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EML4551-2

Team ##: Project Name

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Abstract

Team 509 senior design project has made history at the FAMU-FSU College of Engineering with their payload design for the 2025 NASA Student Launch competition. This is a yearly competition that includes colleges around the country. The competition includes designing, building, and launching a rocket with a payload. The team had to design, build and test the payload. Team 508 will design the rocket itself. Previous teams' college have struggled to create a working payload to go with their rockets, making Team 509 the first team to do so. The payload had to meet all of NASA's strict requirements. These include ensuring the safety of model astronauts called STEMnauts, sending flight data accurately with radio signals, and placing the payload into the rocket. To complete these goals, the team used the engineering design process. This included writing an in-depth report on the scope of the project, interviews with NASA's board of judges breaking down the necessary functions of the payload, brainstorming ideas, and building prototypes. Through this process the team designed a payload that meets all competition needs and helps the rocket team with their mission. Once the final payload design was made, testing was done on the payload's structure to make sure that it can handle the forces during launch. These tests included drop tests, vibration tests, and load barring testing on the mounting system. Furthermore, the team looked at the payload's electronics systems by making sure that the sensors and computers work under real-life flight conditions. By using this design process and thorough testing, Team 509 designed and placed a successful payload into Team 508's rocket for the 2025 NASA Student Launch. The team was able to score and compete against other teams achieving a breakthrough for the college.

Keywords: Rocket, Payload, Design

Acknowledgement

We extend our sincere gratitude to our sponsors *insert sponsor* for their financial contribution, which helped fund the critical components of our payload design and the travel expenses associated with the 2025 NASA Student Launch Competition. We are deeply appreciative of their backing and generosity as it played a pivotal role in bringing our vision of the design to fruition.

Additionally, we would like to extend our deep gratitude to our advisors, Dr. Taylor Higgins and Dr. Shayne McConomy, for their invaluable guidance, expertise, and unwavering support throughout this project. Their wealth of knowledge, insightful feedback, and dedication allowed us to overcome challenges and refine our design to successfully achieve our goals. Dr. Shih's expertise in aerodynamics and propulsion systems has been invaluable, while Dr. McConomy's systems integration guidance has been crucial to the success of our project. Their contributions and mentorship not only enriched our technical skills but also fostered the development of our team into engineering professionals.

Equally important was Eric Adams and the rest of the staff at the FSU Innovation Hub who allowed us to use the state-of-the-art SLS Nylon Fusion 3D printer in the fabrication of critical payload structural components. We are extremely thankful for their generosity in allowing us to produce high-quality, intricate parts with exceptional precision and structural integrity. This was invaluable to our design we are incredibly grateful for the assistance and support.

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Notation

F	Force
P	Momentum
m	mass
v	velocity
t	time
d	diameter
l	length
PL	Pull-out load
G	gravity
MHz	Mega-hertz
BA	Back Angle
BOF	Ball of Foot
BOFRP	Ball of Foot Reference Point
CAD	Computer Aided Design
CDC	Centers for Disease Control and Prevention
CU-ICAR	Clemson University - International Center for Automotive Research
DDI	Driver Death per Involvement Ratio
DIT	Driver Involvement per Vehicle Mile Traveled
Difference	Difference between the calculated and measured BOFRP to H-point

DRR	Death Rate Ratio
DRS	Driving Rehabilitation Specialist
EMM	Estimated Marginal Means
FARS	Fatality Analysis Reporting System
FMVSS	Federal Motor Vehicle Safety Standard
GES	General Estimates System
GHS	Greenville Health System
H13	Steering Wheel Thigh Clearance
H17	Wheel Center to Heel Pont
H30	H-point to accelerator heel point
HPD	H-point Design Tool
HPM	H-point Machine
HPM-II	H-point Machine II
HT	H-point Travel
HX	H-point to Accelerator Heel Point
HZ	H-point to Accelerator Heel Point
IIHS	Insurance Institute for Highway Safety
L6	BFRP to Steering Wheel Center

Chapter One: EML 4551C

1.1 Project Scope

1.1.1 Project Description

The objective of this project is to design and integrate a payload into a high-powered rocket for the 2025 NASA Student Launch Competition. This competition is an annual event for universities around the country to design, test, and fly rockets. Each year, the competition organizers define requirements for the rocket, as well as a payload to be housed within the rocket. This year, the FAMU-FSU College of Engineering has organized two teams to compete in the competition: a rocket team and a payload team. This year's payload will meet all of NASA's design requirements and will integrate into Senior Design Team 508's high-powered rocket. This will promote the FAMU-FSU College of Engineering as a serious contender in the competition for years to follow.

1.1.2 Key Goals

Key goals are used to further define the project description by expanding on specific expectations for the design. The key goals for Team 509 are the survivability of the four human models (STEMnauts) during the test flight of the rocket, an accurate transmission of a minimum of three predefined flight parameters, and the successful integration of the payload into Team 508's flight vehicles.

The STEMnauts are physical representations of crew members present inside the payload of the rocket. It is the goal of Team 509 to design the payload in such a way that the STEMnauts survive throughout the full duration of the rocket launch mission. This includes takeoff, flight, landing, and recovery. The metric of survivability has been determined. Furthermore, what will be used to physically represent the STEMnauts has been determined.

Another important key goal for the team is the accurate radio transmission of a minimum of three predefined flight parameters. Competition organizers have defined eight flight parameters that can qualify for the three flight parameters that must be tracked. These parameters include:

- Temperature of landing sight
- Apogee reached
- Power status
- Orientation of on-board STEMnauts
- Time of landing
- Maximum velocity
- Landing velocity
- Calculated STEMnaut survivability

Team 509 strives to transmit a minimum of three of these parameters per competition requirements. The specific flight data transmitted, the method of collection, and the metric of accuracy have been determined.

Team 509 strives to integrate the payload into Team 508's flight vehicle. In previous years, FAMU-FSU College of Engineering teams have been unable to integrate a payload into the competition rocket. The success of this goal would ensure that Team 509 surpasses previous student launch teams, and this will continue to solidify the FAMU-FSU College of Engineering's legitimacy in the competition. A crucial point of this goal is that the payload can be integrated into the rocket team's vehicles. Part of the competition is to design both a full-scale and a subscale rocket. According to competition requirements, each rocket must include a payload, or at minimum, a payload substitute. This means that both a full-scale and sub-scale payload design must be fabricated and evaluated successfully.

If all goals are achieved, then Team 509 will have a high chance of making it to the 2025 NASA Student Launch and has a chance to be scored for the first time in FAMU-FSU College of Engineering history thus bringing positive recognition to the college.

1.1.3 Markets

The primary market for this project is the NASA Marshall Space Flight Center's (MSFC) Artemis department competition judges. The NASA competition judges will determine the team's success through the completion of deliverables throughout the design process and the success of the payload at competition. The judges will assess whether the payload has met the criteria on page 64 of the NASA student launch handbook due to the content being the standard for a successful payload project delivery. Satisfying this market is of uttermost importance, due to the results of the project having more significance to the judges.

The secondary markets consist of the FAMU-FSU College of Engineering which includes faculty, graduate, and undergraduate students currently enrolled in the College of Engineering. The American Institute of Aeronautics and Astronautics Club, along with students local to the city of Tallahassee are also the secondary market when it comes to our payload project. These are the important individuals who are inspired by the hard innovative work our team has to offer through this project. Students from the various campuses and clubs in the area are very influential in whether or not projects like this can succeed along with continuing. If the students and locals are not current team members in the AIAA club before the competition, they typically will express their interest based on the work we present to them. Stem engagement from students and locals can also increase due to the results team 509 can produce. Our project success also creates opportunities for possible new areas of study in the field of avionics within the College of Engineering. The faculty at the College of Engineering can justify such additions if the team is successful at the competition.

This leads into another market for this project being the FAMU-FSU College of Engineering which includes faculty, graduate, and undergraduate students currently enrolled in the College of Engineering. With a successful showing at competition, this project can bring recognition to the university and feed involvement in extra-curricular activities at the school. This makes the College of Engineering an important market to analyze throughout the duration of project.

A final market to pay attention to during the project are aviation companies like Boeing, Lockheed, Raytheon, and Northrop Grumman Corporation. These companies have been at the top of the aviation industry for years. Analyzing their products and strategies can grant the team vital information to be successful throughout the course of the design and development process.

1.1.4 Stakeholders

Stakeholders include all individuals or organizations with stake in a project. Stake is defined as a financial, legal, or other tie to the project and the project's actions. For this project, the upper-level stakeholders include all members of the Senior Design Team 508: NASA Student Launch Rocket Team. The rocket team is leading the competition. This includes determining budget and project resources. It is also the responsibility of the team to ensure that the payload integrates within the rocket team's flight vehicles. Because of this, Team 508 is identified as a primary stakeholder in the project.

Additional upper-level stakeholders include faculty and staff members of the FAMU-FSU College of Engineering. Dr. Shane McConomy is the professor of the senior design project and will act as the lead sponsor. This makes Dr. McConomy one of the main stakeholders in the project. Another stakeholder at the university is Dr. William Oats. Dr. Oats is the Dean of the Mechanical Engineering Department at the FAMU-FSU College of Engineering. His stake in the project lies in the recognition gained by the college with the completion of a successful project. Previous years have been unable to successfully qualify for the competition due to an incomplete payload design. A successful payload would allow the university to qualify for the competition and bring awareness to the college's growing aeronautics curriculum. The final stakeholders at the university include teaching assistants for the 2024-2025 Senior Design Course: Elias Haase, Tripp Lappalainen, and Jacob Schmitt.

The final stakeholder in the project includes the Federal Aviation Administration (FAA). The FAA is the nation's leading government regulatory body in the field of aviation. Since this payload will be housed in an unmanned aerial vehicle, the team must abide by all safety regulations and standards set by the government organization. This makes the FAA a pivotal stakeholder in the project.

1.1.5 Assumptions

Along with key goals, markets, and stakeholders, assumptions about the project must be made to ensure the project's success move forwards. Team 509 will assume fair weather conditions on the day of launch. This includes wind speeds of less than 12 m/s, no precipitation, and temperatures in the range of 0-38 degrees Celsius. It will also be assumed that the rocket will be launched from an elevation of approximately 5 m. As the NASA Student Launch project is split into two senior design teams, team 509 must assume the competence of the rocket team (Team 508). It will be assumed that the rocket that carries the payload will function as intended on the day of launch and that the proper communication channels between the two teams will be present to facilitate the successful integration of the payload into the rocket. Team 509 will also be assuming that the NASA range safety officer will be equipped with an FTM-300DR transceiver at the competition and that no major modifications are made to the nature of the competition or to the timeline of events or deliverables. Furthermore, it will be assumed that legal regulations relevant to the civilian operation of high-powered rockets and radio communications will not be changed in a way that undermines the project. Finally, it will be assumed that all members of team 509 will retain the ability to contribute to the project throughout its duration. Any of these assumptions being false may significantly impact on the scope, timeline, or budget of the project.

1.1.6 Conclusion

Team 509 will collaborate directly with Team 508 to ensure that the payload gets integrated into the rocket successfully. The team will ensure that the payload is able to transmit the appropriate data via radio after the rocket has landed and that the STEMnauts survive the flight. Generating money through donors, getting feedback from stakeholders, and analyzing primary and secondary markets will promote the team's success and ensure a successful payload for the 2024-2025 NASA Student Launch.

1.2 Customer Needs

For this project, the customer is the NASA Artemis program as they oversee the competition. Team 509 developed a questionnaire to better define the competition requirement.

The team determined the answers to this questionnaire by sending emails to the event organizer, accessing the 2024-2025 NASA Artemis Student Launch Competition Handbook, and speaking with the faculty advisor, Dr. Shayne McConomy. Using these responses, the team was able to interpret needs that will assist in the engineering design process for this project. Table 1 shows the questions, customer responses, and the interpreted needs that were gathered by the questionnaire.

Table 1: Table of customer interview questions, customer responses, and the interpreted need of the design.

	Questions	**Customer Response**	**Interpreted Needs**
1.	What is the nature of the STEMnauts?	"Mass is completely up to you. STEMnauts are sort of a continuation from last year where teams had a variety of ways to incorporate them. What we told teams last year was to be creative and have fun with them. If you want to look at our social media posts (X and Facebook) under NASA Student Launch you can see some promo videos we released of our STEMnauts. Now those might be a bit big since you need to launch 4 of them in a rocket, but I think you'll get a good idea from that."	STEMnauts must resemble astronauts. Creative representations of STEMnauts are required.
2.		"Payload shall transmit on the 2-M band. A specific frequency will be given to	They payload must transmit on 2-M band.

	What frequency is the radio transmitted on?	the teams at the competition. NASA shall use the FTM-300DR transceiver"	Payload must be capable of utilizing specific frequencies.
			The payload must be compatible with an FTM-300DR transceiver.
3.	What are the payload constraints?	"The payload must abide by FAA rules and regulations. The payload shall not have any protrusions from the vehicle prior to apogee that extend beyond a quarter inch exterior to the airframe. All transmissions shall start and stop with team member call sign. Teams shall submit a list of what data they will attempt to transmit by NASA receiver by March 17. Teams shall transmit with a maximum of 5W, and transmissions shall not occur prior to landing. Teams shall not transmit on the specified NASA frequency on launch day prior to landing."	The payload must follow FAA and NRA rules and regulations.
			The payload must be contained within the rocket.
			The transmission of the radio signal must be controlled by the operator.
			Payload must operate at, or below, 5W of power.
4.	What are the structural integrity requirements for payload?	"The payload must be capable of keeping the STEMnauts safe throughout the takeoff, flight, and landing of the vehicle."	The payload must be able to structurally withstand landing conditions of rocket

5.	What information is being transmitted?	"Teams shall choose a minimum of 3 pieces of data from the below list to a maximum of 8 to transmit to the NASA receiver: time of landing; maximum velocity; landing velocity, G-forces sustained; calculated STEMnaut crew survivability; temperature of landing site; apogee reached; battery check/power status; and/or orientation of on-board STEMnauts"	The payload must be capable of retaining and transmitting a variety of data
6.	What power source is being used?	"Specific power source is not specified; however, power source must be separate from the rocket's avionics power source."	Payload must have its own independent power source.
7.	Will the payload interact with the rocket in any way?	"Payload will be secured inside the rocket during flight; however, data from rocket's avionics cannot be used to transmit payload data."	The payload electronics must be independent from the rocket's Payload must be location relative to the rocket must not negatively affect the rocket's flight path.
8.	Are there any size or weight requirements?	"Any UAS (Unmanned aircraft system) Payload weighing more than 0.55 lbs. shall be registered with the FAA (Federal Aviation	The team must register the payload with the FAA and have the registration number on the rocket if the payload exceeds 0.55lbs.

		Administration) and the registration number must be marked on the vehicle.”	
9.	What laws or regulations need to be considered? (What are the requirements of qualifying?)	Teams shall abide by all FAA and NAR rules and regulations	The team must read through the FAA and NAR rules and regulations to see the qualifying needs for our payload and what we must avoid adding.
10.	How will the payload be used?	The payload will safely fly a flight capsule housing STEMnauts. The capsule will be able to transmit rocket and landing site data to a NASA-owned receiver located at the launch site, via radio frequency.	The payload will be designed to not pull above the number of forces of gravity that a human can realistically sustain while avoiding injury. The payload will use electronic radio devices to transmit data.
11.	What are the criteria for evaluating the payload’s success?	“The payload will successfully transmit data the team chooses when the vehicle lands. The payload will not have any extensive protrusions from the vehicle before apogee. The team will fly safely and responsibly following basic guidelines.”	The payload must relay a variety of predefined flight information The payload must be contained within the rocket. The payload must abide by all governmental standards. The payload must relay data at a predefined time
12.	When and where is the competition?	“The competition will be in Huntsville, Alabama.	The payload must be capable of withstanding the environmental

		Launch week will begin on Wednesday, April 30, 2025, and launch day will be Saturday, May 3 with a backup launch day on Sunday, May 4.”	conditions of Huntsville AL during the spring and summer months.

Using the NASA Student Launch Handbook, communication between competition organizers and meeting with the team faculty sponsor, the customer needs assessment was completed. Through careful interpretation, several key needs were identified. The payload must transmit a series of predetermined flight data at a specific time, on a specific frequency. The data collected must be collected only by the payload system. The system must operate in various weather conditions and have the strength to keep four human models safe throughout the test flight. The payload system must abide by all government rules and regulations defined by the FAA and the NAR. Furthermore, through discussion with the team faculty sponsor, Dr. Shayne McConomy, the team must utilize a systems engineering approach to maintain a high degree of communication between the senior design team that is focusing on the rocket portion of the project.

1.3 Functional Decomposition

1.3.1 Introduction

An essential step in the design process is the production of a Functional Decomposition. The objective of a Functional Decomposition is to reduce the complexity of large systems by decomposing the system’s functions into minor functions and displaying the connections between these systems and functions. This allows the team of engineers to communicate to the customer exactly how the product will be broken down from the largest system to the simplest functions of the system. Detailed structures like Functional Decompositions highlight even the smallest functions and are of uttermost importance to both the customer and the designer, due to the ability to signify requirements that must be met. The Functional Decomposition also aids the rest of the design process by outlining how different systems within a design interact with one another. Within a Functional Decomposition it is necessary to have both Hierarchy Charts and Cross Function Matrixes as visual representations. The tiny details are what attribute to the much larger task at hand, and this breakdown makes it manageable.

1.3.2 Data Generation

The data gathered for this Function Decomposition was gathered from the Student Launch Handbook along with research our team did on industry metrics. Our team also had conversations with our sponsor, advisor, and other stakeholders who recommended certain functions to be implemented. A large majority of the data was given in the Nasa Student Launch Manual, which included all the requirements to satisfy the status of a successful payload. The requirements provided were important customer needs, but simply fulfilling those requirements would not result in a successful product. There were some requirements left for our team's interpretation purposely, for example survivability metrics of the STEMnauts. The handbook did not specify what was considered a survivable payload, therefore making research a necessity. For our metrics to be justifiable to our customers, the metrics had to align with the aerospace industry standards of survivability. After multiple team meetings with our sponsor Dr. McConomy and advisor Dr. Higgins, more data generation would occur due to the need for more functions.

1.3.3 Hierarchy Chart and Cross-Reference Table

The Hierarchy Chart and Cross-Reference Table are visual representations of how the systems and functions all work with one another. The Hierarchy chart displays a linear relationship between the systems and functions. This means that the payload can be broken down into systems and those systems broken down into functions that describe what the system must do to accomplish its tasks. Figure 1 shows the Hierarchy Chart for the Payload.

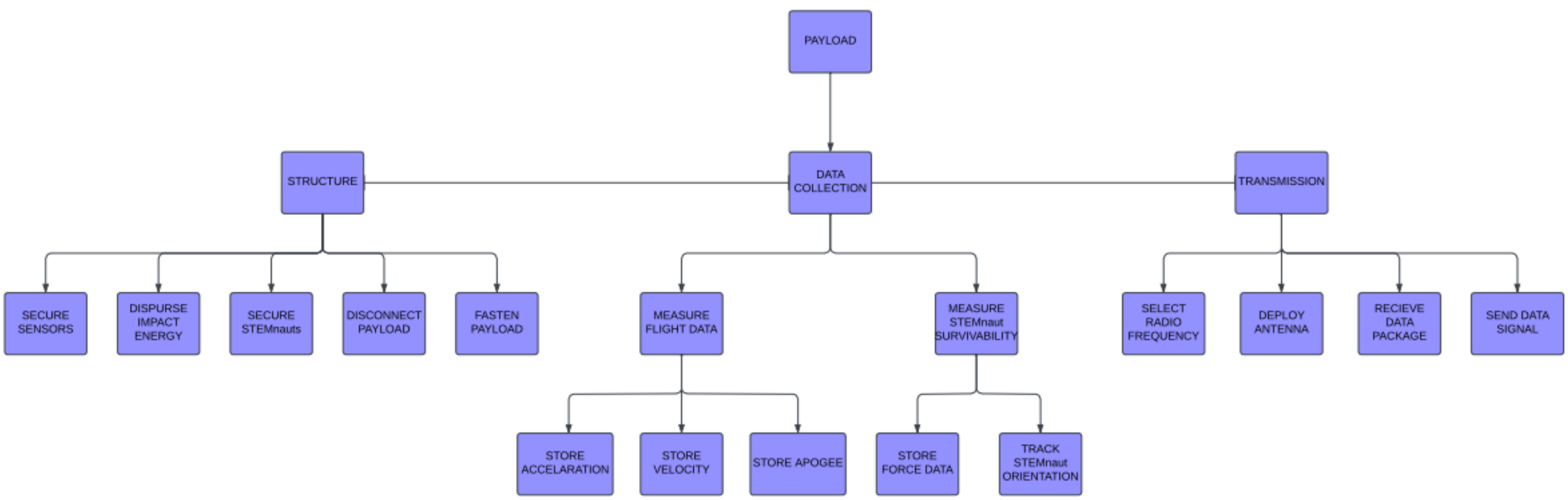


Figure 1: Functional decomposition for payload design.

In the hierarchy chart the Payload was broken down into three systems the structure, data collection, and transmission. Minor functions subsequently follow these systems. The construction of this hierarchy chart began with first addressing the needs and requirements of the customer. These needs and requirements come from a combination of handbooks, meetings, and research as stated above in the evidence manual. Furthermore, there were functions put into place to accommodate each requirement. These functions further define what a system must accomplish to be successful. In the hierarchy chart, functions are categorized under only one system; however, the functions can interrelate with other adjacent systems. This is why the cross-reference table becomes helpful. The Cross-Reference Table is an aid to the Hierarchy Chart, showing the more complex connections between different systems and functions. The Cross-Reference table is still easy to read, and highlights functions that affect or are dependent upon systems, they may not directly fall under in the Hierarchy Chart. Table 2Table 2 shows the Cross-Reference Table for the above Hierarchy Diagram.

Table 2: Cross-reference table of the rocket's payload functions and systems.

Functions	**System**		
	Structure	Data Collection	Transmission
Disperse Impact Energy	X		
Secure STEMnauts	X		
Disconnect Payload	X		
Fasten Payload	X		
Secure Sensors	X	X	X
Store Acceleration		X	X
Store Velocity		X	X
Store Apogee		X	X
Store Force Data		X	X
Track STEMnaut Orientation	X	X	

Select Radio Frequency			X
Deploy Antenna	X		X
Receive Data Package		X	X
Send Data Signal		X	X
Total:	7	8	9

Many of the minor functions are related only to their respective system, especially for the structure system. Most of the structures' functions are independent from the rest of the system other than designing space and securement for electrical components. In contrast, the data collection and transmission systems are much more interconnected, as all sensors and electronics in the data collection system need to be compatible with the communication protocols and hardware of the transmission system.

1.3.4 Connection to Systems

There are three systems for the payload. The systems are structure, data collection, and transmission. The priority of the systems was ranked on a scale of 1 to 15 by summing the number of functions each system is related to. Transmission was the highest priority, scoring a 9, followed by data collection then structure. Transmission was ranked the highest because a lot of the points in the competition will be based on the fact if the data is sent and displayed on the FTM-300DR transceiver. From Table 2 the only minor functions that transmission was not interdependent for was fasten payload, disconnect payload, secure STEMnauts, track STEMnaut orientation, and disperse impact energy.

The second highest ranked system was Data Collection, scoring an 8. For the project there are a minimum of three data points that must be tracked by the payload. For the transceiver to receive anything or get accurate data the data collection system must be precise and operating as intended on flight day. The functions for this system include four data points for the project as well as secure sensors, send data signal, and receive data package.

The lowest ranked was structure, scoring a 7. The structure's main goal is in charge of making sure that the STEMnauts and the hardware in the payload remain unharmed upon impact. Although this system is vital for the success of the payload, based on this breakdown, the other systems hold a higher value than this one. This revelation does track on the nature of the competition, where data transmission is being held as the highest priority and the largest metric for success. The functions relating to the system are to disperse impact energy, secure STEMnauts, disconnect payload, fasten payload, secure sensors, track STEMnaut orientation, and deploy antenna.

1.3.5 Smart Integration

The payload requires integrating functions across various systems within the design. Each individual function can apply to systems to which they don't directly connect. An example of this is shown in the function: "Send Data Signal". This function directly applies to "Transmission" sub-system; however, there must be careful coordination between the "Transmission" system and the "Data Collection" system to ensure the data that is being transmitted is the correct. Several other minor functions hold the same level of cross-correlation between systems. Measuring/storing flight data and tracking/storing STEMnaut orientation are direct functions of the Data Collection system; however, these functions also apply to the Transmission system since the collected data will have to be transmitted via a radio data package. This concept also applies to Transmission systems receive the data package from the Data Collection system.

Furthermore, deploying the antenna is a direct function of the transmission system; however, to deploy the antenna, a method of deployment must be built into the payload's structure. Since the "Deploy Antenna" function applies to two adjacent systems, the function enters the same category as the previous functioned mentioned.

There is one function that maintains a high level of cross-correlation between all three of the major systems in the payload. Securing the sensors in the payload relates to the Structure, Data Collection, and Transmission systems of the payload. Securing the sensors is directly related to the structure of the payload; however, the safety and security of the sensors will have a significant effect on both the Data Collection and Transmission. This result of the cross-correlation table is expected for the project. Since a major key goal of the competition is the transmission of specific data points, the security of the sensors that are collecting the data is a vital function that the team must consider when moving forward with the project.

1.3.6 Action and Outcome

The outcome of the Payload is to create a control system that will protect STEMnauts throughout the launch, collect necessary data from the launch, and transmit signals from the rocket back to a competition radio. To ensure the safety of the STEMnauts the team must be able to secure them in the Payload. The team must also create a Payload that will withstand the different forces acting upon it to limit the amount of G-force exserted on the STEMnauts. During the launch the Transmission system will receive data from our sensors onboard the Payload and transmit important details about our launch mission such as apogee, acceleration, velocity, etc. We must also be capable of choosing a specific radio frequency so that our Payload would be relaying radio signals to the competition radio. The Payload will have a disconnection system that will separate it from the Rocket body when intended to ensure the Payload does not receive any unintended forces that may negatively affect the STEMnauts or sensors.

1.4 Target Summary

1.4.1 Introduction

The targets and metrics written were based on the functional decomposition. The lowest level functions from the functional decomposition were used to create metrics and the targets corresponded with these metrics. Identifying the correct targets and metrics will help the team be successful in the project and figure out conceptual designs to satisfy the targets and metrics.

1.4.2 Critical Targets

Critical targets are mandatory for the project. Every critical target ensures the success of the project. They are essential and if one critical target is not met the whole project will be considered a failure, and the customer needs will not be fulfilled. Along with critical targets there are other targets but there is a major distinguishment. If a complication were to occur the consequences would not be as grim if it were to be just a regular target, however if our system was not able to send a data signal that would be a very big problem which would categorize it as a critical target.

Critical targets stem from critical functions. Our team did an in-depth analysis of every function, and we came made a list of functions we deemed important. The list consists of fastening payload, securing STEMnauts, dispersing impact energy on STEMnauts, dispersing impact energy on payload body, measuring altitude, measuring acceleration, measuring temperature, measuring STEMnaut acceleration, selecting radio frequency, sampling sensors, and sending data signal. These functions were generated from the specified requirements that were provided by the customer, and it was made very clear if they were not satisfied the payload would be considered a failure and what receive a bad score. This section discusses the mission critical targets, but the other targets that are involved with the other minor functions can be found in the Appendix.

Our critical targets were defined through research on different specifications that would directly apply to the critical function it pertained to. This information is addressed more in depth in the “Target and Metric Derivation” section.

1.4.3 Target and Metric Derivation

The metric for success for the “Fasten Payload” function will be the maximum pull out load of the fastener securing the payload to the rocket body. To determine the target pull-out load for the fastener, an analysis of possible landing conditions of the rocket was performed. Based on this analysis, the reactive force holding the payload within the rocket can be determined with the following formula:

$$F = P = \frac{mv}{\Delta t}$$

F is the reactive force holding the payload within the rocket, *v* is the expected landing velocity of the rocket-payload system, *m* is the estimated payload mass, and Δt is the estimated time interval over which the rocket-payload system lands. In this calculation, the landing velocity of the rocket was determined to be approximately 9 mph, the payload mass was estimated to be 5 mph, and the impact time-interval was 50 ms. Based on this momentum analysis of the landing conditions of the rocket, the maximum pull-out load that could be applied to the mounting fasteners of the payload will be 41.02 lbf. With this target maximum pull-out load, information on the fastener can be determined using the following formula (Barrett, 1990):

$$PL = \frac{\pi d_m F_s l}{3}$$

Where PL is the maximum pull-out load, d_m is the pitch thread of the screw, F_s is the yield strength of the tapped material, and L is the thread engagement of the fastener.

The metric for determining the success of the "Secure STEMnauts" function will be the physical displacement of the STEMnauts within the payload. Ensuring the STEMnauts remain secured in place helps prove survivability and reduce vibration caused by the rocket's flight. The target for this will be a physical displacement ≤ 2 mm.

The metric for evaluating the "Disburse Energy Impact on STEMnauts" function will the multiple of gravitational acceleration applied to the STEMnauts at landing. The maximum short-term acceleration applied to the average person is 4-6G's; however, for trained fighter pilots, the maximum is 9G's. With the assumption that the STEMnauts will be trained for extreme conditions, the target for this will be a maximum impact acceleration of 9G's (Federal Aviation Administration, 2001).

The metric for success of the "Disperse Impact Energy on Payload Body" function will be a function of the damage sustained on the body after 3 test launches. The team constructed a damage scale to evaluate the payload structure after testing. Table 3 states the damage scale used.

Table 3: Table describing custom damage scale for payload structure.

Degree of Damage Value	Description of payload after 3 launches
1:	No damage occurred.
2:	Minor damage that does not affect payload operation. Minor damage is defined as surface level scraps and/or dings.

3:	Mid-level damage that does affect payload operation; however, the damage can be easily repaired. Mid-level damage is defined as small cracks and/or chips in payload structure.
4:	Major damage that does affect payload operation; however, can still be repaired with some effort. Major damage is defined as large cracks and/or large chips in payload structure.
5:	Catastrophic damage to payload that cannot be repaired. Catastrophic damage is defined as a complete breakdown in the payload structure.

Using this damage scale, the team's target for this function will be a degree of damage of 2. This means that after 3 test launches, the payload may receive minor damage (surface level chips and scratches); however, this damage cannot affect payload operation or structural integrity.

The metric for success of the "Measure Altitude" function will be range of altitudes that the payload's altimeter can operate within. The rocket is constrained to altitudes below 5500 ft and launches from a low altitude (near 0 ft). Therefore, we define the target operational altitude range for the altimeter to contain at least the range from 0-5500ft.

The metric for success of the "Measure STEMnaut Acceleration" function will be a data collection range. As stated previously, the target maximum acceleration of the STEMnauts at landing is 9 G's based on an analysis of fighter jet pilots. Based on this, the target range in which the payload will be capable of collecting acceleration data on the STEMnauts will be 0-10G's.

The metric for success of the "Measure Temperature" function will be the range of temperatures that -the payload's thermometer can operate in. Per the project assumptions, the payload is expected to operate in conditions from 0-38 degrees Celsius, so we define this as the target range of temperatures that can be measured.

The metric for success of the "Select Radio Frequency" function will be the range of frequencies that the payload can transmit on. The payload is required by NASA to transmit on a frequency within the 2-meter band that will be specified at the competition. To account for any frequency that NASA may select for us, we will define the target range of transmittable frequencies to be any frequency on the 2-meter band, namely 144 – 148 MHz.

The metric for success of the “Sample Sensors” function is the frequency with which measurements can be recorded from the sensors. The payload is required to record information about specific flight events using its onboard sensors. These sensors will need to be sampled at some frequency which will correlate to some resolution. Higher sample rates will yield better resolution and will allow the payload to rely less on interpolation. We define the target sample rate to be 20Hz, which from our research is the standard operating frequency of most commercial barometric altimeter modules. All other components of the system will need to be capable of operating at or above this sampling rate.

The metric for success of the “Send Data Signal” function is the power with which the signal will be sent. Per the NASA Student Launch Handbook, all transmissions will be no greater than 5W of power, so we define the target to be less than or equal to 5W.

Table 4: Table of the Critical Functions, Targets, and Metrics.

Function	Target	Metric
Fasten Payload	41.02 lbf	Pull out load
Secure STEMnauts	0.09 in	Physical Displacement
Disperse Impact Energy on STEMnauts	9 G	Acceleration
Disperse Impact Energy on Payload Body	2	Degree of Damage
Measure Altitude	0-5500 ft	Measurement Range
Measure Acceleration	0-10 g	Measurement Range

Measure Temperature	0-38 Celsius	Measurement Range
Measure STEMnaut Acceleration	0-10 G	Measurement Range
Select Radio Frequency	144-148 MHz	Frequencies of Operation
Sample Sensors	20 Hz	Sample Frequency
Send Data Signal	5W	Transmission Power

Note. This is only a summary of some of the most essential functions, the rest can be found in Appendix C.

1.4.4 Methods of Validation

To reach the target metric of Fastening the Payload we will run test simulations on our payload to see how well we can mount the payload. This will be done by measuring the reactive force that will be holding the payload to the rocket. The force may be found through the P constant, maximum pull-out load, which is found through measuring the thread of the nails and the strength of the of the material holding onto the payload. After an attempted simulation is complete, we will gain the information needed to calculate if our metric has been hit and that we can fasten the payload with ease without the fear of it falling off during the final flight. The simulations will be done through FEA (Finite Element Analysis) to allow us to get quick and effective data about our payload without risking damaging it severely.

To make sure that the STEMnauts remain secured in the payload we must run simulations to the payload that will resemble the flight. This will allow us to see how our STEMnauts will react to the conditions they will endure during the flight and how they can be displaced if in any way. We can use this information to better understand what our STEMnauts will be experiencing in their flight and how we can avoid them from scrambling all around the payload the whole flight and ensure they will be secured too their seats with minimal to no damage.

Assuming the STEMnauts go through the same training as trained fighter pilots we will be aiming for our STEMnauts to endure a maximum of 9Gs of impact acceleration. This will be done through simulations and possible subscale implementation to get both theoretical and practical data that will help us understand how our STEMnauts will be affected. We can gain much needed information from these types of tests to make sure our STEMnauts are able to withstand the amount of G's they will endure and give us an idea of what we can implement to avoid any unnecessary damage to our STEMnauts.

To test the disbursement of Impact energy on the Payload body we will conduct real world simulations on the body. This can range from implementing it into the subscale rocket to simply dropping it from a high elevation and seeing the effects on the payload. This would allow us to gauge the results based on our graph in the Metrics portion of our project, where 1 meant no damage and a 5 was a Catastrophic disaster. Based on these tests and simulations we can fix our payload to be able to withstand the impacts it will have both in flight and landing.

To get an idea if our sensors are going to be able to store data, we will first have to configure them to make sure we are getting accurate data. We will then be able to conduct trials on our sensors to make sure we are recording the data. This can range from moving our sensor around to see if it's detecting the right elevation, allow the sensor responsible for acceleration to enter free-fall to determine acceleration, change the temperature around the senor to detect changes in the temperature, etc. This will allow us to do as much fine tuning of our sensors so they can work perfectly fine on the day of the flight. This will then lead to storing the data that will be held in our microcontroller as this is where we will be communicating to the RF module. This will be done by creating an algorithm that will store all the data as separate variables so none of the data overlaps and causes confusion.

When implementing our radio frequencies, we must adhere to the NASA handbook which is a 2M band. This is a 2-meter band which ranges from 144-148 MHz radio frequency range. In this range we are allowed to transmit our data and communication from our RF module. We must also implement an antenna to our payload that will be able to give us a range of 5,000 ft to send our radio frequencies. This will be done by setting up our RF module to be able to transmit at the 144-148 MHz range using a transceiver to check if we are transmitting at the right frequency. Once that is done, we can test it by placing the payload on a moving object and then once it comes to a halt it can relay the data to us through the transceiver.

1.4.5 Other Needs Addressed

To compete in the 2025 NASA Student Launch competition the NASA handbook has a list of regulations and requirements to be able to fly. These are additional targets and metrics for the competition. Power transmission is a metric for the competition and the target is that the power is less than or equal to 5 Watts (National Aeronautics and Space Administration (NASA), 2024). Another metric that the team must follow is the length protruding from the airframe and the target for this is less than or equal to a quarter inch (National Aeronautics and Space Administration (NASA), 2024). The payload must have a minimum charge time of 3 hours (National Aeronautics and Space Administration (NASA), 2024), because delays on the launch pad may occur so it must be on standby.

1.4.6 Summary of Other Targets

This paper has discussed mission-critical functions, targets, and metrics for the project; however, there are additional functions, targets, and metrics. Additional targets include isolation of the altimeter from light sources at an incident angle less than 45 degrees, shielding of electronics from electromagnetic radiation with a field strength greater than 1 V/m, 3 degrees of freedom in the measurement of STEMnaut orientation, the ability to measure the onboard power source from 0-12 volts, at least 16 KB of RAM, a transmission range of 5000 ft, and that the payload can be disassembled from the rocket in less than 10 minutes. While these targets are not deemed mission critical, team 509 will strive to meet them so that our payload can be as successful as possible.

1.5 Concept Generation

1.5.1 Introduction

This section discusses the concept generation phase of the project. In this phase, the team utilized concept generation tools to develop a total of 100 conceptual designs. This section focuses on 8 of the 100 concepts. These 8 designs were determined to have the highest probability of success. The complete list of all 100 concepts can be found in Appendix D.

1.5.2 Generation Tools

During the ideation process, 4 concept generation tools were utilized by the team. Due to the complexity of this project, the use of these tools allowed the team to efficiently generate a variety of concepts. The concepts used during this phase include: crap shoot, morphological chart, battle of perspectives, and forced analogy.

Crap Shoot

The Crap Shoot method for concept generation is a brainstorming technique that relies on randomness to spark new ideas. It enables the team to slightly filter out bias. The random elements and ideas are assigned to a respective number on the dice. Multiple dice are rolled and from the roll is a given outcome that is completely unexpected. The objective of this method is to break away from typical, predictable thinking, and let unusual or surprising ideas emerge. This approach can be helpful when the team is stuck in a creative rut or wants to come up with something unique. It encourages the team to think outside the box and embrace the unpredictable nature of this method.

Table 7: *Crap shoot die designation.*

	Die 1 - Landing	Die 2 - Material	Die 3 – Electronic Configuration
1	Parachute Only	Acrylic	Wireless Network of Modules
2	Parachute/Deployable Arms	ABS (Acrylonitrile Butadiene Styrene)	Custom Board
3	Parachute/Propellers	Balsa Wood	Hybrid System
4	Parachute/Airbag	Aluminum	Separate Modules
5	Parachute/CO2 Thrusters	Fiberglass	Commercial Flight CPU
6	Parachute/Wheels	Carbon Fiber	FPGA

Let me know if you need anything else!

Morphological Chart

The morphological chart has rows containing the payload system and the solutions for each system. The solutions the team came up with were based on the low-level functions of each structure. Once the problem was identified the solutions were inputted to the table. A concept can be generating by picking a solution from each category and combining them as one concept.

The order can be changed multiple times, which corresponds to 50 different concepts. The Morphological chart is shown below in Table 8.

Table 8: *Morphological Chart.*

Payload System	Solutions				
Structure	Shock absorbing foam	Wood	Airbag cushions	Nylon 12	Liquid crystal elastomers
Data Collection	Velocity, acceleration, apogee	Acceleration, apogee, orientation	Apogee, orientation, temperature	Orientation, temperature, velocity	Temperature, apogee, velocity
Transmission	Antenna attached to the nose cone	Antenna out of the bottom	No antenna	Antenna out of the nose	Antenna out of the side

Battle of Perspectives

The battle of perspectives method is a method of ideation that separates individuals into groups with each group having its own unique background or perspective. The groups then come up with various solutions to a problem. This allows the problem to be analyzed from different angles in hopes that the team can develop an array of diverse solutions. For this project, the team developed two main groups, 1) students in various STEM majors and 2) students in other majors.

Forced Analogy

In the process of Forced Analogy, we use a random set of arbitrary nouns to obtain different attributes from them and use these attributes to work towards a design solution. Our team used Force Analogy to determine which words we would use for this example. Each team member got a word and was told to get five attributes from their given noun. The results of this process a listed below in Table 8.

Table 8. Force Analogy words and attributes

Selected Words	Attributes				
Blender	Capacity	Attachment Capacity	Speed	Power	Material
Hammock	Fabric	Weight Capacity	Length	Hanging Mechanism	Portability
Satellite	Orbit Type	Solar Panels	Communicatio n	Payload	Thrusters
Helmet	Shell Material	Visor	Ventilation	Padding	Strap
Tire	Tread Pattern	Size	Load Rating	Speed Rating	Rubber Compound

Note: The attributes listed in the table are used to relate the selected words to our payload

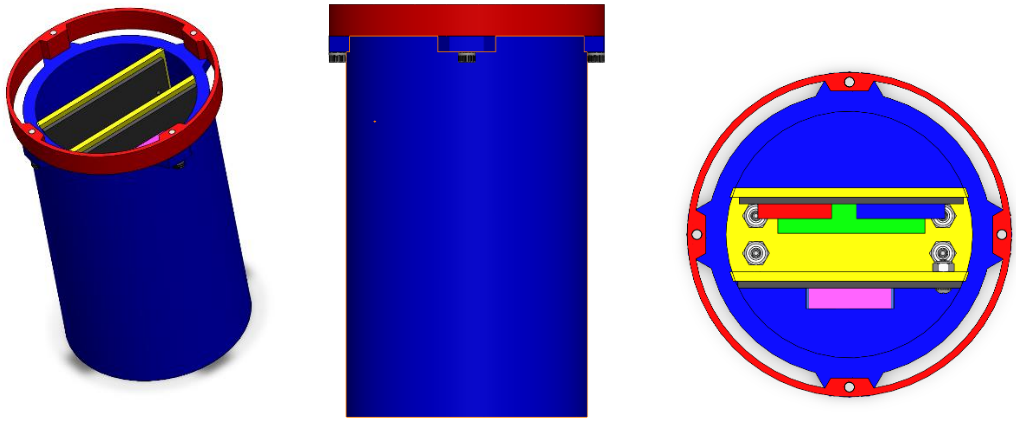
1.5.3 High-Fidelity Concepts

After 100 concepts were generated, 3 conceptual designs were chosen by the team to have a high probability of success.

Concept 1.

The first concept generated during the ideation process was a small cylindrical capsule mounted below the nosecone of the rocket. Inside the capsule houses the payload's electronic components. Figure 1 shows several views of this conceptual design.

Figure 1: *Isometric view (left), side view (middle), and top view (right) of high-fidelity concept 1*

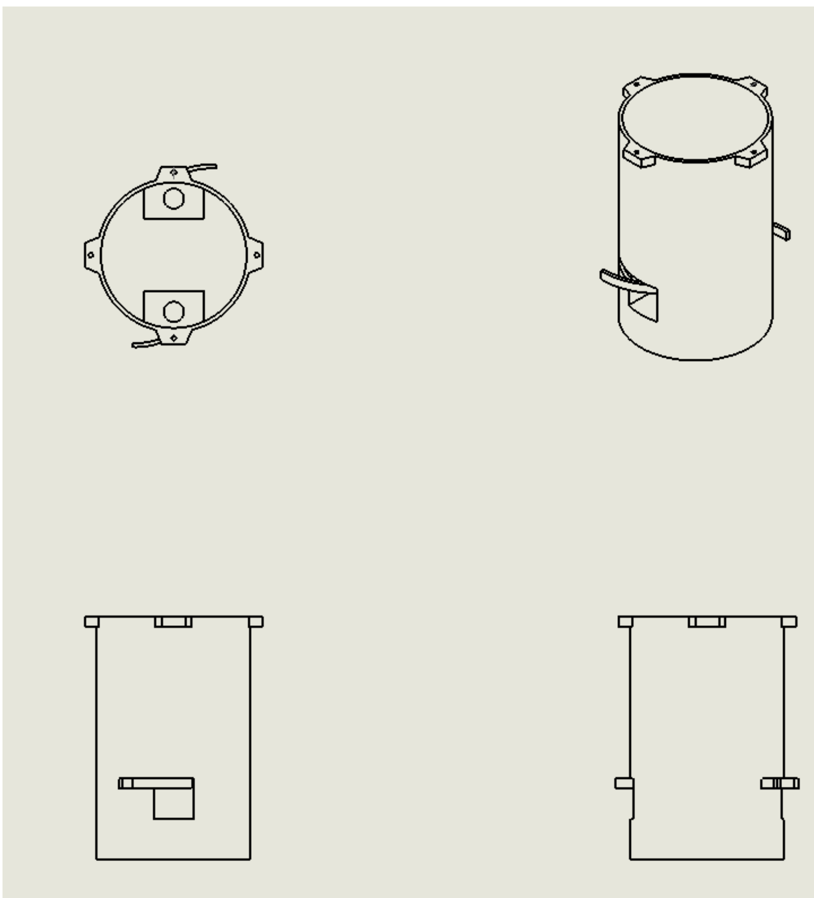


In red, the mounting bracket is shown. The bracket would be secured inside the bottom of the nosecone using a high strength epoxy. The payload capsule (blue) would fasten to the bracket with screws. A separator would mount inside the capsule to separate the payload into different chambers to house the electronic trays. These electronic trays would hold sensors, batteries, and RF modules for data collection and transmission. This design does not include a mechanism to physically deploy the radio antenna. The design assumes that the RF module can transmit through the structure; therefore, the antenna is permanently deployed within the capsule.

Concept 2.

Structurally, Concept 2 is like Concept 1, making use of a cylindrical capsule with electronic modules secured in trays. The major difference is that a deployable antenna extends through the nosecone and out of the top of the rocket. This will require that the radio module be mounted in the top-center of the capsule, as opposed to near the outside of the capsule like Concept 1. There will also be a linear motor positioned at the top of the capsule to extend the antenna. Because the rocket will always fall to its side upon landing, the antenna deployment will never be obstructed by the ground in this design. We are constrained to sub 5w transmissions by the rules of the competition. We hope to transmit from the inside of the payload bay (Concept 1) and will test if this is possible at <5W once the radio module arrives. Concept 2 allows for a simple deployable antenna but may have adverse effects on the rocket team. If a deployable antenna should be required, we will have to discuss with the rocket team before proceding.

Concept 3.



This Payload is not a complete redesign from concept 1. It is inspired by the original design utilizing the same flanges to attach it to the nose cone, which would have an aluminum bracket epoxied into it. This design would also allow for the electronic trays to also easily slide in and out of the payload like the original model. The Stemnauts would be placed in 4 different corners due to motors and flaps being added to this design. The Stemnauts would no longer be gathered in one compartment due to the motors and motor housing taking up those areas. The purpose of the servomotors is to actuate the flaps attached to the motor shafts. These arms are placed there in the event the payload and the rocket cone land in an awkward position inhibiting the radio antenna to transmit a signal. The arms would actuate pushing on the terrain it is in contact with, allowing the payload to reorientate itself on the ground to free the antenna from possible barriers that may disturb its data transmission. The flaps and antenna are flush with the payload body. Our team is unsure about the final configuration of the antenna due to us having to wait for the electronics delivery. This concept is designed for the circumstances of the radio transmission antenna having to protrude from the side of the payload. Our team will make our final decision with the rocket team, due to another viable option of sticking the antenna through the nose cone.

1.5.4 Medium Fidelity Concepts

Once the high-fidelity concepts were determined, 5 other concepts were labeled as medium-fidelity. This means that these concepts also have a high probability of success; however, they still have areas of concern for the team.

Concept 4.

One medium-fidelity concept would be adding another compartment to the payload to add more space to our payload. This would be done by using the two outer openings of the payload CAD as the place where we put all our sensors and STEMnauts in these compartments. This will allow us to have a separation in our components, so that there is more space for our different components to work without interference.

Concept 5.

The medium fidelity concept is a Payload structure made of shock absorbing foam with sensors that store velocity, acceleration, and apogee with an antenna that is sticking out of the top of the rocket to transmit data. This concept was generated from the morphological chart method.

Concept 6.

Concept 6 is a medium fidelity concept where all electronics modules would be integrated into a single custom PCB within the payload. This design would minimize space within the capsule, allowing more space for the STEMnauts or a smaller overall capsule.

Concept 7.

Concept 7 is a medium fidelity concept. In this concept, the payload's structure would be the nosecone of the rocket. The payload data collection and transmission systems would be mounted onto trays and these trays would slide into slots cut into the rocket's nosecone. Bolts to mount the electronic trays would come in from the outside of the nosecone. Plugs would then be used to cover the caps of the screws. The radio antenna would be permanently deployed from the tip of the nosecone.

Concept 8.

For Concept 8 would see the use of airbags to be able to cushion the fall of the payload onto the ground. This will help us avoid any significant damage to our payload and will help allow us to make sure our STEMnauts are secured and safe. To implement this we will place these airbags in the smaller compartments of our payload and implement a sensor to help detect some contact so that the airbags activate on time. This concept was generated from the crap shoot method.

1.5.5 Other Conceptual Designs

The team developed a total of 100 conceptual designs during the concept generation phase of this project. The complete list of all 100 designs can be found in Appendix D. This section of the report discusses 8 of the 100 designs. These 8 designs were determined to have the highest probability of success.

1.6 Concept Selection

1.6.1 Introduction

Once the team generated a large quantity of concepts, a detailed selection process was used to determine the best concept. The goal of this selection process was to use an analytical process to numerically derive the best concept based on competition requirements and engineering characteristics. This detailed selection process utilized tools like the House of Quality, Pugh charts, and an Analytical Hierarchy Process (AHP).

1.6.2 House of Quality

The House of Quality consist of two tables that compare customer needs to one another. These tables start the process of concept selection. Values from the binary pairwise table and house of quality table are used to be computated in other. The binary pairwise comparison table takes the customer needs and compares them against one another. The team evaluates which customer need is more significant. The number one represents the the most significant need in the comparison between the two customer needs and the number zero represents the least significant. They are across from one another in the diagonal matrix. This is done until the square matrix is full of ones and corresponding zeros. The rows and columns are then summed up. The sums display the relevance of each customer need, with the highest value being the most relevant. These values are displayed under the total column and are called the importance weight factors. This is a technique used to eliminate as much bias as possible, and it helps the group consider which needs emphasis should be placed on when it comes to project design.

The importance weights are taken from the binary pairwise table and are placed into the House of Quality along with the corresponding customer needs. The house of quality consist of customer needs and engineering characteristics. Engineering characteristics are targets that are highly important when it comes to the success of the design project. This table allows the team to go through and rate how much relevance an engineering characteristic has towards a particular customer need. The rate can either be a 1, 3, 5,7, or 9. The value of one is an indicator that the engineering characteristic does not have much relevance when it pertains to the specific customer need. The value of nine is an indication that there is high relevancy. The values in between are other levels of relevancy. Once this matrix is full, the ratings are multiplied by the corresponding importance weight. The ratings are summed up by column, resulting in a raw score for each engineering characteristic. These rawscores are then divided by the importance weight factor which is all of the rawscores summed up together. From this calculation relative wight percentage can be determined and the engineering characteristics can be ranked, the number one indicating the highest rank. These values can then be used in the Pugh Chart.

Table 1: *Binary pairwise comparison for payload customer needs*

Pairwise Comparison	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	Total
1. STEMnauts must be creative representations	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. The payload must transmit on a 2m-band	1	-	1	1	0	1	1	1	0	1	1	0	1	1	0	10
3. Payload must transmit at specific frequencies	1	0	-	0	0	1	1	0	0	0	0	0	1	1	0	5
4. Payload must be compatible with an FTM-300DR	1	0	1	-	0	1	1	1	0	1	1	0	1	1	0	9
5. Payload must abide by all NAR and FAA regulations	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	14
6. Payload must not protrude more than 0.25" from the rocket	1	0	0	0	0	-	1	1	0	1	1	0	1	1	0	7
7. Transmission of radio signal must be controlled by the operator	1	0	0	0	0	0	-	0	0	1	0	0	1	1	0	4
8. Payload must transmit at or below 5W of power	1	0	1	0	0	0	1	-	0	1	1	0	1	1	0	7
9. Payload must structurally withstand rocket's landing conditions	1	1	1	1	0	1	1	1	-	1	1	1	1	1	1	13
10. Payload must transmitt a variety of data	1	0	1	0	0	0	0	0	0	-	0	0	0	0	0	2
11. Payload must have an independent power source	1	0	1	0	0	0	1	0	0	1	-	0	1	1	0	6
12. Payload's electronics must be independent from rocket's	1	1	1	1	0	1	1	1	0	1	1	-	1	1	0	11
13. Location of payload must not negatively impact rocket's flight	1	0	0	0	0	0	0	0	0	1	0	0	-	0	0	2
14. Payload must not pull above the multitude of gravitational accelaration that a human can survive	1	0	0	0	0	0	0	0	0	1	0	0	1	-	0	3
15. Payload can withstand flight stresses	1	1	1	1	0	1	1	1	0	1	1	1	1	1	-	12
	14	4	9	5	0	7	10	7	1	12	8	3	12	11	2	n-1 = 14
Check	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	

Table 2: *House of Quality table for payload engineering characteristics*

		Engineering Characteristics										
Improvement Direction		↑	↓	↓	↓	↑	↑	↑	↑	-	↑	↓
Units		lbf	in	G	-	ft	G	∘C	G	MHz	Hz	W
Customer Needs	Importance Weight Factor	Fasten Payload	Secure STEMnauts	Disperse Impact Energy on STEMnauts	Disperse Impact Energy on Payload Body	Measure Altitude	Measure Accelaration	Measure Temperature	Measure STEMnaut Accelaration	Select Radio Frequency	Sample Sensors	Send Data Signal
1. STEMnauts must be creative representations	0	1	7	7	1	1	1	1	5	1	1	1
2. The payload must transmit on a 2m-band	10	1	1	1	1	5	5	5	5	9	5	9
3. Payload must transmit at specific frequencies	5	1	1	1	1	5	5	5	5	9	5	9
4. Payload must be compatible with an FTM-300DR	9	1	1	1	1	5	5	5	5	9	3	9
5. Payload must abide by all NAR and FAA regulations	14	7	3	5	5	3	3	3	7	3	3	5
6. Payload must not protrude more than 0.25" from the rocket	7	5	3	3	3	1	1	1	1	1	1	9
7. Transmission of radio signal must be controlled by the operator	4	1	1	1	1	3	3	3	3	7	3	3
8. Payload must transmit at or below 5W of power	7	1	1	1	1	3	3	3	3	5	5	9
9. Payload must structurally withstand rocket's landing conditions	13	9	9	9	9	1	1	1	1	1	1	1
10. Payload must transmitt a variety of data	2	1	1	1	1	9	9	9	9	1	9	7
11. Payload must have an independent power source	6	3	1	1	1	5	5	5	5	3	3	7
12. Payload's electronics must be independent from rocket's	11	3	1	1	1	9	9	9	9	5	9	3
13. Location of payload must not negatively impact rocket's flight	2	7	3	1	3	1	1	1	1	1	1	1
14. Payload must not pull above the multitude of gravitational accelaration that a human can survive	3	3	9	9	7	1	1	1	1	1	3	1
15. Payload can withstand flight stresses	12	7	5	5	9	1	1	1	1	1	1	1
Raw Score	3092	445	327	351	397	379	379	379	435	433	369	543
Relative Weight Percent (%)		14.39	10.58	11.35	12.84	12.26	12.26	12.26	14.07	14.00	11.93	17.56
Rank Order		2	11	10	5	6	6	6	3	4	9	1

1.6.3 Pugh Charts

The Pugh chart compares concepts to a datum using top engineering characteristics. The datum is a reference concept that the team came up with. The engineering characteristics for Pugh chart one was the top five engineering characteristics from the House of Quality (HOQ). The teams high and medium fidelity concepts that were generated from concept selection were the eight concepts used in the Pugh chart. The datum was chosen based on a design idea that the Zenith club came up with. The datum was a rectangular aluminum tubing in which sensors are mounted to the inner walls of the tubing. A flange is welded to the top of the rectangular tubing and screws connect the flange to the nosecone of the rocket. Each concept was then compared to the engineering characteristics of the datum. If both the concept and the datum were the same as satisfying the engineering characteristic the cell would get an "S". If the concept was better than the datum, the cell would get a "+" and if the concept was worse than the datum it would get a "- ". The Number of minuses and pluses were then summed up for each concept, which would influence Pugh chart 2. Pugh chart 1 is shown below in Table 3

Selection Criteria	Criteria Weight	Zenith 1 Rectangular Prism Design	Concepts							
			Cylindrical capsule below nosecone, electronic trays to house sensors, fixed antena, single custom PCB	Cylindrical capsule, electronic trays to house sensors, deployable antenna out top of rocket	Cylindrical capsule below nosecone, electronic trays to house sensors, flaps on payload to reorientate payload while on the ground	Cylindrical capsule, an extra tray to house the stemnauts and sensors independently, mounts to nosecone	Shock absorbing foam, storing velocity, acceleration, apogee, antenna sticking out the top of rocket	Cylindrical capsule , electronic modules all separate	Data collection and transmission mounted onto trays that slide into nosecone of the rocket, bolts would mount the trays, antenna permantly deployed from the noseconse	Airbag cushion structure , compartments for the sensors and STEMnauts, and a fixed antenna
Send Data Signal	17.56%	Datum	S	+	S	S	S	S	S	S
Fasten Payload	14.39%		+	+	S	S	S	S	-	-
Measure STEMnaut Acceleration	14.08%		+	S	S	-	S	+	S	-
Select Radio Frequenecy	14.00%		S	S	S	S	S	+	S	S
Disperse Impact Energy on Payload Body	12.84%		+	+	-	+	+	S	-	+
Number of (+)			3	3	0	1	1	2	0	1
Number of (-)			0	0	1	1	0	0	2	2

Table 3: *Pugh chart 1 for payload conceptual designs*

Pugh chart 2 takes the concept that has a moderation of plusses and minuses and uses it as the datum for its comparison. The engineering characteristics remain the same for the chart, but the concepts in the chart are the top four concepts (most number of plusses) from Pugh chart one. The top three concepts from Pugh chart 2 move onto the Analytical Hierarchy Process (AHP). Pugh chart 2 is shown below in Table 4.

Selection Criteria	**Criteria Weight**	**Cylindrical capsule, an extra tray to house the stemnauts and sensors independently , mounts to nosecone**	**Concepts**			
			Cylindrical capsule below nosecone, electronic trays to house sensors, fixed antenna, single custom PCB	Cylindrical capsule, electronic trays to house sensors, deployable antenna out top of rocket	Shock absorbing foam, storing velocity, acceleration, apogee, antenna sticking out the top of rocket	Cylindrical capsule , electronic modules all separate
Send Data Signal	17.56%	Datum	S	+	S	S
Fasten Payload	14.39%		+	S	-	S
Measure STEMnaut Acceleration	14.08%		S	S	S	+
Select Radio Frequenecy	14.00%		S	S	S	S
Disperse Impact Energy on Payload Body	12.84%		+	S	+	S
Number of (+)			2	1	1	1
Number of (-)			0	0	1	0

Table 4: *Pugh chart 2 for payload conceptual designs*

1.6.4 Analytical Hierarchy Process

This section discusses the team's Analytical Hierarchy Process. This process was used to determine the final concept selection and to show consistency within the team's criteria and metrics. The first step in the Analytical Hierarchy process is to rate the criteria against each other in the criteria comparison matrix as shown in Table 5. In this matrix, each criterion is compared to every other by assigning relative importance weights. A weight greater than one indicates that the row criterion is more important than the column criterion. The weight of the antidiagonal entry to a given entry (same criterion but row and column switched) must be the reciprocal of the given entry. All integer entries must be odd numbers less than 10 (1,4,5,7,9). Odd numbers are chosen so that division by zero does not occur. The sum of the columns gives the 'loss' of each criterion. Criteria with a small value are deemed to be most important and those with a larger are deemed less important. Table 5, the team determined that Disperse Energy on Payload Body and Fasten Payload were the most important criteria.

Table 5: *Criteria comparison matrix*

Criteria Comparison Matrix [C]					
Selection Criteria	#1	#2	#3	#4	#5
1. Send Data Signal	1.00	0.33	5.00	1.00	0.20
2. Fasten Payload	3.00	1.00	5.00	5.00	1.00
3. Measure STEMnaut Acceleration	0.20	0.20	1.00	0.20	0.14
4. Select Radio Frequency	1.00	0.20	5.00	1.00	0.33
5. Disperse Energy on Payload Body	5.00	1.00	7.00	3.00	1.00
Sum	10.20	2.73	23.00	10.20	2.68

Table 6 is a normalized version of Table 5. In this table, sums are taken along the rows, which makes larger values correspond to higher importance. All values are also normalized so that they sum to 1. In this table, the result for each criterion can be thought of as its fractional importance of the total importance.

Table 6: *Normalized criteria comparison matrix*

Normalized Criteria Comparison Matrix [NormC]						
Selection Criteria	#1	#2	#3	#4	#5	Criteria Weights {W}
1. Send Data Signal	0.098	0.122	0.217	0.098	0.075	0.122
2. Fasten Payload	0.294	0.366	0.217	0.490	0.374	0.348
3. Measure STEMnaut Acceleration	0.020	0.073	0.043	0.020	0.053	0.042
4. Select Radio Frequency	0.098	0.073	0.217	0.098	0.125	0.122
5. Disperse Energy on Payload Body	0.490	0.366	0.304	0.294	0.374	0.366
Sum	1.000	1.000	1.000	1.000	1.000	1.000

Table 7 is used to check the relative importances from Table 5 for internal consistency. It is important that paradoxical comparisons not be made. For instance, it would be nonsensical to say that A is greater than B, which is greater than C, and then also say that C is greater than A. Table 7 uses a consistency vector to check that the entries to Table 5 are consistent.

Table 7: *Consistency check for criteria comparison matrix*

Consistency Check		
{Ws}=[C]{W}	{W}	Cons={Ws}./{W}
Weighted Sum Vector	Criteria Weights	Consistency Vector
0.643	0.122	5.267
1.900	0.348	5.457
0.213	0.042	5.080
0.645	0.122	5.277
1.984	0.366	5.425

From Table 7, the random index values can be determined. For consistency, CI, must be less than 0.11, which is the case in Table 8. There are other values in Table 8 that characterize the data, but it is CL that is most important when determining consistency.

Table 8: *Random index values for criteria comparison (Used for consistency check)*

Random Index Values (RI)	
λ	5.301
RI	1.110
CI	0.075
CR	0.068

Finaly, once the criteria weighing has been determined to be consistent, the criteria ratings for each concept, as determined in previous sections, can be used to determine the final concept. These results are pictured in Tables 10 and 11 and are discussed in detail in section 1.6.5.

Table 10: *Final rating matrix for all AHP concepts*

Final Rating Matrix			
Selection Criteria	Concept 1	Concept 2	Concept 3
1. Send Data Signal	0.200	0.600	0.200
2. Fasten Payload	0.480	0.405	0.115
3. Measure STEMnaut Acceleration	0.480	0.405	0.115
4. Select Radio Frequency	0.260	0.633	0.106
5. Disperse Energy on Payload Body	0.633	0.260	0.106

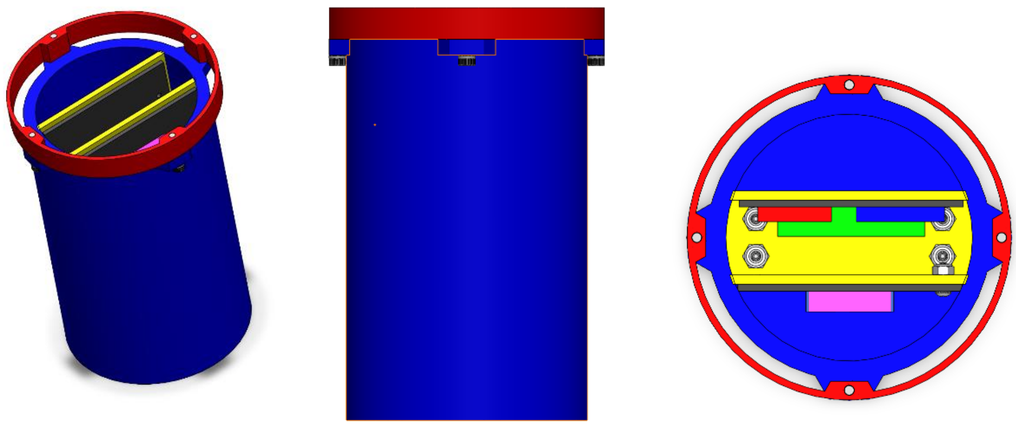
Table 11: *Alternate values for all AHP concepts*

Concept	Alternate Value
Cylindrical capsule below nosecone, electronc trays to house sensors, fixed antena, single custom PCB	0.475
Cylindrical capsule, electronic trays to house sensors, deployable antenna out top of rocket	0.404
Cylindrical capsule , electronic modules all separate	0.121

1.6.5 Final Selection

After completing the entire concept selection process, the concept with the highest rating from the final rating matrix in the AHP was Concept #1 from the team's high-fidelity concepts. Figure 1 shows several views of this design.

Figure 1: *Isometric view (left), side view (middle), and top view (right) of final payload design*



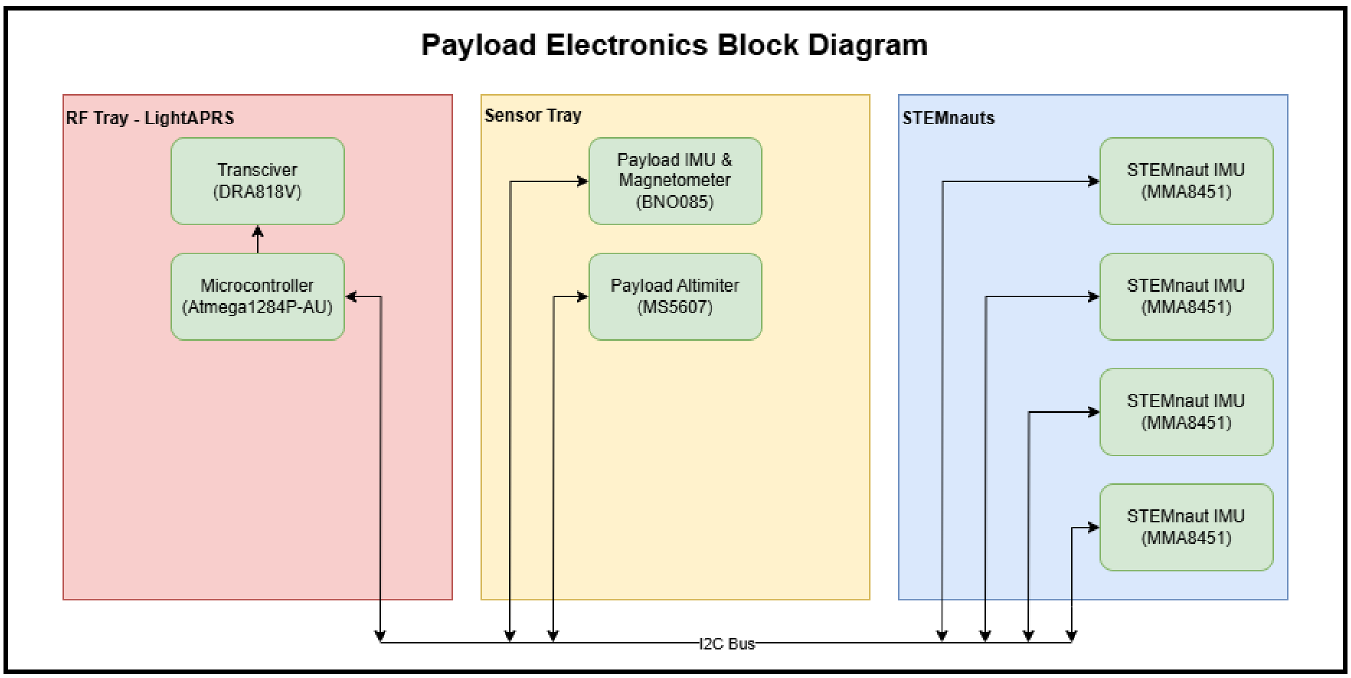
Structural Design

This design includes a Nylon-12 cylindrical capsule that mounted to an aluminum bracket secured in the rocket's nosecone. In Figure 1, the aluminum bracket is shown in red, and the capsule is shown in blue. The bracket will be imbedded into the bottom of the rocket's nosecone. It will be secured in this position with a high strength epoxy. The bracket will have threaded holes for the capsule to mount to. The capsule will be 3D-printed using FSU Innovation Hub's Nylon-12 3D Printer. Inside the payload capsule, it is broken up into three chambers. These chambers are separated by a custom aluminum divider. In Figure 1, this divider is shown in yellow. The divider will be machined from 0.125" thick aluminum flat stock by the FAMU-FSU College of Engineering Machine Shop. The electronics systems of the payload will be secured on 0.09" thick aluminum electronic trays and those trays will be mounted to the flat walls of the aluminum divider. The STEMnauts will be housed in the bottom most chamber shown in the top view of Figure 1.

Data Collection and Electronics Design

This design separates sensor modules into individual breakout boards. These boards will be located on the RF tray, Sensor Tray and on the STEMnauts themselves. Figure 2 shows a block diagram of the electronics. This diagram illustrates the locations of each module and how they communicate on an I^2C Bus.

Figure 2: *Final payload electronics block diagram.*

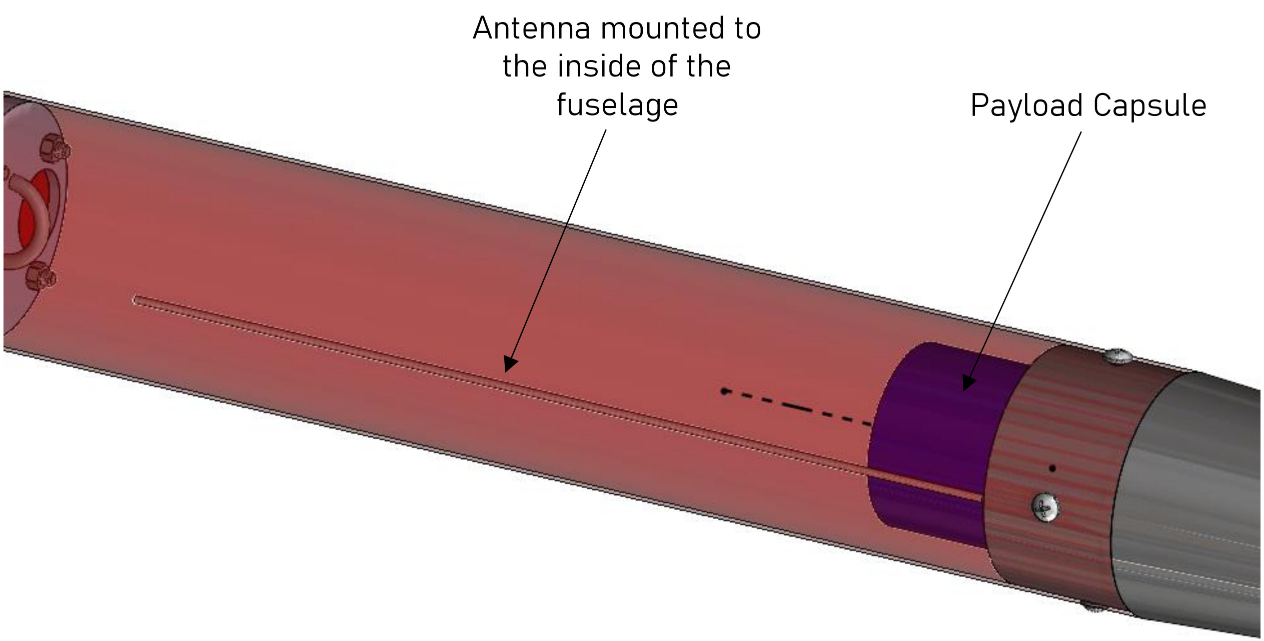


Transmission Design

The final design of the payload transmission system utilizes a fixed antenna and the LightAPRS RF module. The antenna will be mounted to the fuselage of the rocket as pictured in Figure 3.

Figure 3: *Final design of fixed antenna configuration*

This antenna will be sufficiently thin so as not to



interfere with the packing of the main parachute that is stored in the forward section. This antenna will be connected directly to the LightAPRS RF module inside of the payload.

1.8 Spring Project Plan

1.8.1 Introduction

The team will do extensive planning for the spring semester, which includes some things like doing the CDR, flight readiness review, and the post launch assessment. In addition to this there will be planning for senior design assignments for things like VDR, Senior design day April 1st, and other team assignments. These plans will be put into a work breakdown structure chart.

1.8.2 Subscale Mass Simulant

The subscale flight will occur on December 14th and a payload mass simulant will be housed inside the rocket for testing. The mass simulant will be printed out of PLA and will be sized down 40 percent. The simulant will just consist of the capsule and will not house electronics. The reason for the simulant is to give the rocket team more data to test how they would fly when actual mass is added to the subscale. The launch will also give the payload team feedback on how the PLA holds upon landing and will let the team see if it can be an alternative to Nylon-12. The mass simulant will be printed by November 26th so the rocket and payload team can plan around any unexpected errors with the print or additional steps to take for the launch.

1.8.3 Testing and Fabrication

Testing and fabrication have already begun as of the writing of this document and will continue into the spring semester. We have a 3D printed a prototype of the payload structure and all primary payload electronics components have been obtained. A subscale mass simulant will be printed by November 26th. This mass simulant will fly on the subscale launch on December 14th and will verify the payload's role in the rocket stability. In the Spring, an FEA will be conducted on to verify the strength of final design and then fabrication will begin. The final version of the payload structure will be printed at the FSU Innovation Hub out of nylon 12. The aluminum mounting bracket and trays will be machined at the FAMU-FSU College of Engineering machine shop. The final version will be subjected to a fit test, drop test, and mounting test. The success of all these tests will allow the payload to be deemed safe to fly. The payload electronics will also be extensively tested in the spring. Transmission attenuation tests will be conducted to verify the theoretical predictions we have made. Range tests will also be conducted to determine the payloads transmission range. The accuracy of our sensors will also be tested early in the semester, allowing us to replace any components that are not working as expected/advertised. A power consumption test will be conducted to determine the size and quantity of lithium polymer batteries that the payload will fly with. A full system flight simulation test will be conducted to verify our flight software, data collection and transmission. A final assembly test will be conducted prior to competition to ensure that the payload can be constructed and armed within the time allotted in the competition.

1.8.4 Critical Design Review

The Critical Design Review (CDR) is the final design of both the rocket and payload systems. In this presentation and report both the rocket and payload team must show all their efforts in the project such as full-scale fabrication, assembly, and integration. From the Payload team, we must be able to show that the design is complete and can be integrated into the rocket. This may be demonstrated through the report and presentation by explaining our design on a system level and how it interacts within the payload and with the rocket itself. We must also elaborate on the payload's electronics using schematics, block diagrams, and explaining how we are powering the payload. There is also an emphasis on the safety of the payload using switches and wattage indicators to make sure the payload is working fine the whole flight and is not a danger to itself or the rocket. We will then explain why we choose all the dimensions and materials for our project and what makes our payload unique. We must submit all of this by January 8th, 2025, and we will have our teleconference presentation between January 15th, 2025 – February 6th, 2025.

1.8.5 NASA Student Launch Competition

The NASA Student Launch Competition is an annual event held in Huntsville, Alabama. It is an event organized to allow colleges, universities, and other institutions from across the nation to design, build, launch, and fly a rocket and payload to assist NASA in their research of high-powered rockets. This is a 9-month process of being able to design, create, and fly a rocket and payload into the sky. As the payload team we can focus solely on the payload aspect of this project. Our objective is to build a payload that houses both sensors and STEMnauts, which are miniature astronauts, that will be able to transmit data, collected from the flight, over a certain radio frequency back to the NASA-owned data transceiver. We must also be able to protect our sensor and STEMnauts from any possible damage throughout the flight and ensure the safety and survivability of our STEMnauts. The rocket launch is set for the first weeks of April from Palm Bay Florida. This is because we will not be able to attend the Rocket launch in Huntsville, Alabama in early May due to graduation.

1.8.6 Senior Design Deliverables

There will be three Virtual Design Reviews for our spring semester. Our group will conclude our project, and on April 1st we will present our final physical product along with also presenting our design on a poster board on Engineering Design Day. This day will allow our team to give an in-depth explanation of how our project was conducted from start to finish. On

Engineering Design Day we'll be able showcase a fully operational rocket payload that was once an idea. Our team will be able to take individuals through the story of the highs and lows of creating a payload capsule. We'll be able to explain who we were able to work alongside a separate rocket team and alongside teammates whose studies differed from one another at the FAMU-FSU College of Engineering.

Our team will have final exams May 1st to finish the spring semester for the courses we are enrolled in. We will display the knowledge we retained throughout the spring semester in the final exams we take. The success of those final exams and our overall grades at the end of the spring semester will dictate the next step which is graduation.

Our team will conclude our senior design projects, and we will finish our spring semester. They will lead us to graduation on May 3rd with our bachelor's in mechanical engineering and electrical engineering.

1.8.7 Work Breakdown Structure

Shown below is the work breakdown structure (WBS) for the team's spring semester. This document breaks down the tasks and timeline for all testing and fabrication tasks for the payload. This WBS will allow for the team to complete all necessary tasks while allowing for enough time to correct errors and iterate the final design.

Figure x: Work breakdown structure for the spring semester.

T509: NASA Student Launch (Payload) Spring Work Breakdown Structure						
Tier One Tasks	**Tier Two Tasks**	**Tier Three Tasks**	**Asignee**	**Story Point (days)**	**Status**	**Due Date**
1. Electronic Systems	**1.01 Radio Testing**				IN PROGRESS	12/6/2024
		1.01.001 Obtain HAM Radio Liscense	Nathan & Neil	2	☑	
		1.01.002 Setup Reciver	Neil	2	☐	
		1.01.003 Attach Antena to radio module	Matthew	1	☐	
		1.01.004 Program Radio module to send simple transmossion	Nathan	2	☐	
		1.01.005 Test Simple Transmission	Donovan	2	☐	
		1.01.006 Program Radio module to send APRS Telemtry packets	Nathan	2	☐	
		1.01.007 Test APRS Telemetry packet transmission	Neil	2	☐	
		1.01.008 Test Long range Transmission	Kyle	2	☐	
		1.01.009 Test Obstructed Long Range Transmission	Nathan	2	☐	
	1.02 IMU Testing				INCOMPLETE	1/1/2025
		1.02.001 Establish I2C communication bus between IMU and microcontroller	Neil	2	☐	
		1.02.002 Write software to sample, filter and log incoming IMU Data	Nathan	3	☐	
		1.02.003 Test IMU's Motion detection	Matthew	2	☐	
	1.03 Altimeter Testing				INCOMPLETE	1/13/2025
		1.02.001 Establish I2C communication bus between Altimiter and microcontro	Neil	2	☐	
		1.03.002 Write software to sample, filter and log incoming Altimiter Data	Nathan	3	☐	
		1.03.003 Write Software to sample temperature Data	Neil	2	☐	
		1.03.004 Test Altimiter temperature and barometric readings	Matthew	2	☐	
		1.03.005 Test that altimiter is sufficently shielded form light in its position on t	Kyle	1	☐	
	1.04 Finilze Code				INCOMPLETE	2/3/2025
		1.04.001 Write Payload payload OS that coordinates all sensors and program	Nathan	5	☐	
		1.04.002 Write flight software to regnize and react to flight milestones	Neil	7	☐	
		1.04.003 Write Transmission program	Nathan	5	☐	
		1.04.004 Test all code individually	Neil	5	☐	
		1.04.005 Test integrated code	Kyle	4	☐	
	1.05 Tray one Assembly				INCOMPLETE	2/3/2025
		1.05.001 Design wiring harness	Neil	2	☐	
		1.05.002 Assembly wiring harness	Kyle	2	☐	
		1.05.003 Secure sensors	Donovan	1	☐	
		1.05.004 Test components	Nathan	1	☐	
	1.06 Tray Two Assembly				INCOMPLETE	2/3/2025
		1.06.001 Design wiring harness	Nathan	2	☐	
		1.06.002 Assembly wiring harness	Matthew	2	☐	
		1.06.003 Secure sensors	Donovan	1	☐	
		1.06.004 Test components	Neil	1	☐	
	1.07 STEMnaut Bay Assembly				INCOMPLETE	2/10/2025
		1.07.001 Design wiring harness	Nathan	2	☐	
		1.07.002 Assembly wiring harness	Neil	2	☐	
		1.07.003 Secure sensors	Donovan	1	☐	
		1.07.004 Test components	Nathan	1	☐	
2. Structural and Mechanical Systems	**2.01 Prototype Assembly**				IN PROGRESS	12/3/2024
		2.01.001 Print mounting bracket	Donovan	1	☑	
		2.01.002 Print capsule	Kyle	1	☑	
		2.01.003 Print divider	Matthew	1	☑	
		2.01.004 Print trays	Kyle	1	☑	
		2.01.005 Order fasteners	Kyle	3	☐	
		2.01.006 Assemble Structure	Matthew	1	☐	

	2.02 Structual Testing				INCOMPLETE	1/6/2025
		2.02.001 Prototype fit-check	Kyle	1	☐	
		2.02.002 Prototype drop test	Donovan	2	☐	
		2.02.003 Record test results	Donovan	1	☐	
		2.02.004 SolidWorks FEA	Matthew	1	☐	
	2.03 Manufacturing Request				INCOMPLETE	1/25/2025
		2.03.001 Order raw material	Kyle	5	☐	
		2.03.002 Machine mounting bracket	Kyle	1	☐	
		2.03.003 Machine divider	Kyle	1	☐	
		2.03.004 Print capsule	Matthew	1	☐	
		2.03.005 Receive mounting bracket	Kyle	5	☐	
		2.03.006 Receive divider	Kyle	5	☐	
		2.03.007 Receive capsule	Matthew	2	☐	
	2.04 Quality Check				INCOMPLETE	1/27/2025
		2.04.001 Inspect mounting bracket	Kyle	1	☐	
		2.04.002 Inspect divider	Donovan	1	☐	
		2.04.003 Inspect capsule	Matthew	1	☐	
		2.04.004 Draft report	Donovan	1	☐	
	2.05 Assemble Structure				INCOMPLETE	2/3/2025
		2.05.001 Assemble chamber one	Nathan	1	☐	
		2.05.002 Assemble chamber two	Neil	1	☐	
		2.05.003 Assemble chamber three	Nathan	1	☐	
3. Senior Design						
	3.01 VDR 4				INCOMPLETE	TBD
		3.01.001 Create slide deck	Kyle	5	☐	
		3.01.002 Edit slide deck	Matthew	2	☐	
		3.01.003 Schedule practice presentations	Nathan	1	☐	
		3.01.004 Submit slide deck	Donovan	1	☐	
	3.02 VDR 5				INCOMPLETE	TBD
		3.02.001 Create slide deck	Matthew	5	☐	
		3.02.002 Edit slide deck	Nathan	2	☐	
		3.02.003 Schedule practice presentation	Donovan	1	☐	
		3.02.004 Submit slide deck	Neil	1	☐	
	3.03 VDR 6				INCOMPLETE	TBD
		3.01.001 Create poster	Nathan	5	☐	
		3.01.002 Edit poster	Donovan	2	☐	
		3.01.003 Schedule practice presentations	Neil	1	☐	
		3.01.004 Submit presentation	Kyle	1	☐	
	3.04 Final Report				INCOMPLETE	TBD
		3.04.001 Edit chapter one	Donovan	3	☐	
		3.04.002 Edit chapter two	Neil	2	☐	
		3.04.003 Abstract	Kyle	1	☐	
		3.04.004 Format	Matthew	2	☐	
		3.04.005 Complete edit	Nathan	2	☐	
		3.04.006 Submit report	Donovan	1	☐	
	3.05 Engineering Design Day				INCOMPLETE	4/1/2025
		3.05.001 Create poster	Neil	5	☐	
		3.05.002 Edit poster	Kyle	2	☐	
		3.05.003 Table Set-up	Matthew	1	☐	
		3.05.004 Present	Nathan	1	☐	

Chapter Two: EML 4552C

2.1 Spring Plan

Project Plan.

Build Plan.

Appendices

Appendix A: Code of Conduct

Overview:

This Code of Conduct states the rules and expectations for Team 509: NASA Student Launch (Payload). This document will apply to the entity of the 2024-2025 Senior Design Project. This document will be updated throughout the project according to the amendment process discussed later in this document.

Mission Statement:

Our mission is to build a successful payload experiment that meets all requirements of the NASA student launch competition and furthers innovation in the field of aerospace.

Outside obligations:

Matthew Archibald:

Outside obligations include being a TA for EML 3012L and EML 3012, as well as being a part of the FAMU-FSU AIAA chapter.

Donovan Dwight:

Outside obligations include Interning at the FSU's Facilities Plant, being a member of FAMU-FSU chapter of AIAA.

Nathan Hardie:

Outside obligations include classes and employment as an LA.

Kyle Mahoney:

Outside obligations include internship with private company and membership with the, FAMU-FSU Chapter of AIAA.

Neil Maldonado:

Outside obligations include being a member of SHPE, Attending a SHPE Convention from Oct. 30th – Nov. 3rd, A member of Phi Delta Theta Tau Fraternity, Senior Course Load, and work as a House Manager at the Southern Scholarship Foundation.

Team Roles:

All Team Roles have been assigned, but each member will have to split efforts into other areas of work throughout the project as need be. The team role explicitly states who is responsible for each role and the operations.

Team Member	**Team Role**
Matthew Archibald	Payload Fabrication Engineer
Donovan Dwight	Payload Test Engineer
Nathan Hardie	Communications Systems Engineer
Kyle Mahoney	Payload Structural Engineer
Neil Maldonado	Data Systems Engineer

Payload Structural Engineer Description:

The Payload Structural Engineer will be responsible for all CAD of the project. The Payload Structural Engineer will be using Finite Element Analysis (FEM) to run simulations on the payload. The Payload Structural Engineer will also be responsible for doing hand calculations and verifying the answers and results in simulations. The Payload Structural Engineer will work side by side with the Payload Test Engineer to verify results conducted from testing.

Payload Test Engineer Description:

The Payload Test Engineer is responsible for researching testing rigs and setting up the appropriate test for the rocket nose cone, separation stage, and payload. These tests will consist of impacts, and displacement of different systems. Rigs will utilize sensors, 3D prototype components of the launch vehicle, and any other means of testing to ensure safe delivery of the payload. The Payload Test Engineer will share results and discuss if improvements are needed. Ensuring the vehicle can separate successfully and survive impact forces is the top responsibility for the Payload Test Engineer.

Communications Systems Engineer Description:

The Communications Systems Engineer is responsible for the design of the radio communications systems on the payload. They will be responsible for selecting appropriate hardware, implementing communication protocols, and adhering to regulatory requirements for radio devices.

Payload Fabrication Engineer Description:

The Payload Fabrication Engineer is responsible for the fabrication of Payload designs and testing equipment. Payload Fabrication Engineering will be responsible for the procurement of materials and detailing the assembly process. The fabrication engineer will work alongside all other members of the team to determine the best process for fabricating various elements of the design.

Data Systems Engineer Description:

The Data System Engineer is responsible for managing, acquiring, transmitting, and interpreting all data collected for the during the flight of the project. The Data System Engineer will work closely with others to acquire data important for both the creation of the rocket and the construction of the Payload. This means using different sensors and data collecting methods to then analyze the data to check the performance of the rocket and payload system.

Communication

Communication between team members will occur in four different modes: GroupMe, Outlook email, text, and phone call. GroupMe will be for all informal, day-to-day communication. Text and phone calls are used only for time-sensitive communication between team members. Outlook email will be used for all communication between the team, and outside entities, and used for formal communication between team members. The barrier between formal and informal communication between team members is at the discretion of the team member starting the communication.

When preparing for a professional meeting, communication will be discussed between the team members. Important questions to be asked, and the team members to ask a specific question, will be determined by the team as a whole BEFORE the professional meeting occurs.

Dress Code

The dress code for the 509 senior design team will be dress shirt, khaki pants, a tie, a belt, and dress shoes for presentations. The tie colors will be either navy blue, black, or red. The dress code for meetings with sponsors will be business casual, which includes a collared shirt with pants. For senior design day the dress code will be the same as presentations.

Attendance Policy

There will be team meetings on Tuesdays and Thursdays following the Mechanical engineering senior design class. All team members will be present for these meetings. Team members will be present at the Zenith club meeting on Fridays at 5:00 PM.

Throughout the semester, there will be advisor, sponsor, and various other meetings that include individuals that are not direct members of this team. All members of the team are expected to be present for these meetings as well. The scheduling process for these meetings will occur during the weekly team meetings and will work to accommodate each team members' outside obligations.

If a team member is absent from two consecutive meetings, and does not provide a valid excuse, one of the following penalties will be applied: 200 pushups, 50 pull ups, or a 3-mile run. For each infraction, one of the three penalties will be chosen through a game of chance. The other team members are free to interfere with the convict as they complete their penalty in any way they see fit. Penalties will be adjudicated and completed within 2 weeks of the infraction.

Conflict Protocol

If issues arise during the senior design project they will be brought to the entire team. The problems will be addressed in front of the whole team. If the same problem occurs an in-person formal meeting will be conducted with the team. The third strike will lead to a team meeting with Dr. McConomy. Dr. McConomy will regroup the team and will evaluate further grading polices for each of the team members. He will be involved in restructuring the workload for each team member. Dr. McConomy will also give constructive feedback on what the team can do to fix further issues. He will be involved in restructuring the workload for each team member.

Amendment Process

If a team member petitions for an amendment to the Code of Conduct, it will be their responsibility to contact all team members regarding their petition. Team member that is petitioning for an amendment will be given the opportunity to argue their stance. Any and all amendments to this code of conduct must be approved by a super majority vote of 4/5 team members. All iterations of the document will be saved with the list of team member votes that approved of them. The responsibility of editing the document will fall upon the team member that first petitioned for the amendment.

Personality Type

Matthew Archibald:

Matthew Archibald was an ESFJ personality type. Matthew scored the highest in the extravert category followed by sensing, feeling, and judging.

Nathan Hardie:

Nathan Hardie got INTP personality type.

Donovan Dwight:

Donovan Dwight was an ENTJ personality type. Has the lowest extravert score, but is intuitive, judging, and thinking.

Neil Maldonado:

Neil Maldonado got ENFJ personality type. People with ENFJ personality are usually optimistic and great leaders as they tend to help others to a common goal.

Kyle Mahoney:

Kyle Mahoney was determined to be an ENFJ personality. This means he is optimistic, thoughtful, and idealistic.

Signatures
This document applies to all members of this team. By signing this document, I agree to abide by all aspects of the Code of Conduct.

X. *Kyle Mahoney* Date: 1/9/25
X. *Neil Maldonado* Date: 1/9/25

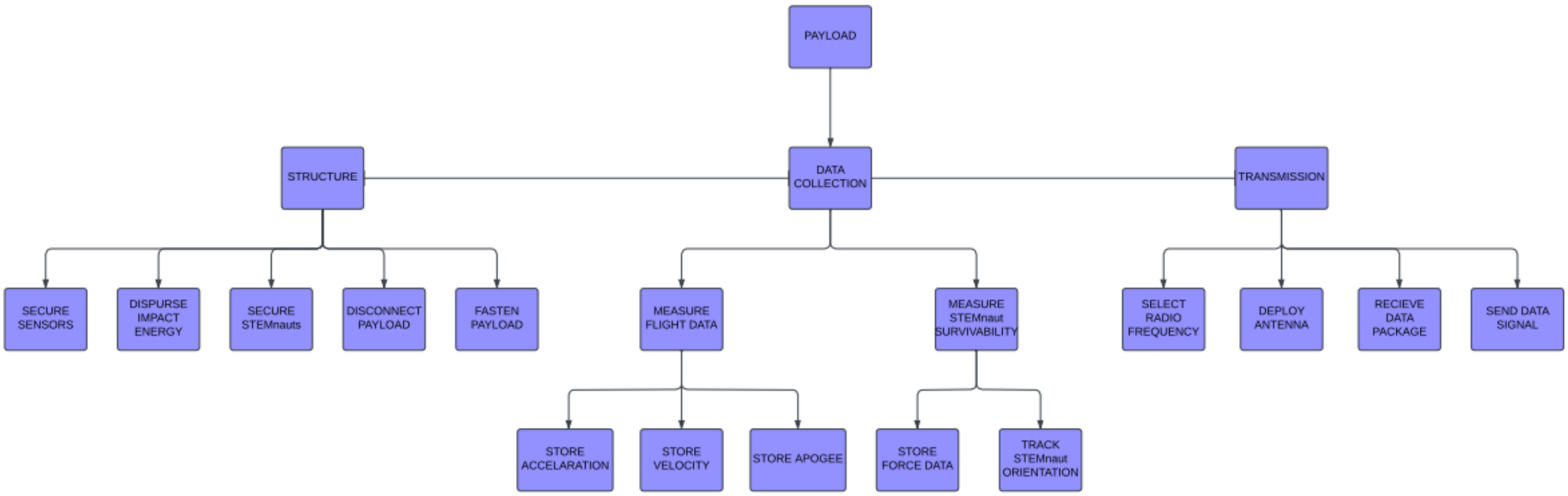
<u>X. *Donovan Dwight*</u> Date: 1/9/25
<u>X. *Matthew Archibald*</u> Date: 1/9/25
<u>X. *Nathan Hardie*</u> Date: 1/9/25

Appendix B: Functional Decomposition

Table 2: Cross – reference table of launch vehicle payload functions and systems

Functions	**System**		
	Structure	Data Collection	Transmission
Disperse Impact Energy	X		
Secure STEMnauts	X		
Disconnect Payload	X		
Fasten Payload	X		
Secure Sensors	X	X	X
Store Acceleration		X	X
Store Velocity		X	X
Store Apogee		X	X
Store Force Data		X	X
Track STEMnaut Orientation	X	X	
Select Radio Frequency			X
Deploy Antenna	X		X
Receive Data Package		X	X
Send Data Signal		X	X
Total:	7	8	9

Figure 1: Hierarchy Chart for Payload Project



Appendix C: Target Catalog

Function	Target	Metric

Fasten Payload	41.02 lbf	Pull out load
Disconnect Payload	10 min	Time
Secure STEMnauts	0.09 in	Physical Displacement
Isolate Altimeter	45°	Angle of Direct Light
Shield RF Electronics		Electronic Interference
Disperse Impact Energy on STEMnauts	9 G	Acceleration
Disperse Impact Energy on Payload Body	2	Degree of Damage
Measure Power	0-12 V	Measurement Range
Measure Altitude	0-5500 ft	Measurement Range
Measure Acceleration	0-10 g	Measurement Range
Measure Temperature	0-38 Celsius	Measurement Range
Store Flight Data	16 KB	Memory
Measure STEMnaut Orientation	3	Degrees of Freedom
Measure STEMnaut Acceleration	0	Measurement Range
Select Radio Frequency	144-148 MHz	Frequencies of Operation
Deploy Antenna	5000 ft	Transmission Range
Sample Sensors	10 Hz	Sample Frequency

Appendix D: Concept Generation Table

Concept No.	Description
1	A shock-absorbing foam structure that measures velocity, acceleration, and apogee, with an antenna attached to the nose cone.
2	A shock-absorbing foam structure that measures velocity, acceleration, and apogee, with an antenna extending out of the bottom.
3	A shock-absorbing foam structure that measures velocity, acceleration, and apogee, with no antenna.
4	A shock-absorbing foam structure that measures velocity, acceleration, and apogee, with an antenna extending out of the nose.
5	A shock-absorbing foam structure that measures velocity, acceleration, and apogee, with an antenna extending out of the side.
6	A shock-absorbing foam structure that measures acceleration, apogee, and orientation, with an antenna attached to the nose cone.
7	A shock-absorbing foam structure that measures acceleration, apogee, and orientation, with an antenna extending out of the bottom.
8	A shock-absorbing foam structure that measures acceleration, apogee, and orientation, with no antenna.
9	A shock-absorbing foam structure that measures acceleration, apogee, and orientation, with an antenna extending out of the nose.
10	A shock-absorbing foam structure that measures acceleration, apogee, and orientation, with an antenna extending out of the side.
11	A shock-absorbing foam structure that measures apogee, orientation, and temperature, with an antenna attached to the nose cone.
12	A shock-absorbing foam structure that measures apogee, orientation, and temperature, with an antenna extending out of the bottom.
13	A shock-absorbing foam structure that measures apogee, orientation, and temperature, with no antenna.
14	A shock-absorbing foam structure that measures apogee, orientation, and temperature, with an antenna extending out of the nose.
15	A shock-absorbing foam structure that measures apogee, orientation, and temperature, with an antenna extending out of the side.
16	A wooden structure that measures orientation, temperature, and velocity, with an antenna attached to the nose cone.
17	A wooden structure that measures orientation, temperature, and velocity, with an antenna extending out of the bottom.
18	A wooden structure that measures orientation, temperature, and velocity, with no antenna.
19	A wooden structure that measures orientation, temperature, and velocity, with an antenna extending out of the nose.
20	A wooden structure that measures orientation, temperature, and velocity, with an antenna extending out of the side.

21	A wooden structure that measures temperature, apogee, and velocity, with an antenna attached to the nose cone.
22	A wooden structure that measures temperature, apogee, and velocity, with an antenna extending out of the bottom.
23	A wooden structure that measures temperature, apogee, and velocity, with no antenna.
24	A wooden structure that measures temperature, apogee, and velocity, with an antenna extending out of the nose.
25	A wooden structure that measures temperature, apogee, and velocity, with an antenna extending out of the side.
26	An airbag cushion structure that measures velocity, acceleration, and apogee, with an antenna attached to the nose cone.
27	An airbag cushion structure that measures velocity, acceleration, and apogee, with an antenna extending out of the bottom.
28	An airbag cushion structure that measures velocity, acceleration, and apogee, with no antenna.
29	An airbag cushion structure that measures velocity, acceleration, and apogee, with an antenna extending out of the nose.
30	An airbag cushion structure that measures velocity, acceleration, and apogee, with an antenna extending out of the side.
31	A nylon 12 structure that measures acceleration, apogee, and orientation, with an antenna attached to the nose cone.
32	A nylon 12 structure that measures acceleration, apogee, and orientation, with an antenna extending out of the bottom.
33	A nylon 12 structure that measures acceleration, apogee, and orientation, with no antenna.
34	A nylon 12 structure that measures acceleration, apogee, and orientation, with an antenna extending out of the nose.
35	A nylon 12 structure that measures acceleration, apogee, and orientation, with an antenna extending out of the side.
36	A nylon 12 structure that measures apogee, orientation, and temperature, with an antenna attached to the nose cone.
37	A nylon 12 structure that measures apogee, orientation, and temperature, with an antenna extending out of the bottom.
38	A nylon 12 structure that measures apogee, orientation, and temperature, with no antenna.
39	A nylon 12 structure that measures apogee, orientation, and temperature, with an antenna extending out of the nose.
40	A nylon 12 structure that measures apogee, orientation, and temperature, with an antenna extending out of the side.
41	A liquid crystal elastomer structure that measures orientation, temperature, and velocity, with an antenna attached to the nose cone.
42	A liquid crystal elastomer structure that measures orientation, temperature, and velocity, with an antenna extending out of the bottom.

43	A liquid crystal elastomer structure that measures orientation, temperature, and velocity, with no antenna.
44	A liquid crystal elastomer structure that measures orientation, temperature, and velocity, with an antenna extending out of the nose.
45	A liquid crystal elastomer structure that measures orientation, temperature, and velocity, with an antenna extending out of the side.
46	A liquid crystal elastomer structure that measures temperature, apogee, and velocity, with an antenna attached to the nose cone.
47	A liquid crystal elastomer structure that measures temperature, apogee, and velocity, with an antenna extending out of the bottom.
48	A liquid crystal elastomer structure that measures temperature, apogee, and velocity, with no antenna.
49	A liquid crystal elastomer structure that measures temperature, apogee, and velocity, with an antenna extending out of the nose.
50	A liquid crystal elastomer structure that measures temperature, apogee, and velocity, with an antenna extending out of the side.
51	Parachute/Deployable Arms - Acrylic - Commercial Flight CPU
52	Parachute Only - ABS - FPGA
53	Parachute/CO2 Thrusters - Carbon Fiber - Hybrid System
54	Parachute/Wheels - Balsa Wood - Commercial Flight CPU
55	Parachute/Propellers - Fiberglass - Wireless Network of Modules
56	Parachute/Airbag - Acrylic - Custom Board.
57	Parachute/Deployable Arms - Aluminum - FPGA
58	Parachute Only - Aluminum - Hybrid System
59	Parachute/CO2 Thrusters - Balsa Wood - Separate Modules
60	Parachute/Wheels - ABS - Commercial Flight CPU
61	Parachute/Propellers - Carbon Fiber - Custom Board
62	Parachute/Airbag - Fiberglass - Wireless Network of Modules
63	Parachute/Deployable Arms - Acrylic - Hybrid System
64	Parachute Only - Carbon Fiber - Commercial Flight CPU
65	Parachute/CO2 Thrusters - Fiberglass - FPGA
66	Parachute/Wheels - Aluminum - Separate Modules
67	Parachute/Propellers - ABS - Custom Board
68	Parachute/Airbag - Carbon Fiber - Wireless Network of Modules
69	Parachute/Deployable Arms - Balsa Wood - Hybrid System
70	Parachute Only - Fiberglass - Separate Modules
71	Parachute/Wheels - Balsa Wood - Hybrid System

72	Parachute/CO2 Thrusters - Acrylic - FPGA
73	Parachute Only - ABS - Separate Modules
74	Parachute/Deployable Arms - Carbon Fiber - Wireless Network of Modules
75	Parachute/Propellers - Aluminum - Commercial Flight CPU
76	Parachute/Airbag - Acrylic - Custom Board
77	Parachute/Airbag - Balsa Wood - Wireless Network of Modules
78	Parachute/Wheels - Fiberglass - Hybrid System
79	Parachute/Propellers - Carbon Fiber - Custom Board
80	Power the electronics with an internal combustion engine
81	Wireless modules connected with Bluetooth
82	Stemnauts placed on a gyroscope so their orientation cannot change
83	Stemnauts placed in neutral buoyancy chamber to disperse impact across their entire bodies
84	Attach antenna to separation cord to get it out of the vehicle
85	Make STEMnauts generate voice audio for transmission
86	Make STEMnuats indestructible
87	Use a radar altimiter
88	Use a magnetometer to detect STEMnaut displacement
89	Use a general purpose SDR module for radio tranmissions
90	Attach the stemnauts together so they only need one imu between the four of them
91	Suspend stemnuats by bungee cord to absorb shock
92	Use solar to power the payload
93	Concept 1 (see section 1.5)
94	Concept 2 (see section 1.5)
95	Concept 3 (see section 1.5)
96	Concept 4 (see section 1.5)
97	Concept 5 (see section 1.5)
98	Concept 6 (see section 1.5)
99	Concept 7 (see section 1.5)
100	Concept 8 (see section 1.5)

Appendix E: Concept Selection Tables

Table 1: *Binary pairwise comparison for payload customer needs*

Pairwise Comparison	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	Total
1. STEMnauts must be creative representations	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. The payload must transmit on a 2m-band	1	-	1	1	0	1	1	1	0	1	1	0	1	1	0	10
3. Payload must transmit at specific frequencies	1	0	-	0	0	1	1	0	0	0	0	0	1	1	0	5
4. Payload must be compatible with an FTM-300DR	1	0	1	-	0	1	1	1	0	1	1	0	1	1	0	9
5. Payload must abide by all NAR and FAA regulations	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	14
6. Payload must not protrude more than 0.25" from the rocket	1	0	0	0	0	-	1	1	0	1	1	0	1	1	0	7
7. Transmission of radio signal must be controlled by the operator	1	0	0	0	0	0	-	0	0	1	0	0	1	1	0	4
8. Payload must transmit at or below 5W of power	1	0	1	0	0	0	1	-	0	1	1	0	1	1	0	7
9. Payload must structurally withstand rocket's landing conditions	1	1	1	1	0	1	1	1	-	1	1	1	1	1	1	13
10. Payload must transmitt a variety of data	1	0	1	0	0	0	0	0	0	-	0	0	0	0	0	2
11. Payload must have an independent power source	1	0	1	0	0	0	1	0	0	1	-	0	1	1	0	6
12. Payload's electronics must be independent from rocket's	1	1	1	1	0	1	1	1	0	1	1	-	1	1	0	11
13. Location of payload must not negatively impact rocket's flight	1	0	0	0	0	0	0	0	0	1	0	0	-	0	0	2
14. Payload must not pull above the multitude of gravitational accelaration that a human can survive	1	0	0	0	0	0	0	0	0	1	0	0	1	-	0	3
15. Payload can withstand flight stresses	1	1	1	1	0	1	1	1	0	1	1	1	1	1	-	12
	14	4	9	5	0	7	10	7	1	12	8	3	12	11	2	n-1 = 14
Check	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	

Table 2: *House of Quality table for payload engineering characteristics*

Customer Needs	Importance Weight Factor	Fasten Payload	Secure STEMnauts	Disperse Impact Energy on STEMnauts	Disperse Impact Energy on Payload Body	Measure Altitude	Measure Accelaration	Measure Temperature	Measure STEMnaut Accelaration	Select Radio Frequency	Sample Sensors	Send Data Signal
		Engineering Characteristics										
Improvement Direction		↑	↓	↓	↓	↑	↑	↑	↑	-	↑	↓
Units		lbf	in	G	-	ft	G	∘C	G	MHz	Hz	W
1. STEMnauts must be creative representations	**0**	1	7	7	1	1	1	1	5	1	1	1
2. The payload must transmit on a 2m-band	**10**	1	1	1	1	5	5	5	5	9	5	9
3. Payload must transmit at specific frequencies	**5**	1	1	1	1	5	5	5	5	9	5	9
4. Payload must be compatible with an FTM-300DR	**9**	1	1	1	1	5	5	5	5	9	3	9
5. Payload must abide by all NAR and FAA regulations	**14**	7	3	5	5	3	3	3	7	3	3	5
6. Payload must not protrude more than 0.25" from the rocket	**7**	5	3	3	3	1	1	1	1	1	1	9
7. Transmission of radio signal must be controlled by the operator	**4**	1	1	1	1	3	3	3	3	7	3	3
8. Payload must transmit at or below 5W of power	**7**	1	1	1	1	3	3	3	3	5	5	9
9. Payload must structurally withstand rocket's landing conditions	**13**	9	9	9	9	1	1	1	1	1	1	1
10. Payload must transmitt a variety of data	**2**	1	1	1	1	9	9	9	9	1	9	7
11. Payload must have an independent power source	**6**	3	1	1	1	5	5	5	5	3	3	7
12. Payload's electronics must be independent from rocket's	**11**	3	1	1	1	9	9	9	9	5	9	3
13. Location of payload must not negatively impact rocket's flight	**2**	7	3	1	3	1	1	1	1	1	1	1
14. Payload must not pull above the multitude of gravitational accelaration that a human can survive	**3**	3	9	9	7	1	1	1	1	1	3	1
15. Payload can withstand flight stresses	**12**	7	5	5	9	1	1	1	1	1	1	1
Raw Score	**3092**	445	327	351	397	379	379	379	435	433	369	543
Relative Weight Percent (%)		14.39	10.58	11.35	12.84	12.26	12.26	12.26	14.07	14.00	11.93	17.56
Rank Order		2	11	10	5	6	6	6	3	4	9	1

Table 3: *Pugh chart 1 for payload conceptual designs*

Selection Criteria	Criteria Weight	Zenith 1 Rectangular Prism Design	Concepts							
			Clindrical capsule below nosecone, electronc trays to house sensors, fixed antena, single custom PCB	Cylindrical capsule, electronic trays to house sensors, deployable antenna out top of rocket	Cylindrical capsule below nosecone, electronic trays to house sensors, flaps on payload to reorientate payload while on the ground	Cylindrical capsule, an extra tray to house the stemnauts and sensors independently, mounts to nosecone	Shock absorbing foam, storing velocity, acceleration, apogee, antenna sticking out the top of rocket	Cylindrical capsule , electronic modules all separate	Data collection and transmsiision mounted onto trays that slide into nosecone of the rocket, bolts would mount the trays, antenna permantely deployed from the noseconse	Airbag cushion structure , compartents for the sensors and STEMnauts, and a fixed antenna
Send Data Signal	17.56%		S	+	S	S	S	S	S	S
Fasten Payload	14.39%		+	+	S	S	S	S	-	-
Measure STEMnaut Acceleration	14.08%	Datum	+	S	S	-	S	+	S	-
Select Radio Frequenecy	14.00%		S	S	S	S	S	+	S	S
Disperse Impact Energy on Payload Body	12.84%		+	+	-	+	+	S	-	+
Number of (+)			3	3	0	1	1	2	0	1
Number of (-)			0	0	1	1	0	0	2	2

Table 3: *Pugh chart 1 for payload conceptual designs*

Selection Criteria	Criteria Weight	Zenith 1 Rectangular Prism Design	Concepts							
			Clindrical capsule below nosecone, electronc trays to house sensors, fixed antena, single custom PCB	Cylindrical capsule, electronic trays to house sensors, deployable antenna out top of rocket	Cylindrical capsule below nosecone, electronic trays to house sensors, flaps on payload to reorientate payload while on the ground	Cylindrical capsule, an extra tray to house the stemnauts and sensors independently, mounts to nosecone	Shock absorbing foam, storing velocity, acceleration, apogee, antenna sticking out the top of rocket	Cylindrical capsule , electronic modules all separate	Data collection and transmsiision mounted onto trays that slide into nosecone of the rocket, bolts would mount the trays, antenna permantely deployed from the noseconse	Airbag cushion structure , compartents for the sensors and STEMnauts, and a fixed antenna
Send Data Signal	17.56%		S	+	S	S	S	S	S	S
Fasten Payload	14.39%		+	+	S	S	S	S	-	-
Measure STEMnaut Acceleration	14.08%	Datum	+	S	S	-	S	+	S	-
Select Radio Frequenecy	14.00%		S	S	S	S	S	+	S	S
Disperse Impact Energy on Payload Body	12.84%		+	+	-	+	+	S	-	+
Number of (+)			3	3	0	1	1	2	0	1
Number of (-)			0	0	1	1	0	0	2	2

Table 5: *Criteria comparison matrix*

Criteria Comparison Matrix [C]					
Selection Criteria	#1	#2	#3	#4	#5
1. Send Data Signal	1.00	0.33	5.00	1.00	0.20
2. Fasten Payload	3.00	1.00	5.00	5.00	1.00
3. Measure STEMnaut Acceleration	0.20	0.20	1.00	0.20	0.14
4. Select Radio Frequency	1.00	0.20	5.00	1.00	0.33
5. Disperse Energy on Payload Body	5.00	1.00	7.00	3.00	1.00
Sum	10.20	2.73	23.00	10.20	2.68

Table 6: *Normalized criteria comparison matrix*

Normalized Criteria Comparison Matrix [NormC]						
Selection Criteria	#1	#2	#3	#4	#5	Criteria Weights {W}
1. Send Data Signal	0.098	0.122	0.217	0.098	0.075	0.122
2. Fasten Payload	0.294	0.366	0.217	0.490	0.374	0.348
3. Measure STEMnaut Acceleration	0.020	0.073	0.043	0.020	0.053	0.042
4. Select Radio Frequency	0.098	0.073	0.217	0.098	0.125	0.122
5. Disperse Energy on Payload Body	0.490	0.366	0.304	0.294	0.374	0.366
Sum	1.000	1.000	1.000	1.000	1.000	1.000

Table 7: *Consistency check for criteria comparison matrix*

Consistency Check		
{Ws}=[C]{W}	{W}	Cons={Ws}./{W}
Weighted Sum Vector	Criteria Weights	Consistency Vector
0.643	0.122	5.267
1.900	0.348	5.457
0.213	0.042	5.080
0.645	0.122	5.277
1.984	0.366	5.425

Table 8: *Random index values for criteria comparison (Used for consistency check)*

Random Index Values (RI)	
λ	5.301
RI	1.110
CI	0.075
CR	0.068

Table x: *Send data signal comparison matrix*

Send Data Signal [C]			
Selection Criteria	#1	#2	#3
Cylindrical capsule below nosecone, electronc trays to house sensors, fixed antena, single custom PCB	1.00	0.33	1.00
Cylindrical capsule, electronic trays to house sensors, deployable antenna out top of rocket	3.00	1.00	3.00
Cylindrical capsule , electronic modules all separate	1.00	0.33	1.00
Sum	5.00	1.67	5.00

Table x: *Fasten payload comparison matrix*

Fasten Payload [C]			
Selection Criteria	#1	#2	#3
Cylindrical capsule below nosecone, electronc trays to house sensors, fixed antena, single custom PCB	1.00	1.00	5.00
Cylindrical capsule, electronic trays to house sensors, deployable antenna out top of rocket	1.00	1.00	3.00
Cylindrical capsule , electronic modules all separate	0.20	0.33	1.00
Sum	2.20	2.33	9.00

Table x: *Measure STEMnaut acceleration comparison matrix*

Measure STEMnaut Acceleration [C]			
Selection Criteria	#1	#2	#3
Cylindrical capsule below nosecone, electronc trays to house sensors, fixed antena, single custom PCB	1.00	1.00	5.00
Cylindrical capsule, electronic trays to house sensors, deployable antenna out top of rocket	1.00	1.00	3.00
Cylindrical capsule , electronic modules all separate	0.20	0.33	1.00
Sum	2.20	2.33	9.00

Table x: *Select radio frequency comparison matrix*

Select Radio Frequency [C]			
Selection Criteria	#1	#2	#3
Cylindrical capsule below nosecone, electronc trays to house sensors, fixed antena, single custom PCB	1.00	0.33	3.00
Cylindrical capsule, electronic trays to house sensors, deployable antenna out top of rocket	3.00	1.00	5.00
Cylindrical capsule , electronic modules all separate	0.33	0.20	1.00
Sum	4.33	1.53	9.00

Table x: *Disperse impact energy on payload body comparison matrix*

Disperse Energy on Payload Body [C]			
Selection Criteria	#1	#2	#3
Cylindrical capsule below nosecone, electronc trays to house sensors, fixed antena, single custom PCB	1.00	3.00	5.00
Cylindrical capsule, electronic trays to house sensors, deployable antenna out top of rocket	0.33	1.00	3.00
Cylindrical capsule , electronic modules all separate	0.20	0.33	1.00
Sum	1.53	4.33	9.00

Table 10: *Final rating matrix for all AHP concepts*

Final Rating Matrix			
Selection Criteria	Concept 1	Concept 2	Concept 3
1. Send Data Signal	0.200	0.600	0.200
2. Fasten Payload	0.480	0.405	0.115
3. Measure STEMnaut Acceleration	0.480	0.405	0.115
4. Select Radio Frequency	0.260	0.633	0.106
5. Disperse Energy on Payload Body	0.633	0.260	0.106

Table 11: *Alternate values for all AHP concepts*

Concept	Alternate Value
Cylindrical capsule below nosecone, electronc trays to house sensors, fixed antena, single custom PCB	0.475
Cylindrical capsule, electronic trays to house sensors, deployable antenna out top of rocket	0.404
Cylindrical capsule , electronic modules all separate	0.121

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