AMSAR 2.0: Autonomous Maritime Search and Rescue

Challenge 1: Surface Autonomous Vehicle for Emergency Response (SAVER)

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I. Technical Section

A. Abstract

NASA's Artemis program is aimed at securing the next lunar landing by 2024. Once achieved, astronauts will conduct operations that explore new parts of the moon's surface, and conduct experiments to better understand the potential habitation of Mars. Ensuring the safety and well-being of NASA operatives is at the forefront of the team's mission objectives. Autonomous Maritime Search and Rescue 2.0 (AMSAR 2.0) is designed as a countermeasure and force multiplier in the event of a launch abort or contingency landing. Equipped with multiple sensing systems for target detection and object avoidance, the hull structure ensures the integrity of the equipment and allows for rapid deployment by a Group 1 or 2 close-range Unmanned Aerial Vehicle (UAV). Immediately upon impact, the accelerometer's limit will be reached, activating the system. A software-defined radio (SDR) takes the input signals from the 121.5 MHz ANGEL Beacon and returns a directional angle to the guidance computer, prompting autonomous maneuvering directly to the target. To increase precision and performance, sensor sub-systems consisting of both object and proximity detection are implemented via a TensorFlow-enabled camera and three ultrasonic sensors. TensorFlow[1] allows AMSAR to recognize astronauts and return a directional vector with increased accuracy to the SDR. To compensate for the lack of depth perception in single-view cameras, an ultrasonic sensor will determine close-range distance. Safety considerations necessitate that AMSAR throttles down the motor when the object and proximity sensors are triggered simultaneously. Upon arrival, the astronaut can access all required survival aid equipment through the use of AMSAR's mechanical hatch.

B. Design Description

1. System Overview

The original prototype (AMSAR) had a few notable vulnerabilities within the structure itself, and in the deliverability of the vehicle for testing day. Testing was previously planned to be implemented with a tablet, however, this does not encompass all safety considerations. Rather, the newly proposed remote control (RC) mode alongside an 'AUTO' [autonomous] mode mitigates operational hazards while adding functionality to the vehicle. This is a highlighted change from the original prototype—other safety considerations have been weaved into the design as the team reviewed feedback from NASA mentors.

AMSAR 2.0 is a fully autonomous system that must undergo multiple mission procedures in order to attain its goal state. Figure 1 shows the System Block Diagram which defines the exact actions and states within the AMSAR 2.0 system. After supplying power, the status LED light situated along the vehicle's hull changes from red to green, indicating the circuit is powered and 'ON'. For safety and testing purposes, the team proposes two inbuilt modes, Autonomous ('AUTO') and Manual ('RC'). Following power-up, the system will be set to 'RC' mode and await the manual signal to switch to autonomous direction-finding. The sensing systems required for mission success following the drop include the accelerometer, software-defined radio, primary and servo motor software, TensorFlow object detection, and ultrasonic proximity detection for collision avoidance.

Structural Integrity

The structure of the vehicle will be created using a combination of 3D printed structural members for shape, and fiberglass for waterproofing and strength. The reason for this change away from 100% 3D printed structure is driven primarily by financial constraints the team faces this year. Given our current budget and the amount of money we could reasonably expect to raise, it is unlikely we will be able to afford to build another fully 3D printed prototype. The switch to fiberglass and 3D printed composite structure will reduce the structural costs of the vehicle by up to 50%. In addition to the material change, the shape of the structure will be changed to increase the internal volume for equipment housing, as well as reduce drag and turbulence around the propeller. The rear of the vehicle will become more streamlined, smoothly transitioning from hull to propeller guard. Further testing and safety considerations are taken into account, such as re-defined placement of the power cables and prop guard.

Circuitry & Wiring

The circuit framework is built around two units of the Raspberry Pi 4 (Model B)—previously implemented to centralize all sensing system data transfer onto one CPU [Pi_1]. Given a 12V DC 25A power supply, the circuit load was managed with a power distribution board (PDB), yielding four subcircuits of equal specifications. The major equipment on each subcircuit is as follows: (a) primary motor and electronic speed controller, (b) unit one of Raspberry Pi 4 [Pi_1], (c) unit two of Raspberry Pi 4 [Pi_2], and (d) Kerberos SDR.

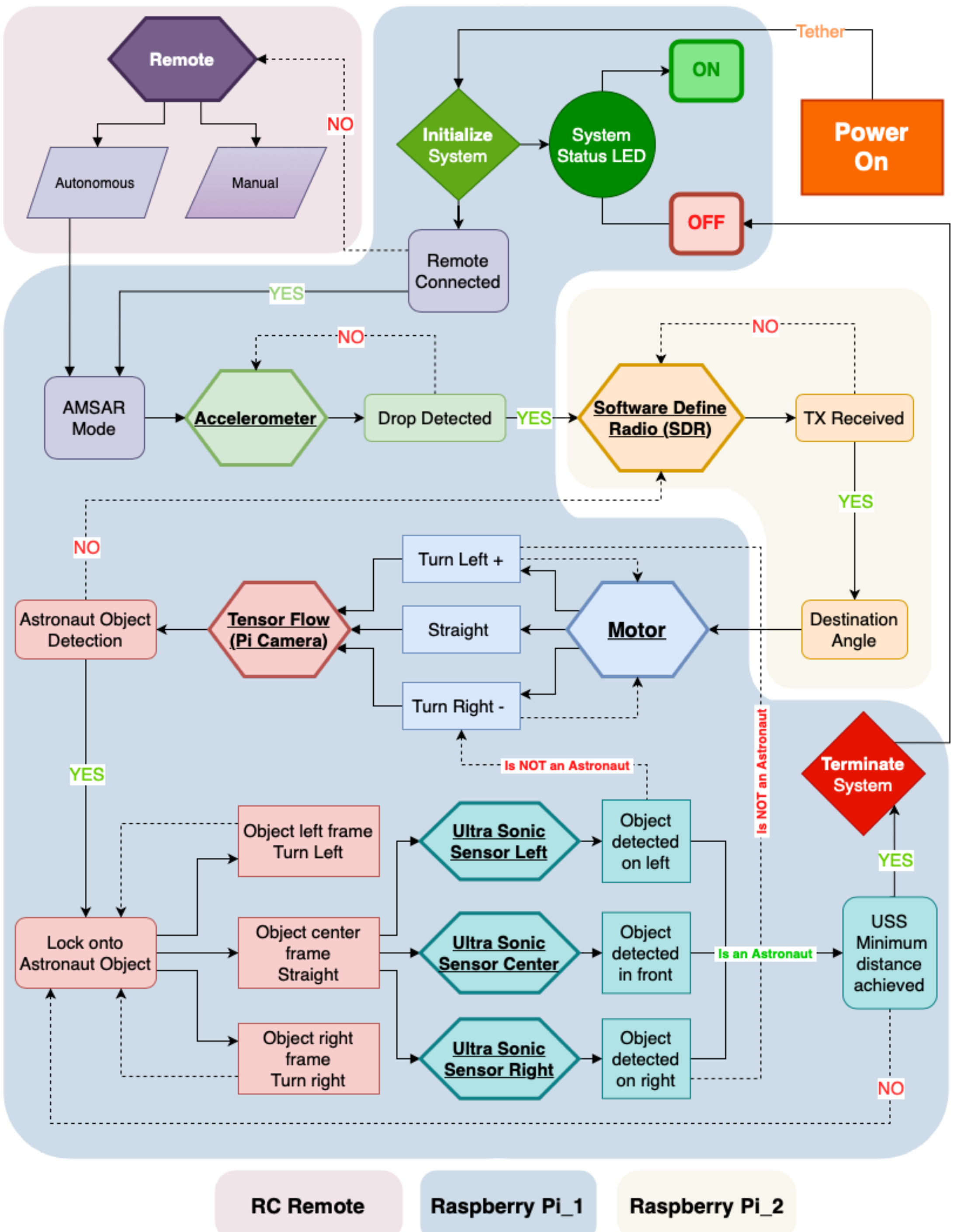


Figure 1. System Block Diagram defining specific actions and states of the AMSAR System.

System Objective: Detect Drop

To detect significant acceleration changes indicative of a drone release and water impact, AMSAR is equipped with the ADXL337 triple-axis accelerometer. The force of impact, tested to be well over 10 G's from the 10-15 meter drop, will initialize

Kerberos SDR, TensorFlow (TF) object detection, and ultrasonic sensor (USS) object avoidance/proximity detection.

System Objective: **Receive Transmission of PLB Signal**

In order to receive transmissions from the ANGEL beacon, the Kerberos SDR (SDR) and its corresponding open-source software is utilized. This encompasses a frequency range from 24 MHz to 1.7 GHz, allowing for testing in 121.5 MHz and 406MHz. Four magnetic omnidirectional antennas with a spacing factor $s' = 0.154$ are arranged to a uniform circular array and allow AMSAR to detect a relative angle toward the ANGEL beacon. The SDR occupies all of the computational power of one of the two Raspberry Pi's.

System Objective: **Motor Control**

There are two divisions of motor control: throttling (dependent upon a drive motor) and steering (contingent with the servo motor). Scripts allowing inputs of the radio frequency for direction finding, object detection, and proximity detection run both motors. The defined maximum throttle is active when the SDR is the only sensor returning an output. Upon visual detection, the throttle is reduced and the repeated triggering of the ultrasonic sensor will halt the throttle completely as a measure of safety. The initial destination is determined from the SDR's output angle, which then allows AMSAR to steer until its forward-facing unit vector is aligned with that of the destination relative unit vector. Turning is dependent on the SDR and object detection outputs, while fine steering control during the final approach is informed by the output of the TensorFlow (TF) computer vision software. Rudder movement is controlled via a servo motor connected at the uppermost hull on the stern. The SDR requires an entire computational unit for stability, and so all of the motor scripts, proximity sensors, and visual sensors are processed on the first Raspberry Pi.

System Objective: **Object Detection**

Once the vehicle has successfully started advancing towards the astronaut in distress, the AuviPal Raspberry Pi Camera begins the detection process utilizing TensorFlow's open API: the model is trained for person recognition in a maritime environment. Upon target recognition, the position of the astronaut within the camera's frame determines subsequent turning and throttling as follows: if the target is located at the center of the frame, AMSAR shall throttle forward; when the target is situated to the left of the frame, AMSAR shall turn left, then proceed to throttle; if the target is to the right of the frame, AMSAR shall turn right, then proceed to throttle (**Figure 2**). The degree of turn shall be directly correlated to the offset between the detected astronaut centroid and the frame center. The first Raspberry Pi houses the Google Coral TPU as a performance optimizer: the current average FPS return is 38.00 FPS relative to the initial 4.0 FPS without the device.

System Objective: **Proximity Detection/Object Avoidance**

The utilization of a single-view AuviPal Raspberry Pi Camera makes the system incapable of depth perception. To compensate for this, AMSAR utilized two Waterproof Ultrasonic Module JSN-SR04T which run following the initial drop and can detect objects in a straight path up to four meters. Acquisition of a target within this range begins the vehicle's deceleration until the ultrasonic sensors are also triggered, indicating the system has achieved its final goal state of reaching the astronaut. As a safety imperative, AMSAR cuts power to the motor if there is no visual feed, yet an object is detected by the ultrasonic sensing system (USS). The software governing AMSAR has been integrated with a median filter to prevent false readings. Power and connection will be provided through the secondary Raspberry Pi 4.

2. Design Changes Matrix

Table 1. Design Changes Matrix

Prior Implementation (if any)	Proposed Implementation	Discussion	Hazard Mitigation
Tablet/Wi-Fi for Testing	Two built-in modes: Manual remote control 'RC' and autonomous 'AUTO'	Widens AMSAR's range of testing from a local wifi connection to a remote control (generally much larger range).	[Any] -- will allow for complete control over the vehicle manually, preventing all possible hazards and ensuring safe shut-off in the event of a problem during operation.
Static Camera Mount	Gyroscopic Mount	Line of camera's view previously altered by up and down translation of boat movement. For calibration purposes and accuracy of measurement, a gyroscopic mount will keep the PiCam level in one plane.	This would apply to blunt trauma from the hazard analysis, as if the camera is not in the right viewing it could affect its ability to detect anyone.
Power cable on bow	New power cable placement on rear	Revisioned orientation where it does not endanger the diver, and consideration for the cable's weight distribution while the boat is turning.	This would apply to electrocution as well as the blunt trauma in the hazard analysis. If it throws the boat off it could result in unfavorable events. It is also important to make sure the power cable is safe as not to cause electrocution.
2x units of USS	3x-5x units of USS	Previous set-up gave 'shadow' in which measurements were unable to be detected. New arrangement gives larger viewing angle with less	This would apply to blunt trauma in the hazard analysis. It provides an extra sensor system to help detect anyone.
Propeller guard	Streamlined propeller guard	The previous propeller guard restricted flow to the propeller, leading to diminished thrust and control.	This would apply to lacerations in the hazard analysis. This would help better flow to the propeller, which is guarded by mesh, and the features will also be rounded.

3. Structures

Design Overview

The structural design of the vehicle is extremely similar to the design that was shipped to the NBL last year with a couple of key differences. First, the vehicle will be longer than before, to allow for more space in the cargo bay. Additionally, the rear of the vehicle will more smoothly transition into the flat back. This change is designed to decrease vortex shedding at the rear of the hull, reducing drag and improving the flow of water into the propeller. Less turbulent flow entering the propeller will improve the maneuverability and thrust of the propulsion system.

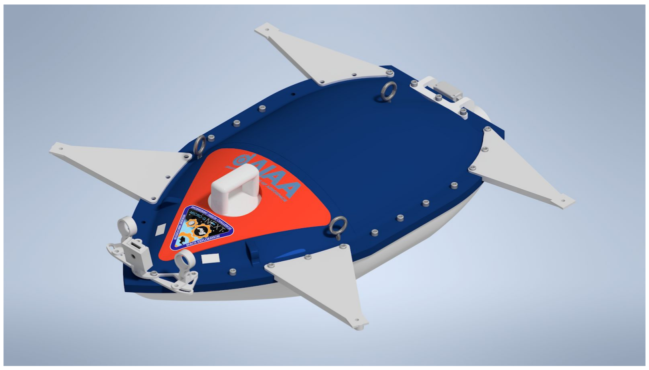


Figure 2. *Overview of overall vehicle design*

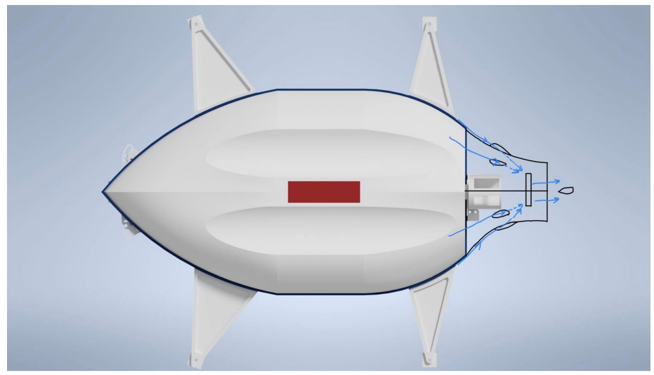


Figure 3. *Proposed rear hull changes*

Sensor Placement

Another significant change to the design this year is the placement of the ultrasonic sensors(USS). From the first prototype, it became apparent that the ultrasonic sensors would become confused with the surface of the water. This would return inaccurate distance measurements, convincing the vehicle that there was an obstacle that wasn't there, or missing one that was. To fix this problem, the sensors will be placed under the water this year, in special openings on the bow of the vehicle, as annotated in the figure below. The ultrasonic sensor array will consist of 3 USS, one looking straight ahead, and two looking off to the side at an angle. This will give the vehicle a clearer picture of its surroundings. The required exact relative positions of the USS will be determined through testing.

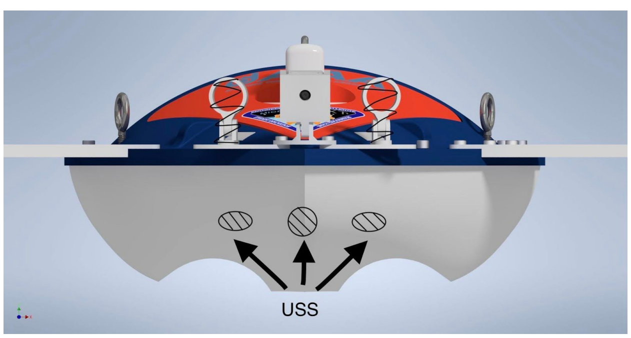


Figure 4. *New Placement for Ultrasonic Sensors*

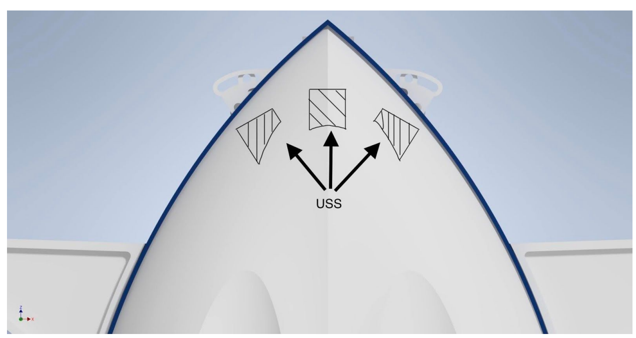


Figure 5. *USS Placement from below*

Handle

On the previous model, the handle was configured to be small and rectangular, in which the astronaut would insert their hand grab and turn. While saving space it was unintuitive to hold as a person could barely fit three fingers and with gloves they could barely fit two fingers. The new design will be a snap clasp similar to the kind used on toolbox covers, but with a larger surface area to make it easier to release with a gloved hand.

Propulsion System

The propulsion system was originally based on a dual internal propeller system with a water intake. However, it was found that an internal propeller system is more susceptible to leakage which would cause a safety hazard. The propulsion system is now based on a single external propeller system. The hull will be redesigned to be more streamlined in the back of the hull to cause less water turbulence. This decrease in water turbulence would make it easier on the propeller to provide lateral thrust; meaning more thrust at no extra power draw on the electrical system. With an external propeller system, you get rid of the safety concern of leakage but now you have to combat another safety concern of possible bodily harm caused by the propeller in motion. As done with the previous model, the propeller system will be fully enclosed within a new hydrodynamic shrouding designed to guide water to the propeller in a more laminar fashion while keeping the propeller blades separated from contact with the astronauts through a combination of small openings and mesh.

Hatch

On the previous model the latch was triangular and included three hatch pins that secured to the cargo bay. However, when unlatched the top of the hatch would be completely detached from the vehicle.This year the hatch would be made with a latching mechanism that would eliminate the three hatch pins which in testing where deemed stiff and now have a permanent connection to the vehicle. This new design has been incorporated to have a smoother opening, utilizing a simpler hinge and clip system, similar to a tool box lid.

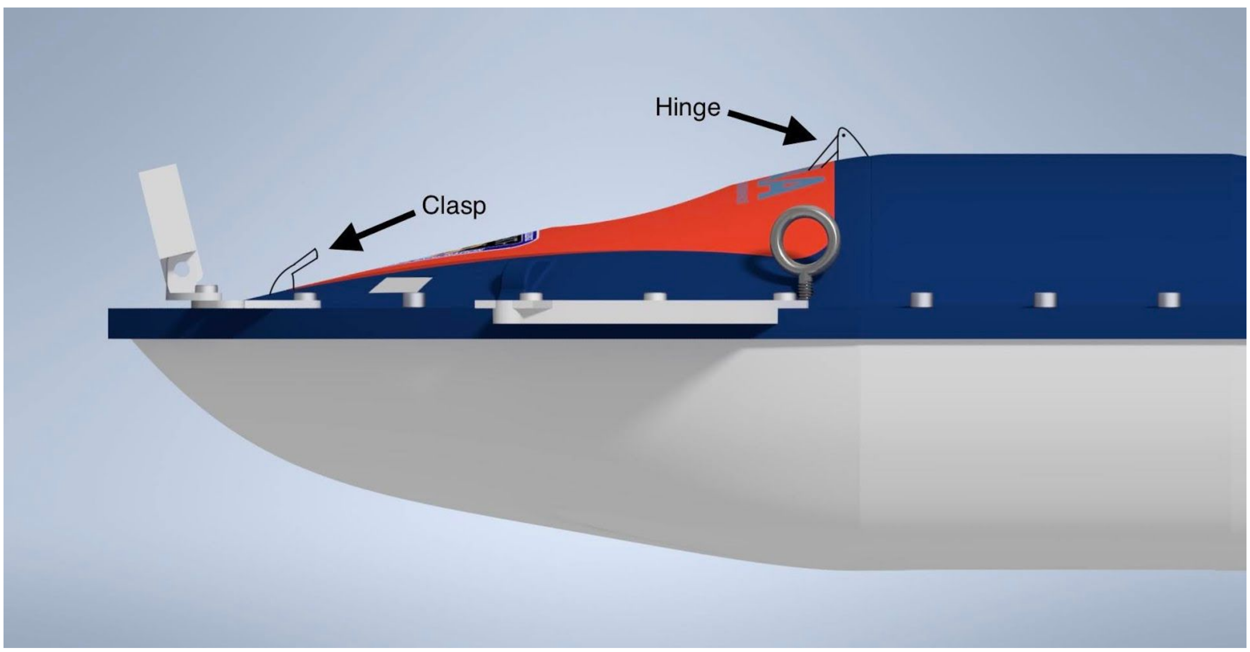


Figure 6: Approximate placement of hinge and clasp on hatch

Waterproofing

Our initial AMSAR prototype testing revealed areas in which waterproofing can be improved. Three main areas we considered waterproofing is the hull, hatch, connection between top and bottom hull. Our previous prototype featured a 3D printed structure, this structure had our ideal strength however due to financial limitations we no longer are able to do the same this year. With new material in place we need to re analyze impact to make sure upon drop at the bottom of our hull will not crack, leaking into the inner system. We fully believe the new fiberglass structure will be able to withstand the impact of a drop based on material strength, however this will be tested via drops prior to being sent to NBL. The hatch will be waterproofed utilizing gasket and the hatched own tight seal. As for the connection between the upper and lower haul we previously used tightly sealed gasket rings, during testing we saw no leaks however we would like to transition away from the rings to a full gasket outline.

Safety Considerations

Overall the structure will have no sharp edges, everything will be rounded out to prevent possible injury to astronauts. Main structures concerns include, drop durability, exterior waterproofing, and the exterior propellor. As mentioned in the previous sections the haul will be made out of fiberglass, and extended drop testing will be performed prior to being shipped to NBL. The strength of the haul will prevent cracks in which water may enter the electronics, as for all other connections such as the hatch and upper and lower haul gasket will be secured tightly. Lastly the propellor will be fully enclosed, with mesh covering any water inlets or outlets. Additionally proper waterproof sticker signage will be included throughout the device to clearly signal to the user any possible hazards for example a propellor blade sticker on the exterior of the propellor shaft.

4. Electronics

As the base framework consists of multiple CPU and sensing systems, power was budgeted to equipment with a consideration of safety. Each of the four solder tabs on the power distribution board (PDB) 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.

Figure 7 gives the circuit diagram implemented in the current version of AMSAR. The converters monitor the input power to subcircuits and ensure proper connections between equipment. A main 25A fuse is soldered just before the PDB supply input, and 3A fuses placed in connection with the major equipment as a guard against overdraw.

The major equipment drawing its own subcircuit is as follows: (a) primary motor and electronic speed controller, (b) unit one of Raspberry Pi 4 [Pi_1], (c) unit two of Raspberry Pi 4 [Pi_2], and (d) Kerberos SDR. The *Component Overview* gives the function, operation, and dependencies of all major components in the system.

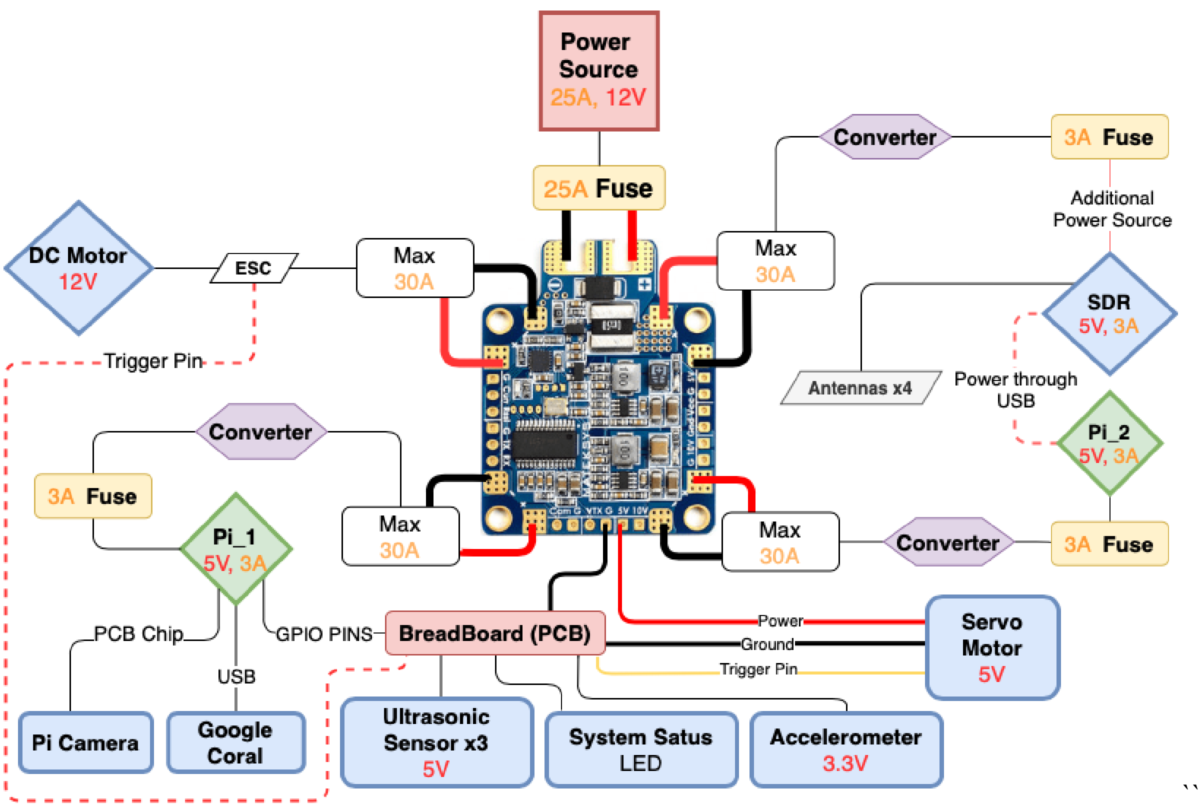


Figure 7. Circuit diagram of AMSAR.

<u>Component Overview</u>: Includes description and function of all hardware/electronics and how they contribute to the above functions

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 a 12 V, 25A DC power source 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 AMSAR and its subsystems.

LIS3DH Accelerometer

- A small, low power accelerometer that can detect from 0 up to 16 g's.
- Used to detect impact and initiate AMSAR 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 AMSAR, it drives the propeller on the stern of the AMSAR.
- Outputs electrical power converted to mechanical energy for driving the propellor shaft.

Servo Motor

- The servo motor is used for controlling the rudder, 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 AMSAR.

Kerberos SDR

- The SDR allows for a variable circular array configuration to sense radio transmissions.
- Outputs directional data in relation to AMSAR's bow of PLB signalling 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 AMSAR 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 Cam

- Small camera which allows the detection of the astronaut in the water.
- Placed on the bow of the AMSAR.
- 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.

ICQUANZX XT60 to USB Fast Charging Converter Support

- 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.

5. Software

Each sensor is defined within its own Python class, through a constructor reserved method <__init__>. Each sensor is initialized upon manual device power-up and set to its configured GPIO pin(s). The "main.py" calls each sensor class in the order as shown in the system block diagram. Until a signal from the accelerometer is detected as above the guard threshold, code will not enter an active-state loop.

Failure Safe - WatchDog

A computer operating properly timer (COP) or a watchdog will be implemented in software to prevent OS malfunctions. A simple watchdog for AMSAR includes a function in main.py which checks each sensor's health each iteration of the active-state loop. For high priority operations in conjunction with safety of the boat, important features like detecting an object with ultrasonic sensor or detecting an astronaut with TensorFlow, It is required that they keep detecting without any delays. Therefore a part of the watchdog will require them to complete in a specific interval of time. If the timer expires before the operation is complete, safety majors will get triggered such as slowing down the speed of the boat for fewer delays.

Basic WatchDog Pseudocode

```
Avg_sensor_time = Value
While True:
    IF sensor_time_taken > Avg_sensor_time then
        Reset Sensor
```

Autonomous Direction-finding

Autonomous direction-finding was implemented in AMSAR using Kerberos SDR hardware (SDR), supplemented with open source software[2] developed by GitHub user, rtlsdrblog. Connected to Pi_2 through its main power port, with additional supply from a power distribution board (PDB), the SDR will initialize at AMSAR's power-up and continuously run. While Pi_2 provided the voltage source and framework for the SDR hardware, Pi_1 communicated data back and forth via a local Wi-Fi connection with the SDR. Because of the nature of AMSAR's functionality, a uniform circular array (**Figure 8**) was chosen as the best design fit for direction finding. Four identical, magnetic whip antennas were placed equidistant from each other on their external mounts and connected through the hull to the SDR via coaxial cables. The team used the following equation:

$$interelement\ spacing\ = \lambda\ *\ s' \qquad (1)$$

to determine the final array spacing factor *s'* for the implemented design, reported as *s'* ≅ 0.154. *The Kerberos SDR Quickstart Guide*[3] lists the ideal value as within the range [0.1, 0.33], with more accuracy as the spacing factor increases. AMSAR's value for *s'* is toward the lower end of the range, and so for future work, the team intends to correct this structurally in the hopes of gaining accuracy in direction finding abilities.

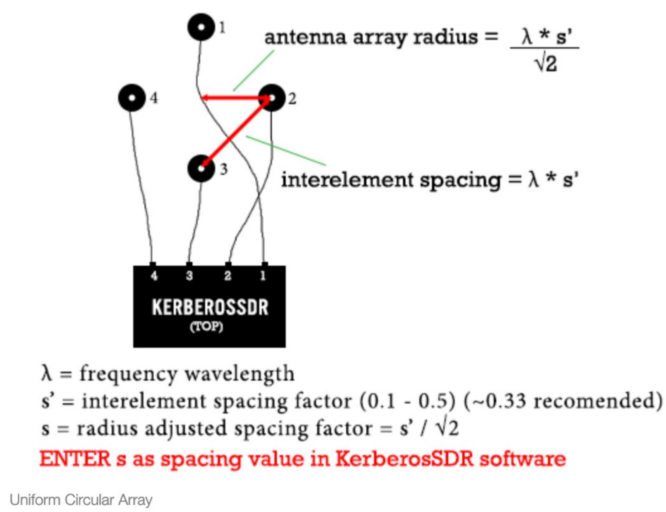


Figure 8. *Uniform Circular Array*[3]

A Python script pulled data from the web-interfacing graphical user interface (GUI) to return a degree value with 0 degrees aligned with Antenna 1. AMSAR's bow was at some angle in relation to the circular array set-up, and corrections were made within software to account for this. All signal processing was done by the Kerberos software itself, with controls for parameters such as antenna gain, filters, decimation, etc. Further testing is needed at a frequency close to 121.5 MHz to determine parameterizations/calibration for a signal at this frequency. During final prototyping, a noise source was out of the team's budget and extensive testing unable to be completed. Still, the SDR GUI reported signals being taken in by the antenna array and a spectrograph of the testing signal (88.7 MHz) successfully displayed. Further work will delve into the location accuracy of the signal with meticulously calculated parameterizations once more testing and knowledge of the device itself is acquired.

Algorithm

Using Raspberry Pi, we plan to implement a *Vector Field Histogram (VFH) algorithm*. The sensors will produce a large dataset which will store every 10th value in order to allow for a balanced database. The data will then be stored and managed in using either a more advanced database system like mySQL or traditional Comma Separated Values (CSV), more testing will determine the system demand. The data will then be parsed, identifying whether there is an object on the left, right, or in front of the vehicle. The closer an object is relative to the side of the vehicle the greater the value will be for the bar graph representing the respective side of the vehicle. There will also be a secondary bar graph for the left, right, and center motors. This graph will display the relative power being sent to the respective motor. If there is something in front of the vehicle, the vehicle will stop and identify if it is an astronaut or an object with the visual systems. If it is an obstacle, then the center sensor bar will increase, and the left or right motors will increase depending on the surrounding environment. The goal is to balance both system graphs and make sure they maintain equilibrium in order to avoid any collision.

Tensorflow/OpenCV

Tensorflow and OpenCV are both an open source API which allows the team to incorporate machine learning in order to identify personnel in a maritime environment. The implemented version of TensorFlow within AMSAR 2.0 will work off of a pre-trained model, “Mobilenet_ssd_v2_coco_quant_postprocess_edgetpu.tflite”. This is optimized for object classification in correlation with the Google Coral Accelerator, producing an average frames/second of approximately 25 fps, enough to successfully recognize personnel in a maritime environment. Along with this as a redundancy, we have also incorporated the OpenCV library in order to allow for more accurate object recognition. OpenCV will be tuned and calibrated to the specific color of the astronaut's suit as a redundancy for Tensorflow. As OpenCV is only relying on pixel color ranges, this will not require the use of ML allowing us to retain our current computational demand of Tensorflow.

Obstacle Detection & Avoidance

To detect and successively avoid any obstacles, AMSAR will implement a variation of the Vector Field Histogram (VFH) algorithm[4] using the onboard array of ultrasonic sensors and motor controls.

Using the reading from each ultrasonic sensor, a *polar density value* ρ is calculated for each sensor at their respective offset angles Θ (angle relative to the front tip of AMSAR). The *polar density values* are calculated and updated in real time.

In a typical implementation of VFH, *polar density values* are proportional to the “certainty values” and inversely proportional to the distance between the sensor and the detected obstacle. In our implementation, we are omitting certainty values to decrease computational overhead.

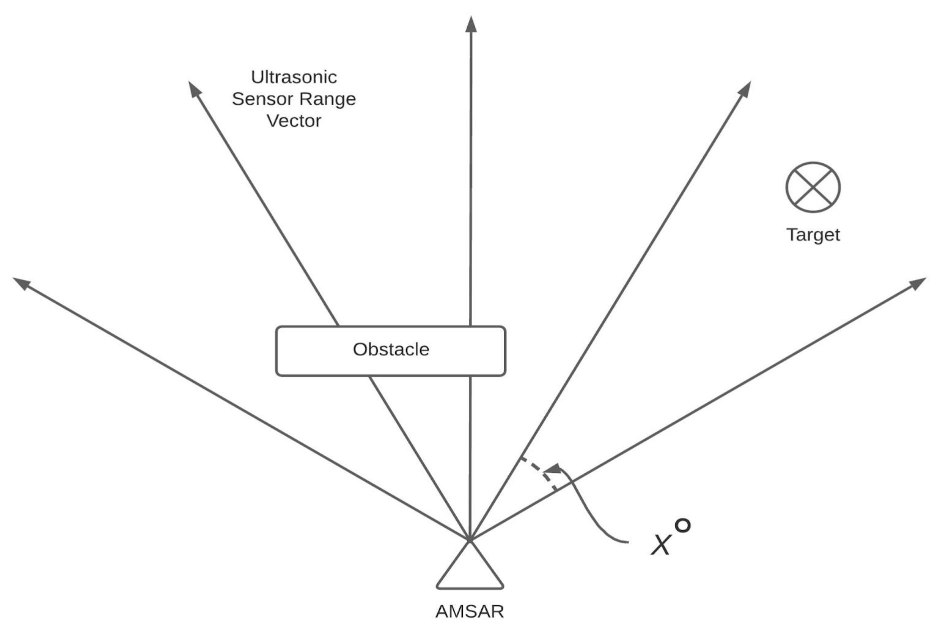


Figure 9: *AMSAR Ultrasonic Range Vector Detection*

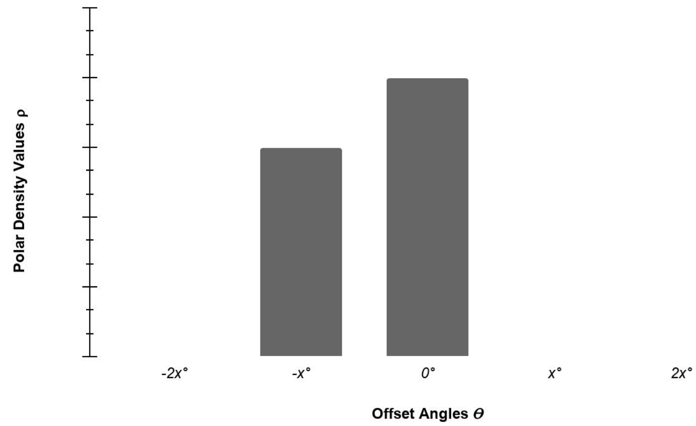


Figure 10: *AMSAR polar density histogram*

If the target's direction relative to AMSAR falls in a *valley region* of the histogram (wherever the *polar density values* are zero or below a certain threshold to account for noise -in this case between *x°* and *2x°*), AMSAR turns the steering in the direction of the target.

If the target's direction relative to AMSAR falls in a *peak region* of the histogram (wherever *polar density values* are above a certain threshold or in other words an obstacle lies in front of the target), AMSAR turns the steering in the direction of the *valley region* closest to the target's direction.

To prevent high speed collisions and give AMSAR smaller turning radii when an obstacle is detected, the speed at which AMSAR travels will be inversely proportional to the *polar density value* reading at the *0°* offset angle (i.e. the front of AMSAR) and the steering angle of the rudder.

VFH is a *local path planner* and does not attempt to find an *optimal path,* as that would require complete knowledge about the environment beforehand.

At the time of writing this proposal, exact equations to calculate *polar density values*, speed, turning radii, angles between ultrasonic sensors *X°* and minimum threshold to discern between *peaks* and *valleys* are arbitrary and will be determined in the future through further testing.

Table 2. Software Risk Evaluation

Risk ID	Risk Description	Relevant Hazard Mitigation
R1	Repeated trigger on USS system fail to determine the direction to avoid	AMSAR can collide with an object causing damage to the structure.
R2	Target acquired by PiCam fails to detect astronaut in water.	AMSAR will fail to terminate its system and will keep trying.
R3	Pi Overheats and reaches its cooldown state.	System will restart and the RC remote will need to set the mode again to initialize system.

6. Manufacturing Plan

The vehicle will be manufactured using a combination of 3D printing and fiberglass. The main shape of the structure will be established by constructing a 3D printed frame that will be assembled in sections. The frame is not itself waterproof, but will serve as a structural guide for the fiberglass layup. The sections of the 3D printed frame will be printed with either PLA or PETG thermoplastic. The sections will be joined using a combination of 3D printed clips, bolts, and PLA friction welding, depending on the strength required for the connection. The fiberglass will be laid over the 3D printed frame one layer at a time. Each layer of fiberglass fabric will be soaked in an epoxy resin. This will allow the layers to form one solid, waterproof outer hull for the vehicle. The 3D printed frame will contain mounting points for all of the internal hardware, as well as the mounting points for the vehicle cover to attach to the lower hull. The cover will mount to the hull using the same method as last year, with approximately 30 ¼-20 bolts around the perimeter of the vehicle. The two halves will be sealed together using paper gaskets, hand cut from sheets into the proper shape for the vehicle. All of the parts that will be 3D printed using fused deposition modeling(FDM) technology can be manufactured in house using a combination of the digital manufacturing lab (DML) at UB and personally owned 3D printers like the Prusa Mini. The PLA and PETG plastics can be sourced from either Amazon or Prusa for approximately $20 per kilogram of material. The fiberglass fabric and resin will also be sourced from Amazon, and the fiberglass layup will be conducted in the AIAA/SEDs lab in Furnas hall at UB by members of the AIAA Micro G team, in accordance to the COVID-19 guidelines for the lab space. Any parts that need to be printed in SLA will be manufactured through a 3D print supplied like CraftCloud 3D.

Gantt Chart

AMSAR 2.0

University at Buffalo

SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

Project Start: Tue, 12/15/2020

Display Week: 1

Months: December, January, February, March, April, May — Weeks 1–22

TASK	ASSIGNED TO	PROGRESS	START	END
Phase 1 Preliminary Testing				
Feedback Adjustments	All	0%	12/15/20	12/22/20
Dye Flow Visualization	Structures	0%	12/15/20	12/22/20
Go over Circuts and Sensors	Electrical/Software	0%	12/15/20	12/22/20
Phase 2 Design Adjustment				
Structure Measurements	Structures	0%	12/22/20	12/28/20
Kerberos SDR	Electrical	0%	12/22/20	1/3/21
Sensor Placements	Software	0%	12/22/20	12/28/20
Purchase Additional Material	Captain	0%	12/15/20	1/11/21
Phase 3 Construction/Coding				
Machine Learning	Software	0%	12/28/20	1/19/21
Beacon Signal Detection	Electrical	0%	12/28/20	1/12/21
Ultrasonic Sensor	Software	0%	1/11/21	1/21/21
Motor Control	Electrical/Software	0%	1/22/21	2/5/21
Soldering	Electrical	0%	2/5/21	2/12/21
Structure	Structures	0%	12/28/20	1/19/21

Display Week: 1

Months: December, January, February, March, April, May — Weeks 1–22

TASK	ASSIGNED TO	PROGRESS	START	END
Phase 4 Assembly/Calibration				
Structure	Structures	0%	2/13/21	3/7/21
Sensors	Electrical/Software	0%	2/13/21	3/7/21
Phase 5 Testing				
Waterproof	All	0%	3/8/21	3/14/21
Accelerometer	All	0%	3/8/21	3/14/21
Signal Detection	All	0%	3/15/21	3/21/21
Motor Control	All	0%	3/15/21	3/21/21
Camera Detection	All	0%	3/22/21	3/28/21
Sonar Detection	All	0%	3/22/21	3/28/21
Run Time	All	0%	3/29/21	4/4/21
Noise	All	0%	3/29/21	4/4/21
Phase 5 Finishing Touches				
Performance Adjustments	All	0%	4/5/21	4/28/21
Shipping		0%	4/29/21	5/9/21

7. Compliance Matrix

Table 3. Official NASA 2021 Micro-g NExT Challenge 5 (SAVER) Requirements

1	The vehicle shall be capable of being dropped from a 10-15 foot height into the maritime environment.
2	The vehicle shall be capable of being carried on a Group 1 (small) or Group 2 (medium), Close-range UAV.
3	The vehicle shall be capable of transporting (carrying or towing), at a minimum, the following items to the victim: a. Water (1 liter minimum - 2.5 Liters max per Human Systems Integration Standard) b. Medical kit (Orion 0.6 lb kit) c. Spare Life Preserver Unit (LPU)* d. Contingency/Spare 406 MHz Second-Generation Beacon (ANGEL) e. Survival Radio Optionally, the following may also be included: f. Inflatable life raft (taking into account size/mass considerations) *Note: A pair of Orion LPU lobes with an existing, integrated ANGEL beacon may be used in lieu of other options for requirement c.
4	The vehicle shall be capable of using existing equipment to detect the ANGEL beacon 121.5 MHz homing signal in order to guide the vehicle toward the beacon.
5	The vehicle shall be capable of traveling to the person in distress via the most direct route in an autonomous manner, including:
	a. Unmanned operation (no local or remote human intervention) b. Self-guided operations to move to the GNSS position c. Programmed with mission profiles to address specifics of rescue scenario
6	The vehicle shall include protections in software/hardware to ensure no harm to the crew upon arrival in their vicinity.

Table 4. Compliance Matrix

Req No.	AMSAR Requirement Design Justification
1	3D printed in SLA resin to maintain structural integrity under the loads of impact with the water's surface. The hull shall be composed of two segments, joined with NBL approved Hi-Solids Catalyzed epoxy and screws. This two-segment design minimizes the possibilities for leakage into the vehicle to occur.
2	3D printed in ABS like tough resin. These materials will help AMSAR achieve a mostly hollow and therefore lightweight design, keeping it within the carrying capacity of the Group 1 UAV (0-20lbs MGTOW).
3	The vehicle shall include a simple mechanical hatch that opens to an internal storage space with a tentative size of four liters. This space shall contain all essential items for the astronaut. The mechanical latch compartment will be sealed and watertight, keeping the emergency items contained within the vehicle until the latch is physically opened.
4	The Kerberos SDR will be utilized to receive the ANGEL beacon's 121.5 MHz transmission. A circular configuration of four omnidirectional antennas with an optimum spacing factor of 0.33 will allow AMSAR to maintain angular degrees toward the beacon with respect to the bow. The equipment is compatible with 24 MHz to 1.7 GHz frequencies, allowing for a received signal range calibrated to the mission needs through KerberosSDR's open-source software.
5	Upon impact, AMSAR shall wait for the transmission from the ANGEL beacon, which will provide the initial

	directional unit vector. Taking the relative direction as an input, AMSAR's integrated software shall steer AMSAR toward the person in distress. The system will also utilize TensorFlow's Object Detection through the Pi Camera to lock onto the astronaut once within range. This allows the motor script to switch to TensorFlow outputs rather than the KerberosSDR outputs, providing a more accurate motor maneuver. AMSAR's maneuverability and object/proximity detection sub-systems already account for a number of situations. For example, a false reading by the ultrasonic sensor will not halt the motors, but a prolonged signal will stop the system to avoid damage.
6	Various aspects of the vehicle's design account for the well-being of NASA operatives including: deceleration upon target acquisition with TensorFlow software, termination of motor power if ultrasonic sensor is simultaneously triggered, implementation of a watchdog within software in the case of a time-out, and custom heat sinks to provide cooling to the Raspberry Pi. An inlet grate will prevent unwanted items or limbs from entering the intake. Waterproof connections will be used with all electronic components, which will be stored in a separate watertight area to keep both the equipment and astronauts safe.

8. Proposed Testing

During Phase II of the challenge, several tests and experiments will be conducted throughout prototype construction. A running list of the proposed methodologies is included below:

- **Drop Test:** Secure AMSAR in drop carrier and lift to a height comparable with the NBL specifications. Release mechanism while AMSAR powered 'ON' and taking data. Record accelerometer reading as the prototype hits the surface of the water.

- **Long Duration Waterproofing Test:** Place empty hull in water while marking time and taking photos. After 12 hours, inspect and remove the structure from water. Note any moisture content within the hull while taking photos for documentation.

- **Monitoring Electronics Temperature:** Power system on and begin reading temperature records from the status of Pi_1 and Pi_2. Mark temperatures every two minutes for a duration of twenty minutes while throttling the motor.

- **RC/Autonomous Mode:** Verify that 'RC' versus 'AUTO' mode are properly installed. Repeat two test runs, one with AMSAR in remote control mode, and the other while autonomously moving.

- **Ultrasonic Sensor Safety Haulting Test:** While completing a test run, place various objects in the vehicle's path. Record object placement in relation to the bow of the boat, and AMSAR's movement response, if any.

- **SDR Configuration Autonomous Test:** Transmit testing signal from supplemental equipment with a frequency near to the 121.5 MHz range. Configure parameters of the SDR software and begin testing signal readings. Place transmitter at eight locations (45 degrees apart with respect to a circle) in relation to the vehicle and switch AMSAR to 'AUTO' mode.

- **Manual Shutoff Test:** Make sure the manual shutoff is working properly.

C. Operations Plan

Prior to Unboxing

The vehicle will not be shipped in a box with packing peanuts, as that proved unsuccessful last year. We shall utilize a pelican case to secure the vessel in place and ship via a wooden crate.

Unboxing Day

The following procedure is to be followed upon delivery to the Neutral Buoyancy Laboratory. Shipment of AMSAR shall contain a hard copy of the following procedures, as well as a parts list and supplementary documentation within a wooden crate and Pelican case containing each part.

Verification of Parts and Vulnerability Check

1. Refer to the parts list and begin unpacking.
2. Check off each received part as the shipment is unboxed.
3. Carefully inspect for damages or other vulnerabilities.
4. Construct the prototype as shown in the assembly guide.
5. Perform Noise Test, Refer to *Noise Test*.

Noise Test

1. Verify prototype is constructed as documented in the assembly guide.
2. Ensure manual switch is turned to 'RC' mode.
3. On land, plug AMSAR 2.0 into the NBL provided power source of DC 12V 25A.
4. Verify LED status light is green.
5. Use controls as documented in the assembly guide to check proper functionality of all AMSAR systems: ultrasonic sensors, PiCam, Kerberos SDR, motors, ESC,and CPUs.
6. While running systems, conduct a noise test at two distances from the source and record measurements: close-range, and target-range [where diver/astronaut would be placed].
7. If the test is optimal, ready for testing in the NBL.

Testing Day

Systems Check

1. Verify prototype is constructed as documented in the assembly guide.
2. Ensure manual switch is turned to 'RC' mode.
3. On land, plug AMSAR 2.0 into the NBL provided power source of DC 12V 25A.
4. Verify LED status light is green.
5. Remote Control Device as desired.
6. If the device performs as desired, ready for test run.

Test Run

1. AMSAR 2.0 should be set to 'RC' mode and manual switch to 'OFF'.
2. Place device into UAV carrier attachment.
3. Plug cables into power source.
4. Set manual switch of AMSAR to 'ON' and turn on power source.
5. Verify LED status light is green.
6. Lift AMSAR to testing height.
7. Set mode to 'AUTO'.
8. Verify system is initialized and software is pulling real-time data.
9. Begin timer and drop the device.
10. Monitor real-time SDR GUI and status report as the device moves through the course.
11. Note the initial condition following the device drop and ensure AMSAR 2.0 begins moving to signal source.

12. Note when AMSAR successfully/unsuccessfully moves around an object.
13. Mark time when target acquired and system dethrottles/shuts down.
14. Instruct diver/astronaut to open the equipment hatch at the appropriate location.
15. Switch AMSAR to ‘RC’ mode and switch to ‘OFF’.

D. Safety

To ensure the well-being of all operatives involved, the research team identified possible safety concerns generated by the device in **Table 5** and specifically outlined how to address these issues, which can be seen below.

Operational hazards were considered, specifically in regards to the testing at NBL, and for the safety of the divers conducting tests. This includes potential hazards to users as well as potential hazards during a testing run. In regards to the user, potential hazards considered include: an exposed propeller, a shape design featuring sharp edges, a user unfamiliar with the vehicle and its functions, as well as the vehicle not decelerating. Negative outcomes include: blunt trauma, incised cuts/lacerations, electrocution, and burns to the user. Warning labels for hazardous areas will be used. Operational directions will be labeled on the capsule before testing. Waterproof connections will be used with all electronic components and will be stored in a watertight case to keep both the components and divers safe.

In regards to potential hazards during a testing run, issues include: visual obstruction of the camera during the mission (by water droplets), collision with maritime objects, and premature motor activation. The consequences of these issues are inaccurate visual detection, damage to the vehicle or objects, and compromisation of UAV drone stability. A protective case acts as a waterproof protectant for the visual equipment, and an additional close-range sensor is in place as a safety measure. The accelerometer will detect initial impact with the water and subsequently initialize the rest of the system.

Hazards such as power connections and waterproofing could have also affected electrical systems. This might cause a non-secured electrical power connection and internal circuitry systems coming in contact with water. Consequences include device shut-off due to lack of power, with water becoming a conductor and the systems short circuiting. This is avoided by using an umbilical cord to connect to AMSAR through an opening in the vehicle cover that will be sealed using an NBL approved epoxy. The required 25A fuse would make sure the components would not overdraw and damage themselves. AMSAR 2.0 will be designed to be constructed in two separate halves. The bolted hull halves and NBL approved Hi-Solids Catalyzed epoxy would prevent water from reaching internal electrical components. There will also be close-range ultrasonic sensors put in place to help prevent object collision.

Table 5: *Hazard Analysis Matrix*

Hazard	Cause	Consequence	Controls and Verification	Status
Blunt Trauma	1) Boat Rams into the astronaut due to failure of shutdown maneuvers. 2) Failure to recognize astronaut	Mild injury to upper body. Fracture and/or muscle tear is unlikely	1) Boat has been designed to decelerate upon recognition of the astronaut by the Pi Camera. 2) The ultrasonic sensors will continue object detection & avoidance maneuvers if the astronaut is not recognized. 3) Manual Emergency Shutdown via tablet	Controls in Place
Electrocution	User is exposed to electrical current in the pool due to hydro-comprom ised electronics	Painful Shock, muscular contractions, potential respiratory arrest	1) Waterproofing of vehicle in place a. Upper and lower hall bolted tightly, utilizing gaske's for watertightness b. Propeller shaft goes through waterproof bearings preventing water from entering c. All holes for exterior components waterproofed utilizing silicone and putty d. Hatch waterproofed utilizing paper gasket and friction fit e. Secured soldered connections with heat shrink and electrical tape f. Verified through water testing 2) Electricity Warning label present	Controls in Place
Lacerations	User put into contact with exposed sharp feature	User experiences cut in suit; potential for open wound and rapid and extensive bleeding	1) The propeller is placed on the stern of the vessel, with a 3D printed guard covering it, preventing damage to finger/clothing. 2) Mesh placed in holes of propeller guard to prevent user from inserting hand. This also stops particles of significant size from entering the propeller, limiting possible damage. 4) The vehicle shape shall be manufactured to have rounded edges, as to mitigate sharp corners. 5) All edges have been sanded to prevent rough edges. 6) Propeller Sharp Warning label present.	Controls in Place

Burns	User contact with overheated vehicle	User experiences first degree burns due to thermal difference	1) Pi tracked temperature during operation if exceeding 60 deg Celsius AMSAR will stop operating until it is below 60 deg Celsius. 2) Testing showed the component with highest temperature was the Coral, running well below 60 deg Celsius.	Controls in Place
Loss of Vehicle Control	Electronics/software failure during autonomous mode	Possible harm to user or NBL environment	1) RC controller will allow manual shutoff during autonomous mode	Controls in Place

E. Technical References

[1]Abadi, M. et al. "TensorFlow: A System for Large-Scale Machine Learning." Vol. 101, No. C, 2016, pp. 582–598. https://doi.org/10.1016/0076-6879(83)01039-3.

[2]Markgraf, S., Stolnikov, D., Hoernchen, Keen, K., Vogel, C., and Welte, H. Rtl-Sdr: Open Source Mobile Communications. https://osmocom.org/projects/rtl-sdr/wiki. Accessed Oct. 23, 2020.

[3]KerberosSDR Quickstart Guide. https://www.rtl-sdr.com/ksdr/. Accessed Oct. 23, 2020.

[4]Borenstein, J., and Koren, Y. "The Vector Field Histogram -." *IEEE Journal of Robotics and Automation*, Vol. 7, No. 3, 1991, pp. 278–288.

II. Outreach Section

A. Introduction

Science Technology Engineering and Math (STEM) are vital components to an advancing society, as innovation and creativity in these sectors has historically induced global advancements (e.g., boosted economies, prolonged health, sustainable initiatives, discovery and understanding of some of the universe's mysteries, and overall improvement to the average standard of living). The National Aeronautics and Space Administration is at the forefront of advancement in aeronautics, space science, and exploration; yet, the scope of NASA's mission further encompasses the betterment of knowledge, education, and innovation for future generations. Driven by a passion for STEM fields, members of the University at Buffalo AIAA Micro-G NExT team hope to make purposeful contributions to the surrounding community even during these difficult times through various outreach endeavors and partnerships with local organizations. The team will implement two methodologies of outreach programming: (1) proactive and (2) passive, whose objectives and procedures are outlined in the following sections.

B. Proactive Programming

I. Say Yes! Science and Exploration Day (Nov. 7th) → Demoing AMSAR capabilities in relation to underlying principles of physics [available here]

Scheduled for Saturday, November 7th is the team's participation in a Buffalo public school-wide [virtual] event. Representatives of UB Micro-g NExT will be giving a presentation titled, "The Physics of Boats". Alongside educating K-12 students on basic principles of buoyancy, Archimedes' Principle, and balancing forces, the demo incorporates the original AMSAR prototype in a live presentation filmed at the University at Buffalo.

II. *Potential* boat design competition with sponsorship from Say Yes! & UB Sustainability

Proposed competition for K-12 students to design a boat out of materials provided, with prize levels based on age grouping. Currently looking into partnership with the Buffalo Maritime Center, which leads hands-on boat construction classes with local high school students. The competition will be advertised through its parent organization, the Saturday Academy with Say Yes! To Education Buffalo, and promoted through the team's website and Instagram.

III. Saturday Academy with Say Yes to Education Buffalo

Saturday Academy with Say Yes to Education Buffalo are an organization we have teamed up in with in the past. These are saturday scheduled zoom events in which we do different activities with, working with different age groups. As of now we have 5 events scheduled, 1 of which we have already done. For our first event we worked with children in elementary school spoke about renewable energy and guided them through building their own mini solar powered cars. For our next upcoming event we are working with high school students and will be doing a panel featuring 6 members of our Micro-G organization, with many of us in different disciplines we will answer questions students have in terms of engineering as a college career as well as talk about our amazing experience working on AMSAR and with NASA this past year. These now Zoom opportunities give us a confirmed audience in which we can directly do mini engineering activities, and educate students on Micro-g NExT, NASA, and overall engineering.

C. Passive Programming

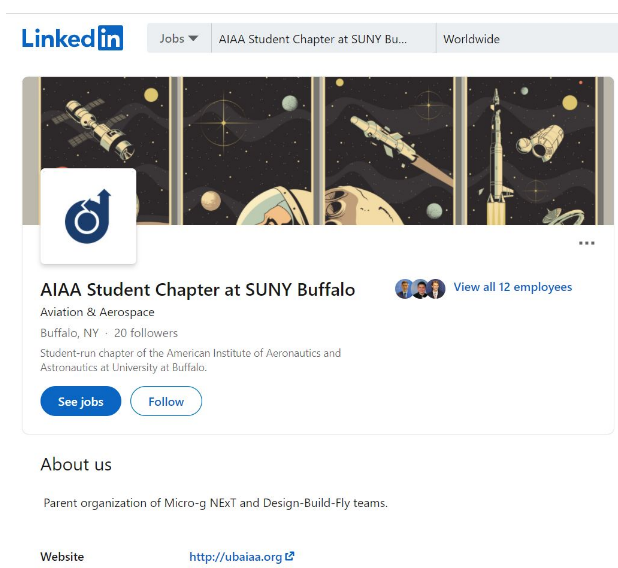
Outreach spreads farther than volunteer activities. Volunteering, although the most effective means of interacting and interesting individuals, it feasibly can not be done with a goal of reaching the entire community. We not only aim to interest our community and the current and younger generation in STEM, but also educate on the purpose behind our team's mission & work, give an inside perspective of the process live, and highlight NASA as an institution. For that reason we have incorporated passive programming. This means of programming will enable our team to maximize our reach in the community, potentially even leading to possible future team members and donors. The methods in which we will achieve this has been outlined below.

UBNow

The University at Buffalo has a web page highlighting news and views for UB faculty and staff. The topics covered on this sight are campus and research news, amongst other things. UB Micro-G NExT was reached out to over the summer, and an article was written about our previous participation in this competition with AMSAR, and about our club. This gave us greater exposure to the UB community, community support, interest toward our project team, and NASA and STEM as a whole within our university community. This article was then also featured on the UB SEAS (School of Engineering and Applied Sciences) website under news and events.

LinkedIn

Social media is our friend, and social media platforms enable individualized content to reach a global audience. With our parent organization, AIAA Student Chapter at SUNY Buffalo, a new LinkedIn page was created for our club. This allows us to connect with each other, and promote our new club website. LinkedIn is the biggest professional social networking site, allowing us to show our involvement in this competition to a big audience.

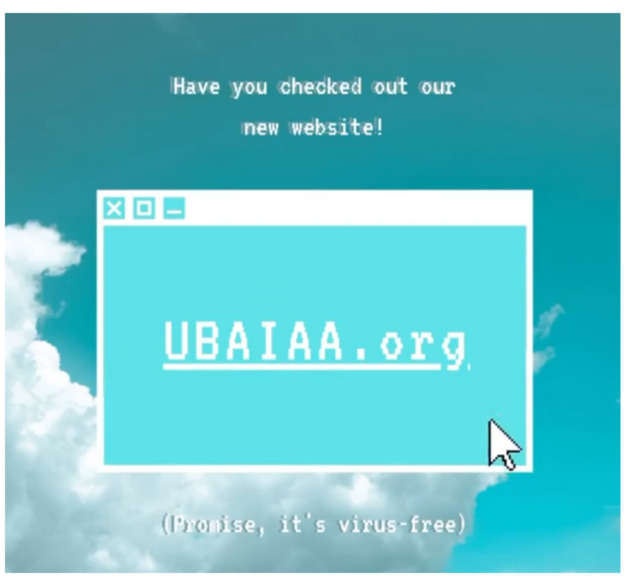


Instagram

Instagram will be the second social media platform we will be utilizing. Our Instagram was created in 2018. Over the summer as well as this current semester we have been keeping up to date on introducing members of our club, posts about when we are meeting, as well as advertising our new club website. Slowly, through maintaining content, we have attracted new followers, up 58 from this time last year. Our aim with social media is to have a community following base, which will view our content and expose themselves to Micro-G, and NASA. This exposure is aimed to generate interest in and understanding of STEM. We aim to use this page to recruit members, highlight our outreach events, and to show the process of going through this project. By viewing our work and effort, people see why we do what we do and understand STEM and gain a greater respect or interest in it. Social media is especially important during these times to help keep us all connected and updated as to what is happening since we cannot all be together in person like usual.

UBAIAA.org

Quite recently we have updated and launched our own website UBAIAA.org. On our website we highlight both our design teams, including members, projects via gallery, google calendar with upcoming meetings and milestones, along with our contact information. This site serves as a way for students interested to get an overview of who we are, what we do, and how to be involved.



D. References

1. http://www.buffalo.edu/ubnow/stories/2020/07/micro-g-next.html
2. https://www.linkedin.com/company/ubaiaa/
3. https://www.instagram.com/ub_aiaa_micro_g_next/?hl=en
4. https://www.ubaiaa.org/

IV. Administrative Section

A. Test Week Preference

Based on the anticipated test weeks for 2021, our team would prefer to test in Week 1, but either could be made to work.

B. Mentor Request

The team would be happy to continue working with NASA Engineers, Cody Kelly and David Watson, if available.

C. **Institutional Letter of Endorsement**

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

October 29, 2020

NASA Johnson Space Center
Mail Code: AE2
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 Phase I project proposal entitled "AMSAR: Autonomous Maritime Search and Rescue" to the 2021 Challenge.

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 student team was successful last year and their design was invited to Phase II of the 2020 competition. The students continue to work with their NASA mentors and also have the support and counsel of the AIAA Student Section Advisor, Mr. Paul Schifferle (who is Vice President of flight research at Calspan Corp.). I understand that any default concerning MAE Department requirements and support of this program could adversely affect the selection opportunities for future teams from the University at Buffalo.

In closing, the UB team has the full support of the MAE Department. If you have any 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
The State University of New York

October 29, 2020

NASA Johnson Space Center
Mail Code: AE2
2101 NASA Parkway
Houston, TX 77058-3696

Dear Micro-g NExT Staff:

As the faculty advisor for an experiment entitled "AMSAR proposed by a team of undergraduate students from the State University of New York 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 final report materials) could adversely affect selection opportunities of future teams from the State University of New York at Buffalo.

Thank you so much for your consideration. Please feel free to contact me via email for any other questions at:

paul.schifferle@calspan.com

Sincerely,

Paul Schifferle
Adjunct Instructor,
AIAA Faculty Advisor

E. Statement of Right of Use

Last Name	First Name	UB Email	Year	Major	Signature	Date
Arevalo	Mirka	mirkaare@buffalo.edu	Senior	MAE	[illegible]	10/30/2020
Bompczyk	Teresa	tbompczy@buffalo.edu	Junior	CP	[illegible]	10/30/2020
Bonnette	Alexandra	arbonnet@buffalo.edu	Freshman	MAE	[illegible]	10/30/2020
Duell	Joshua	jjduell@buffalo.edu	Junior	MAE	[illegible]	10/30/2020
Field	Liam	liamfiel@buffalo.edu	Grad Student	MAE	[illegible]	10/30/2020
Flynn	Sean	spflynn2@buffalo.edu	Senior	CIE	Sean Flynn	10/30/2020
Gardener	Allison	aagarden@buffalo.edu	Senior	MAE	Allison Gardener	10/30/2020
Hernandez	Joshua	hernand5@buffalo.edu	Freshman	AE	[illegible]	10/30/2020
Johnston	Kevin	kljohnst@buffalo.edu	Senior	EE	Kevin Johnston	10/30/2020
Kallyan Tatar	Imon	imonkall@buffalo.edu	Sophomore	CS	TATAR	10/30/2020
Kerkezis	Abigail	arkerkez@buffalo.edu	Junior	MAE/AE	Abigail Kerkezis	10/30/2020
Kong	Timothy	tkong5@buffalo.edu	Freshman	CS	[illegible]	10/30/2020
Maurya	Tamaghan	tamaghan@buffalo.edu	Senior	CS	[illegible]	10/30/2020
Ombase	Vedant	vedantom@buffalo.edu	Freshman	CS	[illegible]	10/30/2020
Sims	Holliday	hesims@buffalo.edu	Freshman	CS	Holliday Sims	10/30/2020
Soto	Brandon	bgsoto@buffalo.edu	Freshman	MAE	Brandon Soto	10/30/2020

Paul T Schifferle

Paul Schifferle, Adjunct Instructor, AIAA Faculty Advisor

F. Funding and Budget Statement

	Expenses	Unit Cost	Quantity	Total Cost
Travel	Flight Tickets	$ 342.00	6	$ 2,052.00
	AirBnb	$ 865.00	1	$ 865.00
	Car Rental (6-person vehicle)	$ 537.00	1	$ 537.00
	Gas	$ 75.00	1	$ 75.00
	Food	$ 11.00	72 Meals	$ 841.50
	Travel Sub-Total			$ 4,370.50
Outreach				
	Say Yes! Science and Exploration Day	$ -	-	$ -
	Boat Design Competition	$ 50.00	-	$ 50.00
	Saturday Academies with Say Yes!	$ -	5	$ -
	Engineering Week	$ 75.00	-	$ 75.00
	Outreach Sub-Total			$ 125.00
Hardware & Materials				
	Raspberry Pi 4*	$ -	2	$ -
	Kerberos SDR-4 Channel Coherent RTL-SDR*	$ -	1	$ -
	Raspberry Pi Camera*	$ -	1	$ -
	LIS3DH Accelerometer*	$ -	1	$ -
	Typhoon Brushless Motor 600-42*	$ -	1	$ -
	Matek FCHUB-6S Power Distribution Board*	$ -	1	$ -
	DS3225 Digital Servo Motor*	$ -	1	$ -
	Google Coral*	$ -	1	$ -
	Telescopic Whip Antennas	$ -	4	$ -
	EFLA1080B Brushless ESC*	$ -	1	$ -
	Assorted Wiring (In addition to existing inventory)	$ 25.00	1	$ 25.00
	Paper Gasket/Waterproofing	$ 20.00	1	$ 20.00
	Miscellaneous (Nuts, bolts, epoxy, lubricants)	$ 50.00	1	$ 50.00
	Hardware & Materials Sub-Total			$ 95.00
Manufacturing				
	Fiberglass Cost	$ 115.00	-	$ 115.00
	3D Printing Cost (room for error included)	$ 285.00	-	$ 285.00
	Shipping Fee (to Houston)	$ 150.00	-	$ 150.00
	Wooden Crate	$ 100.00	1	$ 100.00
	Styrofoam, Packing Paper, and Bubble Wrap	$ 30.00	-	$ 30.00
	Pelican Case	$ 200.00	1	$ 200.00
	Manufacturing & Shipping Sub-Total			$ 880.00
	Total Cost			**$ 5,470.50**

To help raise these funds, two fundraisers are being planned to partner with local restaurants. Nearby restaurants are offering a percentage of sales to fundraising groups who partner with them. We also plan to apply to the New York Space Grant which aims to support education and outreach of space related research and events. It also aims to inspire, engage, and educate students in STEM disciplines, and to prepare the future STEM workforce for high technology industries, especially in New York State.

G. Parental Consent Forms

All participating members are over the age of 18.