Project Sparrowhawk

September 20, 2021

2022 NASA Student Launch – Proposal

UNT Robotics Aerospace Division
University of North Texas: College of Engineering
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1.1 Objective

UNT Robotics Aerospace Division intends to compete in the 2022 NASA Student Launch Competition. We are a team which is passionate about rocketry, aerospace, and engineering. UNT Robotics has a mission to bring great opportunities to students at the University of North Texas and help fund and support projects and competitions. The NASA SL competition will help our students and team members apply their knowledge, learn new skills, solve problems, and compete at a national collegiate level. The competition will further allow us to conduct STEM outreach in the community and inspire and foster the imaginations, creativity, and curiosity of the next generation of scientists and engineers. Our enthusiasm and love of rocketry and robotics puts us in a perfect position to conduct workshops, competitions and events with local schools, community programs and organizations to bring the same passion we have for STEM to our community. We hope to not only become a highly competitive team, but also to create a legacy for future students to carry on and to inspire the community to get involved. We have a track record of bringing robotics opportunities and long-term programs and outreach in our community, and aerospace is the next opportunity in our grasp.

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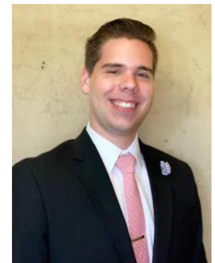

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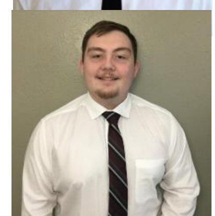

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1.7 Organizational Structure

There are currently 19 students dedicated to this project from start to finish, ten of whom are student design leaders in different sections of the project. We were also able to work through the mechanical engineering department to recruit two Capstone design teams to work with us on the project. These Capstone design team have been adapted to the project schedule. The Capstone design 2 team will be graduating this semester and have been assigned to design, build, and test our subscale airframe, electronics, and recovery system. The Capstone design 1 team will be graduating in May of 2022, so they have been assigned to developing the payload system for the project. Everyone involved will be participating in multiple sections of the project, but there are individuals responsible for major work areas to ensure continuity for reporting and meeting the planned production cycle milestones. These are some of the key areas that we have identified as essential for the planning, production, and development process:

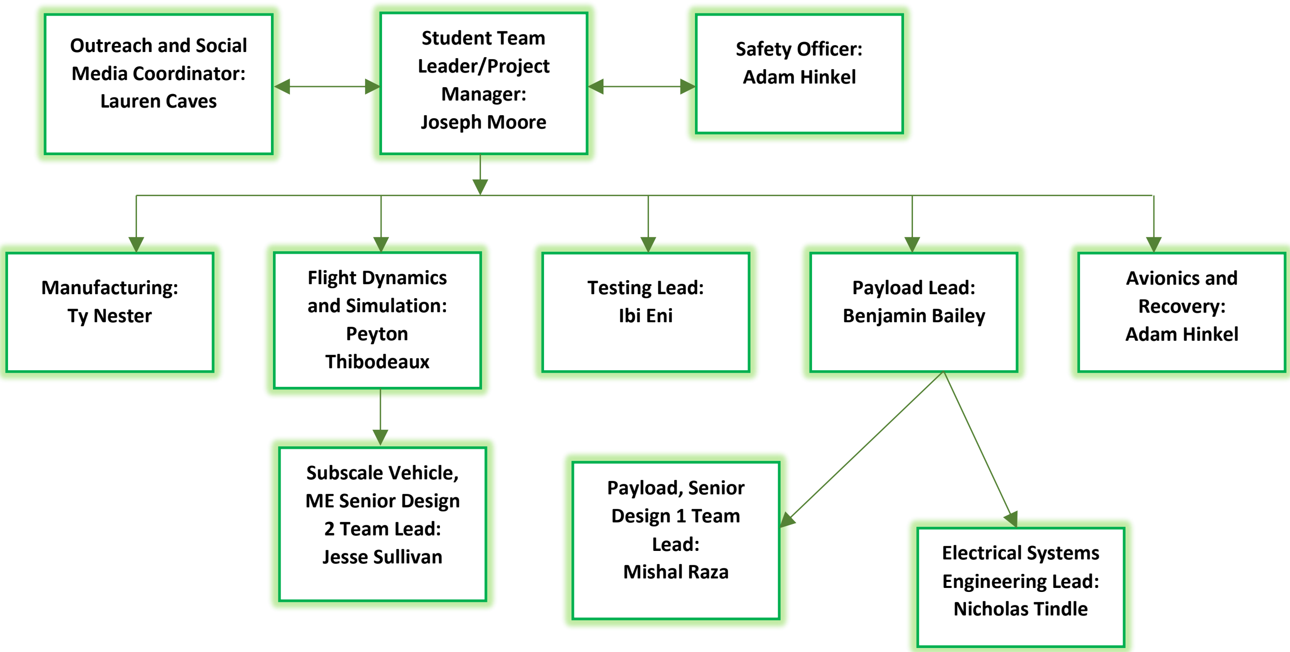

Figure 1: Team Organizational Flow Chart

1.8 NAR/TRA Sections

Our team will have access to multiple launch sites in our area offering at least two launch opportunities per month. Tripoli North Texas (Prefecture # 58) and the Dallas Area Rocketry Society (NAR section 308) each have multiple launch sites within two hours of the university that we intend to utilize for our sub-scale and full-scale rocket launches. The team will also be receiving mentoring from Jack Sprague, NAR and TRA LVL 2 certified, and a member of both TNT and DARS. Several members of our team are either TNT or DARS members, which will help facilitate planning and communication through these groups.

1.9 Hours Invested in Proposal

Up to this point, through brainstorming, attending meetings, researching, and writing the proposal, the team has invested 162 hours.

2. Facilities and Equipment

2.1 University of North Texas Discovery Park: Aerospace Division Workspace

Description

Our team has a dedicated workspace in the manufacturing area of Discovery Park. All manufacturing, planning, fabrication, and assembly is conducted in this area. Any energetic testing of subassemblies will be conducted in the open spaces surrounding Discovery Park to avoid injury to personnel or damage to property.

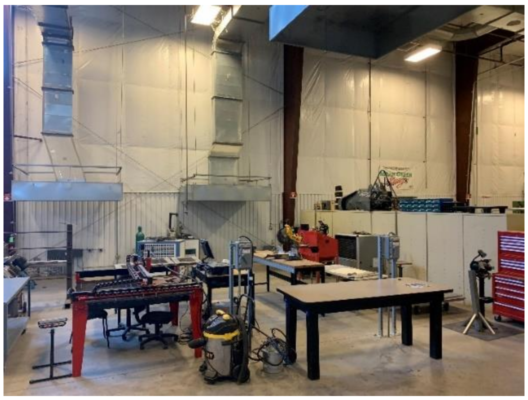

Figure 2: Aerospace Division Workspace

Hours and Required Personnel

This facility is available 24 hours a day, seven days a week. A team lead will need to be present to conduct work in the project area. If there is to be any work done using tools or equipment with safety labels, the safety officer or a qualified designee will need to be present while the work is conducted.

2.2 University of North Texas Discovery Park: Engineering Manufacturing Facility (EMF) Lab

Description

Team members will have access, once proper safety training is conducted, to the EMF Lab at Discovery Park. The EMF Lab is dedicated to offering advanced manufacturing services such as fabrication of mechanical prototypes, proof of concepts for machinery, 3D Printing, Laser Engraving, and CNC precision machining. This will allow production of machined airframe or payload parts in house and in a controlled environment.

Figure 3: EMF Lab

Hours and Required Personnel

This facility is available Monday through Friday from 8am to 4:30pm. There is always a qualified person employed by the university present during these hours. For our own safety precautions, the rocketry team members will only operate these machines in teams of two people, one of whom will be a qualified safety officer or designated person.

2.3 University of North Texas Willis Library: The Spark Makerspace

Description

Willis Library on the UNT main campus has an additive manufacturing lab that UNT students can use for free at any time during business hours. There is an array of different machines that can 3D print parts and prototypes from a variety of different materials, as well as manufacturing circuit boards, laser cutting, milling, and CNC equipment.

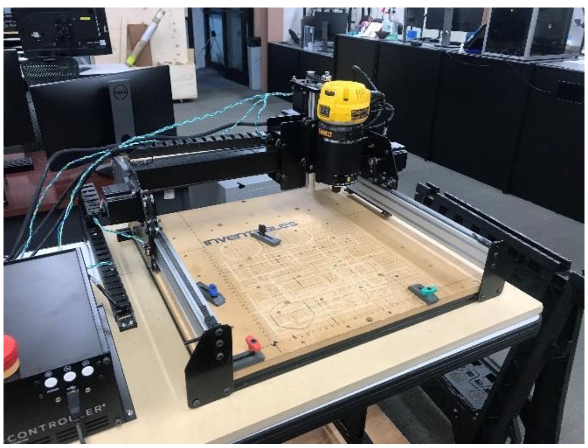

Figure 4: Plastics and Wood CNC Machine

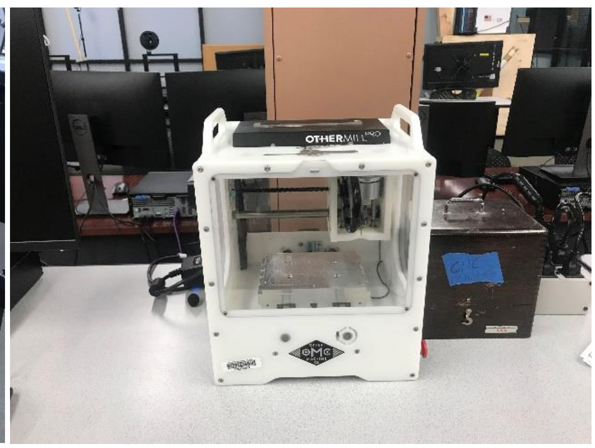

Figure 5: Circuit Board CNC Machine

Hours and Required Personnel

The Spark Makerspace is available for use or consultation from 7am to 7pm Monday through Friday. There will always be qualified UNT personnel present and use of any potentially dangerous equipment by team members will require the two-person rule, having one person act as a safety observer and double check actions while work is in progress, as well as being trained by the Makerspace personnel on safe operation of the machines.

2.4 Discovery Park Senior Design Lab

Description

The Senior Design lab is a dedicated workspace for the current seniors to work on their Capstone design designs. We will use this space with their permission, to do any composites work during the manufacturing process because the space is climate-controlled and large enough to allow us to roll a large composite airframe tube.

2.5 Required Supplies

- Masking Tape
- Mechanics gloves
- Latex/vinyl gloves
- Black Powder

- Electric Matches
- Fireproof Insulation
- Epoxy Resin
- Fiberglass/Carbon fiber fabric
- Paint rollers and plastic spatulas
- Mylar rolls
- Balsa Plywood
- Wood Glue
- Cyanoacrylate (CA)
- Various 3D printing filaments
- Nylon shear pins and rivets
- Various electronic components
- Altimeters, batteries, etc.
- Peel ply
- Respirators

2.5.1 Manufacturing Equipment

- Lathe
- Laser cutting machine
- Various 3D Printing equipment
- Hand tools
- Table Saw
- Router
- Drill
- CNC Machine
- Rolling Setup for Mandrel
- Vacuum pump system for vacuum impregnation
- Various molds for fiberglass/carbon fiber production

2.5.2 Testing Supplies

- Safety Glasses
- Precision Electronic Scale
- Remote Igniter system
- High Speed Camera
- Timer/Stopwatch
- Voltmeter
- Thermal Camera
- Material Science Lab (for testing mechanical properties of material samples)

2.5.3 Computer Software

- SolidWorks: CAD design and FEA analysis
- MATLAB: Control systems design
- ANSYS: CFD analysis
- Discord: Virtual meeting and collaboration
- Google Docs: Document sharing, storage and editing
- OpenRocket: Launch vehicle design, configuration planning, and simulation
- Visual Studio: writing and editing software to be used in any subsystems and payload

3. Safety

The high-power rocketry team at the University of North Texas holds the safety and well-being of its members as the highest priority. The responsibility for safety falls to the Safety Officer and Project Manager. Additionally, each member of the team is tasked with having the skills and knowledge to identify potential hazards and to use the appropriate safety procedures to mitigate them. To ensure all team members involved in the production, testing, and operational process are aware of the hazards associated with general construction and the hazards inherent to high power rocketry, all team members will be required to read the team safety SOP, enclosure (1), and sign it acknowledging that they understand the hazards and will follow procedures to mitigate the risks.

3.1 General Safety Requirements [1]

1. Teams will utilize launch and safety checklists.
2. The team will identify a student safety officer who is responsible for all items in section 5.3 of the NASA SL Handbook.

3. Teams will abide by all rules and regulations of the RSO for local launches for all test flights.
4. Teams will abide by all FAA rules and regulations.
5. All team members understand and will abide by the following safety regulations:
   a. Range safety inspections will be conducted on each rocket before it is flown. Each team shall comply with the determination of the safety inspection or may be removed from the program.
   b. The Range Safety Officer has the final say on all rocket safety issues; therefore, the Range Safety Officer has the right to deny the launch of any rocket for safety reasons.
   c. The team mentor is ultimately responsible for the safe flight and recovery of the team's rocket; therefore, a team will not fly a rocket until the mentor has reviewed the design, examined the build and is satisfied the rocket meets established amateur rocketry design and safety guidelines.
   d. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

3.2 Safety Plan

The team will maintain a safety plan throughout the project to ensure safety measures are properly followed:

1. Responsibilities will be assigned to an authority for oversight of our safety procedures.
2. The team will identify hazards and characterize all mitigation strategies.
3. The team will formulate procedures for all testing, manufacturing, and launches.
4. Extensive testing of components will be done.
5. The design will incorporate uncertainty analyses, surrogate modeling, parameter updating of simulations as needed

3.3 Risk Assessment and Mitigation Factors

Our goal through applying risk mitigation and making risk decisions is to lower the risk assessment code (RAC) for each activity by at least one RAC value.

Risk Severity		Risk Probability			
		Likely/Immediate A	Probably B	May C	Unlikely D
Catastrophic	1	1A	1B	2C	3D
Critical	2	1A	2B	3C	4D
Moderate	3	2A	3B	3C	5D
Minor	4	3A	4B	5C	5D
Negligible	5				

Table 1: Risk Assessment Matrix [2]

3.4 Assessment Worksheet

Operational Risk Management Assessment Worksheet:							
Identify Hazards			**Assess Hazards**	**Make Risk Decisions**		**Implement Controls**	**Supervise**
Operation	Hazard	Causes	Initial RAC	Develop Controls	Residual RAC	How to Implement	How to Supervise
Fiberglass Layup	**Epoxy-Resin** skin contact, eye contact, fumes inhalation	Chemical spills, burns from curing epoxy, and reaction fumes	2A	Eye pro, gloves, respirators, and protective clothing will be worn during operations	4B	PPE will be available in the workspace, and all team members (TM's) will be trained and briefed on	There will be a Safety officer or designated person present for all hazardous operations.

						safety hazards present.	
General Parts Construction	Serious injury	Power tools malfunction, inherent hazards associated with, or improper use of tools.	2C	Wearing eye pro, ear pro, and work gloves while using appropriate machinery. Train personnel on proper use and troubleshooting of tools.	3D	PPE will be available in the workspace. All personnel admitted to certain areas will finish required hazard training. TM's will be trained and briefed on hazards present.	There will be a Safety officer or designated person present for all hazardous operations.
Energetic Testing of components and subsystems	Burn or impact injury	Black powder ejection charges	2C	Wearing eye pro, ear pro, and work gloves while around testing area. Train personnel on proper use and troubleshooting of component systems.	3D	PPE will be available in the workspace. All personnel admitted to certain areas will finish required hazard training. TM's will be trained and briefed on hazards present.	There will be a Safety officer or designated person present for all hazardous operations.
	Shock/ electrocution	Electrical circuit testing	3C	Ensure proper grounding and handling techniques area followed.	5D	PPE will be available in the workspace. All personnel admitted to certain areas will finish required hazard training. TM's will be trained and briefed on hazards present.	There will be a Safety officer or designated person present for all hazardous operations.
	Impact injury	Actuator malfunction	3C	Wearing eye pro and gloves while working with any energetic systems.	5D	PPE will be available in the workspace. All personnel admitted to certain areas will finish required hazard training. TM's will be trained and briefed on hazards present.	There will be a Safety officer or designated person present for all hazardous operations.
Painting Launch Vehicle Components	Skin/eye contact, fumes	Spray Paint and clear coat	2A	Eye pro, gloves, particulate masks, and protective clothing will be worn during operations. Masks can be omitted if painting is done outside.	4B	Workspace is in a well-ventilated area. PPE will be available to all TM's in the workspace. TM's will be trained and briefed on hazards present.	There will be a Safety officer or designated person present for all hazardous operations.
Launch Day and Test Launches	Loss of vehicle	Motor Failure	2C	Only use COTS motors.	3D	Inspect motor upon receipt and before use.	Records of this inspection will be kept by the project manager.
	Range Fire	Motor failure, motor	2C	Only use COTS motors. Follow	3D	Inspect motor upon receipt and	The project manager must be

		retainer failure		NAR/Tripoli range safety guidelines for range fires. Conduct modeling and testing of motor retention system.		before use. Inspect retention system when assembled and as part of the pre-flight checklist at each launch.	present and inspect this component before each launch.
	Injury to personnel or damage to property, loss of vehicle or components	Detonation/ Deflagration of Motor	2C	Only use COTS motors. Follow NAR/Tripoli range safety guidelines for minimum safe distances. Follow NASA SL guidelines for vehicle construction to minimize the likelihood of projectile/ fragmentation production.	3D	Inspect motor upon receipt and before use. Utilize NAR/Tripoli minimum safe distances and follow instructions from the RSO and RCO of the launch.	Project manager, or designated safety person will inspect components during and after construction. Components will be inspected before and after each launch to ensure they are safe to reuse or identify the need for replacement.
	Loss of vehicle/ damage to property/ personal injury	Recovery system failure	1B	Charge all batteries, bring extras to each launch. Inspect parachute and drogue, and all lines. Verify ejection charges by ground testing prior to launches. Follow NAR guidelines for weathercocking to prevent vehicle from falling on top of people/property at the range. Build in redundancies to ensure that there are backup recovery systems.	2C	Follow pre-flight checklists to ensure that each system is ready and working properly.	Project Manager and safety officer will sign off on each pre-flight checklist prior to declaring a vehicle ready to launch. If any part of the checklist is incomplete the vehicle launch will be postponed until launch readiness can be verified.
	Fin Damage	Recovery system Failure or landing speed miscalculation	2C	Build for redundancy in the recovery system. Reinforce fins with carbon fiber to increase shear strength and prevent breaking. Design fin-can to be swapped out if necessary. Conduct failure testing to determine strength of fins before assembly.	3D	Follow pre-flight checklists to ensure that each system is ready and working properly.	Project Manager and safety officer will sign off on each pre-flight checklist prior to declaring a vehicle ready to launch. If any part of the checklist is incomplete the vehicle launch will be postponed until launch readiness can be verified.
	Body Tube Failure	Zippering caused by deployment of recovery system	2C	Base material strength on worst case. Employ "zipper-proof" design techniques wherever possible in construction.	3D	Stress-test all airframe elements to ensure survivability during in-flight events. Redesign or reinforce when necessary.	Before assembly of flight ready vehicle, production checklist must be signed by project manager and manufacturing lead to ensure that each element meets the stress

							even criteria established during design phase and testing.
	Body Tube Failure	Forces exerted at launch, during flight, recovery events, or landing exceed design parameters	2C	Base material strength on worst case. Limit weight of launch vehicle only when it does not sacrifice required strength. Conduct FEA and CFD/wind tunnel testing to predict worst case forces on airframe components.	3D	Stress-test all airframe elements to ensure survivability during in-flight events. Redesign or reinforce when necessary.	Before assembly of flight ready vehicle, production checklist must be signed by project manager and manufacturing lead to ensure that each element meets the stress even criteria established during design phase and testing. All elements will undergo necessary ground testing prior to certification for flight.
	Premature Separation of Airframe Sections	Expansion of trapped gasses within sealed sections, forcing stages apart	3C	All airframe components that would normally be sealed will have appropriately sized vent holes added to allow trapped gasses to escape as they expand.	4D	Once all components are ready to be assembled, they will be inspected to ensure that the correct holes have been added prior to prepping for launch.	Before assembly of flight ready vehicle, production checklist must be signed by project manager and manufacturing lead to ensure that each element meets the stress even criteria established during design phase and testing. All elements will undergo necessary ground testing prior to certification for flight.
All in-person activities	COVID-19 Exposure/ Contracting the virus	Infected persons spreading the virus to others in close proximity.	2C	Team members will have ready access to masks and hand sanitizer, as well as handwashing sinks. Sick team members will not be permitted to come into the work areas or attend meetings in person.	3D	All meetings will be conducted in-person and online simultaneously to allow members to stay home and participate. TMs in the work areas will be limited to necessary personnel.	UNT policy requires every person not vaccinated to get tested each month. All students are encouraged to wear masks while indoor. Team members will be asked to agree to limit risky activities for the good of the team.

Table 2: ORM Assessment Worksheet [2]

3.5 NAR/TRA Procedures

NAR High Power Rocketry Safety Code [3]:

1. **Certification.** I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.
2. **Materials.** I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.
3. **Motors**. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
4. **Ignition System.** I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.
5. **Misfires.** If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.
6. **Launch Safety.** I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.
7. **Launcher.** I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour, I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.
8. **Size.** My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high-power rocket motor(s) intended to be ignited at launch.
9. **Flight Safety.** I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.

10. **Launch Site.** I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).
11. **Launcher Location.** My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the **appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.**
12. **Recovery System**. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.
13. **Recovery Safety.** I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

MINIMUM DISTANCE TABLE

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 — 320.00	H or smaller	50	100	200
320.01 — 640.00	I	50	100	200
640.01 — 1,280.00	J	50	100	200
1,280.01 — 2,560.00	K	75	200	300
2,560.01 — 5,120.00	L	100	300	500
5,120.01 — 10,240.00	M	125	500	1000
10,240.01 — 20,480.00	N	125	1000	1500
20,480.01 — 40,960.00	O	125	1500	2000

3.6 NAR/TRA Mentor Actions

Support:

- Mentoring team members who wish to certify level 1;
- Providing guidance and feedback during the project;
- Asist in planning for STEM outreach.

Design and Configuration:

- Review preliminary and adjusted plans to include structural designs, motor type and specifications, recovery system design, payload and component designs, subscale vehicle design.

Safety:

- Review all checklists to ensure team, vehicle, and flight readiness and safety;
- Review safety reports and updates.

Manufacturing:

- Review and advise on manufacturing procedures and techniques;
- Review materials and plans for use.

Launches:

- Supervise all launches;
- Purchase and handling of all level 2 motors, to include purchase, transportation, storage and preparation;
- Preparation of other energetic materials, i.e., black powder ejection charges.

3.7 Safety Briefing

All members of the team will be briefed on hazard recognition and accident avoidance through mandatory safety orientation sessions conducted aerospace division workspace, and through safety briefings conducted in the EMF on campus. A separate pre-launch meeting will be held prior to each test launch to brief team members on the regulations and safety codes that must be followed at the launch site. A copy of the team general safety briefing and signed roster is included as enclosure (1) at the end of the Safety SOP.

4. Technical Design

4.1 General Vehicle Requirements [1]

1. The launch vehicle and payload must reach an apogee altitude of 4,000-6,000 feet above ground level (AGL). Target altitude must be declared at the PDR milestone and will be used for scoring.
2. The vehicle must carry at least two commercially available altimeters that are specifically designed for initiating rocketry recovery events.
3. The launch vehicle must be designed to recover and be reusable. It will not have more than (4) independent sections.
4. The launch vehicle must be designed to be made flight ready at the launch site within 2 hours of the FAA waiver opening.
5. The launch vehicle must be capable of remaining flight ready for 2 hours at minimum without losing functionality.
6. "All teams will successfully launch and recover a subscale model of their rocket prior to CDR." [1] This can occur at any time from proposal award to CDR deadline. The requirements for subscale flight are listed in the 2022 NASA Student Launch Handbook section 2.18.
7. Full scale demonstration flights are required, and their stipulations are outlined in section 2.19 of the NASA SL Handbook.
8. The team's name and launch day contact information will be in or on each separate section of the rocket.
9. Any Lithium polymer batteries must be distinguishable from other hardware and marked as a fire hazard.

4.1.2 General Vehicle Description

The launch vehicle will carry an unmanned aerial system (UAS) that will locate and reunite with the launch vehicle in the launch area. The entire airframe and payload bay have been initially designed to hold a large payload which will allow the team to adjust designs and specifications of the payload size, position, and jettisoning method throughout the design and development process.

The forward airframe consists of the nose cone, avionics, nose cone parachute, forward body tube, payload bay, and main parachute. The nose cone will hold a GPS transmitter for tracking the vehicle for recovery. The main parachute and shock cord will connect the forward airframe to the avionics bay via U-bolts.

The avionics bay will couple the forward and aft airframes. It will be joined to both airframe sections with sheer pins that will break at each deployment event. The avionics bay will hold the altimeter, battery, and dual-deployment electronics.

The aft airframe consists of 4 carbon fiber fins (removable fin can design), 3 centering rings, 75mm motor tube, thrust ring, drogue parachute, and main parachute. Shock cord and the drogue chute will connect the avionics bay and aft airframe with a U-bolt on the avionics bay and eyebolt on the forward centering ring. The shock cord on the drogue parachute will also remove the main parachute bag from the aft airframe. The centering rings will all be secured with epoxy. The fins are through-body design for maximum strength and will be secured to the motor tube, body tube, and two rear centering rings with epoxy. The thrust plate will transfer the forces from the K1000T motor to the airframe during flight.

An OpenRocket design shown in figure 3 shows the center of pressure (CP) as a red dot and the center of gravity (CG) as a blue dot. The design accounts for a 3-pound payload mass. The pre-launch vehicle weight including a full motor and payload tube is approximately 8.4 kg. With the engine installed the CG is 188 cm from the tip of the nose cone and the CP is 215 cm from the tip of the nose cone. These measurements make our preliminary design stability 2.13 cal. The preliminary design has an overall length of 3.066 m and a major diameter of 12.7 cm.

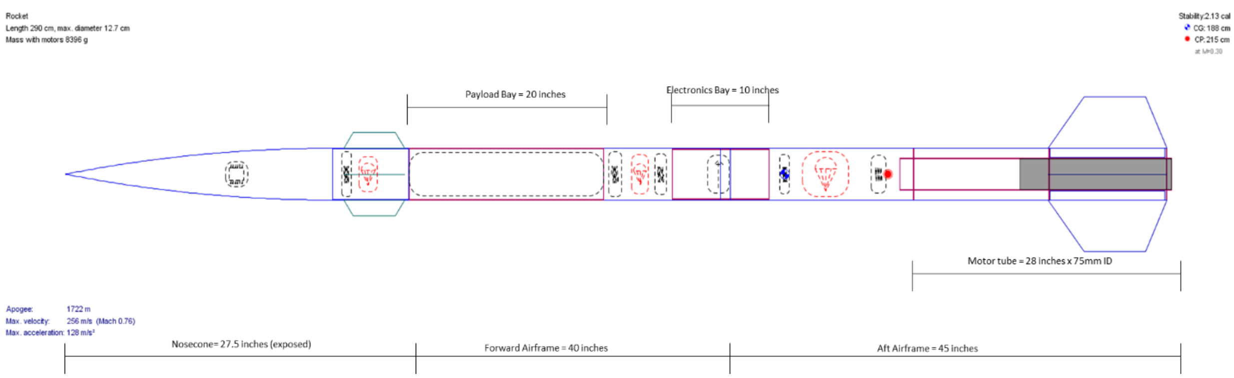

Figure 6: 2D Open Rocket model of the Vehicle

4.2 Preliminary Material Selection and Justification

Primary materials for construction of the launch vehicle will be woven fiberglass, carbon fiber, and plywood.

4.2.1 Fiberglass

Mechanical Properties	Range	Units
Density	2.55-2.6	mg/m^3
Bulk Modulus	43-50	GPa
Compressive Strength	4k-5k	MPa
Ductility	0.026-0.028	
Elastic Limit	2750-2875	MPa
Hardness	3k-6k	MPa
Poisson’s Ratio	0.21-0.23	

Shear Modulus	30-36	GPa
Tensile Strength	1950-2050	MPa
Young's Modulus	72-85	GPa

Table 3: Expected Mechanical Properties of Fiberglass [4]

4.2.2 Carbon Fiber

Mechanical Properties	Range	Units	Application Style
Young's Modulus	70	GPa	
Density	1.6	g/cc	
Tensile Strength	110	MPa	
Compressive Strength	110	MPa	
Shear Strength	260	MPa	In Plane
Poisson's Ratio	0.1		
Shear Modulus	5	GPa	

Table 4: Expected Mechanical Properties of Carbon Fiber [5]

4.2.3 Plywood

Laminated thin layers of wood makes for a lightweight and robust structure at a fraction of comparable material costs; therefore, we will be using plywood for most internal components like bulkheads and centering rings that we can laser cut to exact specifications. We will also use plywood as a core material for our fins, reinforcing them with Carbon Fiber or Fiberglass for strength. The following table shows the expected mechanical properties of plywood:

Mechanical Properties	Range	Units	Application Style
Tensile Strength	26.7-34.5	MPa	Parallel to face
Modulus of Rupture	0.0483-0.0689	GPa	Parallel to face
Flexural Modulus	8.20-10.3	GPa	Parallel to face
Compressive Strength	31.0-41.4	MPa	Parallel to face
Shear Modulus	0.138-0.207	GPa	In Plane
	0.586-0.758	GPa	Through thickness
Shear Strength	1.72-2.07	MPa	In plane
	5.52-6.89	MPa	Through thickness

Table 5: Mechanical Properties of Plywood [6]

4.3 Construction Methods

4.3.1 Airframe Fabrication

Fiberglass airframe sections will be produced using a wet layup technique. This technique uses a mandrel to simultaneously wrap woven fiberglass while impregnating it with epoxy. This method of fabrication allows us to control the wall thickness while ensuring that all airframe components have a uniform inside diameter, which is important for manufacturing matching coupler components, as well as planning for the sizing of internal payload tube components.

4.3.2 Fin Fabrication and Construction

Fins will be constructed from laser-cut balsa wood cores, which will then be covered completely with several layers of woven carbon fiber and processed by vacuum impregnating the core and carbon fiber with epoxy to create incredibly light and strong fins. Our intent is to use a fin-can design that can be replicated and replaced if needed, or reused in the future.

4.3.3 Coupler, Avionics and Electronics Bay Fabrication

These components will be made by taking donor sections from the mandrel-rolled airframe section. The section will then be split in two halves to make molds that can be used to make coupler halves that can be joined later and will have the outer diameter exactly matching the inside diameter of the airframe tubes. The molds will allow us to use fiberglass or carbon fiber fabric (depending on the location in the vehicle) and use a wet layup process to make parts within the mold, and then join the halves with more fabric and epoxy once they are ready.

4.4 Projected Altitude

Our preliminary design and simulation have our maximum altitude above ground level will be approximately 5,300 feet. We intend to keep our altitude as close to one mile as possible as an internal goal for the team.

4.5 Recovery System

4.5.1 General Recovery System Requirements [1]

1. The main parachute cannot be deployed lower than 500 feet
2. The apogee event cannot have longer than a 2 second delay
3. Motor ejection is not permissible
4. Every system/subsystem utilizing electronically initiated recovery events will be successfully ground-tested prior to being launched.
5. Maximum kinetic energy for any independent section of the vehicle will not exceed 75 ft-lbf at landing.
6. The recovery system will contain redundant COTS altimeters, each with its own dedicated, commercially available battery, capable of being turned on for at least 2 hours, each armed with a dedicated mechanical arming switch that can be locked in the “armed” position. These switches must be accessible from the exterior of the airframe when the rocket is in the launch configuration.
7. Recovery system electronics will be independent of payload electronics.
8. Removable shear pins will be used for main and drogue parachute compartments.
9. Recovery area is limited to 2,500 feet radius from the launch pad.
10. Descent time is limited to 90 seconds from Apogee to touchdown (Launch Vehicle).
11. An electronic GPS tracker will be installed in the launch vehicle, as well as the payload compartment and any untethered subsections, and each GPS tracker will actively transmit the position of each subsequent part to a ground receiver.
12. Recovery system electronics must be shielded from all other on-board electronic devices during the entire flight of the vehicle to ensure proper safe operation of recovery electronics.

4.5.2 Planned Recovery System Design

Dual deployment will be used for recovery in keeping with the general requirements in the Student Launch Handbook. Each system will use built-in redundancy to reduce the chances for deployment failure as well as the distance the launch vehicle and subsystems will drift away from the launch site.

Dual altimeters with separate batteries will initiate an ejection charge as close to apogee as possible to deploy the drogue parachute without causing damage to the vehicle. At a second predetermined altitude during descent, the main parachute will be deployed to safely land the vehicle on the ground. In conjunction with main parachute deployment, a third parachute will be deployed to carry the nosecone safely to the ground to clear the way for payload deployment from the forward airframe. The backup ejection charges will not exceed 2 seconds delay for each intended event.

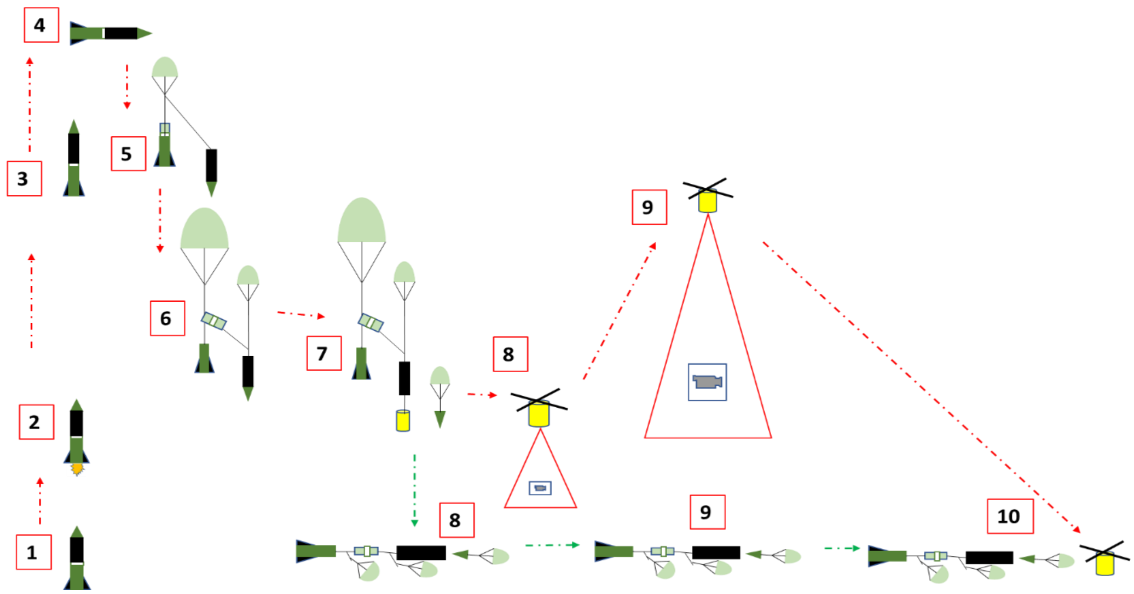

Figure 7: Recovery Diagram

4.6 Projected Motor Brand and Designation

To reach our one-mile altitude goal, the current plan is to use an Aerotech K1000T 75mm RMS motor. With an average thrust of 1066 Newtons [7] the launch vehicle's thrust to weight ratio is 12.95:1 and gives us a large margin over the minimum T/W ratio of 5:1.

4.7 Payload

4.7.1 General Payload Requirements [1]

1. "Teams shall design a payload capable of autonomously locating the launch vehicle upon landing but identifying the launch vehicle's grid position on an aerial image of the launch site without the use of [GPS]." [1] If the designs are safe, legal, and follow the challenge intent, they will be at the discretion of the teams.
2. Teams will generate their own gridded map of the launch field that does not exceed 5,000 ft by 5,000 ft in size. Each grid will not exceed 250 ft by 250 ft.
3. The launch vehicle and all jettisoned components must land within the gridded launch field.
4. GPS cannot be used to accomplish the payload mission (it is solely for tracking purposes).
5. The gridded image must be high quality and can be a satellite or aerial photograph.
6. Energetics are not permitted for surface operations.
7. Must abide by FAA and NAR regulations.
8. Any experiment element, including UAS payloads which are designed to be jettisoned during flight will require real-time RSO approval for release from the vehicle in flight unless exempted during the CDR milestone by NASA.
9. UAS systems must abide by FAA special rules for model aircraft.

4.7.2 Detailed Description of Projected Payload

Our projected payload design is a cylindrical quadcopter. This UAS will be jettisoned using piston ejection in flight and the rotor booms will be raised by a rotary cam while exiting the payload tube. The bottom of this UAS will have ample room to house electronics, as well as a downward facing camera to identify the main vehicle landing area and any fiduciary landmarks programmed into the UAS software. Our plan is to not only have the payload identify the launch vehicle landing zone, but also design it to reunite with it at the landing site. The payload UAS will come down with the main launch vehicle and upon authorization from the RSO will detach from the main vehicle and ascend to a predetermined height to begin photographing the landing zone. We intend to use a combination of visual location with mounted cameras and tracking with a radio beacon mounted inside the launch vehicle that will begin transmitting upon landing and allow the UAS to track its location. This will resemble an emergency beacon on some marine personnel recovery systems. Once the UAS has identified the launch vehicle, it will relay the location back to the team's base station using LoRaWAN technology.

Figure 8: Cylindrical Quadcopter

Our second payload concept will consist of a UAS system that will be housed within the payload tube in the forward airframe section. The UAS will be a folding quadcopter complete with electronics and a camera system that will allow the UAS to locate and move to the main launch vehicle after it lands. An internal tube within the payload tube will be capable of self-righting using weighted detents and bearings, and then gently ejecting a sled carrying the UAS. Once the sled is pushed out of the payload tube, a CO2 activated balloon will carry the quadcopter free of the sled and any obstacles and after ascending to an appropriate elevation the quadcopter will extend fully and make itself ready for flight. Once ready for flight, the quadcopter will take flight, detach from the balloon, and ascend to a predetermined altitude, identify the landed launch vehicle, and move to its location using the same methods as the primary payload design. Again, once the UAS has identified the launch vehicle, it will relay the location back to the team's base station using LoRaWAN technology. After detaching from the UAS the balloon will be deflated remotely so that it can be collected to prevent waste.

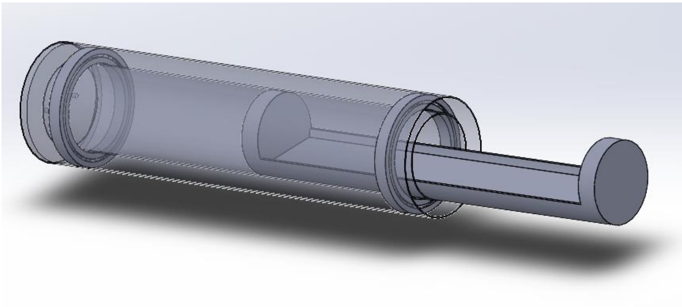

Figure 9: Isometric View of Projected Payload Tube and Sled Assembly (SolidWorks)

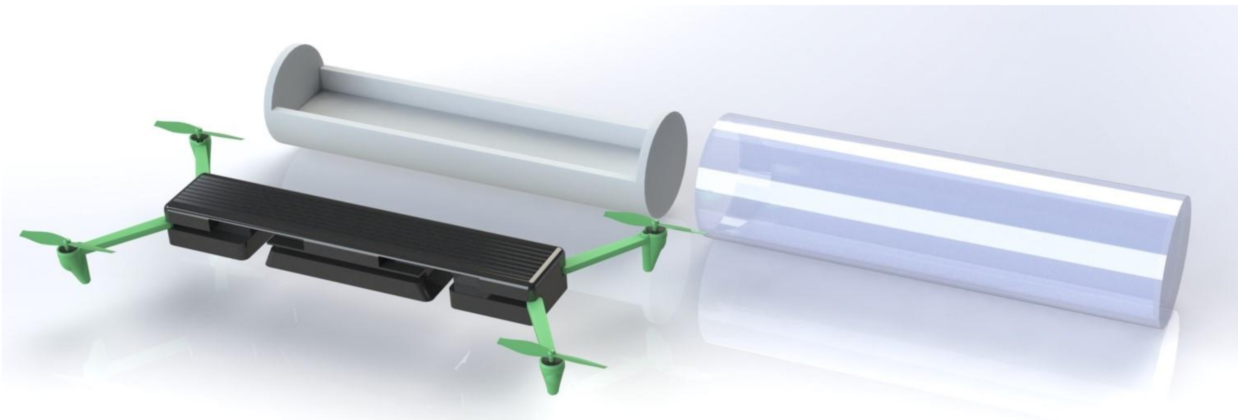

Figure 10: Expanded Quadcopter, Sled, and Internal Payload Tube

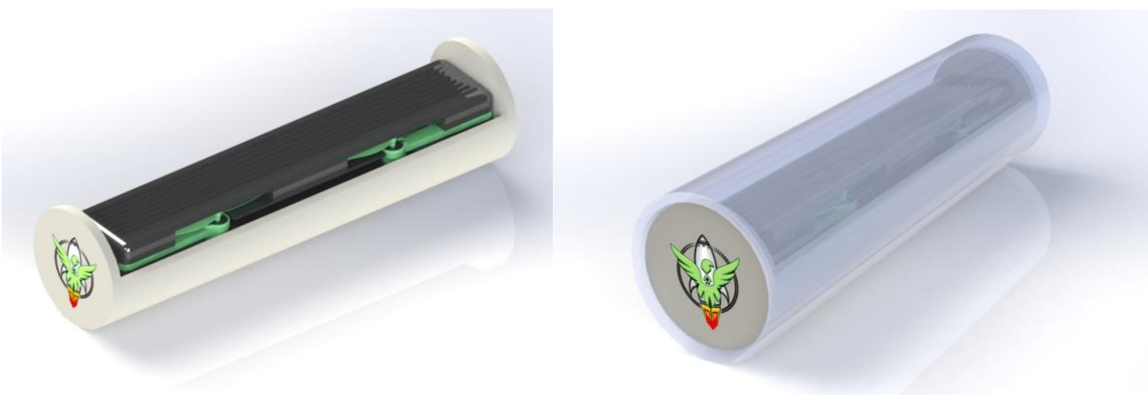

Figure 11: Internal Payload Tube and Sled with Quadcopter Stowed

4.8 Major Technical Challenges and Solutions

4.8.1 Airframe Fabrication

We intend to fabricate our own airframe tube sections from fiberglass fabric and epoxy/resin using a wet layup process. Our first hurdle was finding a designated workspace large enough for our purposes, and then to find material to use as a mandrel for rolling our tubes. We have spent countless hours combing the internet for how-to videos, and even spoke to another local college that competed in last year's NASA SL competition to get advice from them on fabricating body tubes. Members of our team have also been practicing these techniques on small scale body tubes to get better at it before moving on to a full-scale rocket body.

4.8.2 Payload Design

The payload is a major challenge for this competition. Designing a UAS is not the difficult part but designing one to autonomously complete a mission and report back to us is our technical challenge. Our team is a division of UNT robotics, so we have a large team of people who are savvy with mechatronics and programming brainstorm solutions for this challenge. We also have members of our team who have completed research projects in the past specifically aimed at optimization of drones, and their experience will serve us well in this endeavor. We are planning to use COTS platform electronics and adapt them to our purposes, and to incorporate LoRaWAN technology to relay the data that our UAS collects back to our base station.

5. Project Plan

5.1 Detailed Development Schedule

This is a tentative development schedule that will help to guide our team through the process for the next 8 months. The dates, including dates provided by NASA are subject to change but these are our current targets for the development cycle as we see it now. We will have to add test flight dates as we work with the local clubs and more milestones may be added as we progress.

Category:	Payload	Manufacturing	Report Writing/Admin	Structural Analysis	Aerodynamics	Launch Day

NASA Deadlines		Team Deadlines and UNT Events	

August 2021

Request for Proposal Release	8/18/2021	Begin Payload Design	8/18/2021
		Mean Green Fling (Student Org Recruiting Event)	Cancelled due to weather
		DARS Sport Launch (Intro and familiarization event)	8/21/2021
		First Day of Fall Classes	8/23/2021
		First Draft of Proposal Finished	8/25/2021
		HPR Team Meeting	8/25/2021
		First Draft of Proposal Revised	8/30/2021

September 2021

Completed Proposal Due (3pm, PDF)	9/20/2021	Initial Launch Vehicle Design Set (OpenRocket)	9/03/2021
		Begin Prototyping Payload	9/03/2021
		Second Draft Proposal Finished	9/10/2021
		Second Draft Proposal Revised	9/15/2021
		Establish component Criteria	9/17/2021
		Payload Prototype 1 Finished	9/17/2021
		Final Proposal Revisions Done	9/19/2021
		Submit Final Draft of Proposal	9/20/2021

October 2021

Awarded Proposals Announced	10/05/2021	Payload Prototype 2 Finished	10/01/2021
Kickoff and PDR Q&A	10/07/2021	Detailed Launch Vehicle Design (OpenRocket)	10/01/2021
Social Media Handle List Due	10/21/2021	First body Tube Layup	10/02/2021
		MATLAB structural limits calculations; SolidWorks FEA analysis	10/02/2021
		SolidWorks component designs finalized	10/10/2021
		Determine requirements for Parachute size, ejection charges, and T2W ratio	10/10/2021
		Cut body tubes to size, create bulkheads, Build Jig for Fin Slotting	10/16/2021
		PDR Rough Draft Complete	10/16/2021
		SolidWorks Sub-scale designs complete	10/20/2021
		Payload Prototype 3 Finished	10/21/2021
		Estimated altitude for full scale flight and launch rail exit velocity	10/21/2021
		PDR Revision Complete	10/21/2021
		Submit Social Media Handle List	10/21/2021
		Build couplers, boat tail, nose cone, and do subscale body tube layup	10/23/2021
		MATLAB and SolidWorks analysis of vehicle stresses and pressures	10/30/2021
		Finalize Payload design and begin designing jettison method	10/30/2021
		Submit PDR Report	10/30/2021

November 2021

PDR report and presentation due	11/01/2021	Begin testing subscale vehicle (wind tunnel, ejection, recovery systems, electronics)	11/03/2021
PDR video teleconferences	11/02/2021-11/23/2021	Payload retention method	11/06/2021
CDR Q&A	11/30/2021	Subscale Components manufacture	11/06/2021
		Complete Subscale Vehicle	11/13/2021
		Prototype subscale payload	11/13/2021
		Full/Subscale altitude calculations	11/17/2021
		Fins	11/20/2021
		Fin Can	11/20/2021
		Updated Flight profiles (OpenRocket)	11/20/2021
		Rough Draft CDR Finished	11/24/2021
		Gridded Map Development (Begin)	11/24/2021
		Thanksgiving Break	11/24/2021 – 11/28/2021

December 2021

		Wood Fill Components	12/04/2021
		Begin Painting Full Scale Vehicle	12/04/2021
		CDR Revisions Complete	12/05/2021
		Finalize Gridded Map	12/05/2021
		Finals Week (No Required work)	12/06/2021 – 12/10/2021
		Winter Break	12/10/2021 – 1/18/2022

January 2022

Subscale Flight Deadline	1/03/2022	Submit CDR and Gridded Map	1/02/2022
CDR Report and Presentation Due	1/03/2022	First Day of Spring Classes	1/18/2022
Gridded map of competition launch field due	1/03/2022	Test Full Scale Components	
CDR Video Teleconferences	1/06/2022-1/26/2022	Make Fin Slots, finish electrical Components, Finalize all manufacturing	
FRR Q&A	1/27/2022	Updated Flight Profiles	
		Finish Full Scale Payload	

February 2022

		Rough Draft FRR complete	
		Revisions for FRR complete	
		Full Scale Test Launch	

March 2022

Vehicle Demonstration Flight Deadline	3/07/2022	Submit FRR Report	3/06/2022
FRR Report and Presentation Due	3/07/2022	Submit FRR Addendum	As Needed
FRR Video Teleconferences	3/09/2022-3/28/2022	Build Vehicle containers for Travel	3/29/2022
		Pack Supplies for Travel	3/29/2022

April 2022

Payload demonstration flight deadline	4/04/2022	PLAR completed	4/29/2022

Vehicle Demonstration re-flight deadline	4/04/2022	PLAR Submitted	4/30/2022
FRR Addendum Due	4/04/2022	Internal After-Action Report completed and archived	4/30/2022
Launch window for teams not traveling to Huntsville opens	4/05/2022		
Launch Week Q&A	4/06/2022		
Travel to Huntsville, AL	4/20/2022		
Optional LRR (Attending)	4/20/2022		
Official Launch Week Kickoff	4/21/2022		
Launch Week Activities	4/22/2022		
Launch Day and Awards Ceremony	4/23/2022		
Backup Launch Day	4/24/2022		

May 2022

PLAR Due	5/09/2022	Final Exams	5/07/2022 – 5/13/2022

5.2 Project budget

Our project budget will include shop and safety materials since this is our first year in the new workspace. That means that our workshop startup costs are included in the total. The total will be roughly $9673 and also includes $200 to cover unforeseen expenses.

5.2.1 Full Scale and Shop Budget

Item	Price	Quantity	U/I	Subtotal
6 in Sch40 PVC pipe (Mandrel)	$120.00	1	20 ft	$120.00
.005 Mylar Roll 48"x100'	$233.95	1	roll	$233.95
Duct Tape	$6.97	2	roll	$13.94
6 oz E-Glass 60" width	$6.10	40	yard	$244.00
3" Rubber Rigid Caster	$3.49	4	each	$13.96
2 in. x 4 in. x 12 ft. STD and BTR KD-HT SPF Dimensional Lumber	$13.55	2	each	$27.10
2 x 4 standard lumber pieces (under 3 ft)	$0.00	10	Donated	$0.00
Epoxy with 3:1 Ratio Medium Epoxy Hardener (kit)	$78.50	1	gallon	$78.50
3-1 Ratio Pumps	$7.75	10	set	$77.50
rotary switch	$10.33	2	each	$20.66
4" Plastic Squeeges/Spreaders	$10.00	2	pack of 25	$20.00
12" Serrated Fiberglass & Carbon Scissors	$44.50	1	each	$44.50
1 QT mix/measure buckets	$33.00	1	Sleeve of 50	$33.00
Tongue Depressors	$10.95	1	Box of 500	$10.95
GP Brushes 2"	$12.25	3	Box of 24	$36.75
5/8" x 4" Fiberglass detail roller	$7.70	4	each	$30.80
Peel Ply Release Fabric (60" width)	$5.10	25	yard	$127.50
Meguiars Mirror Glaze No.8 11oz	$11.45	5	each	$57.25
Emerald Green Liquid Color Pigment	$9.60	1	each	$9.60
12 oz. Protective Enamel Gloss Crystal Clear Spray Paint (6-Pack)	$25.62	1	6 pack	$25.62
Green Fiber R13-R60 Blown in Insulation (biodegradable)	$9.68	1	Bale (18+ lbs)	$9.68
11 in. x 5.40 in. Recycled Paper Towels 2-Ply	$13.85	2	6 pack	$27.70
3 ft. x 144 ft. Brown Rosin Paper	$14.51	1	roll	$14.51
1 inch masking tape	$1.89	10	roll	$18.90
1 Gal. Safety First Isopropyl Alcohol Disinfectant Jug	$29.99	1	gallon	$29.99
1500lb test Kevlar shock cord	$1.10	50	ft	$55.00
58" shock cord protector	$15.99	2	each	$31.98
5mm plywood	$8.00	5	each	$40.00
Attachment Hardware				$30.00
Motor Retainer (75mm)	$75.83	1	each	$75.83
E-match Kit	$80.00	1	each	$80.00
Stratologger CF	$69.95	2	each	$139.90
Raven 4 Altimeter	$160.00	1	each	$160.00
Parachute Protector (Nomex)	$8.26	4	each	$33.04
Main Parachute	$120.00	1	each	$120.00
Drogue Parachute	$40.50	1	each	$40.50
Motor	$300.00	2	each	$600.00
Motor Casing (75mm RMS)	$500	1	each	$500.00
Miscellaneous				$200.00
			Total	$3,232.61

5.2.2 Sub-Scale Production and Testing budget

Our team has acquired the full-scale launch vehicle from "Team Rocket", which was a Capstone design team from University of North Texas that successfully made it all the way to the final launch for NASA USLI 2017 competition. We plan to use that airframe as a subscale launch vehicle to test our recovery system, electronics, and possibly our payload. This is an ideal situation because this airframe has already proven that it can be successfully launched and recovered and meets the design and safety standards of NASA SLI and NAR. Using this Airframe will also save our team time and money developing a subscale airframe and will allow us to focus on design and innovation for the overall mission. This subscale vehicle's inner workings have already been stripped as well, so this year's team will be able to start with a working shell and create a complete sub-scale vehicle that meets our current designs and mission. We were also able to salvage its main parachute and shock cord for reuse.

Item	Price	Quantity	U/I	Subtotal
Motor	$250.00	2	each	$500.00
Drogue Parachute	$40.50	1	each	$40.50
Recovery Hardware				$30.00
Motor Retainer (54mm)	$70.00	1	each	$70.00
			Total	$640.50

5.2.3 Team Travel Budget

The team plans to use University vehicles to drive to the launch with all our equipment and roughly 20 team members.

Item	Cost	
Transportation	$800.00	
Hotel	$5,000.00	
	Total	$5,800.00

5.3 Funding Plan

We are currently working with the university to find sponsors for the team. We intend to offer sponsors name and logo space on our team shirts, table-top presentation banner, social media page, and on the competition rocket body. We are also building a resume book containing the resumes of each team member. We hope to appeal to industry leaders who have vested interest in the manufacturing practices and engineering that goes into design and development of a composite airframe containing a semi-autonomous robotic payload. We are submitting sponsorship requests to some larger companies in the area through some of our Alumni connections there as well.

We have also recruited 2 Capstone design teams as subcommittees to our project. Each Capstone design team is given $1000-$1,500 by the university to develop, test, and complete their project. This means that our team, including the 2 Capstone design teams will benefit from an added $2,500 for the project budget.

5.4 Sustainability Plan

This year we are starting a mentoring system where new members can learn the engineering process involved in planning, building, and designing Project Sparrowhawk in the NASA SL competition directly from team leaders. The mentoring process prepares mentees for future competitions and Aerospace related projects. Finally, we have several active alumni who have been helping us financially with donations and connections with sponsors.

5.4.1 Establishing and Maintaining Partnerships

We are currently engaging potential sponsors and plan to use established relationships and UNT alumni to maintain/create partnerships with local companies going into the future.

5.4.2 Engaging Successive Classes of Students in Rocketry

UNT Robotics actively recruits at introductory level courses in STEM majors at our university. The first two weeks of each semester our officers present to all introductory Mechanical, Electrical, and Computer Engineering courses in person to generate interest in our project-based student organization and to inform the new underclassmen of our mission and purpose. Recruiting freshman is vital to our sustainability because with time comes experience and being able to work with students throughout their entire undergraduate careers allows our organization to successfully plan and complete exciting and advanced projects. Our target audience is not restricted to any single major, and our 370+ membership includes all STEM majors.

5.4.3 Industry and Community Partners

Our first community partner is Girard Contracting, a local general contracting company that has agreed to help supply some building materials to our team for the purposes of building shelves and workbenches as we create our brand-new workspace. We are setting meetings with aerospace, manufacturing, and composites related companies nearby to see if we can generate further interest in partnerships with our organization.

5.4.4 Team Member Recruitment

This is a continuing effort to ensure that our team has enough talent and ingenuity to succeed in the tasks set forth by NASA. Our current team is comprised mostly of Junior and Senior level engineering students who have demonstrated a drive to work on the project and potential for leadership. During the first two weeks of each semester, we go to the entry level mechanical, electrical, and computer engineering courses and pitch our organization and the benefits of membership to freshmen students. Team leadership was able to work with the engineering department this year to recruit 2 teams from Senior Design 1 and 2 (our university's engineering "Capstone design" course) to work with us through the year on this project as subcommittees on critical sections of the project, and we have assimilated them into our team as individual members as well. We also attend community events hosted by the university to showcase our projects and recruit new members from the attendees.

5.4.5 Funding Sustainability

We have ongoing partnerships with local electronics and robotics equipment suppliers including Elegoo, ServoCity, and Respec, as well as Alumni who have made financial contributions to our organization. We intend to continue developing these relationships even as we look to create new partnerships.

5.4.6 STEM Engagement Activities

Our intent is to conduct workshops in the community based on age groups of the children involved. For elementary students we plan to talk about some basic rocket features and apply them to creating stomp rockets or water rockets. For middle school and high school aged children, we plan to build Estes model rockets as a group and have a group launch at the end of the workshop or at a later date if the school cannot sustain a low altitude model rocket launch, which would cause us to move part of the event to another location.

5.4.6.1 Evaluation Criteria

We will create an evaluation page for the Parents/Educators of the participants to evaluate our team members efficacy at presenting the material and engaging the participants. There will also be a verbal feedback opportunity with the participants to see if they enjoyed the event and learned something new. Success criteria for our team at these events will be if the students have fun, learn something, and find new interests, and of course the event was conducted safely. As we head into this competition, the team is striving to not only enrich ourselves academically, but also engage k-12 youth, and instill into them a passion for discovery and the goal to pursue higher education.

The Dallas-Fort Worth area has more than 300,000 students pursuing k-12 education, many of which have already been inspired by NASA and shows like ‘Cosmos’ to pursue STEM as a future career or get involved in STEM activities. The aim of the UNT High Power Rocketry Team is to lead an engaging experience in rocketry, space, and everything in-between that appeals to both students who are already engaged in STEM, and those who are new to it.

The ability to make an engaging, exciting, but also educational outreach event is paramount to achieving the main objective, so evaluation forms will be handed to educators, parents, and students at the end of the events to gauge which aspects were the most and least popular. These forms will be used to continuously improve how the team conducts these outreach events to make the largest impact possible.

5.4.6.2 STEM at the Park

This event is after the Flight Readiness Review date, but our team would like to make this a recurring event each year for part of our sustained STEM outreach program.

Date: Mid-March 2022

STEM at the Park is an annual event that offers adult, middle, and high school students the opportunity to experience engineering and computer science at the University of North Texas through hands-on projects and activities. The UNT High Power Rocketry Team will be hosting workshops to teach students about how rockets fly and then have the students utilize what they’ve learned in a hands-on activity where they can build and launch their own model rockets

5.4.6.3 Mars Collection Rover

Date: February 2022

Mars Collection Rover is a series of workshops we will be hosting for around 100 students at Alice Moore Alexander Elementary. This will be one of the largest engineering outreach events hosted by

UNT. In this workshop, students will be sending sample collecting rovers to Mars! After splitting into groups of 4-5, students will work together to construct their own intake mechanism out of household materials such as cardboard and popsicle sticks which will be attached to the front of their controllable robot car to build their Mars Rover. Then all the groups will compete on our custom-built Mars surface to see who can push the most rock samples into their collection space. After each round, they will be given time to adjust their intake mechanism to continuously improve their sample collecting efficiency. The purpose of this workshop is to teach students how to design for function.

5.4.6.4 Scouts STEM Engagement

Date: Late October

This event will be a partnership with Dallas Area Rocket Society, at which we engage the Scouts in building model rockets. Once built, they will have a competition to see who can land their rocket closest to a designated landing zone on “the Moon” which is a large tarpaulin placed at another spot on the launch field.

5.4.6.5 Shultz Elementary STEAM Club

Date: 10/19, 11/2, 11/16, 1/25, 2/8, 3/1

Shultz Elementary’s STEAM Club is an afterschool program aimed at getting k-2 grade students inspired and motivated for careers in the STEAM field. Each grade level has about 20 students per semester. We will be reading “Curiosity: The story of a Mars Rover” by Markus Motum and doing a rocket themed coloring activity with the kindergartners, building popsicle stick rocket models with the 1st graders, and launching bottle rockets with the 2nd graders.

References

[1] National Aeronautics and Space Administration, "2022 NASA Student Launch : Handbook and Request for Proposal," 18 August 2021. [Online]. Available: https://www.nasa.gov/stem/studentlaunch/handbook/index.html. [Accessed 18 August 2021].

[2] "www.beaufort.marines.mil," 28 August 2007. [Online]. Available: https://www.beaufort.marines.mil/Portals/53/ORM%20Worksheet.pdf. [Accessed 21 August 2021].

[3] National Association of Rocketry, "NAR.org," [Online]. Available: https://www.nar.org/wp-content/uploads/2018/08/High-Power-Rocket-Safety-Code.pdf. [Accessed 20 August 2021].

[4] Granta Design Limited, "AZO Meterials," [Online]. Available: https://www.azom.com/properties.aspx?ArticleID=764. [Accessed 20 August 2021].

[5] ACP Composites, "Commercecontent.azureedge," December 2014. [Online]. Available: https://commercecontent.azureedge.net/0012-content/Mechanical-Properties-of-Carbon-Fiber-Composite-Materials.pdf. [Accessed 20 August 2021].

[6] Forest Products Laboratory, "MatWeb," Prentice Hall, 1990. [Online]. Available: http://www.matweb.com/search/DataSheet.aspx?MatGUID=bd6620450973496ea2578c283e9fb807&ckck=1. [Accessed 19 08 2021].

[7] "thrustcurve.org," [Online]. Available: https://www.thrustcurve.org/motors/AeroTech/K1000T/. [Accessed 10 09 2021].

[8] "14 CFR Part 101 - MOORED BALLOONS, KITES, AMATEUR ROCKETS, AND UNMANNED FREE BALLOONS," [Online]. Available: https://www.law.cornell.edu/cfr/text/14/part-101. [Accessed 18 September 2021].

[9] "14 CFR Part 107 Small Unmanned Aircraft Systems," National Archives, June 2016. [Online]. Available: https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-107. [Accessed 10 September 2022].

Enclosures

Enclosure (1): General Shop and Range Safety Standard Operating Procedure (SOP)

High Power Rocketry General Safety Standard Operating Procedure (SOP) and Safety Briefing

UNT Robotics Aerospace Division

Record of Changes and Review			
Date	**Change (w/page #) or Review**	**Reviewed/Changed by:**	**Signature**
This is designed to be a fluid document that can be changed or updated as the need arises to adapt our team safety SOP to meet new challenges. All updates will be logged on this page and a copy of this SOP will be available at every launch and in the manufacturing workspace. If any person has questions related to safety, please bring them to the attention of the team Safety officer, Adam Hinkel. This document will also be reviewed monthly to ensure that it is current. To participate in manufacturing or launch activities, all participants will be required to sign the final page of the SOP acknowledging that they understand the risks and procedures. Signing this document does not constitute a waiver of liability.			

1. General Team Safety Statement of Understanding

All team members understand and will abide by the following safety regulations:

a. Range safety inspections will be conducted on each rocket before it is flown. Each team shall comply with the determination of the safety inspection or may be removed from the program.
b. The Range Safety Officer has the final say on all rocket safety issues. Therefore, the Range Safety Officer has the right to deny the launch of any rocket for safety reasons.
c. The team mentor is ultimately responsible for the safe flight and recovery of the team's rocket. Therefore, a team will not fly a rocket until the mentor has reviewed the design, examined the build and is satisfied the rocket meets established amateur rocketry design and safety guidelines.
d. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

2. Operational Risk Management Worksheet for all Operations

Risk Severity		Risk Probability			
		Likely/Immediate A	Probably B	May C	Unlikely D
Catastrophic	1	1A	1B	2C	3D
Critical	2	1A	2B	3C	4D
Moderate	3	2A	3B	3C	5D
Minor	4	3A	4B	5C	5D
Negligible	5				

Figure 4: Risk Severity and Probability Matrix

Operational Risk Management Assessment Worksheet:							
Identify Hazards			**Assess Hazards**	**Make Risk Decisions**		**Implement Controls**	**Supervise**
Operation	Hazard	Causes	Initial RAC	Develop Controls	Residual RAC	How to Implement	How to Supervise
Fiberglass Layup	**Epoxy-Resin** skin contact, eye contact, fumes inhalation	Chemical spills, burns from curing epoxy, and reaction fumes	2A	Eye pro, gloves, respirators, and protective clothing will be worn during operations	4B	PPE will be available in the workspace, and all team members (TM's) will be trained and briefed on safety hazards present.	There will be a Safety officer or designated person present for all hazardous operations.
General Parts Construction	Serious injury	Power tools malfunction, inherent hazards associated with, or improper use of tools.	2C	Wearing eye pro, ear pro, and work gloves while using appropriate machinery. Train personnel on proper use and troubleshooting of tools.	3D	PPE will be available in the workspace. All personnel admitted to certain areas will finish required hazard training. TM's will be trained and briefed on hazards present.	There will be a Safety officer or designated person present for all hazardous operations.

Operation	Hazard	Causes	Initial RAC	Develop Controls	Residual RAC	How to Implement	How to Supervise
Energetic Testing of components and subsystems	Burn or impact injury	Black powder ejection charges	2C	Wearing eye pro, ear pro, and work gloves while around testing area. Train personnel on proper use and troubleshooting of component systems.	3D	PPE will be available in the workspace. All personnel admitted to certain areas will finish required hazard training. TM's will be trained and briefed on hazards present.	There will be a Safety officer or designated person present for all hazardous operations.
	Shock/ electrocution	Electrical circuit testing	3C	Ensure proper grounding and handling techniques area followed.	5D	PPE will be available in the workspace. All personnel admitted to certain areas will finish required hazard training. TM's will be trained and briefed on hazards present.	There will be a Safety officer or designated person present for all hazardous operations.
	Impact injury	Actuator malfunction	3C	Wearing eye pro and gloves while working with any energetic systems.	5D	PPE will be available in the workspace. All personnel admitted to certain areas will finish required hazard training. TM's will be trained and briefed on hazards present.	There will be a Safety officer or designated person present for all hazardous operations.
Painting Launch Vehicle Components	Skin/eye contact, fumes	Spray Paint and clear coat	2A	Eye pro, gloves, particulate masks, and protective clothing will be worn during operations. Masks can be omitted if painting is done outside.	4B	Workspace is in a well-ventilated area. PPE will be available to all TM's in the workspace. TM's will be trained and briefed on hazards present.	There will be a Safety officer or designated person present for all hazardous operations.
Launch Day and Test Launches	Loss of vehicle	Motor Failure	2C	Only use COTS motors.	3D	Inspect motor upon receipt and before use.	Records of this inspection will be kept by the project manager.
	Range Fire	Motor failure, motor retainer failure	2C	Only use COTS motors. Follow NAR/Tripoli range safety guidelines for range fires. Conduct modeling and testing of motor retention system.	3D	Inspect motor upon receipt and before use. Inspect retention system when assembled and as part of the pre-flight checklist at each launch.	The project manager must be present and inspect this component before each launch.

Operation	Hazard	Causes	Initial RAC	Develop Controls	Residual RAC	How to Implement	How to Supervise
	Injury to personnel or damage to property, loss of vehicle or components	Detonation/ Deflagration of Motor	2C	Only use COTS motors. Follow NAR/Tripoli range safety guidelines for minimum safe distances. Follow NASA SL guidelines for vehicle construction to minimize the likelihood of projectile/ fragmentation production.	3D	Inspect motor upon receipt and before use. Utilize NAR/Tripoli minimum safe distances and follow instructions from the RSO and RCO of the launch.	Project manager, or designated safety person will inspect components during and after construction. Components will be inspected before and after each launch to ensure they are safe to reuse or identify the need for replacement.
	Loss of vehicle/ damage to property/ personal injury	Recovery system failure	1B	Charge all batteries, bring extras to each launch. Inspect parachute and drogue, and all lines. Verify ejection charges by ground testing prior to launches. Follow NAR guidelines for weathercocking to prevent vehicle from falling on top of people/property at the range. Build in redundancies to ensure that there are backup recovery systems.	2C	Follow pre-flight checklists to ensure that each system is ready and working properly.	Project Manager and safety officer will sign off on each pre-flight checklist prior to declaring a vehicle ready to launch. If any part of the checklist is incomplete the vehicle launch will be postponed until launch readiness can be verified.
	Fin Damage	Recovery system Failure or landing speed miscalculation	2C	Build for redundancy in the recovery system. Reinforce fins with carbon fiber to increase shear strength and prevent breaking. Design fin-can to be swapped out if necessary. Conduct failure testing to determine strength of fins before assembly.	3D	Follow pre-flight checklists to ensure that each system is ready and working properly.	Project Manager and safety officer will sign off on each pre-flight checklist prior to declaring a vehicle ready to launch. If any part of the checklist is incomplete the vehicle launch will be postponed until launch readiness can be verified.
	Body Tube Failure	Zippering caused by deployment of recovery system	2C	Base material strength on worst case. Employ “zipper-proof” design techniques wherever possible in construction.	3D	Stress-test all airframe elements to ensure survivability during in-flight events. Redesign or reinforce when necessary.	Before assembly of flight ready vehicle, production checklist must be signed by project manager and manufacturing lead to ensure that each element meets the stress even criteria established during design phase and testing.

Operation	Hazard	Causes	Initial RAC	Develop Controls	Residual RAC	How to Implement	How to Supervise
	Body Tube Failure	Forces exerted at launch, during flight, recovery events, or landing exceed design parameters	2C	Base material strength on worst case. Limit weight of launch vehicle only when it does not sacrifice required strength. Conduct FEA and CFD/wind tunnel testing to predict worst case forces on airframe components.	3D	Stress-test all airframe elements to ensure survivability during in-flight events. Redesign or reinforce when necessary.	Before assembly of flight ready vehicle, production checklist must be signed by project manager and manufacturing lead to ensure that each element meets the stress even criteria established during design phase and testing. All elements will undergo necessary ground testing prior to certification for flight.
	Premature Separation of Airframe Sections	Expansion of trapped gasses within sealed sections, forcing stages apart	3C	All airframe components that would normally be sealed will have appropriately sized vent holes added to allow trapped gasses to escape as they expand.	4D	Once all components are ready to be assembled, they will be inspected to ensure that the correct holes have been added prior to prepping for launch.	Before assembly of flight ready vehicle, production checklist must be signed by project manager and manufacturing lead to ensure that each element meets the stress even criteria established during design phase and testing. All elements will undergo necessary ground testing prior to certification for flight.
All in-person activities	COVID-19 Exposure/ Contracting the virus	Infected persons spreading the virus to others in close proximity.	2C	Team members will have ready access to masks and hand sanitizer, as well as handwashing sinks. Sick team members will not be permitted to come into the work areas or attend meetings in person.	3D	All meetings will be conducted in-person and online simultaneously to allow members to stay home and participate. TMs in the work areas will be limited to necessary personnel.	UNT policy requires every person not vaccinated to get tested each month. All students are encouraged to wear masks while indoor. Team members will be asked to agree to limit risky activities for the good of the team.

Figure 5:ORM Assessment Worksheet

1. Workspace Safety Brief

- All workspaces on the UNT campus have specific safety requirements and hazard training requirements associated with them. Any person not trained for any workspace will not be able to perform activities within that area or with the associated equipment until that training is completed.
- Appropriate personal protective equipment (PPE) will be worn at all times while working in any of the shop/lab spaces with hazardous machines or processes. These PPE items will be stored in each workspace and sourced/provided to each person by the team.
- Whenever working with paints, epoxy, and sanding, the appropriate level of respiratory protection will be worn.
- Disposable gloves, hearing protection, masks, and respirators will be provided whenever necessary.

Closed toed shoes must be worn whenever working in the Aerospace workspace.

Power tools will not be used unless there are two people present who are trained to use the tools safely.

Report all incidents and near misses to the safety officer.

Testing involving ejection charges will only be conducted in open spaces and under the supervision of the team's NAR/TRA mentor.

Fire Extinguishers and emergency eyewash stations are placed throughout the J-wing, and it is everyone's responsibility to become familiar with their locations.

A roster will be kept by the safety officer showing which safety training requirement each member has completed.

Clean up all spills immediately.

Keep the shop area clean and free of trash and tripping hazards.

Backpacks and personal items will only be stored in designated areas.

Whenever you are finished with any tools, return them to the toolbox.

When you finish with power tools, ensure that they are turned off and unplugged.

If a tool is broken, report it to the safety officer and the Robotics inventory manager so that it can be replaced.

Rags, towels, and any chemical residue will be disposed of properly. Do not throw chemical soaked towels in the garbage or pour excess into the drain. All epoxy/resin waste will be allowed to cure in the open and cooled before disposing of it.

2. Range Safety Brief

“Range” is defined as a dedicated launch field approved of and supervised by NAR/TRA personnel.

NAR High Power Rocketry Safety Code [3]

14. **Certification.** I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.
15. **Materials.** I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.
16. **Motors**. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
17. **Ignition System.** I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch and will use a launch switch that returns to the “off” position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.
18. **Misfires.** If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher’s safety interlock or disconnect its battery and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.
19. **Launch Safety.** I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.
20. **Launcher.** I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour, I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor’s exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.
21. **Size.** My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high-power rocket motor(s) intended to be ignited at launch.
22. **Flight Safety.** I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation

Administration airspace regulations when flying and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.

23. **Launch Site.** I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).
24. **Launcher Location.** My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the **appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.**
25. **Recovery System**. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.
26. **Recovery Safety.** I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

MINIMUM DISTANCE TABLE

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 — 320.00	H or smaller	50	100	200
320.01 — 640.00	I	50	100	200
640.01 — 1,280.00	J	50	100	200
1,280.01 — 2,560.00	K	75	200	300
2,560.01 — 5,120.00	L	100	300	500
5,120.01 — 10,240.00	M	125	500	1000
10,240.01 — 20,480.00	N	125	1000	1500
20,480.01 — 40,960.00	O	125	1500	2000

NASA Safety Requirements:

6. Teams will abide by all rules and regulations of the RSO for local launches for all test flights.
7. Teams will abide by all FAA rules and regulations.
8. All team members understand and will abide by the following safety regulations:
   a. Range safety inspections will be conducted on each rocket before it is flown. Each team shall comply with the determination of the safety inspection or may be removed from the program.
   b. The Range Safety Officer has the final say on all rocket safety issues. Therefore, the Range Safety Officer has the right to deny the launch of any rocket for safety reasons.

c. The team mentor is ultimately responsible for the safe flight and recovery of the team's rocket. Therefore, a team will not fly a rocket until the mentor has reviewed the design, examined the build and is satisfied the rocket meets established amateur rocketry design and safety guidelines.
d. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

By signing this page, you are agreeing to abide by all safety requirements set forth in this SOP, as well as all applicable regulations from NASA, Local Authorities, UNT, and the FAA. Safety mishaps will be logged to mitigate future hazards. Any deliberate or negligent violation of these regulations and this SOP will result in the student being removed from the team. Each person on the team has a responsibility to each other and themselves to act with the safety of every other person in mind.

Date	**Name**	**Signature**


UNT SPARROWHAWK