667	14.15	42.98333333	638.55
16	2.25	40.4	48.38333333	832.7333333	16	0.716666667	14.86666667	42.98333333	681.5333333
17	2.25	42.65	48.38333333	881.1166667	17	0.716666667	15.58333333	42.98333333	724.5166667
18	2.25	44.9	48.38333333	929.5	18	0.716666667	16.3	42.98333333	767.5
19	2.25	47.15	48.38333333	977.8833333	19	0.716666667	17.01666667	42.98333333	810.4833333
20	2.25	49.4	48.38333333	1026.266667	20	0.716666667	17.73333333	42.98333333	853.4666667
21	2.25	51.65	48.38333333	1074.65	21	0.716666667	18.45	42.98333333	896.45
22	2.25	53.9	48.38333333	1123.033333	22	0.716666667	19.16666667	42.98333333	939.4333333
23	2.25	56.15	48.38333333	1171.416667	23	0.716666667	19.88333333	42.98333333	982.4166667
24	2.25	58.4	48.38333333	1219.8	24	0.716666667	20.6	42.98333333	1025.4
Refuel #1		58.4	360	1579.8	25	1.183333333	21.78333333	60.98333333	1086.383333
25	1.633333333	60.03333333	46.58333333	1626.383333	26	1.183333333	22.96666667	60.98333333	1147.366667
26	1.633333333	61.66666667	46.58333333	1672.966667	27	1.183333333	24.15	60.98333333	1208.35
27	1.633333333	63.3	46.58333333	1719.55	28	1.183333333	25.33333333	60.98333333	1269.333333
28	1.633333333	64.93333333	46.58333333	1766.133333	29	1.183333333	26.51666667	60.98333333	1330.316667
29	1.633333333	66.56666667	46.58333333	1812.716667	30	1.183333333	27.7	60.98333333	1391.3
30	1.633333333	68.2	46.58333333	1859.3	31	1.183333333	28.88333333	60.98333333	1452.283333
31	1.633333333	69.83333333	46.58333333	1905.883333	32	1.183333333	30.06666667	60.98333333	1513.266667
32	1.633333333	71.46666667	46.58333333	1952.466667	33	1.183333333	31.25	60.98333333	1574.25
33	1.633333333	73.1	46.58333333	1999.05	34	1.183333333	32.43333333	60.98333333	1635.233333
34	1.633333333	74.73333333	46.58333333	2045.633333	35	1.183333333	33.61666667	60.98333333	1696.216667
35	1.633333333	76.36666667	46.58333333	2092.216667	36	1.183333333	34.8	60.98333333	1757.2
36	1.633333333	78	46.58333333	2138.8	37	1.475	36.275	66.38333333	1823.583333
37	1.158333333	79.15833333	44.78333333	2183.583333	38	1.475	37.75	66.38333333	1889.966667
38	1.158333333	80.31666667	44.78333333	2228.366667	39	1.475	39.225	66.38333333	1956.35
39	1.158333333	81.475	44.78333333	2273.15	40	1.475	40.7	66.38333333	2022.733333
40	1.158333333	82.63333333	44.78333333	2317.933333	41	1.475	42.175	66.38333333	2089.116667
41	1.158333333	83.79166667	44.78333333	2362.716667	42	1.475	43.65	66.38333333	2155.5
42	1.158333333	84.95	44.78333333	2407.5	43	1.475	45.125	66.38333333	2221.883333
43	1.158333333	86.10833333	44.78333333	2452.283333	44	1.475	46.6	66.38333333	2288.266667
44	1.158333333	87.26666667	44.78333333	2497.066667	45	1.475	48.075	66.38333333	2354.65
45	1.158333333	88.425	44.78333333	2541.85	46	1.475	49.55	66.38333333	2421.033333
46	1.158333333	89.58333333	44.78333333	2586.633333	47	1.475	51.025	66.38333333	2487.416667
47	1.158333333	90.74166667	44.78333333	2631.416667	48	1.475	52.5	66.38333333	2553.8
48	1.158333333	91.9	44.78333333	2676.2	49	1.341666667	53.84166667	66.38333333	2620.183333
49	0.566666667	92.46666667	41.18333333	2717.383333	50	1.341666667	55.18333333	66.38333333	2686.566667
50	0.566666667	93.03333333	41.18333333	2758.566667	51	1.341666667	56.525	66.38333333	2752.95
51	0.566666667	93.6	41.18333333	2799.75	52	1.341666667	57.86666667	66.38333333	2819.333333

52	0.566666667	94.16666667	41.18333333	2840.933333	53	1.341666667	59.20833333	66.38333333	2885.716667
53	0.566666667	94.73333333	41.18333333	2882.116667	54	1.341666667	60.55	66.38333333	2952.1
54	0.566666667	95.3	41.18333333	2923.3	Refuel #1		60.55	360	3312.1
55	0.566666667	95.86666667	41.18333333	2964.483333	55	1.341666667	61.89166667	66.38333333	3378.483333
56	0.566666667	96.43333333	41.18333333	3005.666667	56	1.341666667	63.23333333	66.38333333	3444.866667
57	0.566666667	97	41.18333333	3046.85	57	1.341666667	64.575	66.38333333	3511.25
58	0.566666667	97.56666667	41.18333333	3088.033333	58	1.341666667	65.91666667	66.38333333	3577.633333
59	0.566666667	98.13333333	41.18333333	3129.216667	59	1.341666667	67.25833333	66.38333333	3644.016667
60	0.566666667	98.7	41.18333333	3170.4	60	1.341666667	68.6	66.38333333	3710.4
61	0.141666667	98.84166667	12.99166667	3183.391667	61	1.2	69.8	66.38333333	3776.783333
62	0.141666667	98.98333333	12.99166667	3196.383333	62	1.2	71	66.38333333	3843.166667
63	0.141666667	99.125	12.99166667	3209.375	63	1.2	72.2	66.38333333	3909.55
64	0.141666667	99.26666667	12.99166667	3222.366667	64	1.2	73.4	66.38333333	3975.933333
65	0.141666667	99.40833333	12.99166667	3235.358333	65	1.2	74.6	66.38333333	4042.316667
66	0.141666667	99.55	12.99166667	3248.35	66	1.2	75.8	66.38333333	4108.7
67	0.141666667	99.69166667	12.99166667	3261.341667	67	1.2	77	66.38333333	4175.083333
68	0.141666667	99.83333333	12.99166667	3274.333333	68	1.2	78.2	66.38333333	4241.466667
69	0.141666667	99.975	12.99166667	3287.325	69	1.2	79.4	66.38333333	4307.85
70	0.141666667	100.1166667	12.99166667	3300.316667	70	1.2	80.6	66.38333333	4374.233333
71	0.141666667	100.2583333	12.99166667	3313.308333	71	1.2	81.8	66.38333333	4440.616667
72	0.141666667	100.4	12.99166667	3326.3	72	1.2	83	66.38333333	4507
73	0.441666667	100.8416667	18.51666667	3344.816667	73	1.758333333	84.75833333	51.98333333	4558.983333
74	0.441666667	101.2833333	18.51666667	3363.333333	74	1.758333333	86.51666667	51.98333333	4610.966667
75	0.441666667	101.725	18.51666667	3381.85	75	1.758333333	88.275	51.98333333	4662.95
76	0.441666667	102.1666667	18.51666667	3400.366667	76	1.758333333	90.03333333	51.98333333	4714.933333
77	0.441666667	102.6083333	18.51666667	3418.883333	77	1.758333333	91.79166667	51.98333333	4766.916667
78	0.441666667	103.05	18.51666667	3437.4	78	1.758333333	93.55	51.98333333	4818.9
79	0.441666667	103.4916667	18.51666667	3455.916667	79	1.758333333	95.30833333	51.98333333	4870.883333
80	0.441666667	103.9333333	18.51666667	3474.433333	80	1.758333333	97.06666667	51.98333333	4922.866667
81	0.441666667	104.375	18.51666667	3492.95	81	1.758333333	98.825	51.98333333	4974.85
82	0.441666667	104.8166667	18.51666667	3511.466667	82	1.758333333	100.5833333	51.98333333	5026.833333
83	0.441666667	105.2583333	18.51666667	3529.983333	83	1.758333333	102.3416667	51.98333333	5078.816667
84	0.441666667	105.7	18.51666667	3548.5	84	1.758333333	104.1	51.98333333	5130.8
85	1.025	106.725	26.78333333	3575.283333	85	2.341666667	106.4416667	71.78333333	5202.583333
86	1.025	107.75	26.78333333	3602.066667	86	2.341666667	108.7833333	71.78333333	5274.366667
87	1.025	108.775	26.78333333	3628.85	87	2.341666667	111.125	71.78333333	5346.15
88	1.025	109.8	26.78333333	3655.633333	88	2.341666667	113.4666667	71.78333333	5417.933333
89	1.025	110.825	26.78333333	3682.416667	89	2.341666667	115.8083333	71.78333333	5489.716667
90	1.025	111.85	26.78333333	3709.2	90	2.341666667	118.15	71.78333333	5561.5
91	1.025	112.875	26.78333333	3735.983333	Refuel # 2		118.15	360	5921.5
92	1.025	113.9	26.78333333	3762.766667	91	2.341666667	120.4916667	71.78333333	5993.283333
93	1.025	114.925	26.78333333	3789.55	92	2.341666667	122.8333333	71.78333333	6065.066667
94	1.025	115.95	26.78333333	3816.333333	93	2.341666667	125.175	71.78333333	6136.85
95	1.025	116.975	26.78333333	3843.116667	94	2.341666667	127.5166667	71.78333333	6208.633333
96	1.025	118	26.78333333	3869.9	95	2.341666667	129.8583333	71.78333333	6280.416667
Refuel #2		118	360	4229.9	96	2.341666667	132.2	71.78333333	6352.2
97	1.083333333	119.0833333	26.78333333	4256.683333	97	2.983333333	135.1833333	73.58333333	6425.783333
98	1.083333333	120.1666667	26.78333333	4283.466667	98	2.983333333	138.1666667	73.58333333	6499.366667
99	1.083333333	121.25	26.78333333	4310.25	99	2.983333333	141.15	73.58333333	6572.95
100	1.083333333	122.3333333	26.78333333	4337.033333	100	2.983333333	144.1333333	73.58333333	6646.533333
101	1.083333333	123.4166667	26.78333333	4363.816667	101	2.983333333	147.1166667	73.58333333	6720.116667
102	1.083333333	124.5	26.78333333	4390.6	102	2.983333333	150.1	73.58333333	6793.7
103	1.083333333	125.5833333	26.78333333	4417.383333	103	2.983333333	153.0833333	73.58333333	6867.283333
104	1.083333333	126.6666667	26.78333333	4444.166667	104	2.983333333	156.0666667	73.58333333	6940.866667
105	1.083333333	127.75	26.78333333	4470.95	105	2.983333333	159.05	73.58333333	7014.45
106	1.083333333	128.8333333	26.78333333	4497.733333	106	2.983333333	162.0333333	73.58333333	7088.033333
107	1.083333333	129.9166667	26.78333333	4524.516667	107	2.983333333	165.0166667	73.58333333	7161.616667

108	1.083333333	131	26.78333333	4551.3	108	2.983333333	168	73.58333333	7235.2
109	0.916666667	131.9166667	24.98333333	4576.283333	109	3.266666667	171.2666667	66.38333333	7301.583333
110	0.916666667	132.8333333	24.98333333	4601.266667	110	3.266666667	174.5333333	66.38333333	7367.966667
111	0.916666667	133.75	24.98333333	4626.25	Refuel #3		174.5333333	360	7727.966667
112	0.916666667	134.6666667	24.98333333	4651.233333	111	3.266666667	177.8	66.38333333	7794.35
113	0.916666667	135.5833333	24.98333333	4676.216667	112	3.266666667	181.0666667	66.38333333	7860.733333
114	0.916666667	136.5	24.98333333	4701.2	113	3.266666667	184.3333333	66.38333333	7927.116667
115	0.916666667	137.4166667	24.98333333	4726.183333	114	3.266666667	187.6	66.38333333	7993.5
116	0.916666667	138.3333333	24.98333333	4751.166667	115	3.266666667	190.8666667	66.38333333	8059.883333
117	0.916666667	139.25	24.98333333	4776.15	116	3.266666667	194.1333333	66.38333333	8126.266667
118	0.916666667	140.1666667	24.98333333	4801.133333	117	3.266666667	197.4	66.38333333	8192.65
119	0.916666667	141.0833333	24.98333333	4826.116667	118	3.266666667	200.6666667	66.38333333	8259.033333
120	0.916666667	142	24.98333333	4851.1	119	3.266666667	203.9333333	66.38333333	8325.416667
121	1.158333333	143.1583333	33.98333333	4885.083333	120	3.266666667	207.2	66.38333333	8391.8
122	1.158333333	144.3166667	33.98333333	4919.066667	121	2.533333333	209.7333333	66.38333333	8458.183333
123	1.158333333	145.475	33.98333333	4953.05	122	2.533333333	212.2666667	66.38333333	8524.566667
124	1.158333333	146.6333333	33.98333333	4987.033333	123	2.533333333	214.8	66.38333333	8590.95
125	1.158333333	147.7916667	33.98333333	5021.016667	124	2.533333333	217.3333333	66.38333333	8657.333333
126	1.158333333	148.95	33.98333333	5055	125	2.533333333	219.8666667	66.38333333	8723.716667
127	1.158333333	150.1083333	33.98333333	5088.983333	126	2.533333333	222.4	66.38333333	8790.1
128	1.158333333	151.2666667	33.98333333	5122.966667	127	2.533333333	224.9333333	66.38333333	8856.483333
129	1.158333333	152.425	33.98333333	5156.95	128	2.533333333	227.4666667	66.38333333	8922.866667
130	1.158333333	153.5833333	33.98333333	5190.933333	129	2.533333333	230	66.38333333	8989.25
131	1.158333333	154.7416667	33.98333333	5224.916667	130	2.533333333	232.5333333	66.38333333	9055.633333
132	1.158333333	155.9	33.98333333	5258.9	Refuel #4		232.5333333	360	9415.633333
133	1.333333333	157.2333333	35.78333333	5294.683333	131	2.533333333	235.0666667	66.38333333	9482.016667
134	1.333333333	158.5666667	35.78333333	5330.466667	132	2.533333333	237.6	66.38333333	9548.4
135	1.333333333	159.9	35.78333333	5366.25	133	1.966666667	239.5666667	62.78333333	9611.183333
136	1.333333333	161.2333333	35.78333333	5402.033333	134	1.966666667	241.5333333	62.78333333	9673.966667
137	1.333333333	162.5666667	35.78333333	5437.816667	135	1.966666667	243.5	62.78333333	9736.75
138	1.333333333	163.9	35.78333333	5473.6	136	1.966666667	245.4666667	62.78333333	9799.533333
139	1.333333333	165.2333333	35.78333333	5509.383333	137	1.966666667	247.4333333	62.78333333	9862.316667
140	1.333333333	166.5666667	35.78333333	5545.166667	138	1.966666667	249.4	62.78333333	9925.1
141	1.333333333	167.9	35.78333333	5580.95	139	1.966666667	251.3666667	62.78333333	9987.883333
142	1.333333333	169.2333333	35.78333333	5616.733333	140	1.966666667	253.3333333	62.78333333	10050.66667
143	1.333333333	170.5666667	35.78333333	5652.516667	141	1.966666667	255.3	62.78333333	10113.45
144	1.333333333	171.9	35.78333333	5688.3	142	1.966666667	257.2666667	62.78333333	10176.23333
145	1.05	172.95	33.98333333	5722.283333	143	1.966666667	259.2333333	62.78333333	10239.01667
146	1.05	174	33.98333333	5756.266667	144	1.966666667	261.2	62.78333333	10301.8
147	1.05	175.05	33.98333333	5790.25	145	1.375	262.575	32.18333333	10333.98333
148	1.05	176.1	33.98333333	5824.233333	146	1.375	263.95	32.18333333	10366.16667
149	1.05	177.15	33.98333333	5858.216667	147	1.375	265.325	32.18333333	10398.35
150	1.05	178.2	33.98333333	5892.2	148	1.375	266.7	32.18333333	10430.53333
Refuel #3		178.2	360	6252.2	149	1.375	268.075	32.18333333	10462.71667
151	1.05	179.25	33.98333333	6286.183333	150	1.375	269.45	32.18333333	10494.9
152	1.05	180.3	33.98333333	6320.166667	151	1.375	270.825	32.18333333	10527.08333
153	1.05	181.35	33.98333333	6354.15	152	1.375	272.2	32.18333333	10559.26667
154	1.05	182.4	33.98333333	6388.133333	153	1.375	273.575	32.18333333	10591.45
155	1.05	183.45	33.98333333	6422.116667	154	1.375	274.95	32.18333333	10623.63333
156	1.05	184.5	33.98333333	6456.1	155	1.375	276.325	32.18333333	10655.81667
157	0.433333333	184.9333333	18.51666667	6474.616667	156	1.375	277.7	32.18333333	10688
158	0.433333333	185.3666667	18.51666667	6493.133333	Landing		277.7	37	10725
159	0.433333333	185.8	18.51666667	6511.65					
160	0.433333333	186.2333333	18.51666667	6530.166667					
161	0.433333333	186.6666667	18.51666667	6548.683333					
162	0.433333333	187.1	18.51666667	6567.2					
163	0.433333333	187.5333333	18.51666667	6585.716667					

164	0.433333333	187.9666667	18.51666667	6604.233333
165	0.433333333	188.4	18.51666667	6622.75
166	0.433333333	188.8333333	18.51666667	6641.266667
167	0.433333333	189.2666667	18.51666667	6659.783333
168	0.433333333	189.7	18.51666667	6678.3
Taxi time		189.7	156	6834.3
169	0.283333333	189.9833333	24.98333333	6859.283333
170	0.283333333	190.2666667	24.98333333	6884.266667
171	0.283333333	190.55	24.98333333	6909.25
172	0.283333333	190.8333333	24.98333333	6934.233333
173	0.283333333	191.1166667	24.98333333	6959.216667
174	0.283333333	191.4	24.98333333	6984.2
175	0.283333333	191.6833333	24.98333333	7009.183333
176	0.283333333	191.9666667	24.98333333	7034.166667
177	0.283333333	192.25	24.98333333	7059.15
178	0.283333333	192.5333333	24.98333333	7084.133333
179	0.283333333	192.8166667	24.98333333	7109.116667
180	0.283333333	193.1	24.98333333	7134.1
181	0.725	193.825	26.78333333	7160.883333
182	0.725	194.55	26.78333333	7187.666667
183	0.725	195.275	26.78333333	7214.45
184	0.725	196	26.78333333	7241.233333
185	0.725	196.725	26.78333333	7268.016667
186	0.725	197.45	26.78333333	7294.8
187	0.725	198.175	26.78333333	7321.583333
188	0.725	198.9	26.78333333	7348.366667
189	0.725	199.625	26.78333333	7375.15
190	0.725	200.35	26.78333333	7401.933333
191	0.725	201.075	26.78333333	7428.716667
192	0.725	201.8	26.78333333	7455.5
193	0.9	202.7	26.78333333	7482.283333
194	0.9	203.6	26.78333333	7509.066667
195	0.9	204.5	26.78333333	7535.85
196	0.9	205.4	26.78333333	7562.633333
197	0.9	206.3	26.78333333	7589.416667
198	0.9	207.2	26.78333333	7616.2
199	0.9	208.1	26.78333333	7642.983333
200	0.9	209	26.78333333	7669.766667
201	0.9	209.9	26.78333333	7696.55
202	0.9	210.8	26.78333333	7723.333333
203	0.9	211.7	26.78333333	7750.116667
204	0.9	212.6	26.78333333	7776.9
205	1.816666667	214.4166667	46.58333333	7823.483333
206	1.816666667	216.2333333	46.58333333	7870.066667
207	1.816666667	218.05	46.58333333	7916.65
208	1.816666667	219.8666667	46.58333333	7963.233333
209	1.816666667	221.6833333	46.58333333	8009.816667
210	1.816666667	223.5	46.58333333	8056.4
211	1.816666667	225.3166667	46.58333333	8102.983333
212	1.816666667	227.1333333	46.58333333	8149.566667
213	1.816666667	228.95	46.58333333	8196.15
214	1.816666667	230.7666667	46.58333333	8242.733333
215	1.816666667	232.5833333	46.58333333	8289.316667
216	1.816666667	234.4	46.58333333	8335.9
217	2.166666667	236.5666667	46.58333333	8382.483333
218	2.166666667	238.7333333	46.58333333	8429.066667
219	2.166666667	240.9	46.58333333	8475.65

Refuel #4		240.9	360	8835.65
220	2.166666667	243.0666667	46.58333333	8882.233333
221	2.166666667	245.2333333	46.58333333	8928.816667
222	2.166666667	247.4	46.58333333	8975.4
223	2.166666667	249.5666667	46.58333333	9021.983333
224	2.166666667	251.7333333	46.58333333	9068.566667
225	2.166666667	253.9	46.58333333	9115.15
226	2.166666667	256.0666667	46.58333333	9161.733333
227	2.166666667	258.2333333	46.58333333	9208.316667
228	2.166666667	260.4	46.58333333	9254.9
229	2.125	262.525	53.78333333	9308.683333
230	2.125	264.65	53.78333333	9362.466667
231	2.125	266.775	53.78333333	9416.25
232	2.125	268.9	53.78333333	9470.033333
233	2.125	271.025	53.78333333	9523.816667
234	2.125	273.15	53.78333333	9577.6
235	2.125	275.275	53.78333333	9631.383333
236	2.125	277.4	53.78333333	9685.166667
237	2.125	279.525	53.78333333	9738.95
238	2.125	281.65	53.78333333	9792.733333
239	2.125	283.775	53.78333333	9846.516667
240	2.125	285.9	53.78333333	9900.3
241	1.316666667	287.2166667	55.58333333	9955.883333
242	1.316666667	288.5333333	55.58333333	10011.46667
243	1.316666667	289.85	55.58333333	10067.05
244	1.316666667	291.1666667	55.58333333	10122.63333
245	1.316666667	292.4833333	55.58333333	10178.21667
246	1.316666667	293.8	55.58333333	10233.8
247	1.316666667	295.1166667	55.58333333	10289.38333
248	1.316666667	296.4333333	55.58333333	10344.96667
249	1.316666667	297.75	55.58333333	10400.55
250	1.316666667	299.0666667	55.58333333	10456.13333
251	1.316666667	300.3833333	55.58333333	10511.71667
252	1.316666667	301.7	55.58333333	10567.3
Landing		301.7	37	10604.3

Flight Time Analysis

Sample

$n := 20$

$d := 264 \cdot n$

$d = 5.28 \cdot 10^3$

$k := 853$

$r := 146.66666666667$

$x := \frac{d-k}{r}$

$x = 30.184$

$y := x + 20$

$y = 50.184$

$z := y \cdot 12$

$z = 602.209$

Variables

n=Number of squares in row
d=distance
k=Distance covered by acceleration & deceleration
r=feet per second

x=Time to cover distance (calculated)
y=Time calculated with acceleration, deceleration, and turn
z=Time to cover 12 lanes

Depicted on the left is an example of the team's calculations for the flight time analysis. These calculations provided us with accurate data regarding the aircrafts' flight time, distance, turns and acceleration and deceleration.

In conclusion, the total time to complete the pesticide application following our proposed search pattern is **2 hours and 58 minutes (178 minutes),** including all thru-flights. Research was conducted (http://extension.uga.edu/publications/detail.cfm?number=B677) that the average plant spacing of sweet potatoes is 12 inches, along with an average row width of 42 inches. In regards to the infected areas, there will be approximately 12,500 plants per acre.

Objective Function Calculation		
Application Volume (reduction desired)		
AV_{Conv}	2400.0000	gallons
AV_{RWDC}	579.4000	gallons
$(AV_{Conv} - AV_{RWDC})/AV_{Conv})$	**0.7586**	
Aircraft Productivity (improvement desired)		
APM_{Conv}	18.1823	acres per minute
APM_{RWDC}	9.6970	acres per minute
$1 - ((APM_{Conv} - APM_{RWDC})/APM_{Conv})$	**0.5333**	
Application Costs (reduction desired)		
AC_{Conv}	$ 21,700.00	per equivalent crop
AC_{RWDC}	$ 4,337.62	per equivalent crop
$(AC_{Conv} - AC_{RWDC})/AC_{Conv}))$	**0.8001**	
Business Profitability		
Operating Expense ($OE_{Year\ 5}$)	$ 3,359,949.42	
Total Revenue ($TR_{Year\ 5}$)	###########	
$(TR_{Year\ 5} - OE_{Year\ 5})/TR_{Year\ 5}))$	**0.7273**	
Objective Function	**0.7048**	

The objective function constitutes four core elements: application volume, acres per minute, application cost, and business profitability that all fall in under achieving precision application spraying. Reductions in application cost and volume compared to the conventional was necessary to ensure precision within every mission, as well as improve our business case by showing improvement within the aircraft's productivity over time. We recognized that, due to our APM being compared to the conventional, the fact that our aircraft will be spraying only the percentage of the field that is infected decrease our aircraft productivity value (although, in perspective, the aircraft productivity should increase due to this strategy).

Our RWDC team solution shows a dramatic decrease for both application cost and volume. Instead of the conventional 2400 gallons per 1 x 1 mile area and 2 x 1 mile area, we managed to reduce it to 579.4 gallons, which resulted in a 76% reduction. Because we introduced a second UAS, the aircraft productivity doubled from 4.8485 acres per minute to 9.697 acres per minute which reduced the total mission time. Additionally, we reduced the application cost by 80%. Our application cost totaled up to $4337.63.

Our UAS system brought in a net cash flow of $15,500,994.75 in year 5. We are able to break even at the end of year one and start off year 2 with our designed system. Additionally, our UAS system will undergo improvements during year two, allowing it to perform more missions at a lessened amount of time.

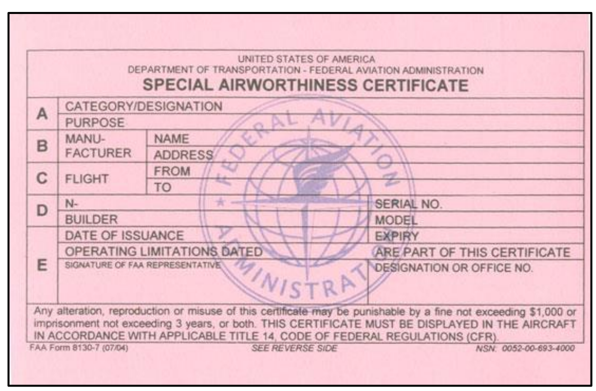
In conclusion, our objective function results to 0.7048, along with reasonable explanation towards achieving precision.

3.5 National Challenge Updated Application Details

The FAA is currently developing new policies that will affect operators' access to airspace in a safe, routine, and efficient manner. We had to ensure that our aircraft was in compliance with FAA regulations while maintaining high productivity. The team created an account under the FAA website to gain access to certificate and application forms. Before applying for certifications, the team will register the UAS along with necessary fees. Our UAV will fall under the private (civil) operator category, as our company is not considered public operators. Because our aircraft is over 55 pounds, both the Skywalker and our pilots need to fit the criteria and go through processes required by the FAA in order to acquire specific certifications. The time it takes to process and gain certification was a realistic factor that we had to incorporate during our final design phase. In the Northern Marianas Islands (specifically Saipan), the integration of UAS is at a bare minimum. Majority of the operations conducted in our area fall under the public sector. The team's compliance within local regulations was another limiting factor. Civil operators such as private companies are generally uncommon in the CNMI. Thus, the team had to conduct extra research and asked for advice from nearby FAA personnel. The existing FAA rules and regulations that apply to our company for domestic UAS operations on the federal, state, and local levels are as follows:

Table 15. FAA Rules and Regulations Complied
Special Airworthiness Certification (SAC): Certification for Civil Operated Unmanned Aircraft Systems (UAS) and Optionally Piloted Aircraft (OPA)
Special Airworthiness Certification: Condition For Safe Operation
Civil Operations (Non-Governmental): Section 333 Exemption
Special Airworthiness Certificate-Experimental Category (SAC-EC)
SAC-Restricted Category (SAC-RC)
Certificate of Authorization or Waiver (COA)

The team must obtain a Special Airworthiness Certificate prior to our operation. We will have to comply with rules under the restricted category for agricultural use. There are, however, exceptions along with extra certifications needed as we plan to use the Skywalker for other commercial applications. In order to obtain the SAC under the experimental category, the company must comply with the rules regarding research and development, crew training, exhibition, air racing, and market surveys. The system must be inspected in order to be "in a condition for safe operation." Additional design requirements that follow our registration include field approval, human factors in aviation safety, original design approval, and approval of safety enhancing non-required


UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION - FEDERAL AVIATION ADMINISTRATION
SPECIAL AIRWORTHINESS CERTIFICATE
A CATEGORY/DESIGNATION
PURPOSE
B MANU-FACTURER NAME ADDRESS
C FLIGHT FROM TO
D N- SERIAL NO.
BUILDER MODEL
DATE OF ISSUANCE EXPIRY
OPERATING LIMITATIONS DATED ARE PART OF THIS CERTIFICATE
E SIGNATURE OF FAA REPRESENTATIVE DESIGNATION OR OFFICE NO.
Any alteration, reproduction or misuse of this certificate may be punishable by a fine not exceeding $1,000 or imprisonment not exceeding 3 years, or both. THIS CERTIFICATE MUST BE DISPLAYED IN THE AIRCRAFT IN ACCORDANCE WITH APPLICABLE TITLE 14, CODE OF FEDERAL REGULATIONS (CFR).
FAA Form 8130-7 (07/04) SEE REVERSE SIDE NSN: 0052-00-693-4000

equipment under 14 CFR 21.8(d). Our personnel crew will consist of experienced pilots that already fit the certification criterion- owning an FAA airman certificate. Time and operational cost will be a tradeoff as both personnel and the aircraft have to comply with the FAA regulations.

Access to the National Airspace System

1. Name of organization		2. Name of responsible person		
MHS Aeronautical Dolphins		Ann Margaret Norcio		
3. Permanent mailing address	House number and street or route number	City	State and ZIP code	Telephone No.
	PO BOX 500799	Saipan	96950	670-234-1937

4. State whether the applicant or any of its principal officers/owners has an application for waiver pending at any other office of the FAA.
Yes.
5. State whether the applicant or any of its principal officers owners has ever had its application for waiver denied, or whether the FAA has ever withdrawn a waiver from the applicant or any of its principal officers/owners.
No.
6. FAR section and number to be waived
Section 333 Exemption
7. Detailed description of proposed operation *(Attach supplement if needed)*
Flying a (modified) UAV sprayer to apply SOLVITAL pesticide on large crop areas (eg. 1x1 by 2x1). The UAV has been built and modified from the Foxbat A-22L, a light sports aircraft.
8. Area of operation *(Location, altitudes, etc.)*
Kagman Agricultural Farm, Saipan; flying 10 feet above sweet potato crop

9a. Beginning *(Date and hour)*	b. Ending *(Date and hour)*
10/31/2015	10/31/2020

10. Aircraft make and model (a)	Pilot's Name (b)	Certificate number and rating (c)	Home address (Street, City, State) (d)
Skywalker	Robert Malate	FAA Private Pilot's License with a visual flight rule rating; AAOC	PO BOX 501370, Saipan, MP
Skywalker	Edna Nisola	FAA Private Pilot's License with a visual flight rule rating; AAOC	PO BOX 501370, Saipan, MP

In order to operate our UAV in the National Airspace System, we must be granted through an approval process under relevant parts of Title 14 of the Code of Federal Regulations. Therefore, must request for authorization to conduct UAS operations in the NAS of approved Prohibited Area or active Restricted and Warning Areas designated for aviation use.

The team will not apply to gain access to the NAS using Advisory Circular 91-57. Our model aircraft is designed for commercial purposes, making it a civil UAS. This removes us from being under AC 91-57. We must demonstrate compliance with applicable sections of Title 14 of the Code of Federal Regulations to operate in the National Airspace System. Limitations to this regulation specifically exclude any personnel to operate a restricted category civil aircraft over a densely populated area, in a congested airway, or near a busy airport where passenger transport operations are conducted. Our access will be granted through the application of a Certificate of Authorization or Waiver (COA). A sample application is provided in the following link: (https://www.faa.gov/uas/legislative_programs/section_333/how_to_file_a_petition/media/FAA_UAS_Civil_COA_Request_v2.pdf). This will be done upon registration of our UAS. It will take approximately 60 days until a formal response is given, meaning this must be obtained before our aircraft will fully operate. The aircraft will then be tested and inspected before executing normal operations. The figure above contains a filled-out application for a COA by the Aeronautical Dolphins.

A Special Airworthiness Certificate- Restricted Category will also be in compliance with our system for the special purpose of precision agricultural spraying under § 21.25. As of March 23, 2015, the FAA granted a "blanket" COA for flights at or below 200 feet, but only to aircrafts below 55 pounds. The team will apply for the SAC-RC upon receiving our COA. This will be at least 120 days before our operation is executed. Obtaining this certificate will also take place before we execute full operations. This process will provide us a legal entry into the NAS, providing us a competitive advantage in the UAS marketplace. The exemption discourages illegal operations, improves safety, and will result in significant economic benefits.

To accommodate the visual line of sight we have to maintain of our aircraft over a 2x1 mile field, we decided to get the FCC Amateur Radio License which enables us to achieve a greater control range of 20-30 miles. With this license, our company will be able to incorporate the DrangonLink FPV system which has a long range radio frequency that requires a license to operate.

In terms of obtaining the FCC license, the team will obtain the Technician License through a process of passing an examination administered by a team of volunteer examiners (VEs). The examination requirements include 35 questions on radio theory, regulations and operating practices. The VEs will determine the license operator class for which we are qualified through a testing of skills and abilities in operating an amateur station. The privilege of getting the technician class license are all VHF/UHF amateur bands, along with frequencies above 30 MHz.

Due to the complications that could occur in maintaining visual line of sight, the team decided to have two methods of maintaining such line of sight during the mission. Method one will rely on our long range amateur radio to maintain a visual line of sight. Method two, depicted in the example mission, consists of our pilots manually monitoring the aircraft when it reaches beyond a mile range in the aircraft monitoring zone. Method two is, however, the safest approach in maintaining a visual line of sight on both aircraft. This is because method one contains a possibility that the aircraft could lead to a collision with other nearby planes. However, we will consider both methods for our mission in maintaining a visual line of sight. The team will obtain the FCC Amateur Radio License and rely on the long video range or manually assign the pilots to maintain the visual line of sight during the mission.

Compliance with the aforementioned FAA regulations will allow our UAS to complete its precision application mission with ease. Our aircraft design, the Skywalker, was modified to ensure precision application. Unlike conventional crop dusters and sprayers, our aircraft is finesse. The deployment of pesticide will only take place when the aircraft is flying above an infested crop. Specific percentages of pesticide will be sprayed over a crop, depending on their infestation level. Uninfected areas, which are the green squares in the mission scenario, will not be flown over unless needed in order to arrive at a destination. These factors significantly minimize wastage in regards to the use of SOLVITAL pesticide and fuel.

During the application of pesticide, our pre-programmed system and autopilot will be able to determine between when it reaches a crop area with low, medium, or high infestation. With our system, the UAV is able to detect what PSI level it needs to spray (the PSI will be 22 lbs. per square inch for low infestation, 25 for medium infestation, and 30 for high infestation). Our data analyst and new sensor payload will assist in observing the crops to ensure that we have executed a successful deployment of pesticide to the area. When considering real-life scenarios, weather conditions became a main concern of the team. There are both positive and negative effects on applying pesticide in the event that is rains in the mission area. In terms of positive effects, the rain water can carry the SOLVITAL into the soil after application, which helps the plant absorb the SOLVITAL directly and quickly. However, depending on the rain-fastness of the product, precipitation after the application of SOLVITAL can wash it away from the leaves and reduce the level of protection. Although rain can aid in a positive way, the team decided it is best if we took a stance at the negative side and avoid spraying SOLVITAL during precipitation. Spraying during precipitation proved to be ineffective, but we are able to execute applications of pesticide before and after it rains. As a result, our team will closely monitor weather forecasts and only execute the mission when it is practical to do so.

Temperature and humidity can also affect the applied pesticide in a detrimental way. The team will closely monitor the temperature and humidity level before executing a mission. However, due to our SOLVITAL application of 500-600 VMD (microns) which is extremely coarse, we will only prevent the mission if the humidity is less than 40 percent and air temperature is above 25°C.

As our company goes further into business, it only demands formality and more room for improvement. So we have decided to legally declare our company as incorporation, and we found many advantages in doing so. According to *Investopedia.com*, these advantages include (1) protection of our assets against the company's liabilities, (2) an easy transfer of ownership, (3) a lower tax rate compared to personal income, (4) more lenient tax restrictions on loss carry forwards, and (5) we can raise capital through the sale of stock. This would involve creating an Articles of Incorporation, and we found the requirements in the CNMI Department of Commerce website, and will adhere to lawfully.

4. Document the Business Case

4.1 Additional Commercial Applications

Our world is ever changing and ever growing. Therefore, in order to compensate for the population growth in the future years, food production has to be more efficient and productive than ever. Additionally, it is predicted that by the year 2050, two billion more people will be added to the world's population, thus the requirement for food production will gradually increase. Farmers are now opted to innovate ways to do the following: increase food production, reduce toxic chemical exposure to their own crops and the surrounding environment, and to reduce costs of maintaining their crops, so as to provide more food while increasing their profits.

Unfortunately, pests are uncontrollable factors of nature, and it has always been a problem that farmers had to cope with. One popular method widely used today, is to spray entire crop fields with pesticide through the use of crop dusters. However, crop dusters are not made for precision agriculture. In as much, these aircrafts are flown all across a crop field, spraying not only the infected areas, but the uninfected areas as well. This method is not only time consuming; it is costly, it damages crops by exposing it to unnecessary chemicals, and it also destroys ecosystems by causing intense toxicity in water systems nearby.

Fortunately, our UAS is designed to satisfy what is needed for today and future precision agricultural needs. Furthermore, the Skywalker is capable of being programmed and flown without a pilot onboard. Equally important, it can spray the correct amount of SOLVITAL solely based on the percent of infestation. Consequently, the Skywalker has also been proven to accomplish a multitude of missions other than precision agriculture. In addition, if regulatory restrictions were to come at an ease, our aircraft will be able to perform missions that include search and rescue operations in large areas, as well as assisting in firefighting and nonmilitary applications. Likewise, the aircraft's large payload capacity, it is capable of applying water to crops with various sizes in the time of a drought or a time where there is low water supply. Above all, in order to stay in accordance with the regulations, the Aeronautical Dolphins thoroughly analyzed the need to obtain such permission to conduct these additional applications in a safe and efficient manner. The SAC-RC is available to civil UAS operators that will permit our system design to perform missions that include the following: search and rescue, reconnaissance, agricultural monitoring, news media operation, firefighting and nonmilitary applications. Thus, this certification will not only permit authorization for our UAS, but also increase our company's market size and productivity while utilizing our manpower and maintaining efficient and low cost performances. An ease to the regulations would allow our aircraft to fly at night to conduct search and rescue missions for emergency purposes, also not limiting the aircraft to weather and night operations unless safety is at risk. The aircraft's nozzles are positioned specifically in a way that allows it to adjust to any crop spacing, as well as making it detachable for other commercial purposes. In short, these additional applications will increase our overall profit.

In fact, our UAS can be used by private aerospace companies and organizations who strive to improve and develop UAS technology. Notwithstanding, our aircraft is able to expand new ideas for further research and commercialization of unmanned aircraft vehicles for educational purposes. The United States is currently competing in the global market with the use of large UAVs for military use. By the way, our aircraft is capable of carrying a large payload capacity, making it capable with current research and development systems that are being developed in the United States today. If regulatory restrictions were at ease, the Aeronautical Dolphins will be capable of exploring well, beyond our borders. In any event, our design will enable us to achieve problem solving, critical thinking, research analysis, and provide special services for our customers.

4.2 Amortized System Costs

In our first year of business, we calculated that we would be performing 480 missions in total. We determined our number of missions per year by deciding upon performing a maximum of 2 missions a day, as it was (determined) that each mission would take roughly 3 hours; having 2 missions a day would mean a total of 6 hours. Adhering to the Department of Labor's standards, we are required to provide our employees at least a 1 hour break time. We would also need another extra hour to (deconstruct) our system and prepare for our next mission the following day, which would then equal to an 8-hour work day (this is technically speaking, although the challenge assumes we are on-site for the mission scenario). In essence, the personnel would be working for 8 hours a day, 5 days a week; also taking into consideration federal holidays and an allotted 2-week vacation time, this would then equal a total of 480 missions a year. This would cost us $2,081,904.11 per year, and $4,337.30 per mission.

4.2.1 Initial Costs

System Initial Cost: $249,939.12

PAYLOAD			
Component	Quantity	Cost Per Item	Subtotal
SPI M1-D Micro Thermal PTZ Multi Sensor HD Camera	2	$ 3,990.00	$ 7,980.00
Boom Tubing .25" (Catalog)	2	$ 59.40	$ 118.80
Spray Boom (holding nozzles)	2	$ 231.24	$ 462.48
Spray Boom Support (not extending)	8	$ 49.97	$ 399.76
Spray Boom Support (extension)	8	$ 35.21	$ 281.68
SOLVITAL Tank (Fuselage)	2	$ 102.72	$ 205.44
SOLVITAL Tank (Wings)	4	$ 74.82	$ 299.28
Fuel Tank	2	$ 21.78	$ 43.56
4001XL-E2H Pump with Motor	2	$ 495.00	$ 990.00
Nozzles	48	$ 4.86	$ 233.28
Total Sensor (Payload) Cost	80	N/A	$11,014.28

Payload: $11,014.28

Air Vehicle Element (UAV) Design-1

AIRFRAME CONFIGURATION DESIGN 1			
Component	Quantity	Cost Per Item	Subtotal
Aluminum Airframes	1	$ 65,798.00	$65,798.00
Total Airframe Cost	1	N/A	$65,798.00

Airframe Configuration Design: $65,798.00

ADDITIONAL FLIGHT CONTROL OPTIONS			
Component	Quantity	Cost Per Item	Subtotal
Autopilot	1	$ 250.00	$ 250.00
PA-16-6330 Mini Medium Force Linear Actuator	6	$ 138.99	$ 833.94
PA-14-4-35 Mini Actuator	2	$ 108.99	$ 217.98
Spoilers	2	$ 86.49	$ 172.98
Pusher Rods	2	$ 44.16	$ 88.32
Total Add Flight Control Cost	13	N/A	$1,563.22

Additional Flight Control Options: $1,563.22

ALTERNATE POWERPLANT (PROPULSION) OPTIONS			
Component	Quantity	Cost Per Item	Subtotal
Rotax 912 ULS 100HP	1	$ 19,377.00	$19,377.00
Propeller	1	$ 2,225.00	$ 2,225.00
Super B 7800 Battery	1	$ 566.00	$ 566.00
Alternator	1	$ 1,340.00	$ 1,340.00
Total Alt Powerplant Cost	4	N/A	$23,508.00

Alternate Powerplant (Propulsion) Options: $23,508.00

ONBOARD SENSOR OPTIONS			
Component	Quantity	Cost Per	Subtotal
Airspeed Sensor	1	$ 45.00	$ 45.00
Global Positioning System (GPS) Sensor	1	$ 50.00	$ 50.00
Onscreen Display (OSD) and Datalogger with Limited Telemetry Reporting	1	$ 250.00	$ 250.00
Total Onboard Sensors Cost	3	N/A	$345.00

Onboard Sensor Options: $345.00

ADDITIONAL OPTIONS			
Component	Quantity	Cost Per	Subtotal
Campbell Commercial Weldless Galvanized Steel Cable	4	$ 3.64	$ 14.56
Windshield (aluminum sheet)	1	$ 66.08	$ 66.08
Doors (aluminum sheet)	2	$ 161.39	$ 322.78
Total Additional Options Cost	7	N/A	$403.42

Additional Options: $403.42

Air Vehicle Element (UAV) Design-2

AIRFRAME CONFIGURATION DESIGN 2			
Component	Quantity	Cost Per Item	Subtotal
Aluminum Airframes	1	$ 46,492.00	$46,492.00
Total Airframe Cost	1	N/A	$46,492.00

Airframe Configuration Design: $46,492.00

ADDITIONAL FLIGHT CONTROL OPTIONS			
Component	Quantity	Cost Per Item	Subtotal
Autopilot	1	$ 250.00	$ 250.00
PA-16-6330 Mini Medium Force Linear Actuator	6	$ 138.99	$ 833.94
PA-14-4-35 Mini Actuator	2	$ 108.99	$ 217.98
Spoilers	2	$ 86.49	$ 172.98
Pusher Rods	2	$ 44.16	$ 88.32
Total Add Flight Control Cost	13	N/A	$1,563.22

Additional Flight Control Options: $1,563.22

ALTERNATE POWERPLANT (PROPULSION) OPTIONS			
Component	Quantity	Cost Per Item	Subtotal
Rotax 912 ULS 100HP	1	$ 19,377.00	$19,377.00
Propeller	1	$ 2,225.00	$ 2,225.00
Super B 7800 Battery	1	$ 566.00	$ 566.00
Alternator	1	$ 1,340.00	$ 1,340.00
Total Alt Powerplant Cost	4	N/A	$23,508.00

Alternate Powerplant (Propulsion) Options: $23,508.00

ONBOARD SENSOR OPTIONS			
Component	Quantity	Cost Per	Subtotal
Airspeed Sensor	1	$ 45.00	$ 45.00
Global Positioning System (GPS) Sensor	1	$ 50.00	$ 50.00
Onscreen Display (OSD) and Datalogger with Limited Telemetry Reporting	1	$ 250.00	$ 250.00
Total Onboard Sensors Cost	3	N/A	$345.00

Onboard Sensor Options: $345.00

ADDITIONAL OPTIONS			
Component	Quantity	Cost Per	Subtotal
Campbell Commercial Weldless Galvanized Steel Cable	4	$ 3.64	$ 14.56
Windshield (aluminum sheet)	1	$ 66.08	$ 66.08
Doors (aluminum sheet)	2	$ 161.39	$ 322.78
Total Additional Options Cost	7	N/A	$403.42

Additional Options: $403.42

CONTROL/DATA PROCESSING & DISPLAY OPTIONS			
Component	Quantity	Cost Per Item	Subtotal
Hobby-grade Remote Control (R/C) Radio	2	$ 750.00	$ 1,500.00
Post Processor PC (Laptop)	2	$ 3,500.00	$ 7,000.00
YAGI-Directional Antenna 900MHz) - Ground Based	2	$ 60.00	$ 120.00
Total Ctl/Data Process/Display Cost	6	N/A	$8,620.00

Control/Data Processing & Display Options: $8,620.00

COMM EQUIPMENT OPTIONS			
Component	Quantity	Cost Per Item	Subtotal
Data Transceiver Set (900Mhz) - High Range	2	$ 135.00	$ 270.00
900MHz Video System - High Power (1500mW)	2	$ 120.00	$ 240.00
Global Positioning System (GPS) Sensor	2	$ 50.00	$ 100.00
Total Comm Equip Cost	6	N/A	$610.00

Communication Equipment Options: $610.00

ADDITIONAL C3 EQUIPMENT OPTIONS			
Component	Quantity	Cost Per Item	Subtotal
Additional LCD Display	2	$ 200.00	$ 400.00
Total Additional C3 Equip Cost	2	N/A	$400.00

Additional C3 Equipment Options: $200.00

SUPPORT EQUIPMENT/HANDING AND STORAGE			
Component	Quantity	Cost Per Item	Subtotal
400-Gallon Refueling Tank	1	$ 5,979.00	$ 5,979.00
2015 Nissan Frontier	1	$17,990.00	$ 17,990.00
7 ft x 16 ft Trailer	1	$ 3,150.00	$ 3,150.00
Chemical-Resistant Coveralls over (included) short-sleeved shirt and short pants	2	$ 33.60	$ 67.20
Chemical-Resistant Gloves	2	$ 4.99	$ 9.98
Chemical-Resistant Shoes plus Socks	2	$ 43.13	$ 86.26
Protective Eyewear	2	$ 2.80	$ 5.60
Chemical-Resistant Headgear (for overhead exposure)	2	$ 34.85	$ 69.70
Chemical-Resistant Apron (when cleaning equipment and mixing or loading)	2	$ 3.91	$ 7.82
Total Support Equipment Cost	15	N/A	$27,365.56

Support Equipment/Handing and Storage: $27,365.56

ENGINEERING & CONSTRUCTION LABOR			
Role	Hours	Cost Per Hour	Subtotal
Project Manager	80	$ 75.00	$ 6,000.00
Design Coordinator	80	$ 50.00	$ 4,000.00
Systems & Test Engineer	80	$ 50.00	$ 4,000.00
Simulations Engineer	80	$ 50.00	$ 4,000.00
Project Mathematician	80	$ 50.00	$ 4,000.00
Marketing Specialist	80	$ 50.00	$ 4,000.00
Assembly Technician	160	$ 25.00	$ 4,000.00
Electronics Technician	160	$ 25.00	$ 4,000.00
Aircraft Maintenance Technician	160	$ 25.00	$ 4,000.00
Total Eng/Construction Labor Cost	960	N/A	$38,000.00

Engineering/Construction Labor: $38,000.00

PAYLOAD		
Payload Subtotal Cost	**$**	**11,014.28**
Air Vehicle Element (UAV) Design-1		
Airframe Configuration Design	$	65,798.00
Additional Flight Control Options	$	1,563.22
Alternate Powerplant (Propulsion) Options	$	23,508.00
Onboard Sensor Options	$	345.00
Additional Options	$	403.42
Air Vehicle Element (UAV) Design-2 (if applicable)		
Airframe Configuration Design	$	46,492.00
Additional Flight Control Options	$	1,563.22
Alternate Powerplant (Propulsion) Options	$	23,508.00
Onboard Sensor Options	$	345.00
Additional Options	$	403.42
Command, Control, and Communication (C3) Equipment		
Control/Data Processing and Display Options	**$**	**8,620.00**
Communications Equipment Options	**$**	**610.00**
Additional C3 Options	**$**	**400.00**
C3 Subtotal Cost	**$**	**9,630.00**
Support Equipment		
Support Equipment Subtotal Cost	**$**	**27,365.56**
Engineering/Construction Labor		
Engineering/Construction Labor Subtotal Cost	**$**	**38,000.00**
TOTAL - System Initial Cost ($AcqCost_i$)	**$**	**249,939.12**

Summary: $249,939.12

4.2.2 Direct Operational Cost per Mission

Direct Operational Cost per Mission: $4,337.62

We have a dual unmanned aircraft system flying at a low altitude, each aircraft with one sensor payload (SPI M1-D Micro Thermal PTZ Multi Sensor HD Camera), one video system, one First Person View headset, data receiver, data logger for sensor data records and storage, GPS, autopilot, and linear electronic actuators. Our mission time is 2 hours and 58 minutes, and our costs per hour include our operational personnel and the unleaded mogas we are using to fuel our aircraft. Each of our systems are operated by one payload operator, one data analyst, one range safety/aircraft launch and recovery maintenance, one launch and recovery assistant, one safety pilot, and one operational pilot. Our costs are defined below:

OPERATIONAL PERSONNEL			
Role	Number Req	Cost Per Hour	Subtotal
Payload Operator	2	$ 35.00	$ 70.00
Data Analyst	2	$ 50.00	$ 100.00
Range Safety/Aircraft Launch & Recovery/Maintenance	2	$ 35.00	$ 70.00
Launch and Recovery Assistant	2	$ 15.00	$ 30.00
Safety Pilot	2	$ 35.00	$ 70.00
Operational Pilot	2	$ 35.00	$ 70.00
Total Operational Personnel Cost	12	N/A	$410.00

Total Operational Personnel Cost (per hour): $410.00

CONSUMABLES			
Component	Quantity Per Hour	Cost Per Qty	Subtotal
Unleaded Mogas	14	$ 4.44	$ 62.16
Total Consumables Cost	14	N/A	$62.16

Total Consumables Cost (per hour): $62.16

Operational Costs Per Hour	
Operational Personnel	**$ 410.00**
Consumables	**$ 62.16**
Operations and Support Costs ($O\&S_{hr}$)	**$ 472.16**

Total per Hour Cost: $472.16

Time to Complete Mission: 2 hrs. 58 minutes (3 hours)

Assuming a system initial cost (AcqCosti) of $249,939.12 and 480 missions for year 1, a Total Acquisition Cost per Hour of $34.71, and the Time to Complete Mission (T) of 3 hours (rounded up), our total costs are shown below:

Total Flight Cost per Hour: $506.87

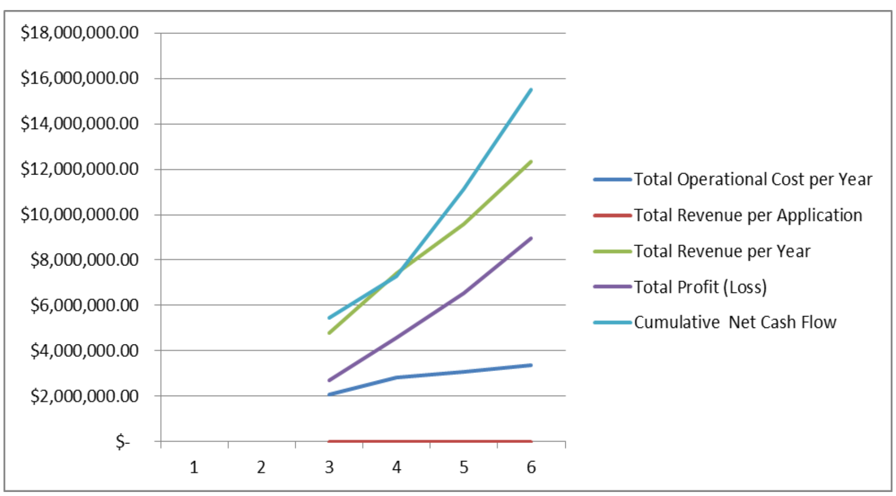
Total Operational Cost per Mission: $4,337.62

4.2.3 Amortization

The team utilized the RWDC cost calculator to find the Skywalker UAS systems' amortization costs. First, we added our system initial cost ($249,939.12) and the total operational cost per year ($2,082,058.22), then divided this total cost ($2,331,997.34) by 480 missions we will be expecting for year 1. The team decided that because of the provided mission time (3 hours), we will be conducting two missions per day. We then multiplied this by five because we will be working 5 days a week, which would total to 10 missions per week. We also took into consideration the federal holidays our employees must have a day off for, and we found that there would be ten federal holidays in the year 2015. We then subtracted these 10 days, or 20 missions, from our total missions per year. Apart from federal holidays, we have decided as a team to provide our employees two weeks off, so we subtracted another 20 missions off our anticipated missions per year, thus equaling into 480 missions per year. Our amortization cost is $4,858.33.

System Initial Cost	$249,939.12
Total Operational Cost per Mission	$4,337.63
Total Operational Cost per Year	$2,082,058.22
Initial Cost and Operational Cost per Year	$2,331,997.34
Total Cost divided by 480 Missions	$4,858.33

Operational Costs Per Hour	Year 1	Year 2	Year 3	Year 4	Year 5
Operational Personnel	**$ 410.00**	$ 410.00	$ 410.00	$ 410.00	$ 410.00
Consumables	**$ 62.16**	$ 62.16	$ 62.16	$ 62.16	$ 62.16
Operations and Support Costs ($O\&S_{hr}$)	**$ 472.16**	$ 472.16	$ 472.16	$ 472.16	$ 472.16
Total UAS Cost Per Hour (over specified number of applications)					
System Initial Cost ($AcqCost_i$)	**$ 49,987.82**	$49,987.82	$49,987.82	$49,987.82	$49,987.82
Number of Applications Per Year (N)	**480**	480	740	800	880
Time to Complete Application (T) [in hours]	**3**	3	2	2	2
Total Acquisition Cost Per Hour	**$34.71**	$34.71	$33.78	$31.24	$28.40
Flight Cost Per Hour ($FCPH_{RWDC}$)	***$ 506.87***	$ 506.87	$ 505.94	$ 503.40	$ 500.56
SOLVITAL Cost $_{RWDC}$	***$ 2,817.00***	$ 2,817.00	$ 2,817.00	$ 2,817.00	$ 2,817.00
AC_{RWDC}	***$ 4,337.62***	$ 4,337.62	$ 3,828.87	$ 3,823.80	$ 3,818.12
Total Operational Cost per Year	***$ 2,082,058.22***	***$ 2,082,058.22***	***$ 2,833,364.62***	***$ 3,059,043.82***	***$ 3,359,949.42***
External Funding (Grants)	***$ (100,000.00)***	$ -	$ -	$ -	$ -
Total Revenue per Application	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 12,000.00	$ 14,000.00
Total Revenue per Year	$4,800,000.00	$4,800,000.00	$7,400,000.00	$9,600,000.00	$12,320,000.00
Total Profit (Loss)	2,717,941.78	2,717,941.78	4,566,635.38	6,540,956.18	8,960,050.58
Cumulative Net Cash Flow	$ 2,817,941.78	$ 5,435,883.55	$ 7,284,577.15	$ 11,107,591.55	$ 15,501,006.75



In the first year of our market analysis, though our costs were significantly high, our revenue proved to be higher than all of our costs, providing us a total profit of $2,717,941.78 and a cumulative net cash flow of $2,817,941.78. The $100,000.00 grant provided to us was subtracted in our year one costs and that helped further ease our payments. We chose to start our business with plenty of room to maximize and examine the growth in our business case. It is also noted that we would be paying for our entire system initial cost in the span of five years, which would be $49,987.82 each year. Our approximate mission time is three hours, and as the years pass, we will gradually improve our system by being able to shorten our mission time into two hours, thus increasing our total missions per year from 480 missions to 740 missions – while still adhering to the standard 40 hours per week for our employees.

By year 4, we will begin to explore further ways to increase our missions and expand our business. In order for us to improve our system, we determined that it would be significantly helpful to add a chopper to assist our UAS in its mission. Because not all fields would be the same and realistically speaking, there are large trees and other obstacles that might inhibit our system from performing at its best capacity; we figured that a chopper would be capable of spraying over a field's challenging perimeter. By doing so, we would greatly increase our missions per year. It would be appropriate at this course of our business to raise our revenue each mission by $2,000.00, thus increasing our annual profit to $6,540,956.18 and our cumulative net cash flow to $11,107,591.55.

As year five unfolds, we will continue to further improve our system and conduct a total of 880 missions that year. We determined that because of our superior solution, it would still be appropriate to raise our revenue each mission to $14,000.00 – still without surpassing the cost of a regular crop duster.

The team knew the utmost importance of the company having to invest their money, time, effort and sweat towards starting off as a funding concept. Our resources in designing the Skywalker UAS is very much available to companies and people who have any special skill set and interest with computers and RC aircrafts. We have developed a mission plan, scope, and deal that will provide our customers the most efficient, precise, fastest and money-saving solution in regards to crop productivity and a return on investment. This greatly urged the team in determining that our provided system proves highly beneficial to our company, investors, and the agricultural sector environment.

4.3 Market Assessment

The FY15 RWDC National Aviation Challenge is one of the best ways to showcase our unmanned aircraft system in precision agricultural operations. The National Transportation Safety Board and the Federal Aviation Administration are one of the many agencies whose concerns have heightened towards aerial agricultural application and the safety of who and what is around while the process takes place. Because of the many inherent dangers that have been contributed by the use of unmanned aircraft systems, the FAA has posed new regulations and restrictions, such as not allowing pesticide spraying from unmanned helicopters and vehicles as it considers them "experimental" vehicles. While specific unmanned aircraft systems are slowly being exempted to use for precision agricultural spraying, crop dusters have long been a great source of investment, garnering millions of dollars from the government to improve its agricultural productivity. There have, however, been many complaints and concerns concerning its safety and reliability. By 2014, there have been over 78 agricultural accidents, in which many were fatal. Crop dusters that conduct blanket coverage of entire fields with pesticide causes enormous amounts of spray drifts that affect the people and damage the surrounding water systems. More than ten fatal incidents with crop dusters and its pilots coming to a crash have been made throughout the last year. There have been numerous complaints regarding crop dusters flying too close to homes, causing injuries to the surrounding people. Aside from increasing agricultural productivity, the use of manned aircrafts flying at low altitudes caused a risk to many and took lives of several. The use of unmanned aircrafts for precision agricultural application, such as the Skywalker, is a product that is cost-efficient, precise, and will save the lives of many.

One regular crop duster costs from $200,000 to $300,000, and as mentioned before, they are inefficient, costly, and can cause damage to many different aspects of its environment. Service from aerial applicator companies would cost at least $22,000, and in contrast, it would only cost our customers $10,000 for each application. As our system improves, and ultimately becomes superior over regular crop dusters, we would be charging a maximum of $14,000 – still below the minimum price of an application from a crop duster. Our system easily defeats the cost a regular crop duster, considering the fact that it is less costly, at $249,939.12 for two aircrafts, and it performs with great finesse.

Compared to the AT-802A crop duster plane, one of the largest single aircrafts, our Skywalker UAV provides a competitive edge towards any aircraft larger than it is. The AT-802A is a manned air tractor with a wing span of 59.2ft payload of 9,249lbs. In comparison, our updated aircraft system has a wingspan of 31.4ft and a payload capacity that is capable of holding at least 61 gallons of pesticide mixture. A wingspan of 31.4ft provides productivity for both large and small field areas as it is capable of performing tight and efficient turns while flying at a low altitude. An aircraft with a large payload capacity is no match for our system as we will be conducting precision application spraying; an aircraft that will follow specific waypoints to ensure an infested field receives the right amount of pesticide while ensuring no spray drift that will contaminate nearby water areas or people. Safety levels are increased with our system as it is unmanned; its telemetry and communications system will be carefully monitored by multi-qualified crew members on the ground, instead of the life of a pilot being at risk flying in the air. Additionally, our system will require fewer personnel than that of the AT-802A, thus reducing our overall operational cost and increasing our business profitability. An AT-802A air tractor itself costs more than $1,100,000.00 not including its application cost. Our aircraft provides more innovative and advanced capabilities while providing efficiency in both application and cost as our total initial cost is only $249,939.12.

To further prove our system's superiority, we sought other UAVs who conduct pesticide applications. The Yamaha RMAX is a helicopter that is considered to be the most advanced commercial UAV in the world. It is powered by a 12hp engine and has the payload capability of 20 kilograms or 5.28 gallons. Our UAS, on the other hand, is powered by a 100hp engine and has the payload capability of 61 gallons – our system's prowess in precision agriculture is evident compared to the best UAV in the world. The RMAX is capable of spraying paddy fields in difficult terrains faster than a manned helicopter, yet equally as expensive. On top of that, the RMAX costs $1,000,000.00. Not only is our system incredibly feasible, but it can also perform with astounding proficiency.

4.4 Cost / Benefits Analysis and Justification

The team made precise decisions that would result in tradeoffs and benefits between our objective function for this year's challenge, and our innovation towards an increase in precision agriculture. Constantly consulting our mentors and retrieving answers from all available resources, the team made its biggest decision by effectively showcasing the following concept: compared to the conventional method which utilizes significant amounts of pesticide and fuel on an entire field, we recognized that core precision agricultural spraying within our system will result in a lower APM, lower cost on a positive ratio, higher productivity within a necessary time frame, and the use of not less but the exact amount of pesticide which will affect the outcome of our objective function. Our four main components of aircraft productivity, application cost, application volume, and business profitability were all affected based on the team's decision to maneuver the aircraft solely above the areas that are infected. This resulted in automated calculations that required specific reasoning for each component. Even with the comparison of this strategy against the conventional method of blanket coverage and spraying an entire field, the team was able to successfully reach the objective function requirement of "1" when rounded our objective function of 0.7048. The RWDC FY15 precision agriculture challenge, along with its objective function, did not limit the team from conducting outside research that allowed us to apply ready-developed technology into our system versus limiting our choices strictly within the catalog.

Sensor Payload Selection:

The team assessed that the numerous capabilities of the M1-D thermal imaging and CCTV camera outweigh its costly variable. Overall, we learned that this investment will result in positive effects in terms of our aircraft productivity and business case. The M1-D is equipped with both high resolution thermal imaging and CCTV visual imaging, which can aid in scientific research and can go as far as identifying the types of pests located within the field. With this implementation on future years, our data analysts are able to gather information and keep track on the state of the infected crops over time. This takes precision to a whole new level, especially with the low price that our company offers per application.

Nozzle Selection

The team's selection of the Guardian Air GA 110-03 was made due to its reliability and ability to be used for applications not restricted to pesticide application. Compared to our state challenge nozzles, the Guardian Air 110-03 costs only $4.86. This lowers our initial cost while providing the team with a solution to the 11-knot wind scenario. Its powerful droplet size ranged from 500-600 VMD (microns) at a rate of 0.215 to 0.253 gallons per minute. These nozzles provide an excellent drift reduction system which minimizes harmful wastage, protecting lives of people and the environment.

Boom Tubing:

To save money and increase precision application, the team designed our own extendable boom tubing. This is efficient for any field or mission scenario. A regular spray boom can only extend as low as the placement of the landing gear, with assurance that it will not interfere with one another. With an extendable boom, the Skywalker can fly anywhere from five to fifteen feet above a crop and still be able to spray several feet lower that its altitude. This ensures that the pesticide will effectively reach the infested crop.

Mission Plan:

With a calculation of a total mission time of approximately three hours, the team recognized that two missions per day along with a five-day work schedule creates a steady yet advantageous start on year 1. Our mission plan was designed based on executing the fewest possible turns, which in turn decreases our overall mission time while saving money on fuel. We will only charge customers $10,000 per mission, which is less than half of the price a conventional sprayer charges. Unlike conventional sprayers, our system will spray only above the infected crop areas. The team has also integrated apps such as Misssion Planner and APM Planner.

Components Selection:

The Aeronautical Dolphins decided to purchase and modify another A-22 Foxbat aircraft. Due to the circumstances of Australia's economy, the cost of the Foxbat has decreased, decreasing our total initial cost. We have implemented the Hobby Grade RC development into our overall system. The Hobby Grade remote control contains a modular characteristic that enables our aircraft's flexibility to be assembles, designed, and with the standard units and dimensions of varying RC equipment. Upon careful consideration regarding aircraft productivity and ability to perform additional applications, the 100hp Rotax 912 ULS engine provides the following advantages to our system: high thrust production, low fuel consumption for increased pesticide tank space, and contains a duel electric ignition. The materials we have selected and modified from the A-22 Foxbat proved efficient as it formed the overall shape of the aircraft as well as provide significant amount of strength and durability to our design.

Breakeven Analysis:

Our company's breakeven analysis was greatly affected by the $100,000 grant given to us to further improve our system. This, along with additional loans, equipped our company with two UAS that will be utilized to complete the mission scenario. There is an indicated sign of profit gain by the first year of our business case. Our yearly revenue ($4,800,000.00) is greater than our operational cost per year ($2,082,058.22), resulting in a total profit of $2,717,941.78. Nearly three million dollars! This is the same concept as we move and improve towards year five. We began our business with providing our customers an affordable deal, and as we improve our system, we increase our revenue per mission, still without surpassing the cost of a regular crop duster.

Finally, the unique design of our system enables us to achieve much more in addition to achieving top-of- the -line precision agriculture spraying. The team has learned that surpassing the variables of a given conventional method is not as much the answer as innovating a well, thought out strategy that will effectively increase precision in agricultural spraying and production; all of which our system has accomplished throughout this year's national challenge.

5. References

Aeroprakt A-22. Retrieved from http://www.aviacons.org/Aeroprakt.pdf

Aircraft Certification. (n.d.). Retrieved June 9, 2015, from http://www.faa.gov/licenses_certificates/aircraft_certification/

Custom Metals & Plastics Supply. (n.d.). Retrieved July 26, 2015, from http://www.onlinemetals.com/

Foxbat Australia. (n.d.). Retrieved January 9, 2015, from http://foxbat.com.au/

HyPro Incorporated. (n.d.). Retrieved April 16, 2015, from http://hypro.com/

JavaFoil. (n.d.). Retrieved March 4, 2015, from http://www.mh-aerotools.de/airfoils/javafoil.htm

New & Used Agricultural Aircraft For Sale / Wanted - Makes. (n.d.). Retrieved September 8, 2015, from http://www.trade-a-plane.com/for-sale/aircraft/special-use/agricultural

Private Pilot Requirements at FirstFlight. (n.d.). Retrieved February 17, 2015, from http://firstflight.com/private-pilot-requirements/

Rotax Aircraft Engines - BRP's Rotax Aircraft Engines. (n.d.). Retrieved July 21, 2015, from http://flyrotax.com/home.aspx

Speedy Metals Online Industrial Metal Supply. (n.d.). Retrieved April 14, 2015, from http://www.speedymetals.com/default.aspx?

Super B 7800 Aircraft Battery. (n.d.). Retrieved May 2, 2015, from http://www.transair.co.uk/sp

University of Nebraska, Lincoln. (2007, Revised 2013) *Spray drift of pesticides.* Lincoln, NE: Kruger, G., Klein, R., & Ogg, C.

Yakolev, Y. Aeroprakt-22LS pilot operating handbook. Kiev, Ukraine. Retrieved from http://www.aeroprakt.kiev.ua/bulletins/a-22ls_eng.pdf