Balloon Assisted Launch System (BALS)
2021-2022 Report

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This paper will cover the tests and findings of the Balloon Assisted Launch System group's work on what goals were being accomplished, the steps taken to achieve these goals, and the outcome of the work done in the 2021-2022 school year. The overall goal of this project is to design a system in which a balloon can carry a rocket above 95-99 percent of the atmosphere before it is launched. The drastically saves on the required fuel and makes it much cheaper to get to space. Our group chose to fill three balloons with helium connected to three out-rods and a down rod to create a moment, and a top plate that the rocket is able to launch from. From the small-scale tests, this design is very stable while it was free floating as long as the stand is built sturdy, and the balloons are not over or under inflated. From the full-scale test, it was found that the stand is not stable, and it is clear that further redesigns of the stand are required for the size rocket used. Some of the major issues that could have caused the full-scale stand to be unstable while the small-scale stand is stable is that the rocket used in the large-scale is much bigger, raising the center of mass too high. Another issue with the large scale is that the rods that support the balloons have to be exactly 120° apart, but in the full scale one of the rods is slightly off, making a stable state difficult to achieve.

I. Nomenclature

A = area
a = acceleration
C_D = coefficient of drag
D = drag
F = force
F_B = buoyant Force
g = acceleration due to gravity
m = mass
ρ = density
r = radius
V = volume
v = velocity
v_t = terminal velocity

II. Introduction

The goal of this project is to send a rocket above the atmosphere before it is launched into orbit. The most practical application for this is to put microsatellites into orbit for much cheaper and easier than launching a rocket all the way up into space from the ground. What makes launching a rocket so much better than launching from the ground is that there are no more losses due to the drag from the atmosphere and the losses from gravity of the extra fuel. However, this creates a lot of challenges and problems that need to be carefully thought of. Mainly, how do you get the rocket to that altitude, how can the rocket be launched when it is so high no one can see it, and, if a stand is used to get the rocket up that high, how can the stand be brought down safely from that altitude?

A. Previous Work

The first step in the overall design process for this project was to research any previous attempts that have been made by other organizations or institutions. This allowed for familiarization with any successful or unsuccessful attempts in the past so that mistakes were not repeated. It was discovered that almost all previous attempts to successfully fly a rockoon used a one-balloon model where the rocket either launches at an angle and flies past the balloon, or it launches directly vertically and flies straight through the balloon and keeps going. We wanted to try something different in attempts to achieve a more stable model with more than one balloon. So, the next part of the design process was to brainstorm any design ideas.

When looking at multiple-balloon model ideas, it was important to pick an appropriate number of balloons. A two-balloon model would have been more unstable than a one-balloon model, but a three-balloon model would theoretically be very stable and have much less opportunity to sway back and forth during flight. In the three-balloon design that was drawn up, the weather balloons were to be evenly spaced at 120 degrees apart, and the rocket was to sit in the center of them on a platform. Attached below the launch platform was a "boom rod" that created a counter moment and provided a significant amount of stability to the overall design. Some sort of string was to be tied from the bottom of the boom rod and out to each of the individual outriggers that the balloons were attached to the end of to provide more sturdiness and ensure that parts of the design did not shift during flight due to wind or any other cause of instability. Lastly, the team was to come up with a way to pop at least one balloon in order to safely allow the structure to float back to the ground without hurting anyone or damaging anything. To accomplish this, an e-match would be attached to the balloon and fired after the rocket takes off successfully.

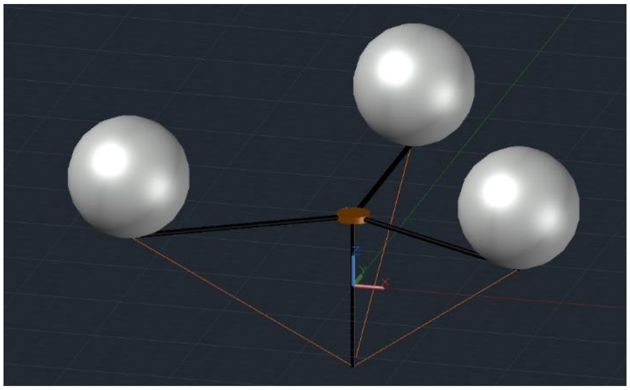


Figure 1 – Final design for the 3-balloon system.

Upon achieving several stable attempts with the small-scale design and devising an electronics box to be the brain of the whole system, it was time to start constructing the full-scale model of this design. This design used bigger balloons, longer out-rods, and a level one high powered rocket. As far as the construction portion of scaling this design up, everything came together nicely in that it was just a larger version of the model that the team had been testing with before. Upon testing the larger model for stability, it was discovered that inconsistencies in the scale-up had caused issues that greatly affected the stability of the balloon stand. One of the main causes of this new-found instability was the weight of the level one rocket raising the center of mass of the structure too high to maintain stability. This is why the initial launch platform design may want to be revisited and revised to be more strong and allow the rocket to sit at a lower level than the balloons.

The first real test of the full-scale model was somewhat of a success in that the team was able to get the high-powered rocket to remotely launch off of the designed structure, but the design was not nearly stable enough to be satisfactory. In the code that controls the launch conditions, it is required that the structure remain within twenty degrees of vertical for at least two seconds after achieving the desired altitude for the rocket to fire. The full-scale model took over three minutes of swaying around in very mild wind conditions to stay still for two seconds and allow the rocket to safely be launched. This is highly impractical and would not work at all in attempting to launch in more windy conditions or at a higher altitude, especially considering that the specified altitude in this test was only thirty feet. Another consideration to be made after this first test was that the charges placed on two of the balloons that were to pop them and allow the stand to float back down were knocked off by the force of the rocket launching. This would not be good in a non-tethered launch because it would be extremely difficult to recover the launch structure after the rocket fired.

B. Calculations

In order to get the rocket and stand off the ground, it is important to figure out how much weight the balloons need to lift. From Newton's second law (Eq. 1), it is known that the lifting force the balloons exert to lift the rocket and stand of the ground is equal to the mass times acceleration.

$$F = ma \tag{1}$$

In order to find the force, the balloons will exert on the stand, it should be determined what the desired acceleration is. However, it is important to find an acceptable launching speed given this lifting force. For this, Eq. 2 shows the terminal velocity of the stand where m is mass, a is acceleration, ρ is air density, A is the area, and C_D is the coefficient of drag of a sphere. Coefficient of drag is slightly different for this problem in that the coefficient of drag for a sphere is known, but the stand has three spheres. It is clear that if the drag for each of the three balloon is the same, it would make the overall drag 3 times that of what it would be with one balloon. Therefore, by looking at Eq. 3 which shows the coefficient of drag for any given area, it can be seen that the coefficient of drag will be multiplied by three if the drag is as well. So, by using the C_D of a sphere and the projected area of all three balloons (Eq. 4), the terminal velocity of the stand can be estimated for a given acceleration.

$$v_t = \sqrt{\frac{2ma}{\rho A C_D}} \tag{2}$$

$$C_D = \frac{D}{\frac{1}{2}\rho v^2 A} \tag{3}$$

$$A = 3 * \pi r^2 \tag{4}$$

By looking at Eq. 4 and Eq. 2, as the area increases, the terminal velocity decreases. However, to make the area increase, the amount of helium that goes into the balloon must also increase which increases acceleration. This is important because when inflating a sphere, as the radius increases, it takes exponentially more helium to increases the radius of the sphere. For example, to increase the volume of a sphere from a radius of two inches to four inches takes 234.57 in^3, but to increase from a radius of four inches to six inches takes 636.7 in^3. Therefore, to keep a small terminal velocity while also maintaining enough lift, a smaller acceleration is preferable to a larger acceleration. For this project, it was determined that a 1 m/s acceleration would provide a way to get the stand up to altitude fast enough while also being at a safe velocity for the rocket to launch at.

To find the force required to lift the rocket and the stand, the total weight of everything must first be found, including the weight of the rocket, fuel, and balloons. Then, Eq. 5 must be used to find the buoyant force from the helium where V is the volume of the balloons, g is the acceleration of gravity, and ρ is the difference in density of air and helium.

$$F_b = \rho V g \tag{5}$$

The final step is to calculate the required volume by dividing the buoyant force by the density different and gravity in Eq. 5. For this project, filling the balloons could only be done by measuring the circumference of the balloon, so the final radius of the balloon was found from the volume of a sphere, and the circumference of the balloon was found from that.

C. Initial Designs

The Like any other design/build process, it was important to scale the entire model down to a size that could be worked with more easily and be tested for stability and any unsuspected flaws in the design. The team started with four-foot carbon fiber rods as outriggers, three weather balloons, and a 3-D printed stand that held the rocket at a level below the balloons that the rocket would fly out of. This design, seen below in Fig. 2, was not very sturdy due to the nature of 3-D printed parts, so the team decided to build a wooden platform for the rocket to sit on instead. This design proved to be much more sturdy and allowed much less room for error as far as parts breaking. It will be touched on later in this report that the first design may need to be revisited due to how the rocket sits down lower than the balloons and would be more stable than it sitting on the same level as the balloons. This lowers the center of mass of the whole structure and would make it fly more steadily.

Figure 2 – Initial Launch Platform Design

The rocket used for the small-scale design and tests was an Estes 1491 Taser rocket. This, being a model rocket with a low powered motor, did not require any license to fly and was great for the design tests due to how lightweight it was and the ability to use A through C motors depending on the desired power of the launch. The team knew that at least one member of the team would need to acquire at minimum level one high powered rocketry license in order to fly a rocket of the scale that was desired. All members of the team constructed certification rockets to be flown with an H motor, but only one of them flew and was recovered successfully in order to attain a level one license. The successful rocket can be seen in section V of this report, and the model rocket used in the small design can be seen below in Fig. 3.

Figure 3 – Estes 1491 Taser Model Rocket Set

III. Procedure for Launching the Rocket

To begin, the stand is assembled first. For this, the down-rod is already glued in for both the small-scale and full-scale. The next step is to place the out-rods in the stand. For the small-scale, the rods are placed under U-bolts and the U-bolts are tightened down. For the large-scale design, the rods are placed under zip-ties and those are tightened. For the large-scale design, the launch rods will have to be placed in next. For this, the rods slide into each separate hole, then a few layers of tape are wrapped around the rod between the wood to ensure the rods will not slip out during launch. Next, the strings need to be measured and cut that tie the balloons to the down rod. These will be used after the balloons are inflated. To inflate the balloons, use the circumference of the balloon calculated from the required lift as mentioned in the calculations section and cut a string to that length. Then, inflate the balloons and wrap the string around the center of the balloon until it reaches the desired size. Once this is done, place a weight on a scale and zero the scale. The string previously cut to tie the balloons down can then be used to tie the balloons to the weight and measure the lift of the helium. The main point to note is that this method is not perfectly accurate as the balloons never sit still and the weight of the string and rubber part of the balloon need to be considered when measuring the weight the helium will lift. Once this is done for all three balloons, they can be tied to the stand. Lastly, the electronics box can be programed and tied to the bottom of the down-rod with zip-ties. The wires of this are run up the down-rod and tied to the out-rods. The charges set to pop the balloons are taped to the side of the balloon and the charge to launch the rocket can be placed in the rocket after the rocket is set on the stand.

IV. Small-Scale Tests

The vast majority of testing with this project was performed on the scaled down version of the overall design. This is because it did not make any sense to work on the large-scale structure until all of the flaws were worked out on the small-scale model. There were not really any initial issues with stability on the small-scale design, which worked out largely in favor of the limited time that was available this year. Because of this, the team was able to move forward with the development of the launch pad. The initial design, shown in Fig. 2 above, was not very sturdy and would be easily broken under the amount of tension that would be experienced under windy launch conditions. This was due to the 3-D printed design, so the next version of the launch pad was constructed out of plywood. This proved to be much stronger and was able to withstand the heat/force of the rocket launching directly off of it.

Development of the electronics portion of this design was able to be devised almost entirely in small-scale, minus the extra components that would be required for a launch at altitude. These extra components consist of several cameras and a GPS locating system. Because the electronics were able to be used on any scale of design, the team was able to work out any issues with the system before advancing to the larger-scale model. The electronics box for the small-scale design contained a gyrosphere to ensure that the rocket would launch within twenty degrees of vertical and an altimeter that would keep the rocket from launching until a specified altitude was reached. The charges for launching the rocket and popping balloons were also integrated into this system and programmed to fire the rocket at altitude, and then pop however many specified balloons after launch so that the stand would safely be returned to the ground without any damage to the stand, property, or any persons below.

One of the main challenges faced during this project was figuring out a way to launch the rocket remotely from high altitude. Given the height we were aiming to launch at, traditional rocket launch methods were unable to be used. We instead had to come up with a way to remotely fire the rocket once it reaches a designated altitude. The main requirement to launch a high-powered rocket is that it can only legally launch within 20° of vertical in any direction. Given that we were launching off of a floating platform freely affected by wind this was something we had to make sure was accurate. In order to accomplish this feat an electronics system had to be designed in order to remotely launch the rocket. This electronic system consisted of an Arduino Nano board, altimeter, and gyroscope working in tandem to make sure the launch went off as planned.

The Arduino Nano is the backbone to the system and was able to be coded using the Arduino IDE system provided with the board. Once activated the code continually checked the altitude and angle of attack in order to make sure all launch conditions were met. The altimeter, a bmp180, gathers an initial reading of pressure at ground level and uses subsequent readings of the ambient pressure to determine how far it has risen in the atmosphere. The gyroscope chip was a mpu-6050 which is a 3-axis accelerometer and 3- axis gyroscope which can read relative position from the three main axis. The accelerometer was positioned with the y-axis pointing into the sky so the only two things that had to be read were the degree changes in the x and z direction. A copy of the code is posted in the appendix down below to get a better understanding of how all of the component's function.

When launch conditions are met there still needs to be a way for this signal to reach the rocket motor and two of the balloons. This was accomplished by sending the signal through three sets of wires attached to the electronics box by a standard outlet plug. The wires had a set of alligator clips soldered onto the end in which an electronic match could be clamped onto. When the code gave the signal that every launch condition was met power would be sent through the first wire in order to launch the rocket. Two seconds later the first balloon would pop due to the second wire and two seconds after that the second balloon would pop due to the third wire. In order to make sure that the rocket was launched when it was truly vertical and not when it happened to swing past the y-axis, a second test was set for two seconds after the first. If the altitude and launch angle were still proper, then the go-ahead signal could be sent out.

V. Full-Scale Test and Future Work

The full-scale launch was conducted at Bluegrass Rocketry club sod farm in Elizabethtown, KY. The full-scale model was designed the same way as the small scale with some minor differences. The first difference was that instead of solid carbon fiber rods for the out-rods, hollow ones were used. The next difference was that instead of two U-bolts to hold down the out-rods, two sets of two crossed zip-ties were used to hold down the out-rods. Both of these decisions were done to conserve weight as it was believed that the hollow rods did not require much strength to withstand any forces, and the U-bolts that could hold the rods down were unnecessarily large for this application. The final difference was that rather than one metal launch rod, two solid, carbon fiber rods were used on either side of the rocket.

The rocket used for this test was Alex Brown's L1 certification rocket than can be purchased and built at the SSTA. A model of this and picture are shown below in Fig. 4.

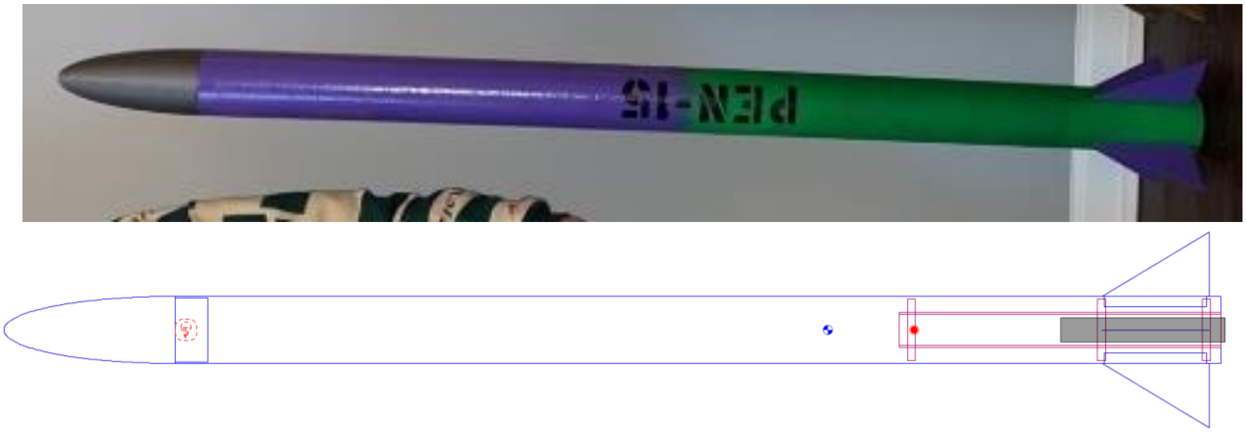


Figure 4 – OpenRocket model and rocket used for the full-scale launch.

For the full-scale launch, the rocket was able to launch, but the stand was not very stable. During preparation for the launch, it was very difficult get the stand to stay upright. There could be several factors to this, but the most probable reasons are that the rocket used is much larger comparatively to the small-scale rocket. This raised the center of mass of the entire structure much higher than the center of mass of the small-scale structure. This would cause the stand to be much less stable. Another problem was that the rods were able to bend too much. The bend in the rods caused any uneven force to be able to tip the structure over, whereas in the small-scale, even if the balloons were slightly different, the stand was still able to float straight. The final problem that occurred was that the force of the rocket was so much that it put a lot of strain on the rods, causing one of the rods to break. Lastly, when building the top plate of the full-scale model, one of the rods was not placed exactly 120° away from the other two rods. This caused uneven forces on one side and made it much more difficult to make the stand stable.

For the future of this project, it is recommended that solid carbon fiber rods be used instead of hollow ones. For the top plate, when drilling the holes in to hold the rods, it is recommended that a small outline of where the holes should be cut is modeled and either printed on paper or a thin 3D printed part be used to show where the holes should be drilled. Lastly, for stability, it is recommended that the stand is made slightly larger, or the rocket made smaller to lower the center of mass, and make the stand much more stable.

As stated before, a copy of the code used for this year is pasted below in the appendix. Using the arduino components listed above and this code you should be able to generate a similar working condition to this year. However, considering your goal is to improve on our initial tests, there are some things we found that could definitely be improved upon. The one major thing that we could not get to was to install a way to personally fire the rocket from a computer so that there would be an opportunity to abort if you noticed something was wrong. There was an attempt to accomplish this but all of the radio parts purchased were faulty and the time taken to resolve this would have eaten into the deadline to create a working model. There are plenty of options for Arduino radio attachments but make sure the range will cover the altitude you are going for. Running the code, we used but adding in a few lines that ask a second Arduino device attached to your computer if you really want to launch is a much needed safety factor if you wish to attempt this at any higher altitude.

The second thing that can be improved upon is lowering the weight of the entire electronics system. Given the fact that the whole rig has to be carried by helium, and the ever-increasing prices of said helium, the more weight you can cut the better. The wires will be a pretty set weight but the box itself can be shrunk significantly if desired. A heavier box does create a good ballast to offset the center of mass of the rocket, but it comes at the cost of needing larger balloons. Further testing should be done to find an optimal solution. The box that was created was based off of the dimensions of a protoboard purchased from the Min Kao parts lab. The board was 4 inches by 4 inches but when all of the electronic pieces were soldered on this ended up being significantly smaller. You should get all of the electronics optimized before moving on to the casing. Another way to cut weight would be to figure out another solution to attach the wires besides the plugs. The plugs were chosen to make transportation of the box and long wires easier but directly soldering the wires to the board could be an option.

In order to accomplish and assemble all of this, the resources that the University has will be a big help in your journey. A lot of the smaller parts like Arduino wires, alligator clips, and transistors are available at the Min Kao parts store. These are all able to be purchased with VolCard money which is very convenient. Some of the harder to get items like the Arduino boards, altimeter, and gyroscope were purchased from Amazon while the long wires and plugs were purchased at a local Lowe’s. All of the 3D printing for the electronics box and any other parts used in any of the builds were done at the University’s ICS lab. Solidworks was used to model any part needed and the ICS has a convenient mobile queuing system that allows you to queue a part at any time of the day and will usually be available for pick up the next day.

VI. Conclusion

A conclusion section is not required, though it is preferred. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. *Note that the conclusion section is the last section of the paper that should be numbered. The appendix (if present), acknowledgment, and references should be listed without numbers.*

Appendix

Table 1 – Lifting Force Calculator

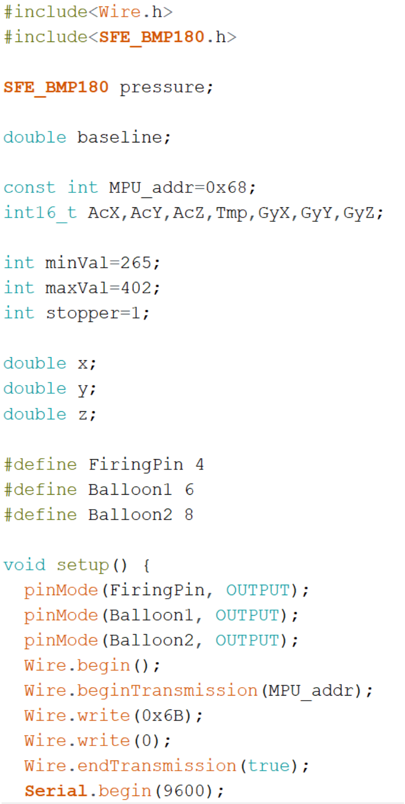
Part	**Number of Parts**	**Weight (g)**		**Bouyant Force**				
				Balloon Diameter (ft)	3		**Required Helium Volume (m^3) with 10% error per balloon**	**0.348656**
Base Plate (model)	1	165		Output				
Launch Rod		37		Volume (m^3)	1.20096			
Carbon Fiber Rods (3ft, .25")	3	180		**Buoyant Force (N)**	**12.32807**		**Required Helium force for a=1**	10.75595
Balloons	3	71					**Helium Volume (m^3) per balloon**	0.34927
Rocket (model)	1	42					**Balloon Radius (m)**	0.436875
Motor (C6-7)	1	25					**Balloon circumfrence (ft)**	9.0058
Paracord (Type 3)	3	50						
			570					
Output								
Total Weight (g)		**995**						
Lift Required (N)		**9.76095**						

Matlab Code for velocity of stand

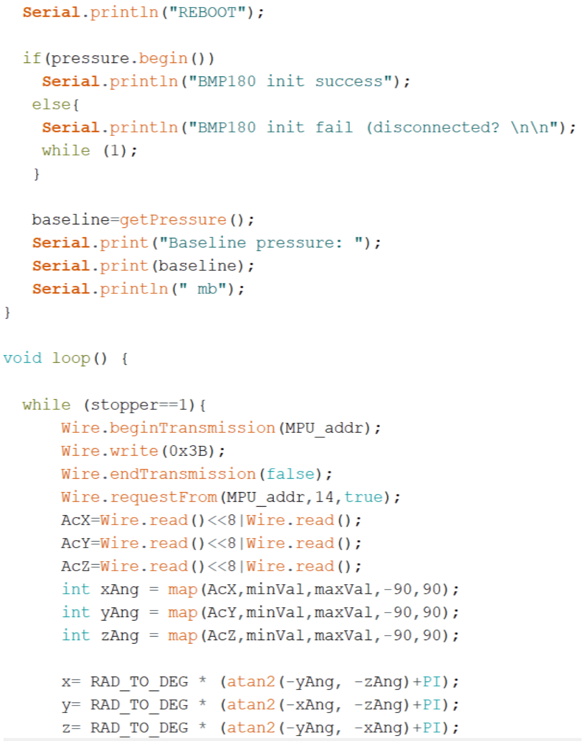
```
%% Inputs
%Weight of structure(grams)
W = 2500;
%Weight of rocket(grams)
Wr = 1000;
%Weight of motor(grams)
Wm = 200;
%Balloon Radius (meters)
```

```
rb = linspace(0.6805,.78935,200); %Put the inflation amount here, not max
inflation
                                   %Should be linspace(starting radius,
                                   %projected max radius, 200)
%Projected max radius - find by finding the slope balloon expansion when
%fully inflated, then put that slope where the required balloon radius is.

%% Constants and Variables
%altitude (meters)
h = linspace(0,3048,200);
%air density
density = linspace(1.225,.90498,200);
%Balloon area
A = 3.*pi.*rb.^2;
%Balloon volume
V = 4.*pi.*rb.^3;
%helium bouyant force
force_He = density - .1786;
F_b = 9.81.*V.*force_He;

%% Calculations
vel_rise = sqrt((4.*(F_b-(9.81*(W+Wr+Wm)/1000)))./(density.*A));
time_rise = sum(15.24./vel_rise)/60; %minutes

%Fall times here are for structure
% vel_fall = sqrt(((4/3).*((2/3).*F_b - (W)*9.81/1000))./(density.*A));
vel_fall = sqrt((2*(W*9.81/1000 - (1/3)*F_b))./(density.*A));
time_fall = sum(15.24./vel_fall)/60; %minutes


vel_fall2 = sqrt((2*(W/1000)*9.81)./(density.*(2/3).*A.*.5));
time_fall2 = sum(15.24./vel_fall2)/60;
%This is the altitude the jollylogic should be set to in order to keep the
%rocket and stand as close to each other as possible

average_ascent = mean(10000./(time_rise.*60)); %ft/s
average_ascent1 = average_ascent/3.281; %m/s
average_decent = mean(10000./(time_fall.*60)); %ft/s
average_decent1 = average_decent/3.281; %m/s

t_total = time_rise + time_fall;

%Vertical distance
    % distance = average_wind_speed*t_total
```

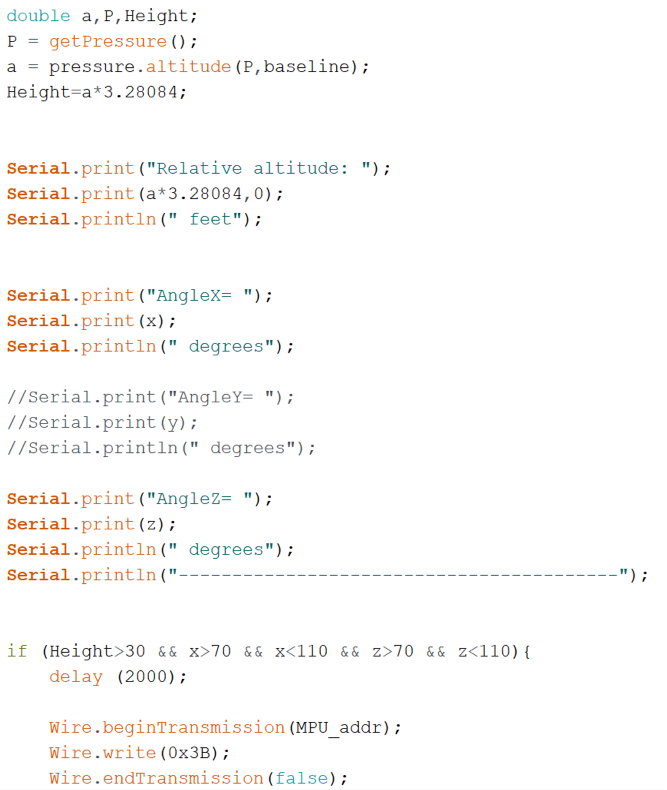
Automated Launch and Balloon Popping Code



```
#include<Wire.h>
#include<SFE_BMP180.h>

SFE_BMP180 pressure;

double baseline;

const int MPU_addr=0x68;
int16_t AcX,AcY,AcZ,Tmp,GyX,GyY,GyZ;

int minVal=265;
int maxVal=402;
int stopper=1;

double x;
double y;
double z;

#define FiringPin 4
#define Balloon1 6
#define Balloon2 8

void setup() {
  pinMode(FiringPin, OUTPUT);
  pinMode(Balloon1, OUTPUT);
  pinMode(Balloon2, OUTPUT);
  Wire.begin();
  Wire.beginTransmission(MPU_addr);
  Wire.write(0x6B);
  Wire.write(0);
  Wire.endTransmission(true);
  Serial.begin(9600);
```



```
  Serial.println("REBOOT");

  if(pressure.begin())
    Serial.println("BMP180 init success");
   else{
    Serial.println("BMP180 init fail (disconnected? \n\n");
    while (1);
   }

   baseline=getPressure();
   Serial.print("Baseline pressure: ");
   Serial.print(baseline);
   Serial.println(" mb");
}

void loop() {

  while (stopper==1){
      Wire.beginTransmission(MPU_addr);
      Wire.write(0x3B);
      Wire.endTransmission(false);
      Wire.requestFrom(MPU_addr,14,true);
      AcX=Wire.read()<<8|Wire.read();
      AcY=Wire.read()<<8|Wire.read();
      AcZ=Wire.read()<<8|Wire.read();
      int xAng = map(AcX,minVal,maxVal,-90,90);
      int yAng = map(AcY,minVal,maxVal,-90,90);
      int zAng = map(AcZ,minVal,maxVal,-90,90);

      x= RAD_TO_DEG * (atan2(-yAng, -zAng)+PI);
      y= RAD_TO_DEG * (atan2(-xAng, -zAng)+PI);
      z= RAD_TO_DEG * (atan2(-yAng, -xAng)+PI);
```



```
double a,P,Height;
P = getPressure();
a = pressure.altitude(P,baseline);
Height=a*3.28084;


Serial.print("Relative altitude: ");
Serial.print(a*3.28084,0);
Serial.println(" feet");


Serial.print("AngleX= ");
Serial.print(x);
Serial.println(" degrees");

//Serial.print("AngleY= ");
//Serial.print(y);
//Serial.println(" degrees");

Serial.print("AngleZ= ");
Serial.print(z);
Serial.println(" degrees");
Serial.println("-----------------------------------------");


if (Height>30 && x>70 && x<110 && z>70 && z<110){
    delay (2000);

    Wire.beginTransmission(MPU_addr);
    Wire.write(0x3B);
    Wire.endTransmission(false);
```

```
    Wire.requestFrom(MPU_addr,14,true);
    AcX=Wire.read()<<8|Wire.read();
    AcY=Wire.read()<<8|Wire.read();
    AcZ=Wire.read()<<8|Wire.read();
    int xAng = map(AcX,minVal,maxVal,-90,90);
    int yAng = map(AcY,minVal,maxVal,-90,90);
    int zAng = map(AcZ,minVal,maxVal,-90,90);

    x= RAD_TO_DEG * (atan2(-yAng, -zAng)+PI);
    y= RAD_TO_DEG * (atan2(-xAng, -zAng)+PI);
    z= RAD_TO_DEG * (atan2(-yAng, -xAng)+PI);

    P = getPressure();
    a = pressure.altitude(P,baseline);
    Height=a*3.28084;

    if (Height>30 && x>70 && x<110 && z>70 && z<110){
        digitalWrite(FiringPin, HIGH);
        delay(2000);
        digitalWrite(Balloon1, HIGH);
        delay(2000);
        digitalWrite(Balloon2, HIGH);
        delay (500);

        Serial.print("Launch Altitude= ");
        Serial.print(Height);
        Serial.println(" feet");

        Serial.print("Launch AngleX= ");
        Serial.print(x);
```

```
              Serial.println(" degrees");

              //Serial.print("Launch AngleY= ");
              //Serial.print(y);
              //Serial.println(" degrees");

              Serial.print("Launch AngleZ= ");
              Serial.print(z);
              Serial.println(" degrees");
              Serial.println("-----------------------------------------");

              digitalWrite(FiringPin, LOW);
              digitalWrite(Balloon1,LOW);
              digitalWrite(Balloon2,LOW);
              stopper=0;
          }
        }
  }
}

double getPressure(){
  char status;
  double T,P,p0,a;

  status = pressure.startTemperature();

  if (status != 0){
    delay(status);
    status = pressure.getTemperature(T);

    if (status != 0){
      status = pressure.startPressure(3);

      if (status != 0){
        delay(status);
        status = pressure.getPressure(P,T);

        if (status != 0){
          return(P);
        }
        else Serial.println("error retrieving pressure measurement\n");
      }
      else Serial.println("error starting pressure measurement\n");
    }
    else Serial.println("error retrieving temperature measurement\n");
  }
  else Serial.println("error starting temperature measurement\n");
}
```