Final report of Observation Balloon For Testing Centers

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Abstract:

This senior design project aimed to develop a non-noisy balloon drone capable of monitoring students during exams to prevent cheating. The primary objective was to design a device that could provide aerial observation without causing disturbance or safety concerns. To achieve this, traditional propellers were replaced with a buoyancy-based system, utilizing the balloon's buoyancy to balance the vehicle's weight. Vertical movement was controlled using a rope mechanism to further reduce noise. The drone was equipped with multiple cameras that transmitted real-time images to a cellphone via Bluetooth, facilitating monitoring and surveillance. Achieving an optimal balance between buoyancy and equipment weight required iterative testing and careful adjustments. The resulting design offers a practical solution for monitoring students during exams in indoor settings, ensuring a noiseless and safe environment.
Keywords: Non-noisy balloon drone; Monitoring; remote control

Contents

1 Introduction

1.1 Problem

Our group aims to design a floating balloon drone that monitors students who are taking tests. The balloon or the drone needs to be non-noisy and provide aerial observation of the students to make sure that they are not cheating. Normally, if we want to use the drone to monitor the students, the sound will heavily affect the students and it may cause danger. Therefore, we want to create a safer machine that can achieve this goal. We can remotely control the direction and the height of the balloon. So the equipment of power system is the most important thing to design. Meanwhile, how to control the balloon flying in the horizontal plane and vertical plane is also another problem. We need to make two different power to let the balloon fly in the space freely.

Also the shape of the balloon cannot be too big since we need to use the machine indoor. We need to connect the camera and the circuit board in the balloon, so how to balance the weight of all the equipment and the buoyancy force that the balloon can provide is a significant thing.

1.2 Solution

Our design is a non-noisy balloon drone that can be controlled by manually remotely to monitor the students that are taking the exam. The most important part is that we need to make it not noisy as the normal drone. We want to use some special way to avoid using noisy motor. For example, we use the buoyancy of the balloon instead of the power of propellers to balance the weight of the vehicle. And we also use the rope to control the balloon up and down to vanish the noise. To make it more useful, we make the drone equipped with several cameras which can send the pictures to our cellphone by Bluetooth. And if possible, we want to use the computer version to automatically detect if there are any students suspected of cheating.

As for the balance between buoyancy and weight, we need to try many times after all the equipment is connected then we need to adjust carefully.

1.3 Visual Aid

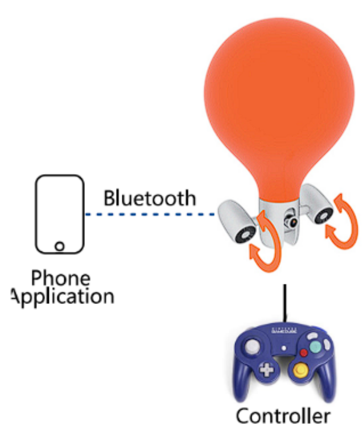

Figure 1: Ideal balloon system

1.4 High-level Requirements List

- The balloon can move freely in horizontal direction and the speed should be less than 0.3m/s and larger than 0.1m/s while moving
- The noise cannot reach to 70dB since it is the maximum amount of noise that the EPA(Environmental Protection Agency) has determined humans can tolerate (without hearing loss, sleep disturbances, anxiety, learning disabilities, etc.).
- It can capture the image of students and the resolution reaches the 720P. Also, it should transmit to user's phone within 1 seconds delay to provide evidence if students are cheating.

2 Design

2.1 Block Diagram

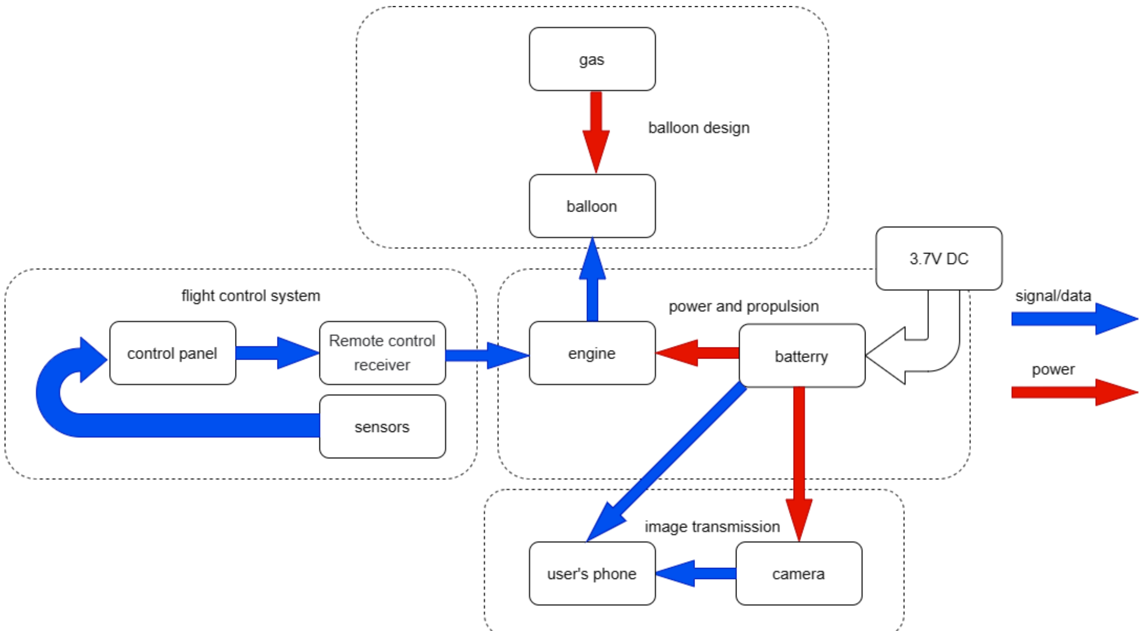

Figure 2: Block diagram and interaction between subsystems

2.2 Interaction between subsystems

According to the figure2 of block diagram, the flight control subsystem needs to interact with the power and propulsion subsystem to ensure that the drone can maintain the desired altitude, speed, and direction. The power and propulsion subsystem, in turn, provides the necessary power for the motor to drive the propellers and control the speed and direction of the drone.

The image transmission subsystem needs to interact with the flight control subsystem to ensure that the drone is in the correct position and orientation to capture high-quality images and videos. The camera needs to be mounted on the drone in a stable manner to reduce the impact of environmental factors such as wind and air resistance.

The balloon design subsystem needs to take into account the requirements of all the other subsystems to ensure that the drone can achieve its desired performance and functionality. For example, the balloon needs to be designed with good stability to reduce the impact of wind on the drone, and it needs to be lightweight to improve flight efficiency and stability.

2.3 Physical Design

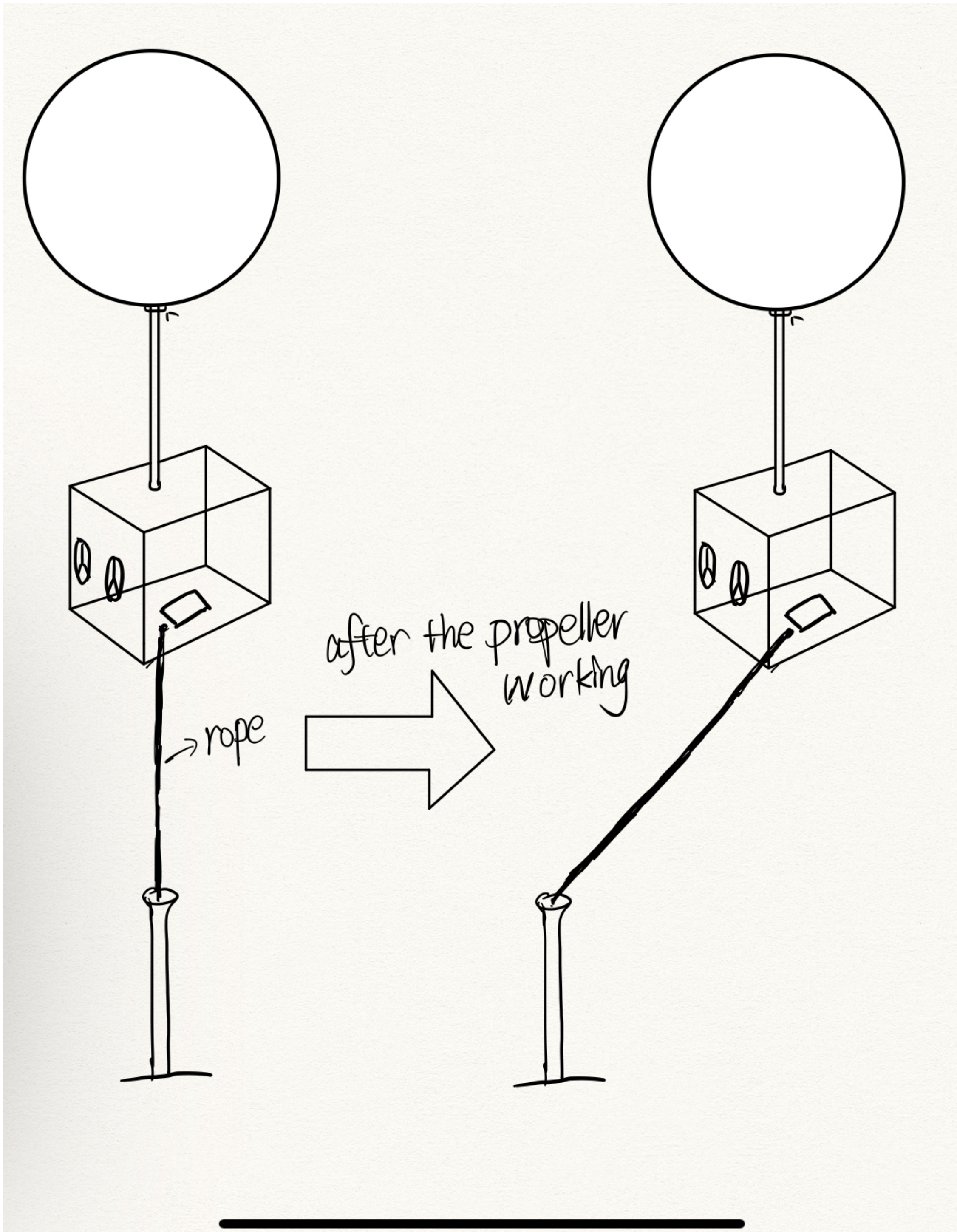

Figure 3: Physical Design version1

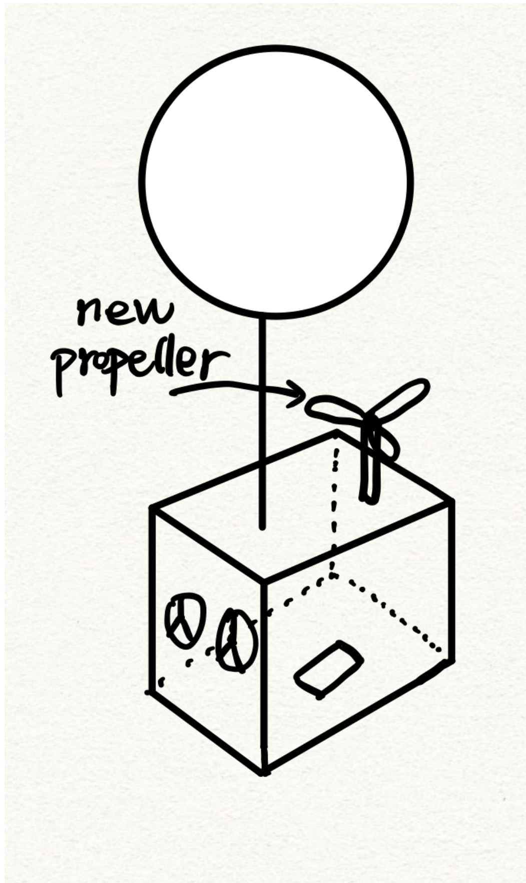

Figure 4: Physical Design version2

2.4 Functional Overview And Block Subsystem Requirements

2.4.1 Flight Control Subsystem

Overview:

In order to allow the balloon to move freely in an indoor environment, we intend to design a control panel including a joystick and other necessary controls to control the speed, height and direction of the balloon's movement. In this subsystem, we select the appropriate sensors to detect the altitude, speed and direction of the aircraft. Throughout the balloon flight, we use algorithms to stabilize the aircraft during flight and adjust the control surfaces for directional control. Sensors collect the height, speed, displacement direction and other information of the balloon and send it to the control panel. After the control panel processes the information, the operator can control the control panel according to the collected information and send instructions to the engine to adjust and correct the flight of the balloon in time.

Requirement:

requirement	verification
1.The battery should must be matched at 7.4V 1500mAh	1. We test the 7.4V 1500mAh battery used in the control panel, it can keep working for at least three hours, which proves that it can meet the basic requirements during the exam. It can keep the flight control subsystem working well and not shut down due to lack of energy.
2. The transmitted power must be bigger than 100mW (board test) and 3dB (air test)	2. We need to build the connection between flight control subsystem and the power and propulsion subsystem. In our test, we used the 100mW transmitted power, and we can successfully send the order to the power and propulsion subsystem and control the flight. And in this test, we can send the order in 100m range which is enough in the exam room.
3.The transmission frequency must be matched at 2.4Ghz which is the ISM(Industrial Scientific Medical) wave band (2400Mhz 2483.5Mhz)	3.The ISM wave band allows the low power and short distance communication in scientific area. So we set the transmission frequency in this wave band and successfully do the test.
4.the sensor must can detect the height change in 0.5 5m, so we choose the 10m laser ranging sensor to meet this requirement.	4.The sensor we choose is 9-36VDC 10m laser ranging sensor, with accuracy in 1mm. So its battery can support it working for hundreds of hours and it also meets our requirement.

Table 1: requirement and verification for flight control subsystem

2.4.2 Power And Propulsion Subsystem

Overview:

In order to achieve the effect of not interfering with the exam, we will choose a suitable motor, which does not have the noise and propeller, but provides the necessary power for the balloon. In addition, we will design and integrate a battery system that can provide sufficient time for the motor and control system. Power management is implemented in this system to monitor battery voltage and ensure the safe flight of the balloon. There are three propellers need to be used in our balloon drone. Two of them are used for horizontal control and one of them is used for vertical control. And each of them is supplied by one motor. And there should be one battery to supply the power of them. There are four requirements we want to consider when selecting the motor: the charging and flight time, the noise level, the weight and the speed of revolution. After the comparison, we choose the 716 hollow cup motor for the propeller motor. And for the battery, we now prefer the 3.7V lithium battery.

requirement	**verification**
1.sufficient flight time. The drone's battery system must provide a minimum of 3 hours of continuous operation to ensure sufficient coverage of exams.	1.Test the balloon several times when using both the propeller motor and the rope-control motor with total power all the time. The desirable situation is that the battery's power is enough for the aiming maintain time which is 3 hours every time.
2.The battery needs to be easily charged. Specifically, it can be charged in a short time while there are two exams successfully.	2.We referred to some resource and the chose the 3.7V lithium battery. If the charge time is less than one hour, it meets the demand.
3.Non-noisy. The motor and propeller of the drone must produce a maximum noise level of 50 dB at a distance of 2 meters to minimize noise disturbance during exams.	3.We searched different types of the propellers. If we test each type in the mode that all of the forward, backward, turning left and turning right in full speed. The desirable situation is that even the noisiest mode is still under the 50dB at the distance of 2 meters. We think that the 5vN20 and 716 hollow cup motors are suitable for this demand.
4.The propulsion of the balloon drone should have enough force to push the balloon drone move.	4.We should remotely control the balloon drone and test the accelerate speed of the balloon which should be more and 0.5m/s2

Table 2: requirement and verification for image transmission subsystem

2.4.3 Image transmission subsystem

Overview:

We'll buy a camera that can capture footage. After the camera takes a picture, we can transfer the picture to the user's phone. We also control the batteries used in the camera system. To be specific, we hope it has high resolution since the purpose of balloon is to capture high-quality images and videos and see if there are students cheating. The camera needs to have a sufficiently high resolution to capture details. And the payload capacity of balloon is limited, so the camera needs to be lightweight and compact to reduce the burden on the balloon. Furthermore, it needs a stabilization system. Since the flight of a balloon can be affected by environmental factors such as wind and air resistance, the camera needs to have a stabilization system to ensure the stability of the images and videos. For the image, we hope the low latency. Balloons need to transmit images and videos in real-time, so the camera needs to have low latency to ensure transmission quality and flight stability.

requirement	**verification**
1.The video transmission is clear, the resolution reaches 720P, and the video frame rate reached 30 FPS. Also, the video delay should be less than 5 seconds. The camera should also have a good zoom capability and be able to rotate in different directions..We need a secure and stable mounting mechanism that can hold the camera in place and prevent it from shaking or vibrating during flight.	1.We will check what we bought is salable product. All the product we got is available. And then We will see the video and the real scene at the same time. Next, we need to measure what the video delay is and compare to our requirement. If the video delay is less than the required value, the requirement will be met; if it is more than the required value, we need to buy a new camera.
2.The weight of monitor should be less than 10 gram because the 10 more grams means we need to add 8.656 dm^3. Without doubt, we hope the balloon as small as possible to avoid disturbing the student in the exam.	2.We need to use a balance to weigh the camera, observe and record the weight of the camera, and compare it with the required value. If the weight is less than the required value, the requirement will be met; if it is more than the required value, we need to buy a new camera.
3.Check if the battery is large enough and make sure it have enough battery life to complete our monitoring tasks. To be specific, it should have a battery life about three hours since most of the exams last for at most three hours.	3.We will do an experiment for it. In order to ensure the integrity of the function, we will constantly adjust and rotate the camera angle during use. If the camera can maintain a good operating state for more than 3 hours under this condition, it indicates that the battery of the camera is available; otherwise, the experiment will be repeated. If that still doesn't work, try a different camera or battery.
4.The balloon must be able to transmit images to the user's cellphone with Bluetooth connectivity over a range of at least 15 meters to ensure that the user can observe the students from a distance.	4.We will do an experiment for it. The user controls the balloon about 20 meters away which is larger than our requirement. If in this "20-meter test " it succeeds, the camera satisfies our requirement.

Table 3: requirement and verification for image transmission subsystem

2.4.4 Balloon Design Subsystem

Overview:

We design the overall structure of the balloon, including shape, color and size, and choose which gas to use based on its weight, durability and strength. And select the materials used for the balloon and its connecting parts. Finally we use 3D printing or laser cutting to create a physical model of the balloon. The design needs to fully consider the stability, control, weight, power, safety, camera, and materials of the drone to ensure that it can achieve the expected flight and mission goals. A balloon-powered drone is easily affected by wind, so it needs to be designed with good stability to reduce the impact of wind on the drone. The balloon needs to be remotely controlled for precise positioning and navigation in the air. The design needs to include wireless control and communication equipment. The weight and size of the balloon can affect the drone's flight performance, so it is important to ensure a lightweight design to improve flight efficiency and stability.The balloon needs to have safety measures to prevent loss of control or crashes. The design needs to include safety switches, loss of control protection, and return functions. And the design is shown in next figure.

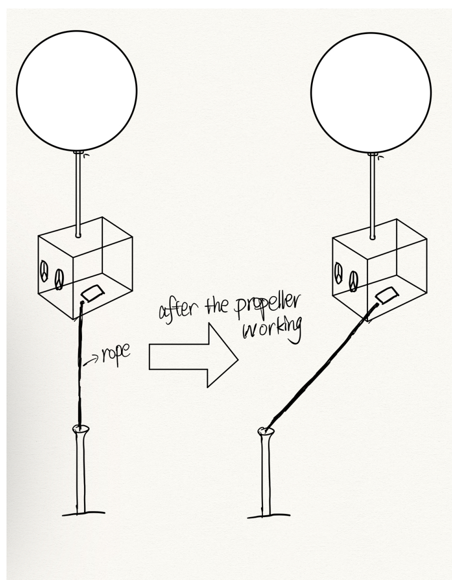

Figure 5: Physical Design Version1

According to the figure 5 of physical design version1, our first version of design was to erect a pole in the middle of the classroom so that the balloons would not disturb the students in flight. The balloon is then filled with helium to make it more buoyant than gravity and the device floats. When the balloon is on the roof, we can use two propellers to control the movement of the device in the horizontal direction. When both propellers are positive, they can go forward. When both propellers are reversed, they can go backward. A positive propeller can turn left and right. At the end of the exam, we can use the motor to pull the string back, which lowers the height of the balloon.

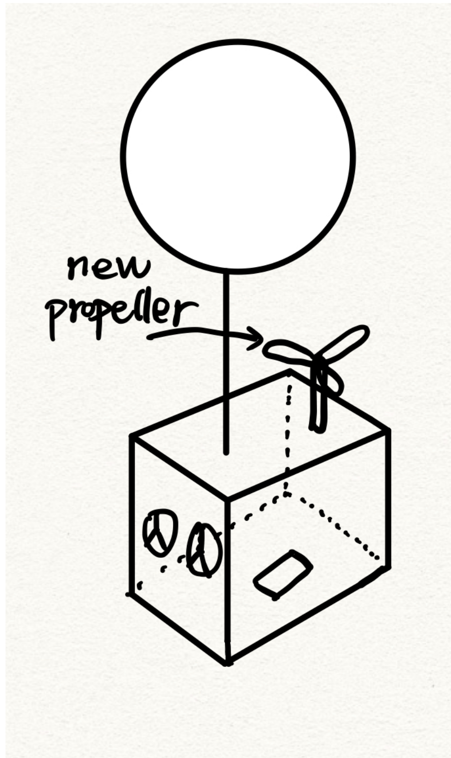

Figure 6: Physical Design Version2

The disadvantage of using a rope is that we can't move the controls up and down easily. We have made finished products before, but the experimental effect is not ideal, can not run normally. So we improved our device by using propellers instead of ropes, simplifying and optimizing the device to some extent. According to the figure 6 of physical design version2, We installed the propeller above the device box. With this newly installed propeller, we can control the rise and fall of the device in a better and more stable way.

requirement	verification
1.The drone needs to be stable at a certain wind speed.	1.Although the balloon will be used in indoor environment, the wind still cannot be ignored. In the experiment, we will use fan to produce wind in horizontal direction and the balloon should be stable in vertical direction. Next, we will use fan to produce wind in vertical direction and the balloon should be stable in horizontal direction.
2.We must ensure the drone will suddenly drop and hurt student. We require the dropping velocity less than 8 km/h, and the acceleration be zero.	2.We will use several balloons as the rising power source. And in the experiment we will pop one of the balloons. After that, we measure the dropping velocity and acceleration. Finally we compare the measured value with our requirement. If the measured value is less than the requirement. The requirement will be met.
3.The rope we use in the design needs to be strong enough. It can bear at least 1kg of weight.	3.We will make the rope bear more than 2kg of weight. If the rope is not broken, the requirement is satisfied.

Table 4: requirement and verification for balloon design subsystem

2.5 Tolerance Analysis

First of all, we should consider the power of the motor and the overall quality of the balloon. Too heavy a balloon, or too little power from the motor, will cause the flight to fail, so we have to determine the mass of the balloon and the type of gas inside.

The design and integration of the circuit is also important, as balloon acceleration may require relatively high power. We need to find and ensure that each component in the circuit is in good condition for its operation. And in order not to affect the exam conditions, we must choose a motor with minimal noise, to achieve a silent effect.

The design of the shape and structure of the balloon is very important. In order to stabilize the flight, we need to design a stable structure.

In order for the balloon to float, we need a buoyancy force greater than or equal to the gravity of the whole device.

$$F_{float} = \rho_{air} g V_{balloon}$$

$$G = m_{He} g + m_{equipment} g$$

$$m_{He} = \rho_{He} V_{balloon}$$

$$m_{equipment} \approx 0.15kg$$

$$\rho_{He} = 0.1786 \frac{kg}{m^3}, \rho_{air} = 1.29 \frac{kg}{m^3}$$

$$\text{then we can get the } V_{balloon} \approx 0.2m^3$$

$$\text{which can let the } F_{float} > G$$

Figure 7: Tolerance Analysis

In our calculations, buoyancy is greater than gravity, which keeps the whole thing afloat. And the volume for the balloon is reasonable which proves that our design is feasible.

It's very important to keep the whole thing stable in the air. To balance the whole thing in the air, the newly installed propeller had to be mounted in the middle of the box so that the center of mass of the whole thing was in the middle.

Also, for the function of moving, we use two propellers as power supply. Although the power is not such large, we do not expect the balloon to move very fast. We just need the propulsion be larger than the air friction.

Next, for the function of detecting. We do a survey about it and find that in houses less than 10 meters high, the 720P camera is strong enough to capture some fine details including if someone are cheating.

3 Cost and Schedule

3.1 Cost

Our fixed development costs are estimated to be 40CNY/hour, in total 70hours for 4 team members. Our parts and manufacturing prototype costs are estimated as flows:

$$Cost = 4 * 40¥/h * 70h = 11200¥ = 1647\$ \tag{1}$$

Description	Quantity	Vendor	Cost/unit	Total cost
Balloon	8	Taobao	4$	32$
camera	1	Taobao	48.2$	48.2$
helium inflator	1	Taobao	35.7$	35.7$
rope	1	Taobao	10.4$	10.4$
remote	2	Taobao	8.6$	17.2$
motor	3	Taobao	11.43$	34.3$
propeller	2	Taobao	20.6$	41.2$
total				219$

Table 5: Cost

This section presents a comprehensive cost analysis for the different components of our project. By carefully evaluating and estimating the financial implications associated with each part, we aim to ensure a realistic budget allocation and effective resource management. The table provided below outlines the cost breakdown for each project component, enabling us to make informed decisions and maintain financial control throughout the project.

All the quantities for the parts estimated above are based on the assumption that the materials will not break during the fabrication, which is typically not the case. So the actual cost of the mechanical part of the system will be more than the estimation above.

$$Totalcost = 1647\$ + 219\$ = 1866\$ \tag{2}$$

3.2 Schedule

The following table presents a comprehensive breakdown of the weekly schedule for each team member involved in the project. This schedule serves as a crucial organizational tool that ensures efficient coordination and distribution of tasks. By assigning specific responsibilities to team members, we aim to optimize productivity, enhance collaboration, and meet project deadlines effectively. The table below outlines the allocation of tasks for each week, allowing for clear communication and alignment among team members.

Week	Yichi Zhang Serial number (1)	Jiajie Wang Serial number (2)	Tunan Zhao Serial number (3)	Shuaicun Qian Serial number (4)
3/13/23	Build the team and make sure the theme (1 2 3 4)	Come up with the initial design and prove its feasibility (1 2 3 4)	Share the design idea with TA and professor and get the feedback (1 2 3 4)	
3/20/23	Finish the document and set the plan in the future (1 2 3 4)	Find the new design of the balloon rising and lowing (1 2)	Buy the model of air vehicle in Taobao (3)	Buy the balloon and camera online (4)
3/27/23	Test for the model air vehicle and prove its feasibility (1 3)	Buy all the equipment we will use and get ready for the assembly (2 4)	Calculate the flight data and make sure the number of balloon (1)	
4/3/23	Collect all the parts to the lab. (4)	Do the initial assembly (1)	Connect the motor with remote control (2)	Connect the motor with propellers (3)
4/10/23	Finish the whole assembly and test for the first time (1 2 3 4)	Locate the error and find the problem (1 2)	Consider the feedback from TA and professor to set a plan to solve the problem (3 4)	M
4/17/23	Base on the test result last week to find a new design to improve the stability of the flight (1 2)	Add the foamed plastic on the surface of camera to avoid the damage between flight (3)	Consider the safety and the controllability of the balloon vehicle. (4)	
4/24/23	Modify the code and try to improve the algorithm of the remote control (4)	Test the endurance of the balloon vehicle(1)	Communicate with TA and professor to get the idea of improvement. (2 3)	e.
5/1/23	Set the improvement into the balloon vehicle (1 2)	Test the final design (3 4)		

Figure 8: Schedule

The weekly schedule has been designed to ensure an equitable distribution of tasks and responsibilities among team members throughout the duration of the project. Each row represents a specific week, and each column represents an individual team member. The table is intentionally left blank to be filled in with the respective tasks and assignments for each week.

Throughout the project timeline, team members will collaborate closely to identify the most suitable tasks for their respective skill sets and areas of expertise. The allocation of responsibilities will be a collaborative effort, allowing team members to contribute to decision-making and task prioritization.

By following this weekly schedule, team members will have a clear understanding of their roles and responsibilities. Regular meetings and progress updates will be scheduled to track the completion of tasks, address any challenges, and ensure everyone remains on track.

The weekly schedule promotes effective time management, coordination, and accountability among team members. It facilitates the seamless execution of the project, ensures optimal utilization of resources, and helps meet the project's milestones and objectives.

4 Ethics and Safety

4.1 Ethics

According to the IEEE Code of Ethics 1[4], as professionals, we hold paramount the safety, health, and welfare of the public and are responsible for promptly disclosing factors that may endanger the public or the environment. Therefore, when testing our balloon flying and doing the helium filling, we will take precautions to ensure public safety.

1. Warning signs will be placed around the test sites to prevent unauthorized entry to potentially dangerous areas.

2. Check all the equipment twice before doing the experiment.

3. Make a plan to deal with the emergency.

4. Shut down all the electric equipment in the classroom before testing.

5. Report the time and location before testing.

As for the IEEE Code of Ethics 4[4], we will avoid any unlawful conduct in our professional activities, specifically relating to laws and regulations regarding balloon flying. Compliance with all regulations and laws is essential to ensure the safety of the public and the environment. Lastly, we will seek, accept, and offer honest criticism of technical work, acknowledging and correcting errors, in line with the IEEE Code of Ethics 5[4]. We will actively seek guidance and constructive criticism from peers and experts to optimize our project and ensure the highest level of technical excellence.

4.2 Safety

1.When we control the flight of a balloon indoors, there is a risk of losing control, so we need to prepare for balloon loss of control and clear the area to avoid injury to people and damage to property. At the same time, since the balloon is filled with helium, if it leaks or bursts indoors, it can have an impact on the indoor air quality, so we must prepare ventilation equipment, such as exhaust fans, and promptly do ventilation work.

2.When installing a motor and camera below the balloon, it is easy to scratch the balloon, so the surface of the balloon should be checked for any risk of air leakage after assembly. During the balloon's flight test, collisions with ceilings, floors, or objects such as tables and chairs are likely to occur, so we should choose a suitable location to minimize the losses caused by collisions.

3. At the crash between the balloon and the surface in the classroom, such as the ceiling, the ground and the desk, we need to shut down the electric equipment. We should also add the foam cotton on the camera to reduce the damage of the crash.

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Appendices

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Figure 9: Schedule