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INTRODUCTION

High Altitude Balloon is a scientific balloon used to study near-Earth environments. With Space described in between 20 km to 100 km. This can be launched to support scientific needs and is handy for its low-cost preparation within the period of around 6 months.

Types of Ballooning

1) Conventional Ballooning:
   It has flights ranging from a few hours to days and is on a direct line of sight using electronics for command and data.

Fig 1: Conventional Ballooning. Source: Columbia Scientific Balloon Facility

2) Long Duration Ballooning (LDB):
   LDB is based on circumnavigation and may last up to three weeks with satellite-based electronic systems utilized for command and data.

Fig 2: Long Duration Ballooning. Source: Columbia Scientific Balloon Facility

3) Ultra Long Duration Ballooning:
   This balloon is designed to operate for about a hundred days and can significantly collect a higher amount of data in one balloon mission.

Fig 3: Ultra Long Duration Ballooning. Source: Columbia Scientific Balloon Facility

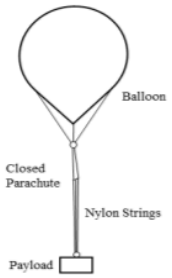

Figure 1: HAB configuration

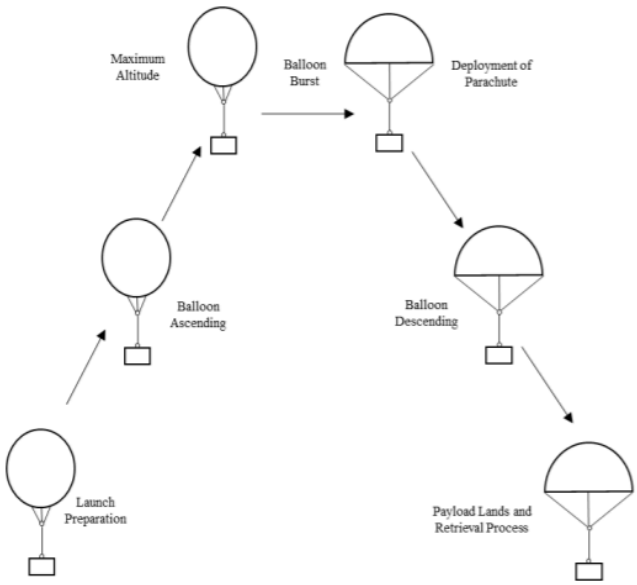

Figure 2: Concept of HAB operation

Fig 4. Source: (Mohamed Thaheer, 2017, p. 64)

The above (fig. 4) shows us the concept of HAB configuration and operation design which is helpful as a schematic figure for further proceedings of building our High Altitude Balloon Model. In this document, we will be majorly focusing on Conventional Ballooning.

LIST OF MATERIALS

Items	Quantity	Link for models	Pricing
Weather Balloon	1	Depends on the payload	
External Camera	1	GOPro Hero7	$259.99
Tracking cell phone/ SPOT Trace GPS Tracker	1	GPS tracker	$109.95
128GB SDCard	1	Sandisk SD Card	$18
Weather Balloon Inflation Nozzle and Hose	1		
Payload Housing box (Styrofoam)	1	Foam box	$11.14
Sim card	1		
Battery booster	1		
24” Nylon Parachute	1	**TFR standard parachute**	$11.05
USB Cable	1		
Inflation brushing	1		
Long Zip ties	2 pcs	Long Zips ties	$17.99
Short Zip ties	3 pcs	Short cables	
Fishing Lines	1	Amazon Link	$8.29
Nitrile gloves	100 pcs	Gloves	$19.99
Raspberry pi			$ 65

RULES AND REGULATIONS

We must abide by local rules and regulations in order to operate our HAB legally and smoothly. Most of the regulations are country specific.

For Nepal

In Nepal, we must follow regulations provided under Civil Aviation Requirements (CAR - 2) for Rules of the Air, APPENDIX 5 Unmanned free balloons.
CAAN differentiates unmanned free balloons into 3 categories:

- Light: Total Payload mass less than 4 kg and do not fall under medium and heavy.
- Medium: Total Payload mass more than 4 kg but less than 6 kg and do not fall under heavy.
- Heavy:
    - Total payload mass 6 kg or more. or
    - Includes a package of 3 kg or more or
    - includes a package of 2 kg or more with an area density of more than 13 g per square centimeter or
    - uses a rope or other device for suspension of the payload that requires an impact force of 230 N or more to separate the suspended payload from the balloon.

Most regulations are required only for medium and heavy categories. Some general regulations that should be considered are:

- Proper authorization must be taken from the state where the launch will be made and balloons other than light should not be operated across the territory of another state without appropriate authorization from the concerned state.
- HAB shouldn't be operated in such a way that creates hazard to other persons or their property not associated with the operations.
- Notifications and Other Specific regulations are required only for Heavy and medium balloons, check out the official document.

For US

In the US, we must follow regulations provided in 14 CFR Part 101 and FAA Air Traffic Organization Policy (JO 7110.65Z), Chapter 9 Special flights, Section 6. Unmanned Free Balloons.

In any case, we must abide by the following rules:

- Any Cellular Phones must be turned off (Airplane mode enabled) for any aircraft and/or balloon as soon as it leaves the ground.
- HAB shouldn't be operated in such a way that creates a hazard to other persons or their property not associated with the operations.

Regulations given in 14 CFR Part 101 Subpart D apply only if the payload meets the following criteria:

- Payload is more than four pounds and has a weight/size ratio of more than three ounces per square inch on any surface of the package
- Or, Payload is more than six pounds and the smallest surface is more than 36 square inches (6 inches by 6 inches)
- In the case of two or more payloads, they weigh more than 12 pounds together
- If a rope or other device for suspension used takes more than 50 pounds of force to break it off.

Most amateur HAB is exempt from regulations and notifications but it is advised to check out the given regulations.

Pre-Flight planning

- ### Key characteristics required for prediction

Before being able to estimate your landing location, there are several key characteristics of your launch that must be known or estimated:

1. Payload weight:
   It includes all the necessary components for conducting the experiment and retrieving the data.

2. Balloon type:
   With the help of habhub estimator, we use a suitable balloon based on the payload weight.

3. Parachute size:
   Helpful in determining descent velocity.

4. Atmospheric conditions:
   This includes wind direction and velocity of a specific date, time, and location

5. Estimated Nozzle Lift:
   Nozzle Lift is the total lift force of the balloon at the attachment point to the payload/parachute. Thus, it is the lift force provided by the Helium minus the weight of the balloon itself and any associated zip ties and attached fill devices that launch along with the balloon.

$$L_{(Nozzle)} = L_{(Total)} - W_{(balloon)}$$

Where,
$L_{(Nozzle)}$ = Nozzle Lift
$L_{(Total)}$ = Total (gross) lift
$W_{(balloon)}$= Weight of the balloon with all associated items. Do not include anything in your "payload" weight (e.g. cameras, trackers, electronics, etc.).

A basic calculation of the expected balloon parameter is presented below,
http://habhub.org/calc/

Balloon type	Volume (L)	Payload (g)	Neck (g)	Burst altitude (m)	Ascent rate (m/s)	Duration (min)
350 Kaymont	3776	2400	3526	16444	5	55
350 Kaymont	2875	2000	2601	18418	4	77
50 Kaymont	2472	1500	2188	19510	4.5	72
500 Kaymont	3957	2400	3561	20266	5	68
1000 Kaymont	4220	2400	3331	29667	4	124

Table 2: Showing required balloon-type for given payload mass and burst ascent rate with other calculated data.

FINAL LIST CHECK

MARK (✓)	Items	Quantity
	Weather Balloon	1
	External Camera	1
	Tracking cell phone/ SPOT Trace GPS Tracker	1
	128GB SDCard	1
	Weather Balloon Inflation Nozzle and Hose	1
	Payload Housing box (Styrofoam)	1
	Sim card	1
	Battery booster	1
	24” Nylon Parachute	1
	USB Cable	1
	Inflation brushing	1
	Long Zip ties	2 pcs
	Short Zip ties	3 pcs
	Fishing Lines	1
	Nitrile gloves	100 pcs
	Raspberry pi	

Flight path prediction

Knowing the key characteristics required for prediction we can simulate it using the https://predict.habhub.org/ (Habhub predictor) to estimate your flight path.

Inputs:

1. latitude/longitude
2. Launch time
3. launch date
4. Ascent Rate
5. Burst altitude
6. Decent rate

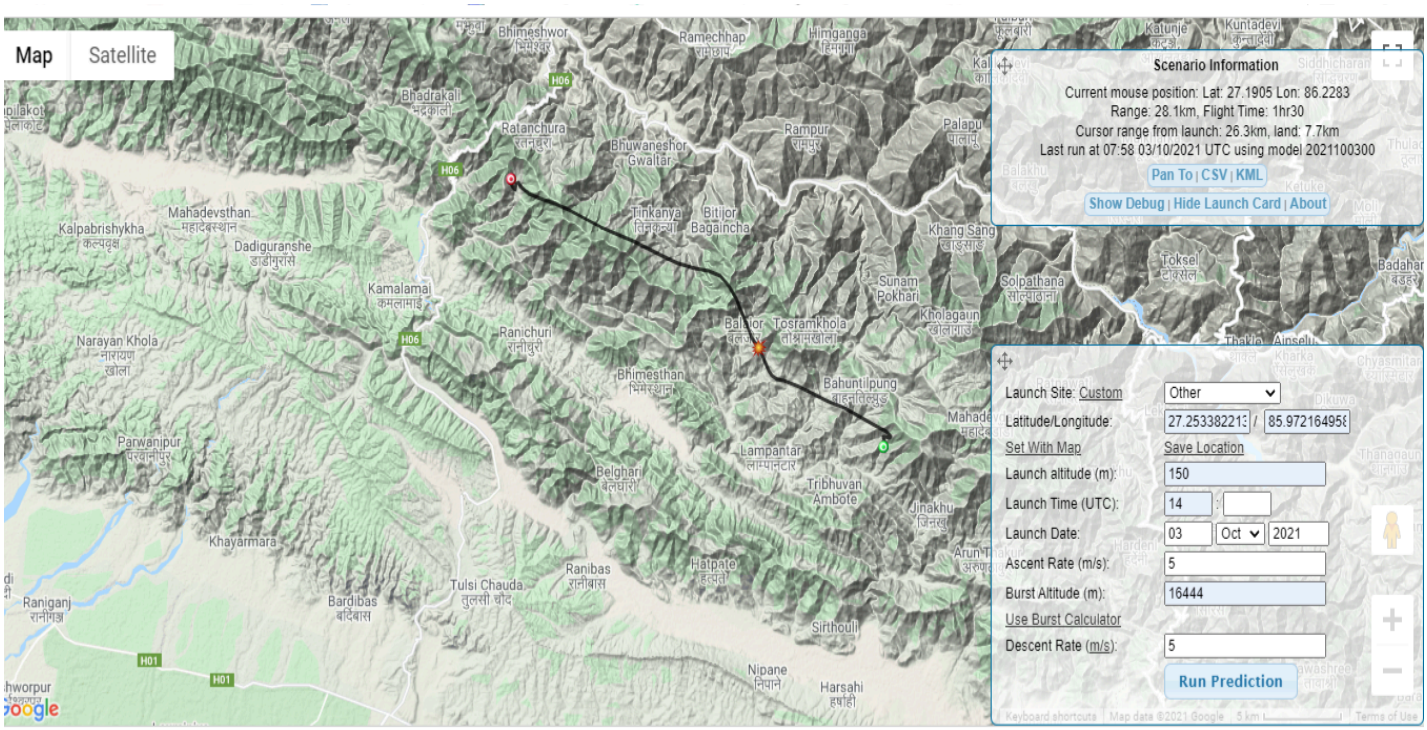

Fig 5. Screenshot of Flight prediction done using a CUSF landing predictor

We considered Vinam, Dhanusha, Nepal as our launched site for HAB with the latitude and longitudinal coordinates as 27.253382 ^{0}N and 85.972164958 ^{0}E respectively on 3rd October, 2021 and predicted it to burst at an altitude of 16400m and land near Jinakhu.

Launch

- **Weather monitoring**:
  For our prediction and calculation of current weather, we will use NASA weather forecast (NASA weather portal) as our source to calculate and at the appropriate conditions of the weather, the balloon will be launched. Weather conditions are monitored from the occurrence of the flight readiness meeting up to the actual release of the balloon.

- **Payload pickup:**
  - Nepal army
  - Self-funding
  - supporting organization that is going to sponsor or support us during our launch.

- **Payload transport to launchpad:**

- **Flight train without inspection:** If we get positive weather conditions for the launch, our team with the coordination of the army will lay out the flight train and do a quick final check of components before the launch, which majorly includes the length of the balloon, checking the damage in a balloon, parachute. and the flight train. After this confirmation, we will be ready to fill the balloon with helium gas.

- **Parachute Preparation**:
  For this part one must need to complete their payload part in order to finalize their parachute, calculations must be done beforehand for parachute preparation.
  i.

-

- **Balloon Inflation:**
  This preparation is supposed to be done one the day of launch. Following the steps, one can prepare for it.
  i. Remove caps and unscrew the Helium tank
  ii. If only the filling hose is not threaded with the hose of the regulator which will be used to inflate the balloon do not open the Helium cylinder because of high pressure.

iii. Ensure that the opening is free from debris by filling some helium and quickly closing the valve.
iv. After checking is completed, tighten the regulator by hand, remove the weather balloon from the elastic band.
v. If not using the Quick-Launch Inflation System (photo), then have some people unfurl the balloon.
vi. Ensuring no twist in the weather balloon, open the helium tank slowly and fill the balloon. After some time, once one has achieved Nozzle lift based on pre-flight calculation we remove the inflation nozzle.
vii. From the list of materials, we use fish scale recording and measuring lift force.

Note: Use Nitrile gloves to prevent hand oils affect the performance of the weather balloon.

- **Payload preparation**

i. With Parachute to the balloon and making a knot attach a hardware section to the parachute and the balloon.
ii. With the backup battery, plug in the camera and cell phone and ensure that they are charging.
iii. For efficient performance, the phone should behold parallel to the Styrofoam wall just as one holds it while talking.
iv. GoPro cameras should be fastened using long zip ties on the outer wall of the Styrofoam box; one may use as many long zip ties as wanted (camera not compulsory for really cheap model).

- **Launch:** Selecting the coordinates of the launch and permission granted by the defense and the air control and airlines of that place and after final check-up of all the data (weather, temperature, and damage in the components), we are all set for launch.

For example, in context to Nepal, our predicted launch site is Viman, Danusha having the coordinates of 27.2533822136, 85.97216495.

In context to the USA, the site for the launch would be Florida having the coordinates 28.148752286793396, -80.62465931330361, Kaymont consolidated, Florida.

Tracking

When it comes to tracking a weather balloon, the three most common options are a satellite tracker, an APRS tracker, or a cell phone.

GPS options	Description
1. Satellite-based	This is the most widely used dummy-proof device that you can throw in your payload for tracking. Using this you can track your balloon anywhere on the planet. The main thing to consider on this is that satellite trackers antennas must be pointed in the sky.
1. Radio towers (APRS)	Require amateur radio license to use it. Unlike satellite-based, it transmits both position and altitude and allows you to determine if your payload is ascending, close to burst altitude, descending, close to landing, etc.
1. Mobile phone tracker	It isn't recommended since it is illegal and most payloads land on the rural areas with no network coverage and so we cannot have recovery. Also,a cellular device that has been used at high altitudes can be easily detected by multiple base stations simultaneously.

Table 3-

We will be using a SPOT trace GPS tracker that uses 100% satellite technology and does not require the cellular network to provide data within the interval of 2½, 5, 10, 30, or 60 minutes as a text or an email to your phone.

Apart from mentioned here, you may also use APRS to track your HAB and get live updates through the open-source tracking software habhub tracker .

Recovery of HAB:

Payload is predicted to land 25 km south of the launch site which is Viman, Dhanusha (27.25338221364063, 85.97216495800588) for Nepal and Florida (28.148752286793396, 80.62465931330361) for the USA. The local authorities of the predicted landing site are informed to notify us when the balloon is seen in their local area.

However, we will be using a Geofencing-based flight termination unit which will terminate when it is about to reach the Nepal-India border (for Nepal). We will use Raspberry Pi (RPi) SBC that reads and controls the sensors, calculates the system's attitude, and generates control commands. We will use the open-source code Linux-mpu9150.