UHABS-6

Preliminary Design Review

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EXECUTIVE SUMMARY (2 PG) [JK]

The success of the UHABS-6 mission relies heavily on the recovery of the BalloonSat modules after launch as specified in the mission statement:

"*The UHABS-6 team will successfully develop a high altitude BalloonSat system capable of carrying small payloads in a near-space environment, while flight testing the Comprehensive Solution for Mission Operations Systems (COSMOS) mission operations software, and return safely to Earth for intact recovery. A recovery system will be incorporated into the BalloonSat system that upon landing in the ocean will be programmed to autonomously propel itself to a designated recovery site for recovery.*"

Due to the importance of the recovery, the UHAB-6 team must ensure that the design, operations, and capabilities of the autonomous recovery system meet the objectives and success criteria of the mission. To fulfill these requirements and constraints, the design concept of UHABS-6 primarily focuses on the recovery vehicle and propulsion system. The major trade studies to develop the design concept for the recovery vehicle and propulsion system involved researching successfully developed and water-related unmanned autonomous vehicles (UAV). Using systems engineering techniques, such as pugh matrix analyses, to compare the different designs of UAVs, the UHABS-6 team was able to develop an autonomous recovery vehicle with a hybrid-propulsion system design concept.

The hybrid-propulsion system relies on two types of propulsion systems, a primary system that converts kinetic energy from ocean wave motion into forward motion, and an auxiliary system that utilizes electrical energy from batteries to actuate a motor-propeller propulsion. For the primary propulsion, the autonomous recovery vehicle uses an oscillating fin to convert the up and down motion of ocean waves into forward thrust. The ocean waves cause the hull/structure of the BalloonSat module to heave up and down with the fin rotating about an joint to always maintain a positive angle of attack with the relative flow. Provided a component of this relative flow is either up or down, a lift force component perpendicular to the flow, and thus in the forward direction, will always be generated. Additionally, the generated lift force also creates a vertical force component acting against the motion of the wave, which could help to dampen the vehicle's pitch and roll motions and reduce the system's probability of capsizing. The oscillating fin is attached perpendicular to the hull/structure of the BalloonSat module by linkage, below and near the bow side of the hull/structure. The oscillating fin does not require power to operate, and allows for the autonomous recovery vehicle to operate for longer periods before reaching a recharge status. As for the auxiliary propulsion, an aircraft propeller and motor system will be attached to the transom of the autonomous recovery vehicle hull/structure, and allows the autonomous recovery vehicle to propel forward in the absence of waves. To control the auxiliary propulsion, a built-in accelerometer in the inertial measurement unit (IMU) will be able to sense the absence of heave acceleration, at which point the microcontroller would activate the auxiliary system. Conversely, the auxiliary system may be deactivated if ocean motion is sensed. With only a singular auxiliary propeller, the autonomous recovery vehicle will depend on rudders for steering.

A flat-hull design for the autonomous recovery vehicle will aid the primary propulsion, the oscillating fin, in generating forward thrust. The flat-hull rides the full upward and downward motion of the wave as the design does not reduce heave. Furthermore, more lift is generated on the oscillating fin to create forward thrust. The flat-hull can be easily manufactured and provides solar cells a suitable platform to mount on.

The autonomous propulsion system will operate utilizing an arduino-microcontroller, GPS, and IMU. The GPS will allow the arduino to compute waypoint navigation to designated recovery site. The IMU has a built-in magnetometer which allows the arduino to orientate the recovery vehicle to face and travel to waypoints, using the propulsion and steering system. Prior to launch, the Ground Station will check the predicted winds and ocean currents. The predicted winds will provide flight trajectory, and allows the team to program the autonomous system to use specified GPS coordinates to both avoid unwanted areas and to take advantage of wave currents to reach the designated recovery site.

The major subsystems of UHABS-6 are: Balloon/C&C Module (BCCM), Recovery Vehicle & Propulsion System (RVP), and Ground Station (GS). The BCCM subsystem is responsible for the electronics and sensors being interfaced in the autonomous recovery vehicle, and also is responsible for the flight system of the BalloonSat. These electronics and sensors will allow the BalloonSat module, or autonomous recovery vehicle, to perform autonomous navigation, collecting environmental & engineering data, collect images, and stream live-video to the GS. The BCCM subsystem major trade studies for the flight system consist of the balloon, parachute, and flight termination mechanisms (FTM). The RVP subsystem is responsible for recovery vehicle, propulsion conducted major trade studies involving hull design hybrid-propulsion system, steering, power systems, and beacons. The GS subsystem is responsible for communications, COSMOS integration, and launch operations. The GS major trade studies focus on the communication components to the C&C module. These components will allow the GS to receive data/video from BCCM, and uplink commands to the BCCM through the use of COSMOS. Base off their trade studies and component selection, the overall system budget for mass, volume, and power are: 6.5lbs, 80 in^3, and 210 watts.

The internal interfaces of the UHABS-6 subsystems is centralized by the BCCM subsystem. The BCCM subsystem physically interfaces with the RVP subsystem, and wirelessly interfaces with the GS subsystem. Through physical interfacing, the BCCM subsystem mounts all avionics to the internal housing of the autonomous recovery vehicle design of the RVP subsystem, and also interfaces the flight system components such as the balloon, parachute, and FTMs to the autonomous recovery vehicle. In addition, the RVP subsystem provides electrical power to the electrical components of the BCCM subsystem. The wirelessly interface of the BCCM and GS subsystem involves the communication relay of data, video, and command signals. The primary external interfaces affecting the UHABS-6 subsystem is centralized by the GS subsystem. The external interfaces affecting the GS subsystem are user input, predicted winds and ocean currents, and providing mission results to Hawaii Space Flight Laboratory (HSFL).

Base off the subsystems major trade studies and component selection, the total financial budget with 20% margin is $2,736. With the current budget of $2,000 from UHM Mechanical Engineering Department, the deficit comes to $736. The UHABS-6 will wait to hear their possible funding sources (Raytheon & UROP) before using their own personal funds or fund raising the difference with Krispy Kreme Donuts.

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LIST OF ACRONYMS AND ABBREVIATIONS

BCCM	Balloon/Command & Control Module
COSMOS	Comprehensive Open-Architecture Solution for Mission Operations Systems
HSFL	Hawaii Space Flight Laboratory
GS	Ground Station
PM	Project Manager
PA	Project Administrator
RVP	Recovery Vehicle & Propulsion System
SI	System Integrator
UAV	Unmanned Autonomous Vehicle
UHABS-6	University of Hawaii Advance Balloon Satellite 6
UHM	University of Hawaii at Manoa
WBS	Work Breakdown Structure

1.0 Introduction [JK]

BalloonSat launches have become a means for many organizations to quickly deploy low-cost instrumented vehicles to collect data, test hardware and software, and perform other miscellaneous tasks in the near-space environment. The HSFL at UHM has taken interest in BalloonSat projects to test their components, sub-assemblies, instrumentation, software, and procedures to aid their missions, and has requested the help of the UHM BalloonSat Program, initiated by Dr. Sorensen, to develop a reliable BalloonSat system. However, unlike the past BalloonSat launches that Dr. Sorensen has conducted in Kansas, BalloonSat launches in Oahu have a high probability of landing in the ocean or mountainous terrain. This factor causes the retrieval of the BalloonSat modules to be difficult and costly especially if the BalloonSat module becomes damaged and/or is not recovered. Therefore, there is not only a need for a reliable BalloonSat that can perform their specific duties and survive the entire flight intact, but also a need for a reliable recovery system that enables ocean landing and autonomous unmanned capabilities for efficient recovery.

With the addition of meeting design requirements of the HSFL and UHM BalloonSat Program, BalloonSat launches and designs must adhere to the rules and regulations of the Federal Aviation Administration (FAA). The rules and regulations for an unmanned balloon-satellite system can be found in Title 14, Chapter 1, Subchapter F, Part 101, and Subpart D [1]. These rules and regulations are placed by the FAA to create a safe, efficient airspace. Violation of these laws and regulations may result in damage to equipment and/or civilians, therefore the design of the balloon-satellite system will need to adhere to those designated constraints.

The predecessors of UHABS projects all shared a similar mission of developing a reliable high altitude BalloonSat to carry a small payload to near-space environment and ensure intact recovery. These UHABS projects usually consist of a styrofoam enclosure payload, except UHABS-3 with a carbon fiber enclosure, and were all equipped with temperature and atmospheric sensors, on-board camera, and GPS. However, only UHABS-3 and UHABS-5 had to incorporate an autonomous recovery system to enable landings on the ocean and autonomously propel itself to a designated recovery site. These missions had to include additional software and hardware, such as motors, propellers, etc.

The general operation procedure of past UHABS missions was to use helium-filled high-altitude balloons to lift the payload to a specific altitude or until balloon rupture. The payload modules then descended, at a specific speed, to ground level by a deployed parachute. The team would track and follow the payload module to the landing site, via GPS, for retrieval. In the case for UHABS-3 and UHABS-5, if the payload module should land in the ocean, the payload would autonomously propel itself to the designate recovery site which was the coordinates of their ground station. According to their final reports, only UHABS-1 and UHABS-4 successfully launched, which neither of those featured autonomous recovery [2] [3].

The autonomous recovery systems of the two previous UHABS missions will influence the autonomous recovery system of UHABS-6. UHABS-3 created a single carbon fiber payload enclosure and applied a paddle wheel system to propel itself through the water [4]. UHABS-5 designed a catamaran styrofoam boat as their single payload enclosure, and implemented thrusters to propel itself through the water. Unfortunately, both of these UHABS mission were unsuccessful with their mission and were unable to create a reliable recovery system [4] [5]. UHABS-3 was proved to be a poor design as water was able to leak into the payload module, and was unable to perform necessary repairs on their broken paddle wheel system as the enclosure could not be reopened after sealing it [4]. UHABS-5 was unable to perform their mission as time ran out due to being unable to fix or replace their electrical motor, which caused the boat/module to vibrate aggressively to the point that the payload module would not propel itself effectively [8]. In addition, these projects mention difficulty with communications between their payload and ground station and had difficulty with integrating COSMOS [4] [5].

The UHABS program is not the only university program, or individual, seeking to develop autonomous recovery systems for BalloonSats. While working on his PhD at Oklahoma State University in 2004, Dr. Seong-Jin Lee conducted intensive research to develop an autonomous recovery of BalloonSats through the use of parafoils to aid the Atmospheric and Space Threshold Research Oklahoma (ASTRO) program [6]. Dr. Lee's mission was to develop a cost-effective, simple, and reliable autopilot system which can be applied to the payload used in the ASTRO project [6]. The final report places a heavy focus on analyzing and modeling the dynamics of parafoils and developing a dynamic program, based on wind predictions, to optimize path-finding during flight [6]. To verify the application of the autonomous parafoil recovery system, Dr. Lee conducted flight simulations using a MatLab/Simulink program [6]. The results of the flight simulations were that the vehicle was able to track the desired path very well under no windy conditions [6]. However, the system took a few seconds to calculate the next waypoint and adjust itself to the correct path [6]. Under windy conditions, the vehicle exhibited signs of noisy movements but was able to stay on the desired pathways [6].

Similarly, other university BalloonSat programs are looking into developing an autonomous parafoil recovery system. Under the Stanford Student Space Initiative, Team Balloonerang from Stanford University have dedicated a parafoil team to fully develop a novel system that can steer the payload to a specified GPS location in hopes to facilitate ease of payload retrieval [7]. The Space Hardware Club from the University of Alabama Huntsville are currently working on multiple BalloonSat projects with one of them being their autonomous recovery system called RAPTOR [8]. From their website, Project RAPTOR is summarized as, "The Ram-Air Parafoil Targeted Object Return (RAPTOR) system is a payload designed for the simplification of high-altitude balloon payload recovery. The objective of the project is to minimize recovery costs for any high-altitude ballooning flight through autonomous targeted landings. RAPTOR is a low-cost, low-weight addition to any payload line, utilizing basic control algorithms, electronics, and commercially available parafoils [8]."

Unfortunately, an autonomous parafoil recovery system is not feasible to develop for the UHABS-6 team. The team lacks time and manpower to develop such a complex recovery system. From reading Dr. Seong-Jin Lee report on autonomous parafoil recovery systems, analyzing and modeling the dynamics of parafoils requires intense research and testing. In addition, to develop a dynamic program taking into account predicted winds would probably a dedicated team in itself, larger than the current 8-member UHABS-6 team.

With the likelihood of BalloonSats launches landing in the ocean of Oahu, the UHABS-6 team will research and develop an autonomous underwater vehicles (AUV) or unmanned autonomous vehicles (UAV), such as boats, drones, and submarines, to use as a design concept for the autonomous recovery vehicle for the BalloonSat module.

2.0 TECHNICAL OVERVIEW (40 PG limit)

2.1 Objectives and Requirements

Mission Statement: [JK]

The UHABS-6 team will successfully develop a high altitude BalloonSat system capable of carrying small payloads in a near-space environment, while flight testing the Comprehensive Solution for Mission Operations Systems (COSMOS) mission operations software, and return safely to Earth for intact recovery. A recovery system will be incorporated into the BalloonSat system that upon landing in the ocean will be programmed to autonomously propel itself to a designated recovery site for recovery.

Objectives and Success Criteria [JK]

ID	Objectives
OBJ-01	To develop a reliable, high-altitude BalloonSat system capable of carrying small payloads to a near-space environment.
OBJ-02	To develop a recovery system which enables the BalloonSat module to safely land in the ocean or land.
OBJ-03	To develop a recovery system able to autonomously propel the payload to a designated recovery site if an ocean landing occurs.
OBJ-04	To utilize and test COSMOS as operation and software for the HSFL.
OBJ-05	To obtain images and video during the flight phase.
OBJ-06	To collect atmospheric and state-of-health data during flight phase.

ID	Success Criteria
SC-01	UHABS-6 reaches and releases modules at the desired altitudes.
SC-02	Parachute deploys after module release to ensure a safe landing. The UHABS-6 modules are highly visible and labeled with contact information to improve recoverability.
SC-03	UHABS-6 modules are designed for ocean conditions and successfully test the autonomous recovery system in the ocean prior to launch.
SC-04	COSMOS successfully integrates the system of the UHABS-6 modules with the GS and perform mission operations.
SC-05	UHABS-6 modules successfully stores on-board and transmits images and live-stream video to the GS.
SC-06	UHABS-6 modules successfully stores data on-board and transmits data to GS.

Top-Level System Requirements Overview [JK]

ID	Requirements
TLSR-01	Shall be capable of carrying small payloads to near space environments.
TLSR-02	Shall consist of a latex weather balloon, parachute, flight termination mechanism, avionics, recovery vehicle, and a propulsion/motor system.
TLSR-03	Shall be able to receive uplink commands from Ground Station.
TLSR-04	Shall land no more than five miles away from the shoreline of Oahu.
TLSR-05	Shall remain intact and fully functional after landing.
TLSR-06	Shall monitor the status of the BalloonSat throughout the entire mission.
TLSR-07	Shall provide the means for the BalloonSat module to be perceptible and identifiable at all times.
TLSR-08	Upon ocean landing, shall autonomously navigate to a designated destination and send a transponder signal with its position as well as other engineering information to the Ground Station on a regular basis.
TLSR-09	Shall use Comprehensive Open-architecture Solution for Mission Operations Systems (COSMOS) software for mission operations.
TLSR-10	Shall collect video and images from the perspective of the BalloonSat module during the flight phase of the mission.
TLSR-11	Shall collect atmospheric and engineering data during the flight phase of the mission.

Constraints [JK]

ID	Requirements
TSLR-12	UHABS-6 design shall be completed by December.
TSLR-13	UHABS-6 shall be built, tested, launched, and recovered by April.
TSLR-14	UHABS-6 mission shall use and test COSMOS.
TSLR-15	The following regulations from the Code of Federal Regulations (4) shall be followed: ● Modules cannot exceed a weight of 6 lbs. ● Payload cannot exceed a weight of 12 lbs. ● Avoid no-fly zones
TSLR-16	Notify FAA prior to launch.

2.1.1 Conceptual Design [JK]

The conceptual design of UHABS-6 primarily focused on the recovery vehicle and the propulsion system. UHABS-6 will meet all requirements and capabilities throughout the flight phase of the mission. However, the success of the UHABS-6 mission depends on the recovery of the BalloonSat module. Due to the importance of the recovery, the UHAB-6 team must ensure that the design, operations, and capabilities of the autonomous recovery system meets the all top-level system requirements and constraints. To fulfill these requirements and constraints, the design concept of UHABS-6 primarily focuses on the recovery vehicle and propulsion system. The major trade studies to develop the design concept for the recovery vehicle and propulsion system involved researching successfully developed and water-related unmanned autonomous vehicles (UAV).

While researching trades studies on unmanned autonomous vehicles (UAV), the UHABS-6 team held a dedicated team meeting to develop UAV criteria based on the customer’s needs. Together, the team developed these UAV criteria to take into consideration when researching possible UAV designs:

- Lower cost: To minimize the budget required for developing the UAV.
- Complexity of code: The difficulty for the Ground Station team to program the UAV propulsion system to perform autonomous navigation.
- Power to Distance Ratio: The total distance traveled versus the amount of power consumption for the UAV.
- Weight: UAV weight approximation to meet the 6-lb module weight limit. Approximated by the major weight factors such as hull/structure design and number of required motors/propellers.
- Manufacturability: The RVP ability to develop the UAV.
- Time to Manufacture: The RVP required time to develop the UAV.
- Accessibility: The ability for the user to easily access any part in the UAV to conduct maintenance, fix, and/or replace in a timely manner.
- Travel Longevity: The durability of the UAV while traveling through the ocean environment.
- Survival Impact: The durability of the UAV to withstand the landing impact during the flight phase of the mission.
- Avionic Protection: The UAV ability to protect the avionics from water during the recovery phase of the mission.
- Resistance to Capsize: The UAVs ability to maintain upright orientation in the ocean environment.

With the list of criteria to consider for the design concept, the UHABS-6 team was able to filter the trades conducted by each member, which the team was able to narrow down their possible design concept to six choices:

1. Airboat: An airboat that propels through the water with the use of a large aircraft propeller above the water. The hull for airboats are usually flat-bottom. However, for the purpose of UHABS-6 mission, the team will consider other hull designs. An autonomous airboat was developed by a company called “Platypus, LLC.” The UAV was designed for environmental monitoring, flood response, fish farming, and other applications [9].

2. Submarine: A long cylindrical, round-faced underwater vehicle shaped similar to a missile/torpedo. For the UHABS-6 mission, the submarine would be designed to only be half-submerged in the water. An autonomous underwater submarine was developed by Bluefin Robotics [10]. As described by a web article, the autonomous submarine would "perform military missions such as intelligence, surveillance and reconnaissance, anti-submarine warfare, mine countermeasures, port and harbor security, rapid environmental assessment, communications relay, mobile acoustic countermeasure and decoy, and unexploded ordnance discovery [10]."

3. Wave-Powered Boat: A surface vehicle that uses oscillating fins to convert vertical motion of waves into lift forces acting in the direction of advance. Many systems operating on this principle have been developed, such as the Wave Glider by Liquid Robotics and a Wave Devouring system by Tokai University [11][12]. The boat propels through the water with underwater propellers on the main boat hull and an attached wave glider [12]. The wave glider is a separate boat-like structure with multiple oscillating fins, and remains afloat a few feet below the boat [12]. These fins on the wave glider uses the ocean wave's up-down motion to propel itself forward [12]. In addition, the wave glider has a propeller for extra thrust when needed [12]. The wave glider is attached, by cord, to the bottom of the hull of the boat, and essentially pulls the boat forward [12]. Furthermore, when the boat depletes all battery power for the propellers, the wave glider can keep the boat moving while the solar panels recharge the batteries.

4. Seaplane: An aircraft which is able to land and takeoff on water. At the University of Michigan, their Autonomous Aerospace Systems Lab team successfully developed an autonomous seaplane called the Flying Fish [13].

5. Quadcopter with Landing Pad: A drone with 4 propellers designed to be light-weight and capable of carrying a payload. Similar to the "WaterStrider" from DroneRafts, the drone is equipped with a buoy-like land pads which allow the drone to safely land and takeoff in the water [14].

The UHABS-6 team decided that the best method to select a design concept was to conduct a pugh selection method. The Airboat design was chosen as the baseline of comparison between the other possible design concepts due to its similarity to the UHABS-5 catamaran design. The rest of the possible designs stray away of a boat design and approaches ocean travel in a different way. The list of criteria was used to compare the baseline, the Airboat, to each of the other 5 possible designs. The UHABS-6 team discussed together how to weigh each criteria, and decided to use a 1-3-5 weighing scale. In Figure 1, the pugh matrix analysis shows how the UHABS-6 team scored each possible design to the baseline design and the overall results.

Criteria	**Weighting**	**Baseline (Airboat)**	**Submarine**	**Seaplane**	**Wave Power**	**Drone w/ Landing Pad**
Lower Cost	1	0	-1	-1	-1	-1
Complexity of Code	5	0	0	0	0	-1
Power to Distance	3	0	-1	-1	1	-1
Weight	5	0	-1	-1	-1	1
Manufacturability	3	0	-1	-1	-1	-1
Time to Manufacture	5	0	-1	-1	-1	-1
Accessibility	3	0	-1	0	0	1
Travel Longevity	5	0	1	-1	1	0
Survival Impact	5	0	1	-1	0	-1
Avionic Protection	5	0	1	1	0	-1
Total:		**0**	**-5**	**-22**	**-6**	**-19**

Figure 1: Pugh Matrix of Design Concepts (UAV)

The results from the pugh matrix analysis shows that the baseline, the Airboat, is the best design based on the current weightings and criteria. However, the UHABS-6 team decided to have their pugh matrix analysis to be reviewed by Professor Marvin Young, a System Engineering course instructor at the University of Hawaii at Manoa. After reviewing the pugh matrix and providing a brief summary of the UHABS-6 mission, Professor Young suggested that there is missing a key criteria, Resistance to Capsizing. A second iteration of the pugh matrix analysis was conducted with the Resistance to Capsizing criteria with the appropriate weighting, as shown below in Figure 2.

Criteria	Weighting	Baseline (Airboat)	Submarine	Seaplane	Wave Power	Drone w/ Landing Pad
Lower Cost	1	0	-1	-1	-1	-1
Complexity of Code	5	0	0	0	0	-1
Power to Distance	3	0	-1	-1	1	-1
Weight	5	0	-1	-1	-1	1
Manufacturability	3	0	-1	-1	-1	-1
Time to Manufacture	5	0	-1	-1	-1	-1
Accessibility	3	0	-1	0	0	1
Travel Longevity	5	0	1	-1	1	0
Survival Impact	5	0	1	-1	0	-1
Avionic Protection	5	0	1	1	0	-1
Resistance to Capsizing	5	0	1	-1	1	-1
Total		**0**	**0**	**-27**	**-1**	**-24**

Figure 2: Second Pugh matrix of Design Concepts (UAV)

The second pugh matrix analysis reduces the score gap between the baseline (Airboat) and two possible designs: Submarine and Wave-power boat. The Submarine breaks even with the baseline with a zero score. The Wave-power boat design came up short compared to the baseline with a negative one score. However, the results of the pugh matrix analysis were inconclusive.

The UHABS-6 team had a final discussion on developing a design concept. The UHABS-6 discussion can be summarized in two parts:

1. A wave-powered boat is just a boat with oscillating fins. The team could attach oscillating fins to a swamp boat or submarine design and use propellers as auxiliary propulsion, similar to the Wave Glider.
2. Taking advantage of conserving battery power with oscillating fins allows the autonomous recovery vehicle to travel further per battery charge before going into a recharge statuses.

Furthermore, the UHABS-6 team decided to select the best features from the possible design concepts to develop an autonomous recovery vehicle with a hybrid-propulsion system. First, use oscillating fins from the wave-powered boats as primary propulsion. Next, use the propulsion system of either airboat or submarine as auxiliary propulsion. Lastly, the flat-hull design of an airboat.

The hybrid-propulsion system relies on two types of propulsion systems, one that utilizes kinetic energy from ocean wave motion and the other utilizing electrical energy from batteries of both a wave power boat and an airboat. As primary propulsion, the autonomous recovery vehicle uses an oscillating fin to take advantage of the ocean waves to create a forward thrust. The ocean waves cause the hull/structure of the BalloonSat module to heave upward and downward which generates lift, upward and downward on the oscillating fin. The generated lifts interact with the fluid flow acting on the oscillating fin which combine to create a perpendicular thrust to the cord orientation of the oscillating fin. The oscillating fin is attached perpendicular to the hull/structure of the BalloonSat module by linkage, below and near the bow side of the hull/structure. The oscillating fin does not require power to operate, and allows for the autonomous recovery vehicle to operate for longer periods before reaching a recharge statuses. As auxiliary propulsion, the aircraft propeller and motor system is attached to the transom of the autonomous recovery vehicle hull/structure, and allows the autonomous recovery vehicle to propel forward in the absence of waves. To control the auxiliary propulsion, the built-in accelerometer in the inertial measurement unit (IMU) will senses the heave on the hull/structure from the ocean waves. Furthermore, auxiliary propulsion activates in the absence of ocean waves and deactivates when ocean motion returns. With only a singular auxiliary propeller, the autonomous recovery vehicle will depend on rudders for steering.

A flat-hull design for the autonomous recovery vehicle will aid the primary propulsion, the oscillating fin, in generating forward thrust. The flat-hull rides the full upward and downward motion of the wave as the design does not reduce heave. Furthermore, more lift is generated on the oscillating fin to create forward thrust. The flat-hull can be easily manufactured and provides solar cells a suitable platform to mount on.

Figure 3 shows a Solidworks model of the conceptual design of the hybrid-propulsion autonomous recovery vehicle.

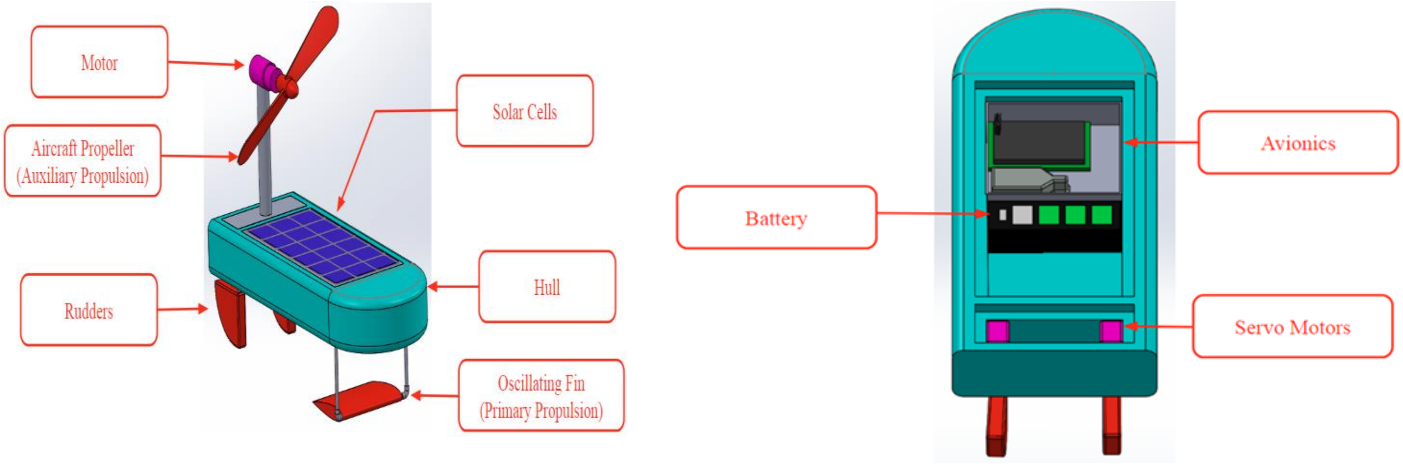


Figure 3: Conceptual Design of Autonomous Recovery Vehicle

2.2 Baseline Design

2.2.1 Top Level System

2.2.1.1 System Architecture [JK]

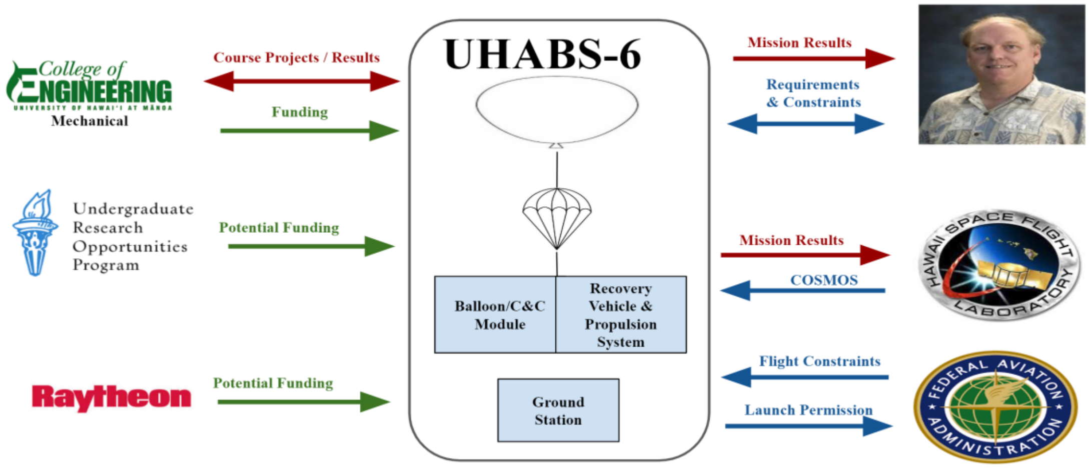


Figure 4: Mission Operational System Architecture for UHABS-6 [15] [16] [17] [18] [19] [20]

Figure 4 shows the external interfaces that affect the overall mission of UHABS-6. The left-hand side shows the current funding source, UHM Mechanical Engineering Department, and other possible funding from UROP and Raytheon. In addition, the UHABS-6 mission is a project for both ME 481 and ME 491 which fall under the UHM Mechanical Engineering Department. On the right-hand side the UHABS-6 mission receives requirements & constraints and provide mission results to both Dr. Trevor Sorensen and Hawaii Space Flight Laboratory (HSFL). The UHABS-6 mission must to the flight constraints of the Federal Aviation Administration and must request permissions, or notify, before launch.

2.2.1.2 Concept of Operations (CONOPs) [JK]

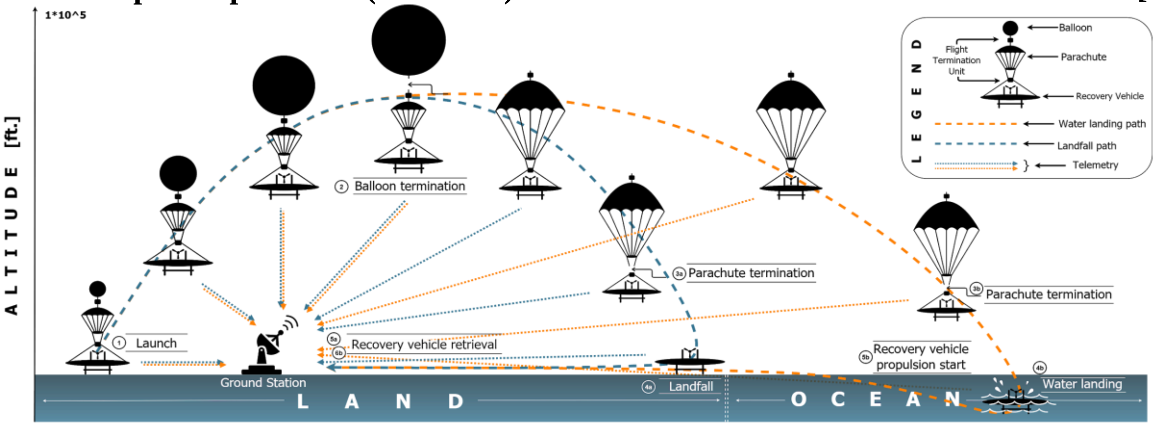


Figure 5: Concept of Operations

The concept of operations (CONOPs), as shown in Figure 5, provides an overall visual of the UHABS-6 operation during the different phases of the mission. Starting at point 1, the GS go through launch operation procedures, and prepare the BalloonSat module for launch. From leaving point 1, the BalloonSat module begins and continues to collect sensor data, images, and streams live-video to the GS for the duration of the flight phase of the mission. At point 2, the balloon will be released at the desired altitude below 100,000 feet from either burst or command of the payload or GS through the FTM. The parachute deploys and descends at a speed less than 15 ft/s. The BalloonSat module will descend either onto land (blue line) or the ocean (orange line). If normal landing occurs, the location beacon activate and will be tracked for recovery. If ocean landing occurs, the second FTM will release the parachute by payload or GS command. Afterwards, the BalloonSat module will autonomously propel itself to a designated site for recovery.

2.2.1.3 Top-level Functional Flow Block Diagram [JK]

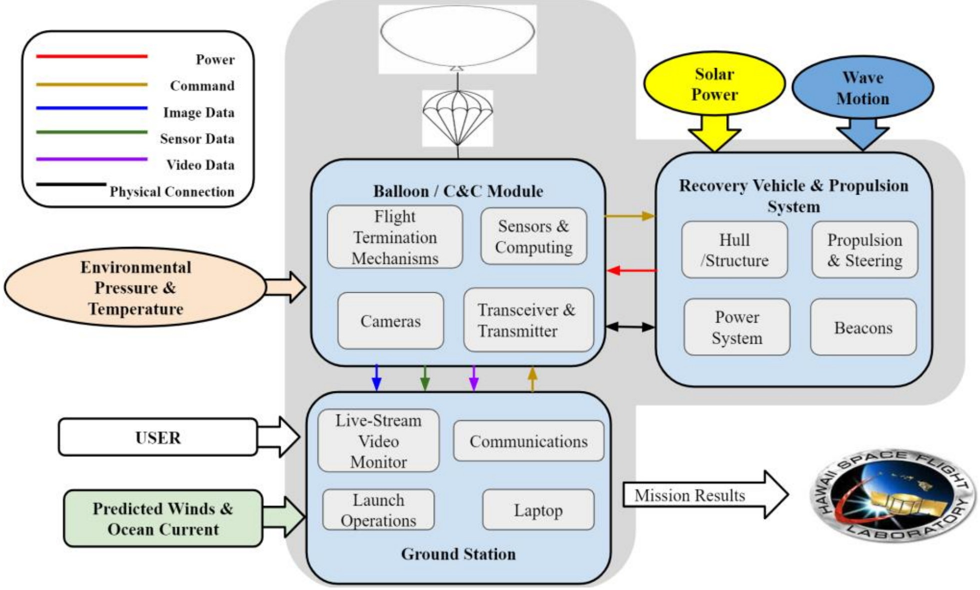


Figure 6: Overall System Functional Flow Block Diagram [19]

The overall system functional flow block diagram, shown in Figure 6, show all the interfaces between the UHABS-6 subsystems and the external interfaces that affect the system. The internal interfaces of the UHABS-6 subsystems is centralized by the BCCM subsystem. The BCCM subsystem physically interfaces with the RVP subsystem, and wirelessly interfaces with the GS subsystem. Through physical interfacing, the BCCM subsystem mounts all avionics to the internal housing of the autonomous recovery vehicle design of the RVP subsystem, and also interfaces the flight system components such as the balloon, parachute, and FTMs to the autonomous recovery vehicle. In addition, the RVP subsystem provides electrical power to the electrical components of the BCCM subsystem. The wirelessly interface of the BCCM and GS subsystem involves the communication relay of data, video, and command signals. The primary external interfaces affecting the UHABS-6 subsystem is centralized by the GS subsystem. The external interfaces affecting the GS subsystem are user input, predicted winds and ocean currents, and providing mission results to Hawaii Space Flight Laboratory (HSFL).

2.2.1.4 Overall System Mass & Volume Budget [JK]

Table 1: System Mass & Volume Budget

Subsystem	**Mass (lbs)**	**Volume (in³)**
Balloon/C&C Module	0.6	23
Recovery Vehicle & Propulsion System	4.9	44
Ground Station	N/A	N/A
Subtotal	5.5	67
20% Margin	1.0	13
Total	**6.5**	**80**

2.2.1.5 Overall System Power Budget [JK]

Table 2: System Power Budget

Subsystem	**Power (W)**
Balloon/C&C Module	5
Recovery Vehicle & Propulsion System	170
Ground Station	N/A
Subtotal	175
20% Margin	35
System Total (W)	**210**

2.2.2 Subsystems

2.2.2.1 Balloon and Command & Control Module

2.2.2.1.1 Subsystem Team Roles & Responsibilities [AQ] [AY]

Subsystem Lead - Akira Yokoyama

- Responsible for communicating subsystem plans with the project manager and avionics development for C&C module.

Subsystem Member - Austin Quach

- Responsible for developing the flight system.

2.2.2.1.2 Top-level Requirements & Constraints [AQ] [AY]

ID	Requirements & Constraints
TLSR-01	Shall be capable of carrying small payloads to near space environments.
TLSR-02	Shall consist of a latex weather balloon, parachute, flight termination mechanism, avionics, recovery vehicle, and a propulsion/motor system.
TLSR-03	Shall be able to receive uplink commands from Ground Station.
TLSR-04	Shall land no more than five miles away from the shoreline of Oahu.
TLSR-06	Shall monitor the status of the BalloonSat throughout the entire mission.
TLSR-07	Shall provide the means for the BalloonSat module to be perceptible and identifiable at all times.
TLSR-10	Shall collect video and images from the perspective of the BalloonSat module during the flight phase of the mission.
TLSR-11	Shall collect atmospheric and engineering data during the flight phase of the mission.

2.2.2.1.3 Subsystem Derived Requirements [AQ] [AY]

ID	Requirements	Parent ID
SSDR-17	BalloonSat shall ascend to a desired altitude, at which the balloon is released by burst or by command of the payload and/or Ground Station.	TLSR-04
SSDR-18	Shall collect state-of-health data of the avionics during flight phase.	TLSR-06
SSDR-19	Shall record video oriented downwards of the BalloonSat during the flight phase.	TLSR-10
SSDR-20	Shall take images in the upwards, downwards, and side directions of BalloonSat module.	TLSR-10
SSDR-21	Shall collect environmental data during flight phase.	TLSR-11
SSDR-22	Shall transmit data and video to Ground Station during the flight.	TLSR-11
SSDR-23	Shall store image and sensor data on-board the BalloonSat module.	TLSR-11

2.2.2.1.4 Major Trades [AQ] [AY]

The major trades for the Balloon/C&C module are the parachute, flight termination mechanism, communications and sensors. The winning selection are highlighted.

2.2.2.1.4.1 Parachute Design [AQ]

The parachute design mainly focused on what type of shape would be most efficient. Assuming that each different shape parachute will be able to descend the payload to 15 ft/s, how much material (surface area), cost of material, and the total weight of the parachute were compared in Figure 7.

Criteria	Weighting (1,3,5)	Round (Baseline)	Cruciform	Hexagonal
Material Durability	5	0	0	0
Ease of Deployment	5	0	1	1
Drag	5	0	0	0
Readily Available	5	0	0	0
Resistance to Tangle Strings	5	0	0	0
Weight	3	0	-1	-1
Price	3	0	1	-1
Total		**0**	**5**	**-1**

Figure 7: Pugh Matrix for Parachute Design [22][23][24][25]

Each parachute was based on the material 1.1 Ripstop Nylon which will be more than enough to descend a maximum payload of 12 pounds. Making a parachute with the same specification as a manufactured parachute is difficult because they use heavy grade equipment; therefore, readily available parachutes were a high requirement. Attaching a shroud disk will decrease the chance of the shroud line tangling.

2.2.2.1.4.2 FTM Design [AQ]

For the flight termination mechanism a hot-wire cut down method using nichrome wire, a solenoid valve, and a servo motor with a connection pin were considered in Figure 8.

Criteria	**Weighting (1,3,5)**	**Solenoid (Baseline)**	**Nichrome Wire**	**Servo Motor & Connection Pin**
Non explosive	5	0	0	0
Functional in severe climates	5	0	0	-1
Power Consumption	5	0	-1	0
Compact	3	0	1	0
Weight	3	0	1	0
Number of Mechanical Parts	3	0	0	1
Total		**0**	**4**	**-2**

Figure 8: Pugh Matrix for FTM Design [26]

From the FAA explosives cannot be launched, going from sea level up to 100,000 feet the atmospheric temperature can range from 20 to -40 degree Celsius. The FTM should have its own power consumption; therefore, the amount of power is limited. The main criteria were being small and compact, and the weight must be minimal compared to the payload.

2.2.2.1.4.3 Communications and Sensors [AY]

The pugh matrix for the avionics do not include weight or volume due to the fact that the compared modules have similar weights and volume and did not affect the decision.

The operating range of the temperature sensor is the most important criteria due to the fact that the sensor has to be able to function within the temperature ranges that it will experience. The board criteria is whether the sensor is already mounted on a board and does not need additional mountings. Error is the least important factor as the sensor is not a critical function needing a low error.

Criteria	Weighting (1,3,5)	MCP9808 (baseline)	DS18B20	T-PRO-DS18b20-Waterproof
Operating Range	5	0	-1	1
Board	5	0	-1	0
Cost	3	0	1	-1
Error	1	0	-1	-1
Total		**0**	**-3**	**2**

Figure 9: Pugh Matrix for Temperature Sensor [27] [28] [29].

For pressure sensors precision is the most important factor due to the fact that pressure at high altitudes is near zero. A precise sensor is needed to determine the slight changes in pressure which will be used to determine altitude.

Criteria	Weighting (1,3,5)	Adafruit BMP388 (Baseline)	Adafruit BMP 280	Adafruit MPRLS
Precision	5	0	-1	-1
Cost	1	0	0	-1
Total		**0**	**-5**	**-6**

Figure 10: Pugh Matrix for Pressure Sensors [30] [31] [32].

For image/video cameras the quality of the image is limited by the data rate that the wireless communications can transfer. As a result resolution does not have much weight in the pugh matrix.

Criteria	Weighting (1,3,5)	ArduCAM Mini OV2640 (Baseline)	ArduCAM Mini OV5642	OV9566
Cost	3	0	-1	1
Resolution	1	0	1	-1
Total		**0**	**-2**	**2**

Figure 11: Pugh matrix for Image/Video Camera [33][34][35]

For the GPS max altitude was the most important quality due to the fact that the BalloonSat should be in contact and sending data to the GS throughout the entire flight. Accuracy is not a major concern as the recovery module is not doing precision navigation.

Criteria	Weighting (1,3,5)	Adafruit Ultimate GPS Breakout(Baseline)	GP-735 GPS
Max Altitude	5	0	1
Accuracy	3	0	0
Cost	1	0	-1
Total		**0**	**4**

Figure 12: Pugh Matrix for GPS [36][37]

The magnetometer in the IMU is critical to the success of the BalloonSat mission and the acceleration will be signaling when the auxiliary power is on and are weighted higher as a result However the IMU all have a similar error for the measurements so cost became the sole deciding factor for which IMU to choose.

Criteria	Weighting (1,3,5)	LSM9DS1	MPU 9150	BNO055
Magnetometer	5	0	0	0
Acceleration	3	0	0	0
Gyroscope	1	0	0	0
Cost	1	0	-1	-1
Total		**0**	**-1**	**-1**

Figure 13: Pugh Matrix for IMU [38][39][40]

The voltage regulator has voltage input, output and amps all weighted equally as the system will not function if the regulator does not meet anyone of these requirements.

Criteria	Weighting(1,3,5)	LM2940CT/NOPB (Baseline)	Diatone 12V 2A	Regulator 7850 TO-220
Input voltage range	3	0	0	-1
Output Voltage	3	0	0	-1
Output Amps	3	0	1	-1
Cost	1	0	-1	1
Total		**0**	**2**	**-8**

Figure 14: Pugh Matrix for Voltage Regulator [41][42][43]

The radio communication module has range and data rate weighted the highest as both of these parameters are critical to for the BalloonSat to communicate to the GS. Frequency is required to match what the GS communication module can pick up. Arduino integration is whether it is made to be compatible with an arduino.

Criteria	**Weighting(1,3,5)**	**Xtend 900 (Baseline)**	**LoRa 900/915**
Max Range	5	0	-1
Max Data Rate	5	0	0
Max Frequency	3	0	0
Cost	3	0	1
Arduino integration	3	0	1
Total		**0**	**1**

Figure 15: Pugh Matrix for Radio Communications (Transceiver) [44] [45]

The microcontroller has processing speed and ram as the highest weighted criteria because the controller will have to run the programming and be able to steer the recovery module. The memory determines how much can be stored on the microcontroller without an external source. Digital I/O pins is how many slots there are to connect other electrical components.

Criteria	**Weighting(1,3,5)**	**Arduino Mega 2560 (Baseline)**	**DEV-14483**	**Arduino Due**	**Arduino Yun**
Processing speed	5	0	-1	1	1
Ram	5	0	-1	1	1
Memory	3	0	-1	1	1
Digital I/O Pins	3	0	-1	1	-1
Cost	1	0	1	-1	-1
Total		**0**	**-15**	**15**	**9**

Figure 16: Pugh Matrix for Microcontroller [46][47][48][49]

The voltage range is the most important criteria of the voltage sensor. If the range does not cover the range needed then the sensor does not give relevant data. The error is not a highly weighted criteria due to the fact that precision is not important.

Criteria	Weighting(1,3,5)	DIYmall Voltage Sensor (Baseline)	INA 219	Phidgets precision voltage sensor
Voltage Range	3	0	0	0
Error	1	0	0	0
Cost	1	0	-1	-1
Total		**0**	**-1**	**-1**

Figure 17: Pugh Matrix for Voltage Sensor [50][51][52]

2.2.2.1.5 Requirements vs Implementation [AY]

ID	Requirements	Implementation
SSDR-17	BalloonSat shall ascend to a desired altitude, at which the balloon is released by burst or by command of the payload and/or Ground Station.	● FTM ● Pressure/Altitude
SSDR-18	Shall collect state-of-health data of the avionics during flight phase.	● Voltage sensor to measure battery ● Internal temperature sensor
SSDR-19	Shall record video oriented downwards of the BalloonSat during the flight phase.	● Video camera
SSDR-20	Shall take images in the upwards, downwards, and side directions of BalloonSat module.	● Multiple cameras will take pictures in specified directions
SSDR-21	Shall collect environmental data during flight phase.	● Various sensors will gather atmospheric data.
SSDR-22	Shall transmit data and video to Ground Station during the flight.	● Wireless transceiver will send data to ground station
SSDR-23	Shall store image and sensor data on-board the BalloonSat module.	● On board SD card will store data

2.2.2.1.6 Functional Flow Block Diagram with External Interfaces [AY]

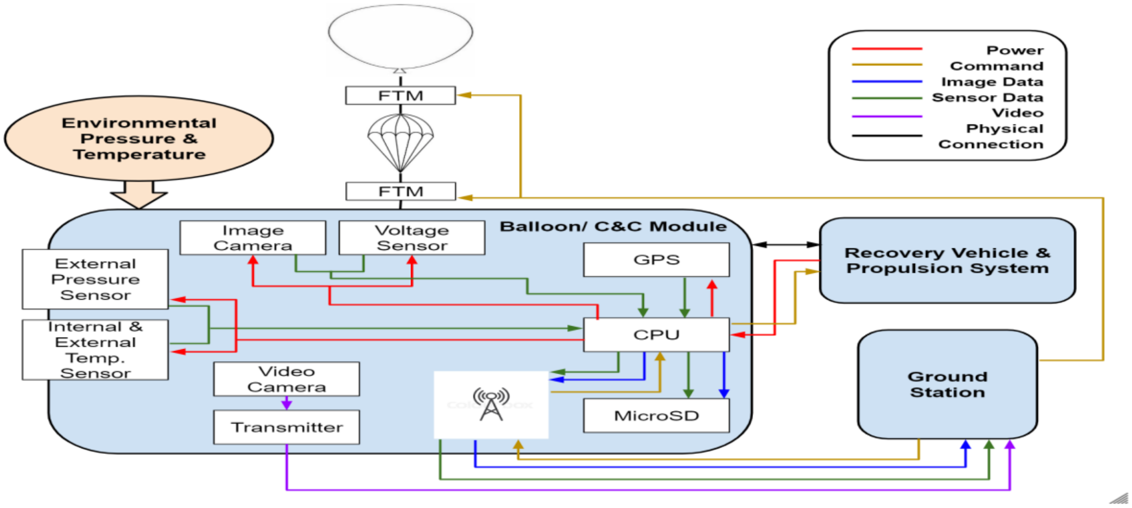


Figure 18: Functional Flow Block Diagram of the Balloon/C&C Module with External Interfaces

2.2.2.1.7 Subsystem Mass & Volume Budgets [AQ] [AY]

Table 3: BCCM Subsystem Mass & Volume Budget

Balloon/Parachute			
Item	**Quantity**	**Mass(oz)**	**Volume(in^3)**
Balloon	1	N/A	N/A
Parachute	1	N/A	N/A
Nylon Cord	8 feet	N/A	N/A
Flight Termination Mechanism			
Item	**Quantity**	**Mass(oz)**	**Volume(in^3)**
Nichrome Wire	6 inch	0.52	N/A
9v Battery	1	1.76	N/A
JST connector	6	1.23	N/A
Avionics			
Item	**Quantity**	**Mass(oz)**	**Volume(in^3)**
Microcontroller	1	1.3	6.6
Pressure Sensor	1	0.03	0.06
Temp. Sensor	2	1.5	6.9

Camera/Video	4	0.7	0.5
GPS	1	0.3	0.3
Voltage Sensor	1	0.03	0.06
Radio Communication	1	0.7	0.13
IMU	1	0.35	0.05
Voltage regulator	1	0.03	0.05
SD Card	1	0.03	0.05
Hand Warmers	1	2	4.6
BCCM Total (lbs)		**0.44**	**19.25**

2.2.2.1.8 Subsystem Power Budget [AQ] [AY]

Table 4: BCCM Subsystem Power Budget

FTM				
Item	**Quantity**	**Required Amps (mA)**	**Required Voltage(V)**	**Required Power(W)**
FTM	2	500	9	9
Avionics				
Item	**Quantity**	**Required Amps (mA)**	**Required Voltage(V)**	**Required Power(W)**
Microcontroller	1	800	12	3.2
Pressure Sensor	1	10	5	0.05
Temp. Sensor	2	2	4	0.016
Cameras/Video	4	20	2.5	0.2
GPS	1	37	5	0.185
Voltage Sensor	1	3.6	5	0.018
Radio Communication	1	580	12	0.7
IMU	1	6	5	0.03
BCCM Total (W)				**4.4**

2.2.2.1.9 Risk Analysis [AY]

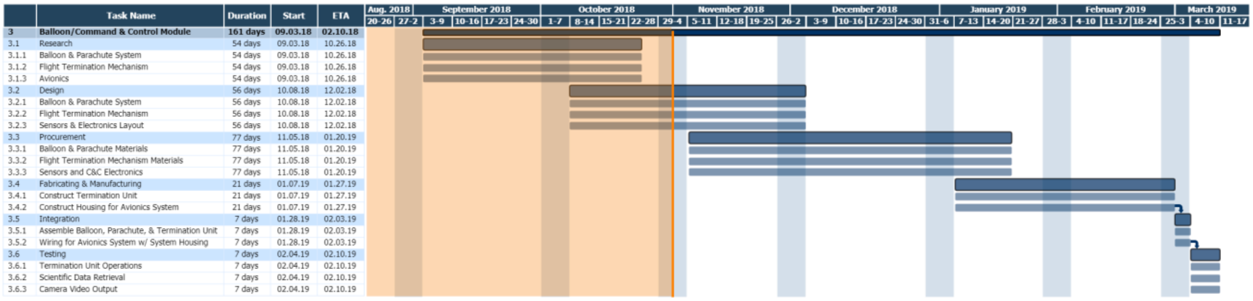
Table 5: BCCM Subsystem Risk Management

Identification	Consequence	Probability of Occurrence	Risk Level	Risk Rank	**Risk Mitigation (Reactive, Proactive)**
Flight termination mechanism failure	2	2	4	Low	- Integrate autonomous release when at desired altitude - Integrate manual release from ground station when above the desired altitude -Have a second FTM
Parachute detachment failure	4	2	8	Medium	-Ensure detachment unit works in all possible environmental conditions -Multiple detachment methods
Air traffic interference with BalloonSat flight trajectory	5	1	5	Medium	-Research sites and find optimal site per FAA regulations -Reschedule launch
Avionics freezes	5	2	10	Medium	-Install heating system -Install insulation -Wait for system to warm up
Lack of electronic knowledge hindering progress	4	4	16	High	-Start electronics systems early -Ask for assistance from people outside of the project

2.2.2.1.10 Testing Plan [AQ] [AY

The parachute design will undergo a decent velocity drop test from a measured altitude with an alike payload and a speed sensor to ensure a decent rate of at least 15 feet per second. The flight termination mechanism will be tested by simulating an environment close to -40 degree Celsius, possibly using the HSFL thermal vacuum chamber. The microcontroller and sensors will be tested to ensure that data is properly recorded by the sensors. The code will be tested to ensure that it functions properly and communicates with other subsystems properly. The GPS will be tested on the ocean to ensure that the ocean surface does not affect the GPS ability to accurately determine location.

2.2.2.1.11 Subsystem Schedule using combined WBS and Gantt chart [AQ] [RT] [AY]



	Task Name	Duration	Start	ETA
3	**Balloon/Command & Control Module**	**161 days**	**09.03.18**	**02.10.18**
3.1	Research	54 days	09.03.18	10.26.18
3.1.1	Balloon & Parachute System	54 days	09.03.18	10.26.18
3.1.2	Flight Termination Mechanism	54 days	09.03.18	10.26.18
3.1.3	Avionics	54 days	09.03.18	10.26.18
3.2	Design	56 days	10.08.18	12.02.18
3.2.1	Balloon & Parachute System	56 days	10.08.18	12.02.18
3.2.2	Flight Termination Mechanism	56 days	10.08.18	12.02.18
3.2.3	Sensors & Electronics Layout	56 days	10.08.18	12.02.18
3.3	Procurement	77 days	11.05.18	01.20.19
3.3.1	Balloon & Parachute Materials	77 days	11.05.18	01.20.19
3.3.2	Flight Termination Mechanism Materials	77 days	11.05.18	01.20.19
3.3.3	Sensors and C&C Electronics	77 days	11.05.18	01.20.19
3.4	Fabricating & Manufacturing	21 days	01.07.19	01.27.19
3.4.1	Construct Termination Unit	21 days	01.07.19	01.27.19
3.4.2	Construct Housing for Avionics System	21 days	01.07.19	01.27.19
3.5	Integration	7 days	01.28.19	02.03.19
3.5.1	Assemble Balloon, Parachute, & Termination Unit	7 days	01.28.19	02.03.19
3.5.2	Wiring for Avionics System w/ System Housing	7 days	01.28.19	02.03.19
3.6	Testing	7 days	02.04.19	02.10.19
3.6.1	Termination Unit Operations	7 days	02.04.19	02.10.19
3.6.2	Scientific Data Retrieval	7 days	02.04.19	02.10.19
3.6.3	Camera Video Output	7 days	02.04.19	02.10.19

Figure 19: BCCM Subsystem Combined WBS and Gantt Chart for PDR

In Figure 19, the red line indicates the systems present state, currently in the middle of the design phase. For next month, up until the Critical Design Review, tests and finalizations will be conducted for the flight system as well as the development for the avionics. Ordering parts are planned for mid-November and being received around January. The start of fabrication and manufacturing will be at the start of next semester. Testing of individual parts will be conducted as soon as the order is received. Testing the subsystem will begin as soon as all the parts are verified to operate accordingly with one another,

2.2.2.1.12 Remaining Issues and Concerns [AQ] [AY]

Tethering plan for the balloon, FTM, parachute, and the payload interfacing must be researched to ensure a safe and accurate flight. Electronics mounting configuration within the system is still an ongoing process due to the size and shape of the components. The specifics for range, data rate, and interface for the wireless communications are still unknown. The range and data rate are given by the datasheets however the given specifications are under ideal conditions with ideal components. The interfacing method and the specifics for how the wireless modules will communicate with each other are still unknown.

2.2.2.2 Recovery Vehicle & Propulsion Subsystem

2.2.2.2.1 Subsystem Team Roles & Responsibilities [TS]

Subsystem Lead - Trevor Shimokusu

- Responsible for communicating subsystem plans with the project manager, and designing the propulsion and steering systems.

Subsystem Member - Reginald Tolentino

- Responsible for the external hull design and materials selection.

Subsystem Member - Christian Feria

- Responsible the designs of the vehicle’s internal housing and insulation.

2.2.2.2.2 Top Level Requirements & Constraints for Subsystem [TS]

ID	Requirement/Constraint
TLSR-01	Shall be capable of carrying small payloads to near space environments.
TLSR-05	Shall remain intact and fully functional after landing.
TLSR-07	Shall provide the means for the system to be perceptible and identifiable at all times.
TLSR-08	Upon ocean landing, shall autonomously navigate to a designated destination and send a transponder signal with its position as well as other engineering information to the ground station on a regular basis.

2.2.2.2.3 Subsystem Derived Requirements [TS]

ID	Requirement/Constraint	Parent ID
SSDR-24	Shall maintain the temperature of the payload within its operating limits.	TLSR-01
SSDR-25	Shall provide sufficient protection to internal components from impact damage.	TLSR-05
SSDR-26	Shall be equipped with a waterproof location beacon that is audible from a distance of at least 100 yards in scrub, and operating continuously for 24 hours.	TLSR-07
SSDR-27	Shall be painted in a waterproof, highly visible color with attached recovery contact information and an American flag that will not be affected by water or sunlight.	TLSR-07
SSDR-28	Shall be equipped with a solar recharging system to provide sufficient power during navigation.	TLSR-08
SSDR-29	Shall utilize the vehicle's location and orientation data to provide power to and actuate the steering and/or auxiliary propulsion systems.	TLSR-08
SSDR-30	Shall overcome oceanic conditions to traverse the distance between the system's landing position and shore.	TLSR-08
SSDR-31	Shall be capable of navigating through predesignated areas determined by predicted current and weather forecasts.	TLSR-08
SSDR-32	Shall protect electronic components from water exposure damage	TLSR-08

2.2.2.2.4 Major Trades [CF] [TS] [RT]

The major trades of the recovery vehicle and propulsion system involve the vehicle's hull, propulsion, steering, and electrical power systems. By exploring trade spaces for each of these systems, preliminary designs were selected with systems engineering tools, such as pugh matrices and analyses by inspection, aiding in decision-making processes.

2.2.2.2.4.1 Hull Shape [CF]

The shape selection for the recovery vehicle were considered with the system requirements and high risk taken into account. The shape of the recovery vehicle would need to prove the ability to be stable and not capsize easily and overcome ocean conditions. For the shape of the recovery vehicle, the hulls that were considered consist of round, flat, V-shape and pontoon which is similar to the structure of a catamaran. Most of these hulls are commonly used in commercial boats today. Boat hulls had a great influence in choosing the shape of the recovery vehicle since the recovery vehicle would need to travel across the ocean in the same way boats do.

For round hulls, this type of hull is a displacement hull which allows traveling on water easy since it pushes water to the side and cuts through the water with minimal propulsion in slow speeds. However, the round hull's biggest problem lies in its stability. The round hull tends to roll sideways in waves making it unstable and easy to capsize. For the V-shape hull, this type of hull is a planing hull which allows the hull to glide on top of the water. V-shaped hulls are known for their ability to slice through water at high speeds giving it a smooth ride. However, v-shaped hulls may roll or bank in turns and would require a lot of power to move at high speeds. For requirement purposes, power is a factor that will need to be limited. For the flat hull, its stability depends on the behavior of the water. The flat hull is stable in calm waters but unstable in choppy waters. Overall, the flat hull offers maximum stability through its ability to slide across the water to achieve maximum speed. Lastly, the pontoon hull is the most stable compared to the other hull because it creates lift and flotation but it is difficult to maneuver. Therefore, it would require more power to steer and turn.

Criteria	**Weighting**	**Baseline* Pontoon**	**Flat**	**Round**	**V-shape**
Resistance to Capsize	9	0	0	-1	0
Drag	3	0	1	-1	0
Manufacture difficulty	3	0	1	1	1
Time to manufacture	1	0	1	1	0
Total		**0**	**7**	**-8**	**3**

Figure 20: Pugh Matrix for Hull Geometry

A Pugh Matrix selection method was used for the determination of the best shape for the recovery vehicle. Criteria such as capsize, drag, manufacture difficulty, and time to manufacture were weighted using values of 1, 3, and 9 with 9 being the highest priority and 1 being the lowest priority. According to the results of the Pugh matrix, the flat hull column highlighted in green is the winning selection. With the flat hull as the shape of the recovery vehicle, the waves of the ocean can be taken advantage of and be used as thrust and forward motion.

2.2.2.2.4.2 Hull Material [CF] [RT]

The material selection for the hull of the recovery vehicle were considered regarding the system and subsystem requirements and risks. The material of the recovery vehicle would need to prove the ability to remain intact and withstand the environmental conditions such as temperature and pressure during all phases of the flight and impact upon landing whether on land or ocean. For the material of the recovery vehicle, the materials that were considered consist of Carbon Fiber Reinforced Polymer, Fiberglass S-Glass Epoxy Composite, Kevlar 49, and Aluminum Alloy 2024. Most of these materials are commonly used in the commercial and industrial industry along with many various applications in defense and space, which makes these materials viable for UHABS-6.

Criteria	**Weight**	**Aluminum Alloy 2024**	**Score**	**Fiberglass (S-Glass Epoxy Composite)**	**Score**	**Kevlar 49**	**Score**	**Carbon Fiber Reinforced Polymer**	**Score**
Strength to Weight Ratio	0.2	169 kN.m/kg	2	1924 kN.m/kg	6	2500 kN.m/kg	9	2457 kN.m/kg	9
Ultimate Tensile Strength	0.4	469 MPa	2	4,800 MPa	9	3,600 MPa	7	1,500 MPa (Length); 40 MPa (Crosswise)	4
Modulus of Elasticity	0.1	73.1 GPa	3	93 GPa	5	112.4 GPa (only fibres); 124 GPa (w/ Reinforced Resin)	7	181 GPa (Length); 10.3 GPa (Crosswise)	9
Thermal Conductivity	0.3	121 W/mK	1	1.35 W/mK	5	0.04 W/mK	9	5-7 W/mK (in plane) .5-.8 W/mK (in traverse)	7
Total	1	3		6.8		7.4		6.4	

Figure 21: Decision-Making Matrix for Hull Material [53][54][55][56]

A Decision-Making Matrix (DMM) shown in Figure 21 was used for the determination of the best material for the recovery vehicle. The criterias used to find the best solution consist of strength to weight ratio, ultimate tensile strength, modulus of elasticity, and thermal conductivity with criteria weighting of 0.2, 0.4, 0.1, and 0.3 respectively. By utilizing a DMM compared to a Pugh Matrix, the materials were able to be compared quantitatively and scored based on its individual performance from the list of criteria. According to the results of the DMM, Kevlar 49 highlighted in green had the higher score compared to the other materials. Therefore, Kevlar 49 will be the hull material selected for UHABS-6 as its material properties suggest it to best perform for our needs, which will be verified through various tests of the RVP subsystem.

2.2.2.2.4.3 Insulation Material [CF]

The insulation material selection for the recovery vehicle were considered with the system requirements and risk taken into account. The insulation material of the recovery vehicle would need to prove the ability to maintain neutral temperature and protection of internal components such as avionics. For the insulation material of the recovery vehicle, the insulation materials that were considered consist of polyurethane foam and polystyrene foam. Most of these insulation materials are commonly used in the construction industry, home insulations, and everyday life.

One of the most common type of insulation material used in everyday life is polystyrene foam. Polystyrene foam is relatively light, cheap, moisture resistant, and has good thermal insulation which is good for the budget of the project and recovery vehicle so that the avionics will not be damaged from water and won't be affected by temperature. The downside of polystyrene foam is that it is highly flammable and brittle. Another type of insulation material commonly used in building construction is polyurethane foam. Polyurethane foam when applied, creates foam that insulates, seals air, resist heat transfer, and provide moisture barrier on walls and corners which are all beneficial to the internal component of the recovery vehicle. In any case the recovery vehicle does not withstand the impact upon landing and causes cracks and seams on the recovery vehicle, polyurethane foam is an effective insulation material that seals air and reduces air infiltration. The disadvantages of polyurethane foam is that it is flammable and the odor can be toxic which could cause health problem to the user if not properly handled and protected.

Criteria	**Weighting**	**Baseline* Fiberglass**	**Polyurethane foam**	**Polystyrene foam**
Resistance	9	0	1	-1
Thermal conductivity	9	0	1	1
Moisture-vapor permeability	3	0	-1	1
Cost	1	0	-1	-1
Total		**0**	**14**	**2**

Figure 22: Pugh Matrix for Hull Insulation [57]

A Pugh Matrix was used to determine the best insulation material for the recovery vehicle. All criteria listed are important except the cost because the overall functionality of the insulation material is what has the most importance. As a result, the polyurethane foam column highlighted in green is the best candidate. According to the mechanical properties, the lower the value of thermal conductivity and permeability, the better the insulation.

2.2.2.2.4.4 Primary Propulsion [TS]

As mentioned previously, the primary propulsion system will utilize an oscillating fin to convert the vertical heave motion of waves into forward motion, advancing the vehicle. It accomplishes this by maintaining a positive angle of attack between a rotating foil and relative flow, thus producing a lift force component in the direction of advance provided a vertical component of relative flow exists. As long as waves provide the vehicle with up and down motion, the vehicle will be thrusted forward.

This type of propulsion is ideal because it does not rely on electrical power from the batteries or solar recharging system, allowing it to travel in cloudy conditions or even at night where solar energy cannot be harnessed. The energy stored in the batteries could then be allocated to different electrical systems such as the servo-motors for steering or avionics for navigation control. Furthermore, since the recovery segment of the mission does not require a system with high speed capabilities, a steady type of propulsion is more suitable. Compared to other propulsion systems that rely on power from electrical sources, the oscillating fin propulsion provides our system with long distance-endurance capability that the mission requires.

Another significant benefit also offered by this type of propulsion includes the stabilization of the hull against pitch and roll motions. According to Terao, the vertical component of lift on the foil acts as a damping force that decreases pitch and roll motions, thus reducing the probability of capsize [58]. Since other propulsion systems, such as the conventional fixed pitch propeller or fan systems, do not provide this type of lift, the oscillating foil system is an ideal design for our mission.

The foils considered for the fin were symmetrical NACA profiles, each of different thicknesses. Therefore, the criteria used to judge each profile were the thickness, which increases with cost and weight, and the maximum gliding ratio, which represents the maximum ratio of the profile's coefficient of lift to its coefficient of drag. Since a smaller thickness and larger maximum gliding ratio were desired, a quantitative pugh matrix was developed, assigning higher scores for more desired values.

As shown in Figure 24, the NACA 0008 was found to yield the highest score due its optimal maximum gliding ratio, and thus performance, and its acceptable thickness, given as 8% of the foil cord length. By designing the foil system to orient itself with the angle of attack at which the maximum gliding ratio occurs, during the instants of maximum heave velocities, high thrusts may be imparted to the vehicle.

Criteria	**Weighting**	NACA 0006	NACA 0008	NACA 0010
Thickness (%)	5	6.00	8.00	10.00
(Criteria - Average)		-2.00	0.00	2.00
Normalized Value		2.00	1.00	0.00
Max Gliding Ratio	10	24.90	26.10	25.90
(Criteria - Average)		-0.73	0.47	0.27
Normalized Value		-1.57	1.00	0.57
Total		**-5.71**	**15.00**	**5.71**

Figure 24: Pugh Matrix for Primary Propulsion [59]

2.2.2.2.4.5 Auxiliary Propulsion [TS]

Since it is not within the scope of UHABS-6 mission to optimize the vehicle's speed, the criteria considered when selecting an auxiliary propulsion system were primarily derived from time and cost constraints. Therefore, factors such as the ease of integration with the vehicle hull, required time to manufacture, and overall cost, were used to select our propulsion system rather than performance related parameters such as maximum achievable speed or thrust.

One type of propulsion system we looked into for auxiliary propulsion utilizes an onboard fan to provide thrust to the vehicle. Although the thrust generated by this type of propulsion is usually less than the traditional submerged propulsion [12], complications stemming from potential leaks and vibration damage are circumvented, since the motor and propeller are placed above the water line with less fasteners and parts required, helping to reduce the system's weight, and simplify manufacturing processes. It follows that integration of this system with the hull is simpler since the motor and propeller shaft do not occupy space within the enclosure of the hull in contrast to the traditional submerged propeller would require compromise of the hull. Issues complicating this system stem from the lack of protection of the motor and propeller from wave and wind conditions that could cause damage to the propulsion system. However, given this system only serves auxiliary functions, and that winds are typically not strong enough near the ocean's surface to cause damage, these issues were not considered as important as the problems this system circumvents.

Another common propulsion design prevalent in the maritime industry utilizes a submerged fixed pitch screw propeller. This propulsion system provides relatively good performance in terms of speed and thrust by imparting kinetic energy to water, which has a higher density than air. However, as mentioned above, these aspects are unnecessary if other issues inherent of this system lead to increased time and cost. Since the shaft of a fixed pitch propeller is connected to a motor housed within the hull, protruding into the water, required manufacturing processes are complicated, thus leading to risks of increased costs or schedule overrun. Moreover, successful propulsion with this system is contingent upon many factors such as sufficient power input from the batteries and solar recharging system, along with adequate protection of electronic component from leaks and vibration damage. Therefore, these complications far outweigh the benefit of the system's ability to propel the vehicle at high speeds.

A motor actuated oscillating fin propulsion system was also considered as an auxiliary means of propulsion. This system relies on a set of linkages working in tandem with a motor and oscillating foil to impart thrust to the vehicle the same way fish use their fins or tails to propel forward. However, despite its potential benefits in providing a high propulsive efficiency [13], the glut of moving parts it requires in order to function adds extra weight and complicates design. Furthermore, complexities stemming from its dynamics, which involves creating certain phase differences between its heave and pitch motions, are current topics of research. This suggests that application of the oscillating fin is more suitable for a project based around technological innovation and development rather than the systems engineering mission of UHABS-6.

By considering the criteria and possible solutions discussed above, a pugh matrix shown in Figure 25 was devised, aligning with the heavy emphasis we've placed on time and manufacturing.

Criteria	**Weighting**	**Baseline* Fan**	**Fixed Pitch Propeller**	**Actuated Fin Oscillation**
Compatibility	5	0	-1	-1
Resistance to Impact	5	0	-1	-1
Weight	3	0	1	-1
Durability	3	0	1	1
Susceptibility to Leakage	3	0	-1	-1
Susceptibility to Vibration Damage	3	0	-1	-1
Cost	1	0	0	-1
Power Efficiency	1	0	1	1
Total		**0**	**-9**	**-15**

Figure 25: Pugh Matrix for Auxiliary Propulsion

The baseline fan propulsion system is observed to be the most suitable for our application for its ease of integration with the hull, and also and its high probability in surviving impact compared to the other systems. However, since the motors and propellers of the fan are above the water and exposed to windy conditions, there is a possibility that issues with the system's durability could arise. Further analyses will be conducted to determine optimal spacing and dimensions to mitigate this risk.

The Turnigy 2205/34 1500kv brushless motor was chosen from three different brushless motors for its relatively high maximum thrust output of 3.4 N at its low cost and weight, when operating with TSG Precision Sport 6x5 remote control aircraft propellers. A HobbyKing 20A ESC will be used to control the motor speed.

2.2.2.2.4.6 Steering [TS]

Similar criteria and weightings, as those used in the auxiliary propulsion trade study, were used to conduct a trade study on the steering system. However, since the success of the recovery segment of the mission depends on the steering mechanism for navigation, durability was chosen to bear a higher importance weighting than that of the auxiliary propulsion. We currently do not have any fail-safe designs to mitigate the risk of absolute failure in the event that the steering system breaks, so a robust mechanism must be implemented into the system from the start of the mission.

The steering systems considered in the trade study of steering systems involved a traditional rudder and servo-motor mechanism, a pair of propellers operating with a thrust differential, and either a rotating hull or propeller using vectored thrust to change direction.

The rudder and servo-motor system utilize conventional below-hull rudders actuated by servo-motors, and was considered for its ease of integration with the hull. Since many remote-control boats use this type of steering, methods for integration of the rudders with the vehicle, along with waterproofing methods are well-documented which could help with implementing this type of steering into our system.

Thrust differential was also considered because it does not introduce control surfaces on the bottom or top of the hull exposed to stressful conditions which may cause damage to the steering system. However, since it requires two motors to actuate the two propellers below the waterline of the hull, extra weight and leakage are issues that could potentially arise.

The last steering system considered is usually found in azimuthing propellers, and utilizes bevel gears to change the direction of thrust. With this type of propulsion, no control surfaces or servo-motors are required, which leads to an increased probability of survival upon impact and throughout the entire recovery segment. However, since bevel gears are required, and the hull would need to be compromised to accommodate the system, complexities of integration and manufacturing could engender issues threatening cost and schedule.

Criteria	Weighting	Baseline* Rudders	Thrust Differential	Vectored Thrust
Compatibility	5	0	-1	-1
Durability	5	0	1	1
Resistance to Impact	5	0	1	1
Weight	3	0	-1	1
Susceptibility to Leakage	3	0	-1	-1
Susceptibility to Vibration Damage	3	0	-1	-1
Cost	1	0	0	-1
Power Efficiency	1	0	-1	-1
Total		**0**	**-5**	**-1**

Figure 26: Pugh Matrix for Steering System

Figure 26 displays a pugh matrix that takes into account the advantages and disadvantages of each system. Although the robustness of the system is prioritized, the rudders were still observed to provide the most suitable design for its simplicity to integrate with the vehicle, along with its low weight and cost.

We plan to use the Turnigy TGY-WP23 waterproof metal gear digital servo-motors for its low weight and cost, as well as its ability to operate in water. By actuating 3D printed ABS plastic fins attached to these servo-motors, steering will be accomplished.

2.2.2.2.4.7 Power System [TS]

The power system subsumes the solar cells, charging circuit, and batteries, which will harness solar energy and provide power to the entire system. To ensure the system can be easily integrated, two Medium Adafruit 6 V solar panels will be connected to an Adafruit solar lithium ion/polymer charging circuit. Using a solar cell and charging circuit from the same manufacturer will ensure a sound interface, allowing efficient regulation and supply of the harnessed solar energy from the solar cells to the batteries. The battery we plan to use is the Turnigy Graphene 2200mAh 3s Lipo pack, which is widely used in the remote-control vehicle industry. Moreover, these batteries are lightweight and well within our budgets, and are distributed by HobbyKing, which is a well-known and reliable vendor.

2.2.2.2.4.8 Beacons [TS]

To ensure perceptibility of the vehicle through 100 yards in scrub, the vehicle will be equipped with an audio and visual beacon. A siren sound home security system was chosen for its low cost, and output of audible signal at 120 dB. A Cree XLamp XHP35 LED light will be attached to ensure visibility of the vehicle for its brightness and viewing angle, ~30000 mcd and 125 degrees respectively, which are relatively high for its cost. Both beacons will activate in the events where the system either makes landfall or enters visible proximity from the designated recovery site.

2.2.2.2.5 Requirements vs Implementation [TS]

ID	Requirements	Implementation
SSDR-24	Shall maintain the temperature of the payload within its operating limits.	● Utilize hand warmers as a temporary heat source during the flight segment of the mission
SSDR-25	Shall provide sufficient protection to internal components from impact damage.	● Use a hull design with a high strength material ● Use a hull geometry that qualifies high local stress concentrations
SSDR-26	Shall be equipped with a waterproof location beacon that is audible from a distance of at least 100 yards in scrub, and operating continuously for 24 hours.	● Use a perceptible/waterproof beacon capable of transmitting a working signal
SSDR-27	Shall be painted in a waterproof, highly visible color with attached recovery contact information and an American flag that will not be affected by water or sunlight.	● Paint the external hull of the vehicle with a bright color ● Attach a tag with the Professor and Project manager's contact information ● Attach an American flag in a waterproof casing
SSDR-28	Shall be equipped with a solar recharging system to provide sufficient power during navigation.	● Use two solar panels will to harness solar energy and charge the lithium polymer batteries
SSDR-29	Shall utilize the vehicle's location and orientation data to provide power to and actuate the steering and/or auxiliary propulsion systems.	● Use a microcontroller to execute necessary steering and/or thrust actuation
SSDR-30	Shall overcome oceanic conditions to traverse the distance between the system's landing position and shore.	● Use a durable hull that protects or prevents against capsize or impact damage
SSDR-31	Shall be capable of navigating through predesignated areas determined by predicted current and weather forecasts.	● The navigation code will take into account ocean current forecasts prior to launch ● Microcontroller will process inputs from the GPS and IMU to calculate waypoints
SSDR-32	Shall protect water exposure damage to electronic components.	● Use strong sealants and reliable waterproofing methods

2.2.2.2.6 Functional Flow Block Diagram with External Interfaces [TS]

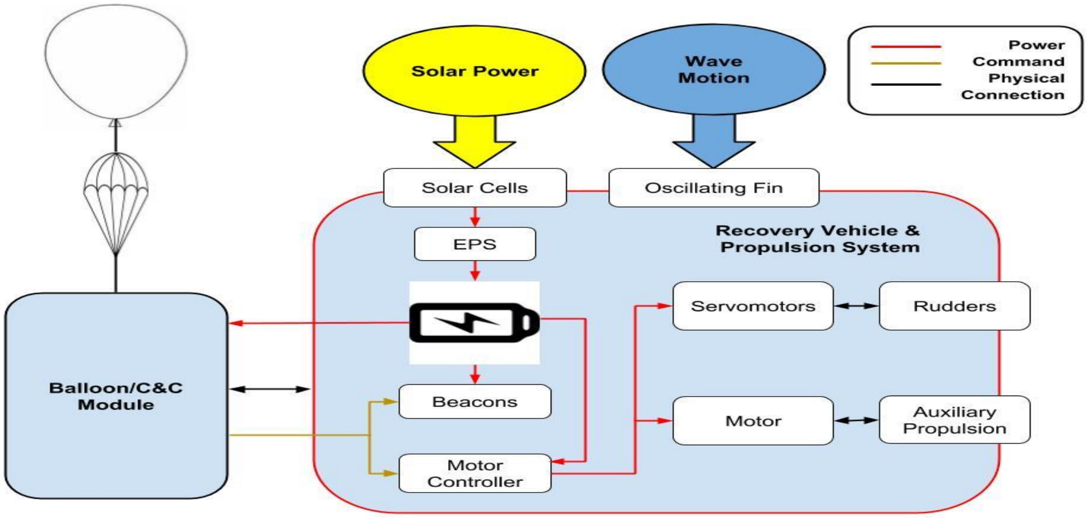


Figure 27: Functional Flow Block Diagram of the Recovery Vehicle & Propulsion with External Interfaces

2.2.2.2.7 Subsystem Mass & Volume Budget [TS]

Table 6: RVP Subsystem Mass & Volume Budget

Propulsion/Motor System			
Item	**Quantity**	**Mass (lbs)**	**Volume (in^3)**
Oscillating Fin	1	0.608	N/A
Servomotor	2	0.053	1.959
Motor	1	0.073	N/A
Electronic Speed Converter	1	0.066	0.942
Propeller	1	0.015	N/A
Rudder	2	0.022	N/A
Enclosure/Hull Structure			
Item	**Quantity**	**Mass (lbs)**	**Volume (in^3)**
Hull	1	2.200	N/A
Insulation	1	0.440	1.342
Steel Rod Connectors	2	0.257	N/A
Electronics			
Item	**Quantity**	**Mass (lbs)**	**Volume (in^3)**
Battery Pack	2	0.464	12.631
USB Lipo charger	1	0.016	0.165
Solar Cells	2	0.198	N/A
Visual Beacon	1	0.022	N/A
Audio Beacon	1	0.191	N/A
RVP Total		**4.913**	**43.707**

2.2.2.2.8 Subsystem Power Budget [TS]

Table 7: RVP Subsystem Power Budget

Propulsion/Motor System		
Item	**Quantity**	**Power (W)**
Oscillating Fin	1	N/A
Servomotor	2	16.8
Motor	1	130.0
Electronic Speed Converter	1	N/A
Propeller	1	N/A
Rudder	1	N/A
Enclosure/Hull Structure		
Item	**Quantity**	**Power (W)**
Hull	1	N/A
Insulation	1	N/A
Steel Rod Connectors	2	N/A
Electrical Power System		
Item	**Quantity**	**Power (W)**
Battery Pack	2	N/A
USB Lipo charger	1	N/A
Solar Cells	2	N/A
Visual Beacon	1	5.3
Audio Beacon	1	1.0
RVP Total (W)		**168.9**

2.2.2.2.9 Description [TS]

Table 8: RVP Subsystem List of Components

Propulsion/Motor System		
Item	**Quantity**	**Model/Material**
Oscillating Fin	1	ABS Plastic
Servomotor	2	Turnigy TGY-WP23 Waterproof Metal Gear Digital Servo
Motor	1	Turnigy 2205/34 1500kv Brushless
Electronic Speed Converter	1	HobbyKing 20A ESC 3A UBEC
Propeller	1	TGS Precision Sport Propeller 6x5 Black
Rudder	1	ABS Plastic
Hull and Insulation		
Item	**Quantity**	**Model/Material**
Hull	1	Kevlar 49
Insulation	1	Polyurethane foam
Steel Connecting Rods	2	Steel
Electrical Components		
Item	**Quantity**	**Model/Material**
Battery Pack	2	Turnigy Graphene 2200mAh 3S 45C LiPo Pack w/ XT60
Charging Circuit	1	USB / DC / Solar Lithium Ion/Polymer charger - v2
Solar Cells	2	Medium 6V 2W Solar panel - 2.0 Watt
Audio Beacon	1	Siren Sound Home Security
Visual Beacon	1	Cree XLamp XHP35

Table 8 displays a preliminary list of all the components we anticipate the RVP subsystem will need. The oscillating fin will be connected with steel rods to the hull, which houses all of the other propulsion components and electrical components except for the solar cells and beacons. The solar cells and beacons, which are external to the hull, will be attached to the hull with epoxy and also possibly fastened with screws. Lastly, connections between the various electronic components will be achieved through connecting wires, cables, and ports.

2.2.2.2.10 Required Analyses [TS]

We must conduct finite element analysis and computational fluid dynamics studies to analyze the system's behavior in response to external conditions imposed during the recovery segment of the mission. These analyses will reveal profiles of stress, displacement, velocity, and pressure, which will help to identify areas that require changes in terms of design or dimensions.

2.2.2.2.11 Risk Analysis [TS]

Table 9: RVP Subsystem Risk Management

Identification	Consequence	Probability of Occurrence	Risk Level	Risk Rank	Risk Mitigation (Reactive, Proactive)
Hull leaks causing water damage to electronics	4	2	8	Medium	- Conduct waterproof tests to ensure the hull is watertight
Vibration damaging electronic components or hull	3	3	9	Medium	- Ensure tight and secure fittings and connections between motors and propellers/rudders
Recovery vehicle capsizes	4	4	16	High	- Optimize the distribution of weight in the module
System breaks upon landing	5	3	15	High	- Reinforce structural supports connecting fin and hull - Conduct FEA simulations to locate and reduce high local stress concentrations

2.2.2.2.12 Testing Plan [TS]

Testing of the parts used in the recovery vehicle and propulsion subsystem will commence as parts are received, which we anticipate to be around mid-January. Notable components that require testing are the oscillating fin system used as the system's primary propulsion, the motor/servo-motors for auxiliary propulsion and steering, the hull which houses the components, and the audio and visual beacons.

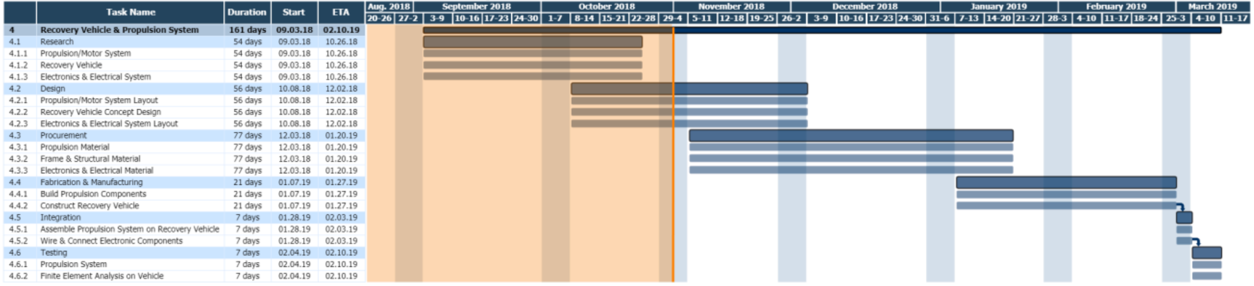
To test the oscillating fin propulsion system, we plan to coordinate with the School of Ocean and Earth Science and Technology to conduct wave tank tests to verify successful propulsion in waves generated within a controlled system. If this test is successful, we will take the system to a harbor or dock to test the system in swells where we can easily retrieve the system.

The servo-motors and motors will be tested by supplying a DC voltage regulated by an electronic speed converter to verify that the components function. The thrust of the motors will then be coupled with the propeller, to measure the thrust output by the auxiliary propulsion system to verify sufficient thrust generation.

The hull will require multiple tests to verify a sound structural integrity, as well as waterproof and insulation capabilities. To test the hull's structural integrity, we plan to conduct a drop test where which we drop the hull from a distance at which the system achieves the maximum descent speed of 15 ft/s upon impact with water. To verify the hull is waterproof, we will submerge the system in water for one hour to observe whether or not water is able to penetrate into the hull. For in the insulation test, we will coordinate with HSFL to use their thermal vacuum to simulate the system in the low temperature and pressure of the near space environment. We will use temperature sensors to verify successful maintenance of the system's internal hull within the anticipated component operating limits.

We plan to test the audio beacon by taking the beacon 100 years out in a forestry area, and observing whether the signals can be perceived by the tester. The visual beacon will be tested by simply turning it on both during night and day to verify sufficient emission from 100 yards away.

2.2.2.2.13 Subsystem Schedule using combined WBS and Gantt Chart [TS] [RT]



	Task Name	Duration	Start	ETA
4	**Recovery Vehicle & Propulsion System**	**161 days**	**09.03.18**	**02.10.19**
4.1	Research	54 days	09.03.18	10.26.18
4.1.1	Propulsion/Motor System	54 days	09.03.18	10.26.18
4.1.2	Recovery Vehicle	54 days	09.03.18	10.26.18
4.1.3	Electronics & Electrical System	54 days	09.03.18	10.26.18
4.2	Design	56 days	10.08.18	12.02.18
4.2.1	Propulsion/Motor System Layout	56 days	10.08.18	12.02.18
4.2.2	Recovery Vehicle Concept Design	56 days	10.08.18	12.02.18
4.2.3	Electronics & Electrical System Layout	56 days	10.08.18	12.02.18
4.3	Procurement	77 days	12.03.18	01.20.19
4.3.1	Propulsion Material	77 days	12.03.18	01.20.19
4.3.2	Frame & Structural Material	77 days	12.03.18	01.20.19
4.3.3	Electronics & Electrical Material	77 days	12.03.18	01.20.19
4.4	Fabrication & Manufacturing	21 days	01.07.19	01.27.19
4.4.1	Build Propulsion Components	21 days	01.07.19	01.27.19
4.4.2	Construct Recovery Vehicle	21 days	01.07.19	01.27.19
4.5	Integration	7 days	01.28.19	02.03.19
4.5.1	Assemble Propulsion System on Recovery Vehicle	7 days	01.28.19	02.03.19
4.5.2	Wire & Connect Electronic Components	7 days	01.28.19	02.03.19
4.6	Testing	7 days	02.04.19	02.10.19
4.6.1	Propulsion System	7 days	02.04.19	02.10.19
4.6.2	Finite Element Analysis on Vehicle	7 days	02.04.19	02.10.19

Figure 28: RVP Subsystem Combined WBS and Gantt Chart for PDR

As shown in Figure 27, we are currently in the middle of the design phase. For the next month, up until the Critical Design Review, we plan to finalize our vehicle hull design and dimensions, as well as the layouts of the propulsion and power system components. We plan to begin ordering parts around mid-November to receive them by January, and start fabrication and manufacturing at the start of next semester. Testing of individual parts will be conducted as soon as we receive them, while testing of the entire subsystem will commence once all the parts are verified to be functional and are configured within the fabricated hull.

2.2.2.2.14 Remaining Issues and Concerns [TS]

The biggest issues we need to address involve the completion of finite element and computational fluid dynamic analyses to gauge the structural and hydrodynamic performances of the hull, as well as force analyses on the oscillating fin to estimate speeds and system behaviors in response to various sea states. To accomplish these tasks, we plan to consult ocean engineering experts to find the most logical, accurate, or efficient ways to simulate and estimate the dynamics of the fin and hull when the system is imposed by conditions of ocean waves. Moreover, these tasks require the design of the hull to be set with all dimensions finalized, tasks which are currently in progress.

Other problems we need to address involve the interface design between the hull of the vehicle and the parachute of the Balloon/C&C module, along with the finalization of the electrical component selection and layout. Although we have completed a preliminary component listing, we will be actively researching and looking into other electronic components that may offer better suitability for the functions our system needs to perform.

In regards to the oscillating fin propulsion system, a spring that restores the fin back to a horizontal position must be attached to the fin to limit its rotation and maintain a positive angle of attack with the relative flow. Therefore, finding the optimal spring and attachment location are tasks we still yet must complete. Furthermore, we need to ensure the fin and its connections can survive the anticipated impact, by conducting simulations and tests, and making necessary design modifications and improvements.

2.2.2.3 Ground Station

2.2.2.3.1 Subsystem Team Roles & Responsibilities [BI]

Subsystem Lead - Bryson Inafuku & Subsystem Member - Ian Fujitani

- Responsible for communicating with PM on subsystem plans, monitoring and assigning subsystem tasks, and sharing updates/statuses on subsystem at team meetings.
- Responsible for all COSMOS programming and keeping track of all hardware that will be used for the ground station such as the antenna, computer, modem, receiver, LCD monitor, and the external battery source.
- Responsible for selecting a launch site, predicting the flight path of the C&C module, and obtaining flight permissions.

2.2.2.3.2 Top Level Requirements & Constraints for Subsystem [BI]

ID	Requirements/Constraints
TLSR-04	Shall land no more than five miles away from the shoreline of Oahu.
TLSR-06	Shall monitor the status of the BalloonSat throughout the entire mission.
TLSR-08	Upon ocean landing, shall autonomously navigate to a designated destination and send a transponder signal with its position as well as other engineering information to the Ground Station on a regular basis.
TLSR-09	Shall use Comprehensive Open-architecture Solution for Mission Operations Systems (COSMOS) software for mission operations.
TLSR-10	Shall collect video and images from the perspective of the BalloonSat module during the flight phase of the mission.
TLSR-11	Shall collect atmospheric and engineering data during the flight phase of the mission.

2.2.2.3.3 Subsystem Derived Requirements [BI]

ID	Requirements	Parent ID
SSDR-33	Shall be able to predict the flight path of the BalloonSat module.	TLSR-04
SSDR-34	Shall collect and report state-of-health (SOH) data of the BalloonSat module throughout the entire mission.	TLSR-06
SSDR-35	Shall be able to monitor and track the location of the BalloonSat module during the recovery phase.	TLSR-08
SSDR-36	Shall integrate COSMOS into both Ground Station & BalloonSat module.	TLSR-09
SSDR-37	Shall receive images and display a live-stream video from the BalloonSat module during the flight phase.	TLSR-10
SSDR-38	Shall be able to receive sensor data from the BalloonSat module during the flight phase.	TLSR-11
SSDR-39	Shall be able to send commands to the BalloonSat module to: release balloon at desired altitude, release parachute before ocean landing occurs, and activate autonomous recovery system.	TLSR-04

2.2.2.3.4 Major Trades [IF]

The major trades of the ground station involve the communications between the separate modules of the ground station. The first to be mentioned is the antenna, which will facilitate long range communications between the ground station and the C&C Module. Important characteristics for the antenna are capable distance range, and capable frequency range. The next major trade is in the type of video receiver used for receiving live-stream video from the C&C Module during the flight phase. Important characteristics for the video receiver are also capable distance and frequency range, as well as cost and power requirements. Trades on the ground station's modem, as well as LCD were also considered. For these components, the characteristics considered by the ground station are the transfer rate in Megabits per second, as well as the resolution and refresh rate.

Criteria	Weighting (1,3,5)	Whip/Monopole (baseline)	Yagi	Loop/Dipole
Range (distance)	5	0	1	1
Range (frequency)	3	0	1	0
Cost	1	0	-1	-1
Total		**0**	**7**	**4**

Figure 29: Pugh Matrix for Antenna [62][63][64]

Criteria	Weighting (1,3,5)	Kimpok Mini Wireless Video Transmitter (baseline)	200km LOS FPV/ UAV Video Transmitter	VFM Long Range Video Transmitter and Receiver	High-Powered Outdoor 2.4GHz Wireless Transmitter/Receiver
Range (distance)	5	0	1	0	0
Range (frequency)	3	0	0	-1	0
Power Requirement	3	0	1	0	1
Weight	1	0	-1	-1	-1
Cost	1	0	-1	-1	1
Total		**0**	**6**	**-5**	**3**

Figure 30: Pugh Matrix for Video Receiver [65][66][67][68]

Criteria	Weighting (1,3)	TP-Link TC-7610 DOCSIS 3.0 (8x4) Cable Modem (baseline)	NETGEAR DOCSIS 3.0 High Speed Cable Modem	SURFboard DOCSIS 3.0 8 x 4 SB6141 Cable Modem
Speed (Mbps)	1	0	0	0
Cost	3	0	-1	1
Total		**0**	**-3**	**3**

Figure 31: Pugh Matrix for Modem [69][70][71]

Criteria	Weighting (1,3)	Samsung SyncMaster 953BW (baseline)	Gateway FPD1975W	Asus VS197 19" Widescreen LCD Monitor
Resolution	1	0	0	-1
Refresh Rate	1	0	-1	0
Cost	3	0	1	-1
Total		**0**	**2**	**-4**

Figure 32: Pugh Matrix for LCD Monitor [72][73][74]

2.2.2.3.5 Requirements vs Implementation [BI]

ID	Requirements	Implementation
SSDR-33	Shall be able to predict the flight path of the BalloonSat module.	● Use a landing predictor program.
SSDR-34	Shall collect and report state-of-health (SOH) data of the BalloonSat module throughout the entire mission.	● Using programmed COSMOS code to collect and report SOH data and also making sure the connection between the transceiver aboard the payload module and the antenna at the ground station will not fail.
SSDR-35	Shall be able to monitor and track the location of the BalloonSat module during the recovery phase.	● Transceiver will send coordinate data to the antenna at the ground station from the GPS on the payload module.
SSDR-36	Shall integrate COSMOS into both Ground Station & BalloonSat module.	● COSMOS software will be set up on a windows laptop.
SSDR-37	Shall receive images and display a live-stream video from the BalloonSat module during the flight phase.	● Transceiver will send images and a live-stream video to the ground station.
SSDR-38	Shall be able to receive sensor data from the BalloonSat module during the flight phase.	● Transceiver will send sensor data to the antenna at the ground station.
SSDR-39	Shall be able to send commands to the BalloonSat module to: release balloon at desired altitude, release parachute before ocean landing occurs, and activate autonomous recovery system.	● Transceiver aboard the payload module and the antenna at the ground station will have constant communication and connection between each other until the end of the mission. ● Programmed COSMOS code to initiate an emergency release of the balloon just in case.

2.2.2.3.6 Functional Flow Block Diagram with External Interfaces [BI]

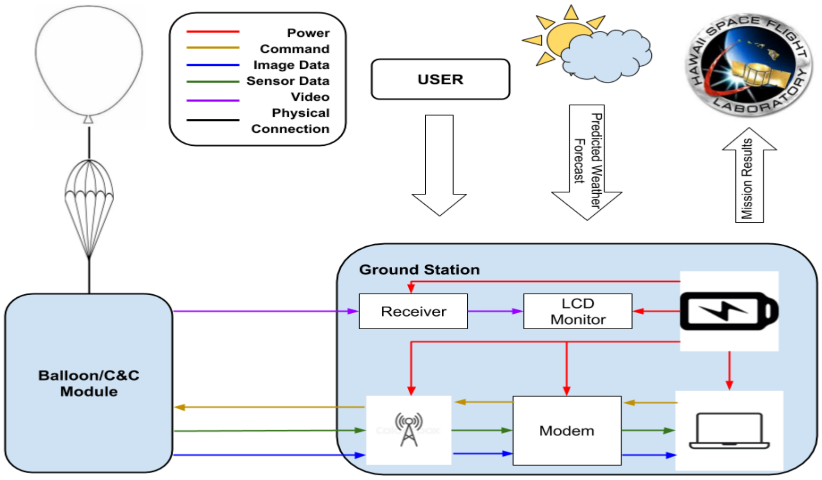


Figure 33: Functional Flow Block Diagram of the Ground Station with External Interfaces [20]

2.2.2.3.7 Subsystem Power Budget [BI]

Table 10: GS Subsystem Power Budget

Subsystem	Component	Sub-Components	Required Amps [mA]	Required Voltage [V]	Required Power [W]
Ground Station	Communications	Transceiver and Receiver	500	12	6
	Laptop		8000	20	160
Subtotal					166
20% Power margin					33
GS Total (W)					**199**

2.2.2.3.8 Description (including schematics, list of components, etc.) [BI]

As shown in Figure 33, the ground station consists of a laptop, an antenna, a modem, a receiver, a LCD monitor, and an external battery source. The external battery source will provide the necessary power to keep the laptop, antenna, modem, receiver, and the LCD monitor running throughout the whole mission. The ground station will be able to send commands from the laptop to the C&C module. Commands such as releasing the balloon at a desired altitude, releasing the parachute before ocean landing occurs, and activating the autonomous recovery system. The C&C module will collect image and sensor data and relay it to the ground station. Also, the ground station will receive a live-stream video from the C&C module. The two external faces that affect the ground station is the user and the predicted winds and ocean currents. All mission results will be given to HSFL.

2.2.2.3.9 Risk Analysis [BI]

Table 11: GS Subsystem Risk Management

Identification	Consequence	Probability of Occurrence	Risk Level	Risk Rank	Risk Mitigation (Reactive, Proactive)
Failure to track the location of the BalloonSat module	5	4	20	High	Ensure GPS data can be received when propulsion system is in the water and tested over various ranges.
Failure of receiving permission for a launch site	5	3	15	High	Research possible launch sites in advance.
Failure to integrate COSMOS	4	5	20	High	COSMOS workshops and additional assistance from HSFL mentors.
Failure to land in the ocean within five miles of Oahu	5	4	20	High	Use landing predictor program.
Failure of receiving image and sensor data	3	3	9	Medium	Ensure transceiver onboard C&C module can send image and sensor data over long distances.
Failure of receiving a live-stream video from the C&C module	3	3	9	Medium	Ensure transceiver onboard C&C module can send a live-stream video to the Ground Station.
Receive poor video quality	2	5	10	Medium	Integrate a receiver that can receive a live-stream video with good quality.

2.2.2.3.10 Testing Plan [BI]

During the testing phase, the antenna will be tested over various ranges on the ground. The connection between the transceiver and the antenna will be tested at a park because there should be no obstructions in the way. The test will be successful if the ground station can receive image and sensor data from the C&C module. Also, the test will be successful if the ground station can receive a live-stream video from the C&C module. In addition, the antenna will be tested when the propulsion module is in the water. The test will be successful if the ground station can receive GPS data from the propulsion module. Also during the testing phase, the ground station team will make sure that the ocean currents do not affect the communications and signals.

2.2.2.3.11 Subsystem Schedule using combined WBS and Gantt Chart [IF] [RT]

Shown below in Figure 34 is the subsystem Gantt Chart for the ground station. The colored line pictured shows our current stage in the project. Currently, the ground station is completing overall design for communications from the ground station to the C&C Module. This involves research into the specifics on our connection properties as well as confirming basic compatibilities. The ground station is also currently exploring the basics of COSMOS, which involves familiarization as well as learning how COSMOS executes missions. In the near future, the ground station is scheduled to acquire parts and do bench-level testing, as well as design and write code for basic testing executions in COSMOS.

	Task Name	Duration	Start	ETA
5	**Ground Station**	**161 days**	**09.03.18**	**02.10.19**
5.1	Communications	161 days	09.03.18	02.10.19
5.1.1	Design	91 days	09.03.18	12.02.18
5.1.2	Procurement	77 days	11.05.18	01.20.19
5.1.3	Test	35 days	01.07.19	02.10.19
5.2	COSMOS	161 days	09.03.18	02.10.19
5.2.1	Research & Familiarization	91 days	09.03.18	12.02.18
5.2.2	Set up	98 days	10.01.18	01.06.19
5.2.3	Integration	35 days	01.07.19	02.10.19
5.3	Launch Operations	35 days	01.07.19	02.10.19
5.3.1	Launch Site Determination	10 days	01.07.19	01.16.19
5.3.2	Wind & Current Calculations	14 days	01.17.19	01.30.19
5.3.3	System Landing	11 days	01.31.19	02.10.19
2	**System Integration**	**33 days**	**02.11.19**	**03.15.19**
2.1	System Assembly	14 days	02.11.19	02.24.19
2.1.1	C&C Module Integrated w/ Recovery Vehicle	7 days	02.11.19	02.17.19
2.1.2	Balloon & Parachute Attached to Recovery Vehicle	7 days	02.18.19	02.24.19
2.2	System Testing	2 days	02.25.19	03.15.19
2.2.1	Communications & Ground Station Connection	19 days	02.25.19	03.15.19
2.2.2	C&C Module Testing	15 days	03.01.19	03.15.19
2.2.3	Recovery Vehicle & Propulsion System Testing	12 days	03.04.19	03.15.19

Figure 34: GS Subsystem Combined WBS and Gantt Chart for PDR (See Appendix

2.2.2.3.12 Remaining Issues and Concerns [BI]

The remaining issues and concerns are seeking additional help from HSFL mentors regarding COSMOS, selecting a launch site, renting an electric generator to power the Ground Station for the duration of the mission, and lastly setting up a COSMOS session with AEV and BoxFarm.

<u>3.0 Management and Cost Overview</u> (15 PG Limit)

3.1 Team Organizational Chart [RT]

UHABS-6 is led by the Project Manager (PM), Jacob Keomaka, who oversees all mission objectives, requirements, and final decisions. He is responsible for team progression; communication with Dr. Sorensen and Saeed Karimi; announcing and scheduling meetings; promoting a safe, productive, and enjoyable working environment; and developing and applying the project management process. Under the PM, the Project Administrator (PA), Reginald Tolentino, is responsible for the financial aspect of the project from budgeting and acquiring funding; planning system and subsystem level tasks; assisting the PM; and communicating between upper management and subsystem leads. The System Integrator (SI), Austin Quach, is responsible for facilitating communication between subsystems; integrating the subsystems; managing system testing; and meeting with the PM and PA. Under the higher level management team, the team is broken into three main subsystems which include the BCCCM, RVP, and GS. The subsystem leads are Akira Yokoyama, Trevor Shimokusu, and Bryson Inafuku respectively and are responsible for generating and communicating tasks to the PM; assigning subsystem tasks and ensuring completion within the required time frame; scheduling subsystem meetings; and sharing updates and statuses of subsystem during general team meetings. The team's organizational chart can be seen below in Figure 35.

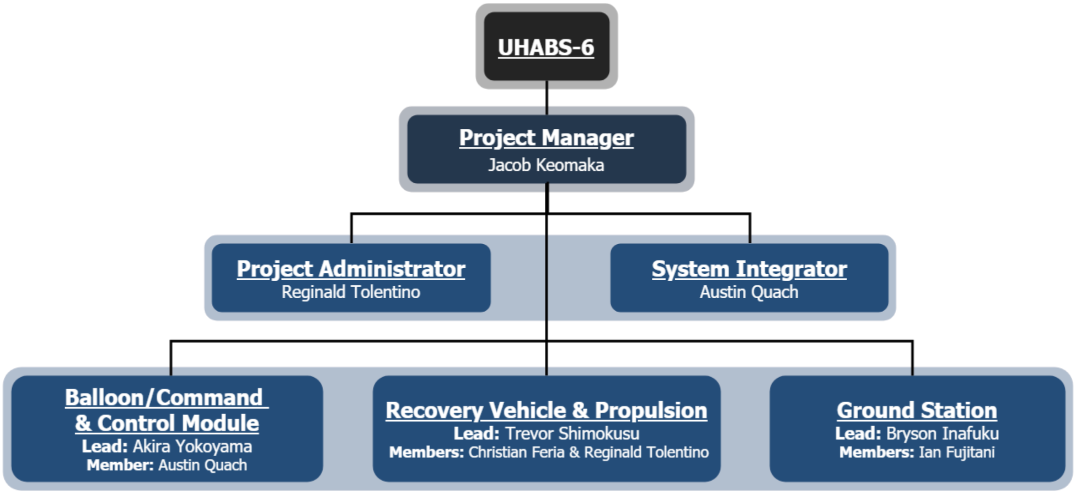


Figure 35: Team Organizational Chart

3.2 General Work Breakdown Structure [RT]

The general Work Breakdown Structure (WBS) in Figure 36 displays the breakdown from Level 1 to Level 3. Level 2 which includes Administration, System Integration, and the three subsystems captures the system level assignments, while Level 3 overarches the tasks that will be accomplished, which were derived from Level 2. For instance, the BCCM will first undergo research, then design, procurement, fabrication and manufacturing, integration, and finally testing. However, since the UHABS-6 team is taking a Systems Engineering approach, iterations between each sequential tasks will be conducted in order to mitigate unforeseen problems and potential failures during the integration and testing phase. In addition, the majority of these tasks are not interdependent meaning that certain tasks are able to overlap and initiate parallel to the prior task even before it has been completed. Refer to Appendix # for a more detailed WBS, which includes the Level 4 subtasks.

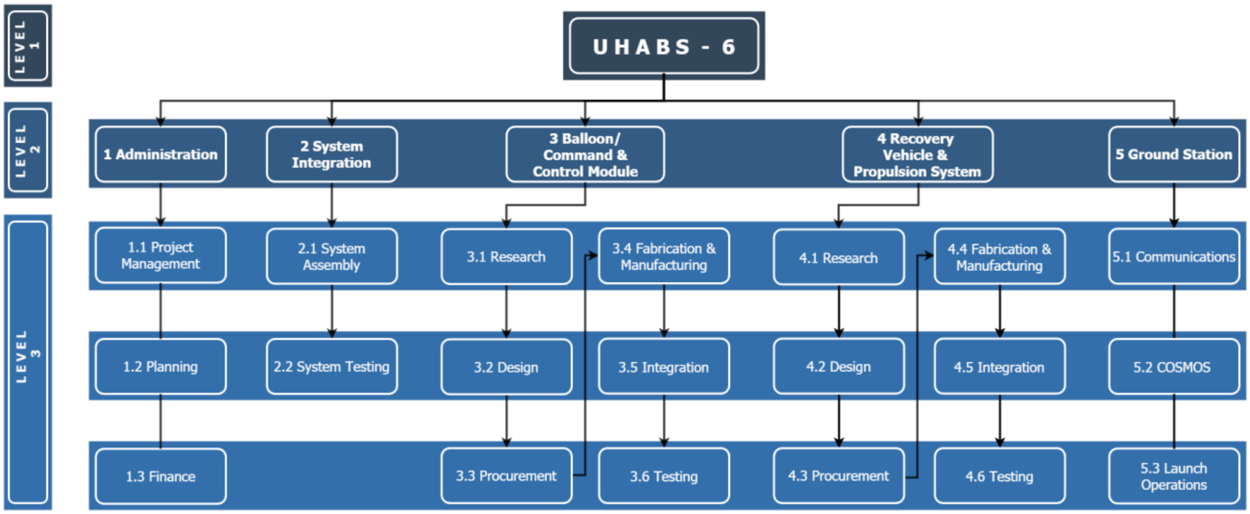
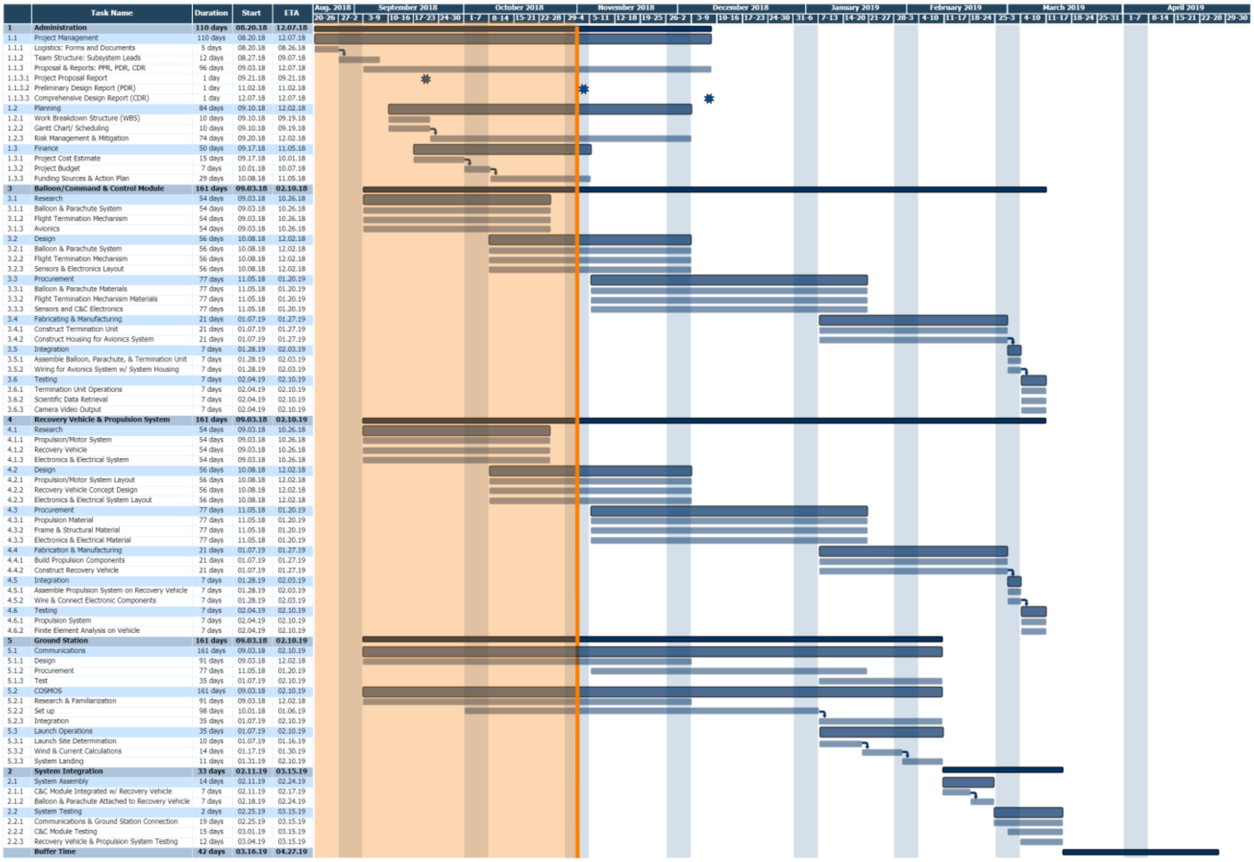


Figure 36: General Work Breakdown Structure

3.3 Gantt Chart [RT]

From the detailed WBS, the Gantt Chart in Figure 37 was generated. The UHABS-6 project started on August 20, 2018 and will have a completion date of all its tasks and operations by March 15, 2019 with a six-week buffer. From the system level, the overall project planning and finance with be completed by the end of the first semester in December 2018. With the orange line indicating the current status, the funding sources and action plan of the project's finances will be wrapping up; the BCCM and RVP subsystems, currently in the design phase, will begin the procurement process heading into the beginning of November 2018 with a full design model completed by December 2018; and the GS will continue to work on the design layout of the communications and the familiarization of COSMOS.



	Task Name	Duration	Start	ETA
1	**Administration**	**110 days**	**08.20.18**	**12.07.18**
1.1	Project Management	110 days	08.20.18	12.07.18
1.1.1	Logistics: Forms and Documents	5 days	08.20.18	08.26.18
1.1.2	Team Structure: Subsystem Leads	12 days	08.27.18	09.07.18
1.1.3	Proposal & Reports: PPR, PDR, CDR	96 days	09.03.18	12.07.18
1.1.3.1	Project Proposal Report	1 day	09.21.18	09.21.18
1.1.3.2	Preliminary Design Report (PDR)	1 day	11.02.18	11.02.18
1.1.3.3	Comprehensive Design Report (CDR)	1 day	12.07.18	12.07.18
1.2	Planning	84 days	09.10.18	12.02.18
1.2.1	Work Breakdown Structure (WBS)	10 days	09.10.18	09.19.18
1.2.2	Gantt Chart/ Scheduling	10 days	09.10.18	09.19.18
1.2.3	Risk Management & Mitigation	74 days	09.20.18	12.02.18
1.3	Finance	50 days	09.17.18	11.05.18
1.3.1	Project Cost Estimate	15 days	09.17.18	10.01.18
1.3.2	Project Budget	7 days	10.01.18	10.07.18
1.3.3	Funding Sources & Action Plan	29 days	10.08.18	11.05.18
3	**Balloon/Command & Control Module**	**161 days**	**09.03.18**	**02.10.18**
3.1	Research	54 days	09.03.18	10.26.18
3.1.1	Balloon & Parachute System	54 days	09.03.18	10.26.18
3.1.2	Flight Termination Mechanism	54 days	09.03.18	10.26.18
3.1.3	Avionics	54 days	09.03.18	10.26.18
3.2	Design	56 days	10.08.18	12.02.18
3.2.1	Balloon & Parachute System	56 days	10.08.18	12.02.18
3.2.2	Flight Termination Mechanism	56 days	10.08.18	12.02.18
3.2.3	Sensors & Electronics Layout	56 days	10.08.18	12.02.18
3.3	Procurement	77 days	11.05.18	01.20.19
3.3.1	Balloon & Parachute Materials	77 days	11.05.18	01.20.19
3.3.2	Flight Termination Mechanism Materials	77 days	11.05.18	01.20.19
3.3.3	Sensors and C&C Electronics	77 days	11.05.18	01.20.19
3.4	Fabricating & Manufacturing	21 days	01.07.19	01.27.19
3.4.1	Construct Termination Unit	21 days	01.07.19	01.27.19
3.4.2	Construct Housing for Avionics System	21 days	01.07.19	01.27.19
3.5	Integration	7 days	01.28.19	02.03.19
3.5.1	Assemble Balloon, Parachute, & Termination Unit	7 days	01.28.19	02.03.19
3.5.2	Wiring for Avionics System w/ System Housing	7 days	01.28.19	02.03.19
3.6	Testing	7 days	02.04.19	02.10.19
3.6.1	Termination Unit Operations	7 days	02.04.19	02.10.19
3.6.2	Scientific Data Retrieval	7 days	02.04.19	02.10.19
3.6.3	Camera Video Output	7 days	02.04.19	02.10.19
4	**Recovery Vehicle & Propulsion System**	**161 days**	**09.03.18**	**02.10.19**
4.1	Research	54 days	09.03.18	10.26.18
4.1.1	Propulsion/Motor System	54 days	09.03.18	10.26.18
4.1.2	Recovery Vehicle	54 days	09.03.18	10.26.18
4.1.3	Electronics & Electrical System	54 days	09.03.18	10.26.18
4.2	Design	56 days	10.08.18	12.02.18
4.2.1	Propulsion/Motor System Layout	56 days	10.08.18	12.02.18
4.2.2	Recovery Vehicle Concept Design	56 days	10.08.18	12.02.18
4.2.3	Electronics & Electrical System Layout	56 days	10.08.18	12.02.18
4.3	Procurement	77 days	11.05.18	01.20.19
4.3.1	Propulsion Material	77 days	11.05.18	01.20.19
4.3.2	Frame & Structural Material	77 days	11.05.18	01.20.19
4.3.3	Electronics & Electrical Material	77 days	11.05.18	01.20.19
4.4	Fabrication & Manufacturing	21 days	01.07.19	01.27.19
4.4.1	Build Propulsion Components	21 days	01.07.19	01.27.19
4.4.2	Construct Recovery Vehicle	21 days	01.07.19	01.27.19
4.5	Integration	7 days	01.28.19	02.03.19
4.5.1	Assemble Propulsion System on Recovery Vehicle	7 days	01.28.19	02.03.19
4.5.2	Wire & Connect Electronic Components	7 days	01.28.19	02.03.19
4.6	Testing	7 days	02.04.19	02.10.19
4.6.1	Propulsion System	7 days	02.04.19	02.10.19
4.6.2	Finite Element Analysis on Vehicle	7 days	02.04.19	02.10.19
5	**Ground Station**	**161 days**	**09.03.18**	**02.10.19**
5.1	Communications	161 days	09.03.18	02.10.19
5.1.1	Design	91 days	09.03.18	12.02.18
5.1.2	Procurement	77 days	11.05.18	01.20.19
5.1.3	Test	35 days	01.07.19	02.10.19
5.2	COSMOS	161 days	09.03.18	02.10.19
5.2.1	Research & Familiarization	91 days	09.03.18	12.02.18
5.2.2	Set up	98 days	10.01.18	01.06.19
5.2.3	Integration	35 days	01.07.19	02.10.19
5.3	Launch Operations	35 days	01.07.19	02.10.19
5.3.1	Launch Site Determination	10 days	01.07.19	01.16.19
5.3.2	Wind & Current Calculations	14 days	01.17.19	01.30.19
5.3.3	System Landing	11 days	01.31.19	02.10.19
2	**System Integration**	**33 days**	**02.11.19**	**03.15.19**
2.1	System Assembly	14 days	02.11.19	02.24.19
2.1.1	C&C Module Integrated w/ Recovery Vehicle	7 days	02.11.19	02.17.19
2.1.2	Balloon & Parachute Attached to Recovery Vehicle	7 days	02.18.19	02.24.19
2.2	System Testing	2 days	02.25.19	03.15.19
2.2.1	Communications & Ground Station Connection	19 days	02.25.19	03.15.19
2.2.2	C&C Module Testing	15 days	03.01.19	03.15.19
2.2.3	Recovery Vehicle & Propulsion System Testing	12 days	03.04.19	03.15.19
	Buffer Time	**42 days**	**03.16.19**	**04.27.19**

Figure 37: UHABS-6 Gantt Chart

3.4 Risk Analysis [RT]

Table 12: Project Management Risk Management

Identification	Consequence	Probability of Occurrence	Risk Level	Risk Rank	Risk Mitigation (Reactive, Proactive)
Late procurement of parts	4	4	16	High	-Buy emergency locally or evaluate part selection. -Start procuring parts post-PDR.
Not meeting deadlines	4	4	16	High	-Host team meeting addressing issue and make adjustments. -PM host weekly team meetings to remind members of upcoming deadlines and check on statuses of each task relating to the deadline.
Lack of funding	5	3	15	High	-Apply for scholarships and reach out to aerospace companies for potential funding. -Fundraising and personal funds
Lack of communication	4	2	8	Medium	-Team meeting addressing and correcting issue. -Top-level management meet weekly.
Significant change in design concept	4	2	8	Medium	-PM host meeting SE and Administration lead to make necessary adjustments. -PM ensures that the SE communicates effectively with subsystem leads.
Lack of organization	3	2	6	Low	-Top-level management meeting to address and correct issue. -Administration and PM coordinate with other and individually meet with SE and subsystem leads weekly.

3.5 Hardware Acquisition Status/Plan [RT]

The UHABS-6 team current procurement plan is to immediately order all the electrical components for the BCCM and GS subsystem. Identified in Table 12 as a high risk, proactive actions will be implemented with early procurement to begin in the beginning of November 2018 to start developing programs for the hardware and testing of the components and its interactions with COSMOS. Additionally, as November and December quickly approaches, the holiday season brings much trouble when it comes to shipping especially with items potentially coming from the mainland and internationally. Therefore, hardware acquisition will be a main priority leading toward the Critical Design Review and end of the semester.

3.6 Financial Budget & Funding Strategy [RT]

Based off of the subsystems' major trade studies and component selection, the total financial budget with 20% margin is $2,736. With the current source of funding from UHM Mechanical Engineering Department at $2000, the difference comes out to be $736, which must be covered from other forms of funding. A visual summary of the system and subsystem budget is shown in Figure 38. Since 'Lack of Funding' was identified as a high risk in Table 12, UHABS-6 has applied for funding through the Undergraduate Research Opportunities Program at UHM for an additional funding of $2,000; however, will not hear back until the end of the semester in December 2018. In addition, a presentation to Raytheon was done for potential funding, but there is no guaranteed funding from this source. As a reactive action, fundraising will be done in order to make up the difference if the $736 is not covered from the funding sources mentioned prior, before having to put in personal funds to meet the financial needs of UHABS-6.

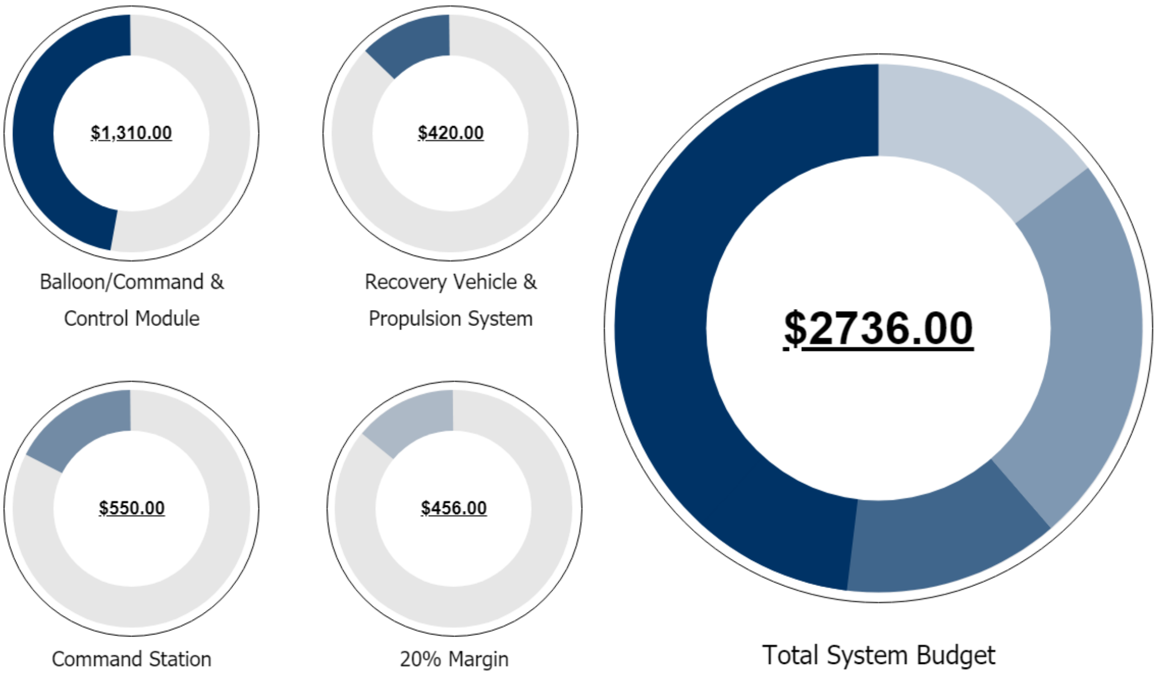


Figure 38: Total System Budget

3.7 Change Log & Configuration [RT]

The design concept for UHABS-6 has not been affected by any significant changes for PDR. The Change Log template is listed below in Table 13.

Table 13: Change Log Template

ID	Subsystem	Requestor	Change	Reason	Affected Subsystems	Date of Change	Approved By

Team members of UHABS-6 must fill out the Change Request Form in order to conduct any type of change affecting the design. The requestor must seek signatures and approval from the top-level management: PM, PA, and SI. Please refer to Appendix for Change Request Form.

4.0 Conclusion (1 PG Limit) [JK]

UHABS-6 has produced a design concept for the BalloonSat module that consist of an autonomous recovery vehicle with a hybrid-propulsion system. The team conducted trade studies to help select the best components to meet their derived requirements each subsystem. Furthermore, the overall UHABS-6 system will meet the system requirements, system operations, and system capabilities to achieve mission success. Post PDR, the team will refine their design in terms of dimensions, component selection/layout, and programming COSMOS. The team will begin procurement of components to start bench-level testing and prepare for CDR.

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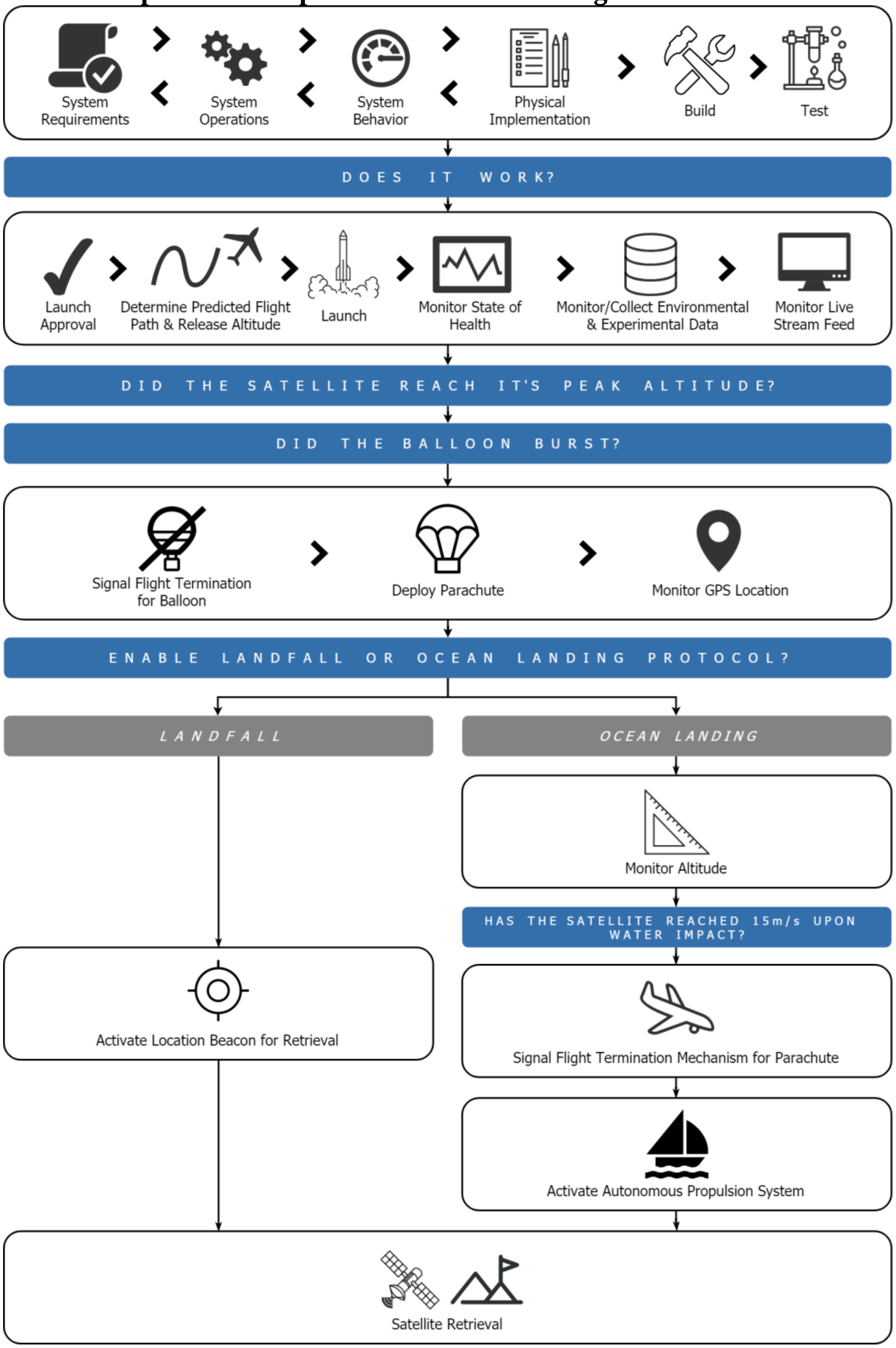
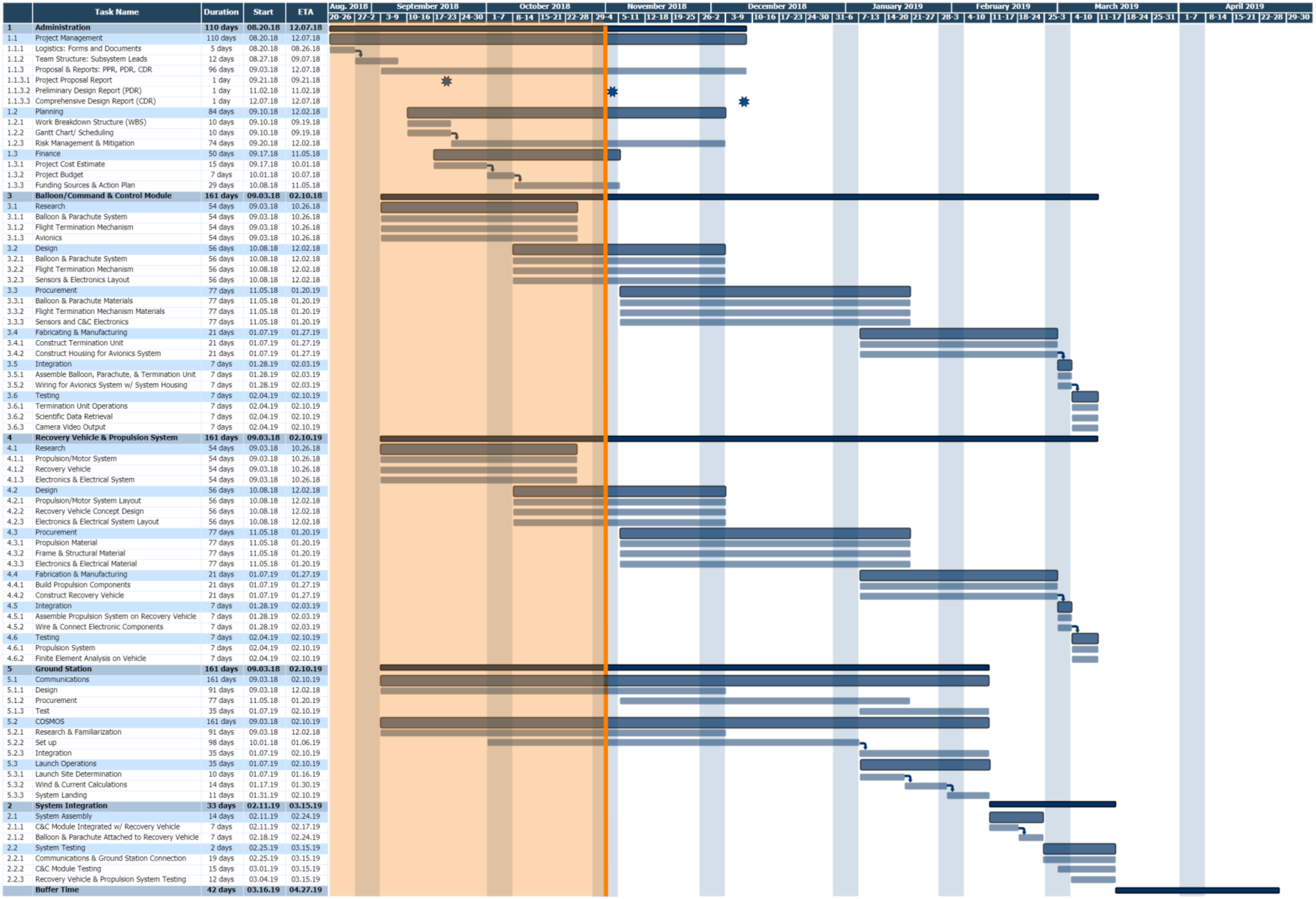
Appendix A: Development and Operations Procedure Diagram [RT]



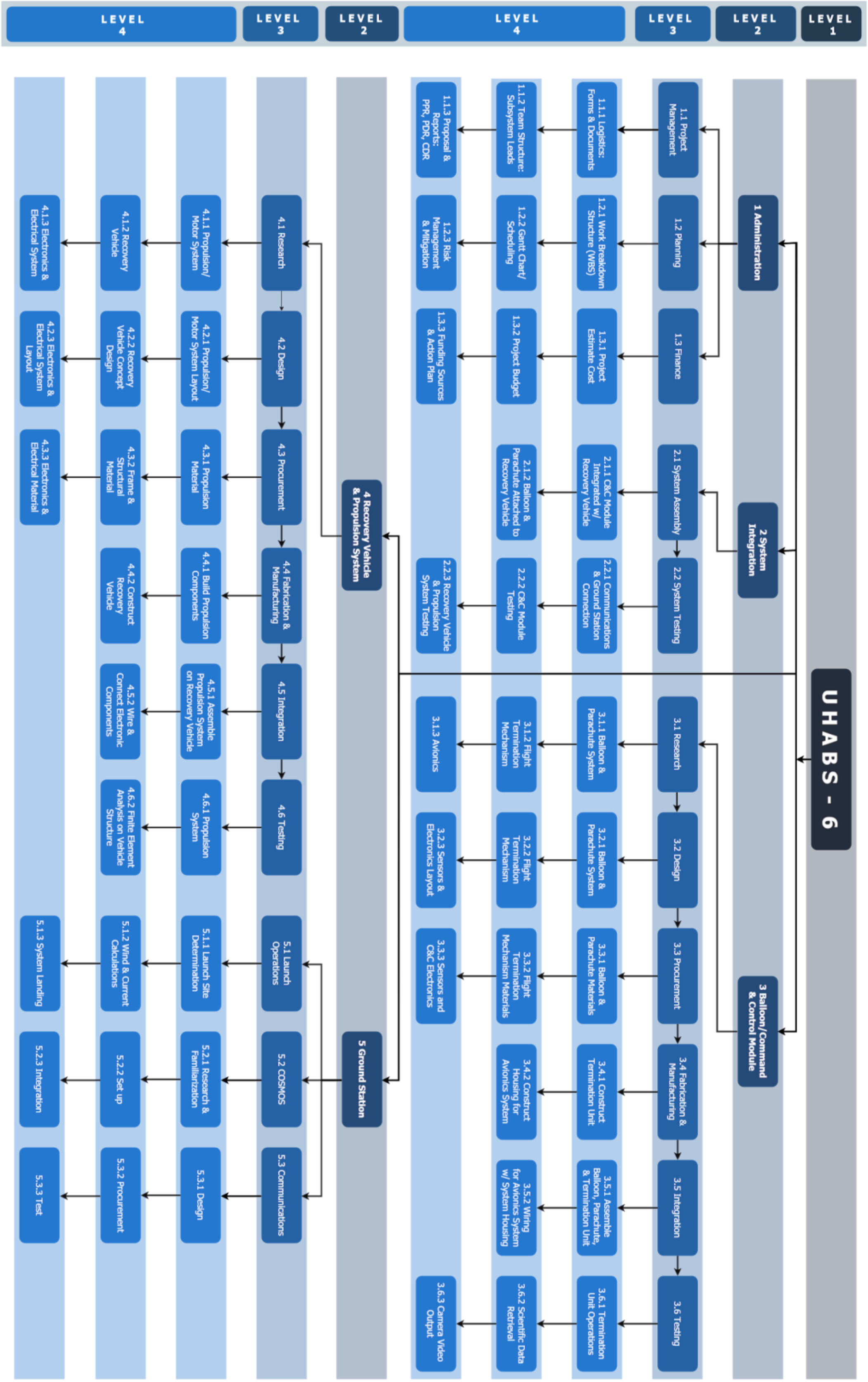
Appendix B: Gantt Chart

[RT]



	Task Name	Duration	Start	ETA
1	**Administration**	**110 days**	**08.20.18**	**12.07.18**
1.1	Project Management	110 days	08.20.18	12.07.18
1.1.1	Logistics: Forms and Documents	5 days	08.20.18	08.26.18
1.1.2	Team Structure: Subsystem Leads	12 days	08.27.18	09.07.18
1.1.3	Proposal & Reports: PPR, PDR, CDR	96 days	09.03.18	12.07.18
1.1.3.1	Project Proposal Report	1 day	09.21.18	09.21.18
1.1.3.2	Preliminary Design Report (PDR)	1 day	11.02.18	11.02.18
1.1.3.3	Comprehensive Design Report (CDR)	1 day	12.07.18	12.07.18
1.2	Planning	84 days	09.10.18	12.02.18
1.2.1	Work Breakdown Structure (WBS)	10 days	09.10.18	09.19.18
1.2.2	Gantt Chart/ Scheduling	10 days	09.10.18	09.19.18
1.2.3	Risk Management & Mitigation	74 days	09.20.18	12.02.18
1.3	Finance	50 days	09.17.18	11.05.18
1.3.1	Project Cost Estimate	15 days	09.17.18	10.01.18
1.3.2	Project Budget	7 days	10.01.18	10.07.18
1.3.3	Funding Sources & Action Plan	29 days	10.08.18	11.05.18
3	**Balloon/Command & Control Module**	**161 days**	**09.03.18**	**02.10.18**
3.1	Research	54 days	09.03.18	10.26.18
3.1.1	Balloon & Parachute System	54 days	09.03.18	10.26.18
3.1.2	Flight Termination Mechanism	54 days	09.03.18	10.26.18
3.1.3	Avionics	54 days	09.03.18	10.26.18
3.2	Design	56 days	10.08.18	12.02.18
3.2.1	Balloon & Parachute System	56 days	10.08.18	12.02.18
3.2.2	Flight Termination Mechanism	56 days	10.08.18	12.02.18
3.2.3	Sensors & Electronics Layout	56 days	10.08.18	12.02.18
3.3	Procurement	77 days	11.05.18	01.20.19
3.3.1	Balloon & Parachute Materials	77 days	11.05.18	01.20.19
3.3.2	Flight Termination Mechanism Materials	77 days	11.05.18	01.20.19
3.3.3	Sensors and C&C Electronics	77 days	11.05.18	01.20.19
3.4	Fabricating & Manufacturing	21 days	01.07.19	01.27.19
3.4.1	Construct Termination Unit	21 days	01.07.19	01.27.19
3.4.2	Construct Housing for Avionics System	21 days	01.07.19	01.27.19
3.5	Integration	7 days	01.28.19	02.03.19
3.5.1	Assemble Balloon, Parachute, & Termination Unit	7 days	01.28.19	02.03.19
3.5.2	Wiring for Avionics System w/ System Housing	7 days	01.28.19	02.03.19
3.6	Testing	7 days	02.04.19	02.10.19
3.6.1	Termination Unit Operations	7 days	02.04.19	02.10.19
3.6.2	Scientific Data Retrieval	7 days	02.04.19	02.10.19
3.6.3	Camera Video Output	7 days	02.04.19	02.10.19
4	**Recovery Vehicle & Propulsion System**	**161 days**	**09.03.18**	**02.10.19**
4.1	Research	54 days	09.03.18	10.26.18
4.1.1	Propulsion/Motor System	54 days	09.03.18	10.26.18
4.1.2	Recovery Vehicle	54 days	09.03.18	10.26.18
4.1.3	Electronics & Electrical System	54 days	09.03.18	10.26.18
4.2	Design	56 days	10.08.18	12.02.18
4.2.1	Propulsion/Motor System Layout	56 days	10.08.18	12.02.18
4.2.2	Recovery Vehicle Concept Design	56 days	10.08.18	12.02.18
4.2.3	Electronics & Electrical System Layout	56 days	10.08.18	12.02.18
4.3	Procurement	77 days	11.05.18	01.20.19
4.3.1	Propulsion Material	77 days	11.05.18	01.20.19
4.3.2	Frame & Structural Material	77 days	11.05.18	01.20.19
4.3.3	Electronics & Electrical Material	77 days	11.05.18	01.20.19
4.4	Fabrication & Manufacturing	21 days	01.07.19	01.27.19
4.4.1	Build Propulsion Components	21 days	01.07.19	01.27.19
4.4.2	Construct Recovery Vehicle	21 days	01.07.19	01.27.19
4.5	Integration	7 days	01.28.19	02.03.19
4.5.1	Assemble Propulsion System on Recovery Vehicle	7 days	01.28.19	02.03.19
4.5.2	Wire & Connect Electronic Components	7 days	01.28.19	02.03.19
4.6	Testing	7 days	02.04.19	02.10.19
4.6.1	Propulsion System	7 days	02.04.19	02.10.19
4.6.2	Finite Element Analysis on Vehicle	7 days	02.04.19	02.10.19
5	**Ground Station**	**161 days**	**09.03.18**	**02.10.19**
5.1	Communications	161 days	09.03.18	02.10.19
5.1.1	Design	91 days	09.03.18	12.02.18
5.1.2	Procurement	77 days	11.05.18	01.20.19
5.1.3	Test	35 days	01.07.19	02.10.19
5.2	COSMOS	161 days	09.03.18	02.10.19
5.2.1	Research & Familiarization	91 days	09.03.18	12.02.18
5.2.2	Set up	98 days	10.01.18	01.06.19
5.2.3	Integration	35 days	01.07.19	02.10.19
5.3	Launch Operations	35 days	01.07.19	02.10.19
5.3.1	Launch Site Determination	10 days	01.07.19	01.16.19
5.3.2	Wind & Current Calculations	14 days	01.17.19	01.30.19
5.3.3	System Landing	11 days	01.31.19	02.10.19
2	**System Integration**	**33 days**	**02.11.19**	**03.15.19**
2.1	System Assembly	14 days	02.11.19	02.24.19
2.1.1	C&C Module Integrated w/ Recovery Vehicle	7 days	02.11.19	02.17.19
2.1.2	Balloon & Parachute Attached to Recovery Vehicle	7 days	02.18.19	02.24.19
2.2	System Testing	2 days	02.25.19	03.15.19
2.2.1	Communications & Ground Station Connection	19 days	02.25.19	03.15.19
2.2.2	C&C Module Testing	15 days	03.01.19	03.15.19
2.2.3	Recovery Vehicle & Propulsion System Testing	12 days	03.04.19	03.15.19
	Buffer Time	**42 days**	**03.16.19**	**04.27.19**

Appendix C: Detailed Work Breakdown Structure [RT]



Appendix D: Change Request Form [JK]

UHABS-6 Change Request Form

Requested by:______________________

Subsystem: BCCM RVPS GS

Position:____________________________

Date of Request:______________________

Change Request #:___________________

Description:

Details:

Justification for Change:

Timeline/Action Plan to Implement Change:

Budget Changes:

Attachments:

- ☐ Detailed timeline with change
- ☐ Itemized budget for the change
- ☐ Drawings and analysis
- ☐ Updated schematic with change
- ☐ Other:_____________________

Project Manager: ☐YES ☐NO

______________ ____________

Jacob Keomaka *Date*

System Integrator: ☐YES ☐NO

______________ ____________

Austin Quach *Date*

Administration: ☐YES ☐NO

______________ ___________

Reggie Tolentino *Date*