Document:	**Concept Development**
Project:	**Weather Balloon Altitude Control System**
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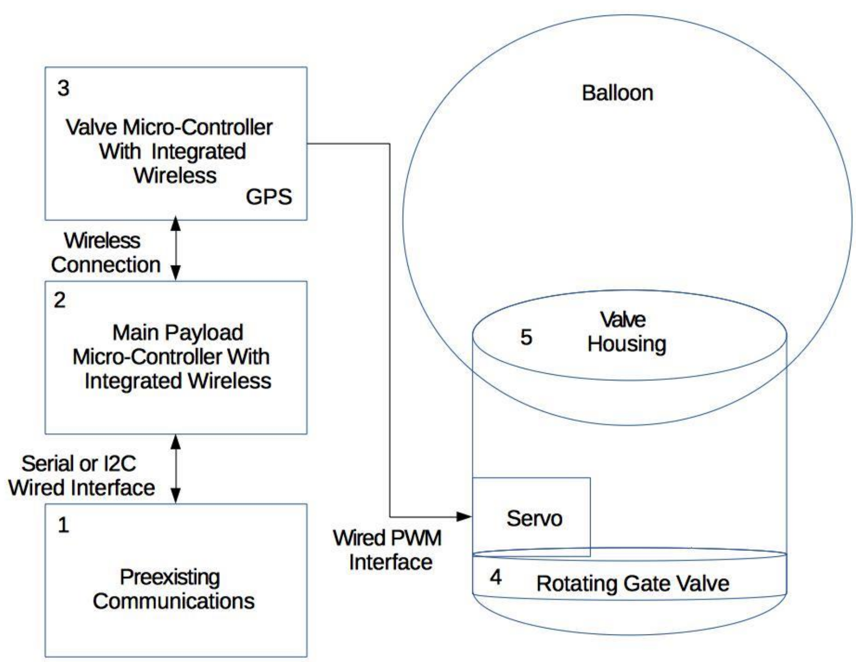
Introduction

The design alternative that was chosen from the decision matrix is a micro-controller with an integrated radio and a rotating gate valve. Now that these design choices have been selected above the others they will be further explained and developed. The individual components will be explained in greater detail along with how they integrate with the other components in the overall system. In order to make the best overall product a number of interviews were performed to get some feedback on how the current design could be improved and if there should be any additional features added. In accordance with the feedback that is received the design will be potentially changed or added to. Even though the seemingly best design has been chosen there is some potential for some design choices to fail. In order to prepare for this possibility a contingency plan is developed and presented here.

Concept Design

In order to achieve the goal of developing a weather balloon high altitude control system a number of alternatives were evaluated. The designs that scored highest in the decision matrix were a microprocessor with a built in wireless receiver and transmitter and a valve with a rotating gate. This is shown below.



The following is a detailed explanation of the different components of the chosen design.

1. Preexisting Communications - This is not part of the design but is something the design will interface with, so it is helpful to understand its function. The BOREALIS program at Montana State University uses an iridium satellite modem for communications between a ground station and the balloon during a flight. The ground station communicates with the modem by sending an email to the Iridium company who then sends it via satellite to the modem on the balloon payload. The modem has a serial connection and three digital pins that can be interfaced with. Other ballooning groups use a variety of different options for communicating with the balloon. Traditionally one of the most common has been using amateur radio with a DTMF encoder and decoder which usually have a serial interface. The goal of this design is to have a system that can be easily interfaced to whatever a given group is using for their ground to payload communications. This will be accomplished be having available Serial, I2C, and digital pins available.

2. Main Payload Micro-Controller With Integrated Wireless - Using the decision matrix the solution for the main payload end of the wireless interface was decided to be a micro-controller with a built in wireless radio. As was mention in the Preexisting Communications section this micro-controller will have serial, I2C and digital pins available for interface with whichever ground-to-payload communication is being employed. This will allow the customer the flexibility to use whatever method of communication they choose. The micro-controller will receive and information sent from the ground and will then be able to transmit that information to the valve controller wirelessly via its integrated radio. The wireless feature will prevent any tangling or other complications associated with using a wired connection between the main payload and the valve.

3. Valve Micro-Controller with Integrated Wireless - A second microcontroller will be used to control the valve servo using a wired PWM signal. This micro-controller will be the same one that is used in the main payload. The Valve controller will receive commands from the main payload via its integrated radio and then according to the received command send a PWM signal to the servo opening or closing the valve gate. Another one of the goals for this design is to have the ability to have the valve operate autonomously. What is meant by this is for the valve to open and close in order to come to neutral buoyance, or float, at a preselected altitude. In order to accomplish this the valve controller will be interfaced to a GPS unit so that it can read altitude data. Using this altitude data in an algorithm the controller, based on rise rates, will determine when and for how long to open the valve in order to achieve the selected altitude.

4. Rotating Gate Valve - The method by which the Helium will be vented from the balloon will be a rotating circular gate valve. This valve will be constructed from milled polycarbonate sheet 0.056 inch thick. The valve will consist of two circular parts that will be overlaid. The outer and larger of the two circles will have four triangular holes placed symmetrically about the inside of the circle, with one #6 hole at its center. This outer circle will be secured to the end of the vent tube by a cylindrical tube cap, also milled from polycarbonate sheet. The inside circle will be the negative of the outer ring, meaning that when the two rings are overlaid and rotated to the correct alignment, the triangular hole in the outer ring are closed off. This inner circle will also have a #6 hole at its center. The inner ring will have a 1/8 inch long #6 diameter pin secured to

its center hole with adhesive. A four point servo horn will be centered and secured to the opposite side with adhesive also. The servo horn will attach to a sub-micro servo, and the servo along with a low powered compression spring will be closed inside of the two halves of the servo casing, which will allow the compression spring to press the servo and inner circle assembly forward, ensuring an adequate seal between the inner and outer gate circles. The two gate circles will also be coated with white lithium grease for lubrication, and to improve the seal made by the two circles in contact.

5. Valve Housing - The valve housing, or main body tube, will be made from polycarbonate tube I.D. 1 inch, wall thickness 1/16 inch. This will be cut in an 8 inch section, and have a rectangular section removed from the lower end to allow for the servo casing to be attached. The gate cap will then be secured, compressing the compression spring slightly. The body tube will also have a balloon retention ring secured around the top to ensure that the balloon will not come off during flight. The body tube will also feature an electronics enclosure on the outside, with dimensions still to be determined.

Evaluation Criteria

In order to make a more desirable product for the customer. A number of interviews with potential customers were performed with the following questions.

Interview Questions

1. Our engineering team is designing a $100 microprocessor-controlled helium valve system which will allow latex weather balloons to maintain a set, pre-selected altitude in the atmosphere. This will allow a scientific payload to remain airborne for up to six hours. Would your team be interested in such a product and how would the increased flight duration be beneficial to you compared with your current flight system?

2. The helium valve being developed will be easy to attach to the industry standard Kaymont latex weather balloons. All mechanics and electronics will be unobtrusive, light weight, and rugged. How important is ease of use for a system such as this, and what concerns would your team have about integrating a valve such as this into your existing flight system?

3. Our design will allow for fully autonomous operation or manual control using your existing flight communications system (or both) to reach the desired altitude. Would your team prefer one mode over the other?

4. Wireless communication is used to communicate between the valve assembly and the main command and control payload. This avoids having to run external cabling which can become tangled or damaged during flight. If wireless communication could also be extended to your other payload electronics to facilitate wireless communication would you be interested in such a feature? Do you have any concerns about the use of wireless communication?

5. Are there any other features your team would like to see incorporated into this product? If so what features?

The interviewees consisted of Berk Knighton, Randy Larimer, Angela Des Jardins, and Jen Fowler. They provided feedback for how the product could be improved and features they would like to see incorporated. This diverse group of potential clients includes educators, product engineers, and field scientists. Through their unique perspectives we can determine if our plan is converging with a perceived need that is currently underserved in the market we hope to enter.

Dr. Des Jardins' Response:

1. “I can think of several experiments that would benefit from a longer exposure to the space-like environment as well as benefit from more time to collect data. Also, a longer flight affords more control for landing in a preferred area.”
2. “Ease of use and reliability are certainly key. At this time, we simply tie the balloon closed and let it burst, so adding a complicating factor would be a big step for us. If instructions and information are very clear, I would feel more confident about using the valve. Other concerns for integrating: we don’t have a method for cutting down our balloon – we just let it pop. We would need some reliable way of terminating the flight at the time we wanted if we were to have a valve. Also, we currently do basic flight predictions with an on-line program that does not have extended flight time available. I would need help in finding out how to predict how long to let the balloon float at what altitude, how long to vent the balloon to get there, and in how to know when I should terminate the flight. Finally, we are thinking about making the transition to hydrogen because it is so much less expensive. You mention that this is a helium valve. I would want to make sure it would be okay for me to use this valve using hydrogen as a lifting gas.”
3. “It seems to me that the only autonomous part of our current flights is that the balloon will pop. Without that, it seems like each flight is so different, I can’t imagine how an autonomous flight would work. That being said, in order to use manual control, I’d need lessons on how to know how much to vent and when to get my desired float time and altitude. Also, in order to use manual control, I’d have to have some way of communicating with the valve, right? We don’t currently have any capability for sending commands, so we’d need that additional piece (and complication) to our set up.”
4. “Reducing tangling sounds great. We don’t currently have any communication going between payloads (as mentioned above) – we just store the data and retrieve it – but if we did have that capability, I could see it being useful.”
5. “I already mentioned the most important features that might be incorporated – a termination mechanism, communication to the payloads, and flight predictions. Can’t think of any others right now.”

Randy Larimer's Response:

1. “Yes a cost effective solution to spend more time in a radiation filled environment would be beneficial for testing redundant computing systems. Since the cost is reasonable more flights could be conducted compared to sounding rockets or larger NASA balloon flights.”
2. “A simple to use system would be beneficial since my team has limited ballooning experience. Can the balloon be filled easily as helium is expensive if we mess up? Is it easy to tell when the system is powered on and working from a distance? We do not want to fiddle with the system.”

3. “Fully autonomous would allow my team to set the altitude and forget it, focusing on our real time data at float altitude. I guess having a backup manual mode would be good if things go bad during the flight. What commands and how do I send them to the valve would be a concern. Is there a format for the commands that I must follow?”
4. “Wireless communication between multiple payloads would be great! What command format would I use to send and receive data on this wireless link? Will the wireless link interfere with any of my other wireless products such as GPS or iridium communication? Will it function next to a noisy GoPro camera or other high speed devices? How many hours of service can I expect from this wireless link? Will it last the entire time?”
5. “Some type of test feature to determine that the wireless communication is working between payloads…LED’s or audio? Some type of addressing for multiple payloads so I know who I am talking to? Cut down or easy fill options would be great!”

Dr. Knighton's Response:

1. “I can see some potential applications for such a device. Since we are in the business of flying radiosondes on routine basis, several hundred a year, it seems unlikely that we would find use in our standard application where we are simply interested in collecting vertical profile data. Severe weather events are times when extended flight times at a specified altitude are desirable and we would definitely find your system useful for this application. “
2. “It's got to be easy to use and robust. Even though we launch often, our group doesn't allocate much time to the process. Because we see this as a special application we are willing to tolerate a bit more fiddling, but we are certainly interested in a device that interfaces well with our existing equipment.”
3. “Autonomous operation for sure. We will know ahead of time what altitude level we will want to study. Our data retrieval system is totally automated and so not having to have a dedicated operator is very important.”
4. “Sounds great for academic ballooning programs, but we don't have any need for communication between our measurement payload and the valve.”
5. “Since we do not anticipate recovering the system cost is critical as is ease of use. Setting the altitude and powering the system needs to be easy. System status lights for power, GPS lock and altitude set point acknowledgement are important features so that we know that it is ready to fly. The ability to be able set the altitude manually or through a smart phone will be helpful. We don't want to have to use a computer to initialize the valve system.”

General trends in the responses of our interviewees will be covered in the Converge Plan section.

Convergence Plan

To build a convergence plan it is important for our team to take into account the feedback received during our interview process (with potential customers) to determine if any changes need to be made to our final design. This ensures that we are correctly gauging the needs of the intended market and that we are providing a product that serves to resolve a need which (we feel) is currently lacking in this market space. Incorporating this feedback also shows that our engineering team is aware of the importance of our client's needs which will help build loyalty between our design team and our clients.

The response from all interviewees was generally positive on all fronts and confirms that our product fits into a very niche market. In the following paragraphs the feedback will be evaluated for each interview question and how that feedback will help us converge our engineering plan towards a completed product.

The first interview question was to gauge overall interest in our overall product from several different perspectives, including academia, meteorology, and engineering. The overall response was positive in confirming that a device such as ours would be accepted and desired. Dr. Des Jardins suggests that the currently available flight prediction software in this sector cannot predict landing zones when the balloon floats/hovers during the flight. As landing prediction is a major component of traditional weather balloon flights we may need to develop our own flight prediction software which can handle our flight profile or find products on the market which have this capability already. Dr. Knighton indicated that he did not see a need in the market for vertical profile radiosondes, however he noted that scientists studying extreme weather would be interested. The potential academic clients were interested in how our product could allow for more advanced, long duration flights for student experiments. Mr. Larimer also mentioned several engineering specific use cases which could benefit from our system such as radiation tolerant computing. From this feedback we note that in general our plan converges with the client's interest in the capabilities it provides to their work. No changes would be required based on this section, however the new areas of interest mentioned by our interviewees may indicate that we have not fully investigated all of the potential uses for our product. It will be important for us to continue conducting market research to find other niche applications for the helium vent.

The second interview question attempts to determine if our proposed design will be easy to use and durable in the eyes of our potential clients. The question also opens the door for any concerns the interviewees have about integrating the valve into their current system. The overall response indicated that there was a slight hesitance to add additional complexity to existing systems. Another common theme was that the system had to be as easy to use as possible to ensure the device is actually used and to prevent errors. This does converge with several of our stated design choices, including reducing external wiring by using wireless data transmission, integrating a fill nozzle into the valve, and designing towards compatibility the industry standard latex balloon. This also indicates that our team needs to potentially spend additional time on the documentation and software design to ensure it is easy to use and configure our product. Finally, Dr. Des Jardins inquired about our system being compatible with hydrogen gas. The industry may start to move towards hydrogen gas as a buoyant gas since helium's price is highly dependent on oil production. As hydrogen is explosive while helium is not this would present an additional engineering challenge and likely also change the procedures for using the valve. While we will likely not change our design plan to accommodate hydrogen at this phase, it will be very important for us to continue to watch the market for helium to ensure our product is viable for the future. Our team must also ensure that sufficient warning is provided to the clients to avoid using hydrogen gas with our product.

The third question is meant to determine how involved the end user will be in the operation and control of the valve. Our team is currently planning to have two main modes: autonomous and fully manual. The autonomous mode attempts to reach a preselected altitude with no input from the user other than initially inputting the altitude. Manual mode would turn off any automatic control functions and would rely on the end user having a method to control the valve midflight, such as another microcontroller or satellite uplink. The feedback received from our interview sessions overwhelmingly suggests that autonomous mode will be the stand out, and preferred, mode of operation. This suggests that we need to invest a significant portion of our development into the code performing the autonomous decisions. We will also need to focus on very thoroughly documenting the proper use of this mode as some clients were apprehensive about how complicated this process may be. There was some interest in the manual control mode but mainly for contingency reasons. A standard protocol document which explains how the end user will interface with and control the valve in manual mode will need to be thorough in scope. The feedback received from these interviews suggests that our current engineering plan will converge with the needs of our clients.

The fourth question asked of our interview panel was used to determine if the wireless communication that we plan to implement would be a useful feature to the clients. Specifically we currently plan to use wireless communication between the valve mechanism and the main control system microcomputer which resides in a command payload below the valve (approximately 20 feet away). An additional feature our engineering team is planning on implementing is a general wireless communication spec which would allow the clients to send data between payloads. This would rely on wireless expansion modules that we would package in with our product. The majority of those interviewed felt the wireless communication with the valve is a great idea that they would like to see implemented. The wireless expansion modules sparked interest for those in academic settings. As with most of our features, the interviewees wanted to know exactly how these modules would work and how they would implement them into their current systems. This suggests again (as a common theme) that we must have very thorough documentation which describes the details required for using these more advanced features. Dr. Knighton suggests that the radiosonde community would not see as much value in wireless communication. Our team will need to determine if this suggests we need to explain the virtues of the wireless capabilities with these groups more thoroughly, or if we need to market the other features of the valve to this specific market (radiosonde meteorological community). The feedback received suggests that our current engineering plan for this feature will converge with the requirements of our academia clients, and our overall system will still be beneficial to the meteorological community.

The fifth and final question was open ended in an attempt to gather any other general feedback the potential clients had to offer. The common themes mentioned were ease of use, confirmation of proper operation, and low cost. Ease of use has been a common theme throughout our interviews which again suggests our documentation needs to be thorough. The overall system must also have features to indicate proper operation and status. LED status indicators were mentioned several times as a way to confirm operation. This was not previously something the engineering team considered so we must implement this feature to converge our plan with our client's needs. Dr. Knighton mentioned cost as a main metric by which our system would be evaluated to the meteorological community. Referencing his suggestions to question four, this may suggest that a second model of our valve could be developed with cost as main design factor. Removing extra features such as wireless communication may result in an inexpensive product which is more desirable to that community. If we implement these suggested features our plan will converge on a product which our clients would be interested in using.

Contingency Plan

There is some chance that our design choices will not work. In order to minimize the impact on the end product it is necessary to make a contingency plan. Two potentially problematic design choices are the valve design (it may not allow for the necessary amount of air flow), and the selected microcontroller configuration (it might not interface as well as we would like or it might consume too much power during operation).

If the microcontroller configuration selected does not work for various reasons the contingency plan is to use the next design alternative that scored the next highest in the decision matrix. This a micro controller with an external radio module. This alternative will provide more flexibility to meet the design requirements because this will allow us to select a micro-controller and a radio module separately giving us more options to choose from. If it is required we could select a low power, less powerful micro-controller for our design. Also a more commonly used microcontroller could be selected, one that has been previously used with a radio module for something similar to this application and has example code available.

There is a question as to whether or not the gate valve will have a high enough flow rate to provide the user with neutral buoyancy within the specified vent time window. The gate valve currently utilizes approximately 45% of the flow area available within the geometry of the flow tube. If the flow rate ends up being inadequate, the butterfly style valve will be used. This valve will allow an estimated 75% of the effective flow area provided by the inner geometry of the flow tube.