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Research Paper

Design and Study of Rockoon

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ABSTRACT:*In this paper the results of analyses and simulations for the design of a small sounding rocket platform, dedicated to conducting scientific atmospheric research and placing micro satellites into orbit and capable of reaching the von Kármán line by means of a rocket launched from it. While recent private initiatives have opted for the air launch concept to send small payloads to Low Earth Orbit, several historical projects considered the use of balloons as the first stage of orbital and suborbital platforms, known as rockoons. Both of these approaches enable the minimization of drag losses. These two methods make it possible to reduce drag losses. This project addresses the issue of utilizing stratospheric balloons as launch platforms to conduct sub-orbital rocket flights. Research and simulations have been conducted to demonstrate these capabilities and feasibility. A small sounding solid propulsion rocket using commercially-off-the-shelf hardware is proposed. Its configuration and design are analyzed with special attention given to the propulsion system and its possible mission-orientated optimization. The cost effectiveness of this approach is discussed. Performance calculation outcomes are shown. Additionally, sensitivity study results for different design parameters are given, the ultimate aim is to enhance low-cost experimentation maintaining high mobility of the system and simplicity of operations. An easier and more affordable access to a space-like environment can be achieved with this system, thus allowing for widespread outreach of space science and technology knowledge.*

KEYWORDS: *Numerical Solution, High Altitude balloon, Balloon Launching System, Stratosphere Launching Vehicle, Platform Stability System.*

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I. INTRODUCTION

James A. Van Allen first put rockoons to practical use when he and his group from the University of Lowa fired several from the Coast Guard Cutter East Wind during its cruise off Greenland in August and September 1952. Van Allen was looking for high-altitude radiation near the magnetic poles and needed a vehicle that could reach well over 80 km (50 mi) with an 11-kg (25-lb) payload and yet still be launched easily from a small ship. The rockoon was the answer. With his rockoons, Van Allen detected considerable soft radiation at high altitudes much more than scientists expected. This was one of the first hints that radiation might be trapped by the Earth's magnetic field. This lead to a major discovery of the radiation belts around the earth and solar radiation interaction with earth's magnetosphere. A Van Allen radiation belt is a zone of energetic charged particles, most of which originate from the solar wind, that are captured by and held around a planet by that planet's magnetosphere. Earth has two such belts, and sometimes others may be temporarily created. The belts are named after James Van Allen, who is credited with their discovery. Earth's two main belts extend from an altitude of about 640 to 58,000 km)

A solid fuel sounding rocket called a rockoon (derived from the words "rocket" and "balloon") is transported into the high atmosphere by a gas-filled balloon before being severed from the balloon and fired. Because it doesn't have to travel through the lower, denser layers of the atmosphere using power, the rocket can reach a higher altitude as a result.

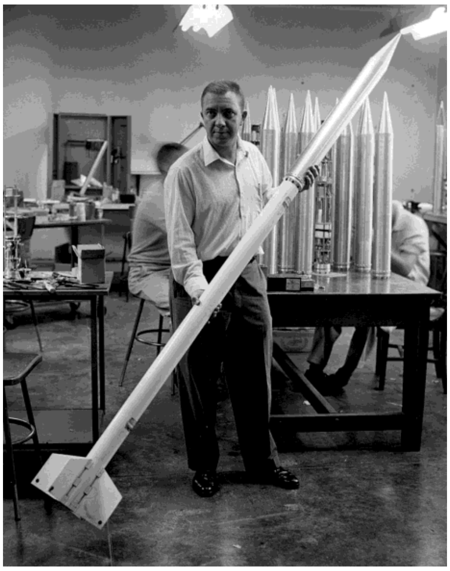

Figure 1 James Van Allen

Figure 2 rockoon first image

As a zero-emission alternative to solid fuel first stage rocket boosters, using high altitude balloons can be very advantageous for environmental preservation. Additionally, because a polyethylene balloon can be constructed for a lot less money than a metal body rocket booster, the rockoon system is both financially and environmentally sound.

We are really interested in rocket systems and lighter-than-air systems, therefore we decided to take on this project because we believe that by applying our prior expertise, we will be able to better understand and grasp the topic. We want to develop a significant and deep concept.

Section 1.01 Literature survey

The device described in this paper is built to encourage customization by researchers thanks to specially segmented and easily adaptable code, the use of the Arduino microcontroller, and the use of inexpensive off-the-shelf components, allowing modification without specialised programming or electronics knowledge. The suggested device, when used as is, captures data just as well as commercial choices while producing it for a mere quarter of the cost. Aaron Price [1] wrote this paper. The use of the Arduino microcontroller is discussed in this paper to aid in our research.

This study's objective was to look into how aerodynamic parameters affected the static performance of a tethered, high-altitude, lighter-than-air platform. A lighter-than-air vehicle and a tether cable were included in the system design, and the basic platform layout of such a system is examined here. The system's static behaviour was modelled using governing equations, and the impacts of buoyancy and aerodynamic lift were parametrically examined depending on the platform's advection distance during stormy conditions. It was established that the hull's buoyancy and aerodynamic lift have nonlinear effects. Analyzed the impact of the aerodynamic drag caused by the tether further in this study article. We came to the conclusion that the cable should preferably have a cross-sectional form similar to an airfoil of a heavier-than-air aircraft because it was demonstrated to have a major impact. To ensure that the drag coefficient is of the order of 10^-1, however, is sufficient [2].

Balloons are made using EVAL (Ethylene-Vinyl-Alcohol) films. EVAL film is expected to be useful for preserving ballast on lengthy flights because it has a distinctive Infrared wavelength absorption band.

A high-altitude balloon that can fly more than 50 kilometres in the air uses thin polyethylene films. Further This kind of balloons will continue to be improved thickness in microns by developing a technique to extrude thin sheets no thicker than five [3].

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The shape of the balloon, which is influenced by the thermal properties of the envelope and lifting gas, and the curvature of the external surfaces, govern the envelope tension. However, studies on the relationship between balloon shape, envelope tension, and thermal effect are scarce. The minimising total potential energy model is solved numerically to estimate the balloon geometrical shape and envelope tension in conjunction with the balloon geometrical shape model and thermal model. Numerical analysis was used to thoroughly examine the impacts of the flight altitude, lifting gas mass, and flight time on the balloon form and stress distribution. The findings demonstrated that the meridional envelope tension exhibits extreme values at the top and bottom of the balloon, and that it is significantly higher than the circumferential tension. Additionally, the changing flight altitude and volume due to the diurnal variation of the lifting gas temperature will modify the shape and envelope tension. The outcomes showed that the theoretical method proposed a means to enhance the high-altitude balloon's structural design [5].

The first single-board nanosatellite to successfully launch in China is called "Tian Tuo 1" (TT-1). Technology demonstration and scientific measurements are TT-1's primary goals. The satellite carries out a substantial amount of single-board architectural feasibility validation research and is designed with a low cost philosophy in mind by utilising a lot of commercially available (COTS) parts. The capability of three-axis stabilisation control is a feature of the satellite. As control actuators, a pitch bias momentum wheel and three magnetic coils are used. The measuring sensors include a three-axis gyro, magnetometers, and solar sensors. The Unscented Kalman Filter (UKF) and QUEST methods are used to determine the attitude of nanosatellites. Analysis of on-orbit data received by the ground station is done to determine how well the attitude control system is working (ADCS).[6]

This paper presents the mathematical design and implementation of an actuator fault-tolerant control system for an underwater robot having four rotatable thrusters where the rotatable action of the thrusters is unconventional to a conventional underwater robotic system. Initially, the dynamic model of the robot is presented. Later, a motion control scheme using a backstepping control technique is made to track a desired spatial trajectory. Two techniques of active fault tolerance control viz., Elimination of Column Method, and Weighted-Pseudo Inverse Method are implemented successfully for single actuator faults on an infinity-shaped trajectory, which is a critical aspect of this study as most of the previous literature reported only on set point control. The methods mentioned above are extended to multiple thrusters failure, but both of them could not handle more than a single thruster failure. Hence, an attempt is made to accommodate two thrusters' failure through the line of sight approach by considering the vehicle as under-actuated. The desired vehicle performance is achieved with this approach. Finally, oceanic currents are modeled to simulate the effectiveness of the methods discussed in the paper to prove the performance capabilities of the control system and fault accommodation schemes under realistic conditions.[7]

The performance of cryogenic propellant response control thrusters in the 40 N class was evaluated through the design, development, and testing of a torsional-type thrust stand. For cryogenic propellant fed reaction control systems at this thrust class, new thrust measurement techniques are required because existing techniques don't produce accurate test data. The main component of the torsional thrust stand is a balanced moment arm rotating around a pair of frictionless pivots. A laser displacement sensor was used to monitor the moment arm's displacement as a result of applied thrust. A method of post-processing was created to extract thrust values from displacement information. Here, the test firing of a LOX/Methane thruster under steady-state and pulsing settings serves as an illustration of the measurement capability of the thrust measurement system. The effects of thruster mass and feed system stiffness on the features of thrust-stand measurement were also evaluated. Both in steady-state and pulsed operation, the measurement system gave repeatable thrust data.[8]

This paper addresses the issue of stratospheric balloon platforms' altitude control. The creation of balloon platforms with the ability to manoeuvre and fluctuate at the stratosphere for various applications based on remote sensing has drawn more attention in recent years. The interest in balloon platform applications has increased, posing new challenges for future applications in light of the current trend of a highly connected world with sensor grids spread across large geographic areas. How to ensure sustainability at constant altitude is one of the main issues that arise in this situation. Although the technologies required to address this issue already exist, low cost and simple to implement solutions are still required considering applications on a wide scale. A theoretical model of the balloon dynamic is presented and verified in this paper. For rubber balloons, a valve control loop method is suggested. The controller is empirically tuned, and numerical simulations are run for performance analysis and a real-world mission case study. By suggesting an altitude control system that permits fluctuation stages, which are typically uncommon with this type of balloon, the suggested approach helps to boost the capacity of rubber balloons.[9]

A highly effective satellite control system that uses free radical thrusters to convert the energy released during the recombination of atomic hydrogen into thrust is detailed numerically. Under the influence of microwave radiation, free radicals are created on board. The satellite control system (SCS) doesn't need any additional energy sources because of its minimal power requirements. A numerical model was developed as a result of the inquiry to calculate the thermo-physical properties of a recombining hydrogen gas mixture in the chamber and nozzle. The chamber and nozzle's geometry were adjusted to reduce the mass of the thruster. The thrusters' dynamic properties were identified.[10]

Using upper air data from high vertical resolution radiosonde observations from six sites, this study investigates the height structure of turbulence and its underlying causes over the Indian peninsula. To determine probable temperature profiles, this data is employed. The Thorpe scale (LT), a measurement of the eddy length scale, is derived from these profiles. This scale is also used to calculate turbulence properties like eddy diffusivity (K) and turbulence kinetic energy dissipation rate (ε). The altitude structure of the Ri< 0.25 occurrence shows that, while turbulence is abundant in the lower troposphere (0–2 km) and upper troposphere (10–15 km), it is extremely rare between 3 and 8 km in altitude. In comparison, there is little turbulence between 3 and 8 km. In general, ~60% of the Thorpe scale (LT) values in the troposphere are less than 250m at all the stations.[11]

II. DESIGN METHODOLOGY

A flying vehicle is designed, developed, and taken to the stage of a flight specific test through a sequence of steps and it is mostly designed in a three-stage process which consists of the conceptual design phase, the preliminary design phase, and the detail design phase. Hence , the standard approach for designing aircraft is

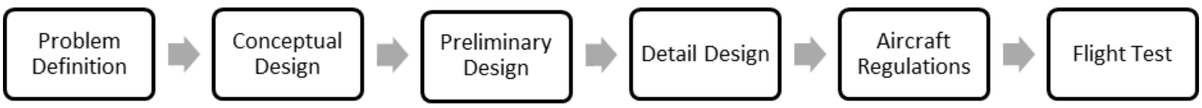

Figure 3 Rockoon Design Process

The conceptual design establishes the initial basic shape and dimensions of a new aircraft. It entails estimating weights and selecting aerodynamic properties that are most appropriate for the mission profile.

In the preliminary design process, the flow field surrounding the aircraft is calculated using computational fluid dynamics and tested in wind tunnels. This phase also includes the investigation of major structural and control factors. The final design is drawn and finalised after any structural instability and aerodynamic flaws are fixed.

Detail design phase deals with the fabrication of the aircraft. It establishes the quantity, style, and positioning of the ribs, spars, sections, and other structural components.

The requirements for acquiring a type certificate for a new design of aircraft are another significant issue that affects the design. Major national airworthiness authorities, such as the European Aviation Safety Agency and the US Federal Aviation Administration, have publicised these rules.

The two main goals of the flight test phase are to

1) identify and correct any design flaws

2) confirm and document

The vehicle's capabilities for regulatory approval or customer acceptance. The flight test phase might include everything from the creation and certification of a new aeroplane, launch vehicle, or reusable spacecraft to testing a single new system for an existing vehicle. As a result, a specific flight test program's duration can range from a few weeks to many years.

The system we aim to design requires following components to be built:

1. A green lift producer i.e the HAB (for the initial phases we are going for a hot air balloon option)
2. A launching platform for the rocket to be launched from
3. Electrical components for the wireless transmission of the ignition signal
4. A mini rocket for launch demonstration

2.1 HOT AIR BALLOON DESIGN PROCCESS:

A hot air balloon is a lighter-than-air object made up of an envelope-like bag that holds heated air. A wicker basket, gondola, or capsule suspended below transports people and a heat source, typically an open flame produced by burning liquid propane. A capsule also carries passengers in some long-distance or high-altitude balloons. Since the warm air inside the envelope has a lower density than the cooler air outside, it is buoyant. Hot air balloons cannot travel higher than the atmosphere, like all other types of aircraft. Since the air within the envelope is at a similar pressure to the air outside, the bottom of the envelope does not need to be sealed. The envelope of modern sport balloons is often constructed of Nylon fabric and a fire-resistant substance, such as Nomex, are used to make the balloon's entrance, which is closest to the burner flame. Although the classic shape is utilised for the majority of non-commercial and many commercial purposes, modern balloons have been created in a variety of designs, including rocket ships and the shapes of numerous commercial objects**.**The double pendulum is illustrated in Diagram1. It is convenient to define the coordinates in terms of the angles between each rod and the vertical. In this diagram m_1,L_1 and θ_1 represent the mass, length and the angle from the normal of the inner bob and m_2, L_2 and θ_2 stand for the mass, length, and the angle from the normal of the outer bob. The simple kinematics equations represent in next section to derive equations of motion by using Lagrange equations

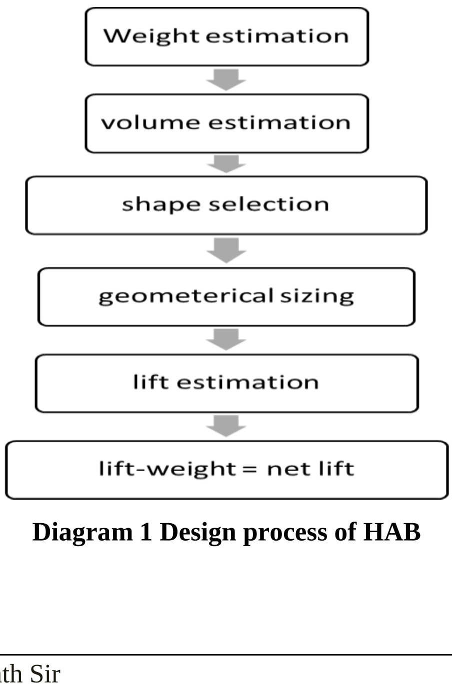

Diagram 1 Design process of HAB

Weight estimations :

- 3d printed V bar = 110 g
- Nosecone = 10 g
- Body tube = 30 g
- Fins = 20 g
- Esp board = 10 g
- Batteries = 56 g
- Diesel = 100 g
- Rocket fuel = 80 g
- Envelope = 96 g

approx. total weight = 512 g

Volume estimation:
Volume of the envelop = mass of the payload /(density of ambient air – density of hot air)
Therefore : 512 / (1.204-0.166)
= 0.4932 meter cube aproxx.

Shape selection:
Top = hexagonal pyramidal
Body = hexagonal prism
Bottom = frustrum of a hexagonal pyramid

Lift estimation:
Archimedes principle : the force of the bouncy acting on any body is the product of density times gravity times volume of the envelope.
Density of ambient air = 1.17 kg per meter cube
Density of hot air = 0.77 kg per meter cube
Volume of the envelop = 2.909 meter cube
There fore, lift = 1.141 kg aprox.

Net lift:
lift -weight = net lift
1.141- 0.512 = 0.629 kg

Conclusion : according to our estimations and calculations we assume that the system will be generating adequate amount of lift.

2.2.Design of the launching platform :
The design of this launching platform is the brainchild of our innovation it is named as 'THE V BAR' as it appears to be like inverted letter V of the English alphabet, this system will be providing attachment between the HAB and the rocket, rocket is made to be clamped with this V BAR and will be detached during the 2nd phase initiation.

III. DESIGN

In this section,We will see the design of hot air balloon and the design of V Bar and study where we design and how.

1. All components are designed in CAD software CATIA. CATIA delivers the unique ability not only to model any product, but to do so in the context of its real-life behavior design in the age of experience. Systems architects, engineers, designers, construction professionals and all contributors can defineCATIA has provided us a perfect platform to design our creative thoughts and bringing our deigns tolife. It has helped us design and estimate the volume of the hot air balloon which in turn helped us to estimate lift and all other necessary parameters and in case of the most innovative component the V BAR was possible to be visualized and analysed only because of catia.
2. The second tool that helped us in the accomplishment of this project is the openrocket open source model rocket modelling software which helped us choose the dimensions of our demo rocket, it has also enabled us to determine the cp as well as cg positions of the rocket.Dimensions of the fins were determined and the length and other parameters of the rocket nozzle.

IV. FABRICATION

1. Hot air balloon : For the initial fabrications of the hot air balloon we have chosen butter paper sheets as material . We have glued these sheets together to obtain the desired shape.
2. V BAR : For the current project we have decided to fabricate this component y the help of 3d printing technology, the material used for the printing is PLA which has a material density of 1.24 g/cc, the finished product that we have obtained after 3d printing weighs around 110 g
3. Rocket nose cone :3d printing technology is utilized in the fabrication of the nose cone of the modelrocket.
4. Rocket tube : The rocket tube is constructed using PVC material which has enabled us to get the required strength to weight ratio as we needed it to be strong and as light as possible.

FIGURE4 OVER ALL ROCKET

V. CONCLUSION

Finally, the fuel testing produced results that were favorable to our goals. We are aiming for hot air balloon fuel, which has a duration of 25 minutes in just 125 milliliters of diesel and cotton mixture and an accent rate of 12 inches per second with a payload of 550 grammes and above, and rocket fuel, which has a thrust of 120 kilograms and a working time of five minutes.

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