Space Ballooning

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***Abstract*—Space is the frontier of the future, bringing new adventure to a new type of pioneer. Technology is the gateway to this un-chartered territory and will allow the senior design class to explore and obtain a glimpse of space though a balloon-borne high altitude satellite. In this paper I am going to describe about the innovative methods of designing the Balloon satellites and their applications. Ballon satellites can be described as the cost-effective satellites (< 819 USD) that could be launched using helium balloons. The satellite will be a facility that can provide common services to an altitude of till 30 km. The data will be relayed to a ground system where the information will be analysed, displayed, and used to track and recover the system. This balloon satellites fitted with orient able propellers at the bottom, fitted with cameras can be used for spying, patrolling at the defence areas similar to UAV's. Weather changes in the atmosphere can be continuously monitored using these satellites. The satellite shall broadcast real-time data, which shall include temperature, pressure, position, humidity, altitude etc. When these satellites reach near space, the helium filled balloon bursts because of expansion inside the balloon, at that point of time when a propulsion engine is used to propel it into the space, saving the cost for rockets. Moreover, the satellite shall be reusable and will be tracked back using a parachute for inter space missions and thus being eco-friendly.**

***Index Terms*—balloon-borne high altitude satellite, cost-effective satellites, weather monitoring, spying, UAV's**

I. Introduction

Balloon Sat, also known as "near space satellites", is increasingly popular tools to put experiments in a near-space environment. Payloads will be attached to the container and the payload depends on the type of the application we need. When the balloon rides through the air, it gets stretched and the balloon bursts when it reaches a point where the pressure inside will be maximum and could be bored by the structure of the balloon.

Now the major aim of introducing this balloon sats come into picture these satellites could be used for monitoring weather changes in the atmosphere at a specific altitude continuously. This balloonsats fitted with a camera can be used for spying in the military regions as these produce no sound and cost effective. This is a new era of using these balloon satellites as unmanned aerial vehicles in defence. These balloon satellites are cost effective and easy to produce [1]-[3]

II. Main Section

A. Structure Description

Balloon Satellites consists of payload embedded into a cylindrical frame. This cylindrical frame will be attached to a parachute through tether chords which run through plastic tubes to prevent the tether cords from cutting the air-frame material, thus structure is defined.

Structure depends on many factors like temperatures, wind pressure, wind velocities, levels of radiation etc. Mostly, the balloon sat functions at an average altitude of 30 km from Earth's surface. At that altitude, temperature in the atmosphere lies around -55 degrees Celsius. So, definite insulation procedures have to be used [4]. Styrofoam can be used for insulating as it is known for its light weight and high insulation or some heat emitters can be used inside to maintain a fixed temperature inside.

A parachute made of nylon or silk fibre can be used for the primary descent control system because of its light weight and high strength required for tearing. This parachute gets fitted to the payload through the tether cords. Secondary descent control system needs to be used for the safe landing of the satellite. This SDS needs to reduce the velocity of the descent to almost 1m/s. For that another propeller or parafoil needs to be used.

B. Dimensional Constraints

Dimensions of the satellites depend on the purpose it is going to be used for. Well, an optimum balloosatellite can be a cylinder of size 20 cm length and 10 cm diameter for the smaller missions. When the altitude of experimentation is more, then large sized balloon needs to be used.

C. Systems Operations Overview

- To create a Balloon Satellite equipped with on-board information storage as well as real time data transmission with video recording capability and instrumentation to support a variety of payloads. The satellite will be a facility that can provide common services to an altitude till 30 km. The data will be relayed to a ground system where the information will be analyzed, displayed, and used to track and recover the Balloon Sat on landing.
- While in flight, the instruments on board the satellite will take measurements of temperature, pressure, position, humidity and altitude through the use of GPS and sensors.

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- A video from the satellite will be recorded and can be recovered and viewed on the ground after the landing.
- Designing the Data Acquisition and Manipulation Systems and the Graphical User Interface for the data retrieved.

D. Payload Requirements

The payload we use depends on our requirements of the satellite. Payload used can be categorized into two categories. Payload used for data transmission and communication, and for the mission objectives. Basic payload items should consist of basic pressure and temperature sensors, arduino boards, humidity sensors, etc.

E. Telemetry

1) Digi XTend 900MHz(RADIO):

This radio utilizes FHSS (Frequency Hopping Spread Spectrum) agility to avoid interference by hopping to a new frequency on every packet transmission or re-transmission. Its transmit power is software adjustable from 1mW to 1W—the maximum output power allowable by governments that use 900MHz as a license-free band. No configuration is required for out-of-the-box RF communication. Default configuration supports a wide range of data system applications. Advanced configurations can be implemented using simple AT or binary commands.

2) 900MHz omnidirectional antenna:

High performance omnidirectional antenna is designed for the 800 MHz / 900 MHz ISM band. Suited for multipoint, Non Line of Sight (NLOS) and mobile applications where high gain and wide coverage is desired. Typical applications include 900MHz Wireless LAN, SCADA, Wireless Video Links and 800 MHz as well as 900MHz Cellular band applications. Features an integral N-Female bulkhead type connector that mounts through the wall of an equipment enclosure. Included with the HGV-906U is a mast mounting kit. Consisting of a heavy-duty steel bracket and a pair of U-bolts, this kit allows installation on masts up to 2.0" in diameter. Features a rugged 1.3" diameter white high intensity fibreglass for durability and aesthetics. It is designed for all weather operation.

3) Channel LS20031 GPS 5Hz receiver:

The LS20031 GPS receiver is a complete GPS smart antenna receiver that includes an embedded antenna and GPS receiver circuits.

Frequency of Update: 5 Hz. The antenna has the capability of Tracking 66 satellites at a time providing fast time-to-first-fix, one-second navigation update and Low power consumption.

4) Electrical and electronics components:

- The electrical and electronics subsystem consists of the power circuitry, various other components to monitor the battery level and the whole pcb layout of the sensors which will be used onboard the balloon sat.
- To power the balloon sat a lithium polymer battery as well as a voltage divider circuit to monitor its levels needs to be used.
- The sensors will be interfaced with an arduino Mega microcontroller which will then send the data to the ground station as well a store it on a SD card

5) EED requirements:

- The main requirement of the EED subsystem is to adequately power the electronics onboard using a battery which is light weight and can withstand extremely low temperatures.
- The various sensors that make up the payload have to send their data simultaneously to the ground station as well as to a sd card on board, for this the sensors should be interfaced with a microcontroller that can then send the data to the ground station via the radio module.

6) Modules trade & selection:

- The modules used in the EED subsystems are the various sensor onboard (which have already been covered), battery, voltage divider circuit, buzzer system, data logging module and the arduino microcontroller.
- Using a voltage divider, we can monitor various battery levels. A voltage divider allows us to measure voltages that are greater than the voltage powering the system If the lithium polymers are at 4.1 to 3.6V, everything is fine. As the voltage drops below 3.6V we know we are outside the 80% capacity and quickly running out of power
- *Data logging:* Open Log is an open source data logger which is simple to use, simple to change. It is a serial logger that will start logging any received serial data at 9600bps it will log it to low-cost microSD FAT16/32 cards up to 16GB
- Buzzer**:** We are using a ***Lily Pad Buzzer*** which is a small buzzer for the Lily Pad system. It uses 2 I/O pins on the Lily Pad main board and creates different noises based on the different frequency of I/O toggling

Once the altitude is below a certain level or if the overall flight timer hits a threshold (like 5 hours) then the buzzer starts beeping. This would help in finding the payload.

7) Power budgeting:

- For powering the components on board 3 lithium polymer batteries needs to be used.
- For sufficient power levels we are summing two 3.7V lithium polymer batteries, 2000mAh each, and a breadboard SMD power supply to regulate the nominal 7.4V down to 5V for the radio.
- One battery is for powering the sensors and the microcontroller whereas the other powers the radio module.
- The combined cost of the batteries, the buzzer and battery level monitor is around 1500 Rs.

8) Power source and distribution inside the satellite:

- Three 3.7V, 2000mAh lithium polymer batteries

- Output of battery to SMD power supply that takes a 6-12V input voltage and outputs a selectable 5V for the radio at 800mA when transmitting at full power
- The other output gives 3.3V to GPS receiver
- The battery gives backup of around 10 hours and powers the radio, GPS, sensors, buzzer system and flashing lights
- The third battery will be used to power a motor connected to propeller which will be used in our secondary descent control system

III. Flight Software and Data Handling

FSDH unit is required for monitoring and display of data from the satellite at the ground station using Graphical User Interface. All the data acquired from the sensors embedded in the balloon sat is stored, processed and relayed to the ground station. This acquired data can be used for interpreting and tracking the status of the balloon sat in real time.

A. Requirements

TABLE I. Table Showing the Data Handling Process

S No	On board the balloon sat	At the ground Station
1	Accumulation of micro data from controller	Reception at ground station
2	Encryption of data to single string	Decryption of data to obtain individual sensor values
3	Copy of string stored to the SD card	Necessary calculations and conversions
4	Transfer of the data to ground station	Display of data in real time and decoding it into graphs or other.

B. Software Development Plan

- For this balloon sat, the flight software needs to be developed using the arduino programming language with additions of embedded C.
- For the ground station, the software needs to be developed using the python programming language in a Raspberry Pi module with the Raspbian operating software installed. The GUI has to be developed for the interface development.

IV. Descent Control System

This descent control system plays an important role in restoring back the satellite after the designated mission. In order to design this descent control system, an initial survey of temperature and pressure conditions at the probable altitude is needed.

At 30 kames of altitude, temperature of the atmosphere is around -55 deg Celsius and pressure varies around 0.5529 atm and on a normal day, the wind speed is considered to be 20 m/s.

So the descent control system we design should survive the above mentioned conditions taking possible fluctuations in the values into account.

A. Calculation of Estimated Drag Force

Friction is present in air. Drag comes into action when the body starts moving relatively to the wind. This Drag varies along the different positions of the satellite. Determination of the low drag region helps us to fix the outer exposed parts like cameras and sensors.

Drag coefficient of a cube = 1.05 (experimented on subsonic wind tunnel)

Formula for C_D=D/(1/2 $\rho v^2 s$) [5]

So drag force = D = ($C_D\ \rho v^2 s$)/2

where

- ρ is density of medium
- v is velocity of the body with respect to air
- s is frontal area of cube

B. Calculations

- Drag acting on the cylinder = C_D*(1/2 ρv^2 S)
- Plan form area (S) for drag acting on top of cylinder is a circle = $\pi d^2/4$ = 0.0314 m^2 for 20 cms diameter.
- Plan form area (S) for drag acting along sideways of the cylinder is a Rectangle = h*d = 0.06 m^2
- Drag acting on top of the cylinder = 0.82*(0.5*0.08891*20^2*0.0314) = 0.457 N
- Drag acting on sideways of cylinder = 0.82*(0.5*0.08891*20^2*0.06) = 0.8748 N

So it is illustrated from the above calculations that drag acting on the satellite structure is minimum at the top when compared to its sides.

V. Descent Control

A. Primary DCS

A Parachute made of nylon and silk fabric will be used for the primary descent. The reason for choosing the nylon and silk fabric is because of its high tearing strength and survivability. Parachutes should be tested by putting weights little more than the payload to know whether material used could survive drag force in air or not.

Radius of the parachute decides the descent velocity required for the mission. The radius of the parachute is calculated by the formula

$$R = (2mg/\pi\ C_d \rho v^2)^{1/2}$$

where m - mass of the payload with parachute

C_d- Coefficient of drag of the body in air

ρ- Density of the air at a particular altitude

v- Descent velocity needed.

B. Secondary DCS

Given below, Fig. 1 shows the catia design of the payload section fitted with propeller for the secondary descent control.

- The secondary DCS will be using a propeller at the bottom.

- This propeller would be fitted to the Styrofoam made body using a cardboard sheet.
- Steel rods will be used to fit the propeller, to give support to it.

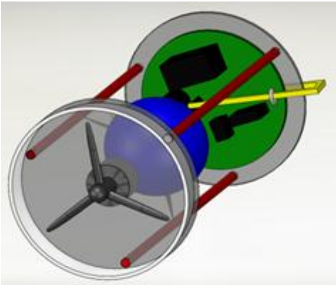

Figure 1. Design of the payload structure with secondary DCS

- The blue coloured chamber shown is the care chamber where delicate electric boards will be kept inside and yellow coloured region is where all the sensors will be put up.
- Direction of the satellite can be controlled by orienting the propeller.

VI. Integration of the Satellite

- Main point in integration is maintaining stability.
- Subsystems inside will be fixed with some cardboard sheets and the space left inside after integrating will be filled with some cloth to get extra added stability from shakes due to wind.

A. Testing Procedures of the Satellite

Near space is a hostile environment, which is intense cold, extreme shaking, high vacuum and intense radiation. So, the satellite built should survive in all the possible conditions.

The tests recommended will be drop test, Cold test, Function Test etc.

1)Drop test:

- The Drop Test verifies that the Balloon Sat can survive landing. This test also ensures the ejection of the parachute from the payload section after the balloon bursts.

Procedure:

a) The landing speed of the near spacecraft is approximately 10 mph, that's about 15 feet per second. Gravity creates this speed when an object has fallen four feet.

b) Load the Balloon Sat with its battery and any other item it is designed to carry. Then drop the Balloon Sat form a height of four feet on to a carpeted or grassy surface. Verify that the Balloon Sat holds together after the shock of impact with the ground.

2) *Cold test:*

- The Cold Test verifies that the Balloon Sat can operate properly when it is extremely cold.

Procedure:

a) Load the battery into the Balloon Sat. Load a Styrofoam cooler with dry ice and let its interior get very cold. Place a wire stand over the dry ice so that the Balloon Sat will not make contact with the dry ice when it is placed inside the cooler.

b) Start the Balloon Sat recording data and load place it inside the cooler. Close the cooler lid and let the Balloon Sat cold soak for about 30 minutes. The Balloon Sat should collect data during the Cold Test.

VII. Fabrication and Assembly of the Sub Systems

- Initially,the internal subsystems of the payload will be fabricated according to the best fit dimension of stability.
- Then we fit a propeller to the cardboard that is used at the bottom side.
- The whole thing will be fitted into the casing made of Styrofoam.
- Parachute tethers will be fixed onto the top casing.That's how fabrication and assembly will be done [6].

VIII. Mass Budgeting

TABLE II. Table Showing the Distribution of Mass

Payload domain	Components	Weight (gms)
	Casing, Top Cover	200
Mechanical Components	Parachute with tethers	100
	Propellers	50
	Small motor for propeller	50
Electronics Components	Sensors, Radio, Battery, On board Computer etc	600

IX. Applications

- This balloon satellite can be used for monitoring the weather changes in the atmosphere at a particular altitude continuously [7].
- This can also be used for aerial imaging of the earth.
- Balloon satellites when developed fully fledged can be used for spying in military operations at times of need during *stealth operations.*

X. Acronyms

- UAV - Unmanned Aerial Vehicle
- C_d - Coefficient of drag
- BSAT / Balloon sat- Balloon satellites
- SDS - Secondary descent control system.

XI. Conclusion

Balloon satellites are not actually in use now-a-days. These satellites look simpler but are very effective in usage. In this innovative paper, I have described the designing and making of this balloonsats.

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