2025 First Nations Launch

First Nations Launch Competition Proposal

For Wisconsin Space Grant Consortium
Northern Arizona University
10-24-2024

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1 General Information

Faculty Advisor: Carson Pete

Advisor Title: Associate Teaching Professor

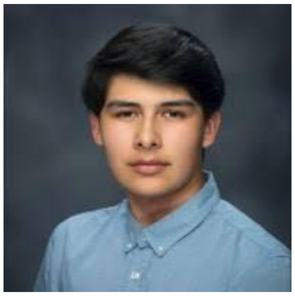
Tripoli Level 2

Student Team Lead: Ryan Yazzie

Student Lead Info: Senior, Mechanical Engineering

CAD Engineer

Tripoli Level 0



Student Safety Lead: Jacob Crofford

Safety Lead Info: Senior, Mechanical Engineering

Manufacturing Engineer, Logistics

Tripoli Level 0

Student Avionics Lead: Brittney Thornton

Avionics Lead Info: Senior, Mechanical Engineering

Avionics Lead, Recovery Lead,

Financial Manager, Website Developer

Tripoli Level 0

Student Testing Lead: Joshua Wilson

Testing Lead Info: Senior, Mechanical Engineering

Simulations Lead, Test Engineer

Tripoli Level 1

NAR/TRA Mentor: Kevin Small

Mentor Title: Secretary

NAR/TRA Section: Tripoli, Phoenix

Tripoli Level 3

2 Facilities/Equipment

2.1 Facilities and Workspaces

Northern Arizona University is host to numerous engineering geared facilities that NAU Space Jacks will utilize during the duration of the First Nations Launch – Mars Engineering Challenge. From design spaces that utilize software for 3D printing, laser cutting, and machining of mechanical components. The main facilities available consist of the Maker Lab in Cline Library, Idea Lab in the Engineering building, and the Machine Shop located on South Campus.

Additionally, NAU is host to numerous labs in the Engineering building with emphasis on student labs for increasing interaction with testing materials and concepts encountered in coursework, or projects such as the First Nation's Launch – Mars Engineering Competition. These labs cater for different applications for Mechanical Engineering Students, Civil and Environmental Engineering, and Electrical Engineering. These facilities include the Advanced Composite Materials Lab, Computer Aided Design Lab, Engineering Design Lab, Thermal Fluids Lab, Structural Testing Laboratory.

2.2 Equipment and Machinery

In NAU's Maker Lab students are exposed to a multidisciplinary workspace that provides a wide range of tools, equipment, supplies, and services that include 3D Printers that are available for all students to utilize for manufacturing concept generations, 3D Scanning, and software development through rental of microcontrollers and accompanying hardware.

The Idea Lab offers students industry standard equipment used in additive or subtractive manufacturing such as Laser Cutters and 3D Printers that utilize a variety of materials intended for numerous applications that are tighter in tolerance in comparison to those located in the Maker Lab.

The NAU Machine Shop offers students opportunities for metal working on industrial equipment. The shop includes various hand tools that enable users to assemble, debur, and apply finishing applications on all components manufactured.

The Advanced Composite Materials Laboratory is an instructional and research facility equipped for the fabrication, testing, and analysis of composite materials. The lab provides support for funded research projects related to composite materials.

The Computer Aided Design Laboratory is an instructional and service facility that is equipped with 33 computers dedicated exclusively to undergraduate student use. Every terminal has various software packages installed, including AutoCAD and SolidWorks. When the lab is not in use for classes, students have access to it for their studies, projects, homework and assignments.

The Engineering Design Laboratory is designated to meet the needs of our Design 4 Practice Program, which enables students to gain experience with kits for a robotics-styled team design class. This space allows for both formal instruction as well as design group work, making it a versatile and functional facility.

The Thermal-Fluids Laboratory is a modern research and instructional facility that emphasizes the design of experiment and report writing skills. It serves as the main environment for experiments for Thermal Science courses and provides support for Senior Capstone Projects with emphasis of thermal-fluids nature.

The Structural Testing Laboratory is reserved for the experimental testing of structural materials and members. This space supports undergraduate and graduate research, and student organizations including activities related to construction. Electronic instrumentation that supports the laboratory includes: three 12-inch stroke string potentiometers, four 200-kip capacity load cells, one 50-kip load cell, one 5-kip load cell, a National Instruments SCXI-1000 data acquisition chassis, National Instruments SCXI-1121 and SCXI-1520 strain/bridge-based temperature and voltage modules, and a desktop computer. Software that supports the laboratory includes National Instrument's LabVIEW and Microsoft Office.

2.2.1 Available Equipment

The Maker Lab includes Makerbot Replicators+ and Ultimaker S7s. Additionally, hardware for software development and microcontrollers are available for checkout such as Raspberry Pi's, Arduinos, and Soldering Kits. These materials and equipment are listed below in Table 1.

Table 1: Northern Arizona University Maker Lab 3D Printers Available

MakerBot Replicator+ 	<u>Specifications:</u> Build Volume: 11.6" x 7.6" x 6.5" Print Material: 1.75 mm PLA Resolution: 0.1mm Nozzle Dimeter: 0.4mm [0.015 in]
Ultimaker S7 	<u>Specifications:</u> Build Volume: 12.9" x 9.4" x 11.8" Print Material: 2.85 mm PLA and TPU Resolution: 0.1 mm Nozzle Diameter: 0.4mm [0.015 in]

The IDEA Lab is located in the Northern Arizona University Engineering building and its equipment are listed in Table 2 below. Many of the instruments will be utilized to prototype components of the rocket such as complex geometric characteristics that cannot be machined or need higher tolerance than what is produced from the Maker Lab printers.

Table 2: Northern Arizona University IDEA Lab 3D Printers Available

FORTUS 250mc 	<u>Specifications:</u> Build Volume: 10” x 10” x 12” Print Material: ABS Stratasys FDM Technology
FORTUS 450mc 	<u>Specifications:</u> Build Volume: 16” x 14” x 16” Print Material: Thermoplastics Stratasys FDM Technology
J35 Pro 	<u>Specifications:</u> Build Volume: 13” x 13” x 6.1” Print Material: i. Rubber-like ii. High Impact iii. Rigid Ultra Visual iv. Translucent v. Bio-Compatible Based on J55 Rotating Tray Platform

MarkForged Mark Two 	<u>Specifications:</u> Build Volume: 12.6” x 5.2” x 6” Print Material: i. Composites ii. Polymers Dual Extrusion Operating on Continuous Fiber Reinforcement (CFR) technology
Ender-3 V3 KE 	<u>Specifications:</u> Build Volume: 8.6” x 8.6” x 9.5” Print Material: i. PLA ii. PETG iii. TPU Print Speed: 500 mm/s Print Acceleration: 8,000 mm/s^2 Auto Leveling
BossLaser HP-3655 	<u>Specifications:</u> Multi-Functional laser that engraves and cuts through metal Cuts through 18 ga Stainless steel (1.02 mm) Equipped with 150 W CO2 laser tube 120 psi rated laser head’ 0.25” high pressure air lines and hardware CW-52000 Water Chiller with Temperature Alert to protect laser tube Vacuum table with tray to capture product Safety door to prevent laser firing with door open

The equipment in NAU's Machine Shop located on South Campus include the following detailed in Table 3. Components that can be machined and constructed of composite materials can be manufactured here, where students can gain hands on experience with fabrication.

Table 3: Northern Arizona University Engineering Fabrication Shop Machinery Available

Hand Tools 	The machine shop is equipped with a wide range of essential hand tools for student use. Common tools like wrenches, screwdrivers, calipers, pliers and files are available to access. These tools are crucial for precision and quick problem solving for fabrication of a rocket components.
Horizontal Band Saw 	A horizontal band saw is utilized for cutting diverse materials like metal, wood and plastics. It contains a long blade that moves in the horizontal plane for precision cuts. This will be useful for material cuts for the rocket frame.

Drill Press 	A drill press is a stationary power tool that allows for drilling holes in various materials. It allows for control over the depth and angle of the holes being drilled. This can be crucial for mountings and creating motor housings for the rocket.
Belt Sander 	Belt sanders are used for smoothing and shaping materials. It utilizes sandpaper to quickly remove material for finishes. This can be useful to use for the rocket frame to ensure a smooth finish to improve aerodynamics for flight.
Bench Grinder 	A bench grinder is commonly used for sharpening tools, removing rust and shaping metal pieces. This can be useful to sharpen metal tools for rocketry build and to possibly remove rust from any of the materials.

Roper Whitney Shear 	Roper Whitney Shear is designed to handle different thickness of metals for cutting and shearing. It's known for its durability, accuracy and clean cuts for assembling components in rocketry building.
Bridgeport Vertical Mill 	Bridgeport vertical mills are useful for metal work and manufacturing. This machine allows for intricate shapes and contours to be machined. They can be used in a variety of industries including aerospace.
Tormach CNC Vertical Mills 	Tormach CNC vertical mills are common type of machinery that just focuses on precision milling, drilling and contouring. It is found more accessible and can be used to execute complex designs for prototyping.

MetalPro Iron Work Shear 	MetalPro iron work shear is cutting machine specifically for sheet metals. This will provide straight cuts through various thicknesses of metal. This may not be used because the team's rocket should not contain big metal parts that require precision cutting.

2.2.2 Machining

Training Needed

Safety training is required to gain access for the engineering fabrication shop. Here we get hands-on opportunity to construct a small material while optimizing safety protocols, with professional supervision. For the Maker Lab and the Idea Lab, there is no training required, however any projects using their machines have to be approved and supervised by a Lab employee.

Plans for Training Members

All sub team leads within the group have basic safety training for the engineering fabrication shop, refer to Appendix. Members that do not have safety training for this machine shop will sign up for safety training by utilizing the NAU's Fabrication Shop website. If the use of more advanced machinery is necessary, then team members will then partake in the advanced machine shop training that involves the safety and use tutorials of the Vertical Mill and the Machine Lathe. Furthermore, all team members plan to become Level One certified through the Tripoli Rocketry Association, if they have not completed so already. Plans to become Level One certified should be completed no later than January of 2025.

2.3 Workspace

2.3.1 Workspace to Store Components

The workspace designated to store rocketry components during the building process will be the Solar Shack that is located on Northern Arizona University campus. The Solar shack is an unoccupied concrete building that has limited access to a few designated faculty and students. In addition, there is a Boom Box located within the Solar Shack that has locks for additional protection for the team's rocketry materials, if needed.

2.3.2 Meeting Space

The dedicated meeting space on campus is the same area for the virtual meeting space. The team meets with the faculty advisor, Carson Pete, once a week in NAU's Engineering building to overview competition requirements, manufacturing techniques, and financial procurement. The team reserves the EPIC (Equal Partners in Inclusive Community) room on Thursdays from 2:30pm to 4:30pm. During this time frame the team also meets with technical advisor, Kelly Gallagher through zoom. The team comes together in person in the same space as our faculty advisor meeting to attend this virtual meeting with our technical advisor.

2.3.3 Campus Laboratories

The Advanced Composite Materials Laboratory testing equipment for specifications such as manufacturing and testing equipment, lab, and design and analysis.

Manufacturing and Testing Equipment:

18" x 18", 850°F hot press

Large Oven

Specimen fabrication equipment

60,000 lbs. Instron universal testing machine

Test fixtures for composite testing

Lab Capabilities:

Specimen and prototype manufacturing: hand layup, high temperature/high pressure press, machining for specimens

Testing facilities using a universal testing machine: standard tension tests, compression and shear properties, bending, sandwich panel properties.

Strain gage instrumentation and data acquisition equipment.

Structural analysis of composite parts, composite design, finite element analysis using COSMOS/M, laminated plate analysis using in-house and commercially available software.

The Computer Aided Design Laboratory includes equipment and computers that enable students to utilize industry standard software such as SolidWorks and AutoCAD, along with additional simulation programs such as Python and MATLAB.

Dedicated to undergraduate student use

Used intermittently for other engineering courses which have core computing components that require a Windows-based environment.

Equipped with 33 computers connected to college server.

The Thermal-Fluids Laboratory has enabled students in Senior Design Projects utilizing state-of-the-art computerized data acquisition equipment to perform experiments. Typical experiments include measurement of fluid dynamic drag, measurement of power output, and measurement of forced convection heat transfer coefficient. The labs facilities consist of:

Hydraulics bench (by Armfield) for fluid mechanics experiments.

Jet impacts by Bernoulli's theorem demonstration experimental setups (by Armfield) that work with the hydraulic work bench.

Extended fin experiment, developed in house

Data acquisition equipment for temperature measurements (by National Instruments) dedicated to the extended fin experiment.

Educational wind tunnel (by Aerolab) with a test section of 1ft x 1ft x 2ft and 12 scaled models.

Accessories for the wind tunnel (data acquisition equipment, smoke generator and wand).

6 Dell OptiPlex 990 Mini-Tower desktop computers with two monitors each.

5 Data Acquisition modules, each with analog input output, digital output, strain gage, and temperature measurement capabilities.

The Structural Testing Laboratory offers students the opportunity to analyze the components of their design using industry standard equipment available through the university. These tests allow for optimization of materials to best suit the needs of the dynamic forces endured by the rocket. Equipment and hardware include:

One 400-kip capacity testing frame and related hydraulic and pneumatic accessories.

Three 12” stroke string potentiometers.

Four 200-kip capacity load cells.

One 50-kip load cell.

One 5-kip load cell.

A National Instruments SCXI-1121 and SCXI-1520 strain/bridge-based temperature and voltage modules and a desktop computer that supports National Instrument’s LabVIEW.

2.4 Server Availabilities

2.4.1 Computer Hardware

The team will have access to two community computer labs within NAU’s Engineering building designated for students to work. Below in Figure 1 shows the EPIC room where the team meetings are held and where the students work together on their projects. The other computer lab is held at the entrance of the Engineering building in the Internet Café. Within these computer labs Dell desktop computers are provided for student use.

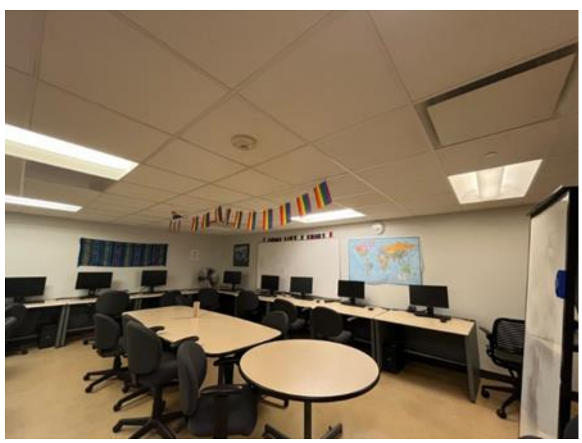


Figure 1: Equal Partners in Inclusive Community

2.4.2 Computer Software

Computer software like Microsoft Word and Google Docs are provided for report writing for students to access. Computer-aided design software like SolidWorks has programmed licenses within all computers accessed in the computer labs of the Engineering building. Internet access is provided through NAU’s server where all students and faculty members have access to any building on campus. Gmail and Microsoft Teams are the team's main forms of contact to reach out to each other and other advisors.

2.4.3 File Sharing Capabilities

File sharing capabilities amongst team members is done by utilizing Microsoft Teams that is provided through NAU's Microsoft 365 package available to students and faculty. The team has a shared channel where they can upload research, schedule, budget and team homework assignments for the Capstone course that this competition is done through for NAU.

2.4.4 Software Licenses

There are five RockSim simulation software licenses appointed to the team. Therefore, each of the four team members has a RockSim license on their personal computers for extra practice and simulation creation. Our faculty advisor, Carson Pete also has a RockSim license on his computer to aid the team in any questions that they may present.

3 Safety

Below are the safety plans set to by the NAU Space Jacks Safety Officer, Jacob Crofford, to ensure the safety of all team members, competitors, and the environment.

3.1 NAR/TRA Personnel Procedures

The NAR/TRA mentor for the 2025 Space Jacks plays a crucial role in ensuring the safety of all team members, specifically new members with little to no experience. They will guide all team members through the required safety procedures outlined by the Tripoli Rocketry Association. They will guide participants through the design process including motor selection, simulation, and assembly to ensure a safe flight from pre-launch setup to landing. They will also ensure all laws related to high powered rocketry are followed including but not limited to the storage, transportation, and use of hazardous material such as black powder charges and high-powered rocket motors. The TRA mentor will have a level two certification from the Tripoli Rocketry Association, so they will directly oversee that the motors are handled, built, and installed correctly. The mentor will have a safety checklist and list of procedures that he will oversee all individuals on the team follow, this will include how to safely handle hazardous material, procedures for pre-flight readiness, post flight recovery procedures, and general safety requirements.

3.2 Hazard Recognition and Accident Avoidance

Hazard recognition and accident avoidance are an integral part of ensuring the safety of all NAU 2025 Space Jacks team members. Each student will be briefed on the potential dangers of every process that will be conducted. Every team member is also planning on receiving a level one certification from Tripoli Rocketry Association with the help of the team advisor, Carson Pete, and the NAU Rocket Club. This will allow every team member to have a basic understanding of the dangers associated with building a high-powered rocket. For example, when handling fiberglass material, it is required that gloves, safety goggles, and long sleeve shirts and pants are worn to minimize the chances of fiberglass getting lodged in the skin or eyes of team members. When handling electronic or flammable/explosive material team members are expected to be grounded with a fire extinguisher near to avoid electrocution and sparking of fires or explosions which could cause damages to property, serious injury or even death. Electronics, flammable, and explosive devices will not be tested in close proximity to avoid a potential chain reaction. By ensuring all members are aware of the dangers and hazards it fosters a culture of safety where all team members are prepared and ready to tackle any potential hazards to protect themselves and all other members of the teams.

3.3 Caution Statements

Before any work is done proper safety documents must be found, read, and understood by all team members. These documents will be stored in the NAU Space Jacks Microsoft Teams channel. It is expected that all team members practice proper safety procedures and have appropriate PPE for all materials and processes. Before any work begins it is expected that a product identification is completed consisting of physical characteristics, physical hazards, health hazards, routes of entry and exit, allowable exposure limits, carcinogenic potential, precautions for safe handling, control measures, and emergency first aid procedures for anything used during the First Nations Launch 2025 competition.

3.4 Compliance with Federal, State, and Local Unmanned Rocket Launches

All NAU Space Jack launches will occur in FAA certified launch sites (Eagle Eye Launch Site in Phoenix, Arizona for test launches and Richard Bong State Recreation Area in Kansasville, Wisconsin for the final competition launch) with FAA certified safety officers present, to ensure all Class 2 – High-Power Rocket limitations are met to ensure a safe launch [1].

3.4.1 Use of Airspace

Federal Aviation Regulations, 14 CFR, Subchapter F, Part 101, Subpart C, outline the guidelines for the operation of amateur rockets [1]. These regulations are relevant for the First Nations Launch 2025 Mars Challenge, specifically the Class 2 – High-Power Rockets.

3.4.2 Definition

A Class 2 – High-Power Rockets is described as any amateur rocket that is not a model rocket and is propelled by a motor or motors with a total combined impulse of 40,960 Newton-seconds [1]. To meet this requirement, we will use either the 54mm DMS Aerotech K400C or K353W motors as outlined in the First Nations Launch 2025 Handbook [2], with impulses of 1,361 N-sec and 1,434 N-sec respectively [3,4].

3.4.3 General Operating Limitations

Using RockSim simulation software we can determine the apogee, final landing position, and trajectory of our unmanned rocket. This will allow us to ensure the rocket has a suborbital trajectory, will not cross into the territory of a foreign territory, and doesn’t create a hazard to the team, our competitors, or any other individual, property, or aircraft [2].

3.4.4 Specific Class 2 – High-Power Rocket Limitations

A Class 2 – High-Power Rocket will not launch if clouds obscure the view of the flight, horizontal visibility is less than 5 miles, or if the rocket will fly into a cloud. The launch must not occur between sunset and sunrise, within 9.26 kilometers of an airport's boundaries, or in a controlled airspace without prior authorization from the Federal Aviation Administration (FAA). A minimum distance of a quarter of the expected apogee or 457 meters must be observed to safely launch the rocket. The final limitations include a person of age eighteen or older who oversees the safety of all individuals involved in the operation and has final authority to approve the launch must present and precautions are taken to control a potential fire started by the rocket. All NAU Space Jack launches will occur in FAA certified launch sites (Eagle Eye Launch Site in Phoenix, Arizona for test launches and Richard Bong State Recreation Area in Kansasville, Wisconsin for the final competition launch) with FAA certified safety officers present, to ensure all Class 2 – High-Power Rocket limitations are met to ensure a safe launch [2].

3.4.5 Air Traffic Controller Notifications

As stated above we plan to exclusively launch at FAA certified launch sites on predetermined safe launch dates with FAA certified safety officers present therefore, the responsibility falls on the event launch coordinator to provide their name, address, date and time of launch, radius of affected area in units of nautical miles, longitude and latitude coordinates of the center of the launch site, expected apogees, duration of event, and any information requested from the Air Traffic Controller. Although we don’t plan on hosting a launch event or launching a rocket outside of an event, we understand the notifications we must provide to the Air Traffic Controller [2].

3.4.6 Information Requirements

As stated previously we don’t plan on launching a rocket outside of an event or hosting an event, but we understand that the FAA must be informed of the number of rockets, type of propulsion, description of launchers, recovery systems, maximum apogee, launch site coordinates, and additional safety procedure [2].

3.5 Commerce in Explosives

Amateur Rockets, Code of Federal Regulation 27 Part 55: Commerce in Explosives describes the requirements to handle explosive materials, including rocketry motors [5].

3.5.1 Definition

A propellent actuated device is defined as a tool, mechanism, or gas generator system that is activated by propellant or releases and directs work through a propellant charge. Rocketry motors made up of ammonium perchlorate composite propellant and black powder charges are not included in the definition of a propellant actuated device [5].

3.5.2 Exemptions

Model rocket motors using an ammonium perchlorate composite propellent or black powder charges with a propellent weight of less than 62.5 grams and designed as single use or reloadable are exempt to the strict storage and licensing procedures placed on other explosives. The 54mm DMS Aerotech K400C or K353W motors as outlined in the First Nations Launch 2025 Handbook [3] have propellent weights of 650 grams and 745 grams respectively. Therefore, storage, licensing, and transportation procedures as outlined below will need to be followed. Black powder used as ejection charges for model rocketry are exempt in an amount less than 50 pounds [2]. We plan on having less than 100 grams (.22 pounds) of black powder at a time and using only 15 grams (.033 pounds) for launches. Therefore, black powder charges are exempt from the storage, licensing, and transportation procedures described below.

3.5.3 Licensing, Storage, and Transportation of Explosive Materials

The only member of the Space Jacks team that will purchase, handle, and store the motors used for the test launch at the Eagle Eye Launch Site in Phoenix, Arizona and final launch art Richard Bong State Recreation Area in Kansasville, Wisconsin is the Faculty Advisor, Carson Pete. Pete has a level two certification from the Tripoli Rocketry Association, so he has been trained in all purchasing, storage, and safety procedures related to rocketry motors designated as explosive material. The motors and black powder charges and any other explosive or flammable material will be stored in the Boom box in the Solar Shack. The Solar Shack is an unoccupied concrete building located on the Northern Arizona University campus that only specific faculty and students can access with the assistance of Carson Pete. The Boom Box is a storage box within the solar shack with an extra pair of locks that only Carson Pete has access to that will hold all hazardous material. If hazardous material is stolen or lost it will be reported within 24 hours to 345 S River Run Rd #210, Flagstaff, AZ 86001, the nearest Bureau of Alcohol, Tobacco, Firearms and Explosives and calling 1-800-461-8841 [5]. Carson Pete will be the only individual receiving and transporting the rocket motors and black powder charges, he will not distribute this material to any team member and will oversee all testing and installation related to the explosive material.

3.6 Fire Prevention

NFPA 1127 “Code for High-power Rocket Motors, details the specifies the procedures and guidelines required to adequately minimize fire dangers when dealing with high powered rocket motors.

3.6.1 Pre-Launch

As stated previously, launches will only be done at FAA certified events with FAA safety officers present, so the Space Jacks will follow all pre-launch safety protocols described by the FAA. The weather conditions will be considered, the rockets electronics will be turned on first and only turned on when on the launch pad, no open flames or flammable debris can be present, and a safe distance of 200 feet before launch must be achieved as described in the safe distance table from Tripoli [6].

3.6.2 Post Launch

When recovering the rocket, a fire extinguisher will be on hand in case a fire starts where the rocket lands after its flight. All debris left by the rocket will either be picked up or will be examined to ensure it will not start a fire.

3.6.3 General Guidelines

When conducting tests with flammable material, Carson Pete, our faculty advisor will be present, and a fire extinguisher will be in an area close and easy to access. Any member of the team touching or working with flammable devices will be grounded to avoid potential electrostatic discharge (ESD) resulting in a fire. Only one flammable or explosive device will be worked on at a time to avoid a potential chain reaction. The area where testing will occur will be well ventilated and isolated. The drogue and main parachutes for the rocket’s recovery system must not be flammable to ensure the rocket is recoverable and safe to retrieve upon landing.

3.6.4 Motor Purchasing, Storage, Transportation and Use

As discussed previously Carson Pete the Space Jacks Faculty Advisor will oversee all purchasing, storage, transportation, and use of rocket motors and energetic devices due to his level two certification from the Tripoli Rocketry Association. He will be the only individual purchasing the 54mm DMS Aerotech K400C or K353W motors, black powder charges, and other explosive devices used for test and final launches. He will also be in full control of the storage and accessibility to these devices, the only key to the Boom Box where the motors will be stored is in Pete's possession. There will be no access to the Boom Box without Carson Pete's direct approval and presence and all work done with the devices found in the Boom Box will be completely and closely overseen by Carson Pete. Pete will oversee the transportation of these devices; when travelling to the test launch site no state lines will be crossed, and the material will be appropriately contained and secured. For the final competition all explosive devices will be purchased in Wisconsin through the competition to avoid transportation issues across state lines and for air travel.

3.7 Acknowledgment of Regulations

The 2024-2025 Northern Arizona University Space Jacks understand that range safety inspections will be conducted on the rocket before flight and the Range Safety Officer has the right to deny the launch of the rocket. We understand that the Range Safety Officer's decision is final and will comply with their determination. It is understood that the team mentor is responsible for the safe flight and recovery of the rocket, so it will not fly until the design is reviewed, examined, and satisfies the amateur rocketry design and safety guidelines as determined by the team's mentor. Finally, we understand that if safety requirements are not met, we will not be able to launch our rocket for the First Nation's Launch 2025 Competition.

4 Technical Design

4.1 Functional Decomposition and Black Box Model

Functional decomposition is a tool used to break down complex tasks into smaller more manageable pieces. In Figure 2 below, a functional decomposition for the First Nations Launch 2025 was generated to allow us to identify all major components of our design and their associated function. The decomposition was useful in breaking down the rocket and allowed us to identify the components that needed to be decided upon in a concept generation and evaluation. Specifically, the nose cone, airframe, sensors, drogue and main parachutes, motor, and fins were identified as components from the functional decomposition that needed to undergo the process of concept generation and evaluation.

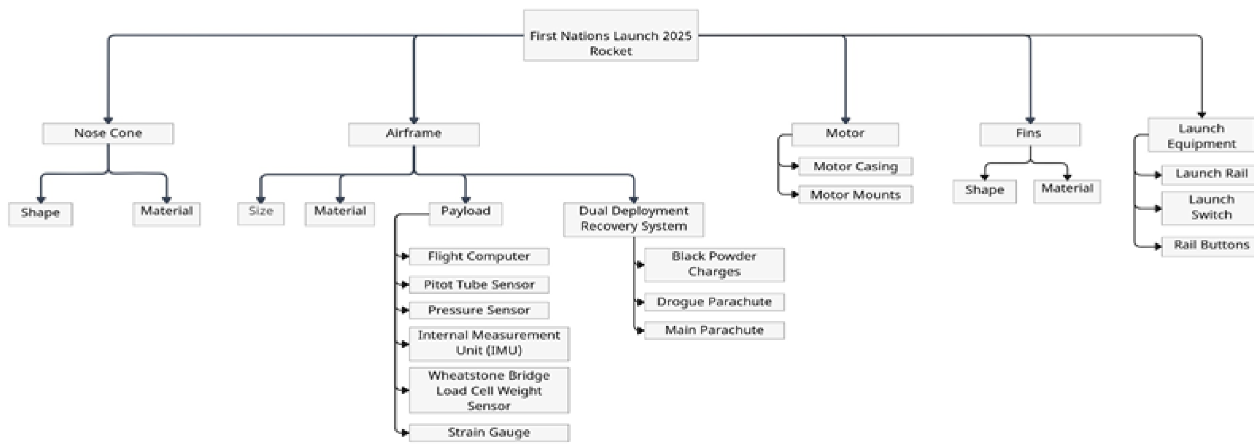


Figure 2: Functional Decomposition

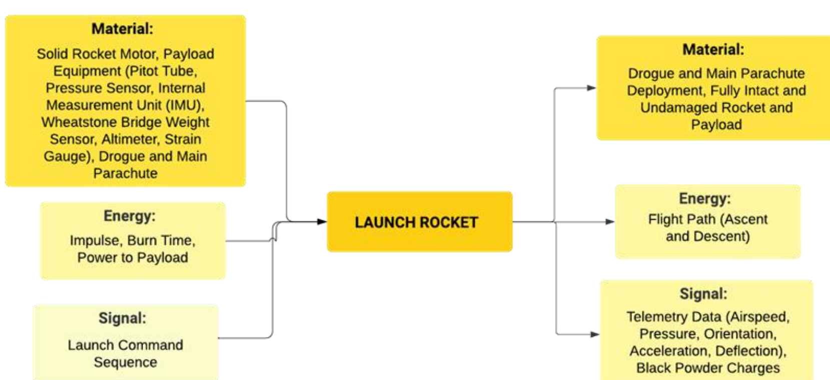


Figure 3: Black Box Model

A black box model for the rocket was also generated seen in Figure 3 above. A black box model is a tool that allows for the complex understanding and analysis needed to achieve a projects goal, specifically launching a rocket for this competition, to be broken down and simplified by looking only at inputs and outputs. The left side of the chart represents the material, energy, and signal inputs required to launch the rocket and the resulting material, energy, and signal outputs are seen on the left side of the chart below.

4.2 Material Selection

Below contain Figures 4, 5 & 6 for the team's material selection. The team was deciding between cardboard, fiberglass, and carbon fiber.

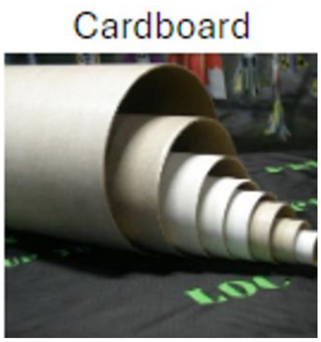


Figure 4: Cardboard Tubes [7]

Figure 5: Fiberglass Tubes [8]

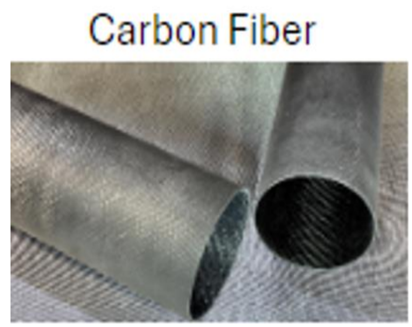


Figure 6: Carbon Fiber Tubes [9]

Table 4: Specification Sheet of Rocket Frame Materials [7-9]

Airframe Material	Diameter	Waterproof	Weight	Length	Price
Cardboard	4"	No	7.8oz	34"	$17.77
Fiberglass	4"	Yes	60.40oz	60"	$182
Carbon Fiber	4"	Yes	40.5 oz	60"	$343

Above is Table 4 which entails the specifications for the rocket frame materials to be considered by the team. Through analysis, the team eliminated cardboard as an option, because of prior experience using cardboard as a rocket frame. Cardboard is not waterproof and during last year's competition, the wind swayed the rocket towards the lake, causing irreparable damage to the rocket. This year, to avoid damage to the rocket frame or its sensors, the team plans on using either fiberglass or carbon fiber. Fiberglass will most likely be the rocket airframe material based on the price and the accessibility of it. Carbon Fiber would be the ideal rocket frame material, due to its durability and properties related to aerodynamics. The team looks to reach out to NovaKinetics AeroSystems, an aircraft manufacturer, that is local to Flagstaff and can donate the team materials for free or discounted.

4.3 Nose Cone Selection

Below in Figure 7 the potential nose cone designs being considered can be seen alongside the specifications for the nose cones performance, Figure 8, and a specification table displaying qualities of potential nose cones found online, Table 5.

Figure 7: Possible Nose Cone Designs [10]

Nose Shape	Wing Speed (mph)	Temperature (F)	Drag Force (g)
Parabolic	39.28	72.0	4.477
Ogive	39.28	72.0	4.942
Long Elliptical	39.27	72.0	4.149

Figure 8: Specifications for Nose Cone Performance [11]

The top three nose cone designs based on their induced drag force at subsonic speeds were determined to be the ellipse, ogive, and parabolic shapes [11]. Looking at Figure 8 above it is clear that the long elliptical shape performs the best followed by the parabolic shape and finally the ogive shaped nose cone. Ideally, the long elliptical or parabolic nose cones would be selected for our final nose cone design but we plan on purchasing our nose cones and after searching online only the ogive nose cone is feasible to procure for this competition.

Table 5: Specification Table for Possible Nose Cones [12-14]

Nose	Material	Diameter	Tip	Weight	Length	Shape	Drag	Price
4" Fiberglass Filament Wound	Fiberglass	4"	Aluminum Tip	1lb. 5 oz.	6-6.5"	Long Ogive	4.942g	$97
4" Plastic Ogive Nose Cone	Plastic	4"	N/A	8.19oz	19.8"	Long Ogive	4.942g	$25.99
4" Fiberglass Standard Wall	Fiberglass	4"	N/A	9.8oz	16 1/2"	Long Ogive	4.942g	$49.30

In Table 5 above three potential ogive nose cones are accumulated into a specification sheet for easy comparison and ultimately a final decision. Analyzing the specification sheet, we determined that the plastic long ogive nose cone priced at $25.99 [13] will be the nose cone we purchase and use moving forward. Since it is plastic, it is cheaper than the fiber glass options and weighs less, these are both factors that will help achieve better flight performance while bringing in little to no drawbacks.

4.4 Fin Selection

Fin selection will be one of the final decisions made for the design of the rocket. Fin shape and size are directly related to the location of the rocket's center of pressure, changing either value will move the rocket's center of pressure. As described in the competition rule book our rocket must have a stability margin of 1-3, this is described as the distance between a rocket's center of gravity and center of pressure with respect to the rocket's diameter. We have decided that to successfully fulfill the competition requirement of having a stability margin between 1 and 3, determining the fin shape and size last would be best as it will allow us to easily manipulate the rocket's center of pressure to ensure the stability margin is between 1 and 3. Therefore, no selection has currently been made for the fin but the fin designs we will be testing and prototyping can be seen below in Figure 9.

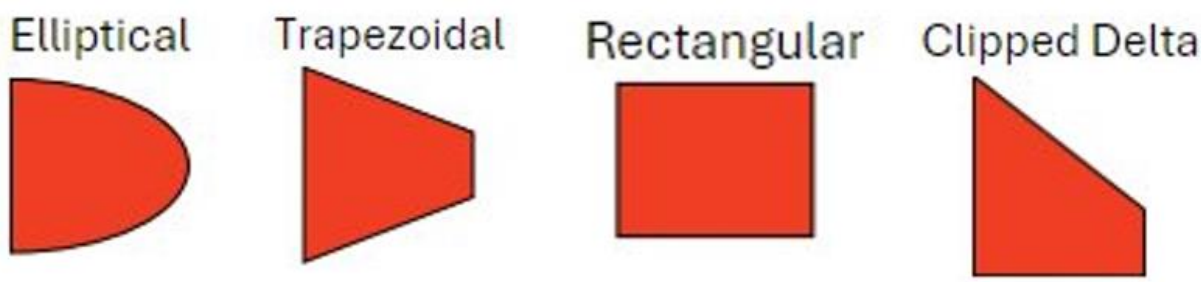


Figure 9: Possible Nose Cone Designs

4.5 Construction Methods

Table 5: Description of Construction Methods

Fins	Fin profile will be exported from the RockSim software in an STL file to be converted in a file that can be used by the university's laser cutter. This method ensures accurate parts production and requires only for the team to submit a work request to the IDEA lab.
Bulkhead	The bulkhead profile will be exported from the RockSim software in an STL file to be

	converted in a file that can be used by the university's laser cutter. This method ensures accurate parts production and requires only for the team to submit a work request to the IDEA lab.
Avionics Sled	The avionics sled will be 3D printed from PLA material offered through the IDEA at the university. This will allow us to print channels for wire management and compartments dedicated to batteries, microcontrollers, and other components for the avionics bay.
Rocket	The launch vehicle will be constructed from COTS materials such as filament wound fiberglass. All components will be sanded down for fitment and ease of separation during flight from ejection charges. We will have the assistance of member from the universities rocket club during construction.

4.6 Technical Requirement Identification and Correlation

To assist the NAU 2025 Space Jacks in identifying and satisfying technical requirements a Quality Function Deployment (QFD) was utilized. The QFD is effective in identifying the most important customer needs to ensure their satisfaction and all their requirements are achieved or exceeded. Generally, a QFD is used to translate general customer requirements or needs into specific quantifiable engineering requirements. Our customer for this competition, the Wisconsin Space Grant Consortium, provided quantifiable engineering requirements for the 2025 First Nations Launch Mars Challenge in the competition rulebook. Due to this we worked backwards from the general QFD structure and converted the engineering requirements provided into general customer requirements. This allowed us to not only understand the specific tasks and goals assigned to us but also helped us see the bigger picture and overall goals of the customer. The different sections of the QFD will be broken up and explained below. To see the full image of the QFD see the Appendix located at the end of the document.

4.7 Correlation of Customer and Engineering Requirements

Figure 10 below shows the correlation between the customer requirements we generated to the technical engineering requirements provided by the Wisconsin Space Grant Consortium. The customer requirements are listed horizontally on the left side of the image, while the technical engineering requirements are listed vertically on the top of the image. Speaking with Carson Pete, our Faculty Advisor, who has many years of experience in this competition and consulting the 2025 competition rule book we were able to assign each of the customer requirements a weight, located directly to the right of the customer requirements. The weights associated with the customer requirements are on a scale of 1-5 with a 1 meaning of very little importance to the customer and a 5 meaning crucial to the customer. Located in the main section of the QFD the correlation between the customer requirements and engineering requirements are weighted. Similarly, to the customer weights the correlation between the two requirements are weighed on a 1-5 scale with a 1 meaning little to no correlation, a 5 meaning direct correlation, and no value meaning absolutely no correlation. The technical engineering requirements were then assigned a technical requirement goal using the quantifiable values assigned in the competition rule book where applicable. Absolute technical importance was calculated for each technical engineering requirement by multiplying the customer weight of each customer requirement by the corresponding correlation of the relationship between that requirement and each technical engineering, and then summing these values for each technical engineering requirement. The inertial measurement unit, strain gauge, pressure sensor, pitot tube, and load weight cell all ended with an absolute technical importance of 118. This means that they are the most important engineering requirements in meeting the customer’s needs, this makes sense as the main goal of this year’s challenge is to collect in-flight data using the five sensors listed previously. Finally, the relative technical importance was calculated by dividing the absolute technical importance of each technical engineering requirement by the total absolute importance of all technical engineering requirements. The relative technical importance is provided in a percentage to show each engineering requirement's importance proportionally on a 100% scale. Once again, the sensors ranked the highest with a value of 8.93% for each, meaning that we will prioritize the sensors to adequately satisfy the customer's needs.

Customer Needs per Competition Rules	Customer Weights	Airframe Diameter	Budget	Drogue Parachute Descent Rate	Touchdown Descent Rate	Apogee	Stability Margin	Young's Modulus (Filament Wound Fiberglass)	Black Powder Charges	IMU	Strain Gauge	Pressure Sensor	Pitot-Static Tube/ Pressure Tranducer	Load Weight Cell	Rail Exit Velocity	Thrust to Weight Ratio
		Technical Requirements														
Follow Launch Saftey Protocols	5		4	4	5	1	5	3	4	5	5	5	5	5	4	3
Rocket cannot exceed budget	4	3	5	1	1	2	2	4	2	5	5	5	5	5		
Rocket must have payload sensors	5	2	5	2	2	2	3			5	5	5	5	5	2	
Rocket needs to have a recovery system	4	2	3	5	5	3	1		5	3	3	3	3	3		
Rocket needs to reach a targeted altitude	4	4	2			5	5	4		5	5	5	5	5	3	4
Rocket will be Aesthetically Appealing (No strange shapes)	3	4	1				3									
Rocket's flight must be stable	4	3	2	3	3	5	5			3	3	3	3	3	4	5
Rockets needs to be durabale for relaunch	2		3	3	3	2	3	4	3	2	2	2	2	2	2	1
Technical Requirement Units		in.	$	ft/s	ft/s	ft.	N/A	kPSI	g	N/A	in.	PSI	ft/s	ft/s^2	ft/s	lbs.
Technical Requirement Targets		4	1500	45-65	15-20	3200-4000	1-3	11,800	1-3	N/A	N/A	N/A	N/A	N/A	52	5:1
Absolute Technical Importance		70	102	72	77	79	107	55	54	118	118	118	118	118	62	53
Relative Technical Importance (%)		5.30	7.72	5.45	5.83	5.98	8.10	4.16	4.09	8.93	8.93	8.93	8.93	8.93	4.69	4.01

Figure 10: Main Body of QFD

4.8 Correlation Between Engineering Requirements

The roof or correlation matrix of the is located at the top of the and can be seen in Figure 11 below. This section of the QFD helps identify correlations between technical engineering requirements, allowing interactions between them to be identified. This ensures that we understand how adjusting some requirements may affect others, which will help us optimize our design to better fulfill the customers' requirements.

Airframe Diameter															
Budget	3														
Drogue Parachute Descent Rate	3	1													
Touchdown Descent Rate	3	1	4												
Apogee	5	2	3	3											
Stability Margin	4	2	3	3	5										
Young's Modulus (Filament Wound Fiberglass)	2	4													
Black Powder Charges	3	2	5	5											
IMU	2	4			2	3	1		3						
Strain Gauge	2	4					1	4	3						
Pressure Sensor	2	4					1		3						
Pitot-Static Tube/ Pressure Tranducer	2	4					1		3						
Load Weight Cell	2	4	4	4			1		3						
Rail Exit Velocity	3		2	2	4	4			4					5	
Thrust to Weight Ratio	4		2	2	5	5			4					4	

Figure 11: Correlation Matrix of QFD

4.9 **Benchmarking**

Benchmarking is located on the right side of the QFD titled Customer Opinion Survey, see Figure 12 below, and is its final section. The purpose of benchmarking is to compare competitors or other products within the same design space to identify potential areas of improvement and industry standard procedures or practices that can be used to improve our product to satisfy the customer's technical engineering needs. Benchmarking can consist of full designs, sub-systems, or components that are used for a similar application. Figures 12, 13, and 14 below are the designs we are using as benchmarks, they include the NAU Space Jacks 2023 Mars Challenge Rocket, an AVA flight controller, and NASA's Orion program.

Figure 12: 2023 NAU Space Jacks Mars Challenge Rocket (Design A for the QFD Benchmarking)

The NAU Space Jacks 2023 Mars Challenge Rocket, Figure 12 above, was selected as it had similar constraints to the 2025 Mars Challenge this year, the rocket had a 4-inch diameter and was made of carbon fiber and fiberglass with assistance from Novakinetics Aerosystems, a local aerospace company in Flagstaff, Arizona. As discussed previously we are currently working on acquiring assistance and material from Novakinetics Aerosystems and aim to have a 4-inch diameter rocket this year, making this an excellent comparison.

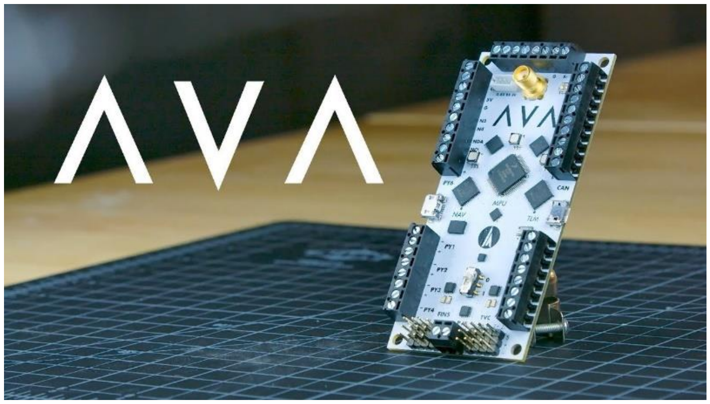


Figure 13: AVA Flight Computer (Design B for the QFD Benchmarking) [16]

Figure 13 above shows a flight computer named All Vehicle Avionics (AVA) which was created by Joe Barnard at BPS Space. Joe Barnard is an avid high powered rocketry enthusiast, who has been manufacturing all rocket components since 2017. We chose to benchmark against the AVA system as the flight computer was created by a small team from their own research and testing. Features within the flight computer is that it has a global positioning system (GPS), utilizes two inertial measurement units (IMUs), integrated the TE MS5711 to measure barometric sensor, and implements the Rohm KX134 High-G Accelerometer. Although our payload will incorporate different sensors such as load cell and pitot tube, our team will ensure that all sensors are compatible with the microcontroller.

Figure 14: Swarm Communications with their Sub-Payload [17]

In Figure 14 above, the Swarm Communications team at NASA showcases their Sub-Payload, which can be deployed using either a spring or rocket ejection mechanism. We selected this project because NASA represents the cutting edge of flight computer design. While we recognize that we may not achieve the same level of performance, we are excited to learn from their advancements.

Customer Opinion Survey				
1 Poor	2	3 Acceptable	4	5 Excellent
			A	BC
C	B	A		
A			B	C
			A	C
		A		C
				A
		A		
			A	BC

Figure 15: Customer Opinion Survey for QFD

4.10 Satisfying Technical Requirements

Below the current 2025 NAU Space Jacks rockets are analyzed on their ability to satisfy the engineering technical requirements listed above in Figure 15.

4.10.1 Recovery System Design

The parachutes were not part of the initial concept generation and evaluation as the 2025 NAU Space Jacks have parachutes from previous years challenges. Below the specification tables and analysis of the parachutes we have in stock can be found that prove the applicability of these parachutes for this year's challenge. Per the 2025 First Nation's Launch Rulebook the parachutes must be flameproof and achieve a descent rate of 45-65 ft/s and 15-20 ft/s for the drogue and main parachutes respectively. The general equation for the descent rate for a parachute can be seen in the equation below.

$$v_{Descent} = \sqrt{\frac{8mg}{\pi \rho C_d D^2}} \quad (1)$$

4.10.2 Drogue Parachute

The drogue parachute that the team is currently considering, is a parachute which we have in stock from previous FNL competitions. The parachute is 30 in Rocketman High Performance Parachute. The specifications Table 6 is located below where we measure the quality of our existing parachute. Using simulation software, RockSim, the descent rate outputted from the drogue parachute release was calculated. For the competition we need an estimated range of 45 to 60 $\frac{ft}{s}$ for the descent rate deceleration. However, through the simulation we estimated the parachute to only output a descent rate of 43$\frac{ft}{s}$. This is not within the designated range for the competition. Nevertheless, it is expected that the mass of the rocket will increase, as a result of variation in component weights and trivial additions to the rocket. Increasing the mass of the rocket will have directly proportional relationship to value of the descent rate for the drogue parachute. Refer to Figure 17 below for the simulation used.

Table 6: 30-in Parachute Performance

Drogue Parachute	Volume	Weight	Coefficient of Drag	# of Gores	Spill Hole Diameter	Price
30in Rocketman High Performance Parachute	10.5 in^3	3.9 oz	2.2	8	5.28"	$90

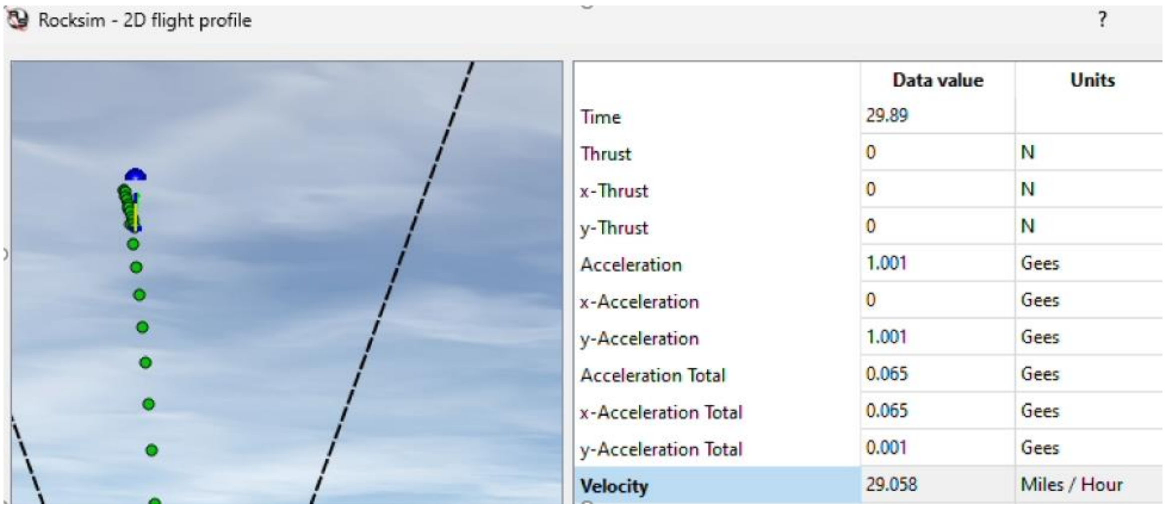


Figure 17: RockSim Simulation of Drogue Parachute

4.10.3 Main Parachute

The main parachute we currently have in storage is the 72in Rocketman High Performance Parachute, its specifications can be seen in Table 7 below. Using RockSim we were able to determine the descent rate achieved by the main parachute assuming conditions similar to those in Kenosha, Wisconsin and using the rocket seen in Figure 18, with a weight of approximately 15.5 lbs. With these variables in place in the image below it can be seen that a descent rate of approximately 11 mph (16 ft/s) was achieved, see Figure 18 below, which falls just within the 15-20 ft/s range required by the competition rules. Therefore, we will be moving forward with the 30in Rocketman High Performance Parachute for our main parachute. As discussed above it's expected that the rocket will gain some additional mass, but it's estimated that the main parachute will still allow us to reach the targeted touchdown descent rate of 15-20 ft/s.

Table 7: 72-inch Parachute Performance

Main Parachute	Volume	Weight	Coefficient of Drag	# of Gores	Spill Hole Diameter	Price
72in Rocketman High Performance Parachute	63 in^3	12.6 oz	2.2	12	12.67"	$170

Figure 18: RockSim Simulation of Main Parachute Descent Rate

4.10.4 Motor Selection

Per the competition handbook, this year's competition gave the choice between two motors to select from. Below are Figures 19 & 20 that analyze the differences between each motor, along with specification Table 8 to aid the team in their decision making.

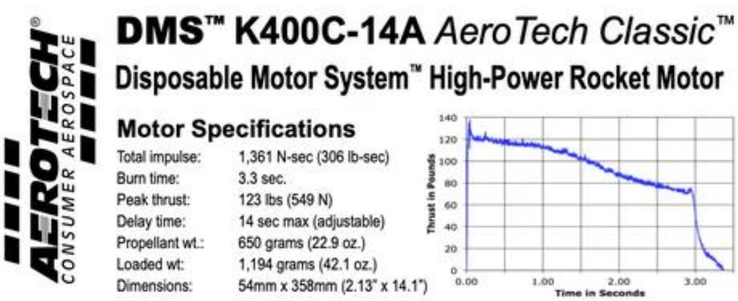


Figure 19: K400C Motor Performance Specifications [4]

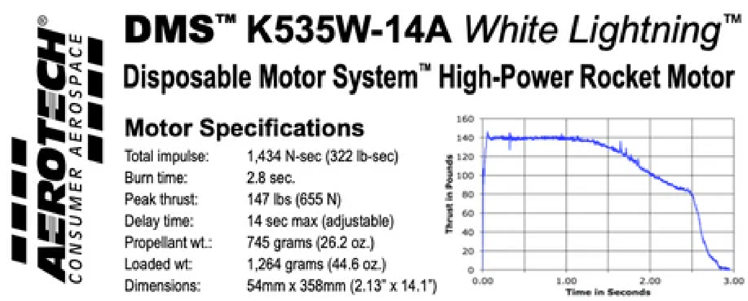


Figure 20: K535W Motor Performance Specifications [4]

Table 8: Specifications of K400C and K535W Motor Performances [3,4]

Motor Specs	Total Impulse	Burn Time	Peak Thrust	Delay Time	Propellant wt.	Loaded wt.	Price
K400C	306 lb-sec	3.3s	123lbs	14 sec max	650g	1,194g	$192.99
K535W	322 lb-sec	2.8s	147lbs	14 sec max	745g	1,264g	$192.99

After further analysis, the differences between motor K400C and K535W are slight. The propellant weight of the K535W is 745 grams, while the K400C has a propellant weight of 650 grams. Therefore, the K535W would produce more thrust and acceleration. The more propellant weight also helps with the mass ratio and flight efficiency. The weight is compared to be 1,194 grams for the K400C and 1,264 grams for the K535W. The team is looking more towards purchasing the K535W with further analysis and practicing simulation creation with RockSim simulation.

4.10.5 Simulation

The simulation was completed using the RockSim software from Apogee Rockets. The team decided to use the measurement provided from Madcow Rocketry to construct the airframes from the filament wound fiberglass tubing. Once procurement of the tubing is made the model will be updated to reflect measured weight and center of gravity for each component. A launch lug will be added to future model to reflect the pitot tube much like the launch lug used to represent the fin defection sensor shield so that the drag can be simulated.

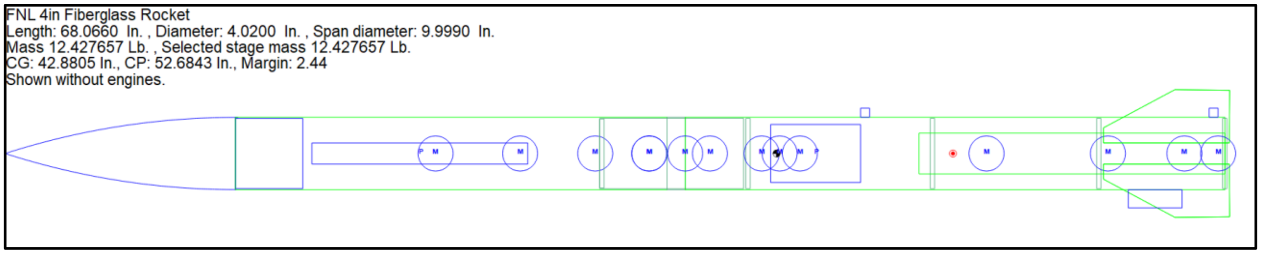


Figure 21 NAU SpaceJacks 4 inch RockSim Model

The team plans on adding additional weight to secure the various sensors for the challenge. The current performance analysis done through RockSim shows that currently both motors are exceeding the targeted apogee with K400C being the motor that closely algins to the target apogee.

Table 9 NAU SpaceJacks Simulation Performance Analysis

Simulation	Results	Engines loaded	Optimal delay	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Velocity at deployment Feet / Sec	Velocity at launch guide departure Feet / Sec	Launch static margin
43		[K535W-14]	14.74	5320.51	671.96	313.72	42.42	78.03	1.15
44		[K535W-14]	14.80	5342.91	672.25	313.72	33.20	78.03	1.15
45		[K535W-14]	14.64	5234.25	666.69	311.97	28.06	77.97	1.22
46		[K400C-14]	13.71	4592.55	585.05	264.54	21.60	71.14	1.26
47		[K400C-14]	13.45	4375.56	560.28	252.61	26.79	69.42	1.37
48		[K400C-14]	12.98	4023.59	521.93	234.47	38.80	66.90	1.52
49		[K535W-14]	14.06	4662.57	596.68	277.41	19.25	73.32	1.48
50		[K535W-14]	13.97	4593.54	588.80	273.58	19.40	72.97	1.60

4.11 Sensor Selection

4.11.1 Pitot Tubes

A pitot tube is a device that measures fluid flow. Specifically for this challenge we have decided a static pitot is the most applicable, it measures total pressure through the tip and static pressure

Figure 22: Static Pitot Tube (Foxtechfpv) [19]

Figure 23: Static Pitot Tube (3dr) [20]

through the holes placed on the sides. This allows dynamic pressure to be calculated and airspeed to be determined which is required per the competition handbook [2].

Table 9: Specification Sheet for Static Pitot Tubes [19,20]

Static Pitot Tube	Weight	Price
foxtechfpv	22 g	$28.90
3dr	3.15 g	$29.90

In Figure 21 & 22 the team analyzed two different types of pitot tubes. After discussions with engineering faculty, we deemed the that a static type pitot tube would work best to calculate dynamic pressure and to find airspeed. The specification Table 9 compared the price and the weight of each pitot tube, because those are the determinants for the final decision. The team needs to keep track of weight and pricing to maintain control.

4.11.2 Pressure Transducer

A pressure transducer is a device that converts pressures from liquids or gases and converts it into an electric signal. This device will be attached to the pitot tube to allow for air speed to be determined

Figure 23: SM6331 [21]

Figure 24: SM5391 [22]

Figure 25: SM7391 [23]

Table 10: Specification Table for Pressure Transducers [21-23]

Pressure Transducer	Pressure Range	Pressure Type	Bit	Total Error	Operating Temp Range (C)	Voltage Range	Price
SM6331	0 to 4.5 PSI	Differential	16 bit	+/-1% digital	-20 to 85	0-3V	$20.16
SM5391	0 to 12 PSI	Differential	16 bit	+/-1% digital	-40 to 105	3.3 - 5V	$19.38
SM7391	0 to 1.5 PSI	Differential	16 bit	+/-1% digital	-20 to 85	0-3V	$20.93

Pressure Transducer is a necessary component if we want to use a static pitot tube to calculate the dynamic pressure. Comparing the options through online research we found three different pressure transducers that would work with our static pitot tubes above. We used the specification Table 10 above to represent the comparison for analysis. The pressure transducers that we were looking into were of differential pressure type. The SM5391 is a possible final pressure transducer because of the range capabilities it holds for pressure and operating temperature.

4.11.3 Pressure Sensor

A pressure sensor is a device that measures pressure, specifically for this challenge it will measure the pressure inside the rocket's avionics bay.

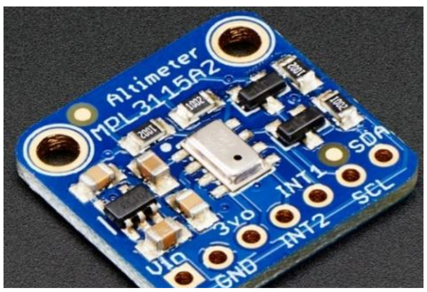


Figure 26: Adafruit MPL3115A2 Pressure Sensor [24]

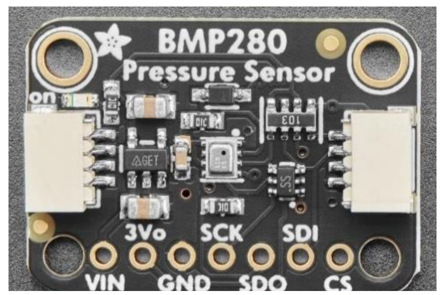


Figure 27: Adafruit MPL3115A2 Pressure Sensor [25]]]

Table 11: Specification Table for Pressure Sensor [24,25]

Pressure Sensor	Pressure Range	Footprint	Voltage Supply	Price
MPL3115A2-I2C	50-110kPa	18mm x 19mm	3 - 5.5V	$9.95
BMP280 I2C	30-110kPa	2 x 2.5 mm^2	3.3 - 5.5V	$9.95

Pressure Sensors were compared in specification Table 11 listed above. We were specifically looking at the pressure range and voltage supply to understand the capability of how well it can collect data for the rocket

4.11.4 Inertial Measurement Units

Inertial Measurements Units (IMU's) are devices used to capture orientation data. The IMU's for this competition must be able to detect 9 degrees of freedom per the competition rules [2]. This means that they must have a built-in gyroscope, magnetometer, and accelerometer.

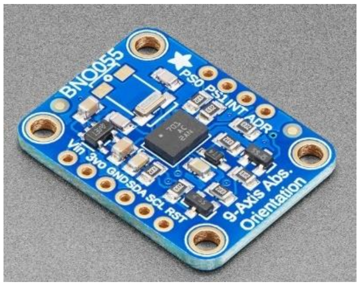


Figure 26: Fusion Breakout IMU [26]

Figure 27: ICM-20948 IMU [27]

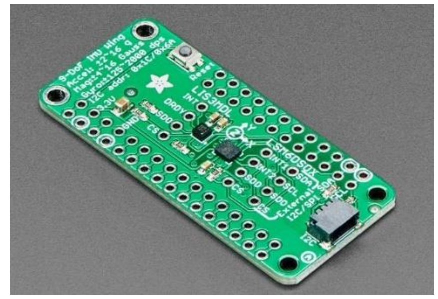


Figure 28: Adafruit Featherwing IMU [28]

The figures and tables above show the Inertial Measurement Units the NAU 2025 Space Jacks are currently considering. The team looked for the gyroscope, acceleration and voltage range for defining the steps for selection and purchasing.

Table 12: Specification Table for Inertial Measurement Units [26-28]

IMU	DOF	Ease of Use	Acceleration Range	Gyroscope Range	Magnometer Range	Footprint	Voltage Supply	Price
Fusion Breakout - BNO055	9	High	+/- 2 - 16g	+/- 125-2500 deg/s	+/- 1300 µT; +/- 2500 µT	3.8 x 5.2 mm^2	2.4 - 3.6V	$35
ICM-20948	9	Average	+/- 2 - 16g	+/- 250-2000deg/s	+/- 4900 µT	3 x 3 mm^2	1.71 - 3.6V	$7.88
LSM6DSOX + LIS3MDL FeatherWing	9	Average	+/- 2 - 16g	+/- 125-2000deg/s	+/- 1600 µT	N/A	N/A	$19.95

4.11.5 Load Cell Weight Sensor

A load cell weight sensor is a transducer that converts a mechanical force, typically weight or pressure, into an electrical sensor. This enables precise measurements of induced loads for testing equipment. For the integration into the rocket, our team will measure the increase and decrease in weight of a unit mass to determine acceleration during any point of the flight.

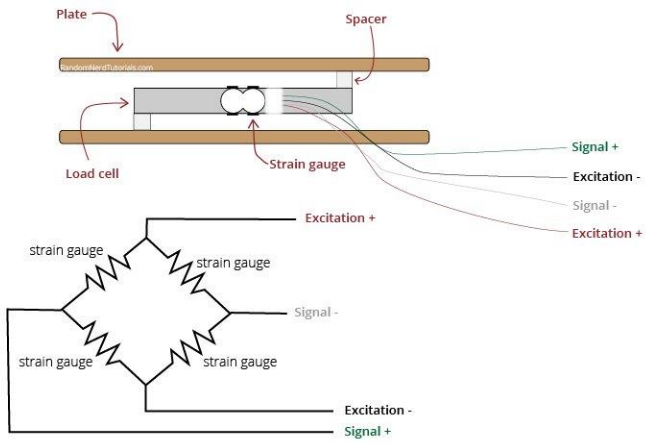


Figure 29: Diagram of Load Cell Weight Sensor System [29]

The team will consider the application of the load cell, and the tolerancing available from industry standard and manufactured load cells to ensure that the tolerance of the instrument is consistent with the application and forces of our rocket. Additionally, amplifiers will have to be considered due to the tolerance and signal output of our load cell. From preliminary research into the concepts, our team is considering the following instruments.

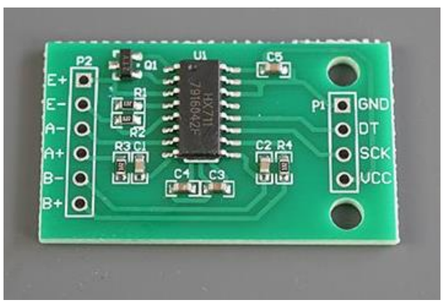


Figure 30: HX711 Amplifier [29]

Figure 31: Adafruit HX711 [30]

Additional research will be conducted on the applications and tolerancing of these instruments and will further the development of the design for these schematics, along with integration into our payload challenge. The parameters the team will consider consist of the measurements including change in resistance, electric signal, signal processing and data storage for compression, tension, shear, and bending deflections.

4.11.6 Strain Gauge

A strain gauge is a device used to measure the amount of deflection in an object. Specifically, for this competition a strain gauge will measure the deflection in one of the rocket's wings.

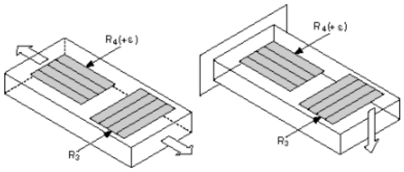


Figure ~~29:~~32: Quarter Bridge Strain Gauge [20]

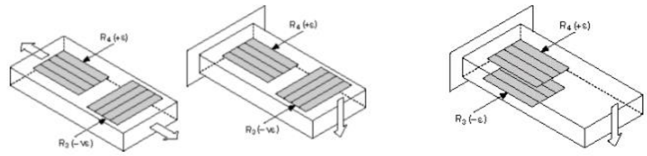


Figure 33: Half Bridge Strain Gauge [20]

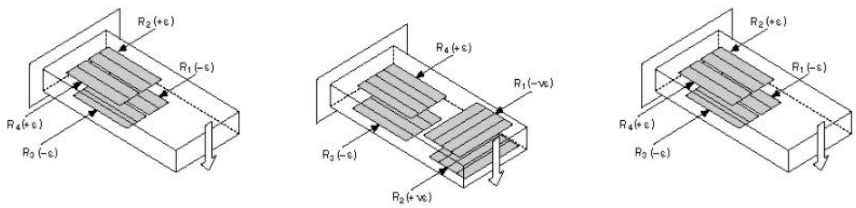


Figure 34: Full Bridge Strain Gauge [20]

Table 12: Specification Table for Strain Gauges [20]

Measurement Type	**Quarter Bridge**		**Half-Bridge**		**Full-Bridge**		
	Type I	Type II	Type I	Type II	Type I	Type II	Type III
Axial Strain	Yes	Yes	Yes	No	No	No	Yes
Bending Strain	Yes	Yes	Yes	Yes	Yes	Yes	No
Compensation							
Transverse Sensitivity	No	No	Yes	No	No	Yes	Yes
Temperature	No	Yes	Yes	Yes	Yes	Yes	Yes
Sensitivity							
Sensitivity at 1000 με	~0.5 mV/V	~0.5 mV/V	~0.65 mV/V	~1.0 mV/V	~2.0 mV/V	~1.3 mV/V	~1.3 mV/V
Installation							
Number of Bonded Gages	1	1*	2	2	4	4	4

Strain gauges come in three main bridge configurations, the quarter bridge, half bridge, and full bridge, this simply describes the number of bonded gauges used with a quarter bridge having one, a half bridge having two, and a full bridge having three. Within these configurations there are also different types affecting the placement of the strain gauges which also changes the sensitivity of the gauges. Each configuration consists of advantages and disadvantages as listed in the specification table above. The requirement for this competition is for the strain gauges to measure the bending strain of the rocket's fins, therefore the Type III full bridge configuration is eliminated. At the current moment we as a team have determined the Type II half bridge configuration to be the best choice. This design will consist of two bonded gauges placed on either side of the fin to achieve a higher sensitivity while keeping the complexity and cost associated with the strain gauges down.

4.12 Microcontroller

The team anticipates utilizing an Arduino microcontroller to be able to incorporate all 5 sensors into a coherent system. Our team realizes that we will need to begin prototyping with our sensors and microcontroller to ensure that the sample rate is sufficient for the flight profile, and is able to store all data onto an SD Card that we would then be able to analyze.

Through our testing, we will determine if we need to upgrade to alternative microcontrollers such as the Raspberry PI system, but would have to ensure that all sensors are compatible with the new operating system.

4.13 Location of Sensors

Currently the 2025 NAU Space Jacks plan on utilizing 3 flight computers spread out across the rocket. The pitot tube, pressure transducer, and its flight computer will be placed on the nose cone as it will allow for a more accurate pressure reading as it's able to more easily puncture the boundary layer that forms around the rocket's body during flight and reach clean laminar air. The pressure sensor, inertial measurement unit, load cell weight sensor, altimeter, and associated flight computer will be located within the avionics bay found near the center of the rocket final assembly. The strain gauge and associated flight computer will be located on the outside of the rockets frame near the fins covered by aerodynamic shaped G-10 Fiberglass material to decrease the amount of drag added to the rocket and protect the sensors and computer. Placing the strain gauge flight computer inside the rocket near the motor was considered. It was determined that the black powder charges and delayed explosion that occur within the motor would create enough pressure to damage the components therefore they will be placed on the outside of the rocket's body.

4.14 Challenge Requirements and Outcomes

Preliminary CAD of the launch vehicle has been created for visualization of the integration of the sensors and avionics bay. These documents will be updated moving forward with any additional information such as specific sensors, flight computers, centering rings, bulkheads, additional couplers etc. The general launch vehicle along with projections of specific components such as the rocket motor housing for the 54 mm K535W Aerotech motor, avionics sled for sensors and flight computers, and cross-sectional view of the internal design are included below.

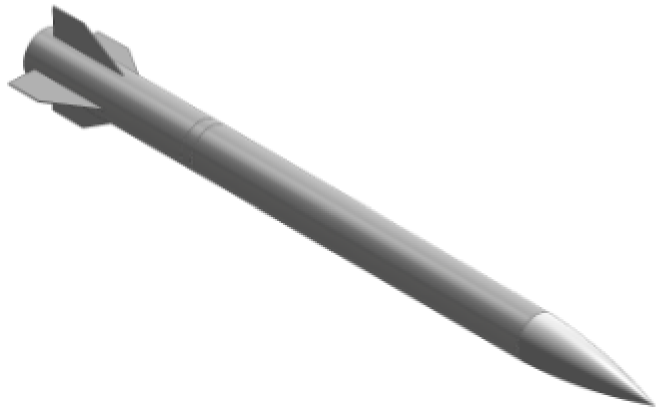


Figure 35: Isometric View of Preliminary Rocket

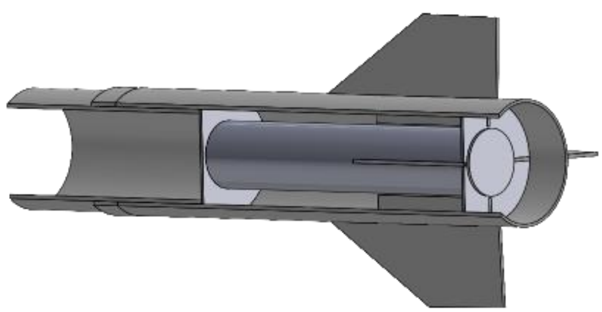


Figure 36: Rocket Motor Housing Preliminary Design

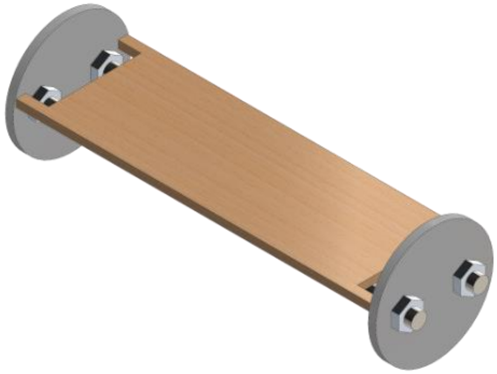


Figure 37: Avionics Sled for Flight Computers and Sensors

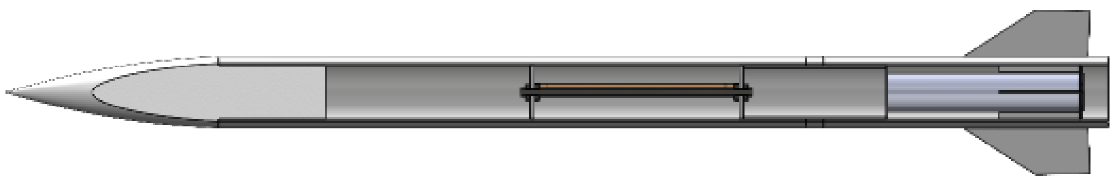


Figure 38: Section View of Preliminary Rocket

4.15 Technical Challenges and Concerns

The major technical challenges come from the integration of the sensors, and how the team will incorporate them into the avionics bay, or other feasible locations. The first consideration the team would have to make was the diameter of the rocket that we would choose to develop and progress on with the competition. While very early in the design process, the team would choose to progress with a four-inch diameter rocket frame that enables our team to work with less drag produced from surface area, less mass, and more affordable given the budget for the project.

The next technical challenge, and major concern for the team would be the integration of our 5 sensors into the frame of the rocket. With the new challenge of implementing sensors to monitor and analyze flight data such as acceleration, telemetry, forces, and deflection, our team needs to decide where we should house these sensors, what instruments we should utilize to gather the best data from sampling rate, storage and processing capabilities, and sensitivity to these changes. Additionally, we must consider the additional weight these sensors will induce, with more power sources in addition to the ones that power the industry standard sensors in the avionics bay.

Specifically with the strain gage, our team is considering the challenge of measuring the bending deflection of the fins. The main considerations are which fins should we measure, meaning should we add additional fins closer to the middle section of our rocket with the avionics bay, or design a housing either externally on the fins or internal rocket frame to measure the fins on the aft end. Because the rocket will be dual deployment, our team cannot extend wires from the middle section to the aft end because of the length of our shock cords being above 30ft, and the heat produced from the motor, and pressure induced from the black powder charges could destroy our sensors if in proximity to the strain gages. The team will begin to perform analysis in RockSim and SolidWorks FEA to analyze our options of external sensors on the frame and internal inside the aft end to evaluate the best design for the team's needs.

Our team will also be finding solutions to the testing of our rocket at full scale, without requiring the purchasing of additional motors. These will include utilizing the laboratories on campus that include tensile and compressional testing, wind tunnels with scaled down geometries determined using Reynold’s identities to mimic the same flight parameters, and FEA analysis with RockSim to better refine our designs.

5 Project Plan

For our project testing plan, we have broken up the challenge into 4 components consisting of vehicle, recovery, altimeters, and challenge components. The following sections break these testing plans down and include milestones of PDR, CDR, and FRR

5.1 Launch Vehicle Plan

The NAU SpaceJacks plan to purchase fiberglass tubing from a vendor who sells rocketry products online. In the past team members have been able to manufacture carbon fiber airframes, with support from a local composite fabrication company, but our time would be better supporting the challenge than to fabricate our own air frames. The choice to go with fiberglass come from past experiences where cardboard air frames were used and resulted in damage and complete loss of majority rocket components. The hope is that the potential for a water landing will not damage our rocket beyond recoverability. The supporting components like fins, bulkheads, and centering rings will be constructed of a similar fiberglass material that are left over from another project at the university. The nose cone will be a component that is reused from previous projects due to the cost and availability of nose cones that fit our air frame. The team understands the risk of reusing components that have undergone multiple flights. We will continue to search for a solution that does not involve reusing old components.

Table 13: Preliminary Design Testing

Preliminary Design Review		
Vehicle Component	Design	Procurement
Nose Cone	3.90" Plastic Nose Cone 16.5" Length (3.75" shoulder)	NOT ORDERED
Airframes	4" G12 Airframe	NOT ORDERED
Coupler	4" G12 Coupler (12 inch)	NOT ORDERED
Bulkhead	G10 Cut From Stock Material	NOT ORDERED
Avionics Sled	3D Printed	NOT PRINTED
Motor Tube	2.2" / 54mm G12 Motor Tube	NOT ORDERED
Centering Rings	4.5"x54mm G10 CR	NOT ORDERED
Fins	G10 Cut From Stock Material	NOT FABRICATED
U-Bolts and Nuts	Owned in Stock From Rocket Club	OWNED
Main Shock Cord	30 Feet, 2800 lbs, Braided Kevlar Cord	OWNED
Main Parachute	72in. (6ft.) Rocketman High Performance CD 2.2 Parachute	OWNED
Main Recovery Blanket	12” x 12” Chute Protector	OWNED
Quick Links	Owned in Stock From Rocket Club	OWNED
Terminal Blocks	Owned in Stock From Rocket Club	OWNED
All Thread Rods and Nuts	Owned in Stock From Rocket Club	OWNED
Batteries	Owned in Stock From Rocket Club	OWNED

Altimeter	Blue Raven Form Factor	OWNED
GPS	Featherweight GPS Tracker	OWNED
Drogue Shock Cord	20 Feet, 2800 lbs, Braided Kevlar Cord	OWNED
Drogue Parachute	36″ Parachute with 106mm spill hole. 8 lines	OWNED
Drogue Recovery Blanket	6” x 6” Chute Protector	OWNED
Motor Retainer	Owned in Stock From Rocket Club	NOT ORDERED
Rail Buttons	1515 Rail Buttons	NOT ORDERED

Table 14: Critical Design Review Testing

Critical Design Review		
Vehicle Component	Testing Plan	Tested Status
Nose Cone	Inspection of materials and construction	NOT TESTED
Airframes	TESTING MATERIAL PROPERTIES -Hoop and Shear tests	NOT TESTED
Coupler	Inspection of materials and construction	NOT TESTED
Bulkhead	Inspection of materials and construction	NOT TESTED
Avionics Sled	Inspection of materials and construction	NOT TESTED
Motor Tube	Inspection of materials and construction	NOT TESTED
Centering Rings	Inspection of materials and construction	NOT TESTED
Fins	Inspection of materials and construction	NOT TESTED
U-Bolts and Nuts	Inspection of materials and construction	NOT TESTED
Main Shock Cord	Inspection of materials and construction	NOT TESTED
Main Parachute	Inspection of materials and construction	NOT TESTED
Main Recovery Blanket	Inspection of materials and construction	NOT TESTED
Quick Links	Inspection of materials and construction	NOT TESTED

Terminal Blocks	Inspection of materials and construction	NOT TESTED
All Thread Rods and Nuts	Inspection of materials and construction	NOT TESTED
Batteries	Ground Testing / Inspection	NOT TESTED
Altimeter	Vacuum Testing and Simulations	NOT TESTED
GPS	Function Testing	NOT TESTED
Drogue Shock Cord	Inspection of materials and construction	NOT TESTED
Drogue Parachute	Inspection of materials and construction	NOT TESTED
Drogue Recovery Blanket	Inspection of materials and construction	NOT TESTED
Motor Retainer	Inspection of materials and construction	NOT TESTED
Rail Buttons	Inspection of materials and construction	NOT TESTED

For the FRR project plan, the NAU SpaceJacks plan on conducting a test launch at Eagle Eye Launch site in Arizona. The launch will test the expected performance of all sensors and flight plan of the rocket. The flight plan will closely resemble the one used in the handbook for the Mars Engineering Challenge. The launch will take place in February of 2025 and overseen by the Phoenix Tripoli Rocket Association.

5.2 Avionics Plan

The avionics components like altimeters, GPS, and redundant systems will be selected based on availability from vendors and university inventory. The Raven 4 has been the go-to altimeter for each competition launch. Prior to using the altimeter for a launch, testing occurs that determines the onboard pressure sensor is working. This is usually achieved through vacuum and simulation testing the altimeters. The GPS is tested for functionality through a walking test where the ground station is powered on and a student's walks around the surrounding area to track the GPS movement.

5.3 Recovery Plan

The recovery section of the rocket is tested using a ground testing method. The students will inspect all recovery components and pack the parachute into the fire blanket. The parachute cord will be inspected as the cord being wrapped and all components will be packed into the airframe. The avionics bay with be sealed and assembled so that the charge wires accessible from the outside of the rocket. The ground testing will allow us to determine if our recovery system is set up properly and there is enough black powder charge to deploy the recovery system. This plan will be carried out prior to any test launch.

Formula 2: Volume of an airframe – Diameter in the insider diameter and length is the unfilled length.

$$Grams(BP) = \frac{454grams}{1lbf} \times \frac{Pressure(psi) \times Volume(inches^3)}{266\frac{inches \bullet lbf}{lbm} \times 3307 \circ R}$$

Figure 39: Black Powder Formula Given Airframe Volume

5.3.1 Requirements Verification Matrix

Table 16: Contemporary Testing Matrix

Requirements	Verification	Testing Status
Airspeed Sensor	Test pitot tube in wind tunnel to determine accuracy and factor of safety	NOT COMPLETE
Pressure Sensor	Test pressure sensor in a vacuum to determine accuracy and factor of safety	NOT COMPLETE
Orientation Sensor	Test each axis of rotation to determine accuracy and factor of safety	NOT COMPLETE
Acceleration Sensor	Test load cell against lateral acceleration to determine accuracy and factor of safety	NOT COMPLETE
Deflection Sensor	Test strain gauges against known values to determine accuracy and factor of safety	NOT COMPLETE
4 in. Minimum Diameter	Measure airframes outer diameter to ensure that all fiberglass tubes are at least 4in minimum diameter	NOT COMPLETE
Apogee 3200-4000	Verify all dimensions of launch vehicle against RockSim to predict the most accurate simulated apogee	NOT COMPLETE
Altimeter	Test all functions of the altimeter and ground testing to ensure proper operation during flight	NOT COMPLETE
Static Stability Margin minimum 1.0	Use RockSim to simulate the margin of stability and adjust center of pressure or center of gravity while adhering to the standards of model rocketry and First Nations Launch competition.	NOT COMPLETE

Rail Exit Velocity minimum 52 fps	Use RockSim to simulate the rail exit velocity and determine the safest motor to use while adhering to the standards of model rocketry and First Nations Launch competition.	NOT COMPLETE
Thrust to weight ration 5:1	Use RockSim to simulate the thrust to weight ratio and determine the safest motor to use while adhering to the standards of model rocketry and First Nations Launch competition.	NOT COMPLETE
Mark Center of Pressure	Use RockSim to simulate the center of pressure mark it on the outside of the rocket prior to launch	NOT COMPLETE
Mark Center of Gravity	Use RockSim to simulate the center of pressure mark it on the outside of the rocket prior to launch	NOT COMPLETE

5.4 Gantt Chart

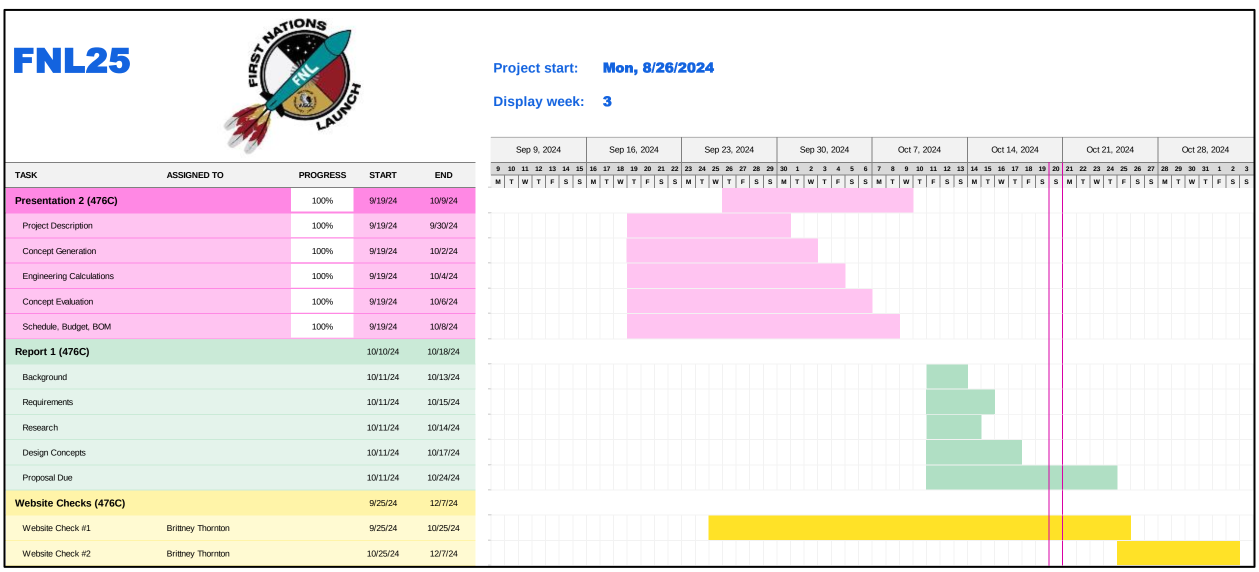


Figure 40: FNL Gantt Chart

5.5 Budget Plan

Table 17: Current Budget Plan

First Nations Launch Rocket Competition			
SpaceJacks			
Northern Arizona University			
Proposed Budget			
Component Description	Quantity	Cost Per Unit	Total
Launch Vehicle			
4" G12 Airframe	2	$145.60	$291.20
4.5"x54mm G10 CR	3	$12.00	$36.00
2.2" / 54mm G12 Motor Tube	1	$41.00	$41.00
3.90" Plastic Nose Cone 16.5" Length (3.75" shoulder)	1	$27.18	$27.18
5 Min. Epoxy 13 oz. Size	1	$30.21	$30.21
30 Min. Epoxy 13 oz. Size	1	$30.21	$30.21
Avionics			
Blue Raven Altimeter	2	$175.00	$350.00
Electronics Bay 3.9" ID x 8" Length	1	$39.59	$39.59
Featherweight GPS Tracker Full System	1	$365.00	$365.00
Single-Pole Double Throw Slide Switch	2	$5.61	$11.22
9 Volt Battery (2 Pack)	1	$8.69	$8.69
Propulsion			
Aerotech 54mm HP SU DMS Motor - K535W-14A	1	$206.50	$206.50
RMS-54/1706 Casing w/Forward Seal Disk	0	$207.70	$0.00
54mm Aft Closure	0	$64.43	$0.00
LOCPROMR54	1	$37.35	$37.35
Recovery			
Shock Cord Mounts (Motor Mount)	1	$4.43	$4.43
Fire Resistant Blanket 12"x12" for up to 4" Airframe	0	$9.96	$0.00
50″ Parachute with 140mm spill hole. 10 lines.	0	$44.25	$0.00
36″ Parachute with 106mm spill hole. 8 lines	0	$22.35	$0.00
5/8" Tubular Nylon 25' with loops sewn	0	$22.70	$0.00
3/8" Tubular Nylon 20' with loops sewn	0	$15.93	$0.00
3/16" Chain Eye Connector (QUICK LINK)	0	$2.25	$0.00

Nickel-Plated 4/0 Swivel, 400# test	0	$3.65	$0.00
Travel			
Air Fare roundtrip (as of 9/13/2024)	4	$447.00	$1,788.00
Baggage	4	$80.00	$320.00
Shipping Rocket	1	$479.83	$479.83
Rental Car	1	$360.00	$360.00
Gas (miles*($3.50 per gallon/25 miles per gallon))	398.4	$0.14	$55.78
Food ($30/day/person)	4	$30.00	$120.00
TOTAL			$4,602.19

5.6 Sustainability Plan

The NAU SpaceJacks have proposed to have this competition established as one of the capstone projects that senior mechanical engineers can enroll in. The team is currently made up of 4 core members who meet on a regular basis to discuss progress and ideas. The team has a reoccurring meeting with the faculty advisor every Thursday to discuss problems and solutions. The team is being led by a former competitor of the First Nations Launch competition and another team member also brings previous rocketry experience to the table. The team is able to attend classes and engage in meaningful participation within the competition project. The also has access to industry partners that have offered to lend their advice and experience to the group. The Tripoli Rocket Association Secretary Kevin Small serves as the group TRA mentor and has previous engagement with the student who competed last year. The students are able to assist with the rocket club’s meetings and recruitment efforts to bring in student who are new to rocketry. This helps to grow the overall student engagement to rocketry and grow the impact of the rocket club at the university. These efforts help the rocket club by gaining attention, so we shift funding and donations to the club as a whole and replenish some of the resources we use the rocket club without solely depending on the funding from the Wisconsin Space Grant Consortium. The team is in communication with other faculty at the university to help with STEM outreach projects and trying to organize a rocket building workshop for one of the surrounding primary schools.

6 Appendix

6.1 Team Members Engineering Fabrication Shop Certification Cards

Each team member has received basic training at the NAU campus machine shop meaning they understand proper PPE and procedures and can enter and work in the machine shop with basic tools.

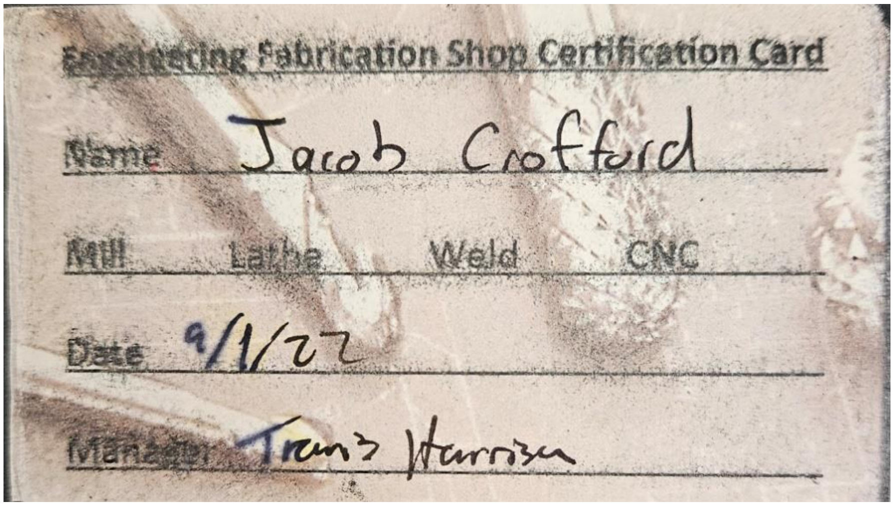


Figure 41: Jacob Crofford Machine Shop Safety Training Card

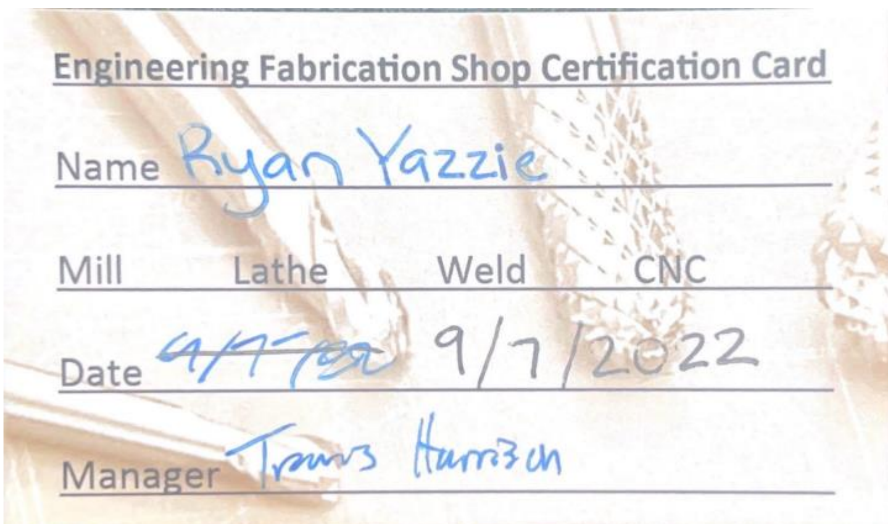


Figure 42: Ryan Yazzie Machine Shop Safety Training Card

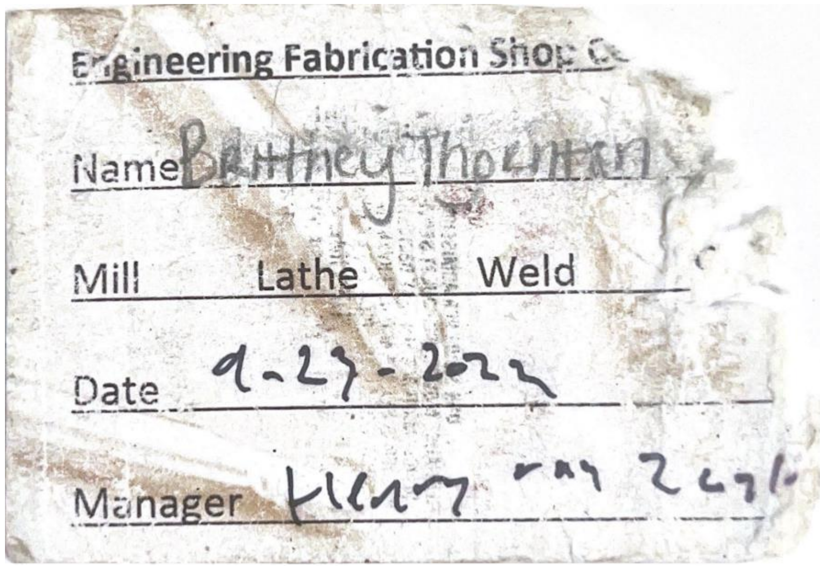


Figure 43: Brittney Thornton Machine Shop Safety Training Card

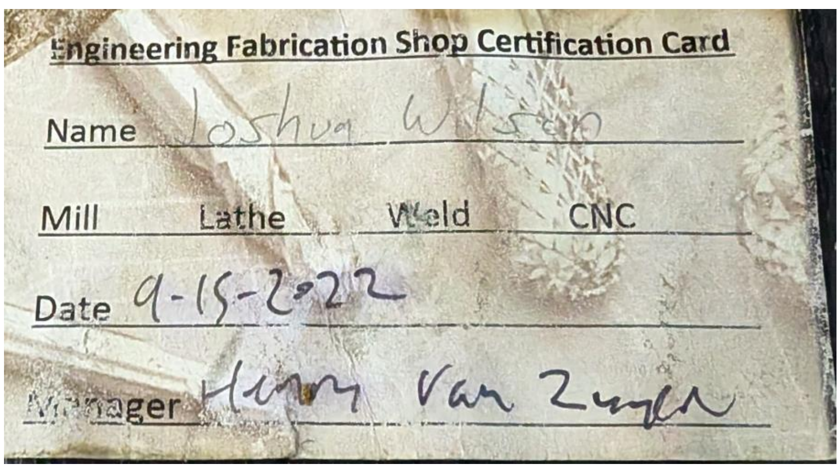


Figure 44: Joshua Wilson Machine Shop Safety Training Card

6.2 Full QFD

	Airframe Diameter	Budget	Drogue Parachute Descent Rate	Touchdown Descent Rate	Apogee	Stability Margin	Young's Modulus (Filament Wound Fiberglass)	Black Powder Charges	IMU	Strain Gauge	Pressure Sensor	Pitot-Static Tube/ Pressure Tranducer	Load Weight Cell	Rail Exit Velocity	Thrust to Weight Ratio
Airframe Diameter															
Budget	3														
Drogue Parachute Descent Rate	3	1													
Touchdown Descent Rate	3	1	4												
Apogee	5	2	3	3											
Stability Margin	4	2	3	3	5										
Young's Modulus (Filament Wound Fiberglass)	2	4													
Black Powder Charges	3	2	5	5											
IMU	2	4			2	3	1		3						
Strain Gauge	2	4					1	4	3						
Pressure Sensor	2	4					1		3						
Pitot-Static Tube/ Pressure Tranducer	2	4					1		3						
Load Weight Cell	2	4	4	4			1		3						
Rail Exit Velocity	3		2	2	4	4			4					5	
Thrust to Weight Ratio	4		2	2	5	5			4					4	

		Technical Requirements															Customer Opinion Survey				
Customer Needs per Competition Rules	Customer Weights	Airframe Diameter	Budget	Drogue Parachute Descent Rate	Touchdown Descent Rate	Apogee	Stability Margin	Young's Modulus (Filament Wound Fiberglass)	Black Powder Charges	IMU	Strain Gauge	Pressure Sensor	Pitot-Static Tube/ Pressure Tranducer	Load Weight Cell	Rail Exit Velocity	Thrust to Weight Ratio	1 Poor	2	3 Acceptable	4	5 Excellent
Follow Launch Saftey Protocols	5		4	4	5	1	5	3	4	5	5	5	5	5	4	3				A	BC
Rocket cannot exceed budget	4	3	5	1	1	2	2	4	2	5	5	5	5	5			C	B	A		
Rocket must have payload sensors	5	2	5	2	2	2	3			5	5	5	5	5	2		A			B	C
Rocket needs to have a recovery system	4	2	3	5	5	3	1		5	3	3	3	3	3						A	C
Rocket needs to reach a targeted altitude	4	4	2			5	5	4		5	5	5	5	5	3	4			A		C
Rocket will be Aesthetically Appealing (No strange shapes)	3	4	1				3														A
Rocket's flight must be stable	4	3	2	3	3	5	5			3	3	3	3	3	4	5			A		
Rockets needs to be durabale for relaunch	2		3	3	3	2	3	4	3	2	2	2	2	2	2	1				A	BC
Technical Requirement Units		in.	$	ft/s	ft/s	ft.	N/A	kPSI	g	N/A	in.	PSI	ft/s	ft/s^2	ft/s	lbs.					
Technical Requirement Targets		4	1500	45-65	15-20	3200-4000	1-3	11,500	1-3	N/A	N/A	N/A	N/A	N/A	52	5:1					
Absolute Technical Importance		70	102	72	77	79	107	55	54	115	115	115	115	115	62	53					
Relative Technical Importance (%)		5.30	7.72	5.45	5.83	5.98	8.10	4.16	4.09	8.93	8.93	8.93	8.93	8.93	4.69	4.01					

Figure 45: Full QFD

6.3 State-of-the Art Literature Reviews

The State-of-the-Art Literature Review (SOTA) allows all team members to identify useful resources for their roles in the FNL 2025 Competition.

6.3.1 Safety (Jacob Crofford)

First Nations Launch Handbook 2024-2025, Standard [2]– The 2025 First Nation's Launch Handbook highlights all important safety guidelines specific to the competition for all individuals. It also identifies some general safety guidelines from the National Fire Protection Association, Tripoli Rocketry Association, National Association of Rocketry, and Federal Aviation Administration. The 2025 Space Jacks will use this for any guidance on safety regulations and procedures to ensure no injuries occur to any team members, competitors, spectators, and ensure all local, state, and federal laws are followed.

National Association of Rocketry (NAR): High Power Rocket Safety Code, Standard [34] – The National Association of Rocketry has specific safety guidelines for high-powered rocketry, the class that the 2025 NAU Space Jacks will be competing in. All rules, procedures, and processes, required to perform a safe launch, including but not limited to acceptable materials, misfire procedures and mitigation, and pre-launch and post-launch safety. This standard will be used extensively to ensure that pre-launch checks are complete and that an acceptable and safe rocket is being flown.

Tripoli Unified Safety Code, Standard [6] – The Tripoli Rocketry Association has created a document that meets or exceeds the codes with NFPA 1127, fire prevention. This document discusses the roles and required procedures that must be followed at a launch site with safe distance tables and rules for recovery and operation provided. This standard will be used to ensure the safety of all individuals at launch sites and to mitigate the potential of fires sparked by the team's rocket.

G-10 Fiberglass Safety Data Sheet, Standard [36] – This is one of many safety data sheets (SDS) that the 2025 NAU Space Jacks will utilize. This specific data sheet is for G-10 Fiberglass the material that we plan to use for the body and fins on the 2025 First Nations Launch Rocket. This safety sheet and all other sheets describe the hazards associated with the material and procedures to safely handle the material. These documents will be reviewed for all materials used during the entirety of this competition to avoid injuries, environmental damage, and the creation of hazards such as chemical spills and fires.

6.3.2 Manufacturing (Jacob Crofford)

Manufacturing Process Selection, Book [37] – This book identifies and evaluates common manufacturing processes. It compares the manufacturing processes based on the feasibility, quality, and cost of the procedure. It also discusses a selection strategy and procedure to ensure the process you choose will be the most effective for your application. Specifically for this competition we will be looking at the joining process and rapid prototyping. Rapid prototyping will be useful to allow for small scale rockets/components to be prototyped and tested. Joining processes will be useful in ensuring all components in the rocket are held down securely by either adhesion, mechanical fastening, or any other method identified to be effective.

Effects of Manufacturing Quality on Rocket Precision, Paper [38] – This paper identifies how costly and impactful poor manufacturing quality has on the flight trajectory of a rocket. It identifies the most common mistakes made during the manufacturing process and how these mistakes affect the flight of the rocket. The most applicable mistake to this competition is motor and nose cone misalignment, as described in the paper this creates an asymmetrical rocket that has a higher normal force applied to it and a higher drag coefficient resulting in a less efficient flight. Therefore, we will be sure to utilize proper manufacturing methods and double check our work to ensure the quality of our rocket

Make High Powered Rockets, Book [39] – This book provides a step-by-step procedure from basic components to the final integration of a model rocket. It also discusses the simulation process and design selection process for high powered rocketry. This book is a great starting point for the team as it identifies all the common parts of a rocket and details their importance and role in a successful flight. It also goes over quality-of-life procedures to ensure the rocket being built is high quality, safe, and functional. The team will review this book to brush up on the uses, application, and best use of the components of the rocket with respect to the final assembly.

3D Printing Technologies, Paper [40] – This paper compares different 3D printing techniques based on print materials and application. It also discusses the material selection process to assist in selecting proper material for every application. Although not every technology found in this paper is accessible to us it provides a good baseline on which to process and material to choose for an application. This paper will be used for prototyping to test designs and to determine if 3D printed material would be worthwhile to use on the final design of our rocket.

University of Mississippi: Advanced Design and Manufacturing of High-Powered Rockets, Paper [41] – This paper is a report from the University of Mississippi which details their steps to achieve success in a similar competition to First Nations Launch 2025. The challenge highlighted in this paper was to reach an apogee of 8000 feet, and the steps to manufacture a rocket to achieve this apogee are detailed. They identify the important components used, their application, and where they are placed in the final assembly. This paper is another resource we will use once manufacturing beings to ensure we are following procedures used by previously successful teams.

6.3.3 Avionics (Brittney Thornton)

Development Steps of Avionics and Flight Control System of Flight Vehicle, Paper [42] – This paper emphasizes the role of simulation technologies, like software-in-the-loop (SILS) and hardware-in-the-loop (HILS), in developing and testing avionics systems for high-risk applications such as UAVs and rocketry. These tools allow engineers to model and evaluate avionics components, such as flight control systems, in a virtual environment before actual deployment, ensuring safer and more reliable operation. The paper also mentions the ongoing research in fields such as avionics and control systems, referencing institutions like KAIST and various companies involved in this area of study.

Introduction to Avionics, Book [43] – This book provides a comprehensive overview of avionics, focusing on the integration and functionality of electronic systems used in modern aircraft. The book covers key components such as navigation, communication, and flight control systems, emphasizing how these technologies work together to ensure safe and efficient flight. The author explains the development of avionics, from basic mechanical instruments to advanced digital systems. The text also highlights the importance of redundancy, safety, and reliability in avionics design to handle flight conditions and ensure continuous operation.

TARS MK4 | High Power Rocketry Flight Computer, Website [44] – This website details the development of the TARS MK4, a high-power rocketry flight computer created by the Illinois Space Society. The website covers everything from schematic design and sensor selection to flight software and power management. It also provides insights into 3D modeling, and iterative design improvements. This source can be valuable for avionics research, because it offers a hands-on guide to developing and refining embedded systems for real-time flight control, telemetry, and navigation.

Model Rocket Flight Computer with Arduino, Website [45] – This website speaks on an Instructables project on building a model rocket flight computer with Arduino. It explains how to use an Arduino microcontroller with various sensors, such as accelerometers and gyroscopes, to collect real-time flight data. The project uses MATLAB coding, which is what the team is most familiar with, this can be useful to understand experimentation and innovation in data logging and control systems. Overall, this source is useful for understanding how to program an Arduino for data collection.

6.3.4 Recovery (Brittney Thornton)

Electrical Architecture of the Recovery System of a High-Powered Rocket with Payload, Paper [46] - The paper outlines the electrical architecture essential for the recovery system of a high-powered rocket with payload. It details the integration of various components, such as sensors and control units, to ensure reliable operation during descent. The authors discuss control algorithms for precise deployment of recovery mechanisms, like parachutes, crucial for safe landings. Additionally, they present testing and validation methods to ensure system robustness before deployment. Overall, the research provides valuable insights for improving the reliability and effectiveness of rocket recovery systems.

Modern High-Power Rocketry Volume Two, Book [47] - This book contains a recovery section that emphasizes the importance of reliable recovery mechanisms, such as parachutes and other devices, which are essential for protecting both the rocket and its payload during descent. The author explores various design considerations, including the selection of materials and deployment mechanisms, as well as the integration of electronics and sensors to monitor flight conditions and initiate recovery procedures. The recovery section also highlights the best methods for testing and validation of a working recovery system to enhance reliability and contain risks.

Design of the Landing Guidance for the Retro-Propulsive Vertical Landing of a Reusable Rocket Stage, Paper [48] – This paper goes over comprehensive guidance, navigation, and control (GNC) framework for the powered landing phase of reusable launch vehicles, emphasizing precision and efficiency in recovery operations. Their research utilizes optimization techniques, enhancing landing accuracy and fuel management, which can be adapted for different recovery scenarios. Overall, this source provides an outline for the recovery of high-powered rockets, addressing the unique challenges posed by their research's dynamics and operational requirements.

High Powered Rocketry Emphasizing Dual-Deployment Recovery Systems, Paper [49] - The paper explains that dual-deployment recovery systems utilize two separate parachutes, a small drogue parachute for initial descent stabilization and a larger main parachute for the final descent. It emphasizes that this method is used to enhance safety and reliability during recovery. The paper further discusses the crucial aspect of calculating the appropriate size of the ejection charge needed to deploy both parachutes effectively. It explains that factors such as rocket weight, recovery system volume, and environmental conditions are considered in determining the correct sizing for black powder. This source is important for introductory knowledge on recovery systems and what to be considering.

6.3.5 Simulations and Testing (Joshua Wilson)

"BP Estimator," Rocketry Calculator, Website - This is a website used to help us calculate the appropriate amount of black powder to deploy the recovery systems. The website outlines the common uses of black powder in rocket recovery system deployment. There are a few different formulas given to use based on the application of your rocket. We will be using the calculations based on the number of share pins used to secure the rocket recovery system from deploying too early.

Design, Analysis and Simulation of a Single Stage Rocket (Launch Vehicle) Using RockSim, Journal – This journal is used as a use case scenario where a team of engineers are using RockSim to simulate the flight of their rocket prior to an actual launch. The results are analyzed against the data collected by the avionics bay flight computer. The highlights of the article are the various components that are involved in the actual flight. Smalls changes to the fins will greatly alter the flight as will the launch conditions, and final dimensions of the launch vehicle.

RockSim Program Guide, Book – This is the programmers guide to using the simulation software RockSim. The index of the book has a catalog of the various equations that are used in the programming of the software. We are able to see the governing equations that give us decent rate, time to apogee, acceleration, and center of pressure. These equations are complex but help in giving team an idea of the components that are affecting that equation.

WSGC Collegiate Rocket Competition Design Analysis â€“ Team ChlAM, Journal - This is an Example of how an engineering team designed a rocket to carry an electronics payload where the goal was to transmit live video feed to a ground station. The team did not hit their expected apogee of 3000 feet above ground level and offered some speculation as to how the difference in simulation versus real flight data was experienced. One of the main causes is speculation of the effect whether had on flight performance, but this reinforces the idea that our simulation has to be as close as possible to emulate the rocket in real life to more accurately predict the flight performance.

"Compression Test of Tubing Used in Rocketry," Peak of Flight Newsletter, Article – This article reviews the compression testing of rocket tubing. The materials tested in this news article are common rocketry tubing material The tested materials include cardboard, blue phenolic tubing, and fiberglass tubing. The article reviews the compression test used to determine the maximum compression each material is tested to and the resulting data as well as a cost analysis for cost to performance decisions. Ultimately fiberglass tubing was superior in strength and moderately priced.

"Low Profile Rail Buttons For Your High Powered Rockets," Apogee Rockets, Website – This website Offers numerous high powered rocketry components that can be purchased for our rocket. This website reviews low profile rail buttons that will used to give the rocket a stable platform to launch from. The rail buttons are a unique design and do not have an exact component that could be matched in Rocksim. This website offers a frequently asked section where the website owner has detailed how to input this particular component onto the rocket so that it can be accurately accounted for in the simulation to affect the drag. This is crucial in determining the final flight performance of our simulated rocket.

"Adafruit NAU7802 24-Bit ADC - STEMMA QT / Qwiic," ADAFruit, Website - This website is the landing page for the aid of fruit amplifier board that will connect directly to an Arduino microcontroller. This page offers resources that our team can use to program an Arduino to collect data from a load bar that we will use to collect acceleration data. This gives us access to python language as well as a Github repo where we can pull code from to ensure that our system is operating as it should. Resources for a pinout PCB board program that we can use to help create diagrams and a logic flow for data and power to be programmed according to how the board is set up to receive input signal and power.

6.3.6 CAD Engineering Resources (Ryan Yazzie)

Shigley's mechanical engineering design, 11th ed., Book [29] - Teaches the required information about internal pressures and failure points in specific materials. Used the equations to determine the relative stressors of internal pressure proudced from black powder charges druing both stages of deployment.

R. C. Hibbeler and Kai Beng Yap, Mechanics of materials, 10th ed. Harlow Pearson, 2018. , Book [34] – Teaches about the mechanical properties of carbon fiber and fiber glass. Used these material properties to create a custom material for G10 Fiberglass in SolidWorks to perfrom FEA on components in the aft end such as the avionics sled.

Nozzle Design for a High-Powered Solid Rocket Motor, Paper [24] – Describes the process, equations, and methods of designing a nozzle for a high-powered solid rocket. While not utilzed in the First Nations Launch directly, we can use the concepts highlighted to develop solutions in aerodynamics for alternative applications.

Design and Aerodynamic Analysis of a Rocket Nose Cone, Paper [25] – Discussed strengths and weaknesses of different nose cone shapes accompanied by flow and aerodynamic equations. Provides evaluations of performance of specific nose cones given parameters such as airspeed, design, material selection, and application.

Structural Design and Analysis of High-Powered Rocket, Paper [26] – Describes general rocket design with emphasis on stability, aerodynamics, and thrust. Used to determine margin of stability equations and simlulations within RockSim.

ASME Y14.5-2009, Standard [27] - American Society of Mechanical Engineers standards for Dimensioning and Tolerancing. Establishes efficient practice of CAD Software such as SolidWorks to best present our design to a wider and highly technical audience.

Rocket Stability Condition | Glenn Research Center | NASA," Glenn Research Center, Website [28] - Describes the fundamental equations to solve for margin of stability.

Computer Aided Finite Element Structural Design and Stress Analysis of Rocket Motor Nozzles Made of Composite - Website [30]

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