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.

stratospheric ballooning | payload stabilization | camera stabilization | near-space photography

1. Introduction

Videos and still photographs are probably the most-engaging type of data collected on stratospheric balloon flights. Even weather service personnel who launch balloons daily, but never send up cameras, are intrigued by the views from "near-space" that we capture. However, rotation and pendulum motion of suspended payloads can seriously degrade the quality of the imagery, blurring still images and making video footage so unsteady that it can be hard to watch, despite the magnificent view.

There are a variety of approaches to deal with this problem, not the least of which is to use "360 (degree) cameras" with image stabilization software. However, before discussing the pros and cons of that approach, let us consider some more-mechanical/less-computational options that have been presented at past Academic High-Altitude (Ballooning) Conferences (AHAC).

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At AHAC 2015 the ballooning team at the University of Minnesota – Twin Cities suggested that one key is to try to prevent stack rotation and swaying from happening in the first place using passive devices [1]. One of their main recommendations was to avoid the use of single payload suspension lines anywhere in the stack, including above the parachute, about which a stack can easily rotate. Instead, tightly couple the stack to the balloon neck with multiple, short lines to take advantage of the fact that weather balloons usually stop rotating at altitude. Figure 4a in Ref. 2 shows one such anti-rotation device used by the U of MN ballooning team during eclipse flights in 2017.

There have been several AHAC presentations about "active" camera stabilization and/or pointing [3, 4, 5], but it is challenging to determine attitude accurately and the hardware required to actively compensate for rotation or swing is heavy and can struggle in the extreme conditions of the stratosphere – especially the low temperatures. Active pointing devices literally cannot keep up under large-motion conditions, such as "post-burst chaos" (every flight) and "ascent turbulence" (some flights).

Another approach, more along the lines of the 360 cameras mentioned earlier, is to use either very wide-angle lenses [6] or multiple cameras and a multiplexer that selects which camera view to record, or transmit, at any given moment [7]. These can be valuable, especially if software stabilization is not available, but cost, complexity, and weight remain challenging.

There may be lessons to be gleaned from the observation that cameras on HASP – the High Altitude Student Platform [https://laspace.lsu.edu/hasp/] that carries payloads for academic teams, suspended under a massive 11 million cubic foot zero-pressure balloon – typically show very little rotation or swinging both during ascent and during float. That is certainly due, in large part, to the huge inertia of that balloon system and, probably to a lesser extent, to the fact that HASP only launches when the winds are light and the weather is good. Ref. 1 suggested, but did not actually defend with any personal evidence, that payloads suspended from balloons that "float" (rather than continuously ascend) are likely to experience less swinging and rotation. In this article we provide such evidence, achieving "HASP-like" stability on balloon flights using latex weather balloons.

2. General Advice for Selecting a Camera for Stratospheric Use

Stepping back even farther than payload stabilization, when trying to "improve photography" on stratospheric balloon flights it goes without saying that an early challenge is simply to keep the camera running for the whole flight. (For the duration of this article, photography will be equated with taking video footage, though the lessons learned should apply to taking still images as well.)

Typical (non-floated) weather balloon flights into the stratosphere often last between 2 and 3 hours, so one needs to select a camera and a memory card (and a resolution) that allows for 3 hours run time, minimum. There are many video cameras that can satisfy this condition in terms of memory, but most cannot run that long on their internal battery. Hence, a typical requirement of a video camera for stratospheric ballooning is one that can record even while plugged in to an external battery pack.

Cameras vary widely in their susceptibility to thermal extremes. Nearly all cameras will struggle to stay running if fully exposed to the bitter cold of the tropopause – well below -40 degrees C. On the other hand, many cameras are also susceptible to overheating which can happen before launch, if exposed to the sun on a summer day, and also in the stratosphere, where the lack of air makes it difficult to transfer excess heat to the environment.

Our ballooning experiences suggest that most cameras do best if mounted inside an insulating "payload box" looking out through an opening in the wall, even though that may interfere slightly with the view of wide-angle lenses. Although it might help to shield the camera from the cold, covering the opening through which the camera looks with a transparent "window" often leads to fogging, so we recommend against that approach. We have seen fogging inside camera lenses too, upon occasion, but fortunately that seems to be quite rare.

3. Recommendations for Three Specific Cameras for Stratospheric Missions

Here are some suggestions about how to operate three specific cameras during stratospheric balloon flights, starting from least expensive to most expensive.

3.1. Lightdow LD4000 Our lowest-cost, go-to video camera for balloon flights is the Lightdow LD4000 (see Fig. 1 and Ref. 8) which usually costs less than $60 (and is sometimes on sale for less than $30!), so you can purchase and fly several of these for the cost of just one of the more-expensive cameras discussed later. We first learned about this camera from another stratospheric ballooning group [9], so it came "recommended for stratospheric ballooning." Considering how inexpensive it is, this camera produces surprisingly-good footage, though it is limited to 32 Gig SD cards (so select the resolution appropriately, to get the required run-time).

To record, first press the power button (which is on the same side as the lens, so you may need to turn the camera on before you cinch it into a payload – beware: cinching it too tightly against a wall can inadvertently turn it off) and <u>then</u> press the record button (do not forget to do that!). The record indicator is a flashing light on the screen, which is located on the back of the camera, so it can be hard to tell from the outside of a payload box whether or not the camera is still recording.

The camera comes with a transparent waterproof case, but for stratospheric ballooning the case only adds weight and not much real value, so we always fly this camera "bare" – mounted inside an insulated payload (looking out through a beveled opening) so that only the lens – not even the entire front of the camera – is exposed to the elements. The camera is not particularly prone to overheating, but it is almost certain to "die" (due to battery chemistry failure) if it is fully exposed to the extremely low temperatures near the tropopause.

The built-in battery is insufficient to last a 3-hour balloon flight, so fly this camera plugged into an external battery pack. One important idiosyncrasy of this camera mentioned in Ref. 9 is the fact that once it is fully charged it will no longer accept charge from an external battery pack. That said, gut-wrenching though this may feel, the best way to fly this camera is to charge the battery pack but fully <u>discharge</u> the camera, plug the two together to start the camera charging, then start the recording. The camera will run while charging up, stop charging (mid-flight), then continue to record while discharging. This should give adequate time to film an entire 3-hour balloon flight.

Fig. 2 shows three Lightdow cameras, each with an external battery pack, looking up, down, and out from a single payload box. To see some stratospheric footage from a Lightdow LD4000 camera, see Ref. 10.

3.2. GoPro HERO5 Session Another go-to video camera for balloon flights is the GoPro HERO5 Session (see Fig. 3 and Ref. 11) which is no longer produced, but can be purchased used for about $200 – inexpensive for a GoPro. This camera produces very-good footage and a 64 Gig SD card is more-than-adequate for a 3-hour balloon flight. The GoPro Session does not have a screen, but it has a wide field of view so it is not hard to point.

To record, just press the power/record button once – easy. Slightly more tricky is figuring out how to lash the camera down without running zip ties across the field of view, since the camera is shaped like a cube. The record indicator is a flashing light on both the front (lens side) and the

Figure 1: A Lightdow LD4000 video camera.

Figure 2: Three Lightdow 4000 cameras pointing up, down, and out, each with an external battery pack, in a small payload box. The total weight of this payload, once rigging is added, is only 22 oz. The total cost is less than that of a single GoPro HERO5 Session camera.

back of the camera, and the lens opening needs to be the full size of the camera since it is shaped like a cube. Hence, it is easy to tell from the outside of a payload box whether or not the camera is still recording (but do not forget to check, before releasing the balloon!).

The camera comes with a mounting frame, not a fully-enclosed waterproof case, but for stratospheric ballooning we always fly this camera "bare" – mounted inside an insulated payload (looking out through an opening that matches the square profile of the camera) so only the lens side – but not the entire camera – is exposed to the elements. This camera can overheat on the ground before launch if the weather is warm and/or it is in the sun. And it is almost certain to "die" (due to battery chemistry failure) if fully exposed to the extremely low temperatures near the tropopause.

The built-in battery is insufficient to last a 3-hour balloon flight, so fly this camera plugged into an external battery pack. Doing so requires opening, or perhaps even removing, the hatch on the side of the camera visible in Fig. 4 (left). Unfortunately, having a charging cable sticking out the side of the camera complicates mounting it. Our current approach to mounting this camera is to place the front of the camera in a laser-cut frame that just fits it, to prevent it from falling forward (outside the payload), then strapping the camera to the frame with the hatch open, and finally strapping the frame to a payload wall, as shown in Fig. 4 (right).

To see some stratospheric footage from a GoPro HERO5 Session camera, see Ref. 12.

3.3. Insta360 ONE RS Our "coolest" video camera for balloon flights was recommended to us by colleagues from the Montana Space Grant. It is the Insta360 ONE RS (see Fig. 5 and Ref. 13) "Twin Edition – Standalone" which costs about $550. We also purchased "Sticky Lens Guards" and a "120 cm Invisible Selfie Stick." This camera needs at least a 128 Gig SD card for a 3-hour balloon flight, due to the large size of the files it produces. It has a screen and comes with two pairs of lenses, one pair for 360 footage and one pair for 4K footage – not quite 360 coverage, but still rather wide angle and better in some ways. So far, we have only used the 360 lenses on balloon flights.

To record, press the power then the record button. We fly this camera on the end of a selfie stick (see Fig. 6), so mounting is easy – just lash the other end of the selfie stick to a payload box. The camera software will even erase the selfie stick from the footage – hence the name "invisible selfie stick." The record indicator on the camera is easy to see when the camera is this exposed.

The camera itself is waterproof and we added sticky lens guards to try to protect the exposed lenses from getting scratched. Unlike the other two cameras, the Insta360 is quite prone to overheating, so it actually does better if it is <u>not</u> flown in an insulated box. Indeed, being in (or close to) a payload box would partially defeat the 360 nature of the footage. The camera can easily overheat on the ground, even if kept in the shade, so do not turn it on until just before launch. In flight the camera will keep itself warm enough to survive being fully exposed to the extremely low temperatures near the tropopause.

The built-in battery is insufficient to last a 3-hour balloon flight, so fly this camera plugged into an external battery pack. But do not let the battery get too cold. Instead, run the cable to the battery pack down the selfie stick and have the battery pack itself inside an insulated payload.

The camera has a huge variety of settings and options, most of which we have not tried, and it also comes with video editing software. One of the most impressive features, at least for stratospheric ballooning applications, is the robust image stabilization which is accomplished using sensors in the camera coupled with image post-processing. One downside of this footage,

Figure 3: A GoPro HERO5 Session camera.

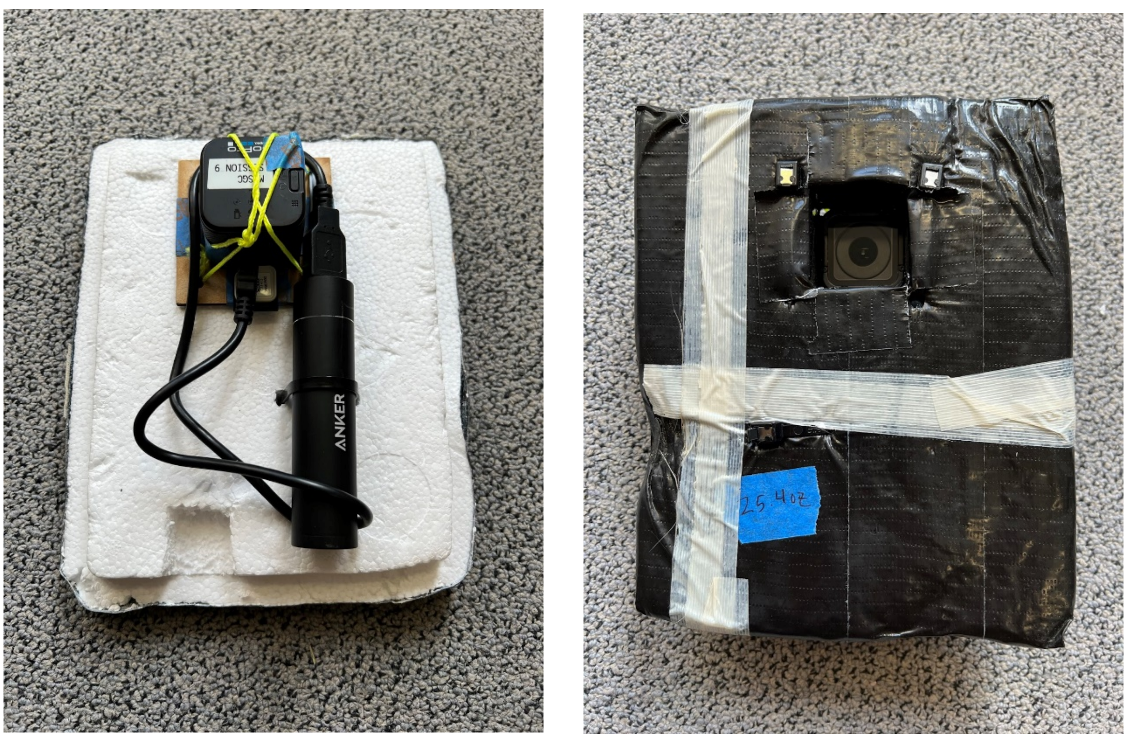

Figure 4: GoPro HERO5 Session, tied to a frame and mounted on a payload lid, along with an external battery. Inside view (left); outside view (right). The camera's hatch needs to be open, or removed, for the charging cable to be plugged in.

Figure 5: An Insta360 ONE RS camera.

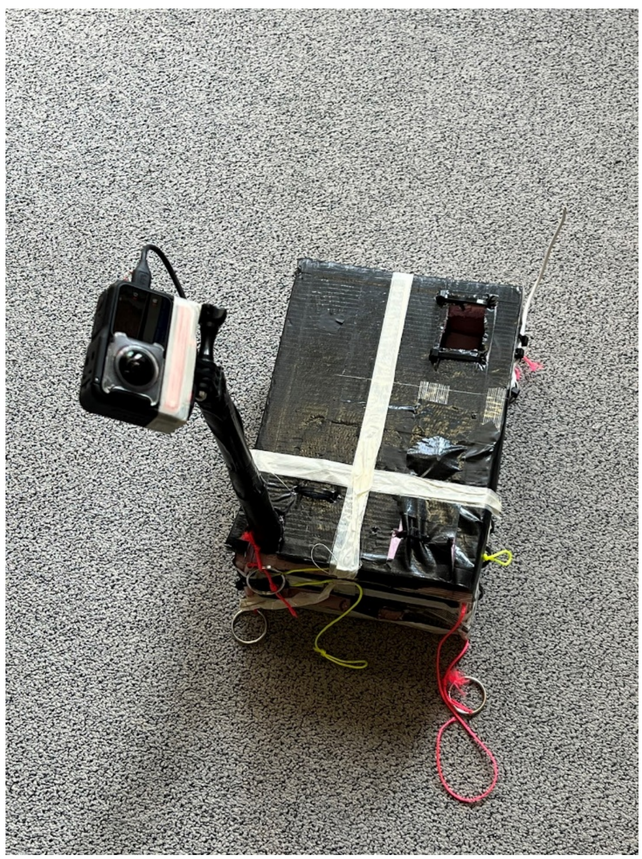

Figure 6: Insta360 ONE RS mounted on a selfie stick. The external battery for the camera is inside the payload box and the battery cable runs along the selfie stick.

and that of all wide-angle photography, is the limited ability to zoom in while trying to maintain high resolution.

To see some stratospheric footage from a Insta360 ONE RS camera, see Ref. 14. What is posted is no longer 360 video, just selections looking in various directions at different times from the original 360 flight footage. In particular, notice how well-stabilized the footage is, especially after the balloon is cut away and the payloads begin to fall under parachute.

4. Impact of "Floating" Balloons on Payload Stabilization

While developing and testing a vent device for potential use during eclipse ballooning missions in 2023 and 2024 [15], we were pleased to notice that our stacks became very quiet when the balloon entered float, resulting in very steady video footage reminiscent of HASP (i.e. massive balloon) footage. See Ref. 12 for both ascent and float footage from a GoPro HERO5 Session camera. This "anti-rotation" occurred despite using a single payload suspension line between the vent in the neck of the balloon and the top payload. (The parachute on these flights was placed on a hook on the side of the top payload – see parachute deployment from such a hook in the Insta360 footage in Ref. 14.) As suggested (without evidence) in Ref. 1, floating a weather balloon is indeed an effective way to mitigate payload swing and rotation even without the use of other anti-rotation strategies, at least in the absence of atmospheric turbulence at the float altitude. Apparently, the random rotation noted in most balloon flights during ascent is due, at least in part, to the relative wind associated with moving vertically through the air (and perhaps turbulence due to the wake of the ascending balloon). Once the balloon stops ascending, swing and rotation naturally die away, even in the thin atmosphere at stratospheric altitudes.

This observation and evidence may impact how weather balloonists attempt to do photography, at least with cameras that do not have robust image stabilization. Venting a balloon into float is not trivial and must be coupled with a reliable active termination procedure since floating removes burst as a natural form of flight termination. However, the benefit of achieving float to photography might be worth the extra effort and complexity, especially for projects such as the "engineering" side (AKA the "video streaming" side) of the NEBP (Nationwide Eclipse Ballooning Project (NEBP) [https://eclipse.montana.edu/]) that plans to field dozens of teams to do eclipse ballooning photography from stratospheric ballooning platforms during the solar eclipses of 2023 and 2024.

Final note: 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), it is possible that the camera will literally end up pointing in the wrong direction and fail to capture the desired footage. That said, anti-rotation schemes (such as floating balloons) may need to be coupled with 360 cameras, using multiple cameras pointing in different directions, and/or active pointing devices to ensure high-quality photography of the targets of interest.

5. Conclusions

Two challenges to doing quality photography during stratospheric balloon flights are (a) keeping cameras operational for long enough in the extreme conditions – especially the low temperatures – encountered on such flights and (b) taking sharp photographs or video from a camera in a payload that is rotating and/or swinging. This article adds to the passive anti-rotation recommendations made in Ref. 1, giving specific suggestions about how best to get long-duration footage from three specific video cameras and pointing out the floating balloons, though challenging to accomplish, may be the best anti-rotation mitigation scheme of all for weather balloon flights.

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