Additional Techniques for Improving Photography on Stratospheric Balloon Flights

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Abstract

Techniques to improve photography on stratospheric balloon missions are of significant interest to the high-altitude ballooning community, as evidenced by the ongoing number of downloads of a paper about stabilization of camera payloads which the University of Minnesota – Twin Cities ballooning team presented at AHAC 2015. This current paper provides suggestions for mounting and powering cameras (sometimes in counterintuitive ways) for 2-to-3-hour ballooning missions, as well as additional ideas for stabilizing camera payloads based on our team's experiences since 2015. Of particular note are passive anti-rotation devices used during eclipse flights in 2017 and, more recently, studying the impact on rotation when cameras are on stacks that are intentionally "floated" (neither ascending nor descending) in the stratosphere. Live video streams from payloads hanging from "big" balloons – zero pressure and superpressure balloons with volumes that can exceed 10 million cubic feet carrying payloads in excess of 1000 pounds – suggest that it is possible to achieve fairly-stable conditions, at least on massive ballooning systems. Active pointing and motion compensation even allow for the operation of telescopes and for time-exposure photography on such "big" ballooning missions. However, stabilizing payloads carried by significantly-smaller balloons, such as latex weather balloons, is particularly challenging since smaller balloon systems are more susceptible to wind-induced motion, including downward "relative wind" and balloon wake turbulence experienced by payloads during ascent. We have found that payload stacks on weather balloon missions can also become very quiet during float, even without the use of explicit anti-rotation techniques. This observation may be of particular interest to balloonists planning to participate in eclipse ballooning in 2023 and/or 2024 where "you've got to get it right the first time" (since eclipses are both short in duration and rare) and high-quality photography is of the essence.

Release of a HASP 11-million cubic foot balloon:
https://www.youtube.com/watch?v=WY1a_pZGDbc

For video streamed from a HASP flight, see
https://www.youtube.com/watch?v=UnDCRe2IVcs

Notice how calm this platform is, both during ascent and especially during float.
Presumably this is due to huge mass (and perhaps, to a lesser degree, because they only launch in calm weather).

HASP launch, Sep. 14, 2021

I aspire for “HASP-quality” stabilization, but on weather balloon flights.

Things that can go wrong – a non-exhaustive list:

- Camera overheats (before launch or at altitude)
- Camera quits mid-flight (because it got too cold)
- Camera view gets fogged up (see photo at right)
- Payload swing and/or rotation blurs images or makes video hard to watch
- Camera becomes detached during flight or upon landing
- Footage on SD card gets corrupted (possibly when camera fails mid-file)

Camera quits mid-ascent:
https://drive.google.com/drive/u/0/folders/1pE86c0rA4WiFh2WLWRO7Xmh70E8s9Xo0

Typical pre-burst rotation (without anti-rotation devices):
https://drive.google.com/drive/u/0/folders/1Bn758l-d-mWgiNleeAhnYB03iXtg2RlF

Turbulence at about 80,000 ft:
https://drive.google.com/drive/u/0/folders/1kWubvS9BoSBHB5dAtY41WkaqJj00OK5_

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https://www.iastatedigitalpress.com/jhab/article/id/13036/

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Review Article

Techniques for Payload Stabilization for Improved Photography During Stratospheric Balloon Flights

Abstract

Payload-box rotation and swing are perennial challenges to achieving high-quality photography (typically videography) during weather-balloon flights to "near-space" (AKA the stratosphere). Continuous camera motion can lead to blurred still photos, nearly-impossible-to-watch video footage, and precludes time-exposure photography required for most astronomical imaging even though altitudes are reached where the daytime sky appears black. Apparently-random payload rotation, persisting even at altitude, can often exceed servo rotation rates and frustrate attempts to do active camera pointing. Here we discuss mostly-passive payload stabilization strategies we, and our collaborators, have used to mitigate and dampen both swing and rotation of suspended payloads on high-altitude balloon missions, primarily on ascent. In particular, we stress the importance of avoiding single "main" lines and of firmly coupling the payload stack to, as opposed to intentionally trying to decouple (rotationally) from, the neck of the balloon. We discuss consequences these strategies have on stack weight and also on the location of the parachute, sometimes displacing it from its normal location hanging between the neck of the balloon and the payload stack. We expect these payload stabilization techniques will be of particular interest to balloonists planning to photograph the total solar eclipse of August 2017.

Keywords: Payload, high altitude photography

How to Cite:

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Fig. 2. Photo of Rick Brennan's built device which was flown, attached by a single line, at the bottom of a payload stack. The central part of the structure contained a video camera. Good stabilization was achieved, but only this bottom payload was stabilized.

Fig. 3. U of MN student Victor Portillo prepares to release a single-payload balloon (parachute and 300-gram balloon are above, out of sight) with a 2-scoop "dumbbell" stabilizer. These two balls were attached to the ends of a single 1-m-long carbon fiber tube, so the device is significantly smaller than Rick Brennan's.

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Fig. 4. A 1600-gram balloon is inflated indoors for an exhibit. Notice the parachute basket and the 8 widely-space load lines extending down to the (white) payload below and to the ends of the 3-m-long booms on the lid of the payload below. The "Goldy Gophernaut" video footage (see YouTube link in main text) came from the black box suspended below the white payload.

Fig. 5. Preparing a 1-D anti-rotation boom for use with a single-payload, 300-gram balloon flight. The parachute will lay in the parachute basket, made from two embroidery hoops (AKA spreader rings). The pvc tube around which the parachute basket is built, will be partially inserted into the balloon neck. The central line holds the load – 2 outer lines prevent relative rotation.

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IV. Stabilization Rules of Thumb

Here is a list of recommendations (not all tested by us, yet) to minimize and mitigate rotation and pendulum oscillation during high-altitude balloon flights.

- Avoid using single rigging lines *ever* – provide a restoring moment by using multiple, spaced, parallel lines running between payload stack components and starting at the balloon neck itself – we recommend 4 lines, though many ballooning groups we know use just 2 lines.
- Use booms, possibly tipped with tennis balls, to increase the moment of inertia – this slows rotation to servo-compensatable speeds, and also makes it more predictable.
- Use cylindrical payloads to reduce the ability of wind to apply forces and torques to the payloads that can foster rotation and/or pendulum motion.

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- Keep payload spacing modest – no more than 6 to 8 times the spacing between support lines – longer lines tend to twist around one another, compromising their restoring moment effectiveness.
- Fly the heaviest payload(s) at the bottom of the stack – light payloads near the bottom can get tossed around and even strike payloads above or become separated and fall free from the stack.
- When doing predictions, actively void hitting the jet stream – clear-air turbulence, on the other hand, is harder to predict and to intentionally avoid.
- Attach air scoops to payloads that you are most concerned about rotating and, if possible, place them at or near the bottom of the stack so they are influenced less by weights below.
- Couple payloads strongly to the balloon neck using multiple, widely-separated lines – the use of single main lines, or even swivels to decouple rotationally from the balloon, allows for excessive payload rotation.
- Use a parachute basket to keep the parachute above multiple support lines and avoid tangling – admittedly this concept needs more testing to ensure reliable parachute deployment.
- If you are able, vent balloons to bring them to a "float" state in the stratosphere – this gives them even more time to reach a low-or-zero rotational or swinging state.

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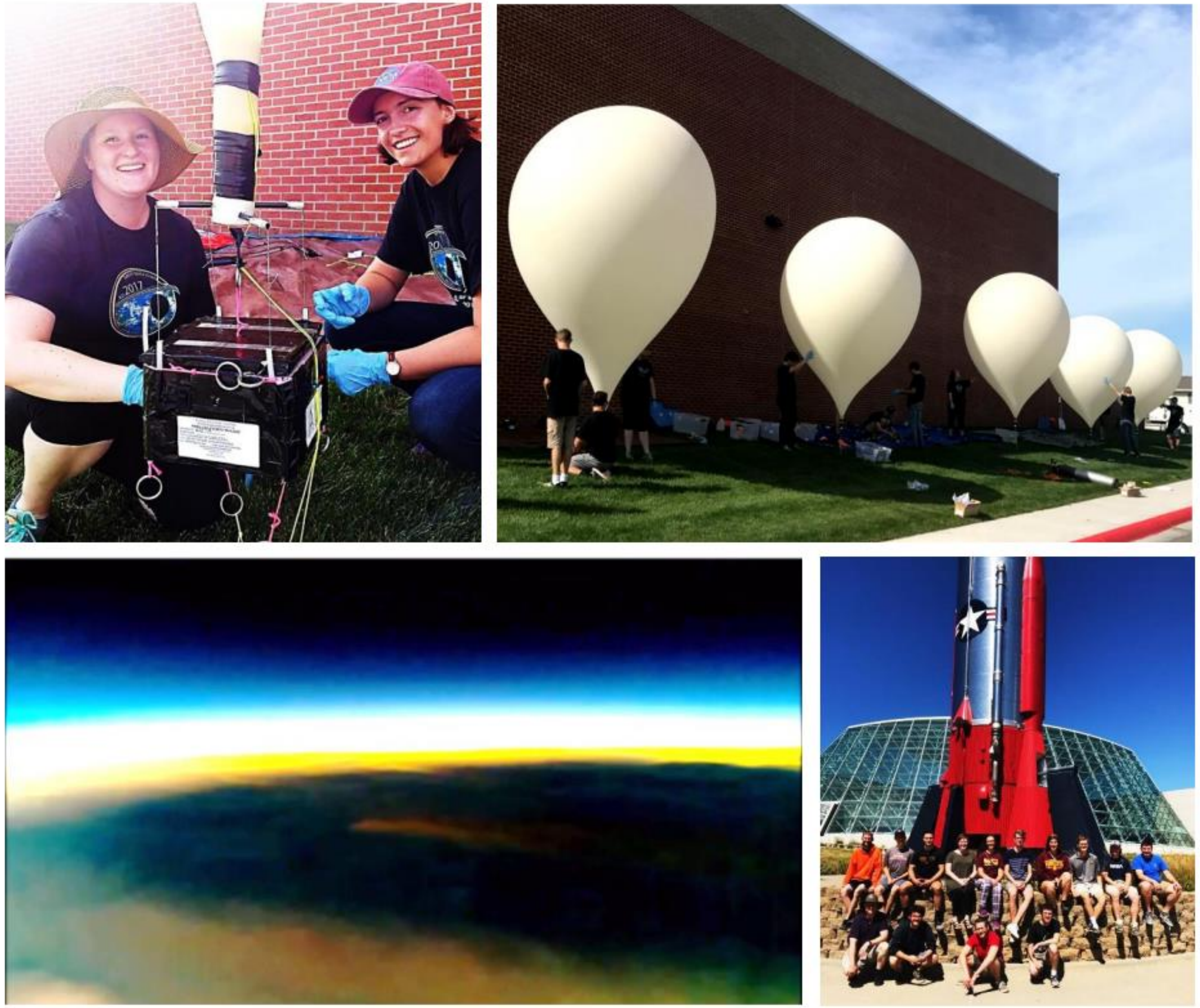

Fig. 4 Images from eclipse trip (left to right then top to bottom): (a) passive anti-rotation device, (b) line of balloons, ready to release, (c) view of receding eclipse shadow from 66,000 feet above Grand Island, Nebraska, and (d) UMTC team (most of it) at Strategic Air Command (SAC) museum on return trip to MN.

https://doi.org/10.31274/ahac.5548

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Video clips from 2017, taken with
This sort of anti-rotation device:
https://dept.aem.umn.edu/people/faculty/flaten/EclipseBallooningWebsite/eclipse_trip.html

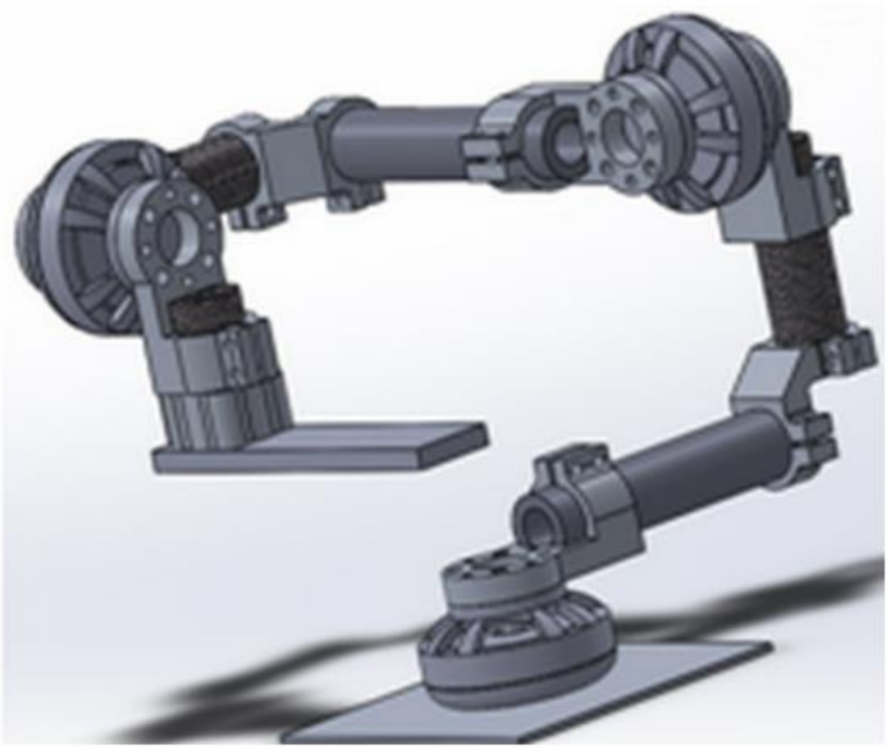

Figure 1.

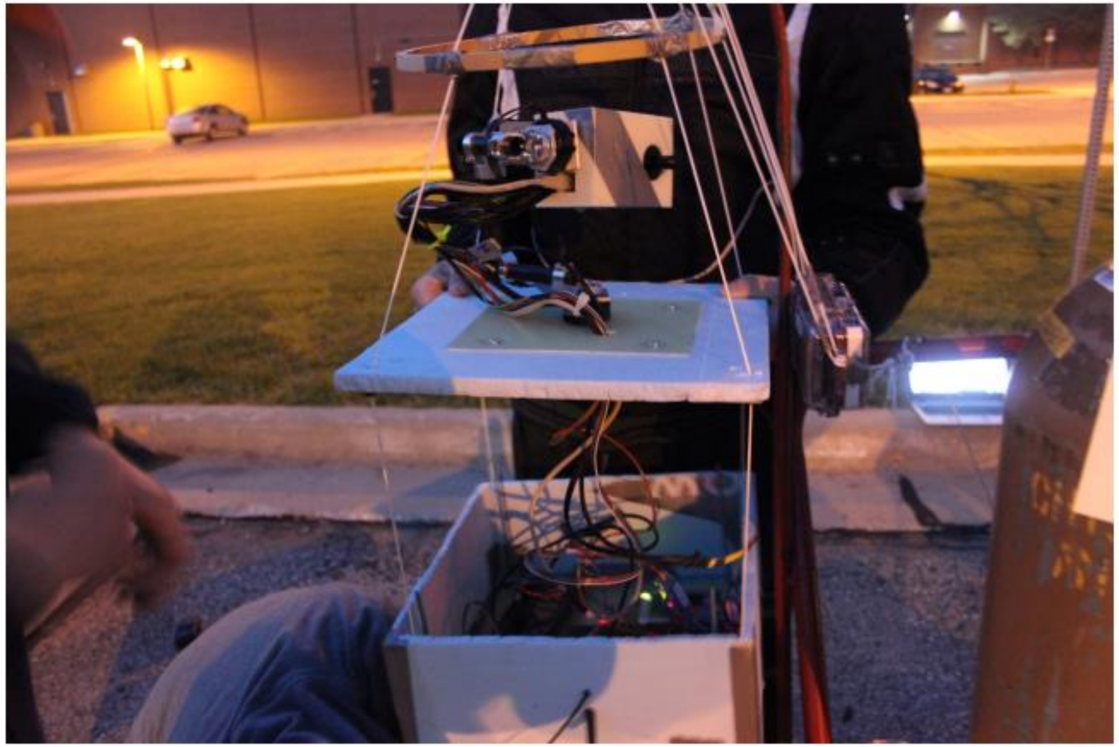

Figure 3.

Gimbal for 3-axis camera pointing control. Plewa et al. doi: https://doi.org/10.31274/jhab.12979

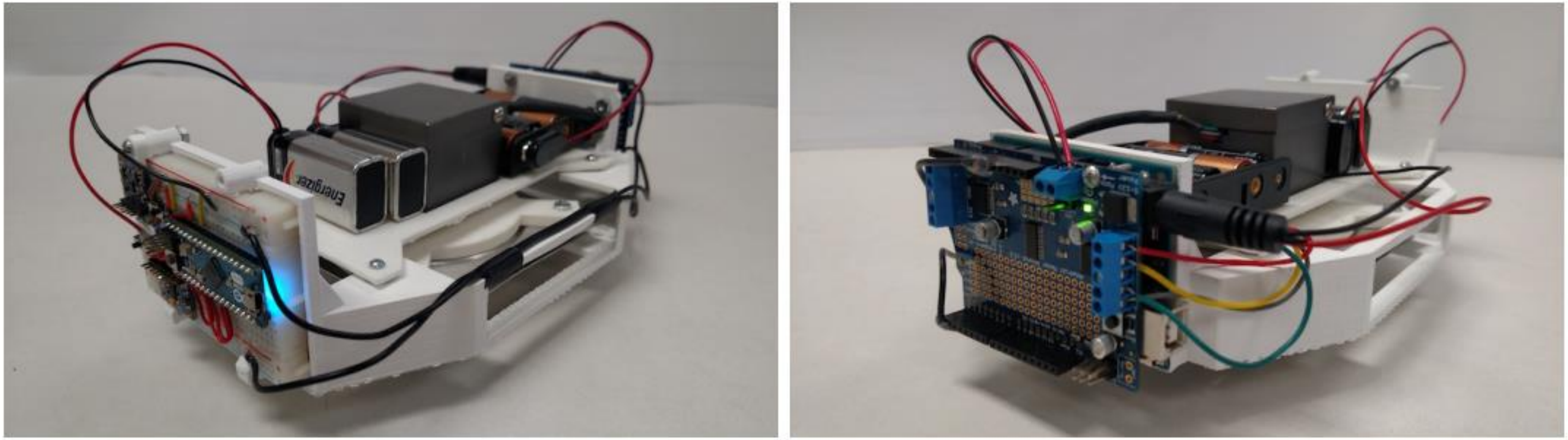

Figure 1. CHAD with the AHRS (left) and motor controller (right) attached. A wire connects the two Arduinos for serial communication, and the stepper motor is in the center inside a steel magnetic shield.

“CHAD” device for active pointing about vertical axis. Kruger et al. https://doi.org/10.31274/jhab.13028

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Turbulence at about 80,000 ft:
https://drive.google.com/drive/u/0/folders/1kWubvS9BoSBHB5dAtY41WkaqJj00OK5_

General suggestions for video cameras for stratospheric balloon flights:

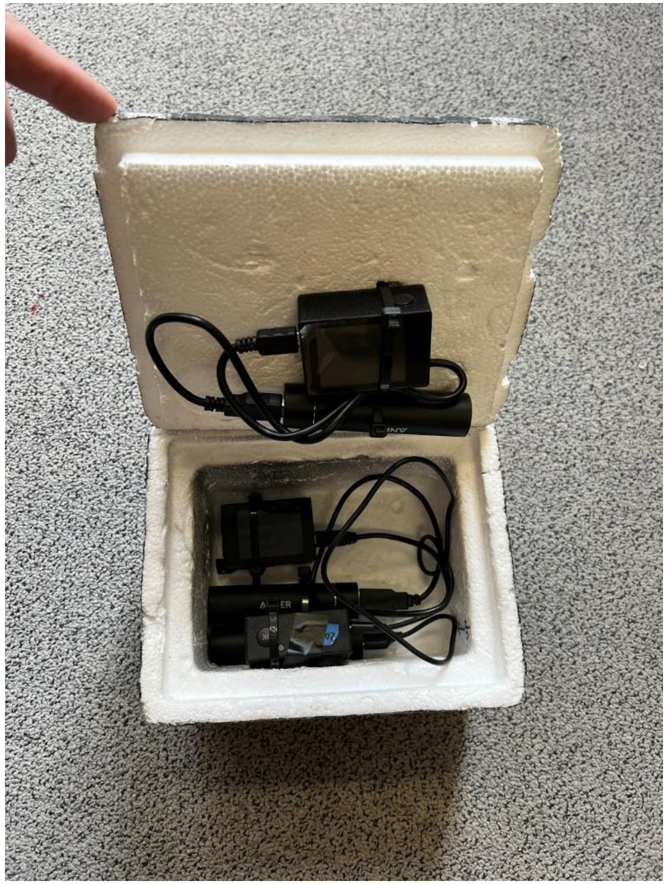
- Select SD cards and resolution for at least 3-hour run time
- If internal battery is insufficient – likely – find a camera that can record while plugged in to an external battery pack
- Ground test (or flight test) the camera, to learn about its tendency to overheat or get too cold
  - On warm/sunny days, keep cameras in the shade as much as possible before launch
  - Except for ones that "run (very) hot," it is usually best to mount cameras inside an insulated payload shell looking out through an opening in the wall, so they are not fully exposed to the outside, especially to the extremely cold temperature at the tropopause. Bevel the opening to avoid restricting the view, if the camera has a wide-angle lens.
- Do not cover openings with transparent "window" material. Although such a window may help keep things warm, this approach risks forming fog/condensate on the window which can ruin the footage.

Lightdow LD4000

Pros:
- Very inexpensive
- Pretty good quality footage
- Has a screen
- Can record while plugged in
- Can survive lens being exposed to cold, if external battery is heated

Cons:
- Two-touch recording – hard to mount
- Limited to 32 Gig SD cards
- Record indicator light hard to see

Ideosyncracy
- *Camera won't continue to charge once full, so <u>launch this **fully discharged**</u> (but plugged in)*



Triple-camera and battery pack installation.

Sample footage: https://drive.google.com/drive/folders/16M-gvld3lJg9XCzmGckzDpAXIqCIUkMF

GoPro HERO5 Session

Pros:
- Very good quality footage
- Can record while plugged in
- Can survive lens being exposed to cold, if external battery is heated
- Can take 64 Gig SD cards
- Record indicator light on front and back

Cons:
- No longer being made
- Much more expensive (~$200)
- No screen (but wide angle lens)
- Need to open/remove hatch to plug it in, making it a bit difficult to mount

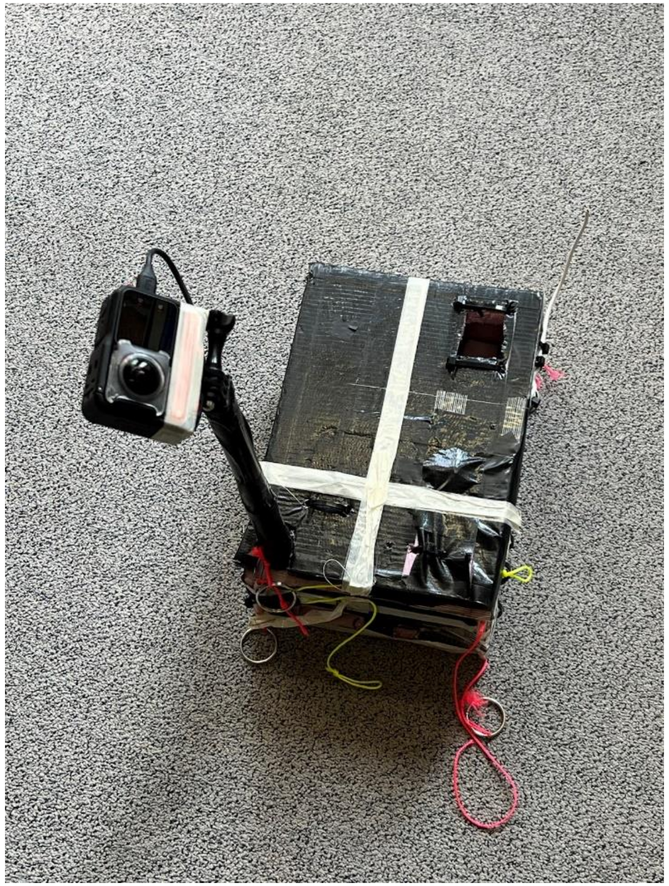
GoPro Session lashed to a plate, with ext. battery.

Sample footage: https://drive.google.com/drive/folders/1BdoCPiGBtSiv0KZUwWpmADL94Puh8pMW

Insta360 ONE RS

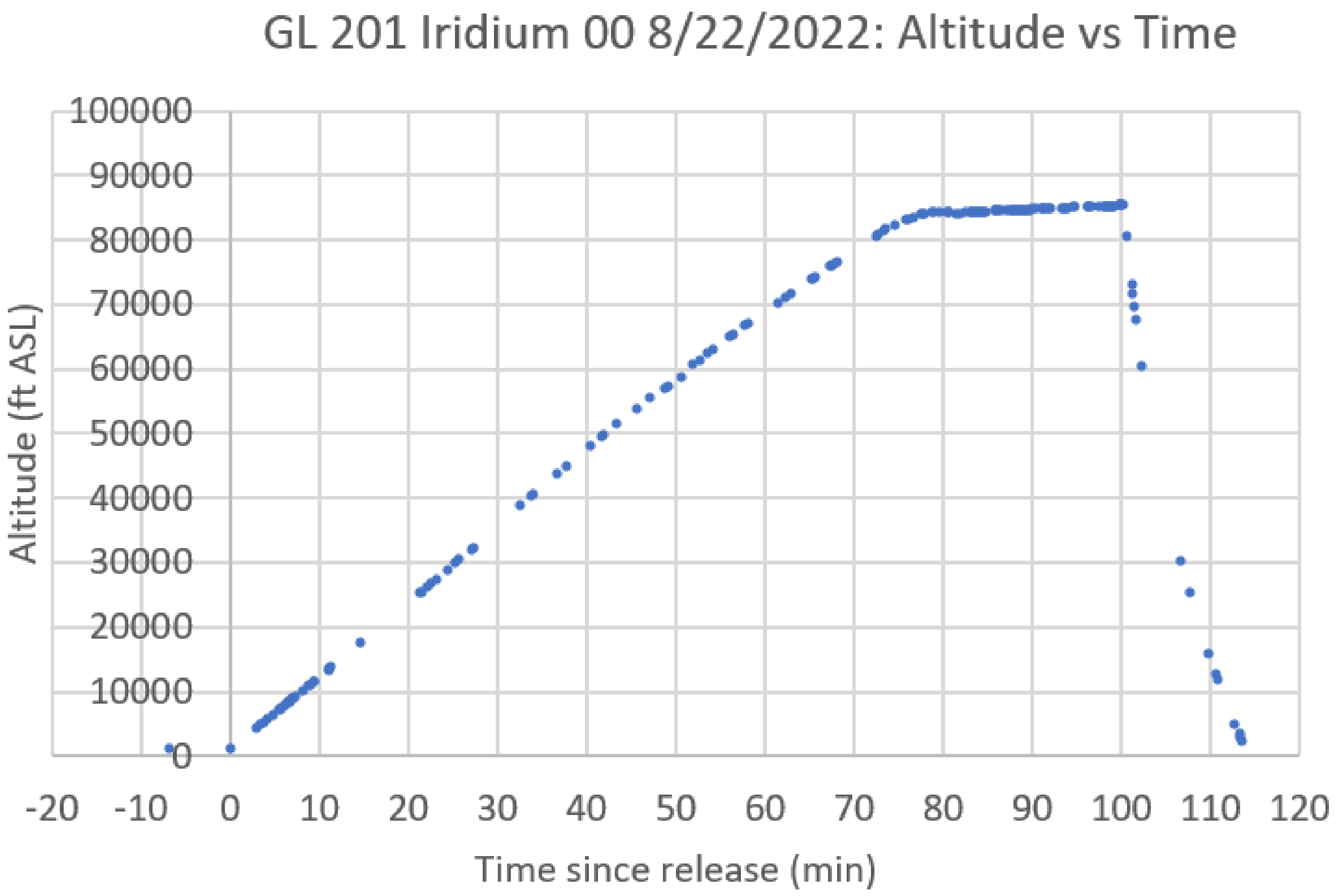
Pros:
- Very good quality footage
- Has a screen
- Can record while plugged in
- Can survive entire camera exposed to cold, if external battery is heated
- Easy to mount (on a selfie stick, which the software can make “invisible”)
- Come with software which does an exceptional job at stabilizing footage

Cons:
- Very expensive
- Needs at least a 128 Gig SD card
- Runs hot, so turn it on at the last minute



Insta360 mounted on an “invisible selfie stick.”

Sample footage: https://drive.google.com/file/d/1kDAb5BTcBpTBYf66Nxw5WoG3AcKdQBG3/view



Watch footage late in ascent, while venting, while floating, then cut-down:
https://drive.google.com/drive/folders/1BdoCPiGBtSiv0KZUwWpmADL94Puh8pMW

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Conclusion (quoting from the Abstract):

"…stabilizing payloads carried by … latex weather balloons, is particularly challenging since smaller balloon systems are more susceptible to wind-induced motion, including downward "relative wind" and balloon wake turbulence experienced by payloads during ascent. We have found that payload stacks on weather balloon missions can also become very quiet during float, even without the use of explicit anti-rotation techniques. This observation may be of particular interest to balloonists planning to participate in eclipse ballooning in 2023 and/or 2024 where "you've got to get it right the first time" (since eclipses are both short in duration and rare) and high-quality photography is of the essence.

Warning (quoting from the Manuscript):

If one manages to stop a payload from rotating, but has a specific target in mind for photography (like an eclipse shadow crossing underneath the balloon from SW to NE), it is possible that the camera will literally be pointing in the wrong direction and fail to capture the interesting footage. That said, anti-rotation schemes (including floating balloons) may need to be coupled with 360 cameras and/or multiple cameras pointing in different directions and/or active pointing devices to ensure high-quality photography of the targets of interest.