



Rotation Mitigation and “OCCAMS + Tungsten” Flight Termination for Eclipse Balloon Missions

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Abstract

Payload stacks can rotate with respect to the balloon right up until burst, especially if attached to the balloon neck by just a single main suspension line. This rotation makes the recording of quality video difficult. Our passive “rotation mitigation” device attaches directly to the neck of the balloon and runs four parallel lines separated by 6 inches from the balloon neck directly down to the payload stack below, often significantly diminishing stack rotation with respect to the balloon, especially at high altitudes. This anti-rotation rigging system is also allows for flight termination. All five strings attaching the stack to the balloon can be released by either an OCCAMS razor-cutter or a tungsten hot-wire cutter. Both the cutting mechanisms can be triggered remotely or autonomously, using an onboard Arduino Mega and/or an XBee radio network.

Background Information

Stack rotation is a nemesis for many ballooning experiments, especially photography that is trying to keep a specific target in view, such as the Moon’s shadow (or the Sun itself) on eclipse flights. Our rotation mitigation system uses multiple lines to lessen rotation. However, this complicates flight termination due to multiple-line attachments. In our system a single line in a cutter payload (see Fig. 1) is severed, releasing all five lines attaching the balloon to the stack. The system is show ready for flight in **Figure 2**.

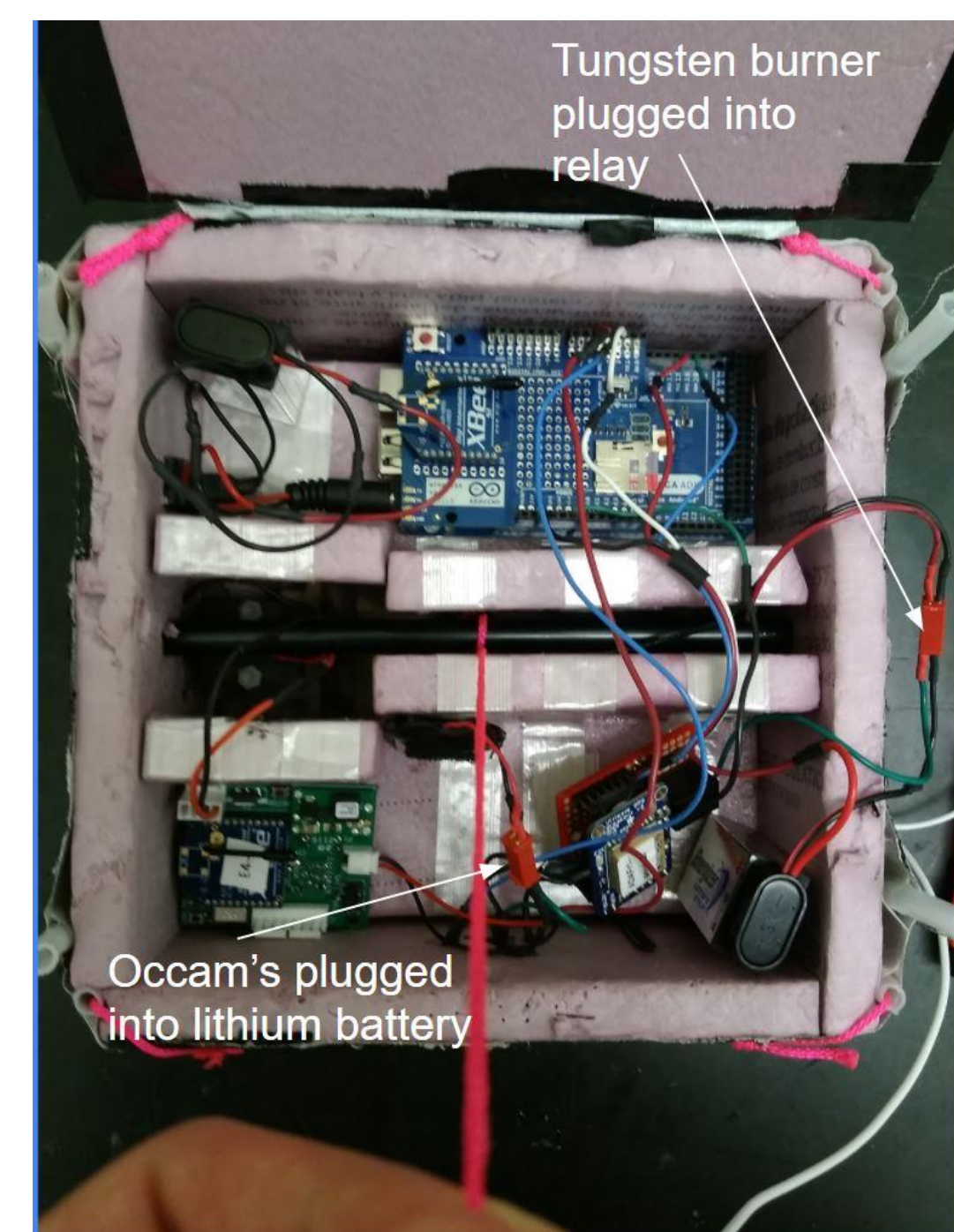


Figure 1

Top view inside the cutter payload.



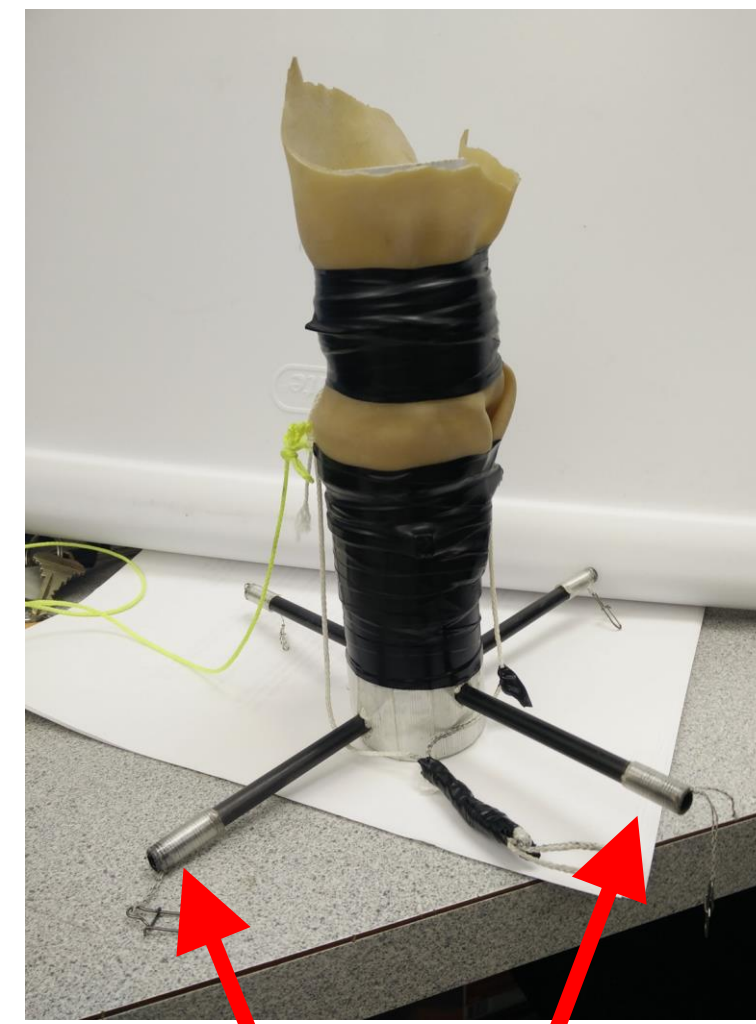
Figure 2

Flight ready anti-rotation system – (plugged) neck insert and cutter payload.

Various balloon flight termination devices have been developed such as the main-line-cutting “OCCAMS” razor-cutter from Montana State University. The OCCAMS system makes use of the Iridium network’s .sbd packet transmission capabilities. Commands can be sent through the Iridium network, which are then transmitted to the OCCAMS razor-cutter via XBee radio. Our team did not have consistent success getting the OCCAMS to cut this way, so we developed an RFD-to-XBee alternative channel as well as a completely separate tungsten hot-wire cutter, for redundancy.

Rotation Mitigation

Anti-rotation Neck Insert



Strapping tape prevents the fishing line from splitting the carbon fiber rods.

Figure 3. Balloon neck inserts, if used, often consist of pvc tubing with zip ties holding the insert in the neck with the payload-bearing line(s) attached to the zip ties. Our anti-rotation neck insert has two carbon fiber rods that allow for four extra rotation-mitigation fishing lines to be attached. These strings minimize the rotation of the payload stack relative to the balloon. This (plugged-tube) neck insert is zip-tied into the neck (beside the main line) after the balloon is inflated.

The “Sandwich” to Spread Anti-rotation Lines

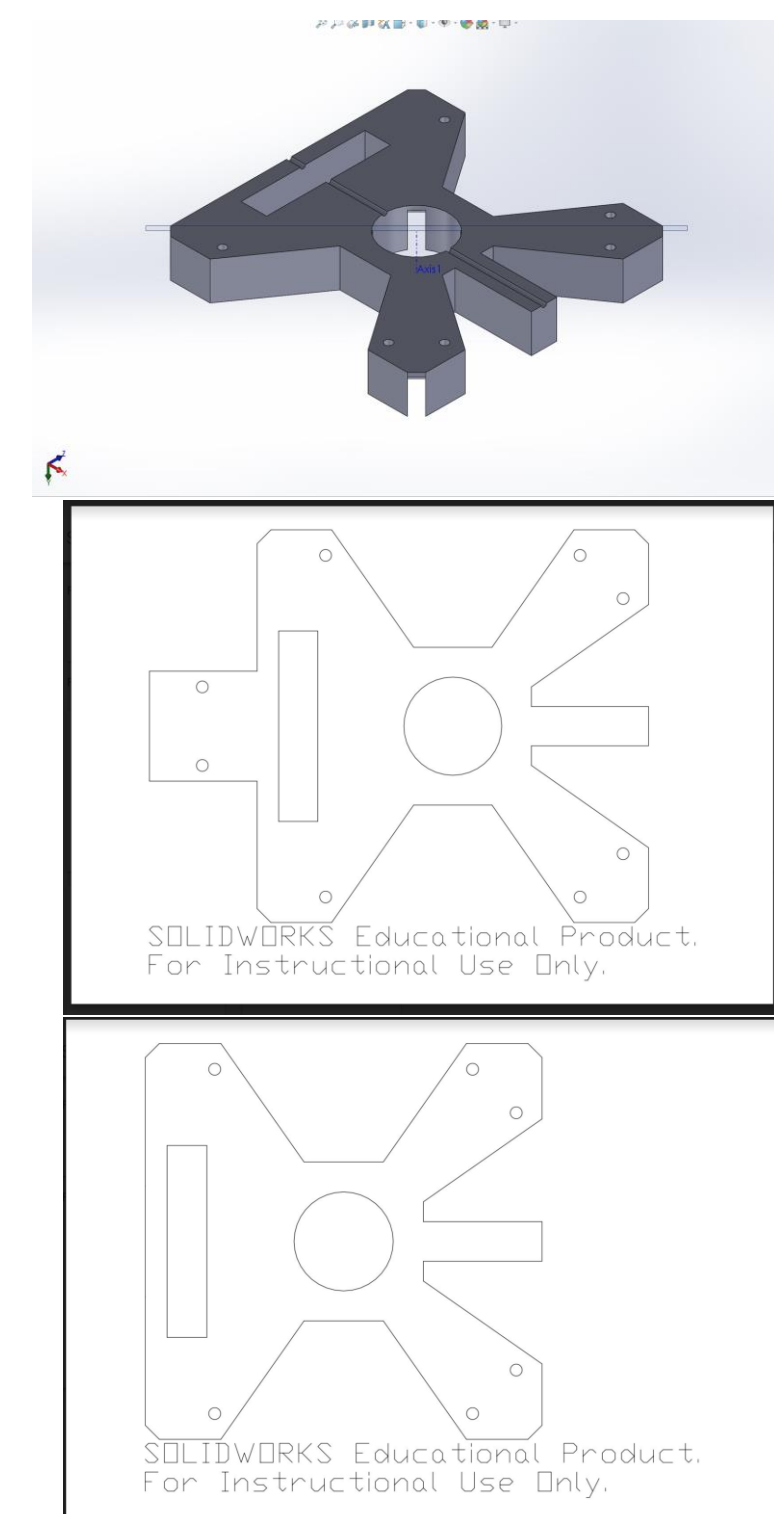


Figure 4. One challenge with having multiple lines connected to one severable line is that the line to be cut must remain straight and be taut at all times, to ensure ease of cutting. To address this issue, we designed a solid 3D printed structure we called the “Sandwich” to guides the four anti-rotation strings, plus the main line, to the central string to be severed. The 3D printed structure has two flat top and bottom pieces, laser-cut from MDF, to ensure all the strings stay in place. The sandwich was designed to accommodate the OCCAMS and tungsten cutter units.

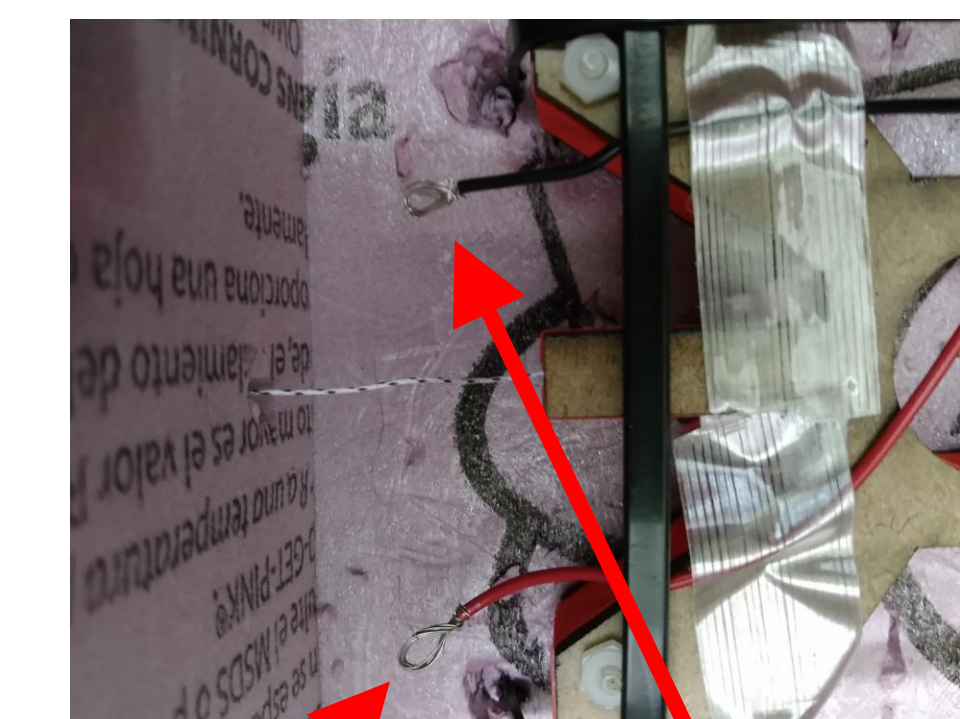
Cutdown Systems

Modified OCCAMS Razor-Cutter



Figure 5. The OCCAMS flight termination system utilizes a razor blade attached to a servo motor to sever the load-bearing line. It was originally designed to be operated through an Iridium-to-XBEE-radio channel. In order to increase the capabilities of the OCCAMS razor-cutter, we added the ability to send cut-down commands to the OCCAMS’ XBee radio using an XBee integrated into our RFD radio payload serving as a communications relay.

Tungsten Hot-Wire Cutter



The Tungsten wire is tied between these two terminals and is in direct contact with the string to be severed.

Figure 6. The “tungsten-cut” system was developed as an independent flight-termination system by our team. It uses two 9V batteries in series, connected with a fine tungsten wire in direct contact with the releasing-string in the sandwich. This system has proven reliable and can be activated using a timer, after reaching a certain gps-monitored altitude, or by XBee radio command using the RFD-to-XBee network. The design uses 0.08 mm diameter tungsten wire, which fully vaporizes. The wire is so fine it is barely visible in **Figure 6**.

Results

Rotation Mitigation

Passive rotation-mitigation systems have become a regular addition on our flight stacks, sometimes even ones without flight termination capabilities. Set-up of the multi-string system is somewhat involved and requires both training and practice. Although they do not always stop all rotation, our anti-rotation devices have a marked, positive impact compared to stacks without anti-rotation devices. Our flight videos have been much more watchable since adding anti-rotation.

Cutdown Systems

Using two independent cut-down techniques, we have achieved redundancy both in the means of triggering flight termination and in the physical mechanism that severs the releasing string. When properly prepared, both the OCCAMS cutter (typically fired “directly” rather than through the Iridium network) and the tungsten-cut have proven reliable means of flight termination. Rigging the sandwich in the cutter payload remains a chore.

Acknowledgements

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