System Assessment of a High Power 3-U CubeSat

Katie Shaw
NASA Glenn Research Center

Small Sat CubeSat Developers Workshop

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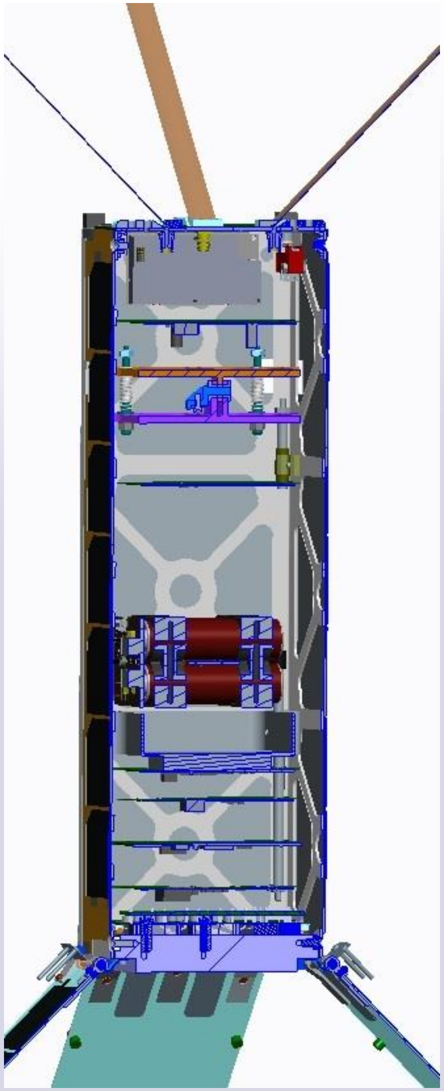
Overview

- Advanced Electrical Bus CubeSat Overview
- Driving Requirements and Constraints
- Power Generation and Storage Solutions
- Thermal Management Solutions
- Packaging
- Conclusion

Advanced Electrical Bus CubeSat Project

- Pathfinder technology demonstration mission for high power CubeSats
  - Demonstrate 100 W distribution of electrical power to a target load
  - Develop a reliable retention and release mechanism for deployable arrays
  - Develop solutions for high power system integration
- Objectives
  - *Resettable* retention and release mechanisms
  - Demonstrate *dual function* hinges for array deployment and power transfer
  - End to end power management and distribution *efficiency*
  - Assess on-orbit *performance* of battery management system
  - Adequate thermal management to demonstrate *operation* of the power management and distribution subsystem in 3-U CubeSat form factor



Driving Requirements

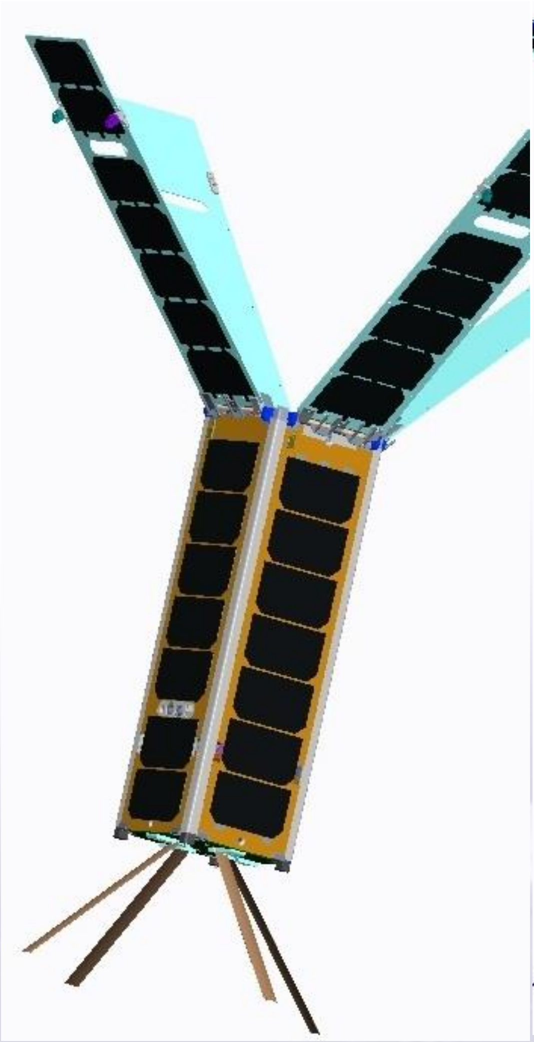
- Distribute 100 W of power to target load
- Maintain electronics within de-rated temperature limits

	Waste Heat (W) by Operational Mode				**Temp Limits (C)**	
	Quiescent, Not Charging	Quiescent, Charging	Transmit	Test	Min	Max
Discharge Circuit	0	0	0	104	-20	100
C&DH	0.5	0.5	0.5	0.5	-20	85
Boost	0.0	0.5	0.5	0.5	-20	85
BMS	0.6	0.6	0.6	2	-20	85
Batteries	0.2	0.2	2	2	0	40
Radio	0.1	0.1	10	0	-20	80
Total	**1.4**	**1.9**	**13**	**109**		

3-U Surface Area Constraint

- Power Generation Capability
  - 0.03 m^2, 28% efficient UTJ cells, 70% Packing Density
  - ~7 - 10 W power generation without active attitude control
- Thermal Radiation Emissive Power
  - Assuming .12 m^2, ε=.9, *Steady State* Surface Temp 85 C to maintain high power electronics below temperature limits, Average Sink Temperature of 225 K
  - 84 W of emissive power if entire 3-U CubeSat area is a radiator
- Concluded that power and thermal management needs for 3-U CubeSat require thermal and energy storage solutions

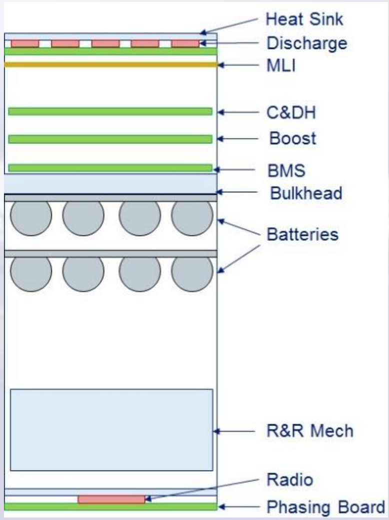
Power Management and Distribution

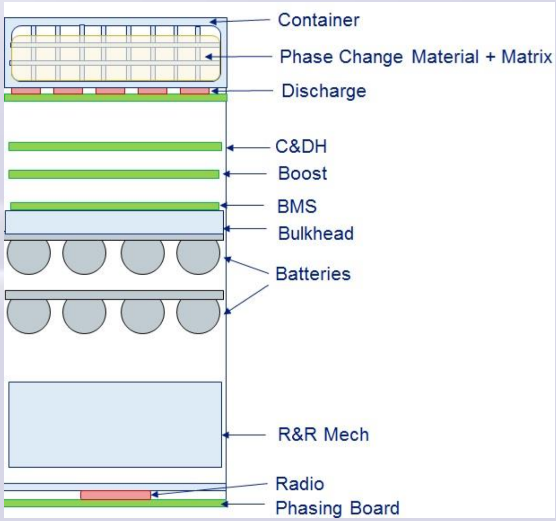


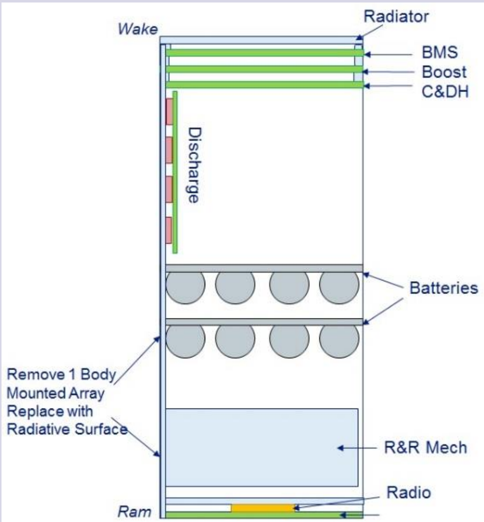
- 4 Body Mounted + 4 Deployable Arrays (COTS)
  - 7S, 2P configuration
  - 10 W generation
- Super elastic Shape Memory Alloy (SMA) hinges provide deployment spring force and power transfer
- Activated SMA resettable retention and release mechanism
- Boost Convertor Battery Charging System
- 80 W-hr COTS Battery Pack
  - 14.4 V, 7 A
  - Discharged at 1.25 C
- Cell balancing battery management system
- Regulated discharge system
  - 95% efficiency

Thermal Management

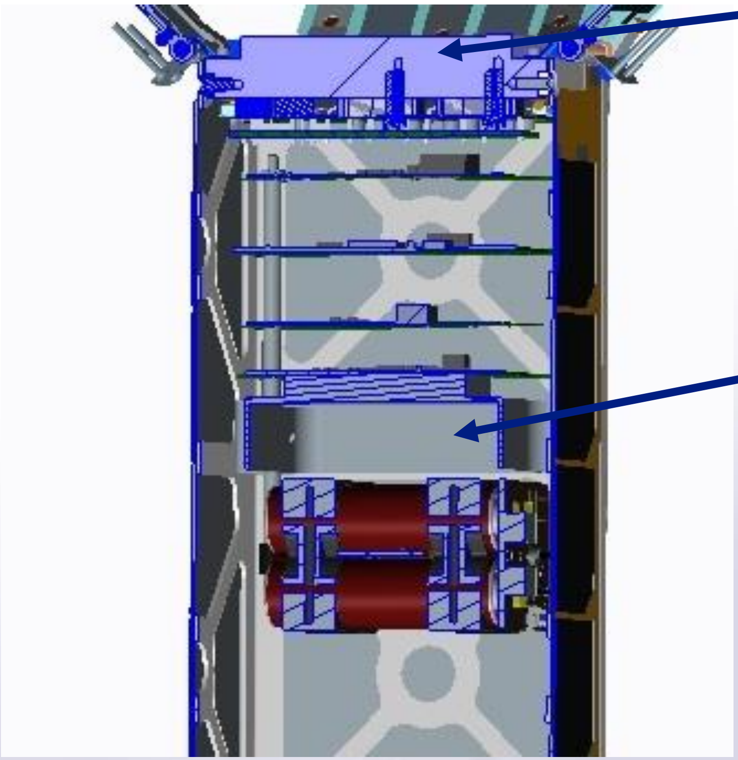
- Store thermal energy from 100 W discharge
  - 100 W electrical power → 100 W of heat is unique to this mission
  - Isolate from the rest of the system as much as possible
- Use body area of CubeSat to reject electronics waste heat and generate power
  - Body mounted solar arrays decrease effective emissive power but adequate to reject electronics waste heat
  - Demonstrate that 3-U CubeSat is capable of managing heat loads from power management and control electronics without additional design
- Options considered





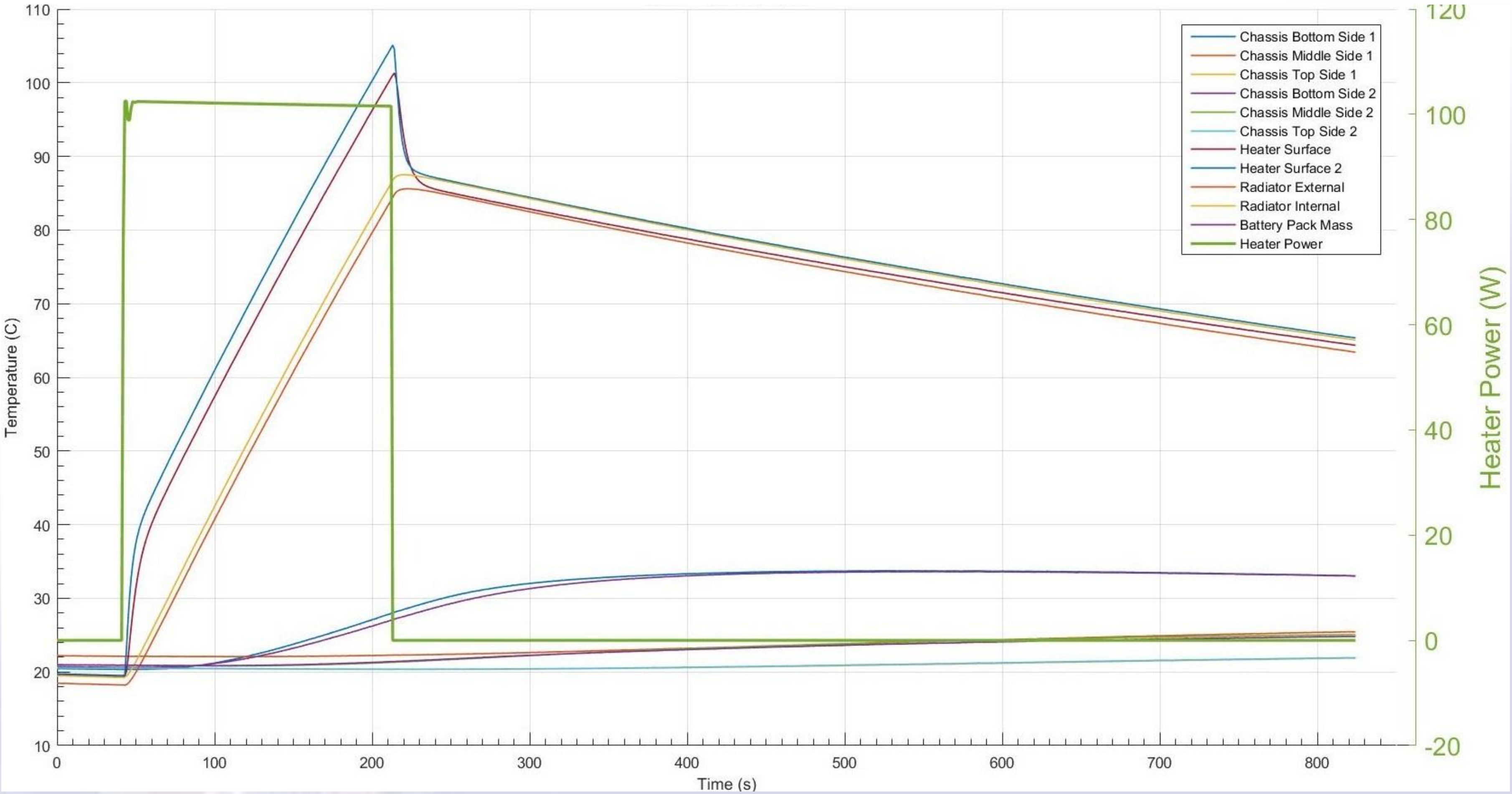


Thermal Management Solution



- 100 W Discharge Circuit
  - 350 g Aluminum Heat Sink
  - Silver Coated Teflon surface finish
  - Isolated from chassis with polymers
- PMAD and C&DH waste heat
  - Bulkhead with conductive path to chassis for electronics with high heat loads
  - Thermally conductive, electrically isolating interface between chassis and body mounted solar arrays
  - Arrays reject heat
- Radio – high emissivity coating to reject heat during peak uplink/downlink transients

Thermal Vacuum Development Test Results

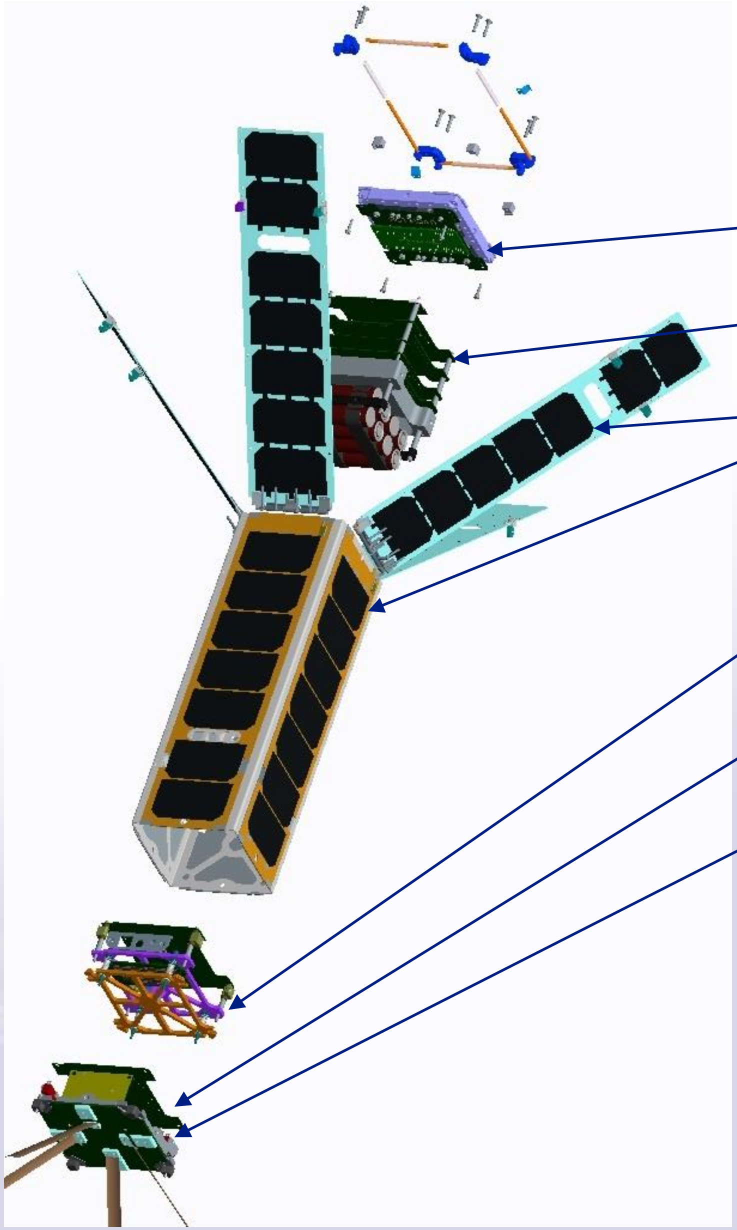


- 350 g heat sink provides ~3 minutes of run time with 100 W distribution at 20 C initial condition

Mass and Volume

	Concepts	*Preliminary Designs*	*Final Designs*
Deployment Mechanism	Push Plate ~30% Internal Volume 15% System Mass	Collet ~30% Internal Volume 15% System Mass	Pin Puller ~20% Internal Volume 5% system mass
100 W Thermal Management	PCM Heat Sink 40 min run time ~30% Internal Volume >30% system mass	Heat Sink 10 min run time 16% Internal Volume 12% system mass	Heat Sink 4 min run time 9% Internal Volume 9% System Mass
Power Generation	Body and Deployable Arrays 14 W 28% system mass	Body and Deployable Arrays 14 W 28% system mass	Body and Deployable Arrays 10 W 16% system mass
Storage	80 W-hr COTS pack 12% system mass	80 W-hr COTS pack 12% system mass	80 W-hr COTS pack 12% system mass

Packaging



	Mass (g)	Internal Volume (cm³)
'Payload'	500	300
PMAD + Battery Packs	800	1000
Solar Arrays	800	n/a
Chassis (COTS)	200	n/a
Retention and Release Mechanisms	210	500
Harnesses and Cables	220	TBD
Radio/Antenna (COTS)	440	400
Secondary Structures	250	n/a
Passive Attitude Control	200	n/a
C&DH	80	200
Total	3500	1500

Conclusions

- High Power (100 W) systems are possible in a 3-U CubeSat with some limitations on operations
  - Peak heat loads can be handled transiently
  - Steady state operation would require deployable surfaces or larger form factor for both power generation and thermal management
- Resettable and robust deployment mechanisms are feasible
  - Challenge to minimize internal volume for ALBus mission specific application
- Dual purpose shape memory alloy hinges for reliable deployment and power transmission are feasible and provide clean integration
- Packaging with margin on mass and volume for other subsystems and/or payloads