Document:	I.) Project Statement
Subject:	Weather Balloon Altitude Control System
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Project Statement

Introduction:

The field of high altitude ballooning is an effective and relatively inexpensive way to deliver scientific payloads to the upper atmosphere for data collection. High altitude balloons can be grouped into two main categories: zero pressure and burst. The burst balloon is designed to ascend constantly until it reaches a certain altitude, at which point it will burst allowing the payload to descend back to the ground. The zero pressure balloon is much larger, and is designed to ascend to a certain altitude, then float until the flight is terminated. The zero pressure balloon is more versatile than the burst balloon as it can float at neutral buoyancy for extended data collection. The burst balloon is significantly less expensive so it is commonly used by facilities that use meteorological sounding packages and university ballooning groups with smaller budgets. The Goal of the altitude control system is to provide the ability to fly the lower cost burst balloon at neutral buoyancy. This will allow users to collect data on a floating platform without the increased expense of a zero pressure balloon. This report will detail the needs description, list the stakeholders of this project, and review the project goals and constraints.

Needs Description:

University level ballooning programs and stations that collect meteorological sounding data typically use relatively inexpensive latex weather balloons to transport their payloads to high altitudes. These balloons are made to fly to a high altitude and then burst, providing no control over the duration or altitude for data collection. For longer duration flights, zero pressure balloons are typically used. Zero pressure balloons provide a long flight duration at a near constant altitude. However, these balloons are many times more expensive than latex weather balloons, which puts them out of reach of smaller ballooning groups. This design will seek to develop a system to use burst latex balloons in place of zero pressure balloons. This will be done by developing a valve that can be inserted into the neck of various sizes of latex balloons to vent helium sufficient to achieve neutral buoyance at a user controllable altitude. This will reduce the cost associated with doing experiments that traditionally required a zero pressure balloon.

Currently the only group that has successfully done anything like this is in the past, outside the military, is the BOREALIS program at MSU. BOREALIS has made a prototype to vent helium. The current system requires a wired connection from the vent to the payload, this allows the user to manually open and close the vent. The improvements that need to be made are to adapt this system for traditional 2000 and 3000 gram latex balloon as well as smaller 200 gram balloons used for weather sondes. The main things that need to be improved are making a valve design that can be used for weather sondes and for larger 2000 or 3000 gram weather balloons, wireless communication between the valve and the main payload, and the valve needs to have the ability to autonomously open and close to achieve neutral buoyance at a user selectable altitude. Using a valve with reduce the cost associated with doing experiments that traditionally required a zero pressure balloon. Being able to wireless communicate with the valve will reduce possible complications such as the wire connected to the valve getting tangled with the parachute. Wireless communication between the valve and the main payload will further reduce the weight of the system. Having the valve autonomously navigate to a desired height will reduce human error and the need for communications between the ground and the balloon during flight.

This system will allow for a broader range of experiments at smaller university level ballooning programs to be done at relatively low cost. Particularly this will provide a stable camera platform for the BOREALIS program to record the 2017 eclipse. Another important application of this system will be for use with weather sondes in extreme weather situations, such as hurricanes. This is will be beneficial because it will allow weather sondes to collect data for longer periods of time and at selectable altitude. This will reduce cost and risk of using aircraft to take these measurements.

Stakeholder List

A low-cost controllable-altitude balloon platform has a diverse group of stakeholders. The stakeholders include the students and campus faculty involved in the program, the Montana Space Grant Consortium, and the atmospheric science community. Each stakeholder has a unique vested interest in the completion of this project as detailed below.

The primary stakeholders are the students and campus faculty directly involved in the program. The students responsible for the project have a vested interest in its completion as it fulfills a graduation requirement for their respective majors. The project also offers them valuable engineering design experience to take with them to their future employer. The campus faculty are also stakeholders in the project's success. Not only are the faculty asked to help guide their students towards successful completion, they are also ultimately responsible for assigning grading marks for the student's work as well. The faculty are also invested in the program to help further Montana State University's reputation of producing excellent engineers.

The Montana Space Grant Consortium (MSGC) BOREALIS program is a stakeholder in this project as they are the organization sponsoring the student's work. MSGC is interested in a controllable-altitude balloon platform for their 2017 total solar eclipse project which hopes to take live images of the total solar eclipse from the stratosphere. A reliable altitude control system for their balloon payload is essential for placing their cameras at the correct altitude to capture the eclipse.

Finally, the atmospheric science community will greatly benefit from this system. Scientists currently use latex weather balloons to measure atmospheric and weather phenomena using measurements obtained as their balloon payload rises through the atmosphere. Once their payload reaches a certain altitude it bursts, terminating their flight and experiment. An altitude control system (such as that being developed in this project) would allow more measurements to be taken before the flight is terminated as the balloon could loiter at a specific altitude without bursting.

In conclusion, the stakeholders include:

- Students and faculty involved in the project
  - Students directly involved in the design, build and testing of the project
  - Campus faculty supporting and grading the students
- Montana Space Grant Consortium
  - MSGC BOREALIS program requiring a stable camera platform in the stratosphere for their eclipse project
- Atmospheric Scientists
  - Scientists involved in measuring atmospheric conditions

Project Goals

The main goal of this project is to provide a system that will allow users to fly payloads at neutral buoyancy using latex weather balloons (Burst balloons). This system will be required to vent the correct amount of Helium from the balloon within the time constraints of the balloon mission. This system will also be required to restrict the flow of Helium adequately enough when closed to eliminate variability in the float altitude. The two sub-goals for this project include autonomous vent control, and short range wireless control of the Helium vent. The autonomous vent control will be an electronic function built into the valve itself. It will have a user interface for selection of float altitude, and a microcontroller that will make vent decisions based on the user selection. The short range wireless control will give the user the ability to control the valve manually by using another long range communication system on a different payload container on the same payload chain. For example: the user would send the 'open vent' command through their standard communication system (e.g. amateur radio or satellite modem), the command would be received by their payload chain attached to their balloon, and the command would be transmitted short range from the communication payload to the valve system.

Project Constraints

The constraints placed on a high-altitude weather balloon system include project length, cost, weight, density, breaking force, temperature, endurance, size, and communications. A detailed look at these constraints is provided below:

- Time
  - The project must be completed within the two semester Senior Design sequence specified by Montana State University
- Cost
  - The project must be completed within the budget assigned to the student group by MSGC
    - Actual dollar amount is yet to be determined

- Weight
  - Valve and control systems must be as light as possible to allow other systems to utilize the total weight allowed (see below)
  - FAA regulations (FAA Part 101 – (a)(4)(ii) and (iii)) require no more than six pounds per payload, and no more than 12 pounds overall total for multiple payloads
- Density
  - FAA regulations (FAA Part 101 – (a)(4)(i)) specify an upper maximum density of three ounces per square inch to avoid catastrophic aircraft damage should a collision occur
    - Determined by dividing the total weight in ounces of the payload package by the area in square inches of its smallest surface
- Breaking force
  - FAA regulations (FAA Part 101 – (a)(4)(iv)) require that any rope or suspension used for the payload must break free with an impact force of no more than 50 pounds
  - Payload must survive impacts with the Earth once the flight terminates
    - Parachute system must reduce speed to 10-20 feet per second depending on payload / experiment requirements
- Temperature
  - All systems must be able to withstand temperatures from -60^{o}C in the upper atmosphere through +35^{o}C at the Earth's surface
  - Mechanical and electrical systems must operate through this range for extended periods of time as indicated in the endurance section
- Endurance
  - Both mechanical and electrical systems must be able to operate for the duration of the mission
    - Typical BOREALIS loiter flights ("zero pressure flights") last approximately 3 hours
    - Typical BOREALIS flights require that any flight systems are operational 30 minutes before balloon launch
- Size
  - While there are no size constraints directly placed on the valve and control systems, they must conform to the weight, density, and breaking force specifications provided above
- Communications
  - Control system must be able to interface and communicate with the current BOREALIS communications payload which includes an NAL Research 9602-LP Iridium satellite modem connected to an Arduino Uno microcontroller
    - Communications protocol / interface can be determined by the designers