FanFlyer - Internal Frame

Preliminary Report

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Figure 1-Novakinetics concept art [1]

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DISCLAIMER

This report was prepared by students as part of a university course requirement. While considerable effort has been put into the project, it is not the work of licensed engineers and has not undergone the extensive verification that is common in the profession. The information, data, conclusions, and content of this report should not be relied on or utilized without thorough, independent testing and verification. University faculty members may have been associated with this project as advisors, sponsors, or course instructors, but as such they are not responsible for the accuracy of results or conclusions.

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1 BACKGROUND

1.1 Introduction

The NAU Fan Flyer team has been given the opportunity to assist NovaKinetics AeroSystems with their design to compete in the Boeing sponsored, GoFly competition. Jim Corning, the CEO of Novakinetics has tasked the team with designing and analyzing an interior steel frame for their manned air vehicle. The steel frame will have to support loads that add to about 900lbs. To take on this task, the team will be learning to use Finite Element Analysis (FEA) and the program Ansys, as none of the members have a background in either. Using Ansys, the team will be able to analyze their proposed designs by locating the weak points and areas of high stress on the steel frames. These calculations will then be checked by the team by performing closed-form solutions by hand.

Novakinetics is looking for a strong and durable frame to act as the backbone for their manned air vehicle. Jim Corning is striving to win the GoFly competition as well as create a market to sell their design with the help of the Fan Flyer team's frame. The GoFly competition is a two year long feat requiring teams from all over the world to generate a personal flying vehicle. After passing the first-year trials, Novakinetics is looking to bring home the million dollar prize in the second year with the help of the NAU Fan Flyer team.

1.2 Project Description

Following is the original project description provided by Novakinetics AeroSystems; "The FanFlyer will have a ladder structure of welded 4130 steel tubing that connects the engine, landing gear, reversing gearbox, pilot restraint harness mounting points, and ballistic parachute harness anchor point. This steel tube structure will also interface with the carbon fiber shell structure that forms the ducted fan housings. Each ducted fan will have a structural outer shell that connects with the steel tube frame, and an inner duct that is removable, along with the fan hub and supports, for maintenance and for easy updating of ducted fan components." [1]. In addition to this, the team has to learn the program Ansys to design this frame.

1.3 Original System

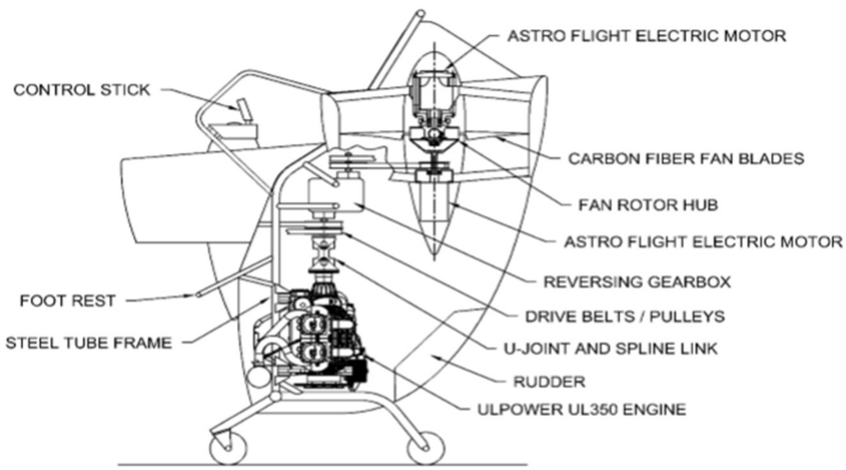

Figure 2 -Original System Layout [1].

The original system structure for the design shown in Figure 2 has already been designed by Novakinetics. The system includes everything for the manned air vehicle besides the steel frame required from the FanFlyer team. Because there was no original system for the frame at the beginning of this project, it is considered a new design. The FanFlyer team can be creative and generate a frame not based on previous designs. Thus, there is no data showing how the original system operated, performed, and failed.

1.3.1 Original System Structure

The original system, as can be seen above in figure 2 houses the four rotors, a combustion engine, generic pilot seat with controls, and generic landing wheels. Figure 3 below shows an isometric view of the rotor, crank shaft, and combustion engineering only. This is the foundation of the original system above in figure 2.

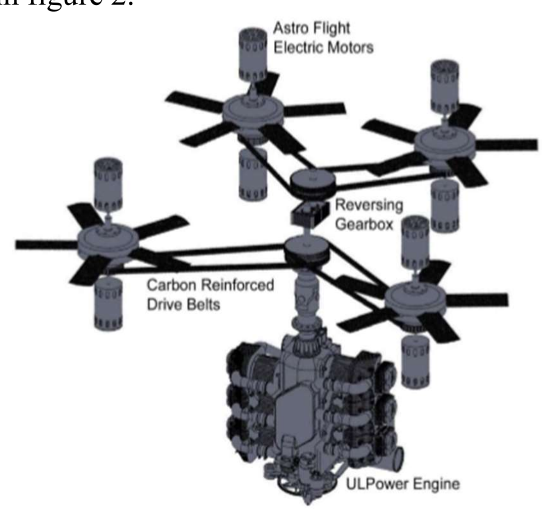

Figure 3 - Powertrain layout [1]

1.3.2 Original System Operation

Because the original system is still in the process of manufacturing, there is no data regarding the operation as it has not been tested.

1.3.3 Original System Performance

This project and Flyer are the first of their kind with Novakinetics and as such there is no original performance because as stated it has not been constructed yet.

1.3.4 Original System Deficiencies

This is not applicable to team FanFlyer at the moment of this report because this is a new project from the ground up.

2 REQUIREMENTS

In section 2 the team evaluates the requirements put forth by the client and engineering industry. The FanFlyer team will use the requirements discussed to prioritize the aspects of the project into an order of operations in which to complete the project to the best manner possible. This is done in order to exceed the expectations of the client by meeting and or exceeding industry standards associated with the project.

2.1 Customer Requirements (CRs)

2.1.1 Lightweight: This requirement was specified by the client as the highest level of importance because in order to compete in the GoFly competition the FanFlyer must first pass the weight limit test. This is why the lightweight requirement was weighted the highest.

2.1.2 Increase factor of safety: This Implies that in the design process the factor of safety should be increased through the inclusion of the structure design. By adding design aspects such as pilot restraints and roll cage design the team aims to achieve this goal. Safety is always paramount and is weighted the second highest of the requirements.

2.1.3 Balance/ Stability: Balance and stability are largely important throughout the aerospace industry. In order to achieve flight, the design must be perfectly balanced and stabilized. This is the reason behind a third highest weighting.

2.1.4 Minimize Joint failure: The FanFlyer will be put under various strains throughout takeoff, flight, and landing. Stress and strains tend to be localized at joints. As a result, it is important that the design be evaluated so that failure doesn't occur within the area of joints. The weighted value is tied for fourth importance as a result of this.

2.1.5 Withstand Impact: Reasonably the FanFlyer design includes numerous safety factors in order to reduces chances of hard or unexpected collisions; however, it is vital that in the unlikely event of such occurrence the frame should be able to withstand the impact of the collision in order to protect the persons and cargo aboard. This requirement has received a weighted score equal to the fourth important requirement.

2.1.6 Strong: Strength is integral in this design project because as it is the main point of contact for the entire structure it must be able to withhold the various stresses it will be placed under. As a result, this requirement was weighted tied for fifth in importance.

2.1.7 Durable: In the future our client intends to license this product for military applications. For this to be a realistic application of the product it must be durable in order to endure the various types of terrain and conditions that the military operates under. For this reason, it is rated as the fifth most important requirement.

2.1.8 Ease of assembly: In order to meet the client's future expectation of producing large scale and commercial applications of the FanFlyer the frame must be designed with manufacturing in mind. Though is isn't a life or death requirement it is still a requirement necessary of consideration and as such is weighted sixth most important.

2.1.9 Aesthetically Pleasing: Our client is designing the Fanflyer with commercialabilty in mind. As a result, it is important that customers appreciate the elegance of the design. Aesthetics play an important role in the consumer market and as a result should be considered for evaluation. The requirement establishes itself as the seventh most important requirement.

2.1.10 Ability to incorporate landing gear: This was not a specific requirement that the client was looking for. He proposed it as more of a challenge to the design team. For that reason, it has been weighted as least important.

2.2 Engineering Requirements (ERs)

2.2.1 Lowest cost of materials: It is important to the client that a budget be considered for a realistic design proposal. Therefore, throughout the project it is important to consider the best performing materials that are priced within reason.

2.2.2 Total empty weight < 625 lbs: The competition requires the total weight including pilot and fuel to be under 900 lbs. Therefore, the design must be engineered with empty weight restraint so that the design will fall within the competition requirements.

2.2.3 Total volume < 275 ft^3: This requirement breaks down even farther into individual requirements for each height, length, and width. For simplicity, however, the restraint was put on the entire volume of the design.

2.2.4 Precision of structural analysis: In industry, in order for regulations to be met the design calculation must be as accurate as possible. As a result, the design analysis must be precise to within a target of 1% of the necessary structural demand.

2.2.5 Analysis Delivered at least 1 month before construction date of March 19th: It is important to have to design and analysis completed and returned to the client before the date in order for project to stay on schedule for the overall competition.

2.2.6 Factor of Safety within aircraft tolerances: The design must meet all industry standards for private flight aircrafts. In order to be considered safe and reliable it is important that the design meet or exceed the industry standard factor of safety.

2.2.7 Structure within standard for FAR part 23 and part 27: The FAA has produced standards for structural loads of small private aircrafts. Since this project technically falls under this definition, it is crucial for the specifications of the structural loads to meet FAR part 23 and 27 and will be used as a guideline throughout the design.

2.2.8 Deflection and Stress within tolerance: Over time it is inevitable that components of the project will wear down with use. It is important that we evaluate the life cycles of the structure to ensure the deflection will not exceed working standard. This may be inevitable, so it is important to understand when these factors become too high to remove the product from operation for safety.

2.2.9 Pilot Drag coefficient < .5: It is important for optimal efficiency and flight control that the drag forces on the pilot not exceed this limit. This is a crucial design element to be considered in the project in order to produce an actual working model.

2.3 Testing Procedures (TPs)

Overall, there are not specific ways that the group intends on evaluating each engineering requirement. In general, and at this point in the project, the use of various CAD software in order to model and evaluate the tolerances and targets set within the engineering requirements is the intended procedure. Hopefully, through correct application and astute attention to detail through the design process, all engineering requirements should fall well within the parameters set.

2.4 House of Quality (HoQ)

The House of Quality was generated in accordance to the list of customer and engineering requirements. The customer requirements were weighted appropriately and connected to corresponding engineering requirements. The customer requirements and engineering requirements correlation is indicated by an x in cross section of both categories. Engineering requirements were established by considering the FanFlyer proposal and whenever applicable the requirements were associated with targets or tolerances. This can be seen in the House of Quality located below. The House of Quality allows the FanFlyer Capstone team to keep design requirement organized and find correlation through the design process.

House of Quality (HoQ)

Customer Requirement	**Weight**	**Engineering Requirement**	Lowest cost of materials	Total empty weight less than 625 lbs	Total LxWxL < 275ft^3	Precision of structural analysis within 1% tolerance or less	Analysis delivered at least 1 month before March 19th	Factor of safety within tolerance for aircraft	Structure within standard for FAR part 23 and 27	Deflection and Stress within tolerances set	Pilot Drag coefficient < .5
Lightweight	45		x	x	x	x					x
Strong	25		x	x	x	x				x	
Minimize joint failure	30					x		x	x		
Increase factor of safety	40							x	x		
Balance/ Stability	35			x				x			x
Aesthetically pleasing	10										
Withstand impact	30		x	x		x		x	x	x	
Ease of assembly and manufacutring	15		x								
Durable	25		x	x		x		x			
Able to incorporate landing gear	5										
Target ER values				625	275					0.5	
Tolerances of Ers						<1%					
Testing Procedure (TP#)			8	2	1	3	9	5	4	6	7

Table 1 - House of Quality

3 EXISTING DESIGNS

Throughout the next section, the FanFlyer Capstone team includes all of the research designs and techniques that have been considered through the project thus far. Within this research we have used these designs to narrow the scope of our project to find a result that will most appropriately fit the expectation of our client. The designs were analyzed and juxtaposed in order to completely understand every aspect of the project.

3.1 Design Research

Although the below references for the Hoverbike & drone car [2,3] could be cited as potential benchmarks they are differences in their lift force generation. Novakiniects has selected the '2017 Can Am Maverick X3' engine to provide power to their circuitry and rotor systems. Whereas both the [2,3] references do not seem to utilize a combustion engine of any type. However, both the below references do make better use of their rotor placements, and if they do not utilize a combustion engine they are far superior designs to what Novakinetics is attempting to produce.

That being said, the flyer design itself is beyond the scope of team FanFlyer. Novakinetics has already begun production of their flyer's exterior and have already laid out where they would like the rotors and engine to be placed. Team FanFlyer is tasked with designing an optimal internal support frame that will hold the pilot, pilot seat, four rotors, combustion engine, and battery pack system. That being said there is not a lot of freedom to research basic internal frame designs for this project. The team is limited by the already decided external flyer frame. Stated differently, team FanFlyer has no say in where the engine, pilot seat, and four rotors will be placed, they are simply tasked with designing of a frame that will effectively support all of these systems, that must be justified by FEA simulations.

Current quadcopter frames were sought and considered to generate basic geometrical conceptions for sketch designs, beyond that there is little creative freedom in how the frame will be researched because given the exterior of the flyer being produced, the internal frame has to fit that model from the inside out.

3.2 System Level

3.2.1 Existing Design #1: Hoverbike

Figure 4 - Full scale pilot test [2]

Figure 5 - Full scale working prototype [2]

figure 6 - ⅓, 2nd gen working model [2]

Figure 7 - 2nd gen upper view [2]

<u>Summary</u>

This Hoverbike in development from Malloy Aeronautics in the United Kingdom, is currently in the testing and funding stages of a personal hovercraft as indicated in the pictures. It is said to combine the flight dynamics of a helicopter with the simplicity & compactness of a personalized bicycle.

The image on the upper left is a test run of the working full-scale prototype being controlled by an actual person. The image in the upper right is the working full-scale prototype itself.

The bottom left & right images are a ⅓ test model of their second generation hoverbike design. This is a remote-controlled drone with no actual person sitting on top of it, driving it.

Notice the difference in rotor designs. The full scale has two overlapping coaxial double rotor systems to provide control and lift, whereas the ⅓ test model has shifted overlapping rotors, that can be seen in the lower right image.

<u>Project Relation</u>

This design and application seem to meet our client's CR, of size and weight. It is essentially a larger overlapped quadrotor that houses one person and given the size of the tester, it would fit within a parking space of 9'x 9'. It also appears to be lightweight, no technical specifications were found when researching this but given the size of the rotors it is not an unreasonable weight.

3.2.2 Existing Design #2: EHang 184 (“EE-hung”)

Figure 8 - Full scale working prototype [3]

Figure 9 - Working prototype CAD drawing [3]

Summary

The Chinese based company EHang has essentially made what Novakinetics is hoping to achieve, only lighter. This drone is programed to transport one passenger to their desired location with the touch of programed button. An entire system mapping out the location of a city can be uploaded via GPS and the passenger touches a preloaded landing pad to fly to on a touch screen and the drone flies itself there. There is no need for flight input from the passenger. They only point and click where they wish to go and the drone does the rest. This is a large scaled coaxial-double-quad-rotor drone with an enclosed seat on top for a person to sit in.

Project Relation

A tag line of the article claims that it is ‘car sized’, and given the picture and accompanying video this design is about the size of a car which certainly should fit within a parking space to satisfy our CR of a 9’x9’ area. The video also shows one person entering the MAV and seemingly flying off, which accounts for the overall weight of the aircraft. Judging by the image of the MAV the largest areas of mass is the cockpit which houses the passenger. It would be a safe assumption that the MAV does not require an automotive engine to power the rotors, thereby reducing the weight. The rotor attachments seem to only be connected to the body via the arms housing electronics and serving as a bridge to the MAV. This seems to imply negligible heat transfer and vibrations.

3.2.3 Existing Design #3: Quadcopter Frames


Figure 10 - Quadcopter A [4]


Figure 11 - Quadcopter B [4]


Figure 12 -Quadcopter C [4]

<u>Summary</u>

These are frames for current remote-control quadcopters that can be purchased & assembled for hobbyists. Although, the sizes are small relative to what team FanFlyer is expected to design, they can serve as a benchmark of what to bare-in-mind when designing the internal frame.

<u>Project Relation</u>

These frames give an approximate idea of what team FanFlyer should aim to consider in the project design. The geometries vary and some layouts are impractical for what is being asked, however, Novakinetics is in essence designing a glorified quadcopter. So, it would be in the best interest of team FanFlyer to keep an open mind about quadcopter frames, at the very least for inspirational ideas, if not small scaled geometric analysis.

3.3 Functional Decomposition

In order to grasp the design concept and product generation breakdown, the Functional Decomposition for the FanFlyer project was broken up into two aspects, ‘The Black Box model’ and a ‘Detailed Decomposition model’.

3.3.1 Black Box Model

The ‘Black Box model’ for the FanFlyer design encompasses the compositional break down of Matter & Energy for the internal frame team FanFlyer is designing, see appendix A. ‘Signal’ is omitted because a visual cue of the frame integrity is beyond the scope of team FanFlyer. Novakinetics will install their own method of validating the performance quality of in-flight frame integrity to their pilot operations system if they choose. This is in large part because team FanFlyer is not being asked to build the frame itself, but rather provide supporting data for Novakinetics to use in making the frame themselves. However, they will not need anything from team FanFlyer aside from the frame construction data to achieve that system on their own. So, this Black Box model will only house ‘materials & energies’.

Materials

For the Matter component of the Black Box model, the following ingredients will go into the physical construction of the support frame:

- 4130 Steel
- Welding materials
- Fasteners (bolts, nuts, rivets, etc.)
- Finite Element Analysis (FEA) data

These result in the constructed output of a metal support frame that team FanFlyer is designing. It is assumed fasteners of some type will be required per justification of Novakinetics during their flyer construction. FEA will be utilized in providing numerical justification for the geometrical design of the frame utilizing computer analysis to support specific geometrical decisions.

Energy

For the Energy portion of the Black Box model the following sources of influence will be experienced by the internal metal frame, or will be entering the system (input) upon its use in the manned aerial vehicle (MAV):

- Forces (stress, strain, gravity)
- Heat
- Vibrations

The functional response, or ‘output’, will be the following:

- countered acted forces to balance the input forces experienced by the frame
- Heat dissipation &/or resistance
- Vibrational damping & redirection

Stress & Strain forces will be experienced by any and all interior members of the frame, in large part of the thrust forces enacted by the attached rotors to give the MAV lift and thrust. These stresses & strains will not only have to be accounted for but also will have to be over accounted for by factors of safety that will be determined when more accurate data of the rotor forces are determined. Gravitational forces will also need to be considered when designing the frame structure because of the weight of the four rotors, engine, pilot seat, pilot, battery supply, and pilot control systems.

Heat control systems for heat generated by the engine, rotor, and mechanical frictions will need to be considered at some point, however, a large part of the team’s analysis will be based on weak spots where the frame is susceptible to high heat stress. The actual heat dissipation and redirection will be in the hands of Novakinetics because they are designing the aerodynamics of the exterior MAV, which should encompass aerodynamic ventilation.

Vibrations that the metal frame will endure is something team FanFlyer will need to consider. FEA simulations will provide an analysis of vibration stresses and will be need to be considered more in the materials and geometry construction.

3.3.2 Functional Model

The Decomposition Functional Model is based on four tiers of consideration to generate team FanFlyer's project design, they are: FEA, Customer Requirements, Imposed Caveats, & Materials. See Appendix B. The project break down of what will generate the team's FanFlyer design will be based on these four tiers of influence. They will serve as the parts to help guide and direct the teams justified design.

- FEA
  The cornerstone of this project, from the initial project description, is Finite Element Analysis. Novakinetics has asked NAU engineering for an analysis for an interior metal frame for their FanFlyer MAV, which will encourage their construction designs of the frame. Novakinetics has already determined the exterior design & geometry of said flyer, and have selected a '2017 Can Am Maverick X3' engine for their initial trials. However, they are still in search of the proper rotors to use. The FEA simulations will have to account for the forces imposed on the frame by the main engine and the four rotors, in conjunction with the weights of the pilot, the pilot seat, pilot controls, battery system, and circuitry systems. Heat and Vibrational analysis will be conducted once the basic enacted forces of stress, strain, gravity, and thrust are designed and accounted for.
  The FEA component of the project is broken into two areas, of 'ANSYS' & 'Theory'. The ANSYS branch is comprised of learning how to use the FEA program ANSYS, where the team will have to double check the results of ANSYS using a closed form hand calculation of the Frame. The theory aspect is learning the basics of FEA theory to better understand the boundary conditions and element constraints of the FEA simulations. Dr. Penado is an unofficial resource for basic questions of FEA because he teaches the FEA class in the spring of each year. Further initiative was performed to find free online courses, lectures, and textbooks to learn FEA on the teams' own time.

- Customer Requirements
  Mr. Corning's requirements, that apply to team FanFlyer, are based on the GoFly competition's constraints of total empty weight of 625 lbs. and total volume of 275 ft^3. As such Novakinetics has already designed & constructed the exterior framework of the MAV. The geometries they have decided upon, based on the competition requirements, are team FanFlyer's baseline requirements to adhere to. The internal Frame itself has a target weight requirement of 50 lbs. with a max of 99 lbs., and the proposed geometry must accommodate the total volume limit, which will include the application of all the mechanical systems.

- <u>Imposed Caveats</u>
  These are forces & phenomena that must be considered due to the presence of the required matter in the MAV, like engine & rotor weights, heat transfer, and vibrations. These forces & phenomena will be experienced by the designed frame and will be accounted for.

- <u>Materials</u>
  The material (matter) makeup of the frame has a baseline material recommendation of 4130 steel, however Novakinetics is open to suggestions regarding alternative materials. Welding various beams & bars in combination based on the design composition will greatly aid in the overall frame strength, but will provide additional matter to the system. Welding joints and fasteners to each other will also be installed in some fashion to the frame for its integration into the MAV.

The layout of these four tiers help to map out all the external and internal influences to team FanFlyer's design. They each encompass a different branch of required influences that the team must adhere to.

3.4 Subsystem Level

3.4.1 Subsystem #1: Finite Element Analysis (FEA)

For subsystem #1, three programs that can perform Finite Element Analysis of solid mechanics are presented: ANSYS, MATLAB, & Solidworks. They each have their strengths and weaknesses when applied to various systems and conditions. For the purposes of FanFlyer, because of simplicity and availability, ANSYS will be utilized.
As mentioned earlier, FEA is what the entire FanFlyer project is based upon. A proper analysis using FEA techniques will help support the desired geometrical designs of the proposed internal metal frame. This analysis will show various stress/strain concentrations of the frame based upon applied loads and forces in relation to the geometrical layout of the designed frame.

3.4.1.1 Existing Design #1: ANSYS

ANSYS is a powerful tool for numerical analysis relating forces and physical phenomena to physical geometrically defined systems. The software has branches in fluid mechanics, solid mechanics, & electricity, among other subjects [5]. For purposes of FanFlyer the structural analysis component of ANSYS will be utilized for the interior support frame of the MAV. It relates to team FanFlyer's project because ANSYS is readily available for the team's use, and can perform reliable FEA simulations, which is what is required per request of Novakinetics.

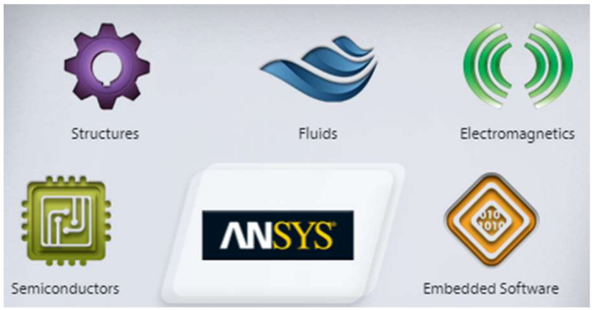

Figure 13 - ANSYS branches [5]

3.4.1.2 Existing Design #2: MATLAB

Matrix Laboratory (MATLAB), has numerous built in mathematical functions that can perform numerical calculations and can produce simple vectorized simulations based upon boundary conditions and mathematical descriptions. These conditions and descriptions require the user to properly input syntax code to generate the proper simulations. This FEA approach is beyond the capability of the members of team FanFlyer. However, its relevance to the project could, when coded correctly, be able to see how the forces & phenomena relate to the frame mathematically. This would help design the frame from a different physical perspective.

3.4.1.3 Existing Design #3: SolidWorks

Solidworks, which is used mainly as a drafting tool for team FanFlyer, also has FEA capabilities for simple geometries. Solidworks will apply to team FanFlyer because the sponsoring professor, Dr. Trevas, recommends that the team attempt basic FEA simulations using Solidworks to gain any results and understanding. Aside from the simple FEA simulations, Solidworks will be utilized for drafting the proposed frame concepts because ANSYS requires a CAD packaged model to perform analysis on.

3.4.2 Subsystem #2: Design Frames from Customer requirements

'Structural Frames' were not a supporting tier of the Functional Decomposition break down addressed earlier, however, customer requirements, and the proposed frames were all designed with Novakinetics requirements in mind. These include: pilot safety, strength/structural-support, weight, and size. The following addresses the main pros and cons of the top three frame designs per decision matrix ranking, and how those pros and cons relate to the project via CRs.

3.4.2.1 Existing Design #1: Concept # 3

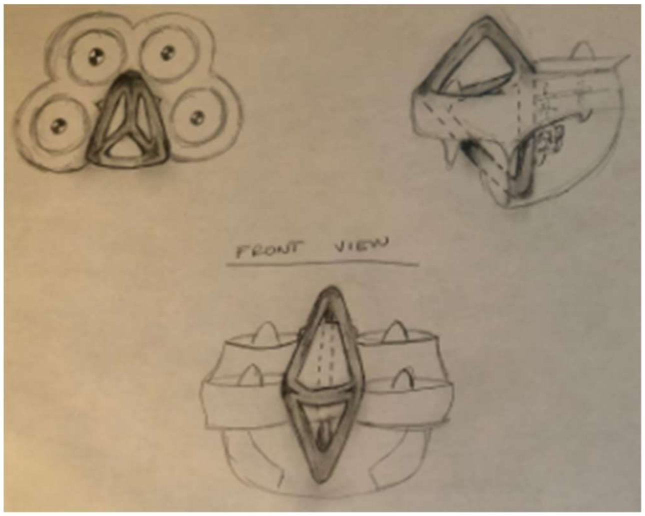

Figure 14 - Concept #3 - Hover Pad Frame

Concept #3 scored the highest of all the proposed frame models with a score of 106 and satisfies the condition of a roll cage that is integrated into the design. A roll cage was not required of team FanFlyer, however, Novakinetics only requested the availability to physically do so on whatever design was provided. The design is stable, balanced and as such provides safety to the pilot. This meets the needs from Novakinetics, assuming the weight is between 50 and 99 lbs. At this point of concept development, it is difficult to properly gage how much the frame will actually weigh. However, the remaining CR's poses a higher chance of being met, according to the team's decision matrix.

3.4.2.2 Existing Design #2: Concept #4

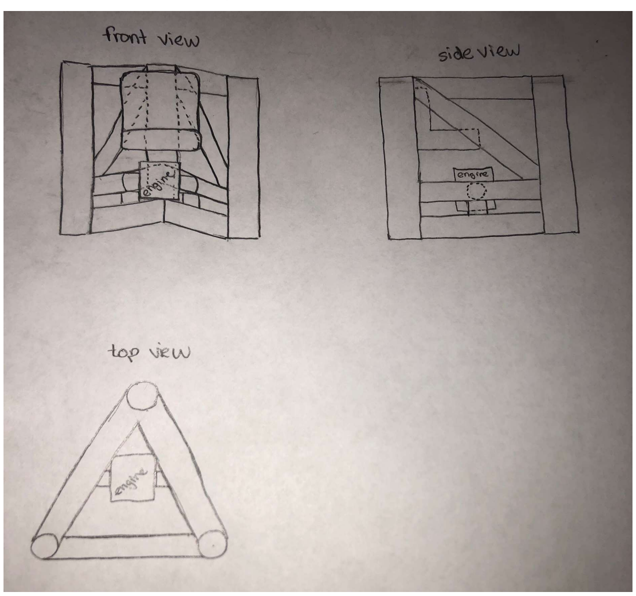

Figure 15 - Concept #4 - Triangular Box Frame

This concept ranked second with a score of 100. It dominates in safety and balance due to its reinforcement supports, but it falls short in weight because of the extra support the frame houses. It is designed to support the pilot, four rotors, engine, and battery systems with ease, however, the weight of the frame is projected to exceed the 99 lb. limit because of the surplus of materials that make it balanced and strong.

This relates to the project because though it satisfies most of the CRs, it fails to meet the weight requirement. This brings to light the intricate balance between function and effective use of materials, it is strong but it requires too much material.

3.4.2.3 Existing Design #3: Concept #6

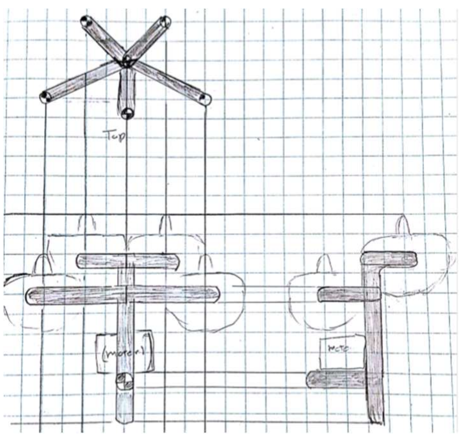

Figure 16 - Concept #6 - Five Point Pole

Concept #6 is the third ranked of the frames, coming in at 96. This ranked the highest in safety and weight, but fell short in stability and balance because of the perpendicular extensions.

Like Concept #4, this relates to the project by having to balance the effective use of materials to its function. It is designed with a practical amount of material, however its lean production is traded out for its strength and balance.

3.4.3 Subsystem #3: Materials

What the frame is composed from is highly important. It will react differently if it were made from metal or plastic, which will determine the life and function of the frame under its intended use. 'Materials' is a design tier from the decomposition model, and also houses welding and fastener materials. However, for the bulk of expected materials, team FanFlyer does not have much experience working with metals or plastics under extreme conditions that the MAV will endure. However, at the recommendation of Novakinetics, welded 4130 steel is offered as a base material for the frame's material construction.

3.4.3.1 Existing Design #1: 4130 Steel

Mr. Corning of Novakinets has recommended 4130 steel as the base material, but is open to alternative justified suggestions. The advantages of this option are that not only was it recommended by a mechanical engineer who is also the president of the Novakinetics, it is incredibly strong, and will yield before it breaks.

This applies to the project in satisfying the integrity of the internal frame of the MAV by yielding before breaking. As such it is incredibly strong and under the correct ratio of cross diameter geometries to thickness (wider diameter & thicker walls, or visa-versa) it can withstand the imposing forces that it is expected to experience.

3.4.3.2 Existing Design #2: Aluminum

Aluminum, although light and strong, can be brittle in comparison to 4130 steel. Under certain conditions and geometries, more Aluminum may be required to equate to the strength of the 4130 steel.

This relates to the project because it was mentioned in meetings with Mr. Corning that certain alloys of aluminums may work, however, further analysis would be required to verify that suggestion.

3.4.3.3 Existing Design #3: Cold rolled steel

Cold roll steel was used before the use of 4130 steel. It is incredibly durable; however, it is heavier and not as hard as 4130 steel is. 4130 steel is somewhat a standard for current aircraft materials because of its simplicity in its workability, of forming, welding, cutting and fastening. Whereas cold rolled steel is not as ‘flexible’ because it is lacking a similar hardness.

This relates to the project because although 4130 steel is far superior, cold roll steel does offer a potential alternative if used accordingly.

4 DESIGNS CONSIDERED

Included within this section are the designs that have been proposed and evaluated thus far. As the project continues there will undoubtedly become more concepts that need to be considered. Each concept has a description and picture associated with it in order to fully explain what the team was aiming for in the design concept. Included in this section is only a portion of the designs considered but were considered to be the best, most creative, or most inspiring to the group.

4.1 Design #1: Smaller Main Design

This design has come from the advice our client gave us for this project, but on a smaller scale and with some additional features. This design is lighter than the clients but does not protect the pilot and is unstable in comparison to the original.

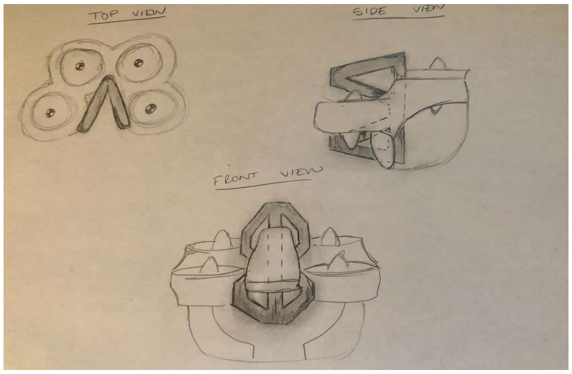

Figure 17 - Design #1 - Smaller Main Design

4.2 Design #2: Three Poll Frame

This design was brainstormed off of Jim Coring's idea of using a 3-point system for the device. Three long poles connect the seat to the outer shell of the design. This design is lightweight, and easy to test and manufacture. However, it is not aesthetically pleasing, not very stable, and has a good chance of joint failure.

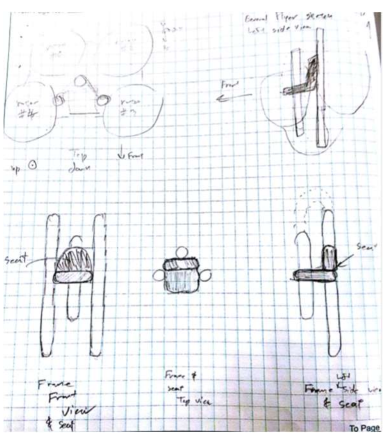

Figure 18 - Design #2 - Three Poll Frame

4.3 Design #3: Hover Pad Frame

This design is another design based off the advice received from our client. This design is light, has near to no possibility of joint failure, is safe and is easy to manufacture. Some disadvantages include that it is not easy to test and it is not very stable.

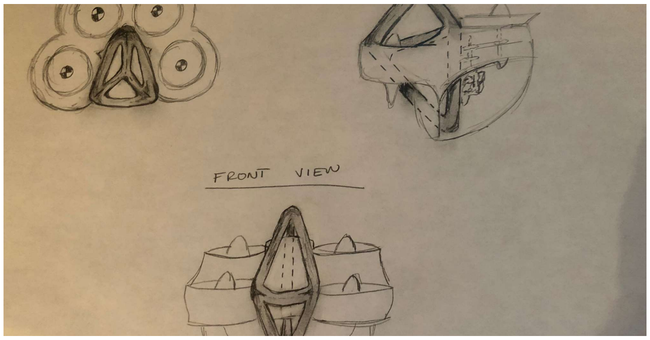

Figure 19 - Design #3 - Hover Pad Frame

4.4 Design #4: Triangular Box Frame

This design is once again conceived from our client's three-point system. It is much like the three-poll frame but with smaller poles and with supports on the right, left, and bottom of the sides of the seat. This design is heavy, provides no ease of load testing and is not very safe. However, it has great stability and a low chance of joint failure.

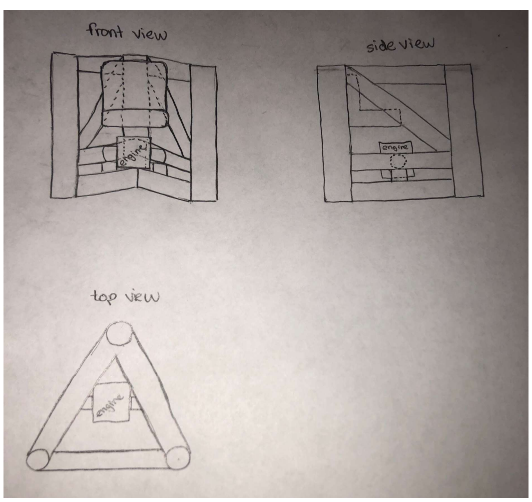

Figure 20 - Design #4 - Triangular Box Frame

4.5 Design #5: Race Car Hover Pad

This design is once again based off the advice our client relayed to us requiring a 3 point-of-contact system. This design is light and should not have joint failure. However, it is not very safe or stable.

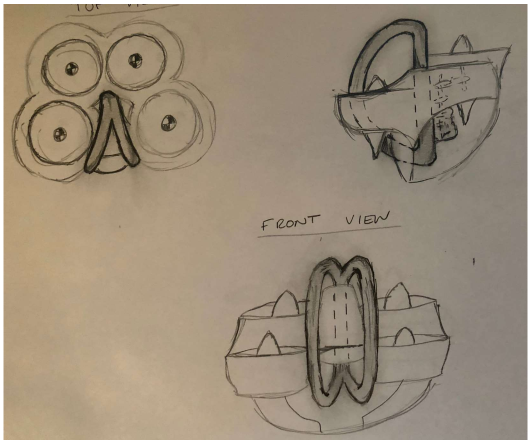

Figure 21 - design #5 - Race Car Hover Pad

4.6 Design #6: Five Point Pole

This design was based off of a five point-of-contact frame instead of three points. It is light, easy to analyze, and pleasing to the eye. However, it is not very balanced and could have joint failure.

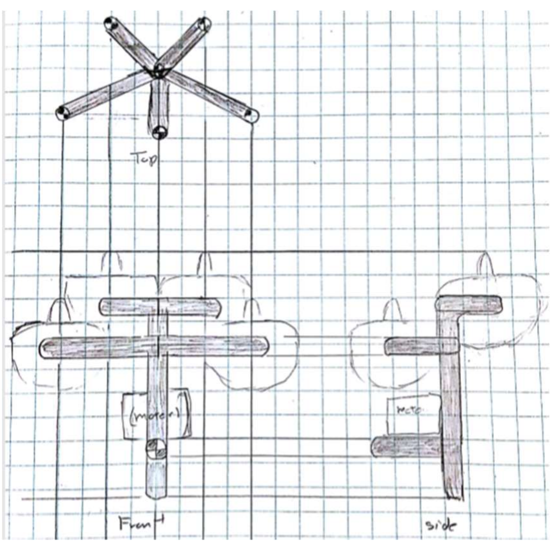

Figure 22 - Design #6- Five Point Pole

5 DESIGN SELECTED – First Semester

Jim Corning wants the FanFly team to aid in his company's participation in the GoFly competition. We are to design an internal frame for the aircraft he has designed. Our Criteria is that it needs to be lightweight, stable, and safe. The design must be within 900 lb. of weight, can stay stable on the ground or in the air for 20 minutes, and has safety measures in case of emergency. Our client also wants our team to keep the device within 9x9 ft ground area. After examining the considered designs we reached a final decision and chose to use design #3.

5.1 Rationale for Design Selection

The design meets our standards by being lightweight and strong. The shape of the design is very difficult to stabilize without a unique form of landing gear and because of this it is also difficult to analyze how it flies. However, it does make the device lighter, prevent joint failure, easier to assemble, and is one of the safest designs. A demonstration of these facts can be seen in the decision matrix in Appendix C.

5.2 Design Description

The design is much like that of the hoverbike described in 3.2.1 only on a larger scale and instead of a bike seat it has a seat more like a race car and has some poles to guard the pilot like a race car does for a driver. If adequate landing gear is built into the design it could stabilize better on the ground. Thanks to its small size it is lightweight and easy to manufacture.

6 CONCLUSIONS

Although the project is very far from truly being concluded as a team it is important to understand the contributions of members toward the project's success, areas in need of improvement moving forward and what has been learned thus far. The Team will hopefully learn from this and apply it moving forward with the project.

6.1 Contributions to the Project's Success

Currently, the team members have had reasonable success meeting assignments and achieving success within the classroom. Success has come by the contributions of the team members for their hard work, time and dedication toward the project. Other notable contributors are the instructor - Dr. David Trevas, TA - Brandon Begay, and team sponsor/Novakinetics CEO - Jim Corning. All of whom have contributed their time, expertise, and guidance throughout the project.

6.2 Opportunities/ areas for improvement

Unanimously, the team has decided that a large area for improvement would be organization and proactiveness for upcoming assignments. Throughout the project it has been identified that while the team performs well under time sensitive assignment due dates, it is preferred to have additional time to review and make sure our work is of the utmost quality. This aids in the reductions of team stress and conflicts within the group as well.

Additionally, the team has come to the conclusions that, however improving, communication within the group is vital toward the success of assignments and the overall quality of the project. Communicating well also allows for assignments to be broken up easily and assures that everyone is contributing equally.

6.3 What the Team Has Learned

Thus far, a quarter of the way to the completion of the assignment in its entirety, the team has learned quite a bit and has a lot to reflect on. In hindsight, the biggest lesson has been that each member brings a certain uniqueness to the group, and in order for the group to perform at the highest caliber, each member needs to express and contribute as much as possible to take advantage of the diversity that comes with being a part of a team project. Since this evaluation the team has worked exponentially more cohesively and have produced standards of work that are exceptional.

7 REFERENCES

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8 APPENDICES

8.1 Appendix A: Black Box model

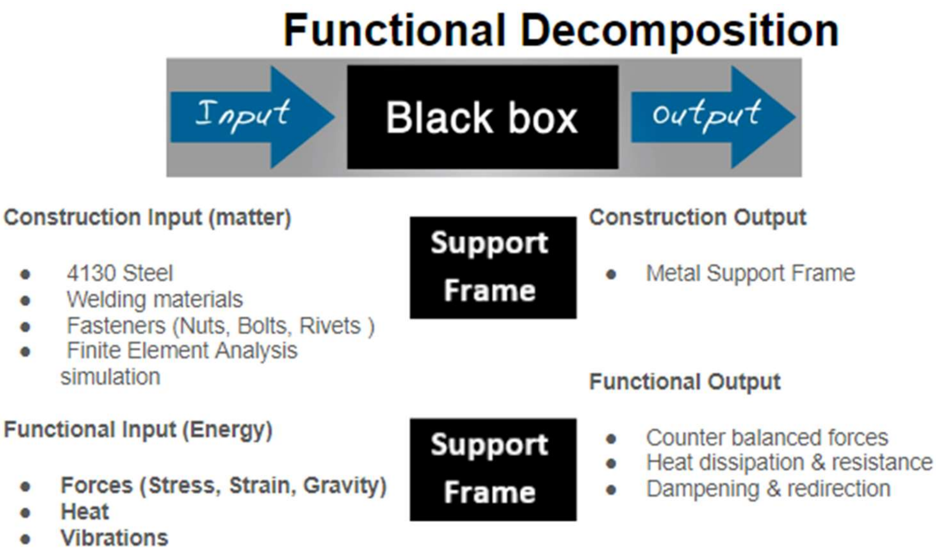

Figure 23 - Black Box model

8.2 Appendix B: Functional Decomposition

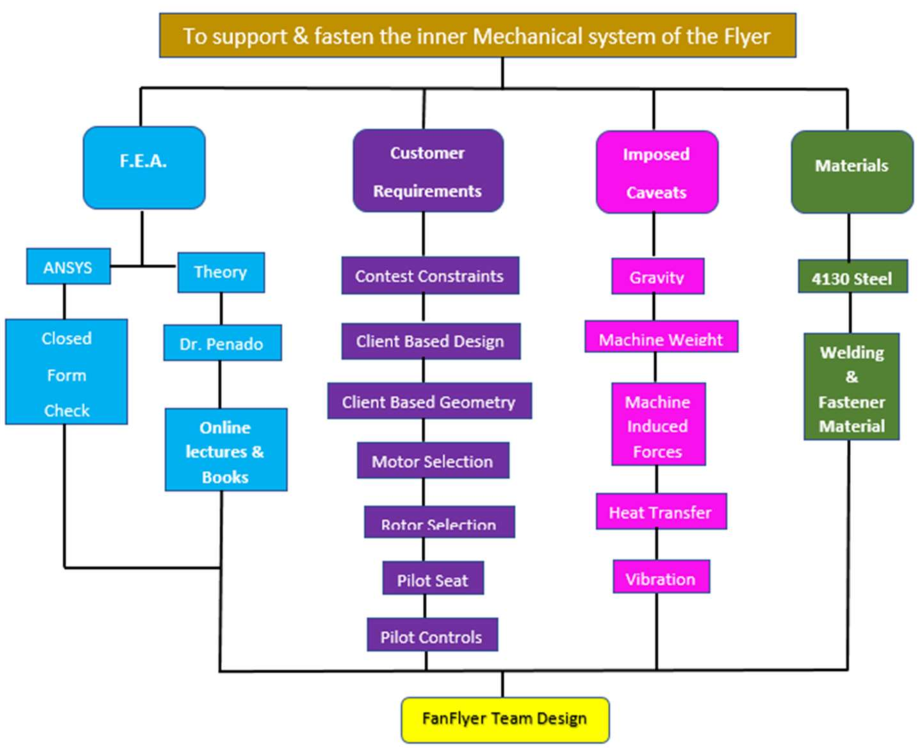

Figure 24 - Functional decomposition

8.3 Appendix C: Decision Matrix

		Design #1		Design #2		Design #3		Design #4		Design #5		Design #6	
	Weighting	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total
LightWeight	5	4	20	3	15	4	20	4	20	2	10	4	20
Stability/Balance	5	2	10	4	20	3	15	3	15	2	10	2	10
Ease of Manufacturing/Assembly	4	4	16	4	16	4	16	4	16	2	8	3	12
Possibility of Joint Failure	4	5	20	2	8	4	16	3	12	1	4	3	12
Ease of Analysis/ load testing	3	4	12	3	9	3	9	3	9	3	9	4	12
Aesthetically Pleasing	2	3	6	3	6	5	10	4	8	4	8	5	10
Safety/ Operator Protection	5	2	10	4	20	4	20	4	20	3	15	4	20
	Total		94		94		106		100		64		96

Figure 25 - Decision Matrix