Characterization of Habian Motion

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***Abstract*—The project, Habian Motion, is concerned with fully mapping the motion of a HAB during flight. The purpose is to understand the forces, temperatures, wind, and pressures to which the HAB will be subjected. This will allow a further analysis of mechanical and electrical components before launch to ensure the safety of the payload.**

Nomenclature

HAB	High Altitude Balloon
PDD	Project Design Document
RIT	Rochester Institute of Technology
SPEX	RIT Space Exploration

I. Introduction

The RIT SPEX HAB team has launched several HABs before. The overall missions, for the most part, have been successful; a successful takeoff, payload operation, and landing. However, there have been a few errors that have caused problems for the payload, and specifically filming. The GoPro has yet to survive a full flight. Unfortunately, the failure analysis is uncertain as the understanding of the conditions at the point of failure are unknown, thus it is difficult to state the method of failure. This project will allow the team to collect a large amount of data which will be used to create a full map of the ambient conditions of the HAB.

II. Primary Objective

The primary objective of the Characterization of Habian Motion is to create a conditional map of the entire flight. The data collection is vital. There are several different events to be measured; ambient temperature, internal temperature, ambient pressure, internal pressure, rotation along the string axis, the pendulum-like motion of the HAB, wind, and solar intensity.

The ambient and internal temperatures will assist in the understanding of thermal stress that may occur due to massive temperature fluctuation, in addition to understanding how, exactly, the temperature changes with altitude. The ambient and internal pressures will allow the team to understand how the thermal diffusivity will change over altitude, in addition to how the ambient and internal pressures differ to create a non-zero pressure differential. The string axis, along which the rotation is defined, is an axial concentric line passing through the, theoretically, straight cable that connects the HAB to the balloon. The rotation is very important to understand because the centripetal forces that ensue could be very high. These forces could causes severe mechanical and electrical problems. The pendulum-like motion of the HAB is very important because it will set the standard for what cable is safe to use to connect the HAB to the balloon. The forces that the cable is subjected to have never been defined, due to the large amount of undefined factors that could increase or decrease the tension. The wind and solar intensity are optional. They would be great to directly measure, however, if all the data is properly collected, these events could be estimated to reasonable accuracy.

III. Benefit to SPEX

The benefit to SPEX would be the product of the conditional map. The map could be open-sourced so any HAB team in the nation could use it for their specific needs. Even if their climate is different, until they can perform the same data collection and analysis, this would be a great starting point for them. The SPEX HAB team would also gain great recognition for their work and they would learn a great deal, from building and launching a HAB to performing complex data analysis and putting the results into a user-friendly map so that others could benefit from their work.

IV. Implementation

This project could possibly build off the horizon detection & computer vision HAB project. The horizon detection would be a perfect method of collecting the sweep angle necessary to calculate the pendulum-like motion of the HAB. The equation for this motion is below.

$$\frac{d^2\theta}{dt^2} = -\frac{g}{l}\sin(\theta) \tag{1}$$

Where; g is gravity, l is the length of the pendulum (in this case it would be the length of the cable), and θ is the angle through which the pendulum moves, also known as the sweep angle. The horizon detection payload will create a vector that spans the horizon. This will be called the horizon vector. The sweep angle is exactly equivalent to the sweep angle of a vector normal to the horizon vector. This can be proven through simple geometry. This method would capture the sweep angle very well.

To collect the ambient and internal pressure and temperature data, the respective sensors will be placed on the outisde of the HAB and the inside. Because the HAB is made of foam, threading sensors through to collect the necessary data should not be difficult. The rotational motion will also be captured

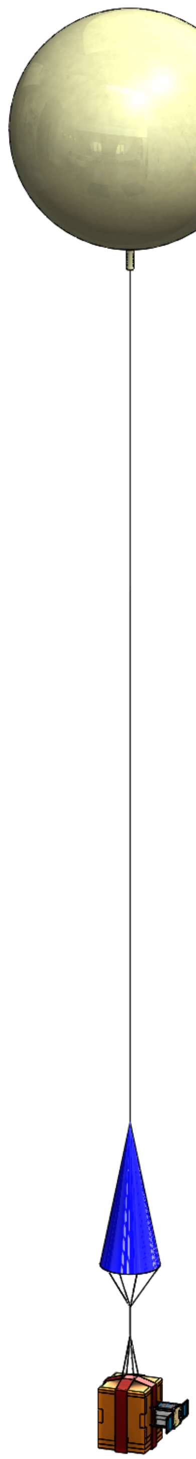

Fig. 1. This is the full proposed HAB model for the flight. The colors may vary.

Proposed Timeline

Week	Description
1	Team Introductions and project planning
2	Sensor selection
3	System Mechanical Design and Analysis
4	Component level tests
5	Payload level tests
6	Payload integration
7	Payload integration
8	Full system tests
9	Launch Preperation
10	Launch & Recovery
11	Data Collection and Organization
12	Data Analysis
13	Data Analysis
14	Creating Map
15	Finalizing Map

through sensors, most likely are IMUs. They are accurate and easy to implement.

A. Deliverables

The deliverables for this project will be the full Habian motion map with the datasets used for the analysis. There will be a fully integrated system with the Computer Vision, Horizon Detection, and the CubeSat. There will be a poster made for Imagine RIT explaining the detials of the mission, and if time permits, the map will be included. If the mission has not flown yet, a representative map will be created in its stead to show visitors the primary goal of the mission. This project does include at minimum, 1 HAB launch. This will take place when the ground is in such a state that the computer vision payload can perform its experiment. The ground must not be snow covered.

B. Milestones

The milestones for this project will be; finding the necessary sensors for measuring the rotation, temperatures, and pressures, determining whether or not it is feasible to measure the solar intensity and wind, integrating the entire HAB payload, performing successful preliminary tests of the sensors, the flight, the data analysis, and the creation of the map. A proposed timeline, for this project, is presented in subsection IV-B.

V. Externalities

A. Prerequisite Skills

There are no prerequisites for this project. All necessary skills will be introduced and taught to a sufficient level. However, the recommended skills are; MATLAB, structural analysis, electrical engineering, basic understanding of calculus, and a basic understanding of linear algebra. The components used for capturing the data will require electrical engineering skills to integrate. The HAB itself must withstand certain forces to be qualifed as flight-ready. MATLAB will be very important during the data analysis.

B. Funding Requirements

An estimated budget for this project is $300. The components for capturing the rotation, temperature, and pressure may need to be purchased. The helium will need be pruchased and stored 1 week prior to the launch. Two cylinders of helium is required for appropriately filling the 1500 cm^3 balloon. Most of necessary mechanical components have been bought and others will be 3D printed. This leaves the rest of the budget to buy necessary, unforeseen components.

C. Faculty Support

Faculty support will be necessary to launch the HAB. They must file a NOTAM and apply for a launch permit that allows a HAB flight with a payload over 6 pounds. This permit appies for a few months. That will most likely be the only faculty involvement. The rest of the HAB project is easily completed by a team of undergraduates, as history has shown.

D. Long-Term Vision

The long-term vision of this project is to increase chances of a successful flight by acknowledging the varying conditions of flight. Understanding the change in temperature and pressure over time will be useful for understanding thermal stress that may arise. The rotation and pendulum forces will also assist in the understanding of mechanical stress on the outer shell, the foam, and the cable that connects the HAB to the balloon.

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