An Investigation of the System Architecture of High-Power 3U CubeSats Capable of Supporting High Impulse Missions

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Problem / Question

Can a high power density 3U CubeSat support the necessary subsystems to execute a high impulse mission?

Introduction

CubeSats, or nanosatellites, are growing in ubiquity in the aerospace community and have the potential to revolutionize the future of spaceflight by providing a more cost and time efficient avenue to perform space exploration missions. However, In their current stage of development, standard 3U CubeSats do not generate enough power to support the subsystems necessary to execute such high impulse missions. This investigation is intended to explore that of a high power dense 3U CubeSat and assess if it can support these subsystems and possibly be used for scientific research missions.

Project Overview

This investigation

- Is an assessment of the feasibility of high power density 3U CubeSats despite their small volumes
- An assessment of the system architecture of a high power dense 3U CubeSat and how its thermal control system maintained the hardware/electronics at steady-state operable temperatures despite the amount of power being generated
- Discusses a viable propulsion option for a 3U CubeSat capable of high power generation

The CubeSat under investigation is the ALBus CubeSat that is under development at NASA's Glenn Research Center.

The ALBus CubeSat

The Advanced Electrical Bus (ALBus) CubeSat will demonstrate the performance of a 100 W capable power management and distribution (PMAD) system and resettable Shape Memory Alloy retention and release mechanisms for deployable solar arrays. The CubeSat will charge batteries to desired stated of charge utilizing a maximum power point tracking algorithm and discharge a maximum of 100 W of power to a load representative of a high power payload. The technology demonstration will prove the designs work in an on orbit environment for follow on missions requiring high power density operations.

The ALBus CubeSat is an example of a high power density 3U CubeSat. The target load representing a high power payload in the system is a discharge board, or bank of resistors.

System Architecture of the ALBus CubeSat

Concept of Operations

- The discharge board will convert the 100W to waste heat via the resistors
  - Not typical to convert all of your power to waste heat
- The waste heat will be absorbed by an aluminum heat sink: the thermal control system

The system supports the flow of the waste heat directly into the heat sink since the discharge board is flush against the heat sink. The spacing of the system also helps to reduce radiation between the PCBs thus decreasing the chance of overheating inside the CubeSat chassis.

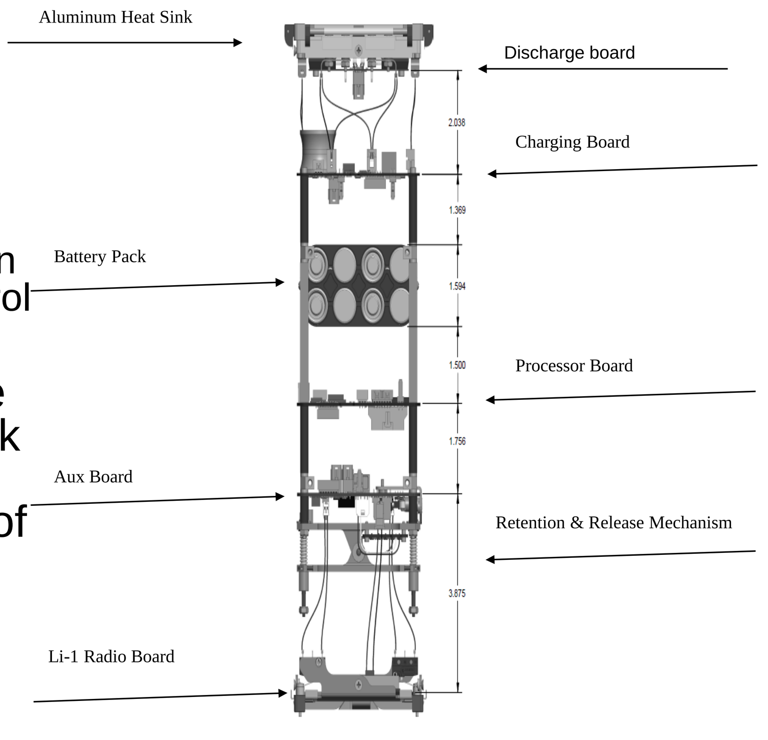
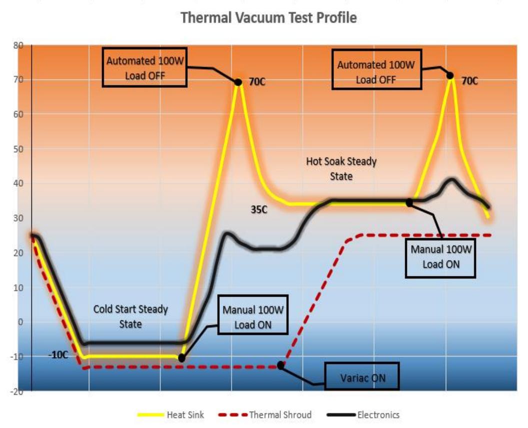


Figure 3: PCB Stack Up by NASA ALBus CubeSat Team

Thermal Testing

A thermal vacuum test was conducted to

- Prove 100W of power was provided to the target load, discharge board, but assessing the amount of heat absorbed by the heat sink (100W Power → 100W waste heat)
- Show that the rest of the CubeSat hardware was kept at steady-state operable temperatures despite the amount of waste heat emitted into the system thus showing that despite their small volumes, 3U CubeSats can thermally control their systems via simple methods like an aluminum heat sink



Data / Observations

Using a MATLAB script to process and plot the data, the 100W capability was proven by using the specific heat equation of

$$Q = mc\Delta T/s$$

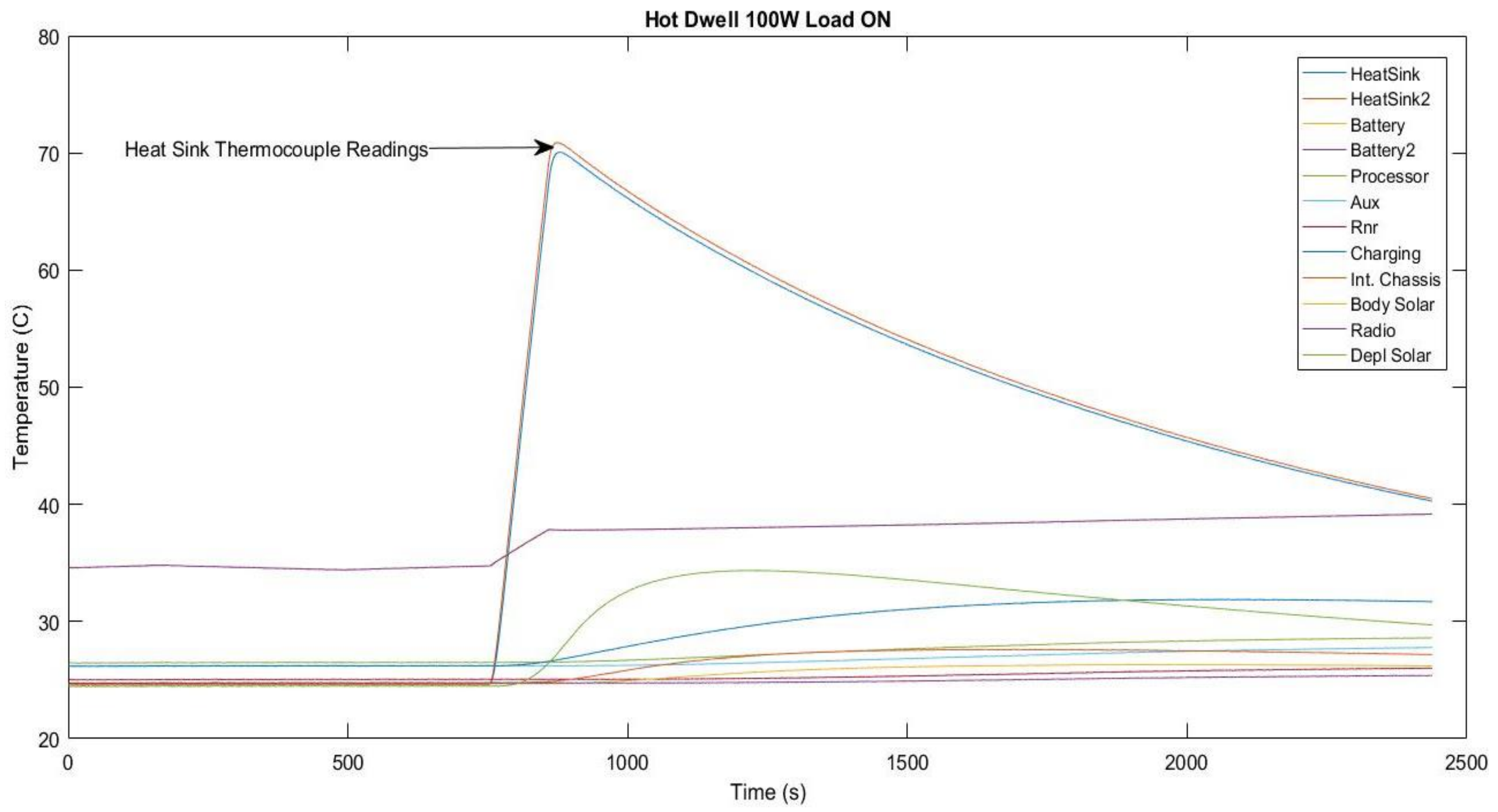
Where Q is heat in Watts, m is mass in grams, c is the specific heat of Aluminum in J/g·K, T is °C, and s is time in seconds. The results are below.

MATLAB Processed Hot Dwell Data

Variable	Value
Max Temperature (C)	70.066
100W Load ON Run Time (s)	109
100W Load ON Run Time (min)	1.817
Heat Sink Weight (g)	265
Specific Heat of Aluminum (J/g·K)	0.9
ΔT of Heat Sink (C)	45.43
Heat Absorbed (W)	99.53

Table 1: Calculations from MATLAB algorithm to determine amount of heat absorbed by the Heat Sink.

Results



Note: During 100W discharge, battery pack is expected to release around 6W of waste heat

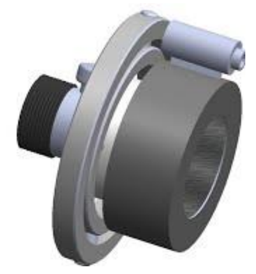
Observations:

- Data shows the expected peak in temperature at 70°C of the Heat Sink thermocouples
- Shows all the other hardware staying within the 25°C – 30°C range which is far below the thermal limits of the various hardware
- Processor and charging boards see a small jump after the 100W discharge is turned on due to their position relative to the Battery Pack and Heat Sink (the only two subsystems emitting noticeable amounts of waste heat), respectively

Conclusion

- Feasibility of high PMAD in a 3U CubeSat is feasible and waste heat can be properly controlled despite the constraints of a small closed volume
- Thus, a 3U CubeSat has the potential to provide enough power to a propulsion system and other subsystems necessary for high ΔV missions

To be more specific, the most viable options for a high power density 3U CUbeSat is the Miniature Xenon Ion thruster because of its size, efficiency and thrust levels.



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