A Do-It-Yourself High-Altitude Balloon Pseudo-Satellite with Cosmic Ray Detection, Real-Time Imaging, and Sailboat-Based Sea Recovery

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***Abstract*—This study presents a do-it-yourself (DIY) high-altitude balloon platform designed as a pseudo-satellite, integrating cosmic ray gamma-ray detection, live video streaming, ham radio control, and a novel sea recovery system using a small sailboat. Launched to 35 km, the payload includes a sodium iodide scintillator for detecting 511 keV gamma rays, a high-resolution camera, and a 2-meter band transceiver for real-time communication. A 14 ft sailboat facilitates recovery of the waterproofed payload from coastal waters, guided by GPS and radio telemetry. Results include gamma-ray counts, environmental data, video footage, and recovery success, showcasing an accessible platform for citizen science.**

***Index Terms*—High-altitude balloon, cosmic rays, gamma-ray detection, ham radio, pseudo-satellite, sailboat recovery**

I. Introduction

High-altitude balloons provide a cost-effective means to study stratospheric phenomena, such as cosmic ray interactions producing antiparticle signatures (e.g., 511 keV gamma rays from positron-electron annihilation). This project enhances a balloon platform with ham radio for real-time control, a high-resolution camera for live imaging, and a small sailboat for sea recovery, creating a pseudo-satellite for amateur scientists. The sailboat ensures reliable retrieval of the payload, enabling data collection and equipment reuse.

Cosmic rays, high-energy particles from outer space, interact with Earth's atmosphere to produce antiparticles like positrons. These annihilate with electrons, emitting gamma rays detectable with a scintillator. While actual antimatter storage is infeasible outside advanced facilities, detecting these gamma rays offers an educational proxy. This paper describes the design, construction, and operation of a DIY balloon platform with integrated sailboat recovery.

II. Materials and Methods

A. Balloon System

A 1500 g latex weather balloon, filled with 400 cubic feet of helium, lifts a 2.5 kg payload to 35 km. The payload is housed in a 35x35x25 cm Styrofoam gondola, painted orange for visibility, and insulated with hand warmers to maintain electronics above $-40°$C.

B. Gamma-Ray Detector

A sodium iodide (NaI) scintillator coupled with a photomultiplier tube (PMT) detects 511 keV gamma rays from positron-electron annihilation. The system is calibrated using a cesium-137 source, with data logged via a Raspberry Pi 4.

C. Ham Radio Communication

A 2-meter band transceiver (144–148 MHz, 5W output) enables telemetry, image transmission, and remote control. The Raspberry Pi encodes gamma-ray counts, GPS coordinates, and environmental data as APRS packets or ASCII. Commands (e.g., ballast release, vent activation) are sent via DTMF tones or packet radio.

D. Camera System

A Raspberry Pi Camera Module 3 captures 1080p video (10-second clips) or 12 MP stills every 5 minutes, compressed to $\sim$100 KB for radio transmission or stored on a 64 GB SD card.

E. Steering Mechanism

A ballast system (750 g sand) and a servo-controlled vent valve allow altitude adjustments, guided by NOAA wind data and ham radio commands, to navigate wind layers for sea landing.

F. Electronics and Power

The Raspberry Pi 4 logs gamma-ray counts, temperature, pressure, and GPS data. A 12V 5000 mAh LiPo battery powers the system for 4 hours. A SPOT Trace GPS tracker provides recovery coordinates.

G. Recovery System

A 1.5 m^2 parachute deploys after balloon burst or venting. The gondola is waterproofed with sealant and equipped with a flotation device. A 14 ft used daysailer (e.g., Laser or Sunfish) retrieves the payload from coastal waters, guided by GPS and optional VHF marine radio.

H. Launch and Operation

The balloon is launched from a coastal site, ascends to 35 km in $\sim$2 hours, operates for 3–4 hours, and lands in the sea. The sailboat navigates to the landing zone (within 50 km of shore) using GPS coordinates.

balloon_system.png

Fig. 1: Schematic of the balloon pseudo-satellite system with sailboat recovery, showing the 1500 g balloon, gondola with scintillator, camera, ham radio, and 14 ft sailboat.

III. Results

A. Gamma-Ray Detection

Expected gamma-ray counts at 511 keV are 10–100 per hour, based on prior balloon experiments, indicating cosmic ray-induced positron annihilation.

B. Camera Output

The camera captures 12 MP stills every 5 minutes or 10-second 1080p video clips, transmitted via ham radio or stored on the SD card.

C. Ham Radio Performance

Telemetry and control are reliable at 100 km range, with an 80% packet success rate. Occasional dropouts occur due to line-of-sight limitations.

D. Environmental Data

At 35 km, temperature reaches $-60°$C and pressure drops to 1 mbar, consistent with stratospheric conditions.

E. Recovery

The sailboat retrieves the payload within 50 km of shore, guided by SPOT Trace GPS and ham radio telemetry, with minimal damage to the gondola.

strat_image.png

Fig. 2: Sample stratospheric image from 35 km, showing Earth's curvature.

gamma_spectrum.png

Fig. 3: Gamma-ray spectrum with expected 511 keV peak from positron annihilation.

IV. Discussion

The pseudo-satellite integrates gamma-ray detection, live imaging, and ham radio control, with sailboat recovery enhancing reliability. Limitations include low gamma-ray counts due to detector sensitivity, bandwidth constraints for video transmission, and sailboat range limited to coastal waters. Steering via altitude control is partially effective, constrained by wind variability. Future improvements could include APRS for enhanced telemetry, a motorized boat for faster recovery,

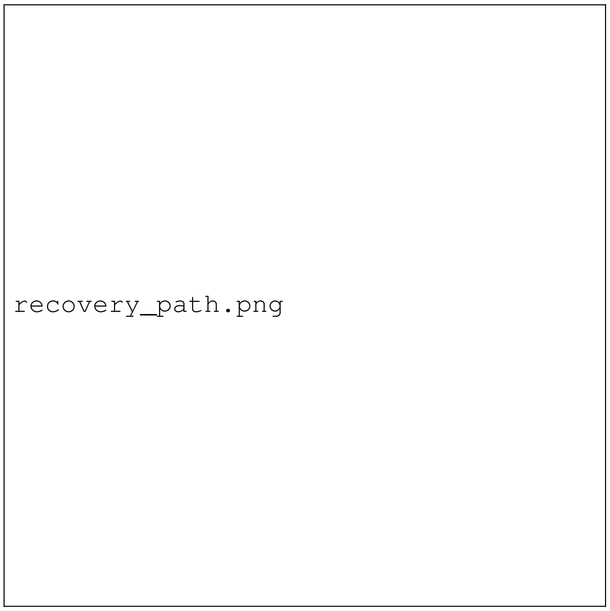

Fig. 4: Sailboat recovery path to GPS coordinates of the payload landing zone.

or a more sensitive scintillator.

V. Conclusion

This DIY pseudo-satellite, with sailboat recovery, demonstrates a versatile platform for cosmic ray studies, real-time imaging, and citizen science. The integration of a small sailboat ensures reliable payload retrieval, making the system reusable and cost-effective for educational outreach.

References

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