NS-61 Anomaly Analysis

# Flight Summary

NS-61 was launched from Everett, PA at ~8:45am on 12/4/16. The payloads for the flight were the command module and Hermes 3.0, a payload provided by CapTech to demonstrate their cubesat system. This document describes the anomalies experienced during the flight relating to:

* Drop of Hermes 3.0
* Pre-burst release of balloon

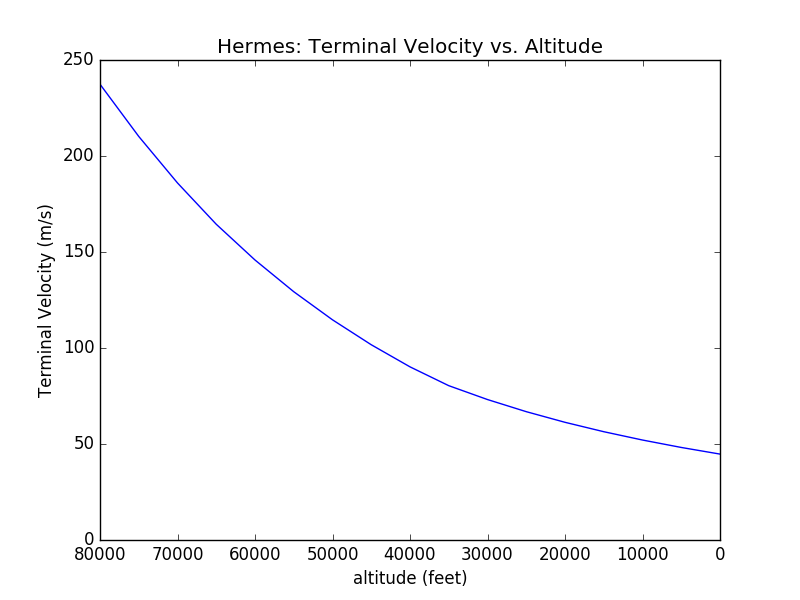
and summarizes the recommended actions to ensure that these anomalies do not recur.

# Hermes 3.0 Drop

## Summary

Hermes 3.0 was enclosed in a thin tupperware container. During the flight, contact with Hermes was lost. Upon recovery it was discovered that the tupperware had been breached in several locations and was missing the majority of the lid and the contents of the payload.

The release of the contents of the payload in this uncontrolled manner is interpreted to be a violation of FAR 101.7 and possibly 101.33(d). Federal laws aside, it is extremely unsafe to drop objects in an uncontrolled manner.



As seen in the above plot, the release of an uncontrolled, CubeSat size and weight object (which is Hermes’ form factor) leads to high terminal velocities. The high altitude, high mach number (~0.8) velocities were probably not reached. However, it is almost certain that terminal velocity was reached by the end of the fall. Depending on the altitude of the crash site, this implies an impact speed of between 44 and 47 m/s. That is approximately 100 miles per hour. It goes without saying that an impact of this speed could severely damage property or severely injure a person, should it hit something or someone. As we fly in the northeastern United States, an overall densely populated area, this risk cannot be ignored, even if we normally fly over forests and farms.

## Anomaly Analysis

Its seems likely that a combination of the thermal and pressure environments caused the failure of the tupperware. Copious amounts of duct tape were used to close the payload and may have inadvertently created a pressure seal. When the ambient pressure dropped during the flight, the pressure forces may have caused the structure to catastrophically rupture, resulting in release of the internal electronics. This may have been facilitated by the increasingly brittle nature of the plastic at low temperatures.

Alternatively, the lid of the container was supporting the 360 camera which was cantilevered off the side so as to capture views of the ground and sky. The temperature profile may have weakened/embrittled the plastic enough to cause the lid failure and release the contents of the payload. The unusually high wind speed at altitude (approaching 190 km/h) and resultant wind loads are assessed to be potential contributing factors to this failure mode.

## Future Actions

Future payload designs may benefit from several changes to the design:

* Payloads should be designed such that, regardless of the type of container they use, are oriented such that a failure of the lid cannot result in the release of the contents. This could be accomplished either by restraining the key contents of the payload (battery, electronics, etc) so that they cannot be removed without human intervention, or by orienting the lid such that it could not be opened in flight (i.e. the isolation tube and payload string pass through the lid).
* Payloads should be designed such that, unless they are a dedicated pressure vessel, they have a certain unobstructed minimum area dedicated to venting (ex, 0.5cm^2 of unobstructed/dedicated vent holes) so that they cannot accidentally pressurize.
* Payloads should limit the use of plastic as a payload container, or should do thermal testing to establish how the container behaves at very cold temperatures.
* Payloads should be designed such that cantilevered loads are integrated into the main structure of the payload.

Pre-Burst Release of Balloon

Summary

Despite poor APRS coverage, balloon “burst” was reported at ~77,000 feet above sea level during the chase. This figure was later revised to 80,001 feet above sea level using Cell Tracker log data. Both of the figures are lower than the predicted maximum altitude of the balloon. Upon recovery of the payload string at the landing site, no fragments of the balloon were recovered or even visibly in the area. Based on the state of the duct tape which attached the payload string to the balloon neck, it is likely that the payload string fell off of the balloon, rather than the balloon having burst.

This anomaly is important to avoid because it leaves the envelope of the balloon intact and in an untrackable state. The balloon may continue to drift for an unknown amount of time after the release of the payloads which could cause issues for commercial aviation.

This anomaly is also unfortunate because it unnecessarily limited the altitude achieved during the flight, potentially reducing the amount of science collected during the flight or limiting the operation of payloads requiring a certain minimum altitude.

Anomaly Analysis

Upon recovery, it was noted that the duct tape loop used to connect the balloon and payload string was unfurled, and the duct tape’s adhesive was not adhering well. The duct tape in question is known to be somewhat low quality; this tape is ostensibly used to prevent the stress caused by the weight of the payloads, combined with good adhesive, from tearing the balloon.

Additionally, it was noted that no zip tie was was used around the neck to ensure the duct tape loop could not slip off. Zip tie usage used to be standard procedure; it should be noted that HELIOS uses a hose clamp for the same purpose. The zip tie procedure was discontinued at some point previously for unknown reasons.

## Future Actions

It’s recommended that both a mechanical and adhesive restraint be used to secure the balloon neck. Zip ties are easy to use and present a low risk to the balloon envelope.