ARIEL

Autonomous Rescue Instrument for Emergency Landing

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

Cornell University Micro-Gravity Team
(Cornell Micro-G)
Cornell University
Sibley School of Mechanical and Aerospace Engineering
108 Upson Hall
Ithaca, NY 14850

Team Contact
Gregory Kaiser
ghk48@cornell.edu
401-536-6770

Primary Team Members

***Gregory Kaiser** - *Team Lead*
ghk48@cornell.edu
2020/Engineering Physics

***Christopher Chan** - *Design & Manufacturing Co-Lead*
cec272@cornell.edu
2020/Mechanical Engineering

Thomas Taffe - *Design & Manufacturing Co-Lead*
tt487@cornell.edu
2021/Mechanical Engineering

Ruojia Sun - *D&M Member*
rs989@cornell.edu
2020/Mechanical Engineering

Emerson Braithwaite - *D&M Member*
ejb268@cornell.edu
2021/Mechanical Engineering

Ben Goldgof - *Business Team Member*
bfg28@cornell.edu
2023/Operations Research

Crystal Hu - *D&M Member*
jh2346@cornell.edu
2023/Electrical Engineering

Amy Huang - *D&M Member*
ach243@cornell.edu
2023/Electrical Engineering

Vivian Huang - *Outreach Team Member*
yvh4@cornell.edu
2022/Computer Science

Jacob Lashin - *D&M Member*
ejb268@cornell.edu
2023/Materials Science and Engineering

Jonathan Lee - *D&M Member*
jsl372@cornell.edu
2022/Computer Science

Eric McNamara - *D&M Member*
erm226@cornell.edu
2022/Mechanical Engineering

Drake Schiller - *Outreach Team Member*
dls396@cornell.edu
2023/Undecided

Maanav Shah - *Outreach Team Member*
mcs356@cornell.edu
2023/Astrophysics

Ryan Tay - *D&M Member*
rt385@cornell.edu
2023/Undecided

Emmi Wyttenbach - *D&M Member*
ezw2@cornell.edu
2023/Undecided

Eric Zhang - *D&M Member*
ewz4@cornell.edu
2023/Computer Science

Student Advisors

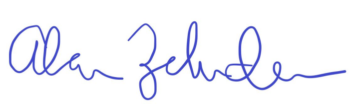
Emma Vedock-Gross - *D&M Student Advisor*
ev225@cornell.edu
2020/Mechanical Engineering

Jaytlen Cantos - *Outreach Team Advisor*
joc39@cornell.edu
2020/Biometry & Statistics

Eshaan Jain - *Business Team Advisor*
esj24@cornell.edu
2021/Psychology

Faculty Advisor

Professor Alan T. Zehnder
atz2@cornell.edu
607-255-9181



Faculty Advisor Signature

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I. Technical Section

A. Abstract

NASA envisions creating a lunar outpost that will facilitate sustained human presence on the Moon by 2028 through the Artemis Program. To this end, NASA is committed to conducting as many as twelve Artemis missions using the Orion spacecraft, including a trip to send a man and woman to the moon in 2024. In the event of a failed launch or reentry, the Orion capsule is likely to make an emergency landing in a maritime environment, at which time the crew will require emergency aid and assistance immediately. Under NASA's Micro-g NExT challenge, academic research teams are tasked with proposing an autonomous surface vehicle to be deployed near the emergency egress site by a close range Group 1 or 2 UAV and transport emergency supplies to the crew of the Orion capsule.

The following document proposes the Autonomous Rescue Instrument for Emergency Landing (ARIEL). ARIEL is a lightweight, canvas-covered watercraft structurally supported by wooden ribs, bulkheads, and longerons. Using two submerged thrusters, ARIEL navigates towards a distress beacon using an antenna and Raspberry Pi to detect an emergency signal and to drive the propulsion system. Emergency equipment is stored in the center of the vehicle and covered by an easily removable tarp sheet. Upon arrival, the crew member will remove the tarp covering, access emergency equipment, and wait for the manned rescue response to arrive.

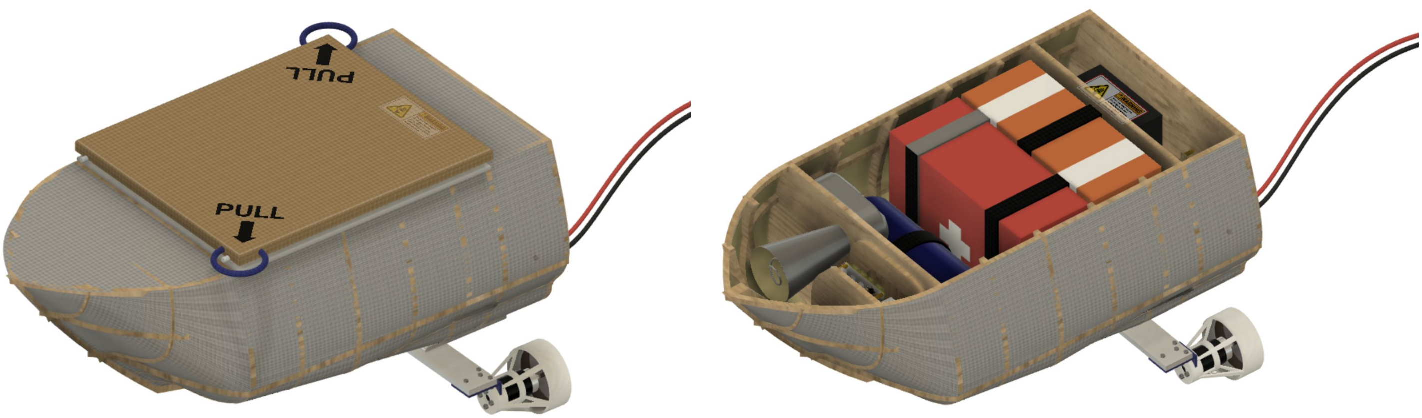


Figure 1: Overall Design (Left) and Top Portion Removed (Right)

B. Design Description

B.1 Vehicle Configuration

Overview

The body structure is responsible for safely delivering the emergency equipment to the astronaut. It is necessary that the body is strong, lightweight, and waterproof in order to successfully accomplish its task. The design is capable of withstanding an impact into water from fifteen feet at speed, while being light enough to be carried on the UAV. Additionally, the structure is sealed against water, such that submersion from impact and operation through the maritime environment does not affect the usability of emergency equipment and functionality of ARIEL's systems.

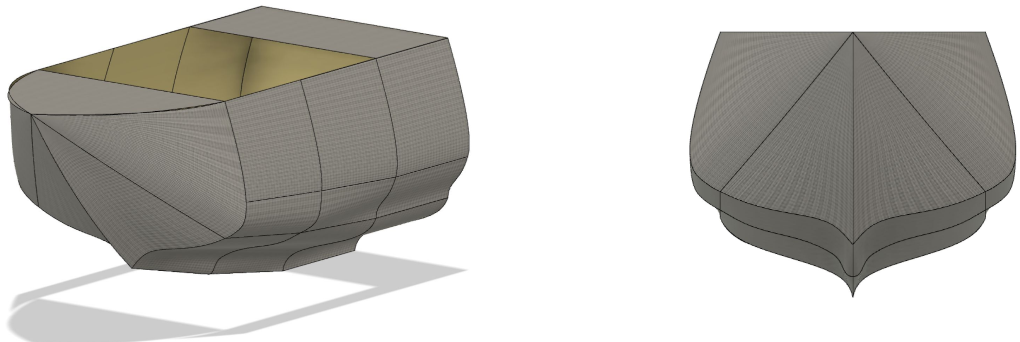


Figure 2: Water-Repellent Canvas Exterior of ARIEL

The body is designed as a semi-monocoque structure in the shape of a ship (Figure 2), with three sections: the forward and aft electronics bays, and the center equipment hold. Two main bulkheads separate these sections and provide waterproof seals between the forward and aft cargo holds. These sections are joined together with an arrangement of wood formers and longerons, with a center keel forming the backbone of the lower hull, as shown in Figure 3. The exterior skin is composed of water-repellent canvas, and is joined to the structure via NASA Neutral Buoyancy Lab (NBL)-approved adhesives (see Section III: Budget Statement). The structure is spaced such that the maximum unsupported canvas area is 2 inches^2.

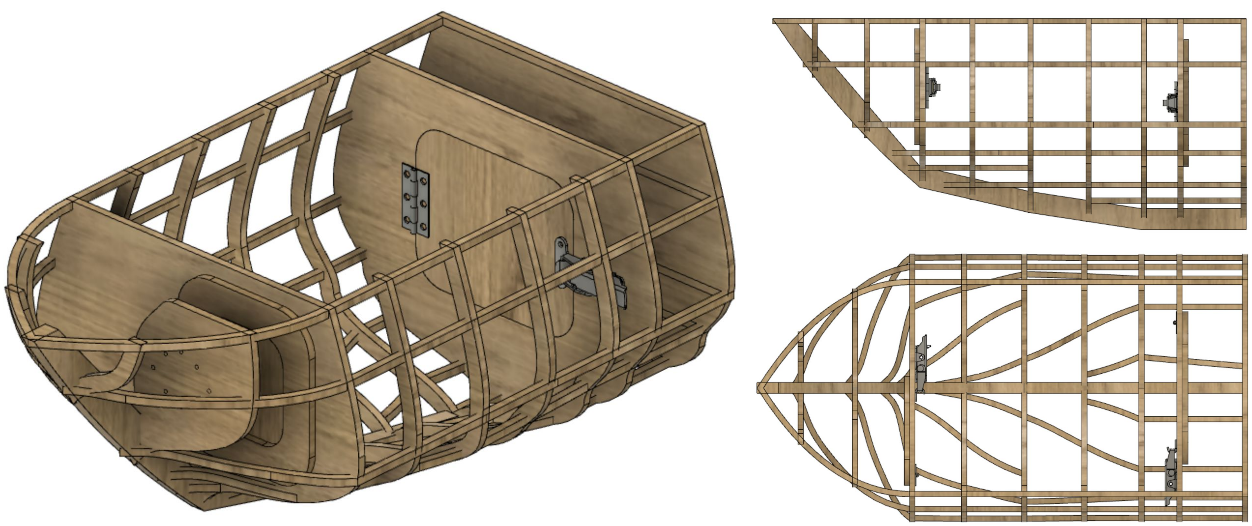


Figure 3: Structural Components Beneath Canvas Skin

The canvas-on-wood design allows for a structural weight of 2.3 pounds, and the total weight of the vehicle with its contents is expected to be 7.42 pounds (see Appendix A). A large keel along the underside increases dynamic stability, while the teardrop cross section (Figure 2) increases static stability.

Forward Electronics Bay

The forward electronics bay is a water-sealed section that houses the Raspberry Pi, Navio, and antenna assembly (see section B.4) as shown in Figure 4. The Raspberry Pi and Navio are mounted on a vibration isolating mount for accurate inertial measurements. The top will be covered by non-removable canvas, and this section is accessed via a sealed door in the bulkhead that opens to the center hold. The door assembly consists of a door, frame, foam seal, hinge, and gasket-sealing draw latch.

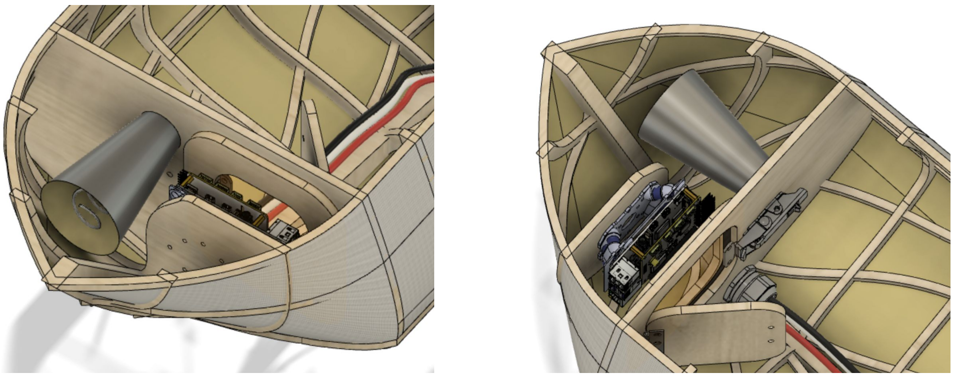


Figure 4: Forward Electronics Bay With Access Door Open (Left), With Top Removed (Right)

Center Equipment Hold

The center equipment hold contains all of the required emergency equipment (see section B.2), as shown in Figure 6. Wires connecting the forward and aft electronics bay will run along the keel through the bulkheads using sealed cable glands.

Aft Electronics Bay

The aft electronics bay contains the motor-controlling electronics, the power supply unit, and connections to the external motors and external power supply (see sections B.3, B.4), shown in Figure 5. This area is completely sealed with the non-removable canvas top, and access to service these components is provided via a sealed door in the lower-half of the bulkhead that can be opened through the center cargo hold. The aft electronics are separated from the forward electronics because significant heat is expected to be generated from these components. The external connections are sealed via water sealed cable glands.

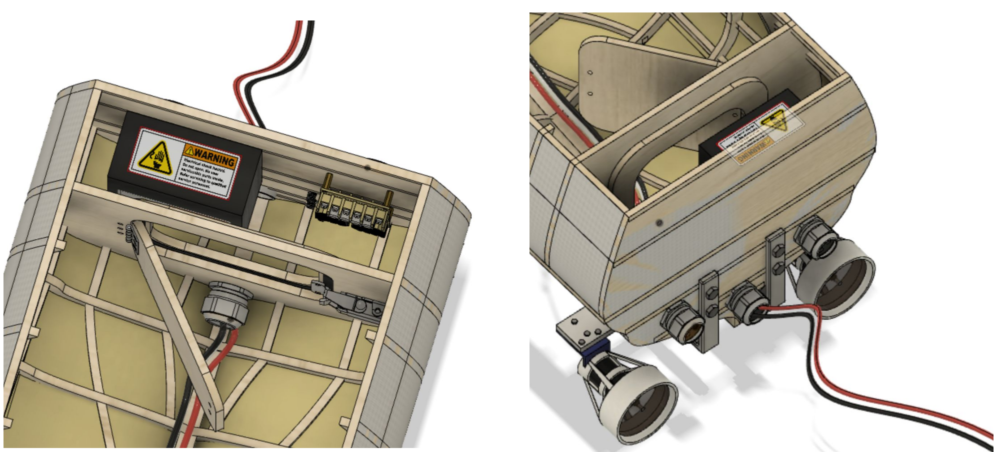


Figure 5: Aft Electronics Bay, With Top Removed

B.2 Body Interior/Emergency Equipment

Overview

The interior structure of the body supports and contains the emergency equipment required for successful astronaut assistance. A foam support structure, velcro attachment points, and tensioned-canvas covering are implemented in order to keep the contents of the vehicle secure and easily accessible upon arrival.

Center Equipment Hold

The center equipment hold features a foam support structure that allows for the larger emergency equipment to be attached. The equipment hold will contain (in order from aft to forward) an Orion life preserver unit (LPU), the Orion medical kit, one liter water bottle, survival radio, and contingency Advanced Next-Generation Emergency Locator (ANGEL) beacon.

Covering Assembly

The covering assembly is composed of a U-channel and a stretched-to-fit tarp that spans the perimeter of the opening to the center equipment hold. The front of the U-channel spans the top length of the forward bulkhead while the back spans the rear bulkhead. The sides of the U-channel connect these two portions. This creates a rectangular structure where the convex side of the channel always faces outside, toward the edge of the boat. This composition allows for a tarp with an elastic waist-band, similar to a fitted sheet, to fit around the U-channel. The tarp will allow for convenient access to emergency supplies and handling by astronauts without incorporating more complicated and costly electronic subsystems. To this end, two rope handles, sized to comfortably fit an astronaut's glove, are located on diagonal corners of the tarp. Additional labeling is included for ease of use and clarity in crisis situations.

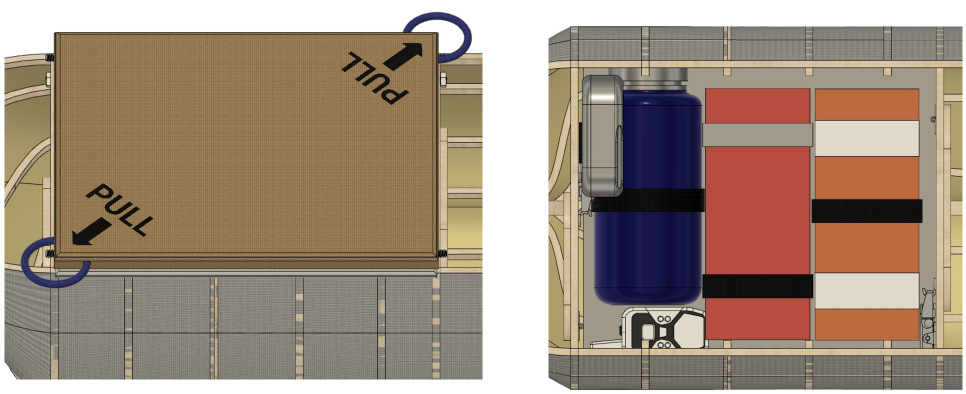


Figure 6: Center Equipment Hold, Covering Assembly (Left), Covering Removed (Right)

Interfacing

The foam support structures press fit in between the two main bulkheads with sections removed to allow for longerons, other structural elements, and electrical cables to pass through easily. The foam support also acts as a surface to which cargo can be attached, and is placed on top of wires running between electronic bays. This floor, along with the bulkheads, allow the cargo to be secured using velcro attachment points. Velcro loops will be sufficient to secure each item individually. The U-channel is attached to the body via four flat brackets, two for each bulkhead. The brackets are on the inside corners of the U-channel. The tarp will easily fit around the U-channel and will be tethered to the forward bulkhead.

B.3 Propulsion

Overview

The propulsion system is responsible for moving ARIEL to the astronaut in distress. To accomplish this task, a two propeller system is implemented. This system can generate sufficient thrust to power the vehicle's motion and to control the direction of its motion with differential drive steering. This eliminates the need for pivoting parts, such as a rudder, and ensures a robust system to withstand impact from the specified drop height of 10-15 feet. Additionally, the propulsion system is durable and easily interfaces with the device body. It consists of two underwater remote operated vehicle (ROV) thrusters with protective housing and a mounting solution for attachment to the device body.

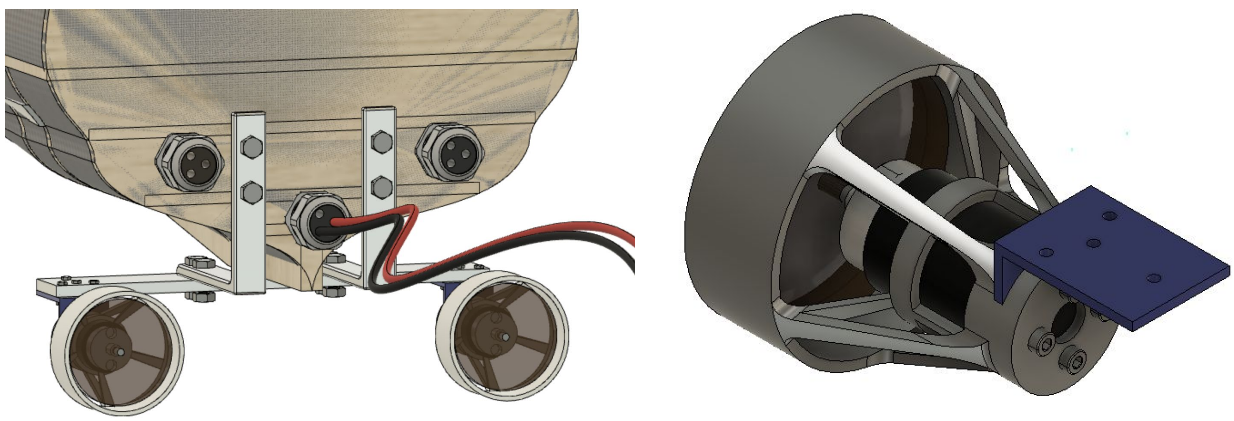


Figure 7: CAD of Full Motor Assembly Mounted on Hull (Left), Motor Assembly (Right)

Motor Assembly

The vehicle utilizes two remotely-operated vehicle (ROV) thrusters for propulsion and steering. In selecting thrusters, our top considerations were magnitude of thrust, ease of interfacing, size, weight, and electrical power requirements. We selected a commercially available 350KV brushless ROV thruster with a 60mm propeller. Each thruster provides 1.1 kg of thrust at 12 V. A rough calculation of drag indicated that the maximum speed of the vehicle will be at least 6mph using these thrusters.

While some remote control (RC) boat motors have shafts that extend through the body of the boat, ARIEL's ROV thrusters are self-contained systems located outside the main body of the vehicle. Only the motor cables (not pictured) are required to enter the vehicle body, which simplifies the challenges of interfacing and waterproofing. Waterproofing is accomplished using cable glands at entry points, as shown in Figure 7, and interfacing of the propulsion system is discussed in detail in the following section. The thrusters' low 0.132 lb weight and compact size make them suitable for ARIEL's weight constraints.

The thruster housing will protect the thruster, particularly the propeller, upon impact with the water after dropping from the drone. The housing will also improve safety, as it prevents crew members' hands from accidently making contact with moving blades, which could result in injury. The housing consists of a cylindrical shell around the propeller connected by ribs to another cylindrical shell around the motor, and interfaces with the existing L-bracket and corresponding screws. The housings will be 3D printed from ABS filament.

Interfacing
Each motor assembly will attach to one end of a horizontal aluminum beam via an L-bracket. One face of the L-bracket interfaces with the motor assembly and the other attaches to the horizontal beam through hex screws and nuts, as shown in Figure 7. The length of the horizontal beam was selected to be longer than the width of the boat, so that the moment generated by the differential thrust of the propellers during steering is sufficiently high. This allows the vehicle to turn quickly and with a small turn radius.

The horizontal beam interfaces with the rear bulkhead of the exterior structure by means of two aluminum L-brackets, distinct from the L-brackets mentioned previously. These L-brackets are oriented such that the motors are situated under, rather than behind, the vehicle, to set the steering location closer to the vehicle's center of mass, while the vertical position of the L-brackets ensures that the propellers are fully underwater with a high margin of safety. The horizontal beam is attached to each of the L-brackets at two points using hex screws and nuts; the rear bulkhead is attached to the other face of the L-brackets in the same fashion. At the threaded locations, the rear bulkhead will include thicker reinforcement. Connections will be reinforced with threadlocker to ensure that the propulsion system remains securely attached to the exterior structure after impact with the water and throughout its operation.

B.4 Electrical Systems

Overview
The electrical systems of ARIEL serve to drive all operations autonomously. As such, the electrical components must accomplish three main tasks: detection and localization of the distress signal, navigation to the distress signal, and maintaining a safe proximity to the source of the distress signal at all times.

Processing Core
The basis for all operation of the vehicle will stem from the processing core. The core selected for the vehicle is a Raspberry Pi paired with an additional board, the Navio 2. While the Raspberry Pi offers a great deal of functionality on its own, the Navio 2 provides several more desirable features in a simple package. Specifically, the Navio 2 contains a global navigation satellite system (GNSS) receiver for location, Inertial Measurement Units (IMUs) for orientation and direction, and a software basis for remotely receiving telemetry data (Emlid Ltd).

The processing core will solve the signal detection and localization problem, as well as the controls problem for directing the overall vehicle. Each is discussed below.

Signal Detection and Localization Algorithm
The basic signal location method finds the vehicle orientation that gives a maximum detected signal strength, and then follows this orientation until the gradient of signal strength decreases. In order to accomplish this, the vehicle will start by rotating in a circle and recording which orientation has the largest received strength. The vehicle will then rotate to that orientation and begin traveling forward. If

signal strength decreases, a new orientation must be found. At this point, the method will start the same circling algorithm again. When in close proximity to the distress beacon, determined by a signal strength threshold, the drive will switch to a proportional-derivative (PD) control algorithm. This will keep the vehicle close to the astronaut, but ensure safety by preventing the vehicle from colliding with the rescue target. Further discussion of the means by which the signal is read is covered in the section on signal detection.

Navigation Control Algorithm

Steering of ARIEL uses differential drive using two submerged motors attached to the vehicle. The control for each motor will be handled via signals generated in the Navio 2 board, which will then go to a motor controller that controls both of the motors through separate channels. The orientation of the vehicle can also be read instantaneously via the Navio 2 and used to update a proportional-integral-derivative (PID) control for maintaining the correct orientation as navigation continues. Thus, the ability for the vehicle to follow a desired path should be robust against perturbations from currents and waves in a marine environment. The navigation subsection contains more details.

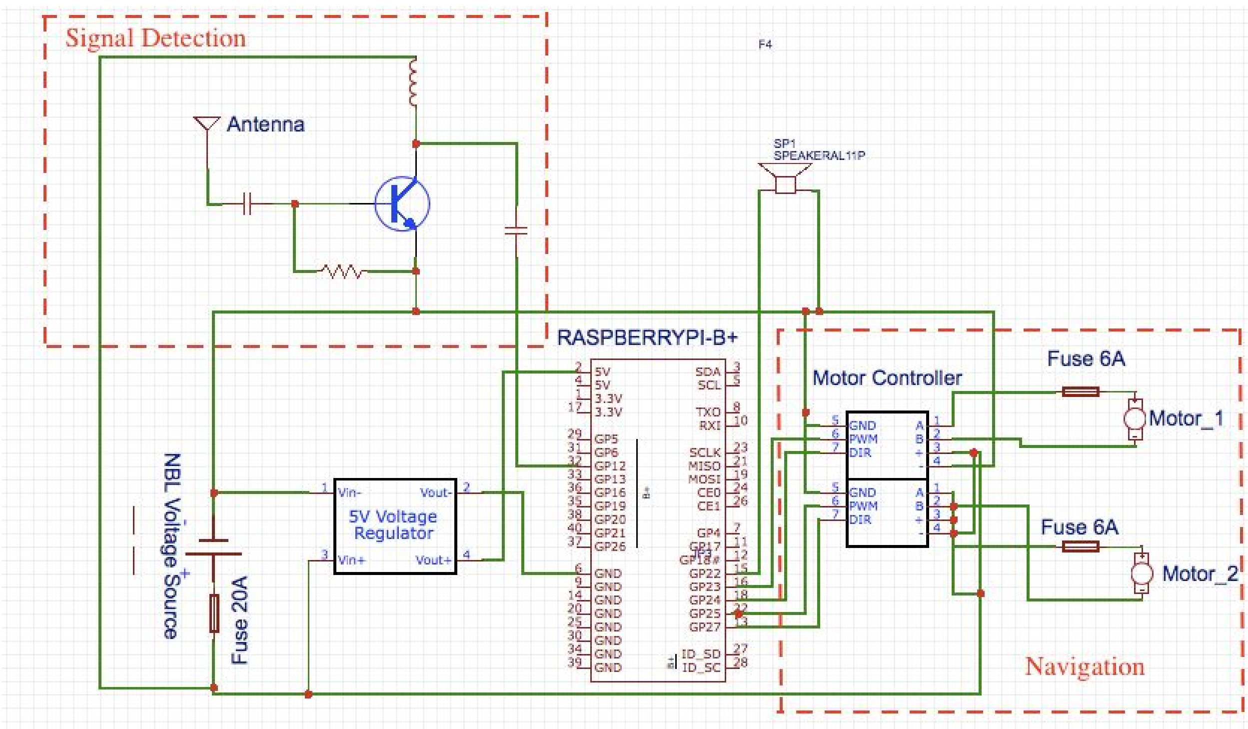


Figure 8: Overall Circuit of the Electronics

Signal Detection Hardware

Our hardware will detect the 121.5 MHz signal given by the ANGEL beacon and localize it to a particular direction, allowing our vehicle to perform basic navigation. A coiled antenna detects the signal, an amplifier circuit boosts the signal strength, and a faraday cage partially encloses the antenna, limiting detection to a particular direction (see section B.1). The signal will then be sampled by the Raspberry Pi, such that a successful fast Fourier transform (FFT) can be performed for signal identification and magnitude. The overall circuit of the system can be seen in the signal detection partition of Figure 8.

The faraday cage around the antenna will be a cone shape, such that the antenna is only able to detect signals for a given arc forward of the vehicle, limiting the field of view. During testing, if this setup is unable to produce a good enough signal-to-noise ratio (SNR) then it would also be possible to employ a pre-processing bandpass filter to the signal to help isolate the 121.5 MHz signal.

Navigation Hardware

Navigation of the vehicle requires a more in-depth look at the operations algorithm. As previously mentioned, the steering paradigm uses differential drive. The algorithm discussed in the processing core section focuses on the continuously updated orientation and acquisition of the goal orientation. These inputs are put into a PID controller in order to follow the best path and have a more robust performance amidst currents and waves in an ocean environment. Upon reaching a chosen received signal strength, the vehicle will switch to a PD control algorithm. The motivation for the change in controller is to help ensure the safety of the person in distress. Upon arriving at the target, if the control algorithm were not switched to PD, the integral term would cause a buildup of applied force while the astronaut is holding the vehicle to extract the necessary supplies, which could cause the vehicle to impact the astronaut at high velocity or rapidly speed away until it could correct itself and return again.

The navigation subsystem functions as a hierarchy, starting from the Raspberry Pi finding course corrections and generating control commands from the Navio 2 board, then controlling the motors via a motor controller, and ending with actuation of the motors. A circuit of this sub-system can be seen in the navigation partition of Figure 8.

Additional Components

By integrating the Navio 2 board, the navigation system is able to provide several additional components of feedback. The vehicle will be able to read its GNSS location and transmit that back to a base station. As an extension of this, the board also provides the ability to track the travel path of the vehicle in real time for monitoring purposes.

Power Budget

The NBL provides a 12V (25A maximum) power supply, which will be tethered to ARIEL via cable glands attached to the hull. The overall electrical system has a complete power breakdown in Table I.

Table I: Current Draw and Power Consumption for ARIEL by Component

Component	Voltage (V)	Maximum Current (A)	Maximum Power (W)
Motor 1	12	6	72
Motor 2	12	6	72
Raspberry Pi & Navio 2 Board	5	2	10
Signal Detection Circuit	5	.060	.3
Noise Generation Circuit	5	.020	.1
Total	**N/A**	**14.08**	**154.4**

ARIEL will not exceed the 25A maximum current draw following the budget above.

B.5 Manufacturing Plan

The bulkheads, formers, longerons, and keel of the main body structure are constructed out of wood. These are all 2-D members, and will be cut to shape using a laser cutter at Cornell University's Rapid Prototyping Lab. Oak plywood was selected because of its high yield strength to density ratio. The wood members are bonded using a combination of NBL approved 0151 HysolEpoxi-Patch Structural Adhesive and self-tapping screws at each joint. The material selected for the canvas was Ottertech® Waterproof Canvas. The PVC layer on one side of the canvas seals the interior from the exterior environment, as the waterproof canvas will cover the entire underside of the vehicle. The canvas is adhered to the wood structure via NBL approved 0151 HysolEpoxi-Patch Structural Adhesive. The same adhesive will be applied inside threads where screws may compromise water-tight integrity.

The U-channel which secures the tarp covering over the emergency equipment will be manufactured from four feet of polyethylene U-channel cut into 12.25" and 10.25" lengths, with a 45° angle cut on at each corner to form the joints. These connection points will be reinforced with marine grade silicone adhesive. The U-channel structure will be attached using commercially available brackets using holes drilled in the U-channel. The tarp will be cut to size and elastic will be sewn into the perimeter, and the rope handles for tarp removal will be sewn onto the corners of the tarp. The foam insert will be cut to fit and the emergency equipment will be velcroed in place.

The components of the propulsion system which require manufacturing are the horizontal bar, the two L-brackets that connect the horizontal bar to the rear bulkhead, and the two housing pieces. The horizontal bar will be milled from 0.25" aluminum sheet stock. The L-brackets are designed to be cut from aluminum 90° angle stock. There will be access length on the vertical face of the L bracket, which will be removed using a bandsaw. The housing pieces will be 3D printed at high quality using Cornell University's Rapid Prototyping Lab.

The required circuit components as well as processing core will be ordered and formed into the necessary circuits via soldering and perfboard use.

B.6 Requirement Compliance Matrix

Table II: Requirement Compliance Matrix for Surface Autonomous Vehicle for Emergency Response

Requirement	Compliance
The vehicle shall be capable of being dropped from a 10-15 foot height into the marine environment	We adjusted the hull shape such that the boat curves out above the water line for better stability. We used this water line to determine placement of the propulsion assembly. The position of the metacentre in our design gives the boat positive stability (see Appendix C). We are in the process of adjusting structural sizing based on ANSYS simulations for a positive margin of safety.
The vehicle shall be capable of being carried on a	Our vehicle with its cargo was designed to weigh 7.42 lbs (see

Group 1 (small) or Group 2 (medium), Close range UAV	Appendix A), under the 7.5 lbs maximum payload of the Boeing Insitu ScanEagle Group 2 Close range UAV (Insitu).
The vehicle shall be capable of transporting (carrying or towing), at a minimum, the following items to the victim: a. Water (1L minimum-2.5L max per Human systems Integration Standard) b. Medical kit (Orion .6lb kit) c. Spare Life Preserver Unit (LPU)* d. Contingency/Spare 406 MHz Second-Generation Beacon (ANGEL) e. Survival Radio	The vehicle is designed to hold a rectangular box capable of containing the specified items between Bulkhead FS7.0 and Bulkhead FS17.5. The dimensions of the water bottle were estimated based on physical measurements taken of a 1L Nalgene™ water bottle. The dimensions for the other emergency equipment was estimated based on images and sizes of commercially available versions of the item. These items are placed in an ergonomically accessible compartment and secured to the structure using hook-and-loop fasteners.
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	The vehicle will acquire the signal from an antenna and will interpret that signal using standard hardware. Our signal detection and navigation control algorithms (see B.4) govern ARIEL's autonomous navigation to the beacon.
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 the GNSS position c. Programmed with mission profiles to address specifics of rescue scenario	a. ARIEL automatically navigates to and stops at beacon location independently after dropping. b. Navigation scheme is based on the homing signal from the ANGEL beacon. The vehicle is capable of receiving and transmitting its GNSS location through the Navio 2 (see B.4). c. ARIEL is pre-programmed for the Orion rescue mission and contains an accessible Raspberry Pi that can be re-programmed for additional mission profiles.
The vehicle shall include protections in software/hardware to ensure no harm to the crew upon arrival in their vicinity	The vehicle's navigation software is written using a PD control algorithm, ensuring it will move slowly and stop when in the approaching the crew. Protective housings around the propeller prevent the moving blades from coming into contact with crew members, and they will be clearly marked as dangerous areas.

C. Operations Plan

Procedure

The following procedure describes how ARIEL will be configured and operated during testing at the NBL. This plan is designed to simulate ARIEL's completion of its mission objectives as accurately as possible.

0. Pre-test: Ensure that tarp and UART power connections are secured.
1. ARIEL will be dropped from 10-15 feet above the NBL by NBL staff to simulate delivery of the vehicle by a Group 2 UAV.
2. ARIEL will begin its detection procedure by detecting the 121.5 MHz homing signal and will then orient itself in the direction of greatest signal strength.
3. ARIEL will be propelled in the direction of greatest signal strength at a maximum speed of 3 mph for diver safety, making adjustments to course as needed.

4. ARIEL will decelerate as signal strength increases.
5. Upon reaching the vicinity of the astronaut, ARIEL will switch to a slow PD controller to maintain proximity to the astronaut.
6. An NBL diver representing a distressed crew member will remove the tarp covering and access emergency supplies as needed.
7. After completion of the mission, ARIEL will be retrieved by an NBL diver.

D. Safety

The primary hazard associated with use of ARIEL will be the potential for the vehicle to make unintended contact with the distressed crew. We mitigate against this potential safety hazard through both software and hardware considerations. ARIEL's navigation and motion control software will be written such that the vehicle will move slowly when nearing the vicinity of the crew, and will stop when it gets close to the crew. Rigorous testing of this system is critical, and will be performed by monitoring motor speed while tracking a test signal. Additionally, the vehicle will never be moving fast enough such that bumping into a crew member would cause significant injury (see section B.4: Navigation Hardware). Sharp edges produced during manufacturing will be filed down and covered by canvas to prevent potential hazards to the crew. The propellers are surrounded by a housing that will prevent a crew member from accidently making contact with them.

The electronic circuitry will have a 20A fuse on the input DC line, which is within the 25A limit for the NBL power supply and is sufficient based on current needs shown in Table I. Beyond the main fuse, each individual motor will also have a 6 A fuse, as these are submerged in water and thus the most vulnerable, and are the largest potential current draws of the system. Motors will be individually tested underwater before being attached to the main body.

ARIEL will employ a sound generator as a means to alert the person being rescued of its approach. Sounds will be generated through a library on the Raspberry Pi, which can then be output to a piezoelectric speaker shown in Figure 8 (WiringPi.com).

NBL Engineering and Safety Requirements for Micro-g NExT

Table III: NBL Safety Requirement Compliance Matrix for ARIEL

Requirement	Compliance
Pneumatic Power Requirements	
Student projects will be allowed to connect to NBL's compressed air (shop air system)	ARIEL will not use compressed air.
All lines, fittings, and pneumatic devices must be rated for a minimum pressure of two and a half (2.5) times the maximum supply pressure	ARIEL will not use pressurized devices..
All pneumatic tools must operate at 90 decibels or less. The tools will be tested underwater for sound level at the NBL.	ARIEL will not use pneumatic tools.

Electrical Power Requirements	
Student projects will be allowed to connect to the NBL's electrical outlet: DC 12V, 25 amp. No other electrical power sources will be allowed.	All manufactured electronic systems will work with the provided power supply either directly or through regulator circuitry. All components operate at or below 12V with a total maximum current of 14.08A (see B.4).
The interface connection will consist of a positive and negative female banana plug connection.	The tool will have two running power lines with the specified banana plugs that will connect to the power supply located poolside during testing at the NBL.
Tool must incorporate a verifiable barrier to electric shock.	All electronics will be insulated from the astronaut and water by the canvas and wooden hull. Fuses cut power in the case of any short circuits. Interactions between the astronaut and electronics are isolated via the bulkhead doors (B.1) and foam support structure (B.2).
The NBL power supply will be located a minimum of 11 feet from the pool edge. Cables must be of sufficient length to reach without tension between the power supply, the controller, and the tool. Specific requirements will be determined based on underwater test location.	50 foot power cables will run to the tool to reach from the power supply to any location in the operational space.
Labels: The hardware provided shall have labels as follows:	
Mate/de-mate alignment marks, operation indicators, as required	Labels on tarp surface will indicate astronaut interaction.
Caution and warning tags for Hazard areas (i.e., pinch points, sharp edges, etc.)	We will add warning labels on the propeller covers. All fuses/electronics will be labelled for shock warning.
Hardware identification	Major components to be labeled include: forward and aft electronic bay entrance door, fuse box, voltage regulator, processing core, and motor controller. Powered wires will be colored red (+) and black (-) to indicate shock danger.

E. Technical References

See Bibliography for references to technical documentation.

II. Outreach Section

A. Brief Summary

The mission of Cornell Micro-G is to reach individuals across diverse ages and backgrounds to introduce them to the wonders of space sciences and the work NASA is doing to learn even more about what is beyond our world. To reach this goal, we must connect with several of the communities that surround us in Ithaca, New York, both in and outside of the Cornell community. In Ithaca, we can connect with kids and adults from a wide range of backgrounds to impress upon them the importance of space exploration and technologies.

We connect with the Cornell community using several different events that allow us to teach many undergraduates, graduates, alumni, and faculty who we are, and why we participate in competitions and challenges like Micro-g NExT. Furthermore, there are several opportunities in Ithaca that allows us to reach a larger audience. We will visit schools and many downtown events to help facilitate conversations about the work NASA is doing. Our events involve engaging with diverse communities and showcasing the general importance of space exploration. We then promote conversations to engage our audience with their view of their own role in scientific advancement. These conversations allow them to think critically about NASA's goals and our own.

B. Plan

Our events are meant to bring excitement about space exploration, and the work done for the NASA Micro-g NeXT competition by our team. The setup for many of our outreach events will include a presentation of who Cornell Micro-G is, details about the Micro-g NeXT competition, and how the tools built every year are related to real world problems NASA faces. Our key audience will be students in primary/secondary school. Therefore, many of our events will involve us travelling to local elementary, middle, and high schools. By visiting students in these age ranges, we will be able to interact with them as they are still developing their interests. We create interactive activities that allow these students to have hands-on experiences with our team. The goal of these trips is to pique these students' interest in NASA, space exploration, and space technology.

Our trips to primary schools will concentrate on the fascinating topic of space sciences. The beginning of our event starts with a presentation that includes a variety of interesting pictures and videos from NASA's public use data. These multimedia images will help grab younger students' attention about how exciting space can be. After presenting the students with an overview of topics like astronomy, atmospheric science, astrophysics, and engineering, we will be able to see what piqued their interest specifically by opening a conversation about what they liked. The next step is to provide a hands-on experience by demonstrating previous tools, and activities which are simple enough for the students to understand the importance of science and technology. We also tailor these activities to the current tool we are working on, so we can connect the presentation back to the Micro-g NeXT competition. At the end of the event we ask the students what they liked most, and encourage them to pursue that interest as they continue their schooling.

Unlike the students in primary school, secondary-school students are a little more educated about space-related topics. Therefore, we can bring in a more in-depth discussion about the work that NASA does and what our team does in terms of engineering and design. Our presentations for these students include the fun videos of NASA, but also go into depth about the technical details that make space-exploration possible. Our activities can be more complex, and include the students being given a task in which they will have to think critically about, with some emphasis on teamwork and communication. They will also be able to engage with us at the end of the presentation of what they liked, what grabbed their attention the most, and if they have any questions about the work NASA or our team does. Since these students are also considering at least the general direction for their careers, we can give them as much information possible about our experiences as undergraduates.

We will also hold an event at Ithaca's local Sciencenter so we can connect with a wide range of kids from different ages (Sciencenter.org). This will help us reach more even more children, since we are restricted to a specific classroom when visiting a school. Additionally, many adults also come to the Sciencenter, so we can mix the topics of our discussion. This event will be very similar to our school trips and will involve presentations and activities for all different ages, which we will have to tune to the kind of crowd gathered.

Below is a list of the specific hands-on activities that we have planned for each section of our audience.

C. Activities

Our team will be providing workshops that feature building activities as well as informational components featuring videos, images, and speaking sections. The activities will be focused on NASA's NBL and its place in space flight technology development, the Orion spacecraft and Artemis Program, autonomous vehicle design, and general engineering principles.

The interactive activities stimulate valuable thought processes in students, such as problem solving, decision making, and critical reasoning. Most of our activities will be done in a small group setting. In many engineering projects, and in this competition, working on a team is necessary. We will teach young students the benefits of working on a team and teach them good collaboration and communication skills. Students will realize that they will be able to accomplish more in a group than they can individually.

We will follow the National Science Education Standards (NSES) for K-12 Science Educators to properly focus on good techniques (National Science Standards). This means that we will have less of an emphasis on the following things: memorization of scientific facts, separating fields of science and engineering, and implementing inquiry as a series of processes. We will instead focus on understanding scientific concepts and developing abilities of inquiry, integrating all aspects of math, science, and engineering, and learning subject matter through a holistic lens which takes into account science, technology, and the impact of a topic on history and society.

Elementary School

Our activities in elementary schools will keep concepts broad in order to allow the main objective to be enjoying the activity and having fun. This ensures that students will want to continue these kinds of activities outside the class. The Artemis program supplies great source material for this kind of content. We will use some of the NASA activities in the “Forward to the Moon with Artemis Explorer” activity set which includes the “Identifying Apollo Lunar Modules” activity and the Forward to the Moon “Trace Your Path” activity (May). We also want the children to have the ability to design something they can take home, so we will bring in supplies that allow the students to build their own prototype of the vehicle.

Middle School

For middle schoolers, our objective is to introduce more of a design challenge. First we will ask that they determine the landing destination of a lunar module based on facts and information we provide. After exploring information from past missions, they will determine their “base site”. The next step will have students develop a lunar lander with given supplies and creative thinking. There will be size and material requirements that students will have to follow. The group with the most effective design, as judged by our team, will be chosen as the “mission director”, thereby winning the challenge. A small dose of competition will spark enthusiasm in the project.

High School

High school-level activities will focus on the autonomous component of our chosen design challenge. We will begin by discussing several techniques in artificial intelligence and how that might relate to our project. Students, in teams, will develop pseudo code or algorithms for a “robot” to find an item on a large grid with obstacles and a “goal item”. The robot has very basic capabilities such as moving forward one space or turning left. We will teach the students several computer science related ideas such as methods, if/else statements, and while loops. We will then have a simulation where the students will map out the path of their robot given their algorithm. The difficulty can be increased by creating obstacles with different characteristics, e.g. moving randomly, preventing movement if collided with, or allowing the “robot” to move differently. Our goal is for students to work in teams to develop an idea, learn some very basic computer programming ideas, and relate those topics to our current project.

University Students

For university students we want to help with collaboration and team building, as this will help any student regardless of their major or study. Activities will be based on engineering and design principles. One activity we have planned is a building challenge. There will be a pre-designed structure placed in a concealed portion of the room. There will be teams set up around the room with the required pieces to replicate the structure. The rule is one person at a time is allowed to go look at the structure at a time and they must wait to return to their team to describe it. This works on communication as well as being able to describe the way a design is composed and instructing teammates to complete a technical task.

Local Families

When we interact with people at the Sciencenter museum or downtown in the Ithaca Commons, we know we are getting young students at a unique time, often with their parents. We want to encourage these students and their parents to bring projects into their home. We help them design model satellites and model straw rockets using paper cutouts and instructions. This will give the young audience a basic understanding of the design, and how and why it works, and they will be able to implement similar projects wherever they are inspired to do so.

D. Online Engagement

This year we want to leverage our online following on Facebook, Instagram, and Twitter into our own outreach channel. This allows us to break down any barriers related to location or attendance, and to allow anyone and everyone to participate. The objective is to increase overall engagement with our pages, and to guide users to explore online resources about our team, or ones that NASA or other organizations have created.

Our followers consist of many types of people, from our friends and supporters here at Cornell University, to people we have met through our university involvement and in-person outreach events, to the general public. We will engage our following with quizzes that challenge viewers to answer questions regarding NASA and space exploration. For example, many people vastly overestimate the amount of money that NASA gets from the average taxpayer. Lots of work can be done with our peers on campus to correct this misunderstanding. Using Twitter's embedded tweet feature we will have a "choose your adventure" thread where a user can make choices on a "space mission" and receive a result. We will also broadcast using Facebook and Instagram Live to show some of our design and testing in progress.

Facebook will allow us to reach people from many different backgrounds through their sharing feature, which allows our message to reach people who may or may not be within the local Ithaca community.

Twitter will allow us to present quick updates on the progress as a team. We will also be able to interact with our followers more directly if they have any questions about our progress, NASA, or any other questions. Being able to interact with our audience in real time will be helpful for engaging interest in our team on campus.

Instagram will allow us to present nicer, more professional pictures and videos of our tool and of our team. This will allow for a tailored public-facing account that shows off our accomplishments to any interested parties.

E. Letters of Agreement

Confirmation of an event at Cayuga Heights Elementary can be found in Appendix section F. A letter from the Cornell organizers of the Sagan Planet Walk in the Ithaca Commons can be found in Appendix section G.

F. Connection to Competition

The activities will be focused on NASA's NBL and its place in space flight development, the Orion spacecraft and Artemis Program, autonomous vehicle design, and general engineering and technical principles.

III. Administrative Section

A. Test Week Preference

Test weeks are listed in order of the team's preference below:
Preference 1: Test Week 2: June 1-6, 2020
Preference 2: Test Week 1: May 18-23, 2020

B. Mentor Request

The Cornell Microgravity team has not had specific contact with any individual at NASA, and would love to be mentored by any individual.

C. Institutional Letter of Endorsement

A letter of endorsement from Associate Dean Mike Thompson is found in Appendix D.

D. Statement of Supervising Faculty

A statement from Alan Zehnder, the supporting faculty member of this team, is found in Appendix E.

E. Statement of Rights of Use

As a team member for a proposal entitled "Autonomous Rescue Instrument for Emergency Landing (ARIEL)" proposed by a team of undergraduate students from Cornell University, 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.

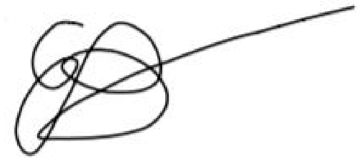
As a team member for a proposal entitled "Autonomous Rescue Instrument for Emergency Landing (ARIEL)" proposed by a team of undergraduate students from Cornell University, I will and hereby do grant the U.S. Government a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States an invention described or made part of this proposal throughout the world.

Gregory Kaiser

Christopher Chan

Thomas Taffe

Ruojia Sun



Emerson Braithwaite

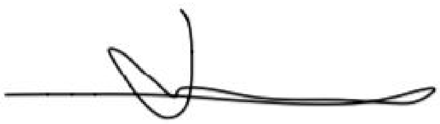
Ben Goldgof

Crystal Hu

Amy Huang

Vivian Huang

Jacob Lashin



Jonathan Lee

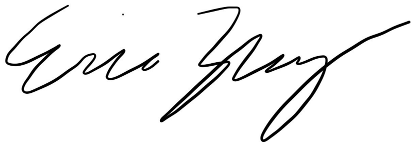
Eric McNamara

Drake Schiller

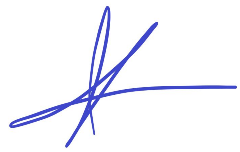
Maanav Shah

Ryan Tay

Emmi Wyttenbach



Eric Zhang



Eshaan Jain

Jaytlen Cantos

Emma Vedock-Gross

Alan Zehnder

F. Funding and Budget Statement

Our team plans to acquire funds institutionally from Cornell University through project team management, as well as through Giving Day, a Cornell-run donation program where alumni and other people within and outside of the Cornell community can donate to specific organizations on campus.

Cornell Micro-G team's financial advisor is Kae-Lynn Wilson. She is the Assistant Undergraduate Coordinator for Project Teams and can be reached at kbw28@cornell.edu.

Below are our expected costs for the project, including potential travel to Houston.

Table IV: Materials and Manufacturing Costs

Part Name	Total Cost
Exterior Structure	
Red Oak Plywood	$126.78
Ottertex Waterproof Canvas	$13.98
Water and Weather Resistant Foam Seal	$12.65
Gasket-Sealing Draw Latch	$17.26
Surface Mount Hinge with Holes	$8.42
No. 8 Screws for Wood	$4.82
Loctite 0151 Exoxy	$17.30

Interior Structure	
Polyethylene	$13.40
Tarp	$12.99
Elastic	$6.99
Rope	$11.96
Steel Bracket	$2.12
Electronics	
Navio 2	$168.00
Speaker	$3.95
Motor Controller	$31.96
20A Fuse	$3.89
6A Fuse	$4.95
Fuse Holder	$4.86
Voltage Regulator	$3.80
ABS 3D Printing	$0.00
Silicon Rubber Mount	$8.50
Copper Antenna Wire	$0.52
Raspberry Pi 4 Model B	$35.00
Hook-up Wire, Assorted	$16.95
RoboClaw 2X15A Motor Controller	$89.95
Propulsion	
350KV brushless ROV thruster	$91.60
Aluminum 6061 bar stock of sufficient size to create horizontal beam	$3.68
Aluminum 6061 Angle Stock 4”x4”	$23.21
ABS 3D printing filament	$0.00
1/4-20 Super-Corrosion Resistant Hex Screws (pack of 25)	$4.99
1/4-20 Corrosion-Resistant Hex Nuts (pack of 10)	$6.37
4-40 Hex Screws (pack of 100)	$10.14
4-40 Hex Nuts (pack of 25)	$13.38
1/2" NPT cable glands, 3 x 5.6mm	$5.07

TOTAL:	**$779.44**

Table V: Travel Costs Projected for 4-Person Travel Team

Hotel	$1,200
Flights	$2,300
Rental Car	$350
Food	$480
TOTAL:	**$4,330**

The overall total for team costs is $5,109.44.

G. Parent Consent Forms

All team members are 18 years or older, so no parental consent forms are required.

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V. Appendix

A. Component Weight Summary

Table VI: ARIEL Component Weights

Part	Weight
Body Structure and Canvas	2.1 lb
Covering Assembly	.28 lb
Orion Medical Kit	.6 lb
Water and Water bottle	2.2 lb
Walkie Talkie	.4 lb
ANGEL Beacon and LPU	.8 lb
Propulsion	.78 lb
Electronics	0.26 lb
Total Weight	**7.42 lbs**

B. Preliminary Test Results

Preliminary testing has verified the stability and hydrodynamics of SAVER's hull shape using a 3-D printed scale model. The model of the vehicle was dropped into water and was able to float, return to an upright position from a 90 degree rotation, and maintain stability when a force was applied at the approximate location where the motors would be.

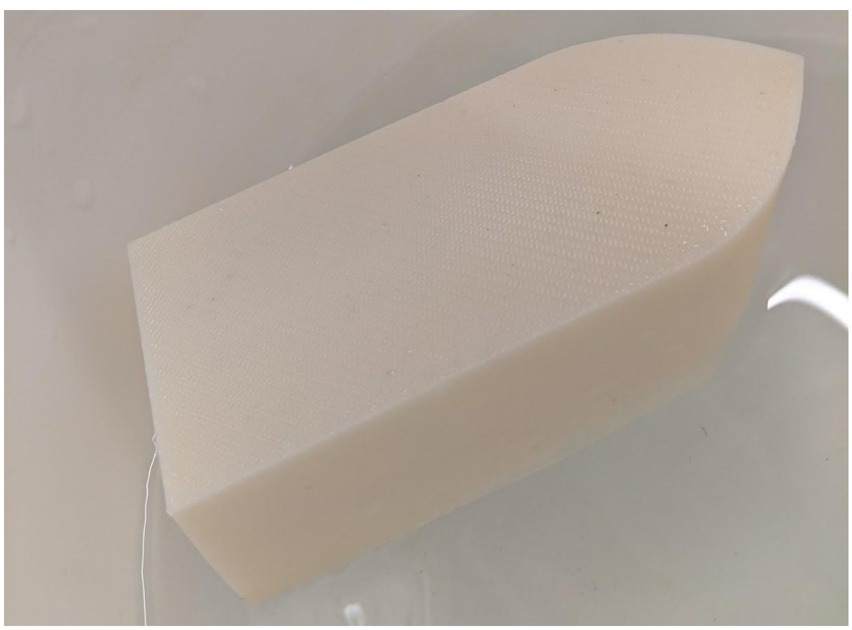

Figure 9: Test Using 3-D Printed Scale Model of Hull

C. Buoyancy Calculations

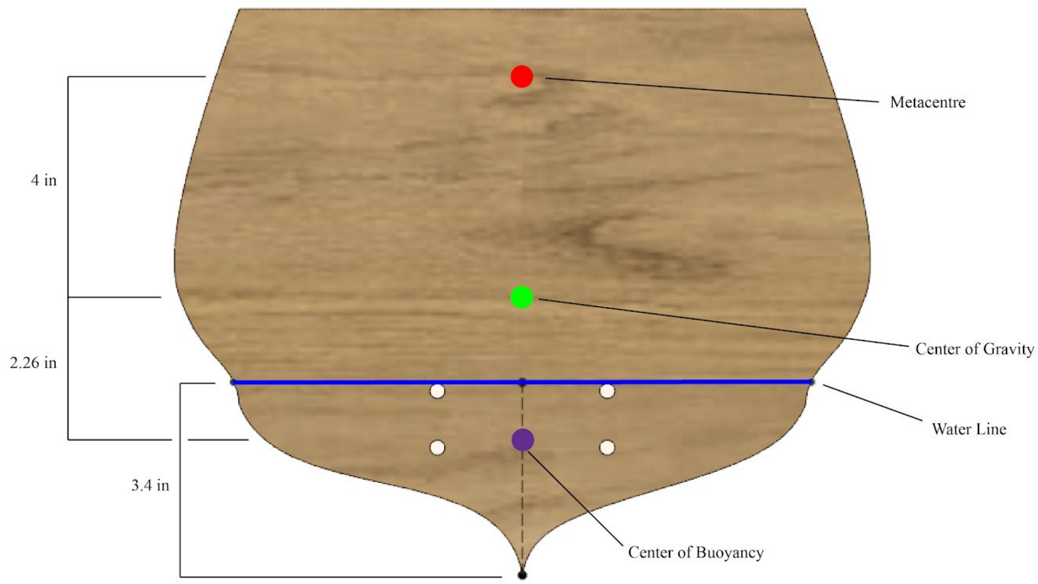

Figure 10: Important Stability Points for ARIEL Hull Structure

The Center of Buoyancy was calculated in Fusion 360 using 3 angles.

$$B(0) = (0, 2.52), B(10) = (1.08911, 2.614), B(5) = (.54, 2.537)$$

$$BM = \frac{(B_y(\theta) - B_y(0))}{sin(\theta)}$$

$$BM(5) = 6.2BM(10) = 6.27 \therefore M(0) = (0, 8.76), G(0) = (0, 4.78)$$

Since $M(0) > G(0)$ the boat has positive stability

D. Institutional Letter of Endorsement

Cornell University

College of Engineering
Michael O. Thompson
Associate Dean for UG Programs
Materials Science & Engineering
328 Bard Hall
Ithaca, New York 14853-1501
t. 607.255.4714
f. 607.255.2365
e. mot1@cornell.edu

October 25, 2019

To: NASA Micro-g NExT Challenge
RE: Endorsement of the Micro-g NExT project team

On behalf of Cornell University's College of Engineering, I am writing to endorse the Cornell Micro-g NExT project team in their efforts to enter the 2020 NASA Micro-g NExT Challenge.

The Micro-g NExT team is one of our Engineering Project Teams who are partially supported (financially and logistically) by the College of Engineering. The college is committed to assisting the team with accessing necessary space, facilities, and intellectual expertise necessary to successfully compete in this program. In addition, the college will help financially both through direct contributions and through assistance in fund raising from alumni and corporate sponsors.

As part of the Engineering Project Teams, Micro-g NExT is expected to abide by all College of Engineering policies and guidelines with respect to safety, ethics, behavior, and travel.

I would also like to thank you for your dedication and efforts encouraging this new generation of engineers and innovators.

Sincerely,

Michael O. Thompson

Michael O. Thompson
Associate Dean for Undergraduate Programs
College of Engineering, Cornell University

E. Statement of Supervising Faculty

Cornell University
College of Engineering

Sibley School of Mechanical and Aerospace Engineering

Alan T. Zehnder
Professor
409 Upson
Cornell University
Ithaca, New York
14853-7501
Ph. 607 255-9181
Fax 607 255-2011
atz2@cornell.edu

October 25, 2019

To: NASA Micro-g NExT Challenge
RE: Endorsement of the Micro-g NExT project team

As the faculty advisor for an experiment entitled "Surface Autonomous Vehicle for Emergency Response (SAVER)" proposed by a team of undergraduate students from Cornell University, 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 Cornell University.

Sincerely Yours,

Alan Zehnder

Alan T. Zehnder
Professor

F. Letter From Cayuga Heights Elementary

Cayuga Heights Elementary
110 E Upland Rd, Ithaca, NY 14850

To: Cornell Micro-G

From: Conor McGivern

Re: Team Visit

Dear Cornell Micro-G Members,

I look forward to having your team visit this November for a presentation and activity. You will have the opportunity to reach out and show what you have been working on, to my class of 24 students. They are all excited for you to visit!

Thank you,

Conor McGivern

4th Grade

Cayuga Heights Elementary

G. Letter From Sagan Planet Walk

SAGAN
PLANET WALK

Hello Cornell Micro-G,

I am with the Cornell Society of Physics Students, and we are organizing the Sagan Planet Walk. I believe you have inquired about participating in this event this year in order to get students and the Ithaca community excited about your work. If any of you are available and would be interested in joining this event again this year, please let me know. We will be setting up an area along the walk for project teams and scientific demonstrations.

Best,

Laura Doyle