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Engaging Multidisciplinary Minority Students in The Aerospace Program and Education at Morgan State University

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Mr. Alamu is a Graduate Research/Teaching Assistant at the Department of Industrial and Systems Engineering, Morgan State University where he conducts qualitative and quantitative research works leading to development. He has participated and led several research work being published in reputable journals and presented at several international conferences.

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Mr. Marc Caballes was born and raised in Bogo City, Philippines. He arrived here in America last 2009. As a kid, every time his Mom asked him to do something, he always looked for the most efficient approach to get the job done. Thus, it is no surprise that he is currently pursuing a doctorate in Systems Engineering at Morgan State University (MSU), where his Professors help him enhance his capabilities in looking for the most optimal solution while delivering quality results. Some people might say that it is okay to make mistakes as long as you learn from them. However, Mr. Caballes beg to differ. For him, it is more convenient to eliminate that ”mistake” before it happens. Hence, he always wants to have an outcome of a 99.9998% success rate (mistake-proof). Marc has extensive knowledge and experience in Additive Manufacturing (AM), 3D Modeling and Design, Design of Experiments (DOE), Systems and Reliability Engineering, Lean Practices and Techniques, and Process Simulations.

Aside from being a Professor in Robotics and Mechatronics Engineering Department at Baltimore City Community College (BCCC), Marc is the team lead in MSU’s Liquid Propellant Rocket Subtask Team, where he reviews and designs the essential rocket components such as the nose cone and all the way to the rocket’s boat tail. In addition, he is also responsible for leading diverse and highly motivated engineering students in the RockOn program, where they implement and test a rocket payload that can measure and record the acceleration, humidity, pressure, temperature, and radiation counts during flight. The payload system was launched on NASA’s Terrier Improved-Orion Sounding Rocket at their flight facility in Wallops, Virginia, and was successfully recovered at the Atlantic Ocean. Marc made several presentations and publications in domestic and international conferences, including MDSGC, FTC, ASEE, SISE, ICTAA, INCOSE, and INFORMS. His maxim in life is, ”Never confuse movement with progress. Because you can run in places and not get anywhere.”

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Ms. Jingwen Xue, Morgan State University

Ms. Jingwen Xue received her Master of Engineering from Morgan State University in 2016 and her Bachelor of Mechanical Engineering in 2012. She worked as Mechanical Engineer in R&D Department of LEM Electronics (China) Co., Ltd from Dec. 2017 to Jan. 2020. She is currently doing her Doctor of Engineering in the field of Environmental Engineering in the Department of Civil Engineering at Morgan State University. She has skills on the design, modeling and simulation of the transducer, plastic box and components, and biomass combustion system.

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Miss Margaret Ajuwon is a current Doctoral student of Industrial Engineering at Morgan State University, Baltimore MD. She completed her master's degree in Industrial Engineering at Southern Illinois University, Edwardsville(SIUE). She currently works as a research assistant for the ongoing rocketry development program in the Department of Industrial Engineering.

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Engaging Multidisciplinary Minority Students in the Aerospace Program and Education at Morgan State University

Abstract

Studies by Morgan Stanley, Bank of America and Merrill Lynch predicted that the space industry will be worth $1.1-2.7 trillion by the end of 2040. The rapidly growing space industry has stimulated a demand for experiences in learning design, simulation, and testing techniques to develop the more efficient liquid rocket engines. This has triggered the current trend in the research and development of rocket engines with increasing numbers of universities participating in student rocketry challenges across the USA. There are many university clubs (e.g., Cornell Rocketry Team, MIT Rocket Team, Portland State Aerospace Space Society, SEDS at US San Diego, etc.) in the nation, but there was no rocketry program at any HBCU among more than 100 HBCUs in the country until last year that Morgan State University (MSU) was awarded an HBCU space challenge grant by BASE 11 to develop the first rocketry program at an HBCU. The rocketry program at MSU just officially started in January 2020 and this study is one of the projects related to the rocketry program. The objectives of this study are to: (1) involve the concepts of the multi-disciplinary engineering education that prepares students to work effectively with others from outside of their major disciplines and (2) develop the first liquid rocket by minority students among the HBCUs. The study involved studying the team structures among existing rocket teams at several universities in order to learn from their wealth of experience; understanding key skills and tools for designing and manufacturing of liquid rocket engines; and identifying the necessary courses for developing aerospace and rocketry program module which cuts across the science and engineering majors. Results and findings from this study will engage more multidisciplinary minority students in the Aerospace Program at Morgan State University.

Keywords: Rocket, Liquid Propellant, Minority, Manufacturing, Multidisciplinary

Introduction/Background

Aerospace engineering involves the designing, testing, and operating of complex aerospace related systems and subsystems. Aerospace engineers develop new technologies for use in commercial aviation, defense systems, and space exploration. This field of engineering often combines various skills obtained from diverse and interdisciplinary engineering backgrounds, specializing in areas such as systems engineering, structural design, navigational guidance and control systems, instrumentation and communications, propulsion systems, computational fluid dynamics, aerodynamics or in the overall fabrication process [1]. A more engaging learning method identifies a critical need to maintain student interest and encourage young minds to seek/pursue a STEM field of study and, ultimately, a career [2].

Morgan State University (MSU) is one of the renowned Historically Black Research Universities in Baltimore, established in 1867 with more than 7,000 enrollments in both undergraduate and graduate programs. MSU offers 60 distinct undergraduate degrees concentrated into 51 majors within 23 broad fields of study. Across all areas of study, MSU awarded 970 undergraduate degrees in 2017-2018. Despite the continuous enrollment, the university still lags the few other HBCUs in the country that offer Aerospace Engineering Program until the year 2018 when the university competed in the student rocketry challenge. MSU won the challenge to commence a rocketry program as the first HBCU college among more than 100 HBCU in the USA. Thus, it was made possible via an initiative from Base 11 of Costa Mesa, California, which awarded a $1.6-million grant to MSU in February 2019 to develop a hands-on, experiential liquid-fuel rocketry lab.

The director of communication at BASE 11 stressed the overall goal of developing a rocketry program in an HBCU as the growing aviation industries are in large demand of aerospace engineers with hands-on experience and skills on liquid propulsion engines. The director emphasized on how establishing a rocketry lab at an HBCU will significantly provide the students' opportunities to participate in the commercial space – which is estimated to become a $2.7-trillion industry within 30 years [3]. The involvement of underrepresented minorities and women in an HBCU contribute to the uniqueness of the project. Bringing more diversity to the field is going to be critical to long-term economic growth as well as America's global competitiveness because it is the technology that is driving the future of humankind [4].

NASA Mission

The National Aeronautics and Space Administration (NASA) is taking a lead role in the effort to inspire interest in science, technology, engineering, and mathematics (STEM) through its unique mission, workforce, facilities, research, and innovations. NASA is continuing to pursue three primary education goals: strengthening NASA's and the Nation's future workforce, attracting and retaining students in STEM disciplines, and engaging Americans in NASA's mission [5]. With the research and education program in a minority population, the administration engages more underrepresented populations through a wide variety of initiatives. Multi-year grants are available to assist minority institutions, faculties, and students in research and education programs pertinent to the NASA missions. The program focuses on recruiting and retaining underrepresented and underserved students in STEM disciplines through the completion of an undergraduate or graduate degree in support of their entry into the scientific and technical workforce. MSU has joined the other participating universities in the Maryland Space Grant Consortium (MDSGC) for the past few years. It has been an active participant through summer internships, seminars, and conferences organized by the consortium all through the years. About 6 to 7 researchers from MSU at both undergraduates and graduates level had the opportunity to present their research work at the 2019 research symposium held at John Hopkins University.

Similarly, two of the authors of this article from the Industrial and Systems Engineering department, together with an undergraduate student in the department of Electrical & Computer Engineering department, represented the university at the 2019 Mid-Atlantic NASA Space Grants Consortia Meeting in West Virginia. The students had the opportunity of presenting their research work to all participants and networking with NASA professionals at the regional level. These

activities have benefitted the university in developing a space program that aligns with the NASA mission statement.

Rocketry Clubs at the United States

The Spaceport America Cup started in 2017 and designed around the Intercollegiate Rocket Engineering Competition (IREC) for student rocketry teams from all over the country and around the world to launch different types of phases – solid, liquid, and hybrid rockets, with target altitudes of 10,000 feet and 30,000 feet [6]. In 2017, there were over 110 teams from colleges and universities in 11 countries that participated in the competition. According to the data from the Spaceport America Cup report, there were a total of 124 teams from 14 countries in 2019, and among them, 83 teams (about 67%) from the US with over 95% undergraduate student participation in the team [7]. Table 1 summarizes some of the university names, rocketry club names, on-going projects with their website. It also shows some of the university clubs that participated in both the Spaceport America Cup and Base 11 with tasks to design, build, and launch a student lead rocket. Other rocketry clubs include:

- WVU Experimental Rocketry - West Virginia University
- Florida Tech Rocketry-Florida Institute of Technology
- Helios Rocketry - Arizona State University
- Portland State Aerospace Society- Portland State University
- Texas Rocket Engineering Lab-University of Texas
- High-Powered Rocketry Club-North Carolina State University
- Cornell Rocketry Team- Cornell University, New York
- MIT Rocket Team- Massachusetts Institute of Technology
- University of Houston's Space City Rocketry Club - University of Houston

Table 1. List of few selected University, Club Name and On-going Projects with Website

University	Club Name & Year Found	On-going Projects	Website
University of Michigan, Ann Arbor	MASA (2003)	Tangerine Space Machine (Anticipated to reach 400,000 ft) PT-163 Liquid Ethanol with Liquid Oxygen Engine	http://masa.engin.umich.edu/
Princeton University	Princeton Rocketry Club (2015)	2020 Spaceport America Cup (solid-fueled rocket) High Power Rocketry (Rocktery Basic Class) Revolutionary Aerospace Systems Concepts Academic Linkage Competition	https://rockets.princeton.edu/

University of California, Los Angeles	Rocket Project at UCLA (2007)	Rocketry Introduction for Student Education (Basics of Rocket engineering and design process) Spaceport America Cup (Prometheus, design & build a hybrid powered rocket) Ares (design, build and test a liquid bi-propellant rocket to 45,000 ft)	http://rocketproject.seas.ucla.edu/index.html
University of Southern California, Los Angeles	USCRPL (2005)	Traveler IV (first entirely student designed and built rocket to fly to space, karman line) Domepiercer (aim to reach highest apogee in amateur rocketry)	http://www.uscrpl.com/
University of South Florida	Society of Aeronautics and Rocketry (SOAR) at USF (2010)	Base 11 Challenges (single staged liquid fuel to the Karman Line) Two Stage (Taurus I) (aim to reach 50,000 ft)	http://www.usfsoar.com/
Loyola Marymount University	Loyola MARS (2016)	Hybrid Rocket Base 11 Challenges	https://loyolamars.com/
Missouri University of Science and Technology	Missouri S&T Rocket Design Team (2015)	Spaceport America Cup (Design a solid rocket to go 10,000 ft)	https://rocket.mst.edu/
Oregon state university	OSU AIAA (2012)	Base 11 Challenges (High Altitude Liquid Engine (HALE), research and development of liquid rocket engine)	https://osuaiaa.com/

As previously mentioned, MSU is the first HBCU University that will have its very own Rocketry Program. However, since it is a "pilot" program and developing stage, the system behind it is very complicated. Thus, to meet the required standards, a set of requirements is very critical in achieving the required information system, which can satisfy the needs. A Unified Modeling Language (UML) is used as an approach for visualizing the system appropriately to help project teams communicate, explore potential designs, and validate the architectural design of the software [8]. Based on the structure and mission of existing rocketry clubs, MSU will build a unique rocketry club that assists students to design and build a student lead rocket.

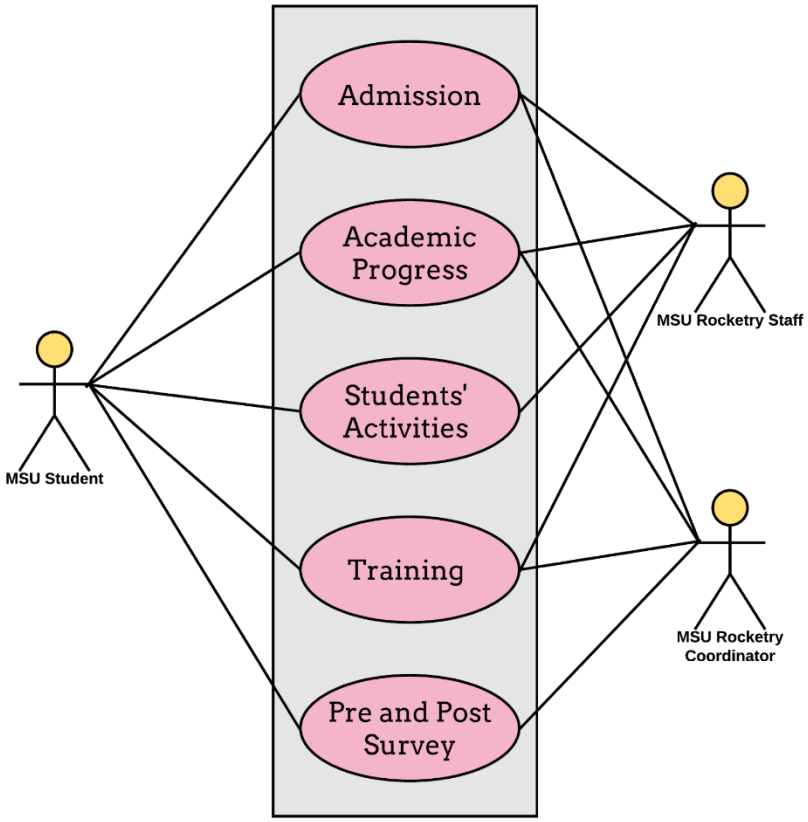

Fig.1 Use Case Diagram of MSU Rocketry Program

Figure 1 shows a Use Case Diagram about the students' learning process in the rocketry program. For the sake of simplicity, three actors – MSU Student, Rocketry Staff, and Rocketry Coordinator, represented the dynamic system of the Rocketry Program at MSU. Even though the goal is to engage a multidisciplinary and diverse group of students, they will still need to follow specific procedures and protocols in order to be qualified. Both the Rocketry Coordinator and Staff can monitor the progress of students be it in a group or individually.

MSU's Rocketry Program Vision and Goal

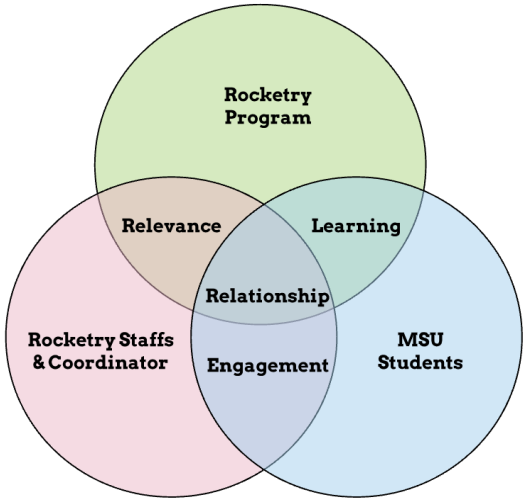

Fig.2 Venn Diagram of MSU Rocketry Program Vision and Mission

MSU has been recognized and hailed as a leader in educating African Americans predominantly and is ranked number one in awarding bachelor's degrees in engineering to African Americans in Maryland. However, MSU's legacy as an HBCU has been undervalued historically as a prime research and development institution to develop and advance aerospace training and workforce competitiveness. All of this changed when MSU received an award from BASE 11 to design, develop, and launch a liquid fuel rocket. MSU Rocketry Program envisions having a multidisciplinary and a diverse group of students working together to build its very own first liquid rocket engine. Due to the approach of MSU Rocketry Program to engage multidisciplinary students, the university is on the path to becoming a national HBCU leader in the development of rocket-based engineering and training for the current century. As shown in Figure 2, different sets of perspectives – Rocketry Staff & Coordinator and students were interacted to promote growth, learning, and experiencing while building a reliable and robust relationship, which serve as the foundation of the rocketry program at MSU.

Core Competencies and Professional Skill Development

As shown in Figure 3, MSU Rocketry Program utilized different types of software based upon the given scenario. By being part of MSU Rocketry Program, students were able to acquire various programming languages such as MATLAB, Arduino, Python, and Raspberry-Pi Software to calculate basic calculation and control of launching activities. The Programming languages are used to (1) define the original math model used to define the rocket system; therefore the simulation, and (2) create an image processing and segmentation for each part of the rocket to show how the system works based on the model. A similar study was also conducted by utilizing MATLAB and Python software to model a steady-state modular simulation of a Liquid Propellant Rocket Engine (LPRE) to evaluate the engine components [9].

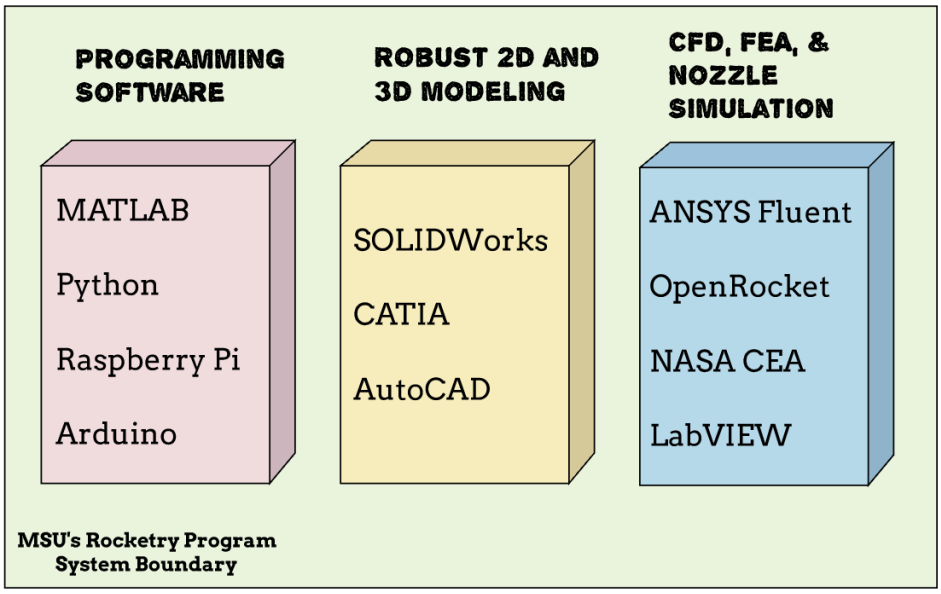

Fig.3 Example of Skills and Software Used in the MSU's Rocketry Program

During the design phase of the MSU rocket engine, students will be exposed and taught how to create 2D and 3D Modelling using SOLIDWORKS, CATIA, and Autodesk's Software, all are widely regarded as the industry standards. This set of skills is essential for the students because it will help them visualize the whole process. They can see the connection for each part and why it is necessary to be there. Moreover, they can make the drawing in an exploded view. Thus, allowing them to manipulate the factors and conditions in order to have a good and efficient system due to the materials' tensile stress and strength. Additionally, students will learn how to create a simulation model based on the input and factors given. The participating students will perform a numerical analysis of the LPRE using computational fluid dynamics (CFD) approach by ANSYS Fluent. Other simulation tools such as OpenRocket, NASA CEA, and LabView will also be used for results comparison. A previous study by [10] explored the use of additive manufacturing in the design and analysis of LPRE nozzle. This forms the benchmark on which subsequent simulation by the MSU rocketry team will rely. A similar study was conducted using CFD modeling in order to evaluate the performance of the turbulent combustion and capabilities of a rocket engine [11].

MSU Rocketry Program heavily emphasizes the importance of learning the overall process of a rocketry system. The team currently comprises of a few students from interdisciplinary fields but widening its horizon to engage several multidisciplinary students. Using several tools for the design of liquid propellant rocket parts will enable the students from diverse fields to communicate efficiently by seeing the practical applications of the different laws of physics (such as the Newton's law of motion) directly to real-life scenarios in order to make analytical predictions – such as fluid flow and heat transfer [12]. In order to develop new courses in the Rocketry Program of MSU, major courses offered in the Aerospace Program by several other universities were investigated. Table 2 shows the core courses that are currently offered in some of the institutions within the aerospace program. Few of these courses are currently offered at various MSU fields of study.

Table 2. Major Course Offerings in Few Selected Universities for their Aerospace Program

Courses of Schools/Universities that Offers Aerospace Program				
Georgia Institute of Technology	***Virginia Polytechnic Institute and State University***	***Purdue University***	***Rensselaer Polytechnic Institute***	***College Park***
Propeller and Rotor Theory	Spacecraft Propulsion	Aeromechanics	Aerospace Structures and Materials	Computational Fluid Dynamics I
Flight Dynamics	Aerospace Propulsion Systems	Flight Dynamics and Control	Aeroelasticity and Structural Vibrations	Aircraft Propulsion and Power
Space Flight Mechanics	Propellers and Turbines	Aerospace Propulsion	Propulsion Systems	Aircraft Flight Dynamics
Structural Dynamics	Booster Design, Fabrication, and Operation	Spacecraft Design	Modeling and Control of Dynamic Systems	
Statics and Dynamics	Internal Combustion Engines	Spacecraft Attitude Dynamics	Fundamentals of Flight	
	Fundamentals of Thermodynamics	Fluid Mechanics		

Figure 4 shows how different multidisciplinary departments, together with the students, will be involved in the rocketry program, specifically in building the rocket. In the flight design, interdisciplinary students from the Department of Physics, Mathematics, Architecture, and Engineering will be involved. While in structural design, Physics, Civil, and Industrial Engineering departments will collaborate. Lastly, engineering students together with mathematics and architecture students will work together for the wind turbine design. It is essential to clarify that a significant objective of this project is the introduction at the undergraduate and graduate level, a systems perspective in fluid dynamics and propulsion engineering [13]. Each student will be

guided and mentored by the Rocketry staff to use the necessary software and modeling such as Finite Element Modeling, Robotics, Computer Programming, and Mathematics, Aerodynamics, AutoCAD and many more technologies. In the end, the Rocketry Program at MSU hopes that both undergraduate and graduate students, even with different backgrounds, will be exposed to Ansys, Matlab, OpenRocket, RocketSIM, and Comsol software tools for analysis.

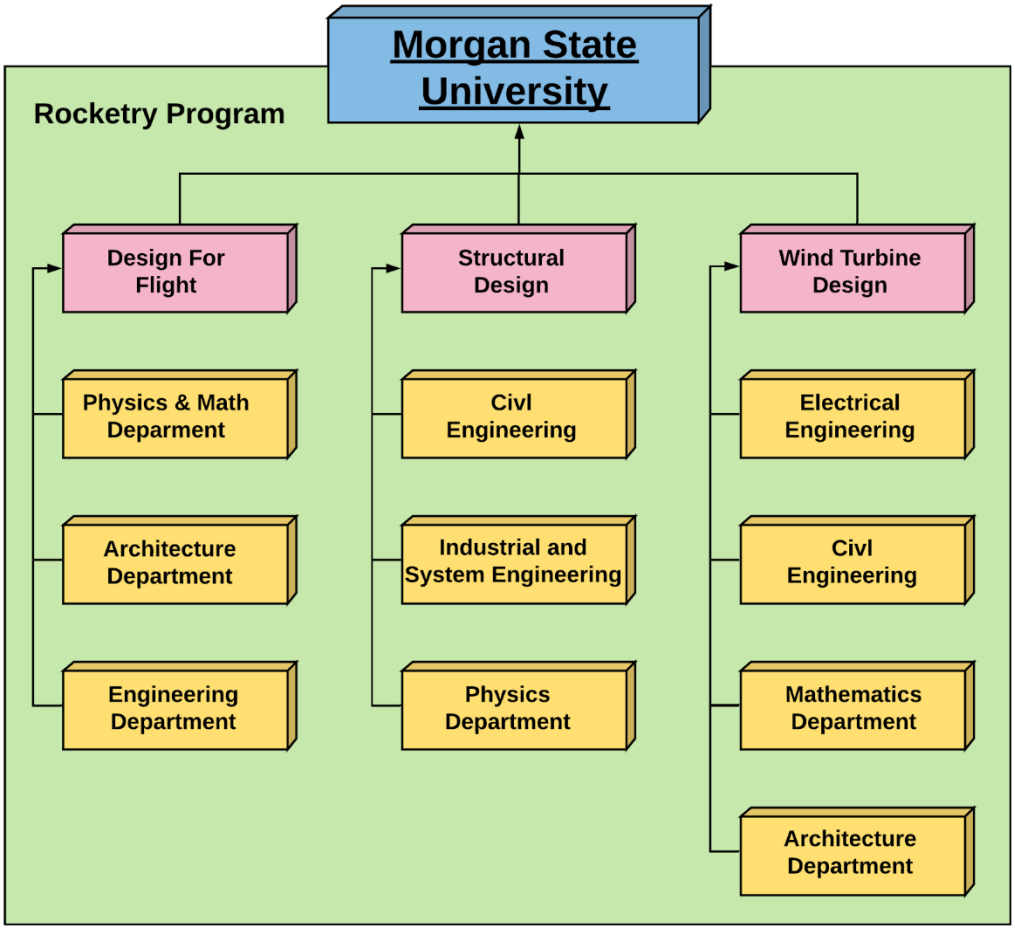

Fig.4 Multidisciplinary Field Engagement in the Rocketry Program

Morgan State University Rocketry Program Evaluation

To measure the impact of the MSU Rocketry program, the authors carried out survey by selecting 30 undergraduate students from different STEM fields (Engineering- Industrial, Electrical & Computer, Civil; Architecture, Physics, Chemistry, and Mathematics). The survey statements were structured to assess the involvement of students currently enrolled in the offered rocket course as elective for the ongoing Spring semester; determine the level of awareness of the rocketry program at MSU; and the enthusiasm for having a rocketry program at an HBCU. The following inquiries were made during the survey:

- What is the level of awareness of the rocketry program by MSU STEM students?
- Are special computer skills needed before enrollment in the program?
- What is the students' view of the rocketry program structure?

- Is there any difficulty in active participation in the program by students with a non-engineering background?
- What is the likelihood of getting immediate employment in aerospace industries upon the completion of the program at MSU?
- What are the challenges and impacts of having a rocketry club at MSU?

The overall survey indicated that the students were excited to hear that the university won the students' rocketry challenge among several universities that competed. As shown in Figure 5-9, the research survey queried the students from diverse STEM fields of study to assess their awareness on the rocketry program at Morgan, participation in rocketry club, computer skills required of them, and their preparation for a rewarding career at NASA and other aerospace industries. When asked about computer skills needed for enrollment, 42.11% agreed that the core technical skills are not needed before enrollment and participation in the rocketry program, as shown in Figure 5. Computer software such as CAD tools, ANSYS fluent, MATLAB, Raspberry pi, Python, among others, are essential tools needed in the rocketry/aerospace program, but the proficiency in these tools is not a prerequisite for students' enrollment in the program. With this in mind, students from non-engineering backgrounds but with STEM majors can be enrolled in the program. The participating students will be made to learn these vital tools as they go through the design and analysis stages of different parts of the rocket propulsion system.

Figure 6 shows that the rocketry program will prepare the MSU students for a rewarding career in aerospace industries as agreed by many of the participants (i.e., 52.63%). 36.84% of participants strongly agreed that having a rocketry club at MSU will aid in increasing the enrollment of students in the program, which will impact the overall enrollment of Engineering students in the university, as shown in Figure 7. There are several clubs and departmental associations on campus with a focus on helping the students in various fields to achieve outstanding success in their career field. Non-HBCU universities that offer rocketry programs have rocketry clubs that embark on several projects in designing, launching, and analysis of propulsion systems. The MSU Rocketry team (i.e., Team Arrow) will be joining these existing universities and establishing collaborations with them for gainful experiences in achieving the set task of launching the first phase of the grant, which is 13,000 ft. Figure 8 shows that only a few students are aware of the rocketry program at Morgan. Through the creation of the rocketry club, this current level awareness is expected to increase as more students will be engaged in the program. As shown in Figure 9, a vast number of survey participants strongly disagreed that non-engineering students cannot participate in the rocketry program. It was able to conform to the objective of this study – to engage students from the multidisciplinary field of studies in the rocketry program.

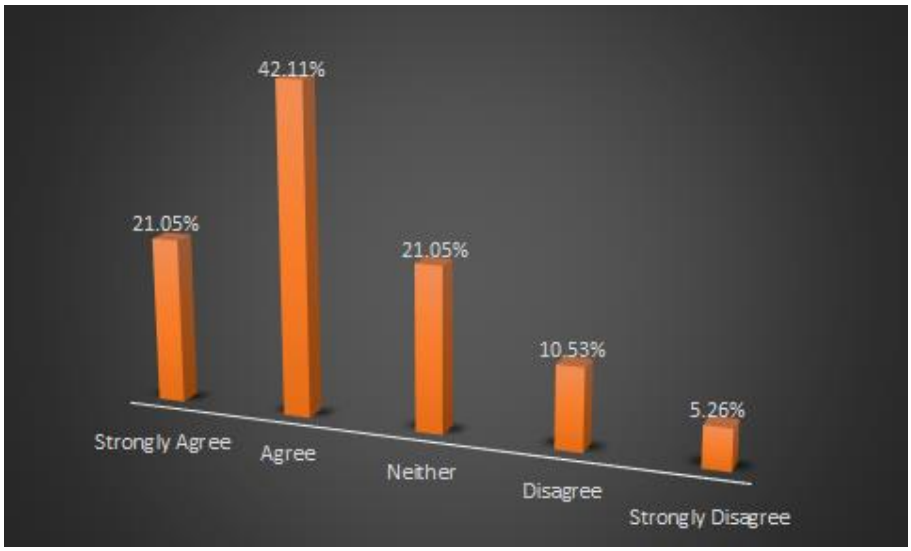

Fig.5 Core Computer Skills Not Needed Prior to Enrollment

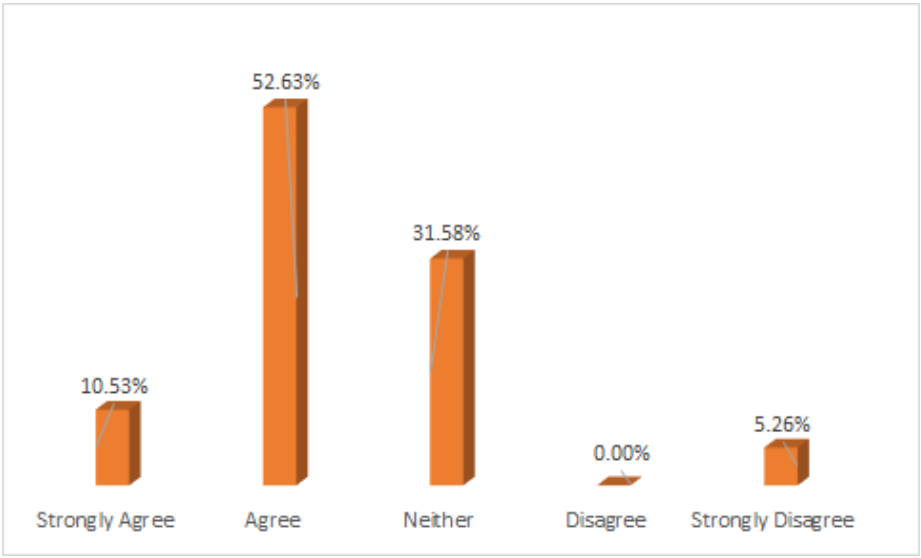

Fig.6 The Rocketry program as a preparation tool for NASA/Aerospace Career

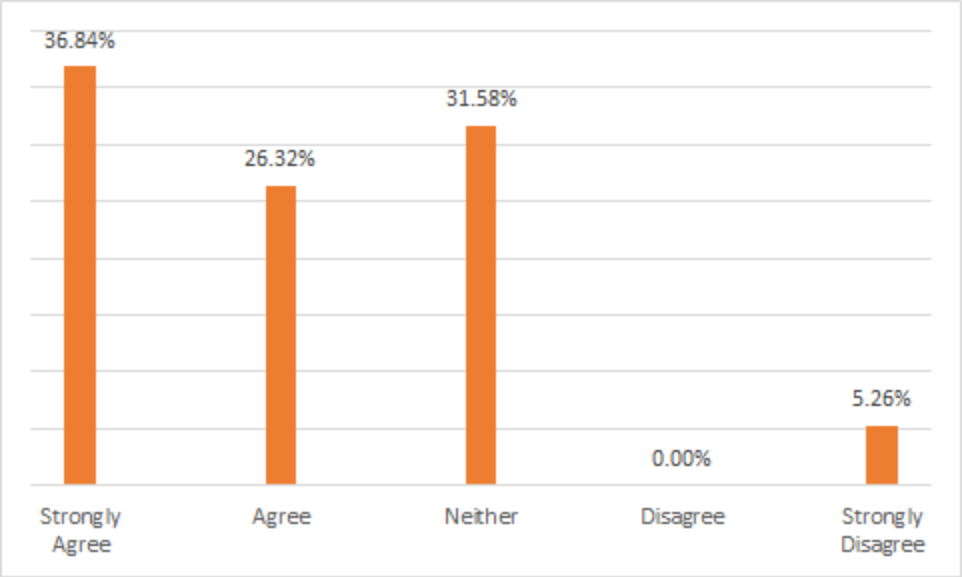

Fig.7 Rocketry Club as a tool for increasing student enrollment

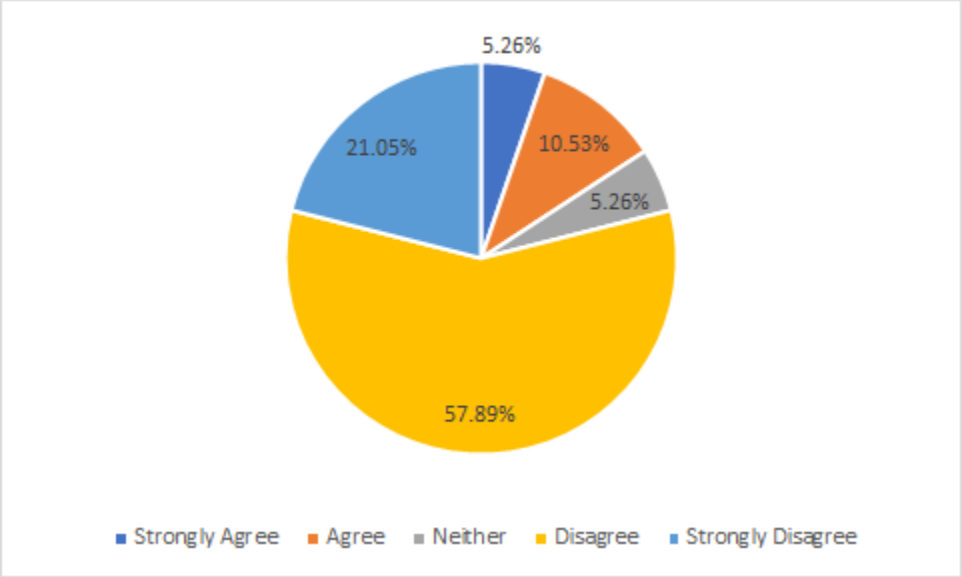

Fig. 8 80% MSU students' awareness of the rocketry program

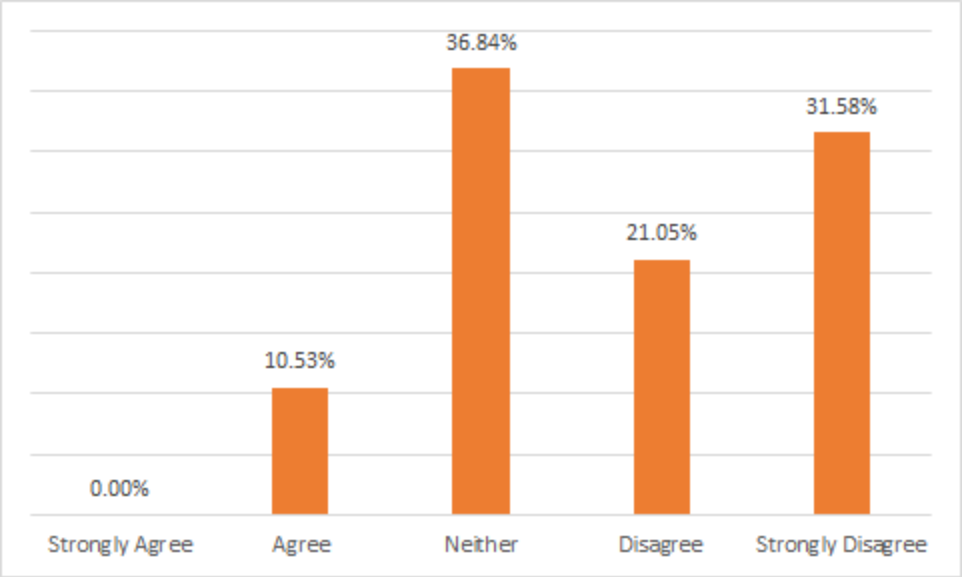

Fig.9 Non-Engineering Student cannot participate in the rocketry program

Conclusion

In conclusion, MSU's rocketry program provides a pathway for multidisciplinary and diverse students who are interested not in building Rockets alone, but as well as Aerospace in general. The program recognized the needs, advantages, and benefits of collaborating with different disciplines, professional backgrounds, and a diversified ethnicity on a single team to achieve a common goal. While the students are involved in developing and fabricating their very own LPRE, they will acquire skills such as programming, 3D Modeling, simulation, and rapid prototyping, that are useful and will prepare them to work effectively and efficiently in the outside world. Based on the given results of the survey conducted, students from different disciplines are excited to collaborate and work together with other students from different fields of expertise.

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