SAVER

Challenge 4: Surface Autonomous Vehicle for Emergency Response

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University At Buffalo Micro-g NExT Research Team 2022 Video Submission

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A. Abstract

As NASA plans to venture back onto the moon in its Artemis program, it is integral that all anomalies and scenarios are accounted for, and with these anomalies come many engineering challenges. The Orion mission is a crewed mission to space for exploratory purposes–taking humans deeper into space than ever before. A major engineering challenge that needs to be addressed directly impacts the safety of the astronauts re-entering Earth. Locating astronauts who land in the ocean and directing emergency survival supplies to them will contribute to a successful mission. The Surface Autonomous Vehicle for Emergency Rescue (SAVER) poses as a solution during a launch abort or contingency landing. The autonomous vehicle will contain multiple sensors for object avoidance and beacon detection. SAVER will be designed for autonomous navigation, but it will allow for teleoperation as well. A software-defined radio (SDR) on SAVER will detect and process signals from the 121.65 MHz Tri-Band Beacon, enabling it to maneuver towards the target. The other subsystems will consist of a TensorFlow-enabled camera and multiple ultrasonic sensors. TensorFlow will allow SAVER to recognize the ANGEL beacon and alter the direction according to the visual input.

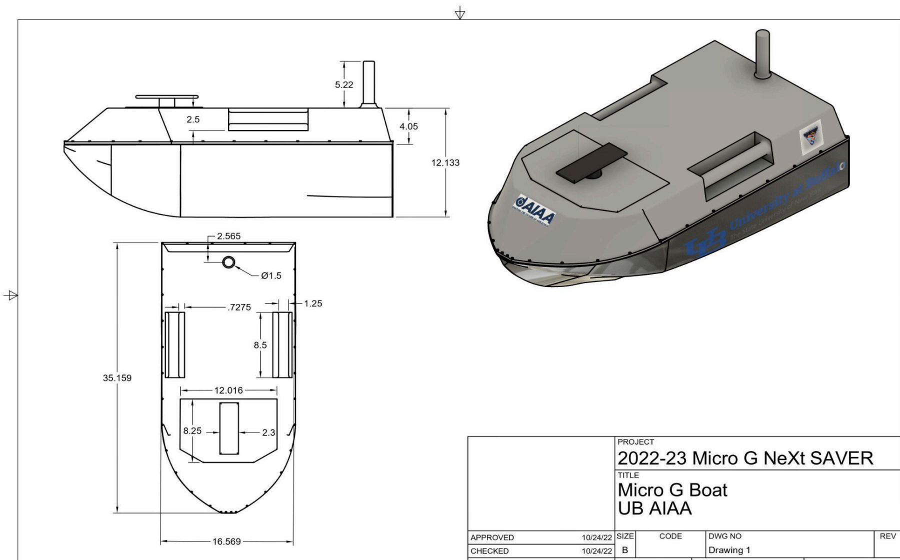
B. Design Description

1. System Overview

The design idea of this vehicle was based on similar ideas from the previous years AMSAR (Autonomous Maritime Search and Rescue) design (2020-21) as well as some online research that is cited below[3,4]. Through research and the use of previous models, the team was able to create a shape that allowed for the majority of the volume to be preserved and for it to be as level and stable as it could be given the size limitations. The need for having a waterproof section for the electronics and having the need to carry a payload led to having a secondary hull where the payload will sit and provide structural rigidity to the vehicle and create a waterproofed area of the boat where the electronics will be stored.

The SAVER (Surface Autonomous Vehicle for Emergency Response) is a fully autonomous system that shall undergo multiple mission procedures tasked with delivering one Platypus Platy 2-liter water bottle and two Toxi-Rae sensors to the astronauts that have just landed back on earth.

Figure 1: Drawing of the SAVER with dimensions



2. Antenna Placement

The vehicle will make use of four telescopic whip antennas. They will be placed on the top of the vehicle due to the signal-blocking properties of carbon fiber which is what the hull will be made of. Placing the sensors on the top of the vehicle gives the SAVER an accurate distance reading. The Kerberos radio will be placed centered towards the back end of the vehicle above the propeller in order to simplify the code that calculates the distance to the destination. This means that it will not have to take into account the offset if it were placed anywhere else on the drone. The antenna placement also acts as a weight stabilizer for the SAVER drone; however, this placement might change due to different needs and the number of antennas.

3. Structural Integrity

The structure of the vehicle will be created with a combination of small 3D-printed structural members with threaded inserts to secure the structure together and a combination of carbon fiber and fiberglass. The main hull and secondary hull will be made from a carbon fiber weave, using a 3D-printed negative in order to get the proper outer dimensions. The top portion of the boat will be made from fiberglass and 3D-printed components. This decision was made since carbon fiber blocks radio signals so it wouldn't be useful as a material in a location where the radio antenna and receivers will be placed. Additionally fiberglass is much cheaper compared to carbon fiber so it is a major factor in cost reduction of the top of the boat given its larger surface area compared to the other components.

4. Circuitry and Wiring

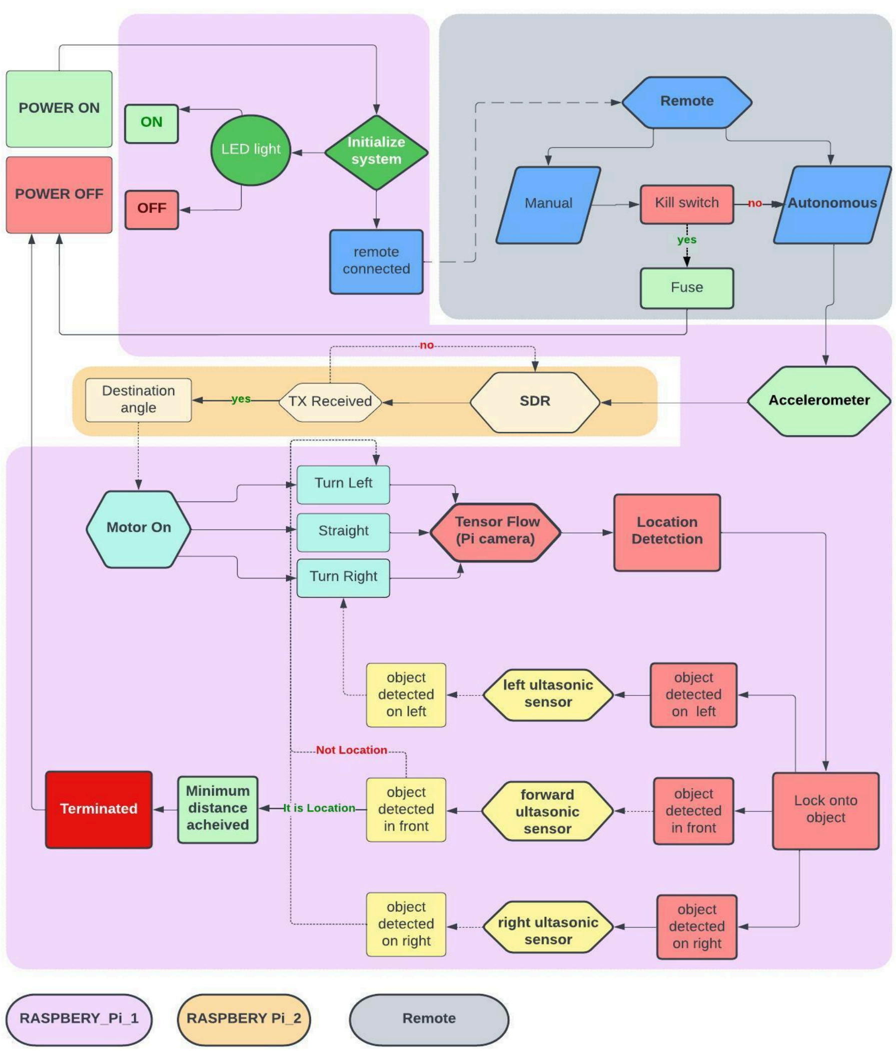


Figure 2: Software flowsheet

5. System Objective

Initialize System

The power is turned on with a remote to start the SAVER. If all systems are working correctly, the system is ready to start and will turn on LED lights. If they do not turn on, the system will be unable to start up. Initializing the system starts up the Raspberry Pi's, along with all of the necessary sensors leading to the SAVER finding its objective.

Receive Transmission of ANGEL Beacon

The SAVER will be using Kerberos SDR with its corresponding software to receive the transmission of the ANGEL beacon. The SDR has a range of 24 MHz to 1.7 GHz to allow for adequate testing with the ANGEL Beacon. Four omnidirectional antennas will be arranged on the four corners of the SAVER for the purpose of weight distribution and to detect a relative angle toward the ANGEL beacon. In addition, it will be using the transmission that was received to determine the angle and direction of the beacon.

Motor Control

The motor has two subdivisions, throttling and steering. It has scripts that allow the input of the radio frequency for direction detection, object detection, and proximity detection to run the motor. The servo motor is responsible for directing the vehicle while the other motor is responsible for propelling the vehicle forward.

Object Detection/Object Avoidance

Sensors located on the outside of the hull will send "messages" to the Raspberry Pi that the motor is connected to. As well as TensorFlow, an open-source API with a pre-trained AI that is connected to a Pi camera for extra assistance of any surface level objects. The Pi camera will also send back messages to the software. The "messages" will go through the program then tell the servo-motor to turn left, right, or stay straight based on any object interference that may disrupt the path of motion.

Proximity Detection

Sensors on the outside of the boat will send "messages" to the Raspberry Pi which the motor is connected to. That will tell the motor to slow down, speed up, remain at the constant speed, or to stop when the target distance has been met.

6. Design Changes Matrix

Table 1: Design Changes Matrix

Design Change	Description
Boat Hull	• Adding in facets into hull to help streamline water around the hull properly • Creating proper drafts for connecting the upper, mid and bottom of the vehicle • Creating a hull which is easily manufacturable and maintains its rigidity when being cut to allow for modifications and mounting points
Hatch to internal payload	• Making a proper attachment mechanism • Change the handle inorder to better fit the astronauts hands in the gloves

Water Jet Thrusters	● Adding the Nozzle on outside of the hull ● Adding internal components into the thruster ● Maintaining a waterproof boat
Antenna Placement	● The amount and placement of the antennas is going to be changed based on availability of the type of antennas
Raspberry Pi Camera	● Will no longer be needed in the design, its no longer apart of the coding process
Battery Placement	● The batteries will be moved around and tested in order to obtain the best weight distribution ● Batteries that are safe to handle and transport

7. Structures

Design Overview

The design idea of this vehicle was based on similar ideas from the previous years' AMSAR vehicles as well as online resources. With these resources, the team was able to create a shape that allowed for the majority of the volume to be preserved and for it to be as level and stable as it could be, given the size limitations [1][2]. Due to the need for having a waterproof section for the electronics and having to carry a payload lead to implementing a secondary hull. The payload will be contained within that secondary hull which will also provide structural rigidity and create a waterproof section for the electronics. The use of a water thruster was decided to provide more safety when the vehicle approaches the astronauts, and also as a way of providing water cooling for the electronics [4].

Figure 3: Rendered SAVER Model

Sensor Placement

The sensors will be placed under the water on the outside of the hull for purposes of avoiding the interference with the carbon fiber hull. Placing the sensors under the water reduces interference with the water's surface to provide a more accurate reading. The ultrasonic sensor array will consist of 3 Ultrasonic Sensors, one just below the tip of the bow, and two placed on either side of the center sensor as shown in figure below thus providing the vehicle a clear picture of the surroundings. The required exact relative positions of the USS will be determined through testing. *Figure 4 and 5 showing the placement of the sensors are located in the appendix.*

Handle

The handles located on both sides of the vehicle were introduced with safety and convenience in mind. Having these handles allows the carrier to hold the vehicle similar to that of a briefcase which allows the carrier to have a more stable grip preventing potential drops. This will also grant the user a less challenging process of deploying the SAVER into the water.

Propulsion System

A water jet thruster would be installed at the stern of the vessel. It would be connected to a 3770 KV brushless motor through a 5mm shaft spinning the blades. The propulsion system intakes water through a mesh intake on the bottom of the boat. This water is pressurized by the water thruster. The water thruster is a set of rotating blades connected to a 5mm shaft driver by the motor as mentioned above. This pressurized water is then converted to a relatively high velocity jet which is then ejected out the rear of the boat. This jet of water sent out the back of the boat will propellel the boat forward due to momentum conservation. A servo will be attached to steer the nozzle to allow for steering the boat in yaw.

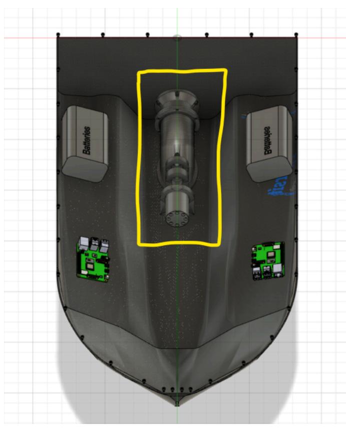


Figure 6: Propulsion System top-down view

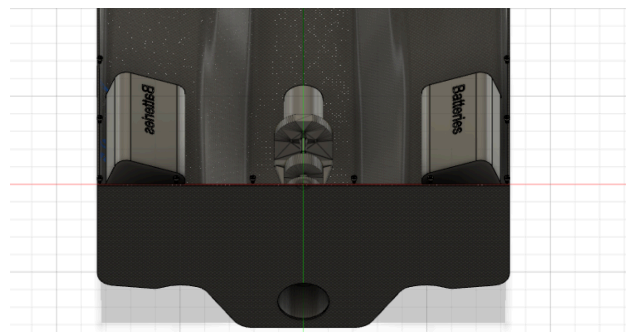


Figure 7:Propulsion System rear view

Hatch

The hatch will be located in the front since it will be directly approaching the astronauts. It will create an even weight distribution throughout the vehicle due to the water thruster, motors, and batteries being located towards the back of the vehicle. This placement was selected with safety in mind in order for the user to avoid the back of the vehicle where the water thruster nozzle is located. The hatch is designed to create an easy way for the astronaut to retrieve the payload, with or without gloves on, which will be secured with a velcro system. The handle of the hatch is 1.5 inches away from the top of the hatch to accommodate for the astronauts if they are wearing gloves [4].

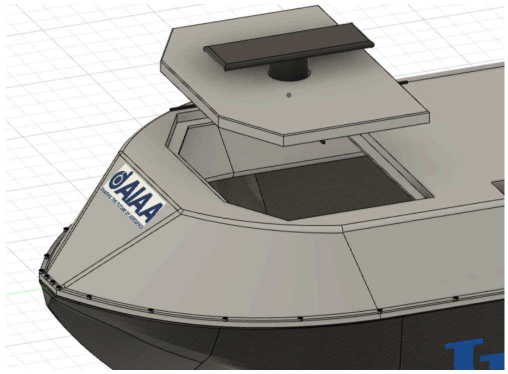


Figure 8: Isometric View of the Hatch

Waterproofing

This is going to be done through a few different means; for the majority of the vehicle, it is going to be done with trapezoidal drafts, marine grade gasket maker, and an assembly of M3 bolts in the positions that they are located on the vehicle (Figure 1) to ensure a tight connection between all the components. Another way waterproofing is going to be done is through the use of a secondary hull. This will act as a barrier from the payload and the moisture-sensitive electrical components in the lower compartment. Furthermore, the top hatch which will be the access point for the payload will be waterproofed as well to maintain the balance of the vehicle. Also, if the SAVER were to encounter waves of any height it would provide a controlled buoyancy and keep the payload from getting wet and ruining any of the parts that are needed to be transported.

Safety Considerations

Safety was an integral part of the team's design process, focusing on hull shape, water thruster, and durability. The hull shape was finished with smooth edges to prevent potential lacerations to users. Durability was also a priority such that it wards off fracturing of the hull under strong impact conditions either from dropping or collisions with waves. Lastly, the use of a water thruster on the SAVER allows the team to circumvent the use of external propeller blades reducing the safety concerns associated with the back of the SAVER drone. In addition, the water thruster design has a mesh at the mouth of the water thruster to prevent any intake of non-water objects. The base framework consists of multiple sensing systems and CPU. Each of the four solder tabs on the power distribution board are rated for a maximum amperage of 30A, while the average equipment draws at DC 3A 5V. Distributed power for each subcircuit was determined based on the immediately dependent device's specifications.

8. Electronics

The base framework consists of multiple CPU and sensing systems, using a power distribution shown in the figure below. Each of the four solder tabs on the board are restricted to a max amperage of 30A, when the average equipment draws at DC 3A 5V. Distributing the power for each subcircuit was determined based on the immediately dependent device's specifications. **Figure 9** gives the circuit diagram that is to be implemented into the SAVER. The converters monitor the input power to sub circuits and ensure proper connections between equipment.

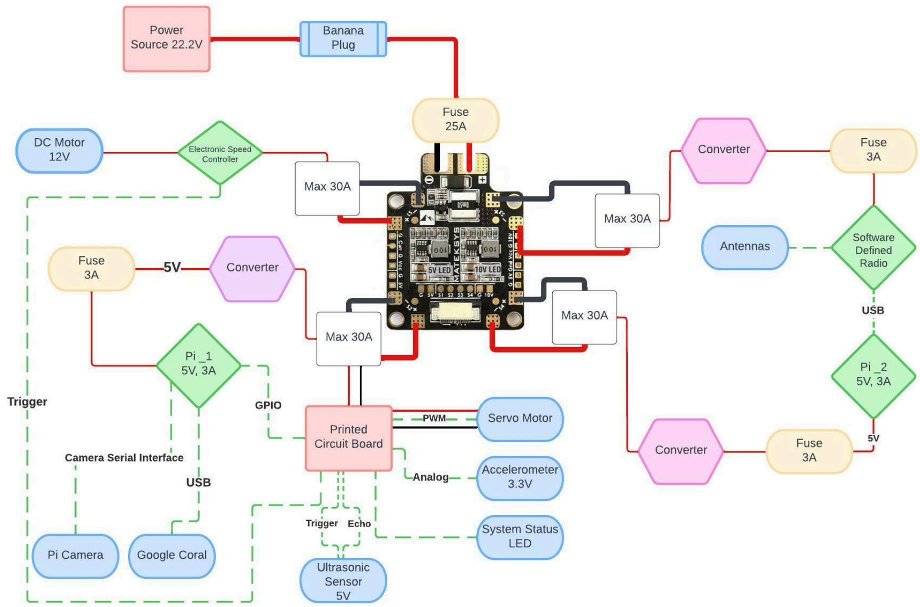


Figure 9: Circuit diagram for the power distribution board

9. Component Overview

Table 2. Electronic Component Overview

Component Name	Functionality
Power Distribution Board (PDB)	• The PDB diverts power to the two Raspberry Pi's, the Kerberos SDR, and the primary and servo motors. • Handles the load from the source and allows for stable sub-circuits. • Connected to two 22.2V 4A DC power sources and is designed to properly distribute power along its branches depending on the load and circuit configuration.
Raspberry Pi4 Model B (2x)	• The Raspberry Pi's are used to provide a framework to read sensor data and power select devices. • Locally host software, converting readable data into actionable and mechanical operations. • These Pi's take data from three ultrasonic sensors, an accelerometer, the SDR, and the Pi Cam. • Once the Pi's have received this data, they actuate the motors to move in whatever direction necessary at the time. • The Raspberry Pi's are central to the function of SAVER and its subsystems.
Accelerometer	• A small, low power accelerometer that can detect from 0 up to 16 g's. • Used to detect impact and initiate SAVER primary functions. • Detects a large impulse, signaling to initiate higher level systems run by the Raspberry Pi's • Powered through the GPO pins on Pi_1.
Electronic Speed Controller	• The ESC interfaces with the Pi's and motors, allowing the Pi to change the speed of the motors. • Converts input signals from the Pi to signals which can drive the brushless motor at the appropriate RPM.

Primary Motor	● This is the primary propulsion device of the SAVER, it drives the propeller on the stern of the SAVER. ● Outputs electrical power converted to mechanical energy for driving the propellor shaft
Servo Motor	● The servo motor is used for controlling the nozzle, allowing for change of direction. ● Takes inputs from the USS, the PiCam, and the SDR which cause the servo to move. ● A priority hierarchy determines which input is received by the servo, and therefore which direction the servo will steer the SAVER.
Kerberos SDR	● The SDR allows for a variable circular array configuration to sense radio transmissions. ● Outputs directional data in relation to SAVER's bow of PLB signaling at 121.5MHz, and can be properly calibrated to the testing environment. ● Takes synchronous voltage readings of each antenna. ● Performs proper calculations based on the calibration arguments and yields a directional vector for storage to CPU memory.
Telescopic Whip Antennas (4x)	● The antennas intercept the 121.5 MHz signal from the ANGEL beacon and feed it to the Kerberos SDR. ● Organized in a circular array for direction finding with a spacing factor of 0.15 as suggested by Kerberos. ● Once plugged into the KerberosSDR in the correct arrangement, they will act as receivers for the direction finding algorithm MUSIC.
Ultrasonic Sensors (3x)	● The ultrasonic sensors detect potentially hazardous objects in the path of SAVER to avoid collisions. ● They detect objects up to 450 cm away and they have a 20 degree cone angle of detection. ● Sends out continuous ultrasonic waves and reads the time lapse between signal and echo. ● Data is recorded by Pi_1.
Google Coral	● The Google Coral is a processing unit that accelerates TensorFlow data returns to decrease mission time and more rapidly detect the target. ● Optimized to process TensorFlow. ● Separates software for accelerated read times and sends data to Pi_1 for storage and further use.
Pi Camera	● Small camera which allows the detection of the astronaut in the water. ● Placed on the bow of the SAVER. ● The data obtained from the Pi Cam is sent to Pi_1 to be analyzed by TensorFlow, this permits the detection of the astronaut in the water. ● The outputs of this process actuate the servo motor and the primary motor.
Fast Charging Converter	● Allows the transmission of power from the PDB to the Pi's and SDR. Interprets the power demands of the component and draws that power from the PDB, converting the voltage and current from the PDB to that requested by the component.

10. Software

SAVER's software will be written in Python and run on Raspberry Pi. Using object oriented programming and external libraries, each sensor, camera and algorithm will be represented as objects. In the main class, a simple graphical user interface (GUI) will be generated, displaying sensor data and power on/off functionality. This computer will establish connection to SAVER and execute the direction finding algorithm. When the target beacon is detected, it will send back an update to the GUI that the destination was found.

Direction Finding/Object Avoidance:

The Software Defined Radio (SDR) will receive the transmission of the ANGEL beacon. To capture the specific signal frequency, the team will create a function using external libraries.This function will determine the relative angle between the boat's bow and the ANGEL based on the received radio signals. The program will also calculate the distance between the target beacon. An object avoidance function will utilize the information the sensors provide to prevent any possible obstructions. Finally, the team will utilize tensorflow to scan the surface of the water for any floating obstacles and cross reference with the ultrasonic sensors. When SAVER has successfully avoided an obstruction, it will make corrections back towards the direction of the ANGEL beacon.

Algorithm:

The SAVER will implement a variation of the vector field histogram (VFH) algorithm. This will allow the boat to go towards its correct destination while simultaneously avoiding any obstacles and correcting itself back towards the path. Using this method, VFH will take into account the weight, height and length of the boat to help avoid the objects at hand. This method takes in real life data of the field and uses it to correctly base its decision upon. This information will be stored in a database (MYSQL) that the program will then parse this information accurately to determine if there is an object on the left, right or in front of the SAVER. In the event there is an object that needs to be avoided, if the boat hits a wall while avoiding an object, it will go in a different direction. Similar to Dijkstra's Algorithm which puts all check "nodes" into a queue to make sure the algorithm does not check it again.

Tensorflow:

Tensorflow is an open source API that allows users to incorporate machine learning. The team will use a pretrained model from tensorflow called "*Model Zoo*" that allows us to successfully detect objects on the surface. Tensorflow receives input from a Pi camera and uses that to detect any potential obstacle in its path so that SAVER can perform object avoidance if necessary.

Table 3. Software Risk Evaluation

Risk ID	RISK DESCRIPTION	Relevant Hazard Mitigation
R1	The Pi Camera fails detecting objects on surface	SAVER will crash into the object
R2	Sensors get overloaded with information	SAVER will not know what direction to go to avoid object
R3	PI overheats and reaches cooldown states	System will restart and remote will be needed to turn on again

11. Manufacturing Plan

All parts to be manufactured in house at the University at Buffalo's machine shop and in lab spaces. Besides that, the majority of the other components are going to be purchased from various sites including Amazon, Ebay, Fiberglass, Composite Envisions and multiple other sites. Then the parts are going to be assembled together with Loctite on the screws and then the major components are going to be joined with a layer of maritime gasket maker in order to insure water tight components.

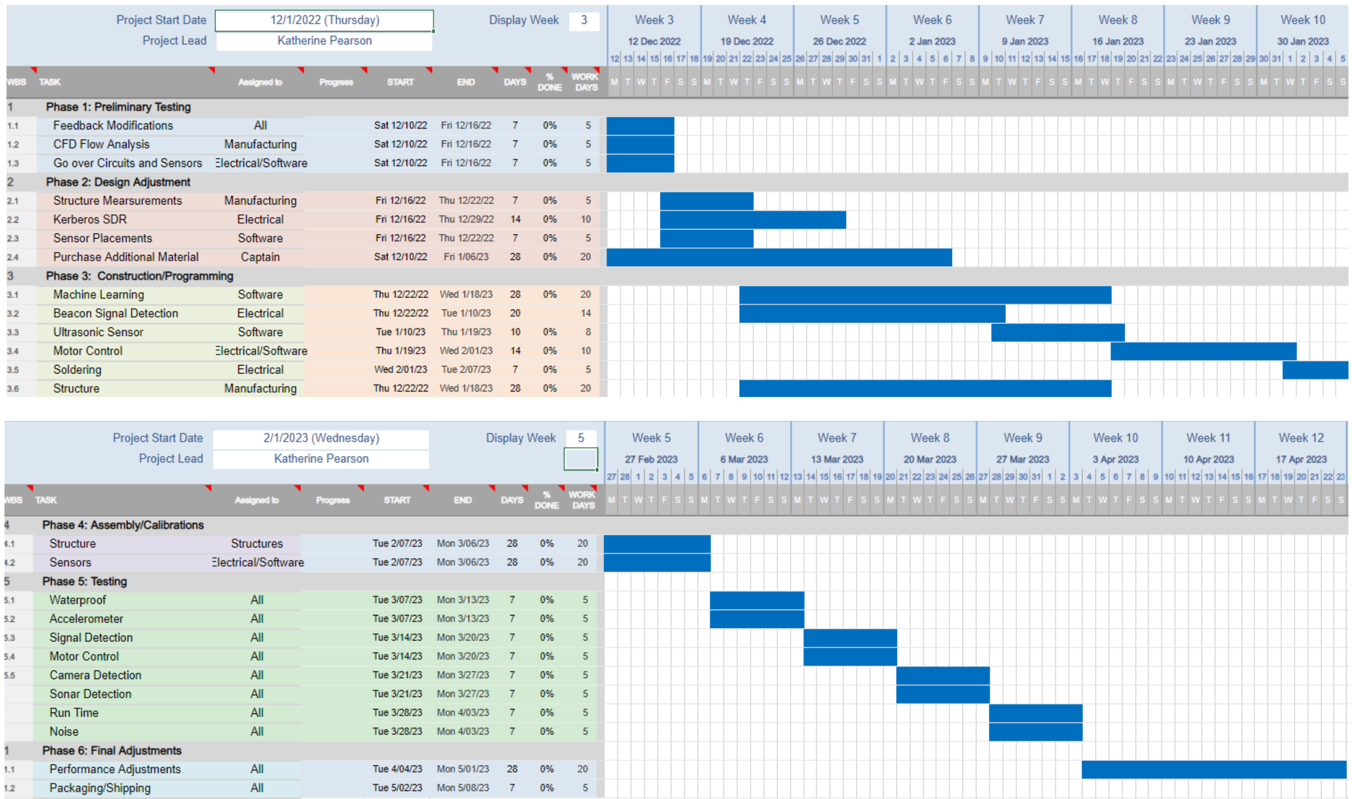


Figure 10 : Gantt Chart

12. Compliance Matrix

Table 4: Compliance matrix

Req. No.	SAVER Design Justifications
1	The SAVER is equipped with a telescopic antenna allowing it to intercept the 121.5 MHz signal from the ANGEL beacon and feed it to the Kerberos SDR.
2	The SAVER will initialize the system within 60 seconds of being placed in the water, the RASBERRY_Pi will receive a unit direction vector towards the homing signal from the SDR. The propulsion system will align with the direction of the homing beacon and will start moving towards the beacon. The Pi cam and the USS are for object detection. The SAVER will avoid all the detected objects and realign itself with the beacon, until the astronaut is found. The Pi Cam is trained for detecting a person using the tensor flow object detection. Once the person has been detected, SAVER will perform maneuvers to maintain the person in the center of the frame and head towards them. The SAVER will slow down and stop once the minimum distance is achieved.
3	The cargo bay is located in the front of the hull, which helps with the overall CG of the boat and prevents the vehicle from flipping over.
4	The SAVER will be equipped with two 6s 4000mAh batteries more than capable of running the SAVER for more than 15 minutes on max output.
5	Extremely compact size, which max dimensions of 18” x 18” x 36” and maximum weight of 20 lbs without cargo

6	Measures have been taken to ensure AMSAR 2.0 is safe to personnel in the test environment. For software, a watchdog has been implemented that will detect time out protocols in the system. Upon detection, the software will force that specific system to reinitialize. AMSAR 2.0 itself will have warning labels for possible hazards. There are numerous fuses throughout the electrical system which ensures component safety in the event of hazardous failure.

13. Proposed Testing

During Phase II of the challenge, the team will conduct many types of experiments and tests throughout the construction of the prototype(s).

- **Stability Testing:** Place an empty hull in water to test the design for stability.
- **Long Duration Waterproofing Test:** Place empty hull in water while recording time and taking photos. Leave the hull for many hours to test the durability of the waterproofing. After 10 hours, remove the hull and inspect for leaks, take note of any moisture content within the hull.
- **Electronic Temperature Monitor:** Power on the systems and begin reading and recording the temperatures of the Pi_1 and Pi_2. The temperature should be recorded every five minutes for a total duration of thirty minutes while throttling the motor to simulate real-time conditions.
- **RC/ Autonomous Mode:** Verify that using RC mode kills the system, otherwise the SAVER is autonomous.
- **Ultrasonic Sensor Object Detection/Avoidance Test:** During a test run place various objects in the path of the vehicle. Make note of object placement and the direction of the bow of the boat, and the SAVER's reaction time.
- **SDR Configuration Test:** Transmit testing signal from supplemental equipment with a frequency of 121.65 MHz. Begin testing signal readings of the SDR software.
- **Manual Kill Switch Test:** During a test run of the software, make sure the kill switch is working properly.

C. Operations Plan

1. Testing Day

Systems Check:

1. Verify the prototype remained intact during travel.
2. Ensure the remote is able to power on the SAVER.
3. Verify LED status lights are on.
4. If the device performs as desired, it is ready for test run.

Test Run:I

1. SAVER is set to 'Autonomous' mode and the kill switch is turned off.
2. Vehicle is placed into the water.
3. Turn the SAVER on.
4. Check that LED status lights are on.

5. Check that the radio is receiving the ANGEL beacon signal.
6. Note the initial condition following the start of the test.
7. Note when the SAVER successfully/ unsuccessfully avoids an object.
8. Record the time when the target is acquired and when the system throttles/ shuts down.
9. Instruction for astronauts to open the hatch and retrieve the delivery.
10. Turn the SAVER off via the kill switch.
11. Instruct the astronaut to gather the SAVER, if able, for purposes of reusing.

D. Safety

Table 5: Safety Matrix

Concern	Cause	Method of Addressing Concern
Electrocution	User is exposed to electrical current in the pool due to hydro-compromised electronics	1) Electrical Warning label 2) Waterproofing the vehicle using a) Gaskets and bolts to hold the top and the bottom together b) Silicon hot glue gun and putty for the wire holes c) Marine epoxy for the hull and the top surface
Blunt Trauma	Unable to detect the Astronaut due to system failure	1) Manual Emergency Shutdown 2) Boat will start slowing down once the astronaut is detected and then it will turn the power off once minimum distance is achieved.
Lacerations	Contact with sharp features of the boat or the propellor	1) The blades are completely enclosed within the jet thrusters 2) The boat shall be manufactured to have rounded edges
Burns	Contact with overheated electronics and vehicle	1) Temperature monitoring using the RASBERRY_Pi, if the temperature exceeded 60 degree celsius, SAVER will stop working until its below 60 degrees 2) The hottest part of the boat was well below 60 degrees.
Water Thruster	Injury due to limb or body ingestion into the water thruster	1) The boat has a mesh or grate covering the water intake which is on the bottom of the boat.

E. Technical References

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II. STEM Engagement Section

A. Introduction

Furthering the excitement for STEM amongst the younger generations became a priority for the club, as it has been observed that it will encourage a greater number of students to pursue STEM degrees. Encouraging students to do so would reflect positively in the societies they belong to. There are direct correlations between the advancement with greater innovation and providing educational opportunities for children in science and engineering. The National Aeronautics and Space Administration has historically been a pioneer in scientific research and development; concerted efforts have been made on their behalf to perpetuate and foster a magnanimous environment for young, promising engineers. The members of the University at Buffalo's AIAA Micro-g NExT Research team would like to follow a similar trajectory by providing opportunities and facilities for the youth in the Buffalo community. It is the club's hope that through these efforts the university and local communities may make purposeful contributions.

Science Technology Engineering and Mathematics (STEM) is important for the advancement of societies as innovation and creativity in this sector have been known to induce global societal growth. Some of the global advancements are through prolonging the health of others, boosting economies, discovering the unknowns of the universe and the oceans, and the overall improvements in the standard of living. The National Aeronautics and Space Administration has been at the forefront of advancements in not only aeronautics, space science, and exploration but also in encouraging the development of knowledge for future generations. The members of the University at Buffalo's AIAA Micro-g NExT Research team hope to make an impact in inspiring future generations to pursue the STEM field and aid in these advancements. The team hopes to make a purposeful contribution to the surrounding community through various outreach activities and partnerships with local organizations. The team is planning to implement two methodologies of outreach programming, those being proactive and passive. The objectives are outlined in the following sections.

B. Proactive Programming

Educational settings are often shaped by uncontrollable systematic factors. Many schools lack any STEM-related clubs, courses, or activities due to a lack of funding. Furthermore, higher level math and science courses exist, but focus purely on the concrete knowledge directly from textbooks. This can be seen from elementary-level schooling to institutions of higher education. Many educational programs teach students theory, but this excludes the hands-on experiences required for students to apply their knowledge. UB AIAA Micro-g NExT believes that true understanding comes from the scientific encounter and application of theory to real-world situations. The exposure encountered through labor type activities helps to activate critical thinking and may even foster a lifelong STEM interest for many students. One of the main focuses of this mission is to provide students with educational activities where they can, at any age, learn key concepts and gain hands-on experience. While the project funding depends on the proposal's acceptance, the team has been in contact with Steven Pilat and Christina Escobar who are the team's outreach liaisons in relation to the programs at Westminster Charter School. The team is also partnering with our university's School of Engineering and Applied Sciences to conduct on campus events open to the public. The team aims to volunteer our time, experience, knowledge, and passion to demonstrate activities that can be conducted within the STEM field. Through these activities the team hopes to inspire newer generations of students to pursue an interest in the STEM field.

Westminster Charter School

In recent years University at Buffalo has worked closely with underfunded schools in the local area. Among these institutions, the team will be visiting Westminster Charter School. This specific volunteering program caters to students grades K-8th, and is promoted through National Grid to bring STEM engagement opportunities to the younger generations. Some of the lessons include basic circuits with lessons in chemistry, along with the science of light and color. This program does have a preplanned list of activities but the directors of the program have expressed their willingness to hear the team's suggestions on new activities to provide the kids. As peer mentors, the team will provide a hands-on opportunity for students to engage with basic exploratory concepts. The team hopes that this program will inspire the students to find an interest in the STEM field.

University at Buffalo Hosted Events

The Micro-g team plans to volunteer at the university held events. One of these events is "Say Yes Saturdays." The team will be working under engineering mentors from Buffalo Engineering Awareness for Minorities (BEAM) to support them in their demonstrations to kids in grades 9th-12th. Each month will focus on a different theme with various demonstrations. This activity occurs once a month at the University at Buffalo's South Campus in Diefendorf Hall. Different companies will come each month to help demonstrate different sides of the engineering field. They are accompanied by employees and scientists in the field of focus for that month. There are multiple sessions to ensure that each group remains small for more personalized interaction and to provide a better environment for easier understanding of the topics. The Micro-g NExT team will work as a level of support to aid these demonstrations once a month. The team hopes that by aiding the demonstration they can help inspire students to find an interest in the engineering field.

Another event during the same time and located in the same place as "Say Yes Saturday " is called "Girls In Engineering " which we also will be volunteering for. This event focuses on energy, engineering climate change and public policy. The activities will focus on themes from fossil fuels, wind, solar, nuclear and alternative energy to sustainable transportation, batteries, and the energy grid. The students, ranging from grades 9th-12th, will receive hands-on experience through the use of projects designed to help explore real world problems. These activities have already been preplanned and the Micro-g team will be assisting in the activities to help the students successfully set the project up and understand the applications it has to a real world situation.

The tentative volunteering schedule can be found in the appendix.

Engineering Week

Engineering Week at the University at Buffalo is typically hosted during the second week in February. This week shines a spotlight on the STEM field to the public and shows the continual need for engineers. The methods of demonstrating the engineering section is achieved through various information sessions, interactive activities, and shows throughout the week. Some of the common events done are guest lectures, Engineering Club showcases, and egg drop contests. At the end of the week, there is a Battlebots competition where various engineering clubs can enter. Each club builds their own bot from scratch and they compete against other engineering clubs to see whose battle bot was built the best that year. The Micro-g team plans to participate in Engineering Week by hosting events for other college students and possibly entering into the Battlebot competition. In past years the team has entered a bot into the competition under the American Institute of Aeronautics and Astronautics (AIAA) and have considered entering this year as well. The activities the team are planning will be focused around the SAVER Micro-g project.

Passive Programming

Volunteering, though beneficial to the community, does not always reach the entire community. The team aims to not only influence the communities current and younger generations in STEM, but also to highlight the purpose of NASA's mission and work. This is achieved by spreading word about the challenges, especially the “SAVER Device”. For this reason, passive programming has been incorporated into the outreach portion of the challenge. By doing so, this maximizes the team’s outreach to the local community and helps to possibly recruit potential new members or donors for future projects.

UB Spectrum

The University at Buffalo has an independent student publication called *The Spectrum*. There are about six-thousand newspapers distributed once per week along with having a website that updates the articles each day. The paper can act as a professional outlet for the 2021-2022 Micro-g challenge to showcase the club to the UB community. The authors foresee no difficulty with obtaining a feature in *The Spectrum* for the Micro-g NExT team. The team would be featured under the “Features” tab within both the paper copy and the electronic website. This section is designed to highlight achievements in the community. In past years, The Spectrum’s Senior Features Editors have responded positively to the feasibility of obtaining an article highlight, and the team expects this year to be no different. Following acceptance, the team will reach out to the editors for two features, one announcing the teams’ acceptance, the project description, and the next steps. The second will be debriefing the final project results and testing at the NBL. This will generate publicity for NASA and for the team, which may result in increased support and interest toward STEM within the university community.

C. <u>Instagram</u>

A new instagram account was created in the early fall semester to create greater outreach to the AIAA community. The account used in previous years was no longer accessible, therefore the team had to start a new account. One main objective for the team for the new account was enhancing engagement; this way, more people feel more enticed to join the meetings. This was primarily done by uploading posts of three different types: meeting dates and times, photos from the meeting showing updates of the SAVER building process, and fun facts that the team could discuss. The page was meant to holistically represent the community the team has worked diligently to create. One that represents an all encompassing, hard working, and enticing space. Since starting the page, it has been well received with great amounts of feedback. Since its inception the page has amassed approximately half the followers of the previous one in a fraction of the time given the number of years the previous account held. The UB AIAA community has overall seen success with the new account and plans on developing more interactive social media features to garner a larger audience.

Figure 10: Current Following of ubmicrog(the team instagram account)

D. UB Linked Open Meetings and Testings

UBLinked is an on-campus event management platform for club activities, special guest speakers, residence hall events, etc. This platform has become a staple in tracking when events are hosted and in checking students in since Covid-19 regulations were developed. Each meeting was made open to the public in case students were not aware of the club but were interested in seeing what the team does. Every student was made welcome to come sit in on what the team does and to help contribute to the brainstorming phase. Local tests planned for the Lunar Anchoring Device prototype will also be open for public viewing. The events of when and where the testing will be conducted will be posted on the Instagram account along with an event on UB Linked. Members of the community will be made aware of events through the UBLinked platform in hopes of educating newcomers on the design process and mission importance.

E. Outreach Appendix

Outreach Confirmed Event Dates	
Date	**Event**
11/20/2022	Westminster Charter School
12/4/2022	University at Buffalo Hosed Events
02/5/2023	University at Buffalo Hosted Events
02/12/2023	Westminster Charter School
03/05/2023	University at Buffalo Hosted Events
04/02/2023	University at Buffalo Hosted Events
04/23/2023	Westminster Charter School
04/25/2023	Westminster Charter School
05/07/2023	University at Buffalo Hosted Events

Table 1: Current List of Teams' Confirmed Outreach Dates

F. Outreach Lesson Plans

2.1 Wind Turbine/ Wind Energy Lesson Plan **UB Sustainability (Micro-g NExT)**

1. Lesson Plan Information
Subject/Course: DIY Renewable Energy
Grade Level: can be adapted for any grade level
Topic: Wind Turbine Activity

2. Expectation(s)

Expectation(s)*:*
Students will learn how wind energy can be harnessed and utilized to power everyday objects. **(Depending on the age group there can be more leeway for letting the students fully designing/constructing their turbines from the bottom up. This will also largely depend on the materials that we have to provide the students so that they can design openly.)**

Learning Skills ***(Where applicable):***

3. Content

What do I want the learners to know and/or be able to do?
The students will be able to make a wind turbine and how that energy works.
Students will know that:

1) Wind energy is a renewable energy source, and its utilization has numerous benefits for the environment 2) The number of spokes on the turbine, strength of wind, pitch of blades, and number of blades will have an effect on the energy output
3) In order to construct a wind powered system that will work at a maximum efficiency, numerous factors pertaining to the design, such as gear ratio and power output, must be considered.

Today learners will:

● Identify the advantages of location for maximum wind power collection
● Explain advantages and disadvantages of different angles of their blades on the wind turbines ● Explain how engineers design and redesign wind turbine technology
● Use multimeters to gauge the power output from their constructed wind turbine

4. Assessment (collect data) / Evaluation (interpret data)
(Recording Devices (where applicable): anecdotal record, checklist, rating scale, rubric)

Based on the application, how will I know students have learned what I intended?
Students will be able to demonstrate their level of understanding by applying the concepts to wind turbines that they can test out the lessons on. From the lesson the students should be able to predict which turbine construction would be able to allow for max wind flow while keeping into consideration the environmental impacts. Further their participation throughout the design process of the turbine and presentation in their wind turbine powered lego house design will be good indicators as to how well the students learned the material.

5. Learning Context

A. The Learners
(i) ***What prior experiences, knowledge and skills do the learners bring with them to this learning experience?*** No prior experiences, knowledge, or skills are needed for the students to understand the concepts, only an open mind and readiness to learn.
(ii) ***How will I differentiate the instruction (content, process and/or product) to ensure the inclusion of all learners?***
(Must include where applicable accommodations and/or modifications for learners identified as exceptional.)
The lesson will be able to reach all students by giving students the chance to learn both from oral presentations and hands-on work that will allow them to fully gauge the concepts and grasp the material. Further, this lesson will include a video representation, hands-on help, and teamwork with other students to help everyone understand what the objective of the lesson is.

B. Learning Environment
The learning environment can be done either indoors or outdoors. For indoor activities, it'll require lots of space for students to construct their turbines and test them with large floor fans. The students will work in teams to design their turbine and power an LED. Each team can grab a different amount of materials for their turbine or can also explore the effects of blade pitch.

C. Resources/Materials
Materials include:

- Scissors
- Duct tape
- Wooden dowel
- Multimeter
- Fin material (basal wood or foam)
- LED
- Alligator clips
- Floor fans
- PVC pipe for construction
- Cutting mats
- Hub materials for turbine housing

6. Teaching/Learning Strategies

INTRODUCTION
***How will I engage the learners?* (e.g., motivational strategy, hook, activation of learners' prior knowledge, activities, procedures, compelling problem)**
Ask students if they can explain what a wind turbine is and why it is good. Students can typically answer these questions and this helps to open up the discussion about this renewable energy. From there start talking about what makes a good turbine and how we use these guys to capture wind (which in all things considering is like another form of solar energy).

MIDDLE:

Teaching: ***How does the lesson develop?***

How we teach new concepts, processes (e.g., gradual release of responsibility - modeled, shared, and guided instruction).

The lesson will start with an engaging conversation and depending on the age group a short presentation with lots of visuals on wind turbines or items that the students can pass around to each other. Next the students will be given supplies and an instruction packet that will walk them through how to assemble everything. Volunteers from the UB Sustainability office will go around to all of the tables and assist the students with constructing their wind turbines. At the end the students will be engaged again with more questions on what they learned, what was the objective, and why is this source of energy important. There will also be a discussion of what worked for them and what did not. This is a good reflection period to get young kids to understand it is alright if something didn't work, but to think critically about why that happened.

Consolidation and/or Recapitulation Process*: How will I bring all the important ideas from the learning experiences together for/with the students? How will I check for understanding?*

To ensure that all the students fully understand what was occurring, you could ask the students in their separate groups to tell you how they think the turbine operates with wind and how that transitions to moving the motor and powering the LEDs. Ensure that the students have a good understanding by encouraging participation and helping students answers, no answer is wrong but ensuring that their thoughts are validated and encouraged will help create a great learning experience with the activity.

Application: What *will learners do to demonstrate their learning?*

Learners will be able to demonstrate their understanding of the topic by answering questions at the end and applying their knowledge to building a wind turbine and showing how its design and construction can light up a small lego building or LED. Further, through a think-tank scenario kids will be able to tell whether or not they have a full understanding of the lesson.

CONCLUSION: *How will I conclude the lesson?*

Conclude the lesson by asking students what did they learn from the lesson, specifically asking them direct questions about how does the design of the turbine affect the power output and what were major obstacles they needed to overcome to increase their power output. Further, asking the kids about examples they've seen about wind energy around them besides near the great lake will prompt them to understand the diversity of wind energy. Lastly, information can be shown to kids that demonstrates that the activity that they did is something that students can do at all levels in education, like competitions in high schools to competitive groups in college. The lesson is just an introduction for students to become more aware of opportunities to learn and explore renewable energy at an educational level that they can potentially use in their future endeavors.

7. My Reflections on the Lesson

What do I need to do to become more effective as a teacher in supporting student learning?

Having some knowledge on solar panels and their effectiveness in direct vs. indirect sunlight as well as what time of year they are more efficient are ways that one can prepare for a lesson prior.

2.2 Solar Panel Vehicle Lesson Plan **UB Sustainability (Micro-g NExT)**

1. Lesson Plan Information
Subject/Course: Solar Panel Vehicle
Grade Level: can be adapted for any grade level
Topic: Solar energy

2. Expectation(s)
Expectation(s)*:*   Students will understand how solar panels work and how the power load of the panels can be altered by changing the amount of the cell that is exposed to direct sunlight.   **(Depending on the age group there can be more leeway for letting the students fully design their cars from the bottom up. This will also largely depend on the materials we have to provide the students so that they can come up with designs.)**   **Learning Skills *(Where applicable):***

3. Content
What do I want the learners to know and/or be able to do?   The students should learn how altering the amount of direct sunlight will affect the power output produced by the solar panel. Students will know that: 1) Solar energy is a renewable energy source, and its utilization has numerous benefits for the environment 2) The angle at which a solar cell is positioned in relation to the sun affects its power output 3) The amount of current produced by a photovoltaic cell is proportional to the amount of light hitting the cell;   Therefore, increasing light intensity or increasing the size of the cell will increase the power output of the cell. 4) In order to construct a solar powered system that will work at a maximum efficiency, numerous factors pertaining to the design, such as gear ratio and power output, must be considered.   **Today learners will:**   Learn how changing the amount of exposed solar cell will affect its performance when running down a race track. They will also utilize the design process to construct a solar-powered car.

4. Assessment (collect data) / Evaluation (interpret data)   **(Recording Devices (where applicable): anecdotal record, checklist, rating scale, rubric)**
Based on the application, how will I know students have learned what I intended?   Students will be able to demonstrate their level of understanding by applying the concepts to toy solar vehicles that they can test out the lessons on. From the lesson the students should be able to predict which cars would be able to knock over the plastic cups. Further their participation throughout the design process of the car and presentation in their solar-powered car design will be good indicators as to how well the students learned the material.

5. Learning Context
A. The Learners   **(i) *What prior experiences, knowledge and skills do the learners bring with them to this learning experience?*** No prior experiences, knowledge, or skills are needed for the students to understand the concepts, only an open mind and readiness to learn.

(ii) ***How will I differentiate the instruction (content, process and/or product) to ensure the inclusion of all learners?*** **(Must include where applicable accommodations and/or modifications for learners identified as exceptional.)**
The lesson will be able to reach all students by giving students the chance to learn both from oral presentations and hands-on work that will allow them to fully gauge the concepts and grasp the material. Further, this lesson will include a video representation, hands-on help, and teamwork with other students to help everyone understand what the objective of the lesson is.

B. Learning Environment
The learning environment will include an outdoor setting (but the lesson plan can start inside and then move outside for the demonstration of the solar vehicles). The students will work in teams to design their car with gear to knock over plastic cups. Each team will have a different car that has a varying degree of the solar panel exposed, while the rest is covered.

C. Resources/Materials
Materials include: 3 toy solar vehicles (can get more for larger groups), 6 plastic cups, legos, double sided sticky tape, cardboard paper, scissors, aluminum foil, paper, stopwatch, various gears with different number of teeth. Resources: TBD (most likely packets regarding solar energy and their applications to cars as well as WNY.
https://www.youtube.com/watch?v=knbUIlLMmUE
https://www.youtube.com/watch?v=luh6IIHPze8

6. Teaching/Learning Strategies

INTRODUCTION
***How will I engage the learners?* (e.g., motivational strategy, hook, activation of learners' prior knowledge, activities, procedures, compelling problem)**
Can engage the students with this: "Who wants to build a car powered with sunlight?"
Strategy is to engage students to understand that they can build, design, create and knowledge for how solar vehicles can work. Further students will be able to be engaged with a hands-on activity that teaches them about solar energy as well as its usage in vehicles and how that can all be applied to a fun activity.

MIDDLE:
Teaching: ***How does the lesson develop?***
How we teach new concepts, processes (e.g., gradual release of responsibility - modeled, shared, and guided instruction).

The lesson would first start out with a discussion about solar cells and vehicles with a video showing what the activity of the day will be centered around. Next the students will be divided into groups and each group will be assigned a solar vehicle. The students will then need to equip their cars with whatever they think is necessary to help it knock over as many plastic cups (pins) in a single run. The students will be able to see the effects of how the different solar cars (each with a varying amount of exposed solar panel) can affect the performance and how it's crucial to be able to utilize the full capacity of the solar panel.

Consolidation and/or Recapitulation Process*: How will I bring all the important ideas from the learning experiences together for/with the students? How will I check for understanding?*

To ensure that all the students have fully understand what was occurring, you could ask the students in their separate groups to tell you how they think their car will operate. Making sure that each student gives a valid reason and isn't just siding with the other, that way all ideas can be heard. Further the kids can fill out a questionnaire gaining feedback on the event and what they were able to take away from it.

Application: What *will learners do to demonstrate their learning?*
Learners will be able to demonstrate their understanding of the topic by answering questions at the end and applying their knowledge to building a car and fitting it with different pieces to knock over pins. Further, through a think-tank scenario kids will be able to tell whether or not they have a full understanding of the lesson.
CONCLUSION: *How will I conclude the lesson?*

Conclude the lesson by asking students what did they learn from the lesson, specifically asking them direct questions about how does the amount of sunlight impacts the cars ability to run, what cars were able to knock over the most cups, and what other ways we can make cars light this run on solar energy. Further, asking the kids about examples they've seen about solar energy around them besides solar cells on their houses will prompt them to understand the diversity of solar energy. Lastly, information can be shown to kids that demonstrates that the activity that they did is something that students can do at all levels in education, like competitions in high schools to competitive groups in college. The lesson is just an introduction for students to become more aware of opportunities to learn and explore renewable energy at an educational level that they can potentially use in their future endeavors.

7. My Reflections on the Lesson

What do I need to do to become more effective as a teacher in supporting student learning?

Having some knowledge on solar panels and their effectiveness in direct vs. indirect sunlight as well as what time of year they are more efficient are ways that one can prepare for a lesson prior.

III. <u>Administrative Section</u>

A. Test Week Preference

We are free to test any day during the test week offered, June 5 through June 11, 2022

B. Mentor Request

The State University of New York at Buffalo Micro-g NExT team would be happy to work with anyone that NASA provided.

C. Institution Letter of Endorsement

University at Buffalo
Department of Mechanical and Aerospace Engineering
School of Engineering and Applied Sciences

October 26, 2022

NASA Johnson Space Center
2101 NASA Parkway
Houston, TX 77058-3696

Dear Micro-G NexT Staff:

I am writing to fully support and endorse the University at Buffalo (UB) team of undergraduate students who are submitting a 2023 Micro-g NExT Challenge Phase I proposal for Orion Crew Safety: Surface Autonomous Vehicle for Emergency Response.

As Chair of the Department of Mechanical & Aerospace Engineering (MAE), I will ensure that the team has access to facilities and dedicated space to continue their designs, as well as other needs for the successful timely completion of the project. The students have the unwavering support and counsel of the AIAA Student Section Advisor, Dr. Aaron Estes. I understand that any default concerning MAE Department requirements and support of this program could adversely affect the selection opportunities for future teams representing the University at Buffalo.

In closing, the UB team has the full support of the MAE Department. If you have concerns or questions, please feel free to contact me at (716) 645-1470 or fbattagl@buffalo.edu.

Yours sincerely,

Francine Battaglia

Francine Battaglia, Ph.D.
Professor and Chair

Department of Mechanical & Aerospace Engineering

208 Bell Hall, Buffalo, NY 14260
716.645.1470
fbattagl@buffalo.edu

www.mae.buffalo.edu

D. Statement of Supervising Faculty

University at Buffalo
Department of Mechanical and Aerospace Engineering
School of Engineering and Applied Sciences

October 26, 2022

NASA Johnson Space Center

2101 NASA Parkway

Houston, TX 77058-3696

Dear Micro-G NExT Staff:

As the Faculty Advisor for an experiment entitled "SAVER" proposed by a team of undergraduate students from University at Buffalo. I concur with the concepts and methods by which this project will be conducted. I will ensure that all reports and deadlines are completed by the student team members in a timely manner. I understand that any default by this team concerning any program requirements (including submission of the final report materials) could adversely affect the selection opportunities for future teams representing the University at Buffalo.

Thank you so much for your consideration. If you have concerns or questions, please feel free to contact me at (716) 645-1430 or aaronest@buffalo.edu.

Yours sincerely,

Aaron Estes, Ph.D.

Faculty Advisor

Department of Mechanical & Aerospace Engineering

217 Bell Hall, Buffalo, NY 14260

716.645.1430

aaronest@buffalo.edu

www.mae.buffalo.edu

E. Statement of Right of Use

As a team member for a proposal entitled “Lunar Anchoring Device” proposed by a team of undergraduate students from the State University of New York at Buffalo, I will and hereby do grant the U.S. Government a royalty-free, nonexclusive and irrevocable license to use, reproduce, distribute (including distribution by transmission) to the public, perform publicly, prepare derivative works, and display publicly, any data contained in this proposal in whole or in part and in any manner for Federal purposes and to have or permit others to do so for Federal purposes only. As a team member for a proposal entitled “Lunar Anchoring Device” proposed by a team of undergraduate students from the State University of New York at Buffalo, I will and hereby do grant the U.S. Government a nonexclusive, non transferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States an invention described or made part of this proposal throughout the world.

Name	Sign Name	Year	Major
Aayush Kumar		SR	Aerospace Engineering
Monica Cortes		JR	Mechanical and Aerospace Engineering
Katherine Pearson		JR	Aerospace Engineering
Xuhelin Cabrera		JR	Computer Science
Jordan Wang		JR	Computer Engineering
Angela Cox		JR	Chemical Engineering
Muhammad Asadullah		JR	Industrial and Systems Engineering
Nur Ashsams		FS	Aerospace Engineering
Jonathan Chen		JR	Industrial and Systems Engineering
Yagmur Aykanat		JR	Mechanical and Aerospace Engineering
Ruspal Rai		JR	Biomedical Engineering
Trevor Conte		JR	Aerospace Engineering

Robert Homewood-McKenzie		JR	Mechanical and Aerospace Engineering
Alexander Podvezko		SR	Engineering Science
Nicholas Mirra		JR	Mechanical Engineering
Ryan Albino		JR	Aerospace Engineering
Brandon Soto		JR	Aerospace Engineering
John Hudi		JR	Aerospace Engineering
Julian Jesse		JR	Mechanical and Aerospace Engineering
Jon Vargas		JR	Aerospace Engineering
Hadley Douglas		JR	Aerospace and Mechanical Engineering
Jonathan Joel Kaj		JR	Biomedical Engineering

Aaron Estes, Assistance Teaching Professor, AIAA Faculty Advisor

F. Funding and Budget Statement

Expenses			
Travel	*Quantity*	*Cost ($)*	*Total Cost $*
Flight Ticket	4	$467.00	$1,868.00
AirBnB	1	$894.00	$894.00
Car Rental (Sedan)	1	$532.00	$532.00
Gas		$100.00	$100.00
Food	60	$13.00	$780.00
Travel Sub-total			**$4174.00**
Outreach	*Quantity*	*Cost ($)*	*Total Cost $*
Proactive			
Westminster Charter School	6	–	-
University at Buffalo Hosted Events	6	-	-
Engineering Week	-	$100	$100
Passive	-	-	-
Outreach Sub-Total			**$100**

** All trip expenses are subject to change based on timing, duration of stay and when it is booked**

G. Materials List

Item name	*Quantity*	*Cost Per Item*	*Total Cost*	*Sourced*
3770 KV Brushless Motor 6S with 5mm shaft	1	$188.00	$188.00	Amazon
150A Waterproof Brushless ESC Electronic Speed Controller with 5.5V/5A BEC	1	$58.00	$58.00	Amazon
HRB 2pcs 6S 22.2V 4000mAh 60C Lipo Battery	1	$116.00	$116.00	Amazon
Zeee Lipo Safe Bag Fireproof Explosionproof Bag	1	$14.99	$14.99	Amazon
Platypus Platy 2-Liter Flexible Water Bottle	1	$15.99	$15.99	Amazon
Raspberry Pi 4 Model B	1	$150.00	$150.00	Amazon
3 Axis Accelerometer Analog Output Accelerometer 3-5V	1	$10.97	$10.97	Amazon
1215 pcs M3 Hex Socket Head Cap Screws Bolts Nuts Assortment Kit	1	$22.99	$22.99	Amazon
AIEX 100pcs 3D Printing Brass Nuts, M3 Threaded Insert Knurled Brass Nuts Female	1	$8.99	$8.99	Amazon
Pair of Gasket makers	3	$10.08	$30.24	Amazon
Polymaker PLA Filament 1.75mm Black PLA Filament 1 kg	6	$22.99	$137.94	Amazon

FCHUB-6S Hub Power Distribution Board PDB 5V & 12V BEC Built-in 184A	1	$29.54	$29.54	Amazon
TotalBoat 5:1 Epoxy Resin Kit	1	$139.99	$139.99	Amazon
KerberosSDR - 4 Channel Coherent RTL-SDR	1	$203.06	$203.06	Aliexpress
Carbon Fiber Fabric 2×2 Twill 3k 50″/127cm 6 oz/203 gsm Hexcel AS4	7	$32.22	$225.54	Composite Envisions
Style 7725 Bi-directional E-Glass	10	$11.95	$119.50	Fibre Glast
Total Cost			**$1,471.74**	

H. Appendix

Figure 4: Front View of Sensors (Shown in white)

Figure 5: Bottom View of Sensors (Shown in White)

I. Parental Consent Forms

All participants are over the age of 18.