NS-68 Failure Analysis

# Flight Summary

NS-68 was launched from Hagerstown, MD at 11:26 AM on July 15, 2017. The flight payloads consisted of four FYSE camera payloads (Sky O. , Space Plant, Space Pong, and Water Balloon), SkyNet, , SlamDunk, and HTB-1 (a HABduino backup to the mini command module). This document describes the failures during flight of:

* Loss of tracking from Mini Command Module
* Failure of the HTB-1 HABduino

And summarizes recommended actions to ensure that these do not occur again.

# Loss of Tracking from Mini Command Module

## Summary

The previously assigned battery for mini command was not charged before flight. This was discovered on the launch pad. With no spare batteries of the proper size, the bottom battery from Main command was swapped with the mini command battery. Packets were received from HABduino W3EAX-13 prior to launch, as well as valid cell tracker messages.

After launch, there was no communication from the HABduino. The last packet received was from a minute and a half before launch. Throughout the duration of the five hours cell tracker was likely on (excluding the possibility of a power failure), no cell tracker texts were received either.

HTB-1 was not functioning on the launch pad, no packets were received while on the pad. It was observed that the HABduino would power on, boot, and sometimes acquire lock, before briefly shutting down and booting again. It was decided that the launch should continue, as W3EAX-13 was working.

## Anomaly Analysis

The fact that both cell tracker and the HABDuino failed suggest a common failure mode. Possible such modes include structural compromise, radio interference, and a power supply failure. The last packet was received from HABDuino W3EAX-13 prior to launch, as was the last cell tracker message. This suggests the failure occurred either prior to launch or very shortly thereafter. Since no evidence of mini-command being structurally compromised was observed at that time, this failure mode is assessed to be highly unlikely.

The fact that mini-command was working well prior to launch suggests radio interference is unlikely. However, there is the possibility that taking the payloads off the ground and raising them up on the string could have introduced interference, either by changing the geometry of the payloads or exposing them to ambient interference. Thus, the possibility of the failure being caused by interference cannot be ruled out.

The only common dependencies of the HABduino and cell tracker are the box structure, battery, and LVC. A power supply failure of some sort thus seems like a likely cause of the system failure. There are two components to the power supply: the battery and the LVC. Since the LVC has been successfully used on previous flights, it seems unlikely to be the cause of the failure. However, it is possible that some wires came loose, causing a loss of power. During the previous launch date, during NS-65, HABDuino W3EAX-12 in main command used the same battery that flew on NS-68 Mini command. On NS-65, the HABduino on the bottom of main command failed during the descent. The investigation into this failure led suggested that the LVC might not have been working properly, though there was no definitive cause established. There was not anything to be believed wrong with the battery. Given the common point of failure and the fact that W3EAX-12 performed nominally on NS-67 (launched concurrently with NS-68), the battery is assessed to be the most likely cause of the failure on NS-68.

The failure of W3EAX-14 in HTB-1 occurred on the pad. The prior night, the system was successfully tested with a 6 volt pack of Lithium Primary Batteries, and then again with an LVC with a 5 volt regulator using an older 1500 mAh Battery. For flight, a 850mAh battery was charged and then placed in the payload. During testing the screw terminals did fail to hold the wires, but these were tightened. This was an unlikely cause of the failure as the HABduino was receiving power on the pad. The payload was not tested with the flight battery, to preserve its charge. The battery should have been able to fulfill the current demands, but the possibility of the battery being damaged and unable to do so cannot be ruled out. The LVC had an input and a 5 volt and 9 volt regulator. The 5 volt regulator was used, as HABduino’s do not perform desirably when getting more than 7 volts. This was put into the barrel jack of the HADduino. The regulator worked the night before successfully, and did not turn off or show any malfunctions on the pad. However, the barrel jack connection goes through the Arduino’s regulator, so the 5 volts would have been reduced further to a voltage where, during transmit, the HABduino might shut down. It was noted that the temperature on the pad was high compared to other launches, and overheating could have contributed to the problems.

The least amount of testing went into the flight battery, as such, it is a likely form of failure. Additionally loose wires and regulator failure can not be ruled out. The Most likely form of failure was the regulator and Barrel jack connection, as the voltage would drop such the HABduino would shut down during the high current draw from transmit.

## Future Actions

Due to the nature of the Lithium batteries used in most payloads, where they are good to around 400 charging cycles, and that many of the batteries in the program are at least two years old, it is recommended that all program batteries go through a static load test for a minimum of an hour to ensure that they will not fail for the duration of a flight no matter how new or old they may be. This will help in diagnosing if any other batteries are displaying the power problems the battery in mini command was displaying. It is also recommended that this procedure be repeated every six to nine months to ensure batteries are properly functioning.

The entire above situation could have been mitigated if the battery on Mini command was charged before flight. Being said, prior to each launch, every payload should check that all batteries they use are charged. If there are spare batteries not being used by any payload, they should also be charged and brought along to the launch in case a battery has died, or something has happened to it.

Additionally, more battery chargers may need to purchased, in order to be able to charge all flight batteries and spares in a timely manner, as all batteries should be stored in a partially charged state to prevent damage. A battery charger should be added to the away materials to help mitigate the risk of not having a fully charged battery on the pad.

# Failure of the HTB-1 HABduino

## Summary

On the launch pad, the HTB-1 HABduino was receiving intermittent power, and would fail when attempting to send a packet. It was deemed a power failure, and NS-68 was flown without the redundancy provided by the HTB-1 payload.

## Anomaly Analysis

The fact that power was being received to the HABduino, although intermittently, suggests some sort of power failure on HTB-1. One cannot rule out an uncharged battery as the source of the problem, although the fact that there was some power coming to the payload, which was acting up when the HABduino tried to transmit packets makes that seem unlikely. There also may have been a problem with the LVC used on HTB-1, which cannot be investigated since the payload has not yet been recovered.

Power was being transferred from the battery into the LVC, into the barrel jack of the Arduino, which was then powering both the Arduino and the HABduino. The LVC was regulating the battery voltage down to 5V, which was then going into the barrel jack, which requires a minimum input voltage of 7V. This seems to be a likely cause for the type of failure in HTB-1: the payload was receiving power, but was unable to draw enough through the barrel jack when trying to transmit.

Faulty wiring is also another possibility that cannot be ignored, although one would expect more intermittent payload power regardless of trying to transmit packets or not. This leads us to believe that the way power was being provided to the payload was the source of power problems on HTB-1.

## Future Actions

All payloads must be tested before launch in their flight configuration in order to avoid payloads work in a tested configuration but not in the flight one.

Once tested in a flight configuration, in order for a payload to make more design changes, one of the following must occur before launch:

* Prove payload functionality in the new flight configuration
* A minimum of four separate individuals must look at the design changes and independently verify the maintained likelihood for a successful flight.