DELTA TECHNOLOGIES

System Performance Specifications

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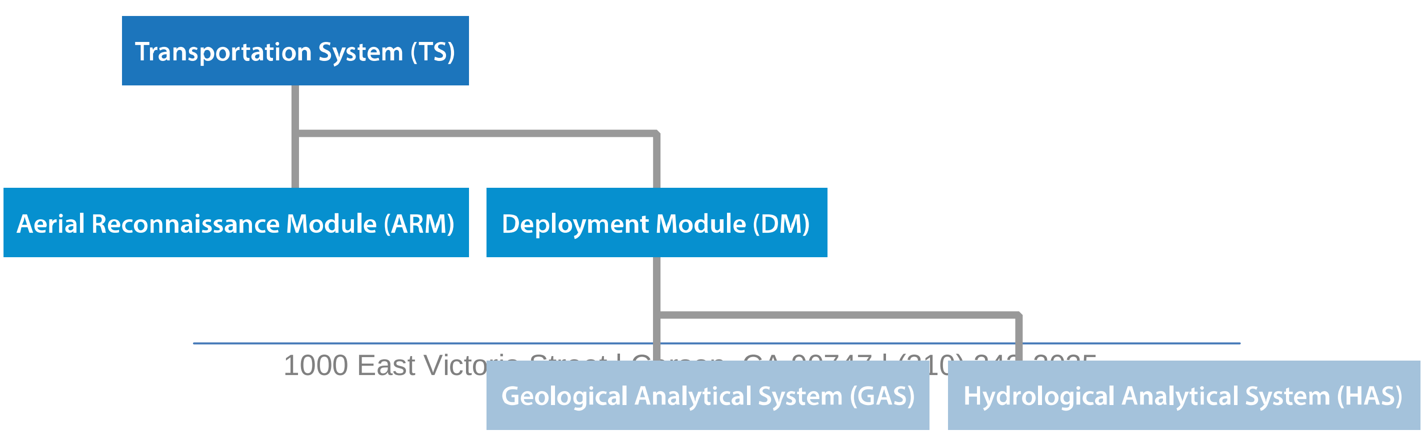
Executive Summary

In order to aid military personnel, Delta Technologies will create a multi-purpose, polymorphic robot, dubbed Mercury.It will be able to traverse over various terrains and perform specific tasks. Mercury has four unique configurations: Transportation State, Flight State, Float State, and Drive State.

The Transportation State is designed for convenient, portable transportation. In the Flight State, the Aerial Reconnaissance Module (ARM) conducts aerial surveillance and creates an accurate, three-dimensional map of a room. In the Drive State, the Deployment Module (DM), which consists of the Geological Analysis System (GAS), will pinpoint the location of mines or improvised explosive devices in the ground with a geophone. In the Float State, the DM, which consists of the Hydrological Analysis System (HAS), travels on the surface of any body of water while simultaneously testing the water's potability. The GAS and HAS are integrated into one mechanism that forms the DM, which operates independently from the ARM. The DM and ARM then recombine to form the Transportation State.

Delta Technologies will be ready to market the product by March 2013.



Mission Statement

CARPA has commissioned Delta Technologies to design, build, and test a fully autonomous polymorphic robotic system in “Project Morpheus.”

Required Morpheus Capabilities:

- Autonomous reconfiguration through three morphs and four states
- Autonomous performance of a valued task in each state
- Capability to perform the series of morphs and tasks at least twice
- Transportable within a protective case, of which Morpheus will be removed from and returned to the case by an operator

Delta Technologies will create a fully autonomous polymorphic robot in order to supplement military personnel with real time information. Before a soldier enters the field, he or she is prepped with information about the job and surroundings; however, because battlefields are not static, the data is liable to be inaccurate by the time the troops arrive. Real-time information allows personnel to adapt to changes in a dynamic situation. Since Mercury will not hinder a soldier’s performance on the field, it will be the paragon of non-combat support equipment.

When soldiers are in any battlefield, situational awareness is necessary for themto complete their mission safely. The more information a soldier knows about his or her surroundings, the more prepared the soldier will be to defend his or herself and complete a task in an efficient manner.

Military tasks have been identified under four overarching categories: Reconnaissance and Intelligence, Transport and Deploy, Search and Disable, and Collect and Analyze. Morpheus will complete a task in each of the categories.

Morpheus Capabilities:

Reconnaissance and Intelligence:Many soldiers die at the hands of explosives and projectiles. If given enough reliable information, soldiers can help prevent causalities from occurring. Reconnaissance and intelligence are extremely important for troops on the ground, especially if they are entering unknown territories. By surveying an area, mapping a room, and relaying back this information in real time, Mercury will help troops know exactly what they are up against whether they are just starting to enter an area or are caught in the midst of a heavy firefight.

Transport and Deploy: Planting C4s involves risks. By transporting a C4 charge to a target location, Mercury will eliminate the potential for injury or death that an allied soldier can face. The possibility for human error is eliminated, and soldiers will no longer have to deal with placing themselves in a vulnerable position by devoting all their attention, if only for a minute, to correctly placing and arming the explosive.

Search and Disable:Undetonated mines have led to many injuries and casualties to both civilians and soldiers. Undetonated mines pose a threat not only during war, but also after the conclusion of a war,when civilians assume that all is safe. Mercury will detect the location of mines in a battlefield to alert soldiers and civilians of possible threats.

Collect and Analyze: Mercury tests its surrounding environment,as well as those of the soldiers. In order to test the water, a sensor suite was placed on one of the buoyancy flaps. When the flaps lower to provide buoyancy, the sensor suite will be submerged in the water, allowing the sensors to take readings of the water. The sensor suite is comprised of two parts: the environmental testing and the water potability testing. The environmental testing consists of a methane sensor and carbon monoxide sensor. With these sensors, we intend to determine how safe the environment is for a soldier to work in.

Scope of Work

Transportation State (TS)

The TS is the first and dormant phase of the Polymorphic Robotic System (PRS). The purpose of TS is to facilitate the transportation of the robot through a compacted durable state. A carrier will position the TS at the desired deployment area, at which point the robot will morph itself into its first functional form: the ARM. TheTS is designed to allow for ease-of-access and provides consumers with a more manageable version of the Mercury.After the robot shifts from the TS formation, it will no longer require external assistance to move.

Aerial Reconnaissance Module (ARM)

After the ARM morphs from Transportation State into the Aerial Reconnaissance Module (ARM), it will release an X4 multi-rotor copter which will perform room or terrain based mapping, from an apt altitude depending on the situation. The multi-rotor copter uses depth adjusted imaging to acquire a digitized version of the environment. From here, the DM and ARM will transmit data among each other by means of a Wi-Fi network, similar to techniques utilized by the military to parallel a communications relay tower in order. The multi-rotor copter must stay within the effective range of the DM's wireless network in order to re-attach properly.

Deployment Module (DM)

The DM will be locating and disabling mines while the ARM is completing its task. The DM will be self-propelled by four wheels and an onboard power supply. It will begin examining a desired area. Once this happens, the DM will facilitate the collect and analyze mission. The DM walls will act as flotation for the entire robot as the HAS begins to take its readings of water.

Hydrological Analysis System (HAS)

The Hydrological Analysis System is a state in which the DM may traverse water to test it for potability. The DM will position itself as close as possible to the body of water, at which point the walls of the DM will drop outward in a manner similar to a moat bridge in order to create a hull which will, with the assistance of pontoons attached to them, displace enough water to keep the DM buoyant. At this point the ARM will position its propellers in such a way that two will be primed to provide the necessary thrust to drive the craft forward.

Geological Analysis System (GAS)

The Geological Analysis System is the final state Mercury will take. The ARM's shrouds will act as wheels for the GAS to navigate on while it reaches and traverses a minefield. The unit's sensor equipment will extend out of the main body through a slit-like opening in one of the outer walls. Once the arm is parallel over the surface of the ground, a geophone will emit sound waves which will be picked up by nearby mines, causing them to reverberate. In turn, three sensors set up in a triangular arrangement around the geophone will pick up the return vibrations and locate the explosive. The triangular arrangement enables the GAS to pinpoint the mines' locations by analyzing the differences between the time one sensor picks up the reverberations in comparison to the rest.

Risks and Assumptions

General

Since, the robot will be operating in a war zone; the possibility of mission failure due to the high number of risks in the environment will be high. The largest risk will be posed by enemy personnel and arms. The small size of the robot, along with the weight restriction, makes it easily susceptible to critical damage by enemy gunfire due to the lack of an armored exterior. The robot itself also poses a risk to the soldiers. If it is damaged or the soldiers are too reliant on it, then they have another variable in the battlefield to worry about.

Manufacturing

Delta Technologies assumes that an equal amount of time will be spent in the computer lab and the machining room.Components, stock, and other materials ordered are expected to arrive on time and in flawless, working condition. Workers are assumed to be able to contribute time towards the overall production of Mercury some time outside of school.

DM and ARM

The DM and ARS need to communicate via means of a wireless network; causing the ARS be limited by a certain range around the DM. Going any further will cause both modules to lose connection with each other and make the task of finding each other again impossible. In addition to this, the DM lacks ample mobility so a hostile troop could easily go in and damage the unit, leaving the ARS without anything to re-attach to and effectively rendering the entire robot useless.

The flight module must always have enough power as is necessary to safely return from the furthest extent that the wireless network allows it to reach, and back to the DM. If it cannot complete this task then the risks include damage due to a fall or not re-attaching itself which puts the soldier at risk if he or she has to go and recover the robot manually.

Geological Analysis System (GAS)

The GAS will be using three geophones to examine the ground for mines and IEDs. This method, although effective, will be using sound waves that may cause minor discomfort. If not properly researched, then the operator could experience mental and physical side-effects such as headaches and dizziness.

HydrologicalAnalysis System (HAS)

The HAS puts the robot into direct contact with water which poses a problem: If the joints are not properly protected, then water may seep in and damage sensitive electrical components. The propellers also need to be isolated from the water.However, since they are also what will power the craft forward, this will be extremely difficult. The robot tipping over will result in a catastrophic failure.

Environmental Risks

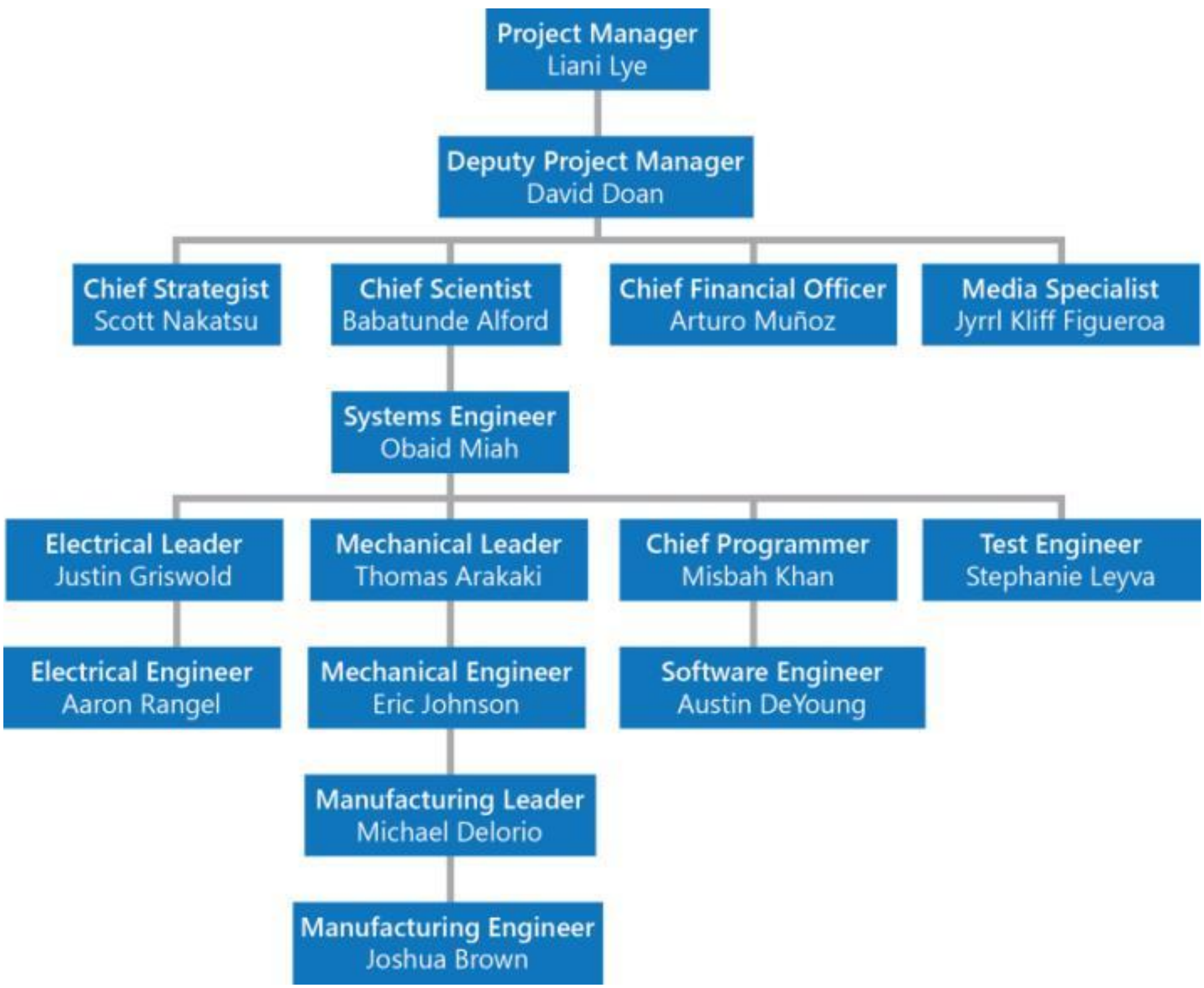
The PRS will to be deployed by military personnel wherever they deem fit, so it’s expected to operate in every possible environment. After taking into consideration that the robot will most likely be deployed on or near a warzone, it’s natural that the PRS must also be able to operate in harsh conditions. All materials used in the construction of the PRS will leave it with a structurally sound exterior that will be able to withstand most of the punishment dealt to it in the field. Although sturdy, the PRS will suffer greatly from a direct hit from a bullet, explosion, or interference by hostile personnel.

Examples of typical locations that the PRS may be used include wastelands, lakes, oceans, and deserts. Complications that can be caused by any bodies of water include short-circuiting and severe damage to any of the electrical components of the PRS. To prevent this from occurring, various procedures will be conducted to ensure that all of the hydro-sensitive parts of the PRS are well-contained and protected.

ID #	Status	Risk Description	L	C	Score	Probability	Mitigation	POC	Risk Realization
1	Open	ARS' needs to stay within the DM's wireless network range.	4	5	20	80%	Coordinate with electrical team to discuss improved range of network.	Khan	Programming team to design "cloud network" to be used for ARS.
2	Open	DM easily overpowered by hostile forces	1	5	5	20%	Ever present risk mitigated only by drop zone location	Doan	DM team designs a payload that has a hull with higher integrity.
3	Open	Geophone's sound waves are potentially harmful	1	3	3	12%	Avoid prolonged exposure to nearby personnel	Arakaki	Assert that the Geophone's sound waves are harmless
4	Open	HAS runs the risk of potential water damage	2	4	8	32%	Coordinate with mechanical and electrical team to discuss possible waterproofing.	Griswold	Flexible plastic material to be used to encase and protect robot's hinges and hardware.
5	Open	The flight module must be able to retain enough energy to complete all the necessary runs.	1	3	3	12%	Work with mechanical team to ensure flight module is efficient enough to complete tasks within assigned time.	Delorio	Module will be programmed to monitor battery power to return to dock before battery dies.

Company Organization Chart

Delta Technologies is split into several subsystems with each employee responsible for a certain aspect of the project. As a result, the team compliments itself nicely with each person specializing in their own respective field. Although members are given a system to work on, they are in no way limited to working on their subsystem.



Job Descriptions

Project Manager. The Project Manager is responsible for the planning, execution, and completion of Project Morpheus and acts as the liaison between the CARPA Authority and the company. The Project Manager is responsible for scheduling work, managing budgets, creating a work breakdown structure, making a resource breakdown structure, determining task dependencies, understanding the milestones and milestone durations, assigning resources to tasks, and implementing time management. Skills required for this position include, but are not limited to, organization, leadership, communication, business management, personnel management, and time management.

Deputy Project Manager. The Deputy Project Manager, called Deputy, is responsible for assisting the Project Manager as well as adopt his/her responsibilities when he/she is absent. The Deputy works closely with the Project Manager to flesh out and develop management goals. The Deputy is responsible for micromanaging as well as helping direct the overall process and goal of the company. The Deputy plans various documents with the Project Manager such as Gantt charts, calendars, and scheduling.

Chief Scientist. The Chief Scientist is responsible for the final design, development and execution of all aspects of the product. He or she must be open to all suggestions and ensure all input is given and recorded. He or she is responsible for facilitating brainstorming sessions design decisions. The Chief Scientist is responsible for researching and exploring the most feasible and innovative ways of advancing our design. In addition, the Chief Scientist provides guidance, leadership, and management to all team members, seeks to understand any problems within the team, and works with the Project Manager and Deputy to maintain efficient company operation.

Chief Strategist. The Chief Strategist is responsible for the planning of the team's strategic approach to the task given in the Statement of Work, provided by the CARPA Authority. The Chief Strategist also collaborates with the Chief Scientist and Systems Engineer to find the most effective way to accomplish the task. This person is tasked with predicting the outcome of the competition.

Chief Programmer. The Chief Programmer is responsible for all software code for the robot. This person must work with the design team and electrical team to ensure that plans are feasible and accommodations are made for the hardware being used. The Chief Programmer is also responsible for coordinating with the Chief Scientist to ensure robot designs and plans can be programmed for. He or she must be clear in expressions of any problems with coding plans or components to allow such programming.

Chief Financial Officer. The Chief Financial Officer is responsible for the management of the flow of funds into and out of the company. The Chief Financial Officer must keep records of all purchases made by the company and purchases cannot be made without the Chief Financial Officer's consent. The Chief Financial Officer is also responsible for making sure that reimbursements are distributed to employees accordingly. In addition, the Chief Financial Officer must ensure that the company has sufficient funds to fulfill the company's needs. This person is responsible for making sure that the company's budget is well-organized and presentable to anyone who is interested. To complete this budget, the Chief Financial Officer must assist in the compilation of the company's bill of materials. While doing so, this person is responsible for making the company's ventures as cost-efficient as possible. As such, this person must work with the entire company to develop a product that both consider the limited budget of the company and the need to produce a durable and functional robot. The Chief Financial Officer also oversees the methods by which the company procures funds, which includes the organization of fundraisers and the management of the solicitation of money from external sources.

Systems Engineer. The Systems Engineer is responsible for planning the system architecture of the entire robot. The Systems Engineer is also in charge of collaborating with all the other subsystems to help coordinate all efforts. He or she will also be able to perform risk assessments and requirement verifications. The Systems Engineering is in charge of assuring the robots functionality in all aspects of the design. He or she is also expected to work with the Chief Scientist to ensure all design changes keep to the functionality of the robotic system. This position is also expected to ensure that new systems to be installed are research and discussed with the Chief Scientist before usage.

Manufacture Leader. The Manufacture Leader works on the development and creation of the physical artifacts, machine and production processes, and technology. Primarily, the Manufacture Leader is responsible for the actual production of the components, delegating responsibilities so to expedite the production of said components. This position is also responsible for ensuring that components are designed in a way that allows them to be produced with available processes. Additionally, they are responsible for coordinating machine time between the two teams, ensuring as little hindrance of production as possible.

Manufacture Engineer. The Manufacture Engineer aids the Manufacture Leader by assisting in the machining of the components. The Manufacture Engineer represents the Manufacturing Team in the absence of the Manufacturing leader.

Media Specialist. The Media Specialist is responsible for the professional projection of corporate presence through branding, imagery, and any other digital-based media. This includes but is not limited to: company business cards, letterheads, ID badges, and presentations. The Media Specialist is also responsible for recording film and editing the documentary regarding the company and their project completion. The Media Specialist also consistently takes pictures during the meeting for use in posters, presentations, etc. Overall, the Media Specialist establishes and enforces the corporate identity of the company.

Test Engineer. The Test Engineer is responsible for testing the functionality of the product before demonstrating it to the public. He or she is also responsible for making sure all systems can withstand certain stress relative to the intended tasks. The Test Engineer is also responsible to see that the robot can repeat designated tasks without any dysfunction. He or she is responsible for test the robot in a variety of environments to ensure optimal operation. The Test Engineer is lastly responsible for working with the Systems Engineer and Chief Scientist to see that all design changes remain to be functional in the parameters of intended tasks.

Software Engineer. The Software Engineer aids the Chief Programmer by collaborating with the Mechanical and Electrical Teams by developing system architecture. The Software Engineer represents the Programming Team in the absence of the Programming Leader.

Electrical Leader. The Electrical Leader facilitates the design of all of the electrical components and ensures proper compatibility between the systems. The Electrical Leader conducts research and performs calculations to create an ideal electrical system for the robot. The Electrical Leader works closely with the Electrical Engineer, Systems Engineer, and Chief Programmer to ensure seamlessness between the systems.

Electrical Engineer. The Electrical Engineer aids the Electrical Leader by providing input towards the design and functionality of the robot's electrical system. This individual is also responsible for filling in for the electrical lead in case of absence, CADing necessary system parts, and assisting the team in any way possible when not preoccupied with a relevant electrical job.

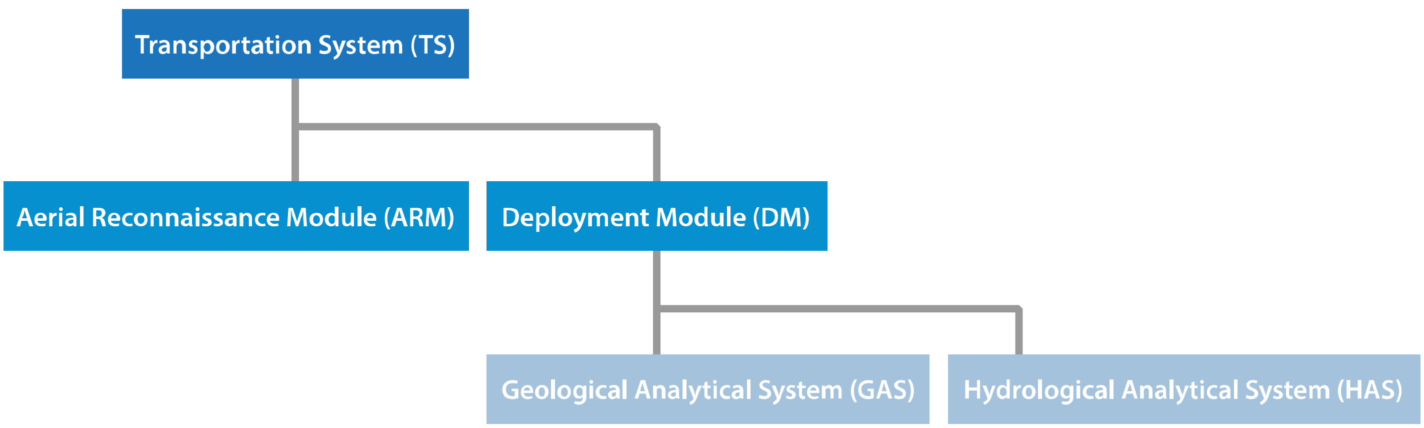
Mechanical Leader. The Mechanical Leader is responsible for the design and functionality of the mechanical systems. This person is in charge of the creation of the best possible design within the given requirements. If the robot is dysfunctional and cannot perform the task at hand, it is the Mechanical Leads job to troubleshoot to and resolve the problem.

Mechanical Engineer. The Mechanical Engineer aids the Mechanical Leader by providing input towards the design and functionality of the robot as well as contributes to the creation and assembly of all mechanical aspects of the robot. Finally, the Mechanical Assistant represents the Mechanical branch in the absence of the Mechanical Leader.

Product Specifications

Transportation State (TS)

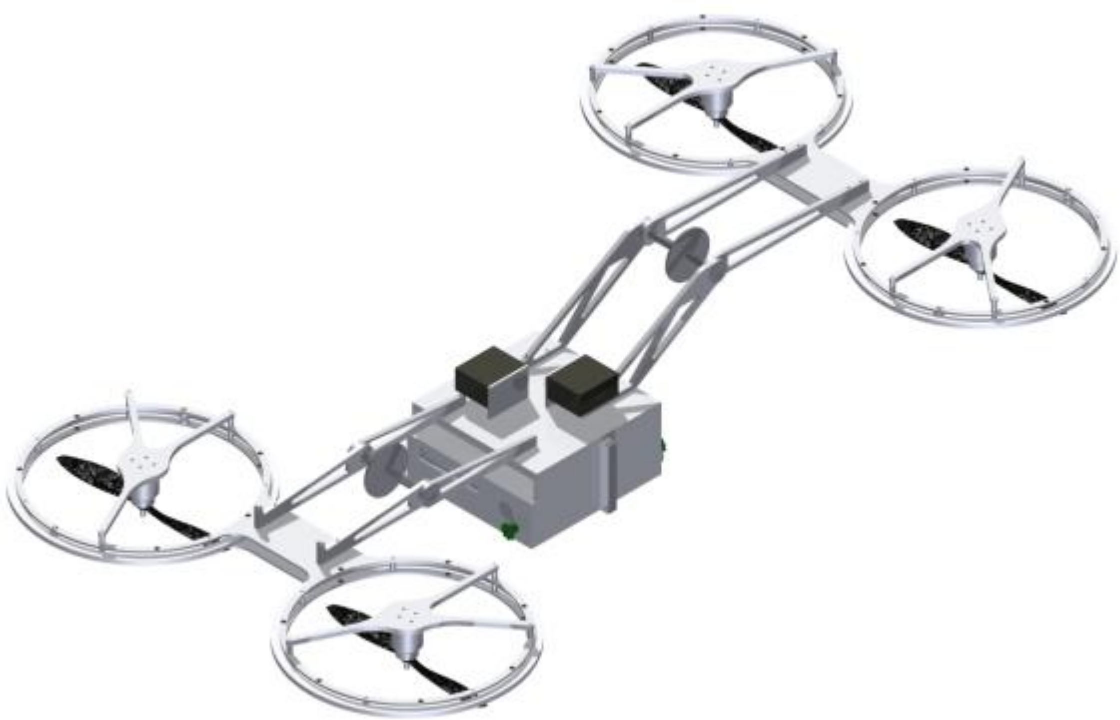
The TS will be compact in size;30 inches long, 16 inches wide and 18 inchestall. It will be durable in design for safe and efficient transporting of sensitive components. When in the TS, Mercury's exterior will be composed of a combination of aluminum for structure and Acrylonitrile butadiene styrene (ABS) for areas which undergo minimal stress. Upon arrival at any desired location the TS will morph into the ARM and DM.



Transportation State

Aerial Reconnaissance Module (ARM)

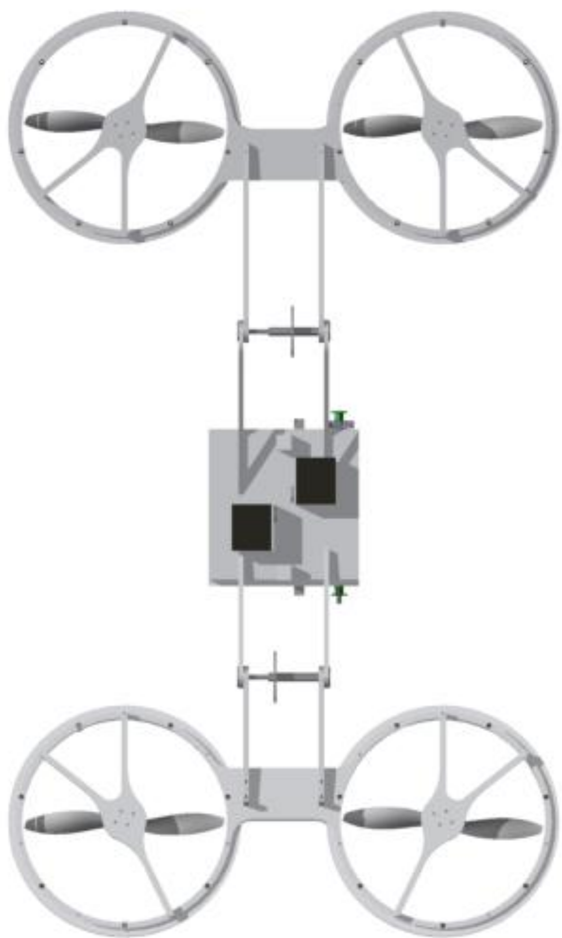
The Aerial Reconnaissance Module (ARM) is a multi-rotor autonomous vehicle that has multiple purposes. When released by the DM the ARM will fly to a desired altitude and will then survey the area with depth sensing cameras and infrared technology to create a 3D rendering. This data will e sent over a network to a remote location. After completing the imaging task the ARM must then locate the DM and reattach itself.



ARM Copter Form

ARM Copter:

The ARM copter is a multi-rotor flight module system that utilizes four rotors for stabilized flight. The ARM copter is designed to give an aerial video feed of its surroundings and perform room mapping for reconnaissance. The ARM copter is designed to relay information to troops about areas that could be hostile. In conjunction with the DM, the ARM copter offers another driving power source in order to gain better traction and offer a variety of sensor and surveillance options.



ARM Shrouds:

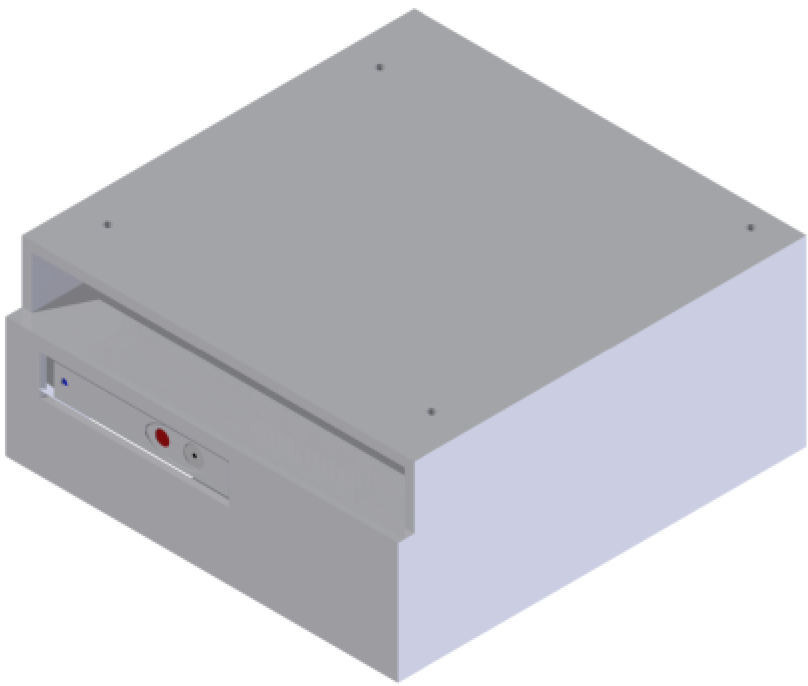
The ARM Propulsion system is protected by a static circular shroud that surrounds the circumference of the propellers as they are in motion reducing the possibility of in-flight collisions that can damage or destroy critical ARM components. They do this by providing a mechanical stop for possible mid-air collisions that may result in the destruction or damaging of the propellers and/or motors. The ARM consists of four shrouds, one for each motor and propeller. Each pair of shrouds is connected together through a wide strut; these are referred to as the shroud unit. These shroud units also function as hubless wheels when they are rotated 90 degrees from their flight position so that the outer rims of the shrouds contact the ground. The ARM has two shroud units, which are able to articulate from transportation state, to the flight state, to the drive state.

The hubless system is implemented using an Ultra-High Molecular Weight Polyurethane (UHMW) outer rim that runs smoothly against aluminum grooved shafts that surround the individual shrouds. Double sided timing belts are wrapped around these UHMW rims and are routed through the middle strut to the other shroud in order to create a tank drive system. Power is provided through the middle strut, which is explained further in the ARM gearing and actuation subsection.

ARM Shroud *Outer Shroud Plate*

ARM Sensor Suite

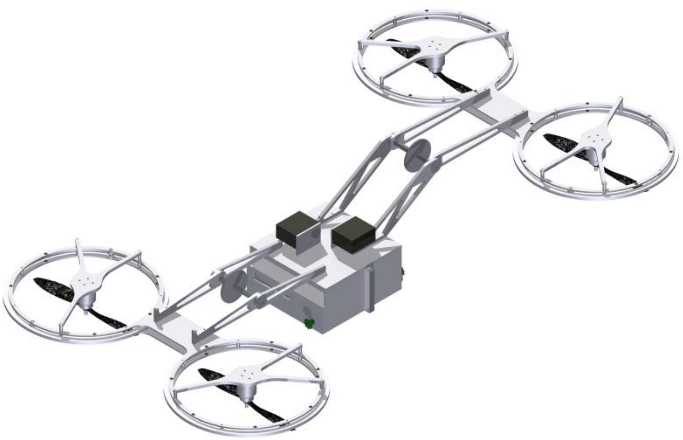
The Sensor Suite houses all electrical and programming components of the ARM system. This is so that we can keep all wiring and programming boards protected and secured. In addition the Sensor Suite offers a securing station for the attachment of the ARM to the DM.

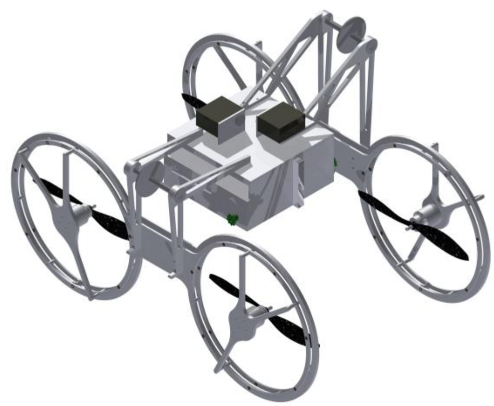


Electronics Housing

ARM Actuation

The ARM has three separate motion systems, the rotation of the propellers, the rotation of the shroud units from one position to another, and the rotation of the hubless wheels. The motion for the rotation of the propellers is provided through the motors, which is further explained in the ARM propulsion subsection. The rotation of the shroud units from one state to another is powered through two high powered servos (name here) that provide a total torque of (insert name here). The servo allows for





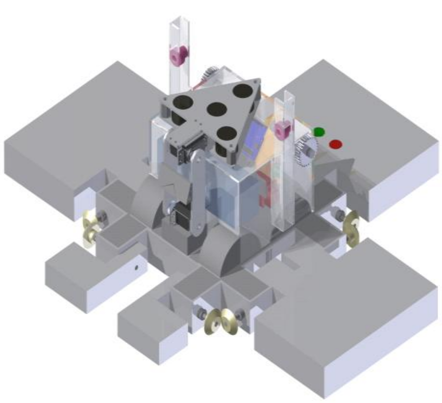
ARM Propulsion

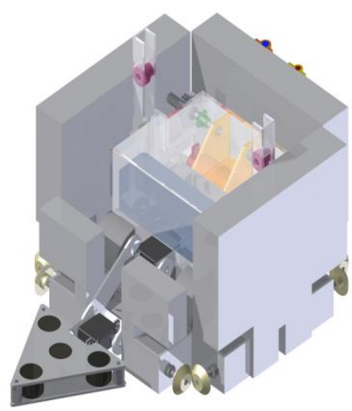
The ARM uses four Avroto M2814-11S Short Shaft 770KV Brushless Motors with four APC 10x4.7 Propellers. The combination of this motor and propeller produces a maximum thrust of approximately 1440 grams with a supplied voltage of 14.8 for each pair. The theoretical thrust of all four motors would be a total of 5760 grams, which is 44% more thrust than needed to lift a projected 4000 gram ARM. This 44% over thrust would allow the ARM to have increased mobility in order to increase in altitude or sharply turn.

Deployment Module (DM)

The Deployment Module (DM) is comprised of two subsystems, the Geological Analysis System (GAS) and the Hydrological Analysis System (HAS). The DM was created for several purposes, including multi-tasking and reducing the mass of the ARM. The DM also powers the shroud drive train and houses the buoyancy flaps.The entire payload is 8″ Tall X 12″ Wide X 12″ Deep. Also, the chassis and the walls of the DM are composed of 1/8″ ABS plastic. The entire DM has a current weight of 9 lbs. The chassis of the DM will also have an easily removable cover that allows access to the drive's components such as the bearings and axles. The most integral part of the DM is the buoyancy walls.

The buoyancy walls on the DM are the main form of flotation for the entire robot. Each wall is about 8″ long, 8″ wide, and 1.75″ deep, with the exception of the front wall which is separated to provide room for the GAS to deploy. The walls are also shelled so that they are 1/8″ thick. The displacement created by the shelled walls exceeds the weight of a 6kg robot, keeping it afloat. The walls actuate on a bevel gear system, so that they turn at the same time. The bevel gear system will be powered by a servo motor that is capable of turning 150oz-in, when the sprocket ratio is 1:2. The 150oz-in will be required to turn the flaps 90 degrees, which in turn will

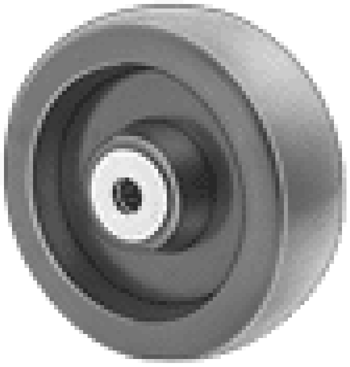




provide flotation for the robot.

DM Drive System

The Deployment Module will be running off a four-wheel drive powered by two 230 RPM motors. Each wheel is composed of polypropylene and is 3 inches in diameter. Each wheel will also have butyl rubber grip tape placed around it to provide increased traction. The approximate speed of the DM will be two feet per second. The motors powering the drive system will be connected to the sprockets accompanying each wheel in a 1:1 ratio. ANSI roller chain will be used to connect all sprockets in the DM. The motors powering the drive train will also be used to power a system that will be turning the shrouds on the ARM. When the ARM connects to the DM a set of gears on each system will be connected to each other. Once the gears are connected and the ARM is able to fold its shrouds down and morph into the TS the motors on the DM will be able to power the shrouds on the ARM.

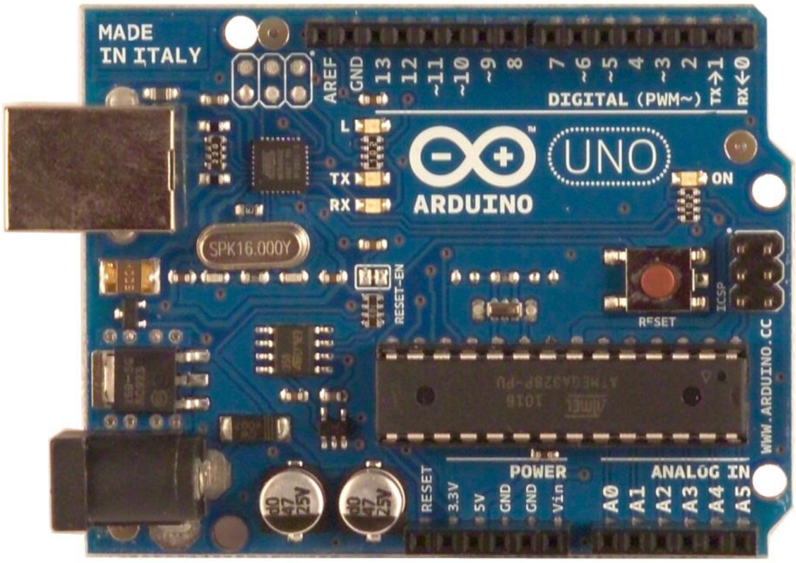


DM Electrical

Battery

The battery used is the Turnigy nano-tech 8400mAh 3S 40~80C Lipo Pack. This is a 11.1 volt battery with 8400 mAh that weighs 641 grams. This battery was chosen as it can be used to power all of our equipment while having a high ampere hour to weight ratio. This ratio was an important constraint, as many batteries with the same specifications weigh over one kilogram. A heavier battery means less weight dedicated to a more robust robot chassis. According to calculations (shown below), this battery can run an 11.1 volt system drawing 17 amperes (the approximate amperage draw of the DM) for 29.5 minutes. Although these calculations do not account for voltage drop or the resistance of the system, they show that under perfect conditions this battery can power the DM for 29.5 minutes, providing more than enough power for the 20 minute time limit while also being very light.

The electronics on the payload include an Arduino Uno board, which receives commands from the motors and acts as a microcontroller, and a Raspberry Pi, which acts as the brain for the Deployment Module. An 8400 milliamp hour Battery Pack is used to provide power for the entire DM which includes the Arduino Uno, Raspberry Pi and all motors. Both boards and battery are mounted inside the water resistant processing cube used to protect all of the electronics for any water damage. The processing cube is also used to support the pinions that are placed on the DM. In order to connect to each other the rack gears on the ARM must connect with the pinions on the DM. The processing cube provides support to the pinions as well as the entire ARM when it lands.


MADE
IN ITALY
AREF
GND
13
12
~11
~10
~9
8
7
~6
~5
4
~3
2
TX→1
RX←0
DIGITAL (PWM~)
L
TX
RX
UNO
ARDUINO
ON
SPK16.000Y
RESET-EN
RESET
ICSP
WWW.ARDUINO.CC
POWER
ANALOG IN
RESET
3.3V
5V
GND
GND
Vin
A0
A1
A2
A3
A4
A5

Calculations

$$Q = Ah\ (3600)$$
$$Q = 8.4\ (3600)$$
$$Q = 30{,}240\ coulombs$$

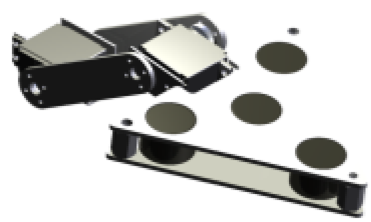
$$V = I \bullet R$$
$$R = \frac{V}{I}$$
$$R = \frac{11.1v}{17A}$$
$$R = 0.65\ \ \Omega$$

$$P = i^2R$$
$$P = 17^2\ 0.65$$
$$P = 190$$

$$P = \frac{QV}{t}$$
$$t = \frac{QV}{P}$$
$$t = \frac{(30{,}240\ coulombs)(11.1v)}{190}$$
$$t = 1800\ seconds$$
$$t = 30.minutes$$

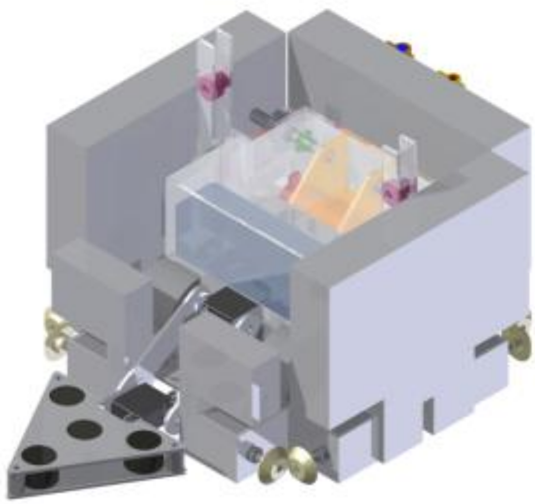
Geological Analysis (GAS)

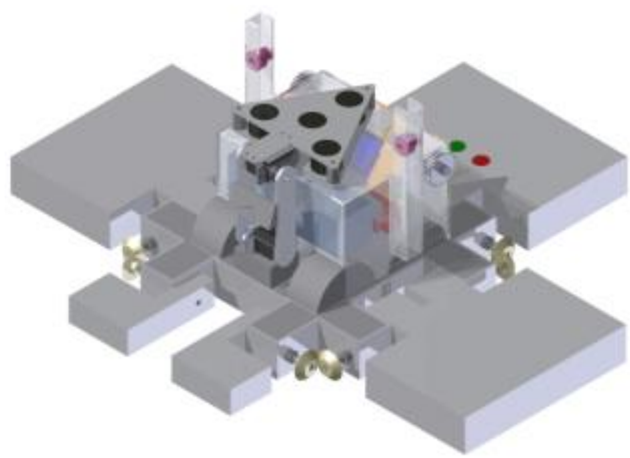
The Geological Analysis System (GAS) touches the ground after being released from the transportation state. The GAS features an arm which, when fully extended, reaches a length of 12.75 inches and has 18 in^2 of surface area. The arm is triangular in design and is fitted with three geophones on the corners and a speaker in the center. The plate is first pressed flat against the ground and the speaker emits a 100 Hz sound into the ground. The sound is 100 Hz because it is the lowest frequency that humans can barely hear and won't harm the operator mentally. The mines underneath will receive the sound and vibrate due to the volume. The geophone positions allow for the mines location to be triangulated due to the differences of each sensor's reading. Since the three sensors are equidistant from each other, the differences can be calculated to find the direction of the mine. The GAS is powered by two HS-645MG servos from Robotshop and is made of eighth inch aluminum.



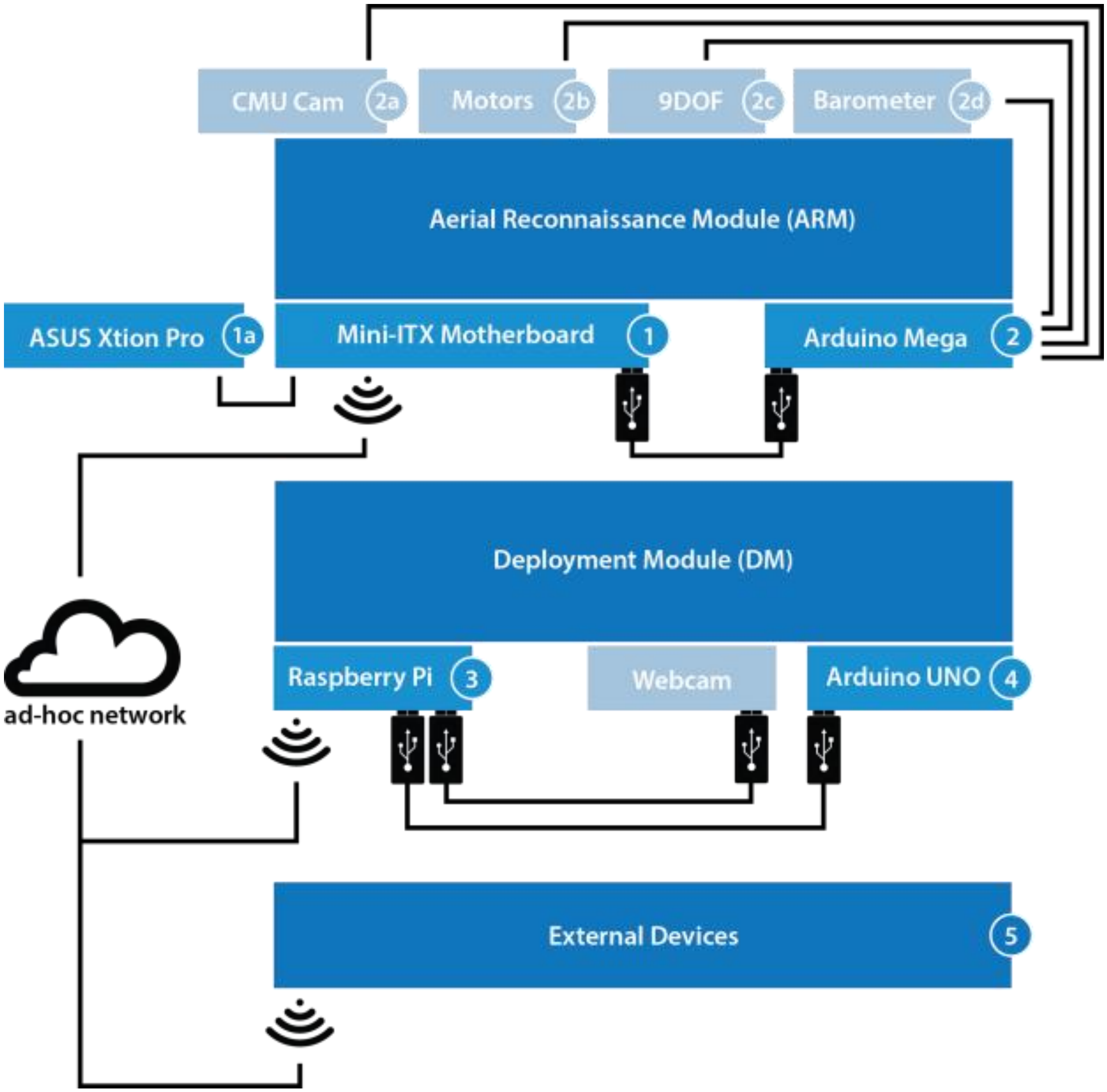
Hydrological Analytical System (HAS)

The Hydrological Analysis System will be used to analyze the pH and temperature of a body of water. It will also have various gas sensors. These sensors will be a methane sensor, a carbon monoxide sensor, and a carbon dioxide sensor. The readings from these gas sensors as well as the pH and temperature readings will give a good indication of the conditions around the body of water. The pH probe and temperature probe will be housed on one of our flotation walls. The housing will have openings, allowing the sensors to be submerged underwater and take the necessary readings.





Programming



As you read through the programming approach, refer back to the flowchart depicted above to help understand the system. The Mini-ITX standard is the smallest standard for motherboards. At 6.7" x 6.7" it is just small enough to fit on a multi-rotor, and still be feasible. The motherboard in question features an Intel Atom D2700 processor, clocked at 2.13Ghz.

The necessity for this in comparison to a single board computer, which is what the alternative would be, is the ability to handle the video streams and raw data that will be coming from the Asus XTION Pro (1a)Live which features RGB and depth sensing, the latter of the two being more relevant. With the camera being able to provide depth images at VGA resolution (640 pixels x 480 pixels) and the processor being able to handle all the incoming data, the task of room mapping can be completed successfully. After the data is received, it will be interpreted based on proprietary algorithms that will attempt to smooth surfaces and stich together images to provide a unique and seamless 3D room map, for the military to utilize strategically.

The Arduino MEGA will mainly be utilized to control the flight sensors, and flight motors for the multi-rotor. The flight sensors will send data to the Arduino which will then be processed by a control loop, and used to autonomously control the multi-rotor. A variety of sensor input is necessary to ensure a smooth and stable autonomous flight. This is important because the Asus XTION Pro (1a)prefers as little disturbance as possible to ensure consistent pictures taken to enable the best possible three dimensional room map. The two main sensors are the 9DOF (2c) and the barometer (2d). The former features a three axis, magnetometer, accelerometer, and gyroscope. This allows for three dimensional relative positional data points of the multi-rotor itself, the monitoring of which enables direct control of the multi-rotor, by changing the velocity of the motors. It should be noted that the relativity in question is to the multi-rotor itself. The barometer (2d) provides height data relative to the earth, which is a useful data point for maintaining constant height, and traversing to different heights for correction. The CMU Cam is utilized to dock onto the detachable payload. It has built in hardware to be able to track color, and along with the Arduino, will be able to track and land on the payload, in order to reattach to it.

The Raspberry Pi, through use of Wi-Fi, is connected to the ad-hoc network to communicate with the Mini-ITX motherboard at large distances and fast speeds. This allows for transferring of data, and notification of when the quadrotor should dock itself onto the Deployment Module. The Raspberry Pi connects to the Arduino UNO through serial.

Arduino UNO

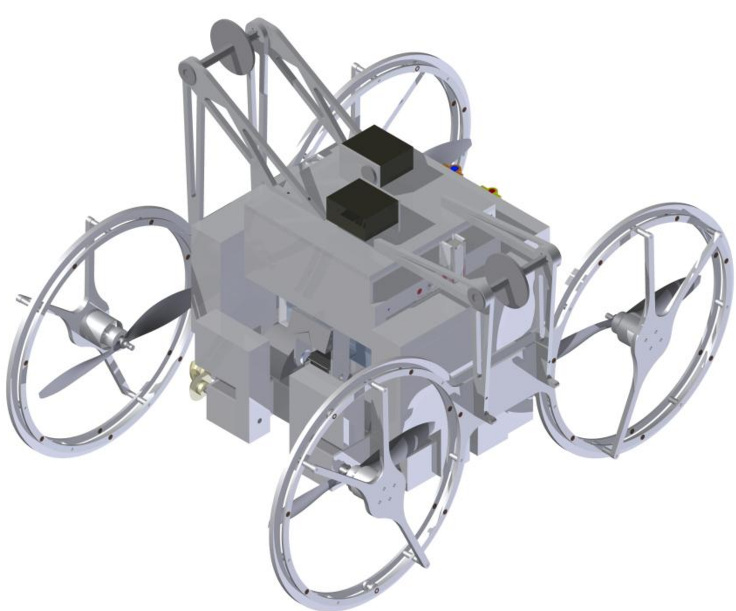
The Arduino UNO is used to control the drive motors and encoders of the Deployment Module. The encoders are integrated into the motors, and will be used to facilitate steady autonomous driving.

The external devices are utilized for data perception. They are connected wirelessly, and allow the user to see data collected.

ARMM/DM INTERFACE

Power interface. The interface between the ARM and the DM is fashioned in a way to share the power output of the motors. This interface consists of gears, sprockets, and bevel gears to properly transfer the motion from the DM motors to the shrouds' hubless wheel system without interfering with any other morphs. As the ARM lands on the DM, a pair of gears on the ARM and DM will mesh as they completely connect, allowing for this transmission of energy.

Latching interface. The latching interface is comprised of a pair of rack and pinions, allowing for a strong mechanical latch. When permitted contact, the pinion will run along the rack, pulling the ARM and the DM closer together until they fully contact.



Electrical Approach

Wire Gauges:

According to American Wire Gauge chart below, the correct wire to use in our payload system is 12 gauge wires. Twelve gauge wireshave a maximum current capacity of 9.3 amperes. Although the largest current draw is 9 amps, the average current draw is 5 amps. Therefore, 12 gauge wires, which have a maximum current capacity of 9.3 amps, are sufficient.

None of our programming equipment draws more than 2 amperes, so this wire will be sufficient for the programming equipment on the payload as well. The water module will also work with 12 gauge wire, as all of its equipment draws less than 1 ampere.

Wire Harnesses:

In order to power separate parts of the DM, a wire harness will be created. Circular plastic connectors will be used to create a wire harness, allowing for easy connecting and disconnecting of the individual parts that make up the system. A connector such as the TE Connectivity 206037-1 can be used to create separate circuits for individual components. This connector allows up to 8 different components to be attached to it. Multiple connectors can be used to allow access to the wiring of each component from one centralized location. These separate components will be easily attached and removed from the connector rather than directly from the battery, making the wiring on the robot much more organized. This will also allow the wiring of the robot to be replaced easier if anything malfunctions.

Bill of Materials

Programming

Description	QTY	Unit Price	Total Price	Weight(g)	Total Weight
Motherboard	1	$74.99	$ 74.99	460 g	460 g
RAM	1	$19.99	$ 19.99		0 g
Flash drive	1	$15.92	$ 15.92	14 g	14 g
Arduino UNO	1	$29.95	$ 29.95	29 g	29 g
Arduino MEGA	1	$58.95	$ 58.95	35 g	35 g
9DOF Sensor Stick	1	$99.99	$ 99.99	10 g	10 g
Barometer	1	$19.95	$ 19.95	10 g	10 g
Raspberry Pi	1	$39.95	$ 39.95	45 g	45 g
Nano WiFi Adapter	2	$11.95	$ 23.90	10 g	20 g
Asus XTION Pro Live	1	$159.99	$ 159.99	230 g	230 g
Ultrasonic Range Finder	1	$49.95	$ 49.95	6 g	6 g
CMU Cam	1	$99.95	$ 99.95		
Webcam	1	$10	$ 10.00	~0g	
			$703.48		859 g

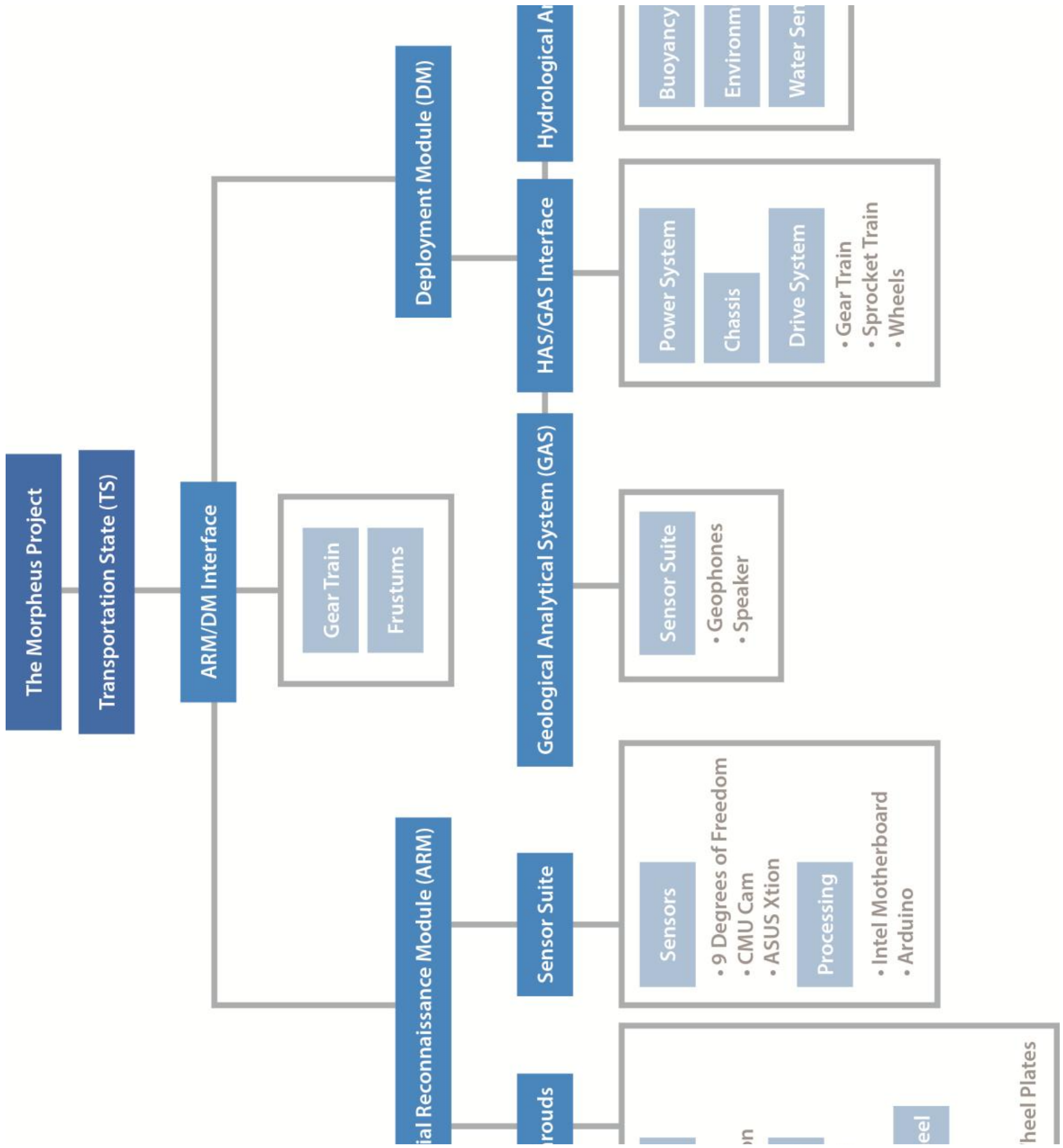
Geological Analysis System/Hydrological Analysis System/DeploymentModule

Vendor	Description	QTY	Unit Price	Shipping	Total Cost	Weight(g)	Total Weight
Parallax	Methane Sensor	1	$ 4.99	$ -	$ 4.99	15	15
Parallax	Carbon Monoxide Sensor	1	$ 5.99		$ 5.99	15	15
Sparkfun	Temperature Sensor	1	$ 9.95		$ 9.95	10	10
Novatech	pH probe	1	$ 44.41		$ 44.41	80	80
Newegg	Motherboard	1	$ 189.99		$ 189.99		0
Robot Shop	pH Sensor shield	1	$ 38.55		$ 38.55	60	60
Progressive Automations	Linear Actuator	1	$ 108.99		$ 108.99	120	120
Lynxmotion	Standard Servo	1	$ 31.49		$ 31.49	55	55
BGMicro	Geophone sensor	2	$ 22.20	$ 6.00	$ 28.20	74	148
BGMicro	Geophone Sensor kit	1	$ 39.95	$ 6.00	$ 45.95	100	100
LynxMotion	Standard Servo	2	$ 31.49	$ -	$ 31.49	55	110
LynxMotion	Servo bracket	2	$ 11.95	$ -	$ 11.95	0.1	0.2
Adorama	USB Mini Speaker	1	$ 12.00	$ -	$ 12.00	113	113
Max Industries	7.25X6.25X1/8	1.1	$ 10.00	$ -	$ 10.00	0.555	1.11
Max Industries	6.25X2.25X1/8	0.2	$ 10.00	$ -	$ 10.00	0.2	0.2
Total					$682.85		827.51

Aerial Reconnaissance Module

Vendor	Description	QTY	Unit Price	Total Price	Weight(g)	Total Weight
Monto RC	Avroto Propeller Motor	4.00	$ 57.97	$ 231.88	$ 100.00	400.00
Monto RC	10" propeller	4.00	$ 32.97	$ 131.88	30.00	120.00
Monto RC	10" propeller	2.00	$ 2.93	$ 5.86	N/A	n/a
Monto RC	10" carbon fiber propeller	2.00	$ 4.39	$ 8.78	N/A	n/a
Hobby King	Turnigy Battery	2.00	$ 43.06	$ 86.12	427.00	854.00
McMaster Carr	Aluminum Threaded Standoffs	40	$ 0.38	$ 15.20		-
McMaster Carr	Button Head Socket Cap Screw	1	$ 4.02	$ 4.02		-
McMaster Carr	Polyethylene Sheet	2	$ 13.13	$ 26.26		-
McMaster Carr	Bronze Sleeve Bearing	56	$ 0.37	$ 20.72		-
Andy Mark	3/8" Hex Bore Ball Bearing	4	$ 2	$ 8.00		-
Andy Mark	Aluminum Sprocket	2	$ 11.00	$ 22.00		-
Servo City	HS-785HB 3.5 Rotations	2	$ 49.99	$ 99.98		-
Servo City	aluminum servo sprockets	2	$ 12.99	$ 25.98		-
Max Industries	Aluminium stock	8.5	$ 2.70	$ 22.95		0
				$709.63		0

Work Breakdown Structure



Yearlong Schedule

Task	%Complete	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun
SPS Document	100%										
SPS Presentation	100%										
ARM Concept	100%										
GAS Concept	100%										
DM Concept	100%										
HAS Concept	100%										
TS Concept	100%										
Proof of Concept Document	0%										
Proof of Concept Presentation	0%										
ARM Prototype	0%										
GAS Prototype	0%										
HAS Prototype	0%										
Programming	0%										
Prototype Testing	0%										
Robot Manufacturing	0%										
Robot Assembly	0%										
Source Control Drawings	0%										
Test and Evaluation/Modification	0%										
IDP Expo	0%										

	In Progress
	Complete
	Not Yet Started

The estimated yearlong schedule begins in September, 2012 and ends in May, 2013. Task deadlines are established by CARPA .These deadlines are determined by Delta Technologies' Engineers based upon their abilities. The schedule will keep on track to accomplish the tasks within the given time.

Marketing Approach

Delta Technologies, established in September, 2012, is a company that gathers several creative minds with the goal of creating innovative technology to address some of the world's most prevalent issues. Delta Technologies was contracted by the CARPA authority to design and build a fully-autonomous, versatile, polymorphic robot now known as Mercury. Delta Technologies had complete freedom to optimize the design in order for Mercury to complete the most relevant jobs for its targeted clients which, in this case, is the military. While developing tasks and goals for Mercury, Delta Technologies had to design with the constraints established by CARPA.

The CARPA Initiative is an entity that aims to challenge various corporate bodies, which are formed by secondary-school students, to develop solutions to some of the most modern engineering issues on a global scale. The ultimate mission of the CARPA initiative is to, as is commonly said, promote the design of an invention and the development of a person to take on an educational challenge. The CARPA Initiative provides the students with an environment that is supportive of interdisciplinary learning and teamwork. The focus of both the CARPA Initiative and Delta Technologies is to engage the students in discovery-based learning to help students realize their true potentials. Delta Technologies has not only been tasked with fabricating a robot for CARPA, but it is also responsible for designating relevant problems of the robot to solve and tasks for the robot to complete. Delta Technologies decided that the robot would complete tasks that could be vital to any group of military personnel. The central tasks the robot was to complete fell under the categories of collect and analyze, recon and intelligence, and detect and neutralize. While developing tasks and goals for Mercury, Delta Technologies had design under constraints put in place by CARPA.

The mounted constraints include:

- The robot must be self-configurable within a three-morph, four-state series.
- The robot must begin and end the competition in a dormant state.
- The robot may not exceed a weight of 6 kilograms and must be transportable in a protective case.
- The tasks (defined by Delta Technologies) below must be completed twice in succession within 60 minutes:
    - Mine detection
    - Aerial reconnaissance
    - Hydrological sample collection and analysis
    - Breach charge deployment

Delta Technologies was able to determine the relevance of these tasks in the scope of military personnel through the use of marketing survey results. The surveys were sent out to gather diverse, professional opinions from past and current engineers and military personnel. Delta Technologies came to a consensus on designating the target demographic as clients interested in purchasing military-grade technology. These tasks were chosen to ensure that soldiers amidst a battlefront are kept as far away from danger as possible.

Market Survey Analysis

Questions and Results:

1. Reconnaissance & Intelligence: Reconnaissance and intelligence are extremely important for troops on the ground, especially if they are entering unknown territories. What should this task include?

Task:	Response Percent	Response Count
Map & survey location/target	**87.1%**	61
Find the direction of a firing gun	50.0%	35
Take pictures of locations	62.9%	44
Record audio/video of living presence	58.6%	41
Convey information to entire unit	70.0%	49
Other (Please specify)	8.6%	6

- From the results, Delta Technologies was able to determine that an emphasis should be placed on mapping and surveying a location or target, conveying information to a collective or unit, and capturing photographs of certain locations.

2. Search and Disable: Undetonated mines pose a threat not only during war, but also after, when many civilians enter zones they think are safe. What should this task include?

Task:	Response Percent	Response Count
Detect mine	77.1%	54
Map out mine location	77.4%	50
Navigate to mine	52.9%	37
Remove and neutralize mine	**81.4%**	57
Other (Please specify)	8.6%	6

- From the results, Delta Technologies determined that of our search and disable tasks, the most valued were mine detection, the identification of mines' locations, and the neutralization of mines.

3. Collect and Analyze: There are a lot of different places where the safety of water cannot be tested. Many of these places cannot be easily accessed by humans. In other instances, the samples collected need to be analyzed. The sample should then be sorted. What should this task include?

Task:	Response Percent	Response Count
Sorting parts based off part catalogue	10.0%	7
Test for potable water	**82.9%**	58
Test for chemicals in water	68.6%	48
Categorize findings	48.6%	32
Other (Please specify)	7.1%	5

- From these results, Delta Technologies determined that of our collect-and-analyze-related tasks, the most valued was the testing for the potability of water.

4. Transportation & Deployment: The military drops supply packages to aid its soldiers. Air drops can be deployed under hostile conditions, revealing the location of soldiers. What should this task include?

Task:	Response Percent	Response Count
Transport object to specific location	**67.1%**	47
Load explosives (ordnance)	47.1	33
Interact with equipment	48.6%	34
Other (please specify)	12.9%	9

- From these results, Delta Technologies determined that of ourtransportation and deployment tasks, the most valued was the transportation of an object to a specific location.

5. Recover and Protect: The military drops supply packages to aid its soldiers. Air drops can be deployed under hostile conditions, revealing the location of soldiers. What should this task include?

Task:	Response Percent	Response Count
Defend cargo	45.7%	32
Defend soldiers	54.3%	38
Retrieve cargo	**68.6%**	48
Disable/disarm approaching enemies	45.7	32
Other (Please specify)	5.7%	4

- From these results, Delta Technologies determined that of our recover and protect tasks; the most valued task was to retrieve cargo.

6. Rank the importance of these problems, with 1 being the most important (Note: options change position with rank):

	1	2	3	4	5	Rating Avg.
Reconnaissance & Intelligence	**70.0% (49)**	14.3% (10)	8.6% (6)	1.4% (1)	5.7% (4)	1.59
Search & Disable	11.4% (8)	**41.4 % (29)**	31.4% (22)	10.0% (7)	5.7% (4)	2.57
Collect & Analyze	4.3% (3)	18.6% (13)	24.3% (17)	24.3% (17)	**28.6% (20)**	3.54
Recover & Protect	2.9% (2)	14.3% (10)	15.7% (11)	**40.0% (28)**	18.6% (13)	3.40
Transportation & Deployment	18.6% (13)	11.4% (8)	20.0% (14)	24.3% (17)	**41.4% (29)**	3.90

- Based on these results, Delta Technologies determined that our task categories would be ranked in the following order of descending importance: Reconnaissance and intelligence, search and disable, recover and protect, transportation and deployment, and collect and analyze.

7. How quickly should these tasks be completed?

	Under 3 Minutes	3-5 Minutes	5-10 Minutes	10+ Minutes	Response Count
Reconnaissance & Intelligence	24.6% (17)	23.2% (16)	18.8% (13)	**33.3% (23)**	69
Search & Disable	14.7% (10)	25.0% (17)	25.0% (17)	**35.3% (24)**	68
Collect & Analyze	11.8% (8)	17.6% (12)	**36.8% (25)**	33.8% (23)	68
Recover & Protect	19.1% (13)	**30.9% (21)**	20.6% (14)	29.4% (20)	68
Transportation & Deployment	18.6% (13)	17.1% (12)	20.0% (14)	**44.3% (31)**	70

- Based on these results, Delta Technologies was able to determine that recovery and protect tasks should be completed in three to five minutes and collect and analyze tasks should be completed in five to ten minutes. It was also determined that Reconnaissance and intelligence tasks, search and disable tasks, and transportation and deployment tasks should be completed in ten or more minutes.

Appendix A: Subsystem Acronyms

TS - Transportation State

ARM - Aerial Reconnaissance Module

DM - Deployment Module

HAS - Hydrological Analytical System

GAS - Geological Analytical System

Appendix B: Patents

Medical Imaging System for Mapping a Structure in a Patient's Body. US20070244369. A system for mapping rooms. Implemented in ARM mapping system.

Hubless Wheel.
US5,419,619. A wheel consisting of two concentric hoops (a stationary inner hoop and rotational outer hoop) with advantageous weight and aerodynamic properties. Implemented in ARM Shrouds.

Flying Apparatus.
US2010/0243794 A1. Flying apparatus is provided including a housing with two or more rotor means associated therewith (multi-rotor flight system). One or more vanes are provided with said apparatus to help stabilize the apparatus in use. Implemented in ARM flight system.

Autonomous Camera Tracking Apparatus, System and Method.
US20120019665. Camera, infrared sensor and a beacon used to track a point and detects the surroundings. Implemented in ARM Sensor Suite.

Device for Mapping Dwellings and Other Structures in 3D.
US6006021. A radar used to establish dimensions and locations of objects in a room using radar and data-points. Implemented in flight reconnaissance 3D mapping.

System and Method for Using Three Dimensional Infrared Imaging to Identify Individuals.
US2010/0189313. Infrared and Range finding sensors used to produce three-dimensional surface models. Implemented in flight reconnaissance 3D mapping.

Robot Obstacle Detection System.
US7155308. Optical emitter emits beam and which gets reflected back to reader. If there is no reflection, the robot goes towards that direction.Considered for DM but deemed too extraneous due to superfluous sensors.

Autonomous Multi-Platform Robot System.
US6496755. Allocates mapping and planning to one navigator robot and allocates task to functional robot. Considered for DM but deemed false advertising because not true multi-tasking.

Screw Drive Vehicle
US6966807. A locomotion method which uses two screw-like pontoon assemblies which have enough traction and buoyancy to allow the cargo to traverse both land and water. Considered as a drive system but replaced by shroud wheels and a ship-like payload hull.

Autonomous Obstacle Avoidance
US7539557. The mobile robot is capable of autonomously navigating through urban terrain, generating a map based on data from the rangefinder and transmitting the map to the operator. Considered for payload but room mapping was being accomplished through the ARM.

Land mine detector

US7173560. An apparatus that irradiates the mines in order to detect their positioning. The radiation is used to mark the mines and radio waves reflect radio signals based on the amount of radiation. Concept reworked into Geological Analytical Unit to detect vibrations from mines.

Autonomously return

US 8,108,092. User Assist Package (UAP) the unique capability to autonomously return to its operator should wireless communications fail. Retrotraverse technology, pioneered to keep troops out of harm's way, is applicable to networked and wireless robots in military, commercial, healthcare and household applications. Additional pending U.S. and international patent applications are expected to protect other critical semi-autonomous capabilities provided by the UAP.

Active Noise Control (ANC)

US6912286. A electrical relay system in which noise is cancelled at the source. The opposite, or inverse of the sound wave emitted is played at the same instance in order to create an absence of noise. Concept can be used to create a stealthier robot while in flight mode.

Sound direction detection. US8174934. A sensor network that can develop a vector model to illustrate the direction of a certain sound. One sensor is used to determine the distinctive sound pressure created by the oscillations of sound waves. A second sensor will record a second sound pressure and an internal processor will be able to determine the direction of the actual sound using a the two pressures and the distance from each sensor to the sound source. Network can be implemented by deployment module to complete “gunfire direction detection” task.

Breach Charge Deployment

US4884506. Explosives charges are placed in the designated location then remotely detonated from a safe distance by radio transmitter. Concept incorporated into the GAS arm. While the DM is detached from the ARM, the DM will move a C4 explosive (simulated by a block of clay) from the briefcase to the designated location and detonated by a soldier.

Multiple robot control system using grid coordinate system for tracking and completing travel over a mapped region containing obstructions

US4674048A control system for a mobile robot calculates the instantaneous position of the robot, and sequentially stores data representative of the respective robot positions. The system studies and stores a range which the robot is to travel, and calculates a running pattern of the robot in the specific range. The robot is allowed to travel within the range without leaving any region untravelled in spite of the presence of obstructions which alters its path, while checking its own position. Also, the robot compensates for dislocations caused by slippage of its drive wheels or errors in the operation of its motors.

Control system for unmanned 4-rotor-helicopter

EP1901153 A1. Conventional algorithms for autonomous control use ideal models with the center of gravity (CG) in the origin of the body fixed coordinate frame. In-flight payload droppings or construction of miniaturized aerial vehicles may cause problems, e.g. because sensors cannot be mounted perfectly in the CG or because the CG is shifted out of the origin of the initially assumed body fixed coordinate system. The consequences are additional accelerations and velocities perceived by the sensors so that these effects have to be covered by the control system. Alternative control algorithms can be implemented in Aerial Reconnaissance Module program to create a more stable platform.

Engagement Management Procedures

Throughout the lifespan of Project Morpheus, CARPA will periodically monitor Delta Technologies' progress by way of three types of evaluations: In Process Reviews (IPRs), Periodic Design Reviews (PDRs), and Critical Design Reviews (CDRs)

In Process Reviews (IPRs). IPRs are weekly verbal progress reports progress indicators aimed for planning purposes. These meetings are internal, relatively informal, and should not last longer than 10 minutes.

Periodic Design Reviews (PDRs). PDRs occur monthly. PDRs are more in-depth progress reports than IPRs.

Critical Design Reviews (CDRs). CDRs are the most important review periods. These major grading periods are conducted by a panel of third-party auditors selected by the CARPA Authority to evaluate Delta Technologies' progress and officially judged by the CARPA Authority. Delta Technologies is responsible for guaranteeing the smooth progress of these meetings.
There will be five (5) CDR's throughout the course of Project Morpheus: System Performance Specification (SPS) Proposal Document, Proof of Concept (POC) Document and Presentation, Technical Data Package (TDP) Document, Trade Show Consumer Marketing, and Project Morpheus Demonstration.

The CARPA Authority schedules all engagements, but Delta Technologies can negotiate dates changes within reason.

CARPA Approval

Rules, Conditions, and Requirements are subject to change by the CARPA authority. All changes will be discussed in class, and be presented to the company teams in writing.

Program Manager – Delta Technologies	Date

Deputy Program Manager – Delta Technologies	Date

Chief Scientist – Delta Technologies	Date

CARPA Authority	Date