2023 HAWAII UNIVERSITY INTERNATIONAL CONFERENCES
SCIENCE, TECHNOLOGY, ENGINEERING, ARTS, MATHEMATICS & EDUCATION JUNE 7 - 9, 2023
PRINCE WAIKIKI RESORT, HONOLULU, HAWAII

INSPIRING STUDENT'S INTEREST IN STEM STUDY THROUGH ENGAGEMENT IN ROCKETRY RESEARCH AND ACTIVITIES

CHEN, GUANGMING ET AL.
DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING
MORGAN STATE UNIVERSITY
BALTIMORE, MARYLAND
USA

Dr. Guangming Chen
Mr. Marc J Louise Caballes
Mr. Samuel Oludayo Alamu
Mrs. Margaret Ajuwon-Alamu
Mr. Raphael Okafor Isaac

Department of Industrial and Systems Engineering
School of Engineering
Morgan State University

Inspiring Student's Interest in STEM Study through Engagement in Rocketry Research and Activities

Synopsis:

This paper discusses the development of rocketry program at Morgan State University (MSU), involving students in design and building rockets. It is the first rocket research program at an HBCU in the country, supported by BASE 11 Foundation since 2020. Although Covid-19 pandemic significantly affected the progress of the program, the MSU rocketry team still made good progress in engaging students in rocket design and related activities. Due to the pandemic impact, the first milestone of the program has been modified to build a more powerful Liquid Propellant Rocket (LPR) and launch it to an apogee of 50,000 feet by the spring of next year, from the original plan to an apogee of 13,000 feet about two years ago. The program has engaged about 20 graduate and undergraduate students in this applied research related to rocket design and rocket launching. These activities have inspired the student's interest in STEM study and attracted not only MSU students but also summer exchange students from other Maryland institutions supported by Maryland Space Grant Consortium. The students also launched the solid-fuel rocket twice in the past two years as rocket-launch practice.

Inspiring Student's Interest in STEM Study through Engagement in Rocketry Research and Activities

Guangming Chen[1], Marc J Louise Caballes[2], Samuel Oludayo Alamu[2],

Margaret Ajuwon-Alamu[2], Raphael Isaac[2]

Department of Industrial and Systems Engineering

Morgan State University

Baltimore, Maryland

(professor[1], doctoral students[2])

Abstract

On a competitive basis, Morgan State University (MSU) received a grant award in 2019 from BASE 11 foundation - a private organization based in California, to establish the first rocket research and education program at an HBCU in the USA. Due to the impact of Covid-19 pandemic and other related matters, the first milestone of the MSU rocketry team has been modified to build and launch a more powerful Liquid Propellant Rocket (LPR) to a higher apogee of 50,000 feet, although the MSU rocketry team has made good progress in rocket design and conducted many activities in rocketry program, such as the rocket airframe design, propulsion simulation analysis and launching solid-propellent rockets twice, *etc*. These progresses and activities have inspired not only MSU student's interest in engineering study, but also the participation interest in rocketry program from the summer exchange students of other Maryland institutions, supported by Maryland Space Grant Consortium (MDSGC). Our rocket airframe team has basically completed the airframe design by using SolidWorks and other CAD software, and by following NASA's Systems Engineering Guidelines for PDR (preliminary design review) and CDR (critical design review). The payload system design is also completed, including GPS, data acquisition device and parachute recovery system. The fabrication will start soon, aimed at a target launch date in late 2023 or early 2024.

Key Terms:
Apogee, Liquid Propellant Rocket (LPR), Solid Propellant Rocket (SPR), Sounding Rocket, Student Engagement in RockOn

1. Background

Inspiring students' interest in STEM (Science, Technology, Engineering, and Mathematics) through engagement in rocketry research and activities is a fantastic way to ignite their curiosity and passion for these fields. Activities in rocketry program combines multiple disciplines, including physics, mathematics, engineering, and computer science, making it an excellent platform for hands-on learning and exploration.

Morgan State University (MSU) was awarded a $1.6 million in 2019 by BASE 11 Foundation, to establish the first rocket research and education program at an Historically Black Colleges and Universities (HBCU) in the USA, after the competition among 12 HBCUs in the country.

MSU has engaged students in rocketry research and activities to inspire their interest in STEM through mentoring and collaborations with institutions and organizations such as collaboration with Purdue University (Aerospace Engineering and Zucrow Labs) - Partnership in Student Training in Rocketry program and Dual Degree Education; collaboration with Johns Hopkins University (Mechanical Engineering and Applied Physics Lab-APL); collaboration with Maryland Space Grant Consortium (Small Supporting Grants and Summer Exchange Students from University of Maryland, Capitol Tech University) and collaboration with the US Army Research Lab, Aberdeen, Maryland.

Although the first milestone in the original MSU proposal was to launch a LPR to an apogee of 13,000 feet in 2021, due to the impact of Covid-19, the objectives of this rocketry project have been modified to build the first Liquid Propellant Rocket (LPR) and launch it to an apogee of 50,000 feet later this year or spring 2024 as well as to build a final LPR and launch it to an apogee of 150,000 feet (about 28.4 miles).

The Covid-19 pandemic has significantly affected the progress of the program, but the team has continued to make good moves. For instance, the airframe team has basically completed the airframe design by using SolidWorks, the payload system design has also been completed, including GPS, data acquisition device and parachute recovery system. The MSU rocketry team also launched a smaller solid propellant rocket in October 2020 and in July 2021 to prepare the students with the tasks of I&T (integration & testing) and the launch activity. Both launches were successful.

Before the solid propellant rocket was launched, the MSU team considered some advantages and disadvantages when evaluating the suitability of solid rockets for specific mission requirements. Some of the advantages of solid rockets can be seen in terms of simplicity, robustness, storage and handling and reliability compared to the liquid-propellent rockets.

- Simplicity: Solid-propellent rockets have simpler design compared to the liquid-propellent rockets since they have fewer components and require less complex systems for propellant storage and management. This simplicity makes them easier to manufacture, more reliable, and less prone to mechanical failure.

- Robustness: Solid rockets are robust, more rugged and can withstand harsh environments. They are less sensitive to external conditions such as temperature, pressure, and vibration. This robustness makes them suitable for applications in extreme conditions, such as military operations and atmospheric reentry vehicles.
- Reliability: Solid rockets are known for their high reliability. Once ignited, the combustion is self-sustaining, and there are no valves, pumps, or complex plumbing systems that can fail. This reliability is important for critical missions where failure is not an option, such as military operations or launching time-sensitive payloads.

Some of the disadvantages of solid rockets can be seen in terms of inability to shut down and lack of reusability and environmental impact.

- Inability to shutdown: Once ignited, a solid rocket cannot be easily shut down. It burns until all the propellant is consumed. This makes abort scenarios or mid-flight adjustments difficult to achieve, as the thrust cannot be quickly halted or reduced.
- Lack of Reusability: Solid rockets are typically not reusable. Once they are ignited and consumed, the entire motor is discarded. This lack of reusability increases the overall cost of launch operations compared to reusable rocket systems.
- Environmental Impact: Solid rockets produce a large amount of exhaust gases, which can contribute to air pollution and have environmental impacts. The exhaust plume of solid rockets contains particulate matters and chemicals that can affect air quality and have ecological consequences, particularly during large-scale launches.

Solid and liquid rockets are two types of propulsion systems used in space exploration and missile but the main differences between them are in table 1 below.

Table 1. Main differences between solid rockets and liquid rockets

S/N	Data	Solid Rockets	Liquid Rockets
1	Propellant	Solid rockets use a mixture of solid fuel and oxidizer, usually combined in a single solid propellant grain. The propellant mixture is pre-packaged and remains solid throughout the mission.	Liquid rockets employ separate liquid fuel and oxidizer components stored in tanks. The fuel and oxidizer are usually highly refined chemicals, such as liquid hydrogen and liquid oxygen.

2	Combustion	The combustion process occurs through the burning of the solid propellant grain. Once ignited, the combustion is self-sustaining until the entire propellant is consumed.	Liquid rockets have a controlled combustion process. The liquid fuel and oxidizer are pumped into a combustion chamber and mixed in precise proportions before ignition.
3	Thrust control	Solid rockets generally have fixed thrust profiles. Once ignited, their thrust output cannot be easily adjusted or throttled during operation. They typically provide constant thrust until all the propellant is depleted.	Liquid rockets offer greater flexibility in thrust control. The flow rates of the liquid fuel and oxidizer can be adjusted to control the thrust output. This allows for precise maneuvering, staging, and throttling during different stages of a mission.
4	Restart Capability	Once a solid rocket is ignited, it burns until the propellant is exhausted, and it cannot be easily reignited.	Liquid rockets can be restarted after shutdown, which allows for multiple firings during a single mission or for orbital maneuvers.
5	Complexity & Reliability	Solid rockets are generally simpler in design and construction compared to liquid rockets. They have fewer moving parts and do not require complex plumbing systems for propellant storage and control. Solid rockets are often considered more reliable and robust, making them suitable for applications where simplicity and reliability are critical, such as military missiles and booster rockets for space launches.	Liquid rockets are more complex and offer greater performance and operational flexibility

2. MSU's Solid Propellant Rocket Design

MSU rocketry team, upon the approval of the BASE 11 rocketry project, set out with the design of solid propellant rocket in order to understand the dynamics of rocket design components, launching, recovery and data extraction following each successful launch, aimed at inspiring students in rocketry program and Aerospace Engineering. The team successfully designed, assembled, and launched the first solid rocket named MSU Panda on October 17, 2020 and a relaunch on July 10, 2021 with each reaching an apogee of 1000 feet. MSU students utilized OpenRocket Simulator to design a constant generic rocket design in terms of the airframe, motor, and fins. Figure 1 shows the Solid Rocket design that was modeled using the OpenRocket Simulation Software, which has a total weight of 7.2 pounds and 52.5 inches in length. Both upper and lower airframes were modeled using a spiral component material that has a density of 0.491 oz/in^3. The motor that was used in this model simulation was Aerotech's H550 that has a total impulse of 313 Ns, an average thrust of 553 N, a maximum thrust of 643 N, and a burn time of 0.567 seconds.

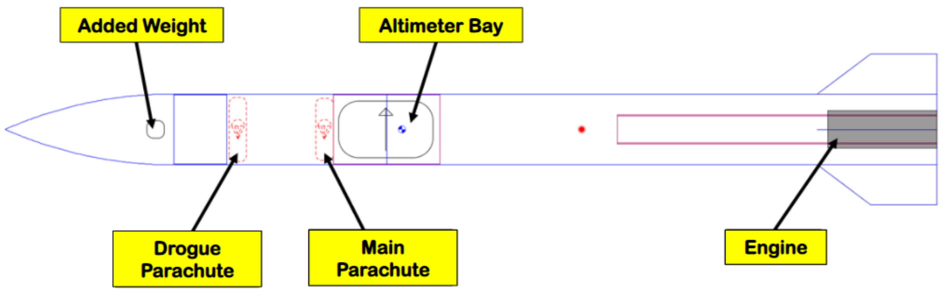

Fig. 1. MSU Panda Design Layout

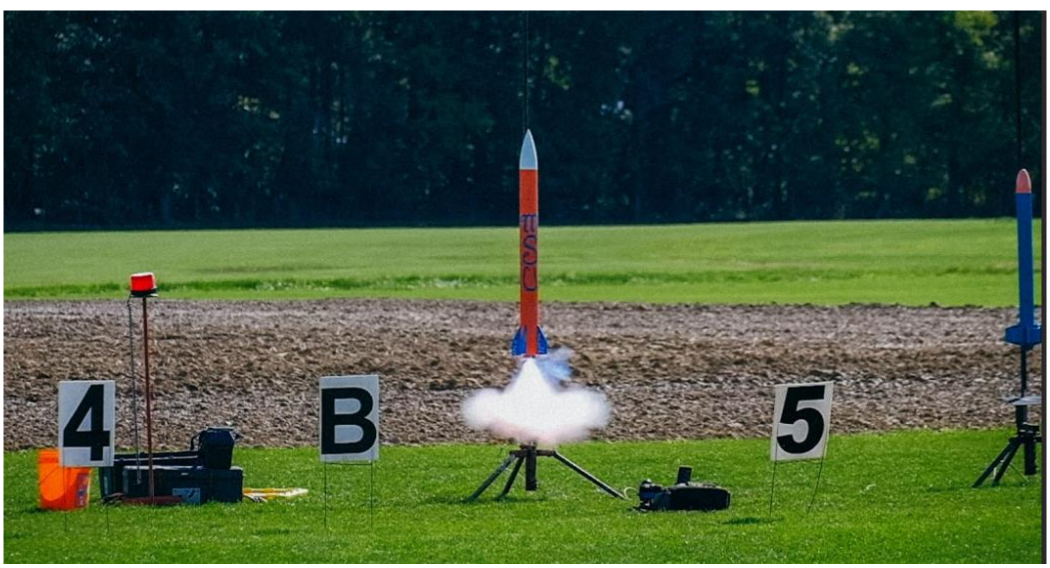

Fig. 2 MSU Panda During Launch

The MSU's Panda rocket consists of three different independent sensors that track the altitude of the rocket during launch. The solid rocket consists of the three major systems - GPS, DAQ, and Recovery which were designed and tested by three subsystem teams. The Featherweight GPS

Tracker, which is rocketry's longest-range tracking system, and the only system designed to work with iPhone devices was chosen not only due to its weight, but also for its reliability. The recovery system of the launch vehicle was responsible for deploying a dual parachute system that includes a drogue and a main parachute. For the MSU solid rocket design, the DAQ team selected Arduino boards with compatible components for developing the DAQ system to remotely collect and monitor real-time pressure and temperature changes during the launching. Arduino board is an open-source platform that consists of both a microcontroller and a part of the software or Integrated Development Environment (IDE) that runs on PC, and then used to write & upload computer code to the physical board. Arduino was selected because of its distinct features such as inexpensiveness, ease to program, open-source software and hardware components with lightweight and small sizes with low voltage requirements. different types of Arduino boards with the ATmega328 processor being considered and reviewed by the DAQ team. For ease of programming and connections, the DAQ team selected Arduino Nano.

The data of both DAQ and Recovery can only be collected once the rocket is recovered. However, for the GPS system, it consists of a tracker which flies with the rocket and a ground station that communicates with the iPhone and immediately starts to record the apogee as soon as the connected switch to the tracker was turned on. Figure 3 shows the graph of the collected results of all the systems and simulations, which are the recovery, GPS, DAQ, 0 mph wind speed, and 20 mph wind speed simulation in terms of altitude per second. Based on the given simulation results, if the wind speed is 0 mph, the apogee that the rocket reaches is 1208 feet, while on the other hand, if the wind speed is around 20 mph then the highest apogee reach is 1180 feet. From the rocket launch data, all the three sensors – recovery, GPS, and DAQ gave the highest altitude of 798, 539, and 732 feet respectively. The observations by the students and the people from the rocket club estimated the altitude was at least 1000 ft. This can be implied that the pressure-based altitude measurements (recovery and DAQ) increased just after the drogue deployment. The pressure inside of the altimeter bay released from the nose side and that was captured. The rocket might fly higher than what it measured from the sensors.

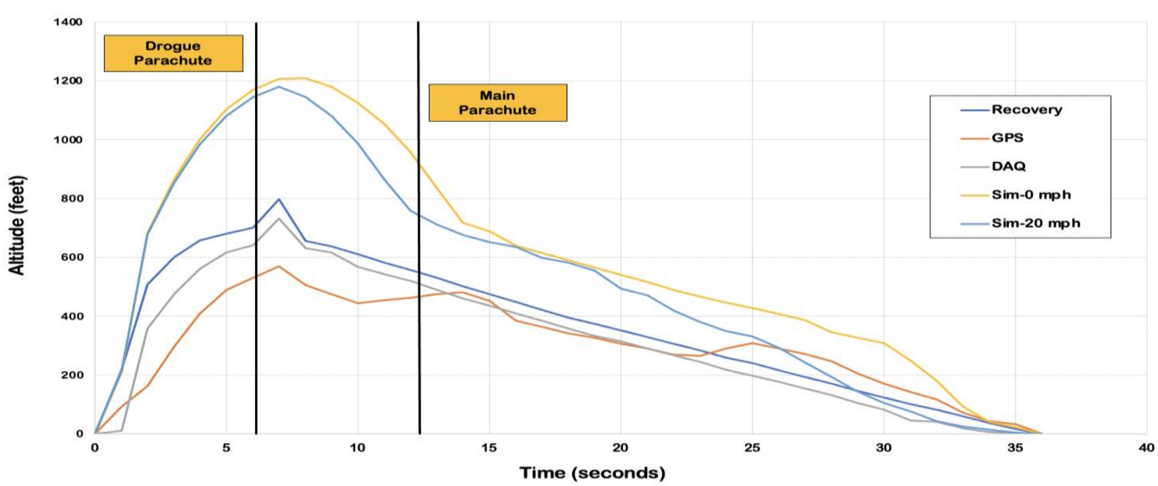

Figure 3. Altitude measurement by Panda's systems

3. MSU’s Liquid Propellant Rocket Design

The MSU Rocketry team is currently designing a liquid-propellant rocket (LPR) which is aimed at attaining an apogee of 50,000 feet with a single-stage rocket. A liquid propellant rocket engine (LPRE) is a kind of rocket engine that uses chemical substances (liquid propellants) as energy and working fluid. In a LPRE, liquid propellant (fuel and oxidizer) reacts in the chamber and produces high-pressure gas which exhausts from the nozzle to make thrust (Wang, 2016). As shown in Figure 4, LPRE includes the nose cone as upper airframe, middle airframe (e.g., payload bay, electronics bay), and lower airframe (i.e., combustion chamber) (Amato, 2020). The recovery system is located in the payload bay while the data acquisition system (DAQ) is installed in the electronics bay.

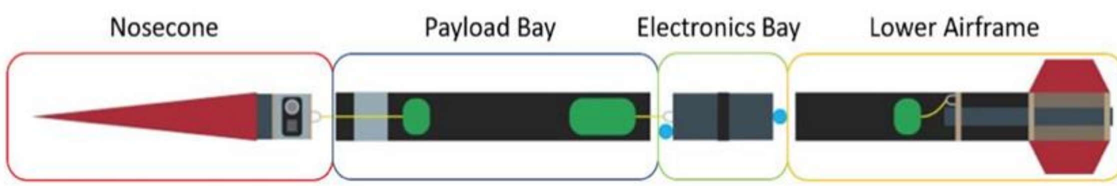

Figure 4. Schematic Diagram of the Liquid Propellant Rocket Engine

Due to its multifaceted role in providing effective flight and cargo protection, the nose cone is an essential component of its design and plays a crucial role in its performance during launch and flight. It aids aerodynamics by lowering air resistance or drag as the rocket travels through the atmosphere (Yang, 2020). The nose cone's streamlined and pointed design allows the rocket to cut through the air more effectively, allowing it to achieve faster speeds. Furthermore, the nose cone contributes to the rocket's stability during ascent. Its well-designed symmetrical form assures a straight and steady trajectory, preventing the rocket from straying off course or tumbling. The nose cone serves as a protective cover for the payload, shielding it from the harsh conditions of atmospheric entry, such as extreme heat and aerodynamic forces (Praad et al., 2016). Therefore, the nose cone's importance lies in its contributions to aerodynamics, stability, and payload protection, ensuring a successful and safe rocket launch.

The nose cone of MSU's Liquid Propellant Rocket (LPR) features a novel feature by including a GPS system. This choice is based on the students' significant experience gathered during prior solid rocket launches. After further investigation, it was revealed that inserting the GPS, especially the Featherweight GPS tracker, within the nose cone produced better results than positioning it in the Altimeter Bay region. The fundamental rationale for this option is to avoid electrical interference on other avionics bay subcomponents. The team successfully prevented the possible electrical interference between GPS and other electronic devices in the Altimeter Bay by placing GPS in the nose cone. Due to its physical separation from the avionics compartment, the nose cone offers a shielded environment that reduces the possibility of electromagnetic interference harming other critical electronic equipment on board. This strategic arrangement enables the Featherweight GPS tracker to work well, giving precise positioning and tracking data without interfering with the performance or operation of other avionics components. Figure 5 illustrates our idea to include GPS into the LPR nose cone and the dedication to technical innovation and dependable rocket telemetry data collection throughout launch operations.

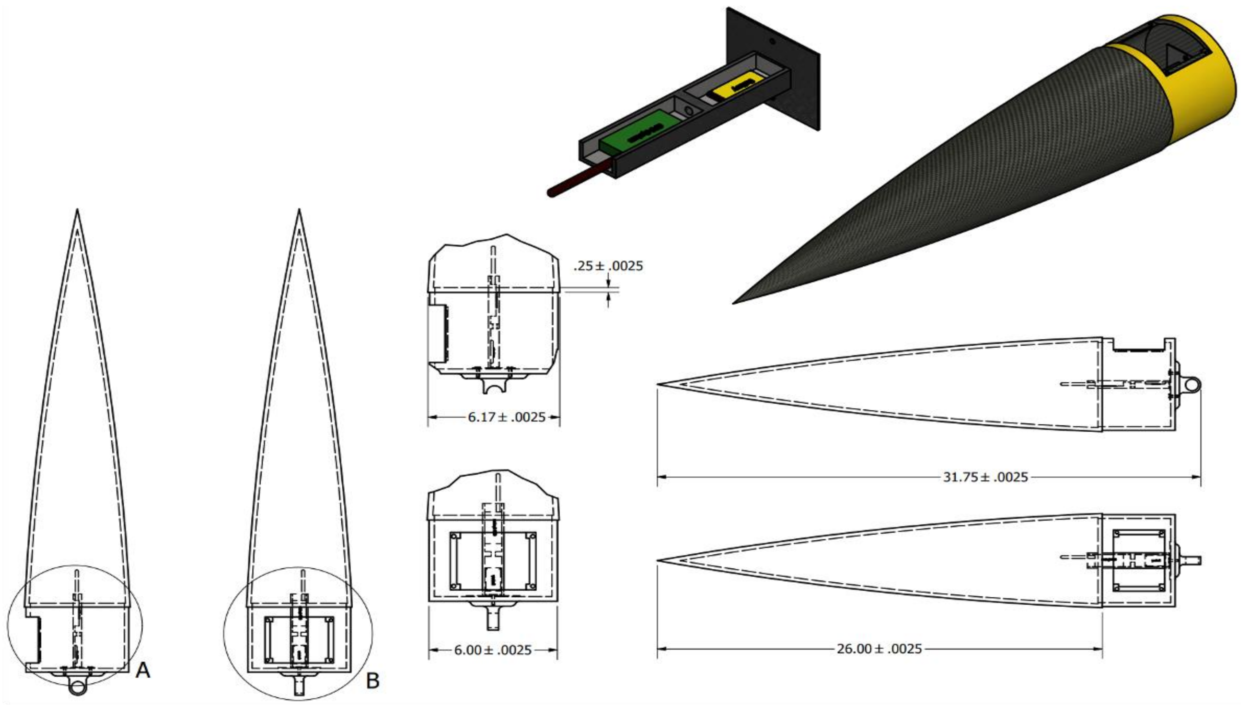

Figure 5: MSU's LPR Nose Cone Design

Figure 6 shows MSU's avionics bay region that is located beneath the nosecone, where it holds the altimeter bay and critical components essential for the rocket's functioning. This portion houses several critical systems, including the Data Acquisition (DAQ) system and the recovery system. The altimeter bay is a crucial area for data collection and gathering during the rocket's flight and launch phases. Aside from its primary function in data collection, the DAQ system in the avionics bay fulfills several other critical functions, monitoring and recording critical characteristics such as altitude, velocity, acceleration, and temperature. These data assist in the post-flight investigation and evaluation of the rocket's performance, allowing future rocket designs and missions to be refined and improved.

In addition to the DAQ system, the recovery system is another critical component present in the avionics bay. The recovery system plays a crucial role in assuring the safe landing of the rocket after flight. It features parachutes and other deceleration devices that aid in slowing the rocket's descent, thereby minimizing the impact force upon landing. By incorporating a dependable recovery system, the avionics compartment preserves the integrity of the rocket and enables the retrieval of valuable payload, scientific instruments, and other mission-specific equipment. Therefore, the incorporation of a reliable recovery system is essential for the success and sustainability of LPR missions.

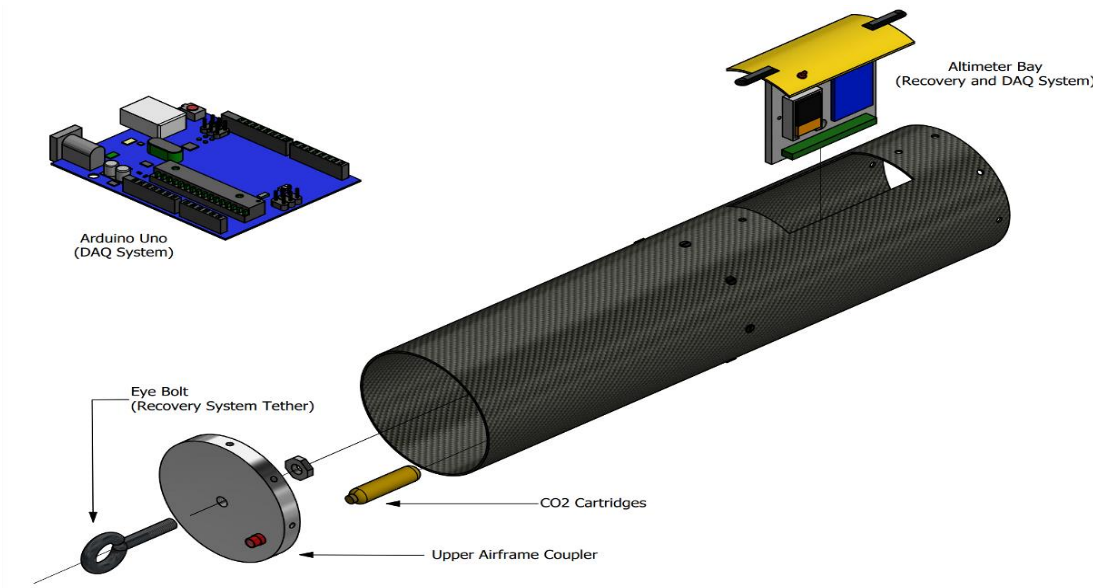

Figure 6: MSU's Avionics Bay Area

The diagram in figure 7 illustrates the MSU's LPR airframe design that is divided into three distinct sections, each of which represents one of the three canisters utilized in the propulsion system. The canisters are filled with Helium (He) to pressurize, Liquid Oxygen (LOX), and Kerosene for the purpose of combustion. These constituents function in accordance with the fundamental principles of rocket propulsion (Cai et al., 2019).

The canister of Helium serves as the pressure reservoir for the rocket. Helium gas is pressurized and subsequently introduced into the fuel and oxidizer tanks to ensure a steady pressure level as the propellants are depleted throughout the duration of the flight. The process of pressurization facilitates the optimal flow of fuel and propellants to the combustion chamber, thereby ensuring their efficient delivery. The combustion process that produces thrust is attributed to the liquid oxygen and kerosene canisters. The oxidizing agent or liquid oxygen is introduced into the combustion chamber where it is combined with kerosene fuel. The propellants undergo a regulated chemical reaction, or combustion, which results in the generation of gas at elevated temperatures and pressures. The ejection of gas through a nozzle at the rear end of the rocket generates a substantial thrust force, which propels the rocket in a forward direction.

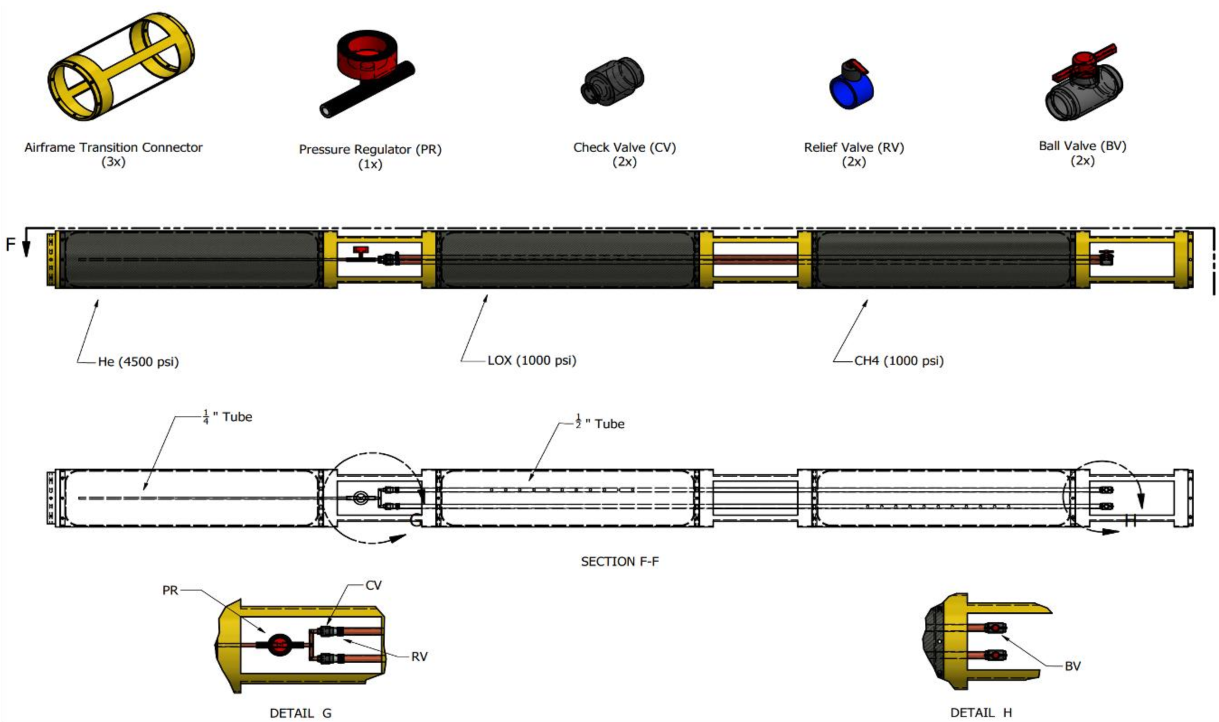

Figure 7: MSU's Airframe Design

Inside the airframe there are a variety of valves which are used to regulate the flow of propellants and ensure operational safety. The pressure valve regulates the discharge of Helium gas from the canister into the propellant tanks, thereby ensuring the maintenance of the intended pressure levels. The unidirectional flow of propellants from the tanks to the combustion chamber is ensured by the check valve, which can prevent any backflow. The primary function of the relief valve is to discharge surplus pressure, to safeguard the system against the detrimental effects of over-pressurization. The ball valve functions as a binary control device, enabling manual regulation of the propellant flow and cessation of fuel supply in exigent circumstances, such as pre-launch or emergency scenarios. The valves and canisters work together to enable the regulated storage, pressurization, and combustion of propellants within the airframe of MSU's LPR, thereby facilitating efficient and dependable rocket propulsion.

The rocket's predicted velocity determines its tail fin components. Low-speed rockets, such as little model rockets, use lightweight materials for their tail fins since dynamic forces are much lower. Rocket tail fins struggle with high aerodynamic forces. Thus, robust, lightweight, and composite materials are frequently employed. MSU's liquid propellant rocket must reach transonic speeds for an apogee of 50,000 ft. Based on preliminary designs, aluminum, carbon fiber, and fiberglass are materials to be used (Bunkley, 2022). Figure 8 shows MSU's LPR boat tail's three obtuse trapezoidal configurations. Li et al. (2018) found that increasing a rocket's surface area improves aerodynamic stability. A wider-based obtuse trapezoid can do this. The increased surface area reduces disruptions like turbulent air currents and rocket centroid asymmetries. This design component enhances flight paths and reduces instability and trajectory variation. Yang et al. (2020) found that an obtuse trapezoid shape controls rocket roll motion. The fins' wider base distributes pressure and forces evenly, preventing uneven rolling. By reducing roll motion, the obtuse trapezoidal fins keep the rocket stable and oriented. Additionally, as per the initial data flight collected through rocket simulation, the results show that using an obtuse trapezoid fin shape should improve aerodynamic stability, roll control, and structural integrity. Rocket configurations may benefit from its precision and consistency.

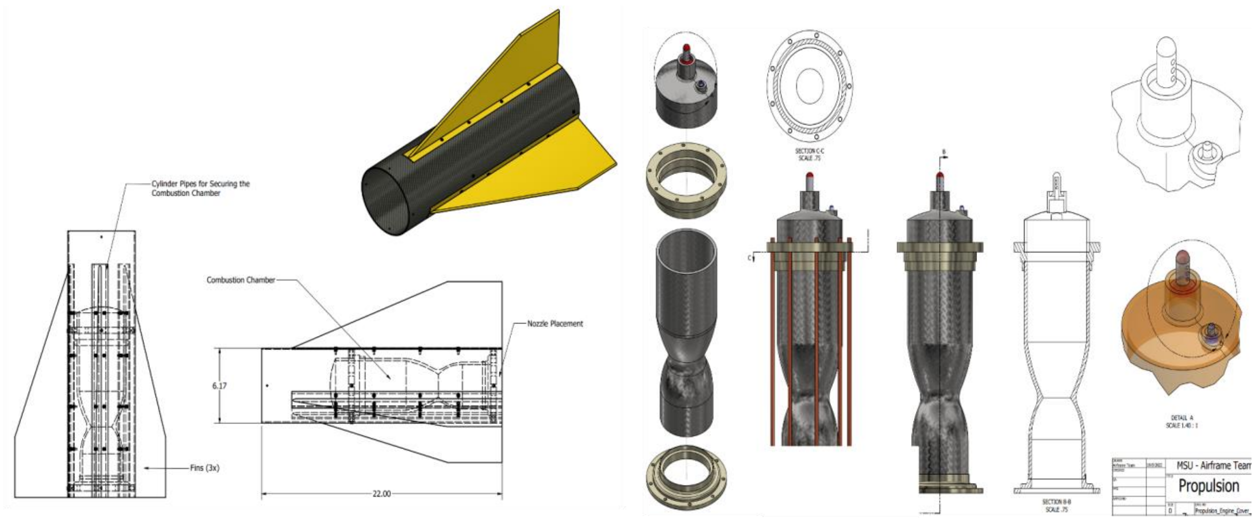

Figure 8. MSU's boat tail with integrated Fin

The MSU LPR design, which is illustrated in figure 9, incorporates several essential components that contribute to its overall functionality and performance. Significant roles are played by the rocket's nose cone, airframe, and fins in its design and operation. The nose cone is carefully designed to reduce air resistance during ascent, allowing the LPR to attain higher velocities and maximize fuel efficiency, while carrying the Featherweight GPS system. The rocket's structural framework is the airframe, which contains the Helium (He) for pressurization, Liquid Oxygen (LOX), and Kerosene for combustion. The airframe integrates a variety of valves, such as pressure, check, relief, and ball valves, to ensure appropriate propellant flow, pressure regulation, and safety during the rocket's operation. The aerodynamic stability and control are facilitated by the rocket's fin design, which typically consists of trapezoidal fins. These fins are strategically placed on the airframe to improve flight stability and reduce roll motion. The increased surface area provided by the broader base of the obtuse trapezoid fin design aids in maintaining the rocket's intended orientation and trajectory. Overall, the rocket design incorporates the optimized shape of the nose cone, the three-section airframe with its associated valves, and the stability-enhancing fin design to produce a well-balanced and effective rocket system. These components work together to optimize performance, enhance aerodynamic characteristics, and ensure the safe and effective operation of the rocket throughout the launch, flight, and recovery phases.

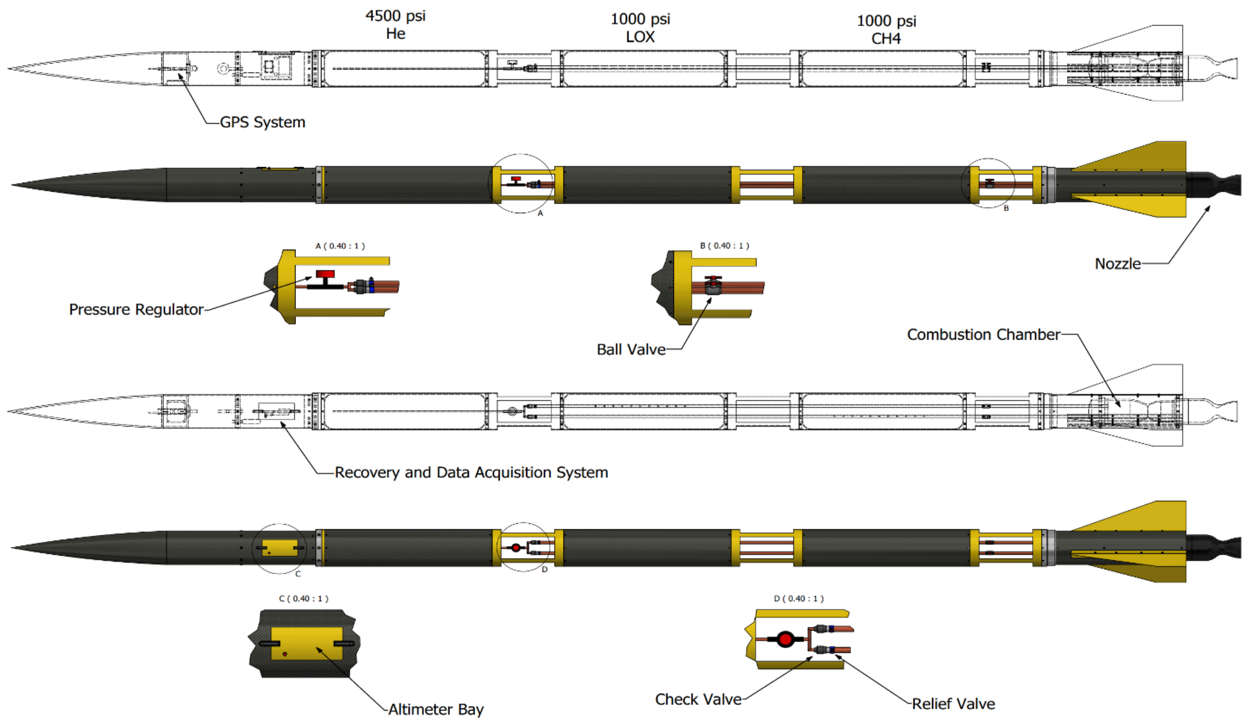

Figure 9. MSU LPR Design

4. MSU Students RockOn Participation

The National Aeronautics and Space Administration (NASA) has an important focus and interest in education and community outreach. One of their programs, the NASA Sounding Rocket Program (NSRP), provides a similar vision and is one of the leading programs in NASA that is very aggressive in inspiring the next generation of professionals in the science, technology, engineering, and mathematics (STEM) field. The NSRP has partnered with the Colorado Space Grant Consortium (COSGC) to provide a "pipeline" of space flight opportunities to university students and professors. The rocketry program at MSU just officially started in early January of 2020 where it aims to promote students' participation, interest, and engagement in the aerospace field while at the same time, broadening their skill sets for future careers (Alamu et al., 2020)

Despite the challenge of COVID-19, MSU students had the opportunity to participate in the RockOn Project starting in 2021 - a yearly workshop organized by the CSGC, Virginia Space Grant Consortium (VSGC), and NASA Wallops Flight Facility (WFF). The students learned and applied skills in building a payload that can collect acceleration, humidity, pressure, temperature, and radiation counts for suborbital space flight. Furthermore, even though it was a virtual training to prevent spreading the variant disease during the pandemic, the students were still able to do testing and integrate a predesigned payload from a kit sent by the CSGC. The payload that the students built was placed on NASA's 40-foot-tall sounding rocket and was launched in their flight facility at

Wallops Virginia, as illustrated in figure 10. NASA's Sounding Rocket was launched on the 24th of June 2021, where it carried the payload that the MSU students designed and assembled. After the rocket was recovered, the payload was sent back again to the students for data retrieval and analysis.

Figure 10: NASA's Terrier-Improved Orion Sounding Rocket

The team of students at Morgan State University was tasked with assembling a payload. Before the pandemic, all teams would meet in Boulder, Co. for a weeklong workshop. However, due to the unprecedented conditions of Covid-19, all the panels were held virtually with Dr. Koehler and recorded video support. MSU's rocketry lab was used in that effect to carry out the assigned tasks. The team created three subtask teams and each team was assigned a specific mission such as the (1) Geiger Counter & Space Shield, (2) Arduino and Flight Code, and (3) Power On Systems Test (P.O.S.T.) The major technical skill required for the RockOn project is the Arduino software for programming the Arduino board and Micro Soldering. Similar to the MSU solid rocket piloting, the data acquisition system (DAQ) team selected Arduino boards with compatible components for developing the DAQ system to remotely collect and monitor real-time pressure, temperature, acceleration and x, y, and z gyroscope changes during the rocket launch, which is illustrated in Figure 11a.

Moreover, the assembly and implementation of the Geiger Counter (GC) played an important role in getting the data needed - number of radiations, which is shown in figure 11b. The GC that was built by the MSU Rocketry Students can detect and measure all types of radiation, which are alpha, beta, and gamma radiation. However, due to the violent behavior of the Sounding Rocket when it is deployed, only beta and gamma radiation are measured, since the alpha radiation is being blocked. The illustration in Figure X shows the full apparatus of the GC, where it has the mini step-up transformer, MC14049CP Hex Inverter, GS 7805 5V Voltage Regulator, IRF830 Power MOSFET, Geiger Tube, and LN555C 555 timer.

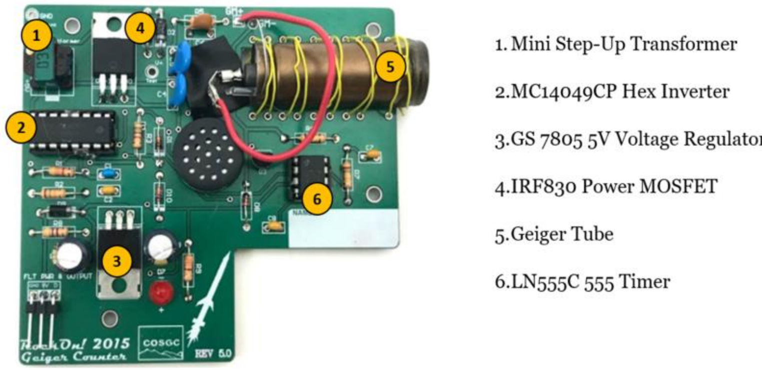

Figure 11a (left): Gyroscope with Arduino UNO attached & Figure 11b (right): Geiger Counter

The Power-On-System Test, also known as POST is performed after the completion of the shield and Geiger counter. POST is perhaps one of the most intriguing sections of the entire project because it aims at verifying that each sensor is working with the Arduino Mega. Table 2 illustrates how POST was performed six times on different sensors: Accelerometer, Geiger Counter, Gyroscope, Pressure & Temperature, Humidity, and SD card during the project. POST operation involves soldering of the sensors, coding in the Arduino, testing and recording their corresponding data. However, in the case of the Geiger counter, soldering was not necessary. The table below shows each of the sensors and their uses.

Table 2. POST System Parameters

Accelerometer	The accelerometer measures forces, determines the orientation and detects how much acceleration will occur during the launch
Geiger Counter	The Geiger counter uses the interrupt signal which is a flag to show the readiness of the data
Gyroscope	The Gyroscope measures rotation on 3 axes of the payload during flight. The gyroscope will tell how fast the rocket is spinning in all 3 directions in space
Temperature & Pressure	To measure temperature and pressure during launch
Humidity	Humidity sensors measure the amount of moisture in the air by detecting changes that alter electrical currents or temperature. The Humidity sensor needs a temperature reading to have a true Relative Humidity (RH)
SD Holder	Stores SD card, that stores all data, and it is transferable to the computer

Each of the POST operations was performed once at a time. This implies that for each sensor, soldering, coding, testing, and recording were performed before moving to the next sensor. This is because it is easier to debug in case of any error since the aim of POST is verification. All sensors except the Geiger counter were soldered using soldering iron and Led(electrodes). The next step, which is coding, was achieved using Arduino software. All codes written were provided by the program manager with all input and output explicitly explained. To perform the test, the Arduino board and the shield were put together, the Arduino board is connected to the computer using a USB cord, also the LED lights are turned on and the codes are uploaded to the Arduino. Once the codes are uploaded successfully without an error, the data is recorded. In conclusion, the SD card which was 16GB was verified by coding in Arduino to store all data. After coding, the SD is inserted into the laptop using micro-SD to ascertain that the data were successfully stored.

Overall, the Rock-on workshop gave many students from diverse backgrounds the chance to have first-hand experience in building a science instrument payload to be flown on a NASA rocket. The workshop also enabled students and inspired their interests in learning electrical and mechanical engineering fundamentals. During the workshop, students carried out preliminary data analysis from all experiments completed. Mentorship from NASA engineers was also available during the office hours, and in addition, participants were able to gain project management skills coupled with increasing their technical knowledge.

5. Concluding Remarks

Engagement of MSU students in rocket design and building program as well as the related activities, has significantly inspired their interests in STEM studies. Students need the basic STEM knowledge and skill sets to complete their assigned hands-on tasks successfully. Our experience and practice related to rocketry and space programs at MSU demonstrate that engaging students in applied research projects and hands-on activities is an effective way to inspire student's interest in the studies, particularly in STEM studies which are usually considered hard by American students, especially under-represented minority students.

Acknowledgements

A special appreciation goes to the Maryland Space Grant Consortium (MDSGC) for providing Morgan State University (MSU) with the opportunity of engaging students in rocketry research and activities as a way to inspire their interest in aerospace engineering and STEM in general. We would like to acknowledge the BASE 11 Foundation for providing a grant to MSU after competition, to establish the first rocket research and education program at an HBCU in the United States of America.

References

Alamu, S. O., Caballes, M. J. L., Yang, Y., Mballa, O., & Chen, G. (2019, October). 3D Design and Manufacturing Analysis of Liquid Propellant Rocket Engine (LPRE) Nozzle. In Proceedings of the Future Technologies Conference (pp. 968-980). Springer, Cham.

Alamu, S.O., Caballes, M.J.L., Chen, G., Qian, X., Xue, J., Yang, Y., Ajuwon, M. (2020) "Engaging Multidisciplinary Minority Students in The Aerospace Program and Education at Morgan State University", *Proceedings of 2020 ASEE Mid-Atlantic Spring Conference*, Johns Hopkins University, Baltimore, MD, March 27-28, 2020. https://peer.asee.org/engaging-multidisciplinary-minority-students-in-the-aerospace-program-and-education-at-morgan-state-university

Amato, N. (2020). *Design, Analysis, and Test of a High-Powered Model Rocket* (Doctoral dissertation, Worcester Polytechnic Institute).

Benson, T. (2014). Brief history of rockets. National Aeronautics and Space Administration. Retrieved from https://www.grc.nasa.gov/www/k-12/TRC/Rockets/history_of_rockets.html.

Brevault, L., Balesdent, M., & Morio, J. (2020). *Aerospace System Analysis and Optimization in Uncertainty*. Springer International Publishing.

Justyn Bunkley, M. J. L. Caballes, M. Ajuwon, G. Chen, "Design Analysis of Rocket Tail Fins Aimed at Higher Apogee by Computer Simulation", *Proceedings of ASEE Middle Atlantic Conference*, New Jersey Institute of Technology, April 22-23, 2022. *https://peer.asee.org/design-analysis-of-rocket-tail-fins-aimed-at-higher-apogee-by-computer-simulation*

Cai, H. H., Nie, W. S., Su, L. Y., Shi, T. Y., & Guo, K. K. (2019). Infrared radiation characteristics of liquid oxygen/kerosene rocket engine plume with different number of nozzles.Spectroscopy Letters, 52(3-4), 159-167.

Defoort, S., Balesdent, M., Klotz, P., Schmollgruber, P., Morio, J., Hermetz, J., & Bérend, N. (2012). Multidisciplinary Aerospace System Design: Principles, Issues and Onera Experience. Aerospace Lab, (4), p-1.

Dong-Hui, W., Yang, F., Fan, H., & Wei-Hua, Z. (2014). An integrated framework for solid rocket motor grain design optimization. Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering, 228(7), 1156-1170.

Fedick, P. W., Bryan, A. M., Smith, R. D., Austin, J. S., & DeKorver, B. K. (2023). Inspiring Future Rocket Chemists: A Hands-On Instructional Event Highlighting the Role Chemistry plays in the Fundamentals of Rocketry. Journal of Chemical Education.

Jenner, L. (2017). Sounding rockets overview. National Aeronautics and Space Administration. Retrieved from https://www.nasa.gov/mission_pages/soundingrockets/missions/index.htm

Kimmel, J. A. (2018). Stability of Nose Cone Design for Rocket Stability. Procedia Manufacturing, 24, 26-32.

Li, H., Chen, Z., Tang, X., Cai, Z., & Zhang, S. (2018). Study on the Design and Optimization of the Airfoil Section of Rocket Fin Based on Numerical Simulation. International Journal of Aerospace Engineering, 2018.

Prasad, S., S. K., Kumar, A., & Kumar, R. (2016). Structural Analysis of a Rocket Nose Cone. Procedia Technology, 25, 960-967.

Wang, Z. G. (2016). *Internal combustion processes of liquid rocket engines: modeling and numerical simulations*. John Wiley & Sons.

Yang, Y., Shang, Y., Dong, J., & Guo, Y. (2020). Roll Control and Stability Optimization of Spin-Stabilized Rockets. Journal of Spacecraft and Rockets, 57(3), 639-648.