Development of a Low-Cost High Altitude Research Platform(HARP)

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Introduction

HARP is a low-cost high altitude research platform that enables K-12 schools and universities to perform near space research. A one-kilogram weather balloon filled with hydrogen is used to provide lift for the payload. The balloon is designed to burst at maximum altitude of 120,000 feet. A 72-inch parachute allows the payload and experiments to make a safe landing. A laptop is connected to the base station that enables communication with the payload and experiments throughout the launch.
Additionally, HARP must follow the following FAA Regulations:
- Weight-to-size ratio less than or equal to three ounces per inch squared
- Weighs less than 12 pounds
- Suspension ropes break with under 50 pounds of force
- File a Notice To AirMan (NOTAM) with FAA 24 hours prior to launch

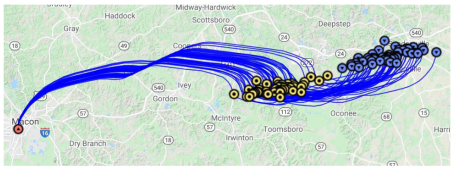

Figure1: Flight Simulations

History/Achievements

Previous launches:
- February 8,2020
  - Top speed: 120 mph
  - Maximum altitude: 112,000 feet
- August 21,2017
  - Filmed the total solar eclipse
  - Payload landed in a lake and was recovered by a team of divers

Figure 2: Solar Eclipse View From HARP Balloon

Figure 3: Filling The Balloon With Hydrogen

Abstract

Mercer University's Machine Intelligence and Robotics Lab founded the High Altitude Research Platform (HARP) in 2014, beginning our high-altitude ballooning team. We joined the Nationwide Eclipse Ballooning Project (NEBP) in Spring of 2023. As our experience as well as our team has grown, we have identified several directions we have begun to pursue. We are currently using the Iridium GPS system to track and communicate with our balloon, and we are moving to the Automatic Packet Reporting System (APRS) to reduce our dependence on proprietary software. We also intend to perform proper launches at least twice a semester and refine other components such as the Suntracker, vent, cutdown, and balloon scout drone. The Suntracker is a payload that will constantly keep its camera pointed at the sun, which uses a gyroscope to counteract the rotation of the payload and keep the camera directed at the sun. The balloon scout drone will be a quadcopter that will receive signals from the balloon and track it once it lands to maintain a point of communication with the balloon if line-of-sight is lost. We are currently using a vent and cutdown mechanism developed by the University of Maryland, and we would like to iterate on their design to interface with APRS. Over the past year, we had a total of 16 students working on NEBP, and 4 of those students have branched off to develop their research associated with high-altitude ballooning. With this in mind, we are restarting our high school STEM outreach program that will allow interested students to get hands-on research and engineering experience by building payloads to launch on our ballooning missions.

Methods and Analysis

We use multiple systems to fly our balloon.

Payloads:
- Iridium Payload
  - Used for live GPS and communication.
- RFD 900 Payload
  - Used primarily for accelerometer data.
- Pterodactyl Payload
  - Secondary data recorder.
  - Records altitude, GPS, and temperature.
- Vent System
  - Connected to the neck of the balloon.
  - Allows for control of ascent rate.
- 360 Camera
  - Contains a 360-camera setup that streams video to the ground station.
  - Has an Insta360 camera mounted externally that records to a SD Card.

Base Station:
- Uses two receiver antennas, one for the RFD 900, and one for the Ubiquity.
- Uses the BRAD tracking software to control the direction and angle of the receiver dish.
- Uses a ubiquity modem to receive live stream data from the balloon.
- Designed by the University of Montana.

Launch Equipment
- Hard Case
  - Contains all necessary tools to launch the balloon.
- Helium
  - Kept in the bed of the truck during filling.
- Tarp
  - Used to provide a cleaner work space.

Figure 4: NEBP Payload Line

Figure 5: NEBP Base Station

Figure 6: Hard case containing launch equipment.

Results

We conducted two full launches during the 2023-2024 school year, one to observe the annular eclipse in October, and another to study the total eclipse in April. In October, our team traveled to San Antonio, Texas, and we launched from Rocksprings, Texas. Due to a failure of the cutdown mechanism, the balloon began decending at 35,000 feet, far short of the target altitude of 100,000 feet. Even thought we did not reach our target altitude, we were able to receive live video and gps data from the balloon. For the April launch we went to Saint Louis, Missouri, and we launched from Williamsville, Missouri. Prior to our launch, a series of updates were made to the iridium network. These updates lead to both of our tracking softwares becoming non functional. This means that we were not able to receveive live video from the balloon. We were still able to access the GPS data from the Borealis tracking website. Our balloons vent system opened early, and it lead to our balloon reaching a maximum altitude of 28,200 feet. In spite of these failures, we were able to get some good data from our on board cameras.

Figure 7: NEBP Tethered Launch March 16, 2024

Conclusion

- This project demonstrates that flying high altitude research balloons is not easy. There are lots of things that need to go right, and one failure can bring a balloon down. Our team has learned a lot from our two flights this year, and that knowledge will help us as we conduct our future flights.

Future Plans

Going forward, we would like to conduct more launches, as well as swtich from Iridium to APRS for tacking.

Acknowledgements

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References

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