-- UHABS-5 Mission Project Proposal

Zeppelin

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Executive Summary [RP]

The University of Hawaii Advanced BalloonSat #5 (UHABS-5) is the first BalloonSat project at UH to be done as an ME 481 senior design project as opposed to an ME 419 Astronautics project. This year, instead of having three months to complete the project, the team will have one full academic year (both fall and spring semesters) to fully design, build, test, and launch a fully functional BalloonSat.

To improve upon previous BalloonSat missions, UHABS-5 will use leftover material from past missions to thoroughly research and test methods in order to find ones that are best suited for a successful mission. Recycling the materials and resources from past projects that work the best for the mission will allow for better allocation of funds. Having a lower-cost BalloonSat will give more flexibility for testing more prototypes and purchasing more materials.

The goal of the UHABS-5 mission is to *provide a reliable high altitude test platform in a balloon satellite that will be operated with the COSMOS software, collect environmental data in a near-space environment and, upon safe descent onto the ocean, autonomously propel itself to a designated recovery site.* To be considered successful, the BalloonSat should ultimately be able to carry a 12-pound maximum payload, consisting of multiple modules that weigh no more than 6-pounds each, into a near-space environment with an altitude nearing 100,000 feet. While doing this, it should also be collecting atmospheric data while flight testing the Comprehensive Open-architecture Solution for Mission Operations System (COSMOS) software, which is used in the Hawaii Space Flight Laboratory (HSFL) here at the University of Hawaii. Furthermore, upon landing in the ocean, the BalloonSat will be programmed to autonomously propel itself to a designated recovery site while maintaining full functionality. This will remove environmental concerns of losing large pieces of styrofoam in the ocean, and prevent losing expensive hardware if the modules got lost. Upon retrieval, the BalloonSat and all of its hardware shall remain mostly intact.

UHABS-5 will be broken down into three subsystems in order to satisfy the objectives and success criteria: ground station, balloon and command & control (c&c) module, and payload and propulsion module. The ground station is responsible for monitoring the real-time data from the BalloonSat (such as state of health and location) and sending commands. The balloon and c&c module contains all of the hardware and sensors for the data, such as a DAQ, thermocouples and an SD card for storage, as well as the parachutes and tethers to slow the descent. This module should be as lightweight as possible since it will be towed to the recovery site by the propulsion module. The payload and propulsion module will hold the cameras, as well as the autonomous recovery system, which will be similar to a small boat.

Balloon satellites are commonly used to research atmospheric conditions. For example, due to the high concentration of hurricanes in the Atlantic Ocean, the forecasters have been launching weather balloons to track their locations, since they are able to capture footage from the atmosphere at a generally low cost [1]. An autonomous recovery, especially in Hawaii where it would most likely land in the ocean, would help with the environmental concerns that come with losing hazardous materials in the ocean. It would also prevent the loss of expensive hardware and recorded data from the satellite. If the recovery system works, it would be beneficial not only for UHABS-5, but other BalloonSat missions and future recovery methods of various spacecraft and satellites.

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Acronyms and Abbreviations

ASUH	Associated Students University of Hawaii
C&C	Command and Control
COSMOS	Comprehensive Open-Architecture Solution for Mission Operations Systems
CT & DH	Command, Telemetry, and Data Handling
EPS	Electrical Power Subsystem
FAA	Federal Aviation Administration
FCC	Federal Communication Commission
P&P	Payload and Propulsion
SAPFB	Student Activity Program Fee Board
SPACER	Safety Tip, Purpose, Agenda, Expectations, Roles
SSD	System Specification Document
UHABS	UH Advanced Balloon Satellite
UROP	Undergraduate Research Opportunity

1 Introduction

1.1 Balloon Satellites [RP]

Balloon satellites (BalloonSat), are modules that use a helium-filled weather balloon to launch payloads into the stratosphere. These balloons are designed to reach altitudes of up to 100,000 feet in order to simulate space-like conditions. These balloons are often used to conduct research and collect atmospheric data. The payload that they carry consist of hardware and cameras. The hardware is necessary to relay and assess data before, during, and after the launch. The type of telemetry data include the balloon's location, temperature, state of health.The onboard cameras record video and photo footage during the launch. After reaching a certain altitude, the balloon pops, or is given a command from its ground station and begins descending back to earth. Once it lands, teams are able to recover the module and analyze its condition post-mission.

1.2 Legacy Projects [RP, JKY]

UHABS-5 is fortunate enough to have four UHABS missions preceding it. These four missions will heavily aide in the design process for UHABS-5. Having access to most of the previous mission's resources will ensure that the team will be able to analyze and research their methods and errors. This will allow us to figure out which aspects of previous missions were most difficult to accomplish, which systems did not work, and, if any missions were unsuccessful, what the causes were. Having previous projects with similar objectives allows for making improvements to old methods to ensure that UHABS-5 is complete and successful in fulfilling all of its requirements and objectives.

Theia 1 MACKworks launched in Spring 2009, successfully bringing a balloon satellite payload into the atmosphere. The module collected various pictures and videos of high altitude. Theia 1 was a special mission because it was the first one to be launched and recovered. It used a 7 megapixel digital camera with 1 gigabyte memory cards.

UHABS-2 MoonReika was the ME 419 class project of Spring 2014. The capabilities of MoonReika was not tested due to the lack of time that the team faced. Because of this, UHABS-2 focused more on the design and structure of their system in hopes to give the next mission a headstart. The design they chose followed a saucer shape for stability, due to wind deflection on their choice of geometry.

UHABS-3 was the ME 419 class project of Spring 2015. This team incorporated an Ocean Mode to their balloon satellite design. Because time was not used wisely, they did not meet their objectives in time and had many issues with their hardware and software. However, they succeeded in providing a valuable lesson for future UHABS projects.

UHABS-4 Clementine launched in Spring 2017 during ME 419. They incorporated a UAS system within their balloon satellite, which would fly their payload back to base. Although they never had a chance to test their UAS system due to technical issues at the last minute, it gave future projects an idea that could be improved.

1.3 COSMOS [KL]

COSMOS (Comprehensive Open-architecture Solution for Mission Operations Systems) would be a highlight aspect of this balloon satellite mission as past projects was never successful in implementing COSMOS into past designs. COSMOS can proved to be a broad and powerful tool if this UHABS-5 is proved to be successful and here why. COSMOS was developed between Hawaii Space Flight Laboratory (HSFL) and NASA Ames Research Center. Its original intent was to support the development and operations of one or more small spacecraft. By successfully implementing COSMOS into this balloon satellite it will demonstrate COSMOS's abilities to be expanded into broader application. Essentially COSMOS is a system that is capable of communicating with multiple modules such as satellites, ground stations, UAVs, and etc. These modules in COSMOS's are known as nodes and agents as demonstrated below in **Figure 1.1**[2] . The agents would constantly communicate with between the modules and the COSMOS software that monitors and reports back and on going changes such as the telemetry of each the modules. As it communicates through COSMOS it ultimates relays back into the ground station network. The software is aimed to easily add or removal additional modules.

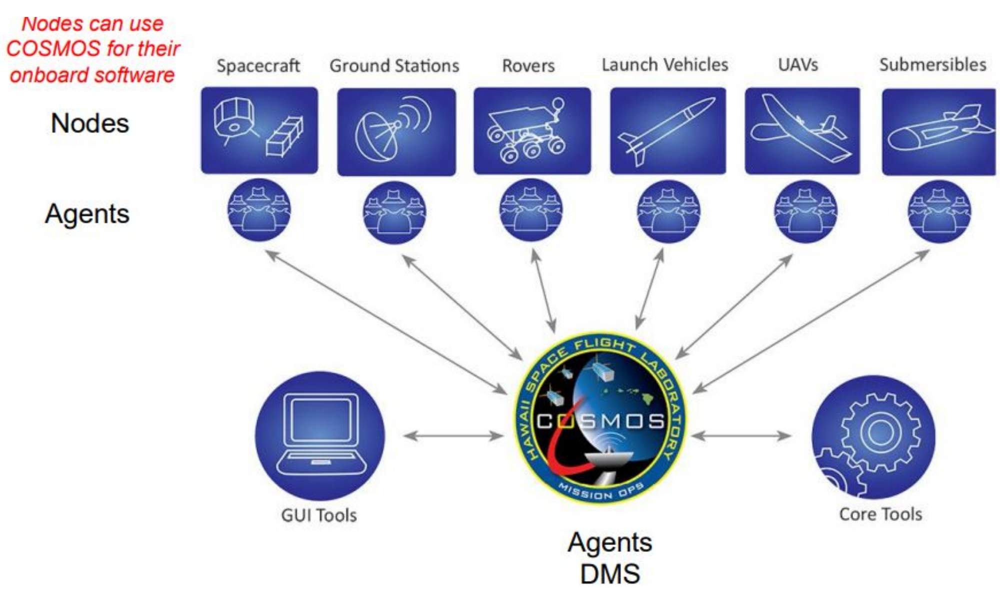

Figure 1.1: A general overlay involved with the communication of nodes and agents of the nodal architecture of COSMOS

COSMOS also offers an abundance of features and interfaces that are relevant in performing mission functions just as Mission planning & scheduling, contact operations, data management, mission analysis, anomaly resolution, simulators & testbeds, ground network, payload operations, flight dynamics and system managements as shown below in **Figure 1.2**[2]. The figure demonstrates how all these features are communicated back to COSMOS, engineers, mission team, and payloads, which relays it all back to the ground station network.

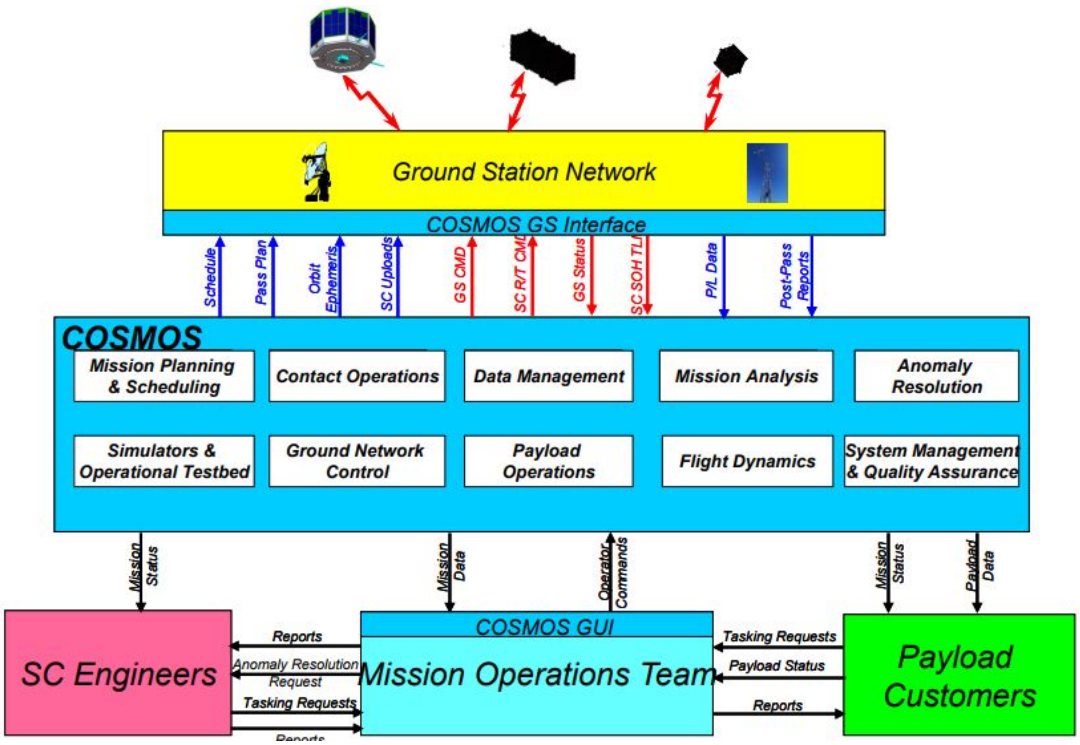

Figure [1.2]: A display of features presented in the middle from COSMOS functional architecture

Although the development of COSMOS is no longer being developed by HSFL or NASA, by integrating and successfully completing UHABS-5's mission it will prove its broad capabilities which may give enough initiative to continue the development COSMOS further.

2 Problem Statement [JT]

Balloon satellites are generally low-cost, quick deploying satellites that collect data and perform other miscellaneous tasks in the stratosphere. However, the balloon satellite's descent back to ground level is highly dependent on variables outside of the user's control, making it difficult for the system to land in a particular area. This problem is magnified when a balloon satellite is launched in close proximity to a large body of water (i.e. Pacific Ocean) where the system will become damaged or completely lost if submerged in said body of water. Therefore, there is a need for a balloon satellite that can not only survive a descent from high altitude, but also autonomously propel itself to a recovery site in a marine environment.

With a solution to a recoverable balloon satellite system, a larger array of experiments and data collection can be conducted in the stratosphere where information is unable to be transmitted to a ground station and must be stored and recovered on board the balloon-sat. The capacity to perform more experiments and test different theories aboard the balloon-sat will eventually lead to breakthroughs in technology and space travel. These breakthroughs have a significant impact on society, as they are prevalent in typical everyday lives (i.e. communications, transportation, logistics, etc.).

Current balloon satellite systems that fail to be recovered can have detrimental effects on the environment. The most common material used on balloon satellite payloads is Styrofoam, as it is both durable and provides insulation for the electronics inside. According to Science Learning Hub [3], Styrofoam is not considered “eco-friendly”, with a Styrofoam cup having a lifespan of 500+ years (to biodegrade). A recoverable balloon-satellite system will eliminate the amount of pollution left behind from non-recoverable balloon-satellite system without compromising the structural integrity and insulation provided from using Styrofoam in the system framing.

From an ethical perspective, an unmanned balloon-satellite system, as proposed, will have to operate within certain boundaries and specifications established by the FAA (Federal Aviation Administration). The FAA [4] implanted these limitations 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 the designated constraints.

Majority of balloon-satellite designs proposed by other teams do not account for their system landing in a body of water. The generic system design consists of a Styrofoam structure payload equipped with temperature and atmospheric sensors, on-board camera, and GPS. A helium filled high-altitude balloon hoists the system into the stratosphere. Upon the high-altitude balloons rupture, the payload system deploys a parachute to slow its descent back to ground level. The system is tracked via GPS by a “chase” team that will follow the trajectory of the balloon satellite and retrieve the system as it lands. Zeppelin’s model eliminates the need for a chase team as the proposed design will lock onto the ground station’s coordinates and autonomously maneuver itself to said coordinates. The design will also account for the varying oceanic environment and will be weather-sealed to protect the payload.

3 Technical Overview

3.1 Mission Statement

The UHABS-5 mission shall provide a reliable high altitude test platform in a balloon satellite that will be operated with the COSMOS software, will collect environmental data in a near-space environment and upon safe descent onto the ocean, autonomously propel itself to a designated recovery site.

3.2 Objectives and Success Criteria [KL]

The mission for UHABS-5 will allow the use of components, equipments, and software from past ME 419 BalloonSat project. With the available resources and funding, UHABS-5 shall design a balloon satellite to meet the objectives of two tasks given.

The first task will be to build a high altitude balloon satellite system that can carry a small payloads that does not exceed the weight of 12 lbs. This balloon satellite shall be constructed of waterproof material and painted in high visible color with recovery information attached that will not deteriorate by water of sun. It shall be capable of ascending to an altitude 100,000 ft and gather environmental measurements, images and science data. These data may be stored onboard to the satellite or transmitted to the ground station. Thereafter the balloon shall burst or have the ability to release from the balloon in order to begin its descent. During the descent, the module shall not fall faster than 15 ft/s with its designated parachute. Upon landing, the balloon satellite shall be able to continuously function for at least 24 hours and will be capable of emitting an audible signal that can be heard from 300 ft. Throughout its journey the BalloonSat shall be able to communicate to ground station in updating its position and speed through GPS.

The second tasks encompasses the recovery system for the balloon satellite. The balloon satellite shall be capable of to propelling itself through the ocean current and wind toward its recovery destination upon landing onto the ocean. It shall have the capability to recharge its batteries through the use of solar cells in order to signal its information to the ground control throughout its journey to the recovery site.

The majority of its success of this mission be placed majority of its weight to the recovery portion. The recovery phase is emphasised because not only has this never been done from previous years, but it also allow the the balloon satellite to be reused for future missions. The next criteria of success will be either linking back the desired data back to ground station in real time or having the on board data be recovered back from its recovery phase.

3.3 Constraints [YT]

The UHABS-5 project is subject to many constraints due to the nature and location. With the high possibility of it landing in water, the UHABS-5 module and its payload has to meet the operational requirements listed in the objectives above for retrieval. The module and payload also has to meet the weight restriction of 12 lbs total, with each module not exceeding 6 lbs. The balloon cannot use a rope or other device for suspension of the payload that requires an impact force of more than 50 pounds to separate the suspended payload from the balloon. Due to the high altitude nature of the project, the modules and its onboard equipments must be able to withstand the pressure difference and temperature change. All design, fabrication, testing, and launch must be completed according to the budget and time frame stated in later sections. The project must obey all federal regulations listed below regarding safety, equipment, registration, launch site, and operation.

- Federal Aviation Administration (FAA) – FAA Part 101 and 14 CFR Part 48
- Federal Communications Commission (FCC) – FCC 22.925

3.4 Top Level Requirements Overview [KC]

3.4.1 Mission Requirements

1. The UHABS-5 shall contain a latex balloon, parachute, command and control (C&C) module, payload and propulsion (P&P) module, and any necessary accessory equipment.
2. The UHABS-5 team shall design the system, provide all required components and materials, fabricate the modules, integrate the system components and test the completed system, launch the system and operate it, and recover the system to analyze and report the mission data.
3. All necessary instrumentation shall be installed within the P&P and C&C modules.
4. The UHABS-5 balloon release altitude shall be calculated prior to the launch date to determine the projected flight path, which should help to fixate the landing zone for the recovery process.
5. The UHABS-5 shall ascend to a set height, where it the balloon will be released from the UHABS-5 either by a preset command or by initiation from ground systems. Both shall be made available to add redundancy to the release process.
6. After balloon release, the UHABS-5 shall descend via parachute while maintaining a downward speed equal to or less than 15 ft/sec during impact.
7. The P&P module shall initiate the autonomous propulsion system after landing and traverse to a predetermined location, where it shall standby for retrieval.
8. The P&P module shall be sufficiently powered to prevail over oceanic wind and waves during navigation.
9. The P&P module shall possess the means to periodically communicate its position to the ground station.
10. Each module shall possess a means of identification and US flag displayed on the exterior. The means of identification shall contain contact information to aid in the return of the modules should they be prematurely recovered. These items shall be both water and sun proof.
11. Each module shall possess a bright or reflective finish that is highly visible on the ocean.
12. Each module shall be waterproof and stay afloat for a minimum of 24 hours.

13. The P&P module shall have an audible location beacon capable of producing an audible signal through 100 yards of scrub. This beacon shall be waterproof and remain operative for a minimum of 24 hours.
14. The internal temperature of the UHABS-5 shall be regulated to the operating limits of its internal components at all times.
15. The UHABS-5 mission should use previous ME 419 class projects, including hardware, software, and design when feasible.

3.5 Operational Concept [RP]

The BalloonSat will be broken down into three subsystems: Balloon and C&C Module, Payload with Propulsion Module, and the Ground Station. A further breakdown of each system's components can be found in figure 2.2.

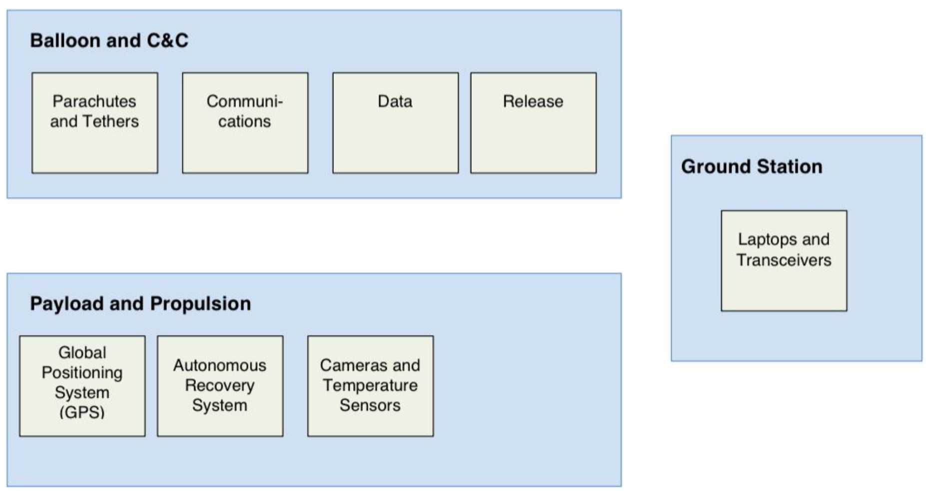

Figure 3.1: Simple Breakdown of Each Subsystem and its Components

The Balloon and C&C module will contain the parachutes and tethers that will slow the descent of the balloon, as well as all of the necessary hardware and software for the communication with the ground station, two-way radio to send telemetry data and receive commands, and release and descent of the balloon when it reaches a certain pressure and/or altitude.

The Payload and Propulsion module will mainly consist of the autonomous recovery system, which requires GPS and temperature sensors. Upon landing, it should transmit its location to the ground station and be able to propel itself to a designated recovery site. The payload portion of this system will consist of the cameras that will record video footage throughout the mission, as well as any extra hardware and sensors.

The ground station receives all the necessary data throughout the mission. This subsystem is responsible to monitor the data as well as send appropriate signals to the system to ensure a successful mission.

3.5.1 Ground Station [RP]

The Ground Station is responsible for monitoring all of the data before, throughout, and after the mission, as well as relaying necessary commands to the BalloonSat with the assistance of long-range wifi. The Ground Station will be equipped with laptops and transceivers which will assist with transmitting data to other operational systems. The COSMOS software shall be utilized for flight and ground operations. The COSMOS software will allow a cohesive connection for all software involving the launch. The ground station team is responsible for running a system diagnostics test and analysis before the satellite is launched. During the mission, it will monitor and report the BalloonSat's state of health data in real time. During its descent and landing, it will monitor the location and ensure that the recovery system is functional.

3.5.2 Balloon and C&C Module [JKY, EV]

The operation of the Balloon and C&C Module is to carry the payload through a helium filled balloon. As the balloon increases in altitude, the different sensors attached to the payload should record information of the atmosphere. The design of the C&C Module will assume the shape of a cube. This is to maximize stability in flight. A cube will allow for easier wiring routes in the payload since the sides are flat. Reflective foil shall be used to cover around the shape since the temperatures at high altitudes can damage electronic equipment, effectively providing insulation. The sides will need to be sealed to have waterproof capabilities because there is a high possibility of landing in water. During descent, the structure of the balloon will have to at least withstand an impact of 15ft/sec. UHABS-4 used a polystyrene material on the outside for insulation while using marine sealant to protect the electronics from water damage. The balloon choice for UHABS-4 was a 600g latex balloon, bursting at an altitude of 50,262*ft*. This design is taken into consideration for UHABS-5. While a bigger balloon bursts at a higher altitude, it also increases the amount of Helium that is consumed. As the balloon reaches maximum altitude, the payload will be detached from the balloon and a parachute will be deployed. The parachute must be able to provide a steady descent velocity for a 12*lb* payload. This parachute must also be tethered to the C&C Module, whilst adhering to the FAA regulations.

The C&C module will be programmed to use COSMOS for its software and tools to trigger commands and deliver data back to the Ground subsystem. The data handled inside of C&C module will be from a two-way radio system, internal and external thermocouples, camera sensor, and an Aerocore sensor, which collects GPS, pressure (barometric and absolute), acceleration data, and altitude. These sensors will provide the UHABS-5 team a state of health for the module as well as data needed to collect. A Raspberry Pi will be used as the CPU of the module since it is expected to run multiple programs simultaneously.

3.5.3 Payload and Propulsion Module [AB, CN]

The payload of the UHABS-5 will be all sensor data taken or stored during the entirety of the mission, including both time in the air and water. This sensor data includes temperature, visual images, audio recordings, orientation, GPS logs, and air pressure. The latter two will be taken from the Gumstix Aerocore 2 located in the C&C module. All of this information will be stored via a microSD card due to its lightweight and ultra small form factor. Should a connection issue between the ground station arise and the data link be severed, if the payload is still recoverable after landing, then the data collected during the flight would still be safe. Additionally, there will be a propulsion module in the same capsule as the payload, together forming the Payload and Propulsion Module, which is responsible for propelling itself back to the designated recovery site after landing in an arbitrary location, likely in the Pacific Ocean.

To obtain temperature readings, the module will be hooked up to multiple thermocouples uniformly aligned throughout the body internally and externally which will be linked to a DAQ data acquisition device ran by the DAQ software. This data will be saved internally as a CSV file and be sent via radio frequency to the Ground Station. Thermistors may also be used for additional temperature data. The reason for multiple temperature sensors is so they can be averaged since the temperature may not be uniformly distributed throughout the container.

Visual data, in the form of pictures, will be acquired via a GoPro camera attached to the exterior of the payload. Previous BalloonSat projects have yielded images that showed the black horizon of space. Team Zeppelin's intention is to reproduce these results, however it is dependent on the altitude at which the balloon can reach before it bursts. The GoPro camera can also record audio, which can reveal events such as the balloon bursting and deflating, as well as wind wildlife.

Although the camera has internal image stabilization, an additional three-axis gyroscope will be used to determine the reference orientation that the camera took images or video. This is important for finding the angle at which a picture was taken, since it may be different for each image depending on wind conditions.

The propulsion module is the autonomous recovery system that will function to maneuver the payload and Command and Control Module to an easily accessible site near Oahu so they can be physically recovered. However, the C&C module contains the GPS module and is in a separate capsule as the P&P module. Thus, the Payload and Propulsion Module must coordinate with the C&C module in order to navigate accurately to a designated recovery site. The propulsion module will use the homing beacon provided by the GPS in order for the ground station to locate its whereabouts. They will be connected via weather protected I²C lines to allow the two modules to communicate. To achieve the recovery goal, the propulsion module will consist of a motorized propeller system powered by the same exterior solar panels and internal battery as the payload and possibly the C&C. The body of this portion should be capable of floating and be aerodynamic to allow for optimized travel through both the air and water. It will also be well insulated and assembled with thermal glues in order to survive the conditions of near space and the ocean such as cold temperatures and water leaks.

3.6 Fabrication Plan [KL, KBC]

In order to gain more experience with high-altitude satellite balloons, the Balloon and C&C Module team shall first assemble the UHABS-4 Balloon and C&C Module as a first prototype. This will allow us to further research and test past models in order to create an improved design and ensure a successful mission. The prototype will also be used for preliminary testing and will help the team to determine whether it would be better to reuse the operational parts, or purchase new parts. After re-assembling and testing UHABS-4 the team will be able to start designing the Balloon and C&C Module for UHABS-5 with a better understanding and will be able to better account for the dimensions and weight of the electrical components needed in the module. Once the design for the Balloon and C&C module is complete the team will 3D print the necessary components and utilize the materials decided upon to fabricate the new design for the module.

The payload and propulsion module would mainly be used for the recovery phase. Since there are several electrical components from previous UHABS missions the Payload and Propulsion Module team will be able to test various designs be reusing old components, many prototypes may be required in order to find a design that will be able to withstand the current and autonomously propel the module along with the balloon and C&C module to the designated recovery point. The design may be based off of a watercraft vehicle in order to effectively retrofit propellers onto the payload. Once the design for the payload and propulsion module is finalized the team will utilize the selected materials to fabricate the design.

Lastly, all electronics used in this mission would first be built outside of the payload prior to finalizing its installation into the two payload. This will make adjusting equipments easier since these equipments may require many trial and error to know if the ordered or designed component is adequate for this mission.

3.7 Testing [KL, JKY]

The testing of the balloon satellite would be divided into sections to test the different requirement and constraints for each subsystem. The different tests will be outlined below if, once the subsystems show satisfactory results the team will be able to move towards a test launch.

The first section would simply be testing its waterproof capabilities. Due to extreme cold temperatures in high altitudes and corrosive properties of the ocean, the payloads would require solid insulated and waterproofed seals. Leak test can done performed on campus submerged in an container for a set duration or out at the beaches to test if salt water would affect the material construction and adhesives.The whole setup can be placed inside a cooler filled with ice or dry ice to test if extreme temperatures will disrupt equipment.

The next section will be focused on testing the communication equipments, images and sensors independently prior to installing into the payloads. Testing of communication will be done on land to determine if the devices and software are able to communicate and track upwards of 100,000 ft without losing signal. The recovery phase will also be tested to see if it is able to charge by solar cells and emits an audible signal to be heard by 300 ft. All these can easily be tested on land by using a car to drive far away to test its range. Electronics can be tested at different distances to see the maximum limit of communication. They can be tested at 1 *ft*, 10 *ft*, 100 *ft*, 1000 *ft*, 1 *mile,* and if necessary 5 *miles*. Propulsion will need be strictly be tested in the ocean to determine its capabilities to move around waves and wind. Parachute testing will be done by dropping test prototypes off of building to see if their falls at its desired rate of descent.

Due to the high prices of helium, the launch test will be the final aspect to test. The balloon will first be inflated with air to test for signs of deflation. This testing will most likely be done at Sandy's beach where all previous balloon satellite were launched. This testing will ultimate check the condition of the balloon and its ability to carry the two payloads.

3.8 Materials [EV]

The materials to be used for UHABS-5 will be gathered from previous launches that were recovered, safe for reuse, and marked for inventory. For the materials that cannot be reused, such as the balloon, they will be purchased new. For most of the subsystems, such as EPS, CT & DH, and communications will be inside of the C&C module and are a part of avionics. The C&C module will be made of a styrofoam housing, with internal metal framing to provide insulation, structure, ease of management, buoyancy, and parachute attachment. The EPS of the avionics includes a CPU, GPS, sensors, and voltage supply. The CT & DH of the avionics include sensors and voltage supply. The communications subsystem will include antennas, a beacon, and cameras. Other materials include a 600g helium-filled latex weather balloon and the propulsion module, various fasteners to attach the modules and the balloon, and the parachute to reduce the landing speed to below 15 ft/s. The propulsion module includes motor, control circuit, paddle wheels, rudder, a voltage supply, a Li-ion battery pack, and solar panels. All said materials are to be attached to a structure that will be buoyant, waterproof, and have ease of steering.

3.9 Special Features [EV]

The special feature of the UHABS-5 is to have it propel itself to a designated coordinated location, in case of an ocean landing. This feature is accomplished with the propulsion module which includes a control circuit that will control how much power is sent from the motor to the paddle wheels to combat against ocean currents and wind while also controlling the rudder to steer it to the pre-designated location. The ground subsystem will keep in contact of its location via the communications subsystem, which houses a GPS, antennas, and a beacon. In order to keep all components powered from the module's oceanic landing till final arrival, there will be Li-ion battery packs for power supply and solar panels on the exterior of the module to maintain capacity in the battery pack.

3.10 Requirement Methodology [KBC, KC]

The requirements of the UHABS-5 will be managed under a system specification document. This will enable traceability from the lowest level product requirements to the work breakdown structure. The SSD will be used during the life cycle of the project and will be amended as the project becomes focused to a single final product. The SSD will contain requirement specifications and an associated objective number and trace code. Each requirement will be rated on priority, risk, and verifiability. In order to verify a requirement has been met, a series of tests shall be conducted to model portions of the UHABS-5 and the results will be analysed to ensure requirement compliance. Future attributes that will be tested include accuracy, precision, repeatability, and selectivity.

3.11 Mass and Power Budget [EV]

The UHABS-5 is limited to a total payload of 12 pounds (up to 6 pounds per module). The modules are divided in two: Payload & C&C and Propulsion. The first module is primarily for atmospheric maneuver and will contain a latex balloon for ascent and a parachute for descent, inside of a styrofoam cooler along with avionics. The second module is the oceanic maneuver and will also carry avionics to propel itself and the first module for safe recovery. The complete mass budget can be found in Appendix B.

Inside of both the C&C and Propulsion modules contain the avionics necessary for a successful ascension/descension, autonomous propulsion, and data collection. The avionics and other electronics in Figure 3.4 that receive and transmit data are sufficient to contact Ground Station where the members to see and store real-time data. The communications of the modules are from two long-range modules to receive and transceive data. The avionics include a gyroscope, a development board, a breakout board, four thermocouples (two interior and two exterior), a GoPro, an Aerocore 2, and a Raspberry Pi. The propulsion of the second module will be from a pair of thrusters. The complete power budget can be found in Appendix B.

3.12 Launch Program and Permissions [JAY]

The FAA has the following restrictions regarding high altitude balloon systems:

- No person may operate an unmanned free balloon-Unless otherwise authorized by ATC, in a control zone below 2,000 feet above the surface, or in an airport;
- At any altitude where there are clouds or obscuring phenomena of more than five-tenths coverage;
- At any altitude below 60,000 feet standard pressure altitude where the horizontal visibility is less than five miles;
- During the first 1,000 feet of ascent, over a congested area of a city, town, or settlement or and open-air assembly of persons not associated with the operation;
- In such a manner that impact of the balloon, or part thereof including its payload, with the surface creates a hazard to persons or property not associated with the operation

Although not required, at least one representative of the team should meet with local FAA officers prior to launch. This will include writing a Notice to Airman Letter (NOTAM) and having a phone contact at the FAA for launch day communication with a list of basic information.

3.13 Safety Procedures [JAY]

All members attended the safety briefing held by Lewis Moore and are held to the established guidelines in the Machine Shop Safety Handbook. This includes, but is not limited to, not working alone in the shop, wearing essential personal protective equipment, keeping hands at least 4 inches from cutting surfaces, turning off machinery before adjusting, and cleaning up after use. The team will minimize dangerous debris and chemicals when machining. No team member should use a machine before first getting adequate training. If there is any doubt about anything, a person with expertise will be contacted. In case of emergency, campus safety and the instructor will be contacted immediately.

Soldering electronic components during fabrication will be heavily implemented. While soldering, hands are to be kept away from the element of the soldering iron. Any manipulation of the element will use tweezers. A wet cleaning sponge is necessary during use to keep the iron clean reducing fumes. The iron is to be put in its stand when not in use and is to be turned off. Protective eyewear is required.

4 Management and Cost Overview

4.1 Project Schedule Strategy [KBC]

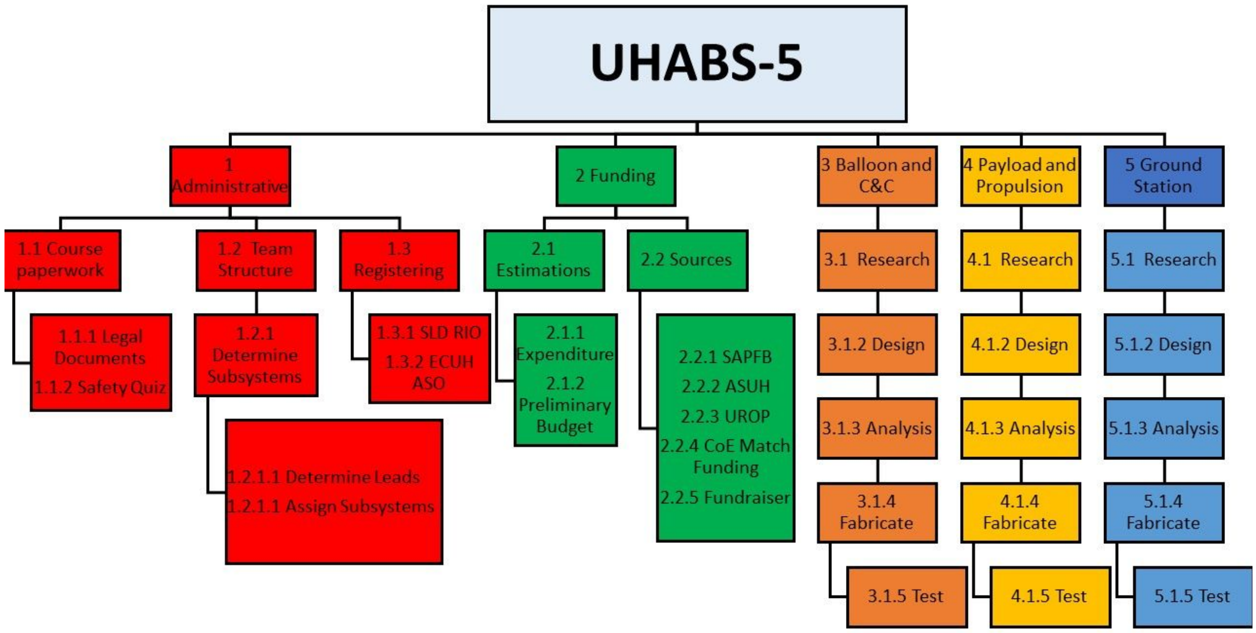

Figure 4.1*: Diagram of the work breakdown structure*

Figure 4.1, above, is a work breakdown structure of the tasks that need to be completed for this project. Figure 4.2, below, is a Gantt Chart which includes milestones, proposed subtasks, and academic deadlines for the 2017-2018 academic year, the Gantt chart also shows the critical path the team needs to follow in order to complete all tasks. The Gantt chart, along with the team calendar, will ensure that the ensure that all team members are aware of the tasks to be completed and who is responsible for them. These tools, along with team collaboration and communication the team will be able to complete milestones, subtasks, and course deadlines.

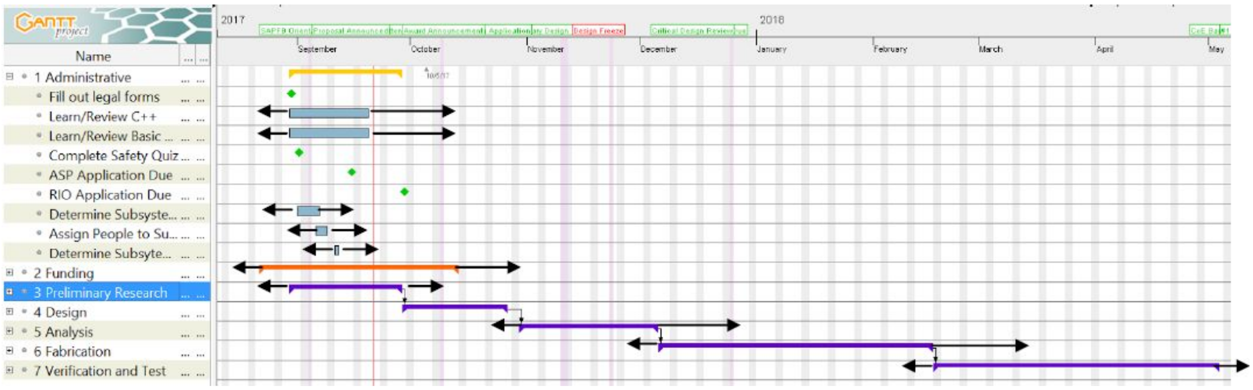

Figure 4.2*: Gantt Chart of the proposed schedule for the year.*

The proposed tasks and subtasks that are included within the team Gantt Chart were based on course requirements and deadlines as well as reflection from previous iterations of high altitude balloon satellite projects done in the past as semester projects. Below is a list of tasks and subtasks for the team, each task has a numerical id. Items without a duration are categorized as deadlines. All proposed tasks are subject to change as the year progresses and are shown in Table

In order to fully define the problem statement, mission statement, objectives and constraints, success criteria, and top level requirements, a loop starting with the mission statement was used to help define major components of the project. The team started with constructing a mission statement, then the team began to determine specific objectives for the project, from there the top-level requirements, solution, and problem statement were defined.

Figure 4.3*: Feedback loop used to determine mission statement, problem statement, etc.*

4.2 Project Budget [DA]

A set budget will be awarded to the Balloon Satellite project from the UH Manoa Mechanical Engineering Department. No official amount has been released yet for the project. Below is a quoted estimated projection of each general scope of the project.

4.2.1 Estimated Overall Budget [DA]

Components from previous BalloonSat projects have been inventoried and shall be reutilized or repurposed to save on costs and for practicality. The quoted cost estimation for this project is based upon the reviewal and analysis of the previous BalloonSat mission's budget shown in Appendix C. The estimate includes the addition of the new and updated requirements of the project such as the higher elevation, and recovery retrieval system after landing in the water. The projected total procurement costs for each scope is shown below.

Table 1: General Budget

Scope of Work	Quoted Estimate
C&C Module	$600
Payload and Propulsion Module	$200
Ground Station	$600
Structural	$200
Helium x2 Tanks	$974
Total Shipping Fees for Project	$500
Total Quoted Estimate	$3074

C&C Module - This scope consists of the avionics, camera, and sensor communication and operation systems. The most expensive aspect of this scope are the telemetry parts for the avionics subsystem. Referencing the cost for Avionics from past BalloonSat projects, more than half of the spending money were for telemetry sensors and its supplementary parts to make sure it effectively collects, communicates and sends data to the ground station. Collectively, the rough estimated cost for the C&C Module scope in general for this project is $600

Structural - Since the BalloonSat will be reaching a near space environment and experience harsh environmental conditions, such as extremely low temperatures, the structural integrity of the BalloonSat is a vital part of the design and can not afford to have corners cut in its budget. The structural scope includes framing, insulating, fastening, 3D printing and anything that reinforces the BalloonSat. Altogether, this scope requires a budget of $200 to allow for the ability to acquire quality products that will most effectively support and protect the BalloonSat.

Ground Station - The ground station generally does not require much only a Transceiver, 2-way radio, antenna, laptop with cosmos, and wifi router. This has been the typical setup for the ground station for the past projects and the estimated budget allowance allocated for ground station for this project is $600.

Payload and Propulsion - This scope's main objective is to design a way to retrieve the BalloonSat after it lands in the sea. The previous recovery method requirements and actions for the past BalloonSat projects were similar to this current project, so their budgets were used as a resource to estimate the budget for this scope. After reviewal, the estimated cost to complete this work is $200.

Helium Tank - Data from past projects show one helium tank costing $486.91 to allow the BalloonSat to reach an altitude of 50,000ft. Since this project is going to be doubling that altitude at least one additional spare tank would be needed for testing and/or backup resources. Total projected cost for 2 tanks of helium is $1461.

The total quoted estimate of how much money will be needed to fund the success of this project is $3074. This quote also considers the ordering of duplicate components and testing.

4.2.2 Funding Strategy [DA]

Options are being explored to assist in the funding of this project. The list of funding programs that the balloon satellite project is currently exploring are listed below:

1. SAPFB
2. UROP
3. COE Match Funding

The option of starting a fundraiser is also a consideration in the funding plan. So far no award has been received from the listed funding options.

5 Conclusion [JKY]

The mission was to design a high altitude test platform with the capability of self-navigating to a retrievable area on land in the case of a landing located in the ocean. The Zeppelin team is split into three major subsystems, each gearing towards the success of a different objective. The Balloon and C&C subteam focuses on designed each component needed during flight. The Ground Station Operations subteam has to be able to retrieve data and document all aerial information. The Payload subteam designs the structure of the self-navigating device to deliver the Zeppelin back to the team. The design as a whole will incorporate the appropriate insulation and watertight objectives to succeed in this mission.

Weight, velocity, and structural design are constraints that provide a guideline for the design of this project.

An estimation shows that the formulation of the Zeppelin will cost around $3074, ideally. This amount includes prices for the C&C Module, Payload and Propulsion Module, Ground Station, structure, helium, and shipping costs. The total cost is also subjected to a ±20% budget margin and is expected to have a smaller margin as a more accurate analysis is done during the fabrication period. Methods of funding this project are to be done prior to fabrication to provide a safety net in the case that Zeppelin runs into unexpected issues and requires replacement parts. To cut prices down, Zeppelin will have a practice test launch, prior to the final test launch, making a total of two launches. The necessary preparations for the hardware and software will have to be done before the practice test launch to insure that everything is working during the launch.

Many balloon satellite teams are done in the mainland United States, providing easier retrieval to their balloon satellites. However, in Hawaii the chance of the balloon landing in water is almost certain thus showing the importance of the need of a successful retrieval device. Learning from the problems from UHABS-4, Zeppelin hopes to design a balloon satellite that improves on their faults. Since UHABS-5 is given double the amount of time that UHABS-4 had, a successful design is guaranteed to be possible if time is used wisely. The goal at the end of this project is not only to successfully create a working test platform but also to gain invaluable experience in aerodynamics and astronautics.

6 References

[1] 2017, "What Old-Fashioned Weather Balloons Foretell about Irma's Track," from https://www.scientificamerican.com/article/what-old-fashioned-weather-balloons-foretell-about-irma-rsquo-s-track/

[2] 2017, "Comprehensive Open-architecture Solution for Mission Operations Systems," from http://www.cosmos-project.org/

[3] 2008, "Science Learning Hub - Measuring biodegradability," from https://www.sciencelearn.org.nz/resources/1543-measuring-biodegradability

[4] 2017, "Federal Aviation Administration - About FAA," from https://www.faa.gov/about/

7 Appendices

Appendix A - List of Requirements

Requirement	Factors which Typically Impact the Requirement	Balloon Sat
Functional		
Coverage	Orbit, scheduling	Roughly 100 miles from Oahu
Responsiveness	Communications architecture, processing delays, operations	Periodic transmission of mission data to ground systems.
Secondary Mission	Communications architecture, processing delays, operations	Navigation to collection site for reuse.
Operational		
Duration	Experiment or operations, level of redundancy, altitude	Operational during the time of launch to retrieval
Availability	Level of redundancy	100% Availability
Survivability	Orbit, Ocean, hardening,	15 ft/s impact, waterproof,

	electronics	operational from -70f to 80f
Data Distribution	Communications architecture	Contact with COSMOS ground-control
Data Content, Form, and Format	User needs, level and place of processing, payload	Temperature, pressure, and density of atmosphere with respect to altitude
Constraints		
Cost	Size and complexity	Initial Budget $2000
Schedule	Technical Readiness	Initial prototype within 6 months, final product within 8 months
Regulations	Law and Policy	FAA Regulation
Political	Sponsor	UH Manoa - College of Engineering
Environment	Orbit, Ocean, mission length	Stratosphere and oceanic
Interfaces	Level of user and operator infrastructure	Communication Relay and interoberaple through COSMOS ground station

Appendix B - Mass and Power Budget

Modules	Component	Mass
Payload	Latex Balloon	~1.3 lb
Payload	Parachute	~1 lb
C&C	Styrofoam Cooler with framing and adhesives (8 in x 6 in x 9 in)	~2.5 lb
Propulsion	Lightweight Manufactured Boat	~1.5 lb
C&C and Propulsion	Avionics	~3.0 lb

Subtotal	**~9.3 lb**

Subsystem	Component	Current Draw	Voltage Source
Avionics	Raspberry Pi	125 mA	5 V (Regulated)
Avionics	Gumstix Aerocore 2	500 mA @ 3.3 V	3.1 - 16.0 V (Raspberry Pi)
Avionics	microSD Breakout Board	100 mA	3.3 V (Raspberry Pi)
Avionics	Teensy 3.2 Development Board	3.9 mA @ 3.0 V	1.7 - 3.8 V (Raspberry Pi)
Avionics	Triple-Axis Gyroscope	6.5 mA	2.1 - 3.6 V (Raspberry Pi)
Avionics	Thermocouples (2 interior, 2 exterior)	Negligible	Negligible
Camera	GoPro Hero 3	1050 mAh	3.7 V (Raspberry Pi)
Communication	XTend 900	Receiver: 35 mA @ 5 V	2.8 - 5.5 V (Raspberry Pi)
Communication	XTend 900	Transceiver: 710 mA @ 30 dBm	2.8 - 5.5 V (Raspberry Pi)
Propulsion	Thrusters	360 mA * 2	3.0 - 3.6 V

Appendix C - Budget

Structural	Current Market Cost 2017 per One Unit
2” Construction Grade Polystyrene	$19.28
Gorilla Glue	$3.89
Thin sheets/angle bar of Aluminum Alloy	$72.15
Acrylic Lenses	$42.98

Nylon bolts/nuts and SST Screws	$0.71
Rubber washers and Gaskets	$4.57
Total	$143.58
Avionics	
Hand Warmers	$38.00
TMP36 Temp. Sensor	$1.50
Arduino Mega 2560	$38.50
Weather Shield (DEV12081)	$39.95
GPS11571 (GPS Receiver)	$31.95
9 Variable IMU (Altitude Module)	$29.95
INA169 (Main BUS)	$8.95
Gumstix	$169.00
Xtend 900	$10.00
GoPro Hero 3	$259.99
Class 10, 32GB Micro SD Card	$13.99
OV2640 with ArduCAM Shield	$29.99
Wireless Camera System C203-B	$36.68
Total	$708.45
Ground Control	
9Xtend OEM RF Module w/Antenna # A09HSM7	$179.99
Radio Receiver	$20.00
ASI301Q Mallory Sonalert buzzer	$3.16
XtendPKG RF	$299.00
Total	502.15

Miscellaneous	
Helium Tank	$486.91
9V Battery Pack	$46.85
Total	$533.76
Grand Total	$1887.94

Above is a previous successful BalloonSat project budget list for all its components with updated 2017 market values. The grand total cost shown in red does not factor in shipping, tax or any duplicate orders of one item nor factor in any new or updated requirements/criteria for the current BalloonSat project. The grand total cost shown in red is merely a reference to estimate a figure for this project's general budget shown in section 4 Management and Cost Overview. The grand total shown is the threshold for the absolute bare minimum cost to successfully build a BalloonSat and fulfill the mission.

Appendix D - Task Lisk

Task Number	Task Description
1	**Administrative**
1.1	Course Paperwork
1.1.1	Legal Documents
1.1.2	Safety QUiz
1.2	Team Structure
1.2.1	Determine Subsystems
1.2.1.1	Determine Leads
1.2.1.2	Assign Subsystems
1.3	Registration
1.3.1	SLD RIO
1.3.2	ECUH ASO
2	**Funding**
2.1	Estimations
2.1.1	Expenditure Estimations
2.1.2	Preliminary Budget Estimation
2.2	Sources
2.2.1	SABFB

2.2.2	ASUH
2.2.3	UROP
2.2.5	Fundraiser
3	**Balloon and C&C**
3.1	Research
3.1.2	Design
3.1.3	Analysis
3.1.4	Fabricate
3.1.5	Test
4	**Payload and Propulsion**
4.1	Research
4.1.2	Design
4.1.3	Analysis
4.1.4	Fabricate
4.1.5	Test
5	**Ground Station**
5.1	Research
5.1.2	Design
5.1.3	Analysis
5.1.4	Fabricate
5.1.5	Test

Appendix E - Team Members

Likeke Aipa is a team member of the payload and propulsion team. Past research experience includes projects pertaining to small satellites and their respective orbital projections.

Drex Arine is the designated fiscal manager and is responsible for ensuring the project stays on budget by monitoring and, if necessary, adjusting each section and subsections allowances to ensure the life and completion of the project. He has been working in construction management for two years as a project engineer part time/full time and is hoping to work in the project management field as a career after graduating.

Andrew Bui is a team member designated to the payload and propulsion module design. He has had past experience in designing a fully functional thermoelectric cooler. This experience is relevant in which he is able to utilize thermocouples and thermoresistors along with the data acquisition devices which will all be used on the payload module.

Karen Calaro is the designated project manager (PM) for the BalloonSat team. As the PM she is responsible for tracking the progress of the project, ensuring that all tasks and subtasks are completed, and ensuring that all requirements for the project are met. She has previously held leadership positions such as ASME President, ASME Vice President, and AISES President. She has also participated in other projects such as Manoa Astronomical Technologies' Pioneer 01-B and a Nanotechnology and Renewable Energy Lab's Personal Power System,

Kanekahekilinuinanaueikalani Clark is the Payload and Propulsion team leader. He is responsible for monitoring the progress of the payload team. Additionally, he is responsible for the programming of the payload systems. He is currently interning for a fire protection firm.

Ka Chon Liu's role in this project is the ground station subsystem. Being in ground station meaning working with the software and electronics that deals with the balloon satellite's communications.. He has had previous experience with C programming as well as working with arduinos and sensors from past projects. This should help speed things up when learning the software portion of the project and be ready to jump in to learn and incorporate COSMO into the design.

Cyrus Noveloso is an additional member to the BalloonSat. He is responsible for overlooking most of the electronic hardware. He is volunteering to work with the team from an electrical engineering course. With his knowledge in EE, he can apply it to making the wires function correctly.

Reagan Paz is the designated systems integrator (SI) for the BalloonSat team. As the SI, she is responsible for making sure each subsystem works properly together. She has previously been the SI for a drone project and held leadership roles in student organizations such as SWE and AISES. She has held one internship in construction/project management and another with a large corporation working on commercial airplanes and hopes she can apply the skills she's learned there within the project.

Yun Feng Tan is the balloon and C&C module subsystem leader, responsible for the design and fabrication of the subsystem module. He has no relevant experience with satellite but will acquire skills needed for the completion of the project.

Jake Torigoe is a senior at the University of Hawaii - Manoa, majoring in Mechanical Engineering. He is responsible for the hardware and electronic aspects of the Ground Station subsystem. His experience in construction management will aid in interpreting part specifications and helping the decision making process.

Emanuel Valdez is the recorder for the BalloonSat team and is working primarily of the Balloon and C&C module subsystem, partaking in the responsibilities of the design, fabrication, and programming for the subsystem. He has previous experience in programming in C++, working with various types of sensors at the Hawaii Corrosion Lab, and slight experience in additive manufacturing. He hopes to provide as much knowledge and resources needed for the team.

Jace Yamaguchi is the ground station team leader. He is primarily working with the hub system in COSMOS communicating with the C&C module and retrieval subsystem from a home station. This includes monitoring thermal and pressure sensors on the satellite, location beacon from the retrieval subsystem, and choosing an appropriate antenna for communicating with the satellite in flight. He has previous experience with C, C++, and Arduino and is learning how to use linux OS.

James Yang is on the BalloonSat team with the focus of electronics for the Balloon and C&C module subsystem. This task is important because he has to be able to retrieve high altitude data by wiring sensors and cameras to the payload. He is currently studying the process to connect these wires. He has previous experience in basic circuitry which he plans to use for this project.

Appendix F - Literature Review

[1] [RP]

This article assisted in finding real-life applications of using weather balloons to research and track data. Forecasters have been using them to track the hurricanes in the Atlantic Ocean since there is a high concentration of intense storms in that area.

[2] [KL]

This source provided an overview of COSMOS and in depth explanation of the design and architecture of the system the system. It also explained the history and intentions for COSMO as well as the entire architecture workflow for both nodal and functional charts.

[3] [JT]

The article was used to determine the time it takes for styrofoam to degrade when exposed to the environment. Science Learning Hub is a learning/teaching resource for students and teachers. It is sponsored by the New Zealand Government and universities.

[4] [JT]

This source helped in clarifying the FAA's intentions in their implication of rules and standards. These restrictions were put in place to maintain a safe, efficient airspace. The FAA website is run by the United States Government.

Appendix G - Team Policies and Expectations

G.1 Team Leadership Structure [KBC]

Zeppelin has six leadership roles; Project Manager, Systems Integrator, Fiscal Manager, Balloon and C&C Module Team Lead, Payload with Propulsion Module Team Lead, and the Ground Station Team Lead.

G.1.1 The Project Manager

The Project Manager is responsible for coordinating and team and leadership meetings. Additionally, they The Project Manager is responsible for coordinating and facilitating team meetings. Additionally, the project manager is responsible for ensuring the team stays on schedule with means including, but not limited to managing the team calendar, creating and managing the project Gantt chart, delegating project tasks, keeping the team task log updated, validating task completion, and monitoring team and task progress.They are also expected to maintain a design log in order to track any changes made from the proposed design to the final product. The project manager is also expected to be the liaison to the projects advising professor and TA.

G.1.2 The Systems Integrator

The Systems Integrator is responsible for reviewing all calculations, drawings, and fabrications to ensure all subsystems meet the set requirements and constraints. Additionally, the systems integrator is responsible for ensuring that all subsystems are compatible and ensuring that all subsystems successfully pass tests before the launch date, if initial tests are not passed they are responsible for overseeing any modifications made.

G.1.3 The Fiscal Manager

The Fiscal Manager's general responsibility is to make sure the project stays on budget by tracking costs, documenting PO's, and finding the most cost effective way to get the job done. The Fiscal Manager is also responsible for finding additional sources of funding in case the funding provided is not sufficient enough to complete the project. The fiscal manager is also responsible for determining the necessity of questionable line items and is authorized to accept or decline unnecessary or irrelevant funding requests.

G.1.4 Subsystem Team Leads

Subsystem team leads are responsible for ensuring that any subtasks designated to their subsystem completed to the quality demanded by constraints and requirements of the project.

Subsystem leads are also responsible for updating the systems integrator and the project manager of the progress made with in the subsystem, and alerting them of and setbacks or concerns.

G.2 Team Decision Making Process [KBC]

Decisions and voting are based on a 7/13 vote. The number of votes in favor for the decision must be at least seven thirteenths of the members present, unless otherwise stated by the project manager. If the votes are split fifty-fifty, the issue will be discussed further and the project manager, systems integrator, and fiscal manager must come to a unanimous decision in order to make the deciding vote. If for any reason a team member disagrees, they would need to notify the project manager in order to address the issue at the following team meeting. It will be their responsibility to notify the project manager of a disagreement, otherwise it will be assumed that all team members agree with the proposed decision.

G.3 Team Meeting Policy [KBC]

Team meeting dates shall be based on team members' availability and when the majority of the team is able to meet. Team meeting dates will be added to the team calendar and a list of meeting dates shall also be accessible to all team members in the team's drive folder. All members are expected to attend team meetings unless they are out of town, have class conflict, on vacation, or sick. Meeting dates outside of lab section shall be emailed at least 24 hours prior to the meeting. At least seven of the thirteen team members must be present in order to conduct business. All team meetings shall be conducted using the SPACER format, and meeting minutes shall be uploaded to the dive folder within 24 hours of the meeting. Team meetings are scheduled for Mondays from 4:30 PM - 5:30 PM with Dr. Trevor Sorensen in HH 309, Mondays from 5:30 PM - 6:30 PM in POST 536, and Wednesdays from 4:30 PM - 6:30 PM in POST 536, excluding all holidays.

G.4 Expected Contribution of Work [JKY]

Each student is expected to designate at least 12 hours per week on the project. Because there will not be a time log, the team follows an honorary system, hoping that each individual member will pull their own weight without supervision. An hour of work includes time that is being worked on designing the project or writing reports. This does not include however, time spent in the laboratory room not working towards the project.

G.5 Tolerance Policy for Non-Cooperative Members [JKY]

During the duration of this project, if a member is found to be non-cooperative, the project manager and systems integrator will be contacted and he/she will be given a strike. If there is a repeat offense, a second strike will be given along with notice to the project manager, systems integrator, and the TA. Lastly if the offense is repeated for a third time, Dr. Sorensen will be notified and grade reductions shall be considered.