High Strain Composite Deployable Booms for Cubesats

13th Annual Cubesat Developers' Workshop,
April 22nd, 2016

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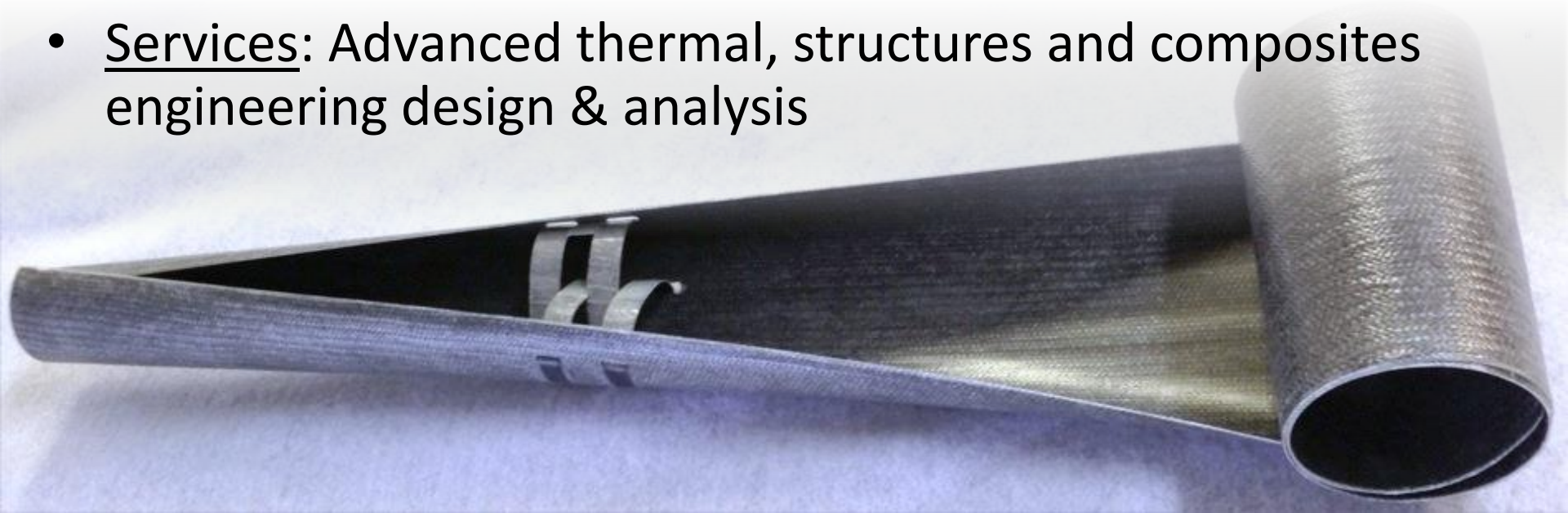
ROCCOR Mission & Approach

Mission

- Reduce space asset cost with enabling and elegant satellite systems

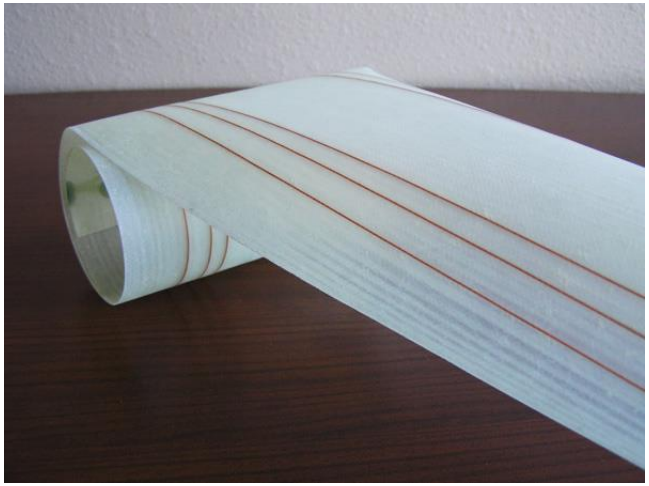
Approach:

- Products: Incorporate low-cost emerging technologies
  - High Strain Composites (HSC) deployables
  - Two-Phase Thermal Management
- Services: Advanced thermal, structures and composites engineering design & analysis

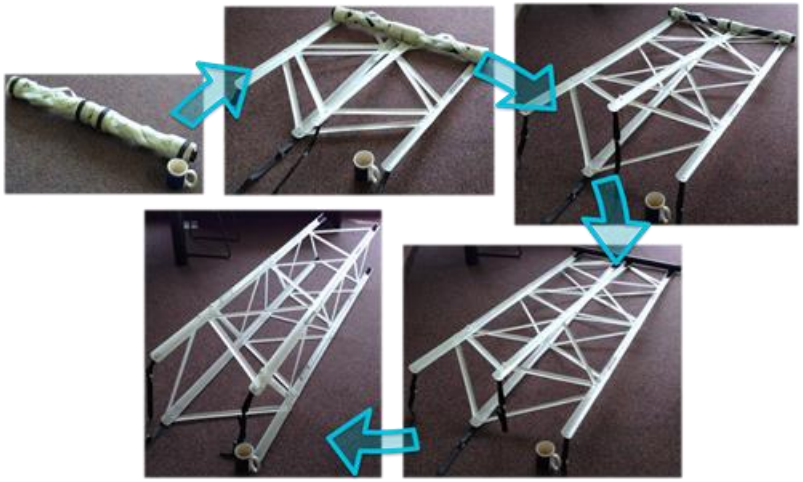


Example HSC Technologies

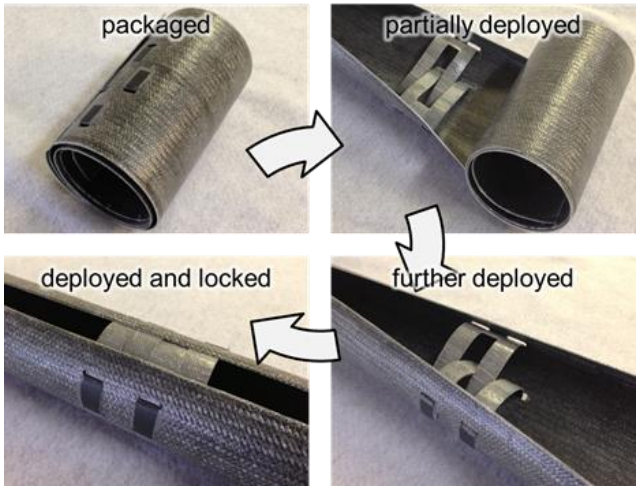
Composite Slit-tube booms



Embedded Conductors



Roll-out Composite Truss



Seam-Lock, (enhanced shear rigidity)

Defining High-Strain Composites

Wikipedia Page Created by Roccor

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High Strain Composite Structures

From Wikipedia, the free encyclopedia

High Strain Composite Structures (HSC Structures) are a class of composite material structures designed to perform in a high deformation setting. High strain composite structures transition from one shape to another upon the application of external forces. A single HSC Structure component is designed to transition between at least two, but often more, dramatically different shapes. At least one of the shapes is designed to function as a structure which can support external loads.

High strain composite structures usually consist of fiber-reinforced polymers (FRP), which are designed to undergo relatively high material strain levels under the course of normal operating conditions in comparison to most FRP structural applications. FRP materials are anisotropic and highly tailor-able which allows for unique effects upon deformation. As a result, many HSC Structures are configured to possess one or more stable states (shapes at which the structure will remain without external constraints) which are tuned for a particular application. HSC Structures with multiple stable states can also be classified as bi-stable structures.

Contents [hide]

HSC Structures are most often used in applications where low weight structures are desired that can also be stowed in a small volume. Flexible composite structures are used within the aerospace industry for deployable mechanisms such antennas or solar arrays on spacecraft. Other applications focus on materials or structures in which multiple stable configurations are required.

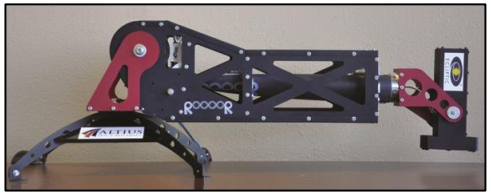
Example of a High Strain Composite Structure wherein the primary structural members are highly deflected fiber reinforced polymer rods. Here the structure is shown partly deployed with the rigid structural shape on the bottom and the coiled stowed shape on the top.

AIAA HSC Technical Subcommittee

- Created Jan 2014
- Chair: Bruce Davis (Roccor)
- Co-Chairs: Tom Murphey (Roccor), Juan Mejia-Ariza (JPL)
- High Profile Members:
  - Sergio Pellegrino (CalTech)
  - Jeremy Banik (AFRL)
  - (Deployable Space Systems)
  - (LoadPath)
- Subcommittee objective:
  - Elevate the profile of high strain composites as an enabler for high performance and low cost deployable structures
  - Standardized requirements and design approaches

Example Slit-Tube Deployers

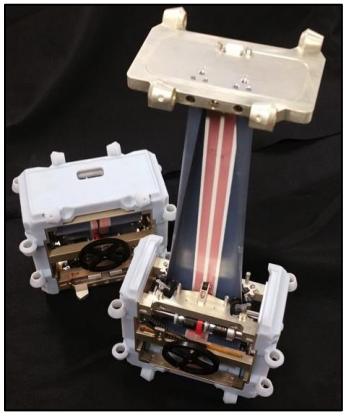
Roccor's Slit-Tube Deployer Family



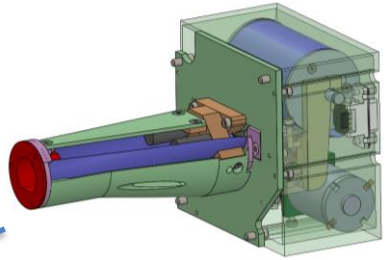
Camera Boom

Compaction Ratio	Precision & Stability	Lateral Stiffness	Axial Loading	Electrical Transmission	Low Cost	Embedded Inserts	Retractability
✓	✓	✓		✓	✓✓	✓	✓
✓✓	✓	✓✓	✓		✓✓✓		✓
✓✓	✓✓	✓✓		✓✓✓	✓	✓✓	✓✓
✓✓✓	✓✓	✓	✓✓		✓✓	✓✓	✓✓✓

Microsat Boom



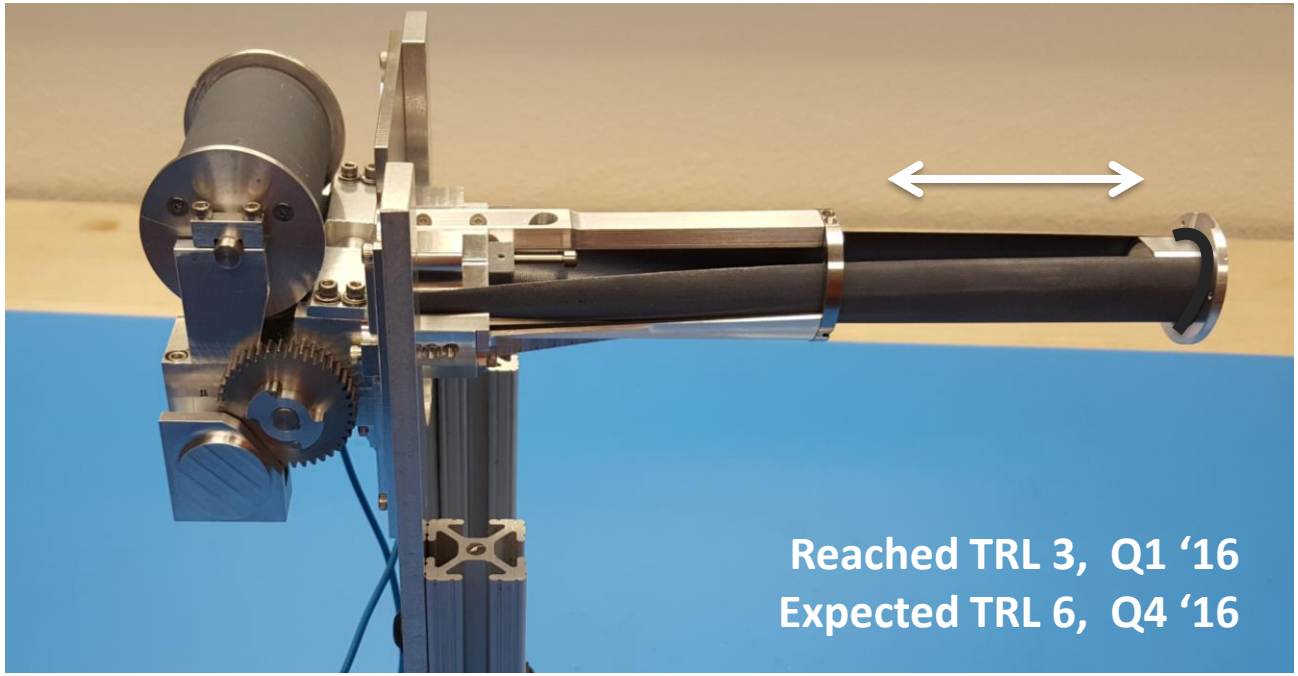
NovaWurks HIMast
(DARPA Phoenix)



1.5U Cubesat Boom
(NASA Magnetometer)

CubeSat Boom Deployer

NASA Magnetometer Boom



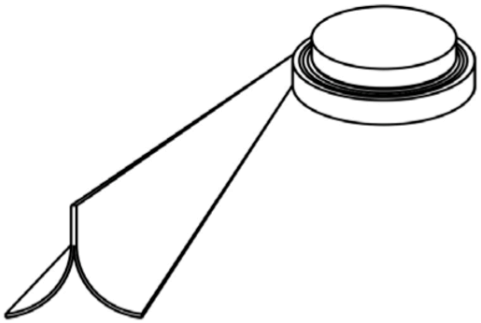
- **Volume: 1×1×1.5U**
- **Length: Up to 1.5m**
- **Mass: <1kg**
- **Low CTE Laminate**
- **Motor Driven**
- **Low Power Draw**
- **Magnetically Characterized**
- **Retractable**

Deployed Performance:

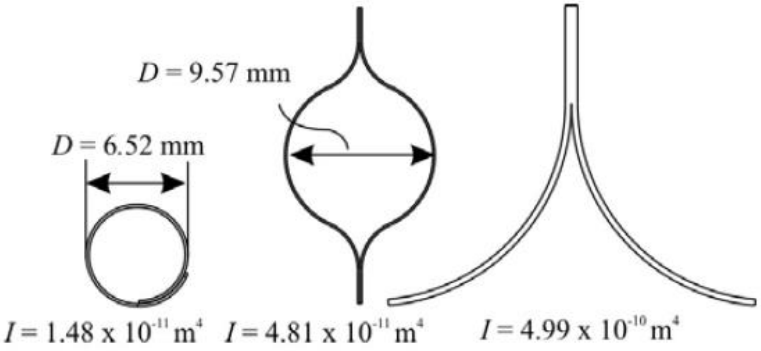
	Stiffness @1m	Strength @1m	Precision
Axial	> 8000 lb/in	90 lb	+/- 0.002 in
Lateral	> 2 lb/in	> 0.5 lb	+/- 0.050 in

Emerging Product: TRAC Boom™

Metallic TRAC Booms Flown:
LightSail 2015 & NanoSail D 2010



Flattened width comparable booms, TRAC boom has



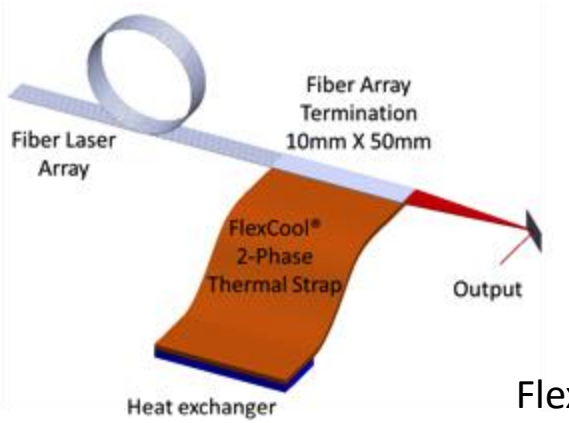
Roccor-manufactured TRAC Booms

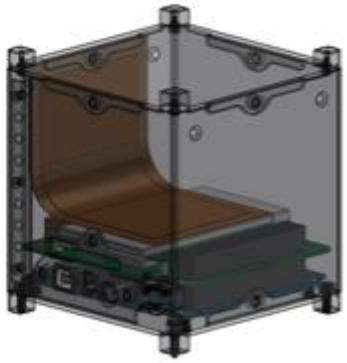
Roccor is developing composite TRAC booms for cubesat applications

Partnering with NASA & AFRL

Two-Phase Flow Products

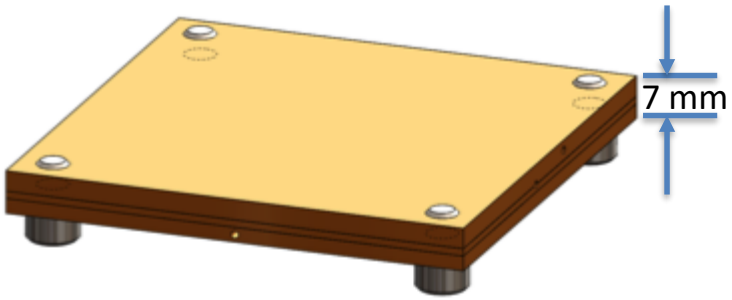
FlexCool™ Thermal Straps





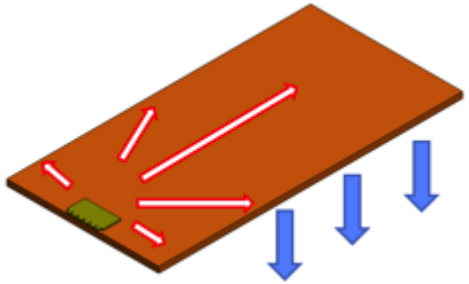
FlexCool™ for CubeSats

SmartCool™ Cold Plates



Active cold plate for high heat flux applications

FlatCool™ Heat Spreaders

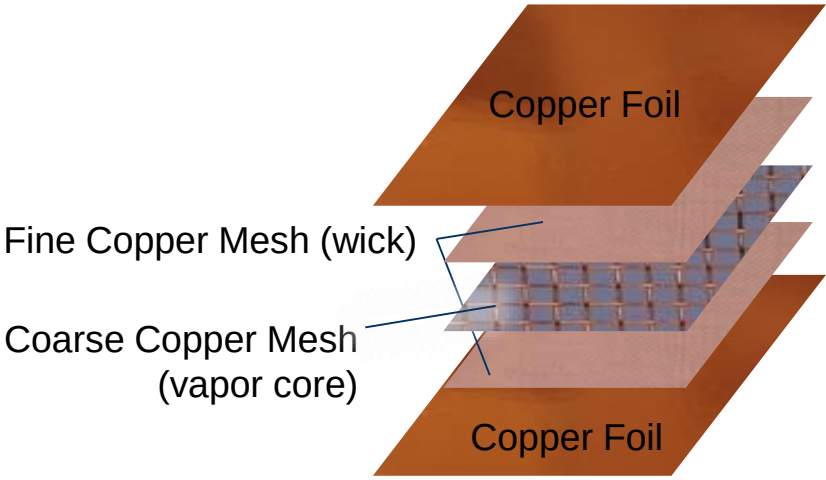


FlatCool™ for Laser Diodes and LEDs

Two-Phase Product Portfolio

Enabling technologies:

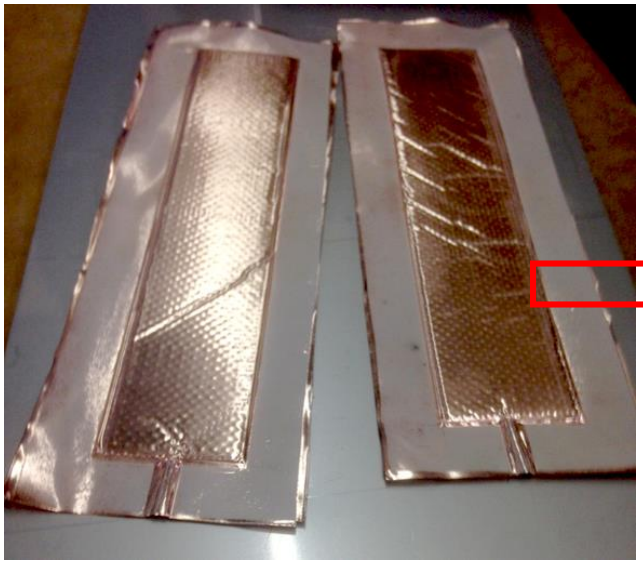
- Commercial-off-the-shelf materials
- Different fluids for matching operating temperatures
- Advanced thermal analysis capabilities
- Scalable manufacturing methods
- Surface treatments for improved wicking and boiling



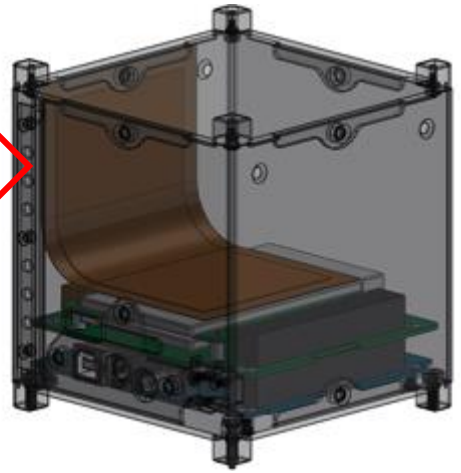
Product	Architecture	Evaporator Heat Flux	Length	Rigidity	Active / Passive
FlexCool	Heat Straps	<10 W/cm^2	High	Conformable	Passive
FlatCool	Heat Spreader	>100 W/cm^2	Low	Rigid	Passive
SmartCool	Cold Plate	>100 W/cm^2	High	Rigid	Active

FlexCool™ Heat Strap

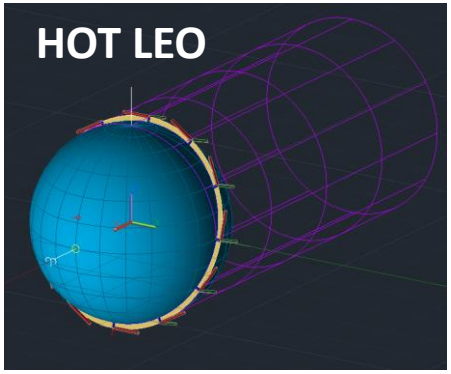
- Thin, conformable heat strap
- Total thickness: < 1 mm
- Thermal conductivity: 3-5 times of copper
- Total mass: < half of copper equivalent
- Internal pressure carrying capability: > 135 psi
- Maximum length: ~30cm



Schematic of FlexCool™ Integrated into CubeSat



Orbital Thermal Environments



$\beta = 72°$

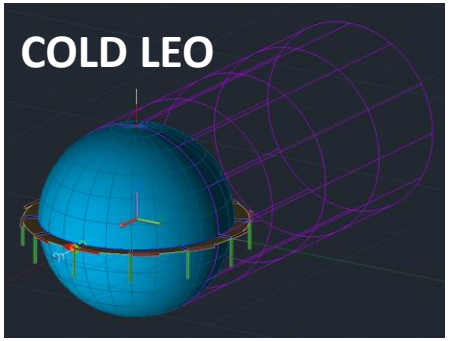
h = 350 km

$\rho_o = 0.35$

$T_{earth} = 300K$

$T_{space} = 4K$

$\tau_{orbit} = 1.52$ h



$\beta = 0°$

h = 1000 km

$\rho_o = 0.1$

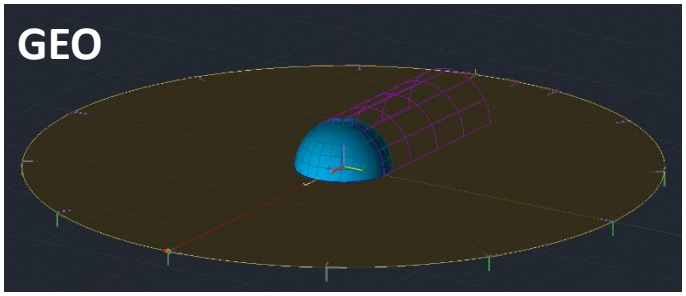
$T_{earth} = 250$ K

$T_{space} = 4$ K

$\tau_{orbit} = 1.75$ h

DEEP SPACE

$T_{space} = 4$ K



$\beta = 0°$

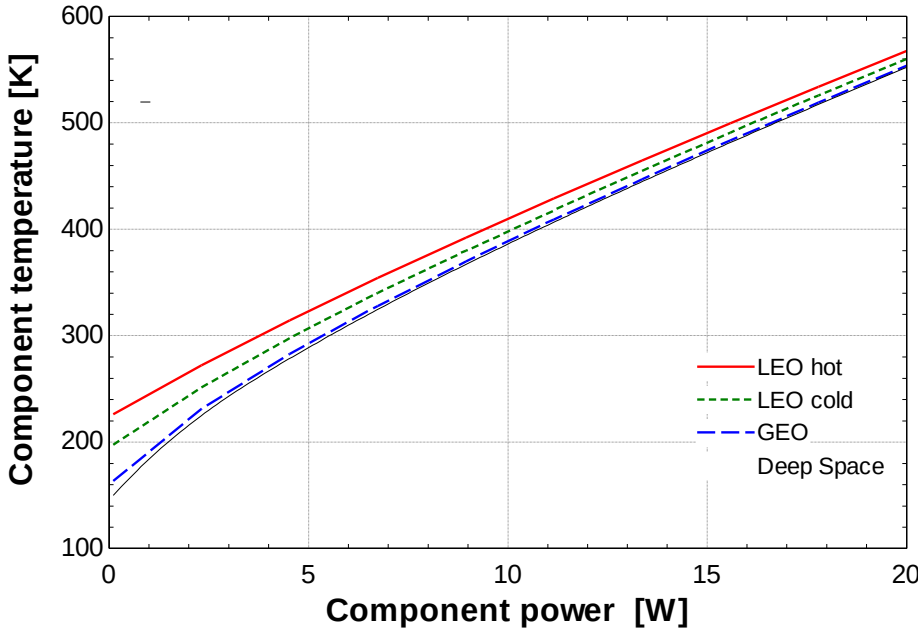
h = 35,786 km

$\rho_o = 0.1$

$T_{earth} = 250$ K

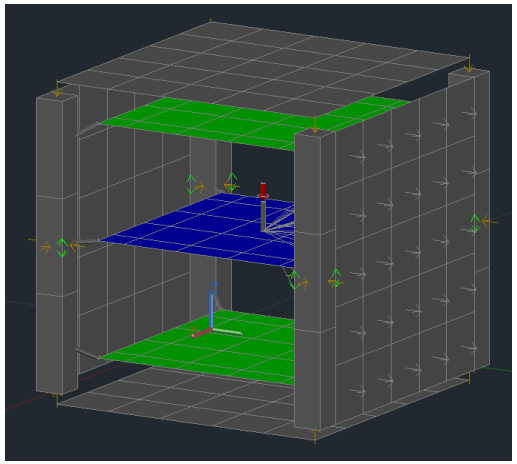
$T_{space} = 4$ K

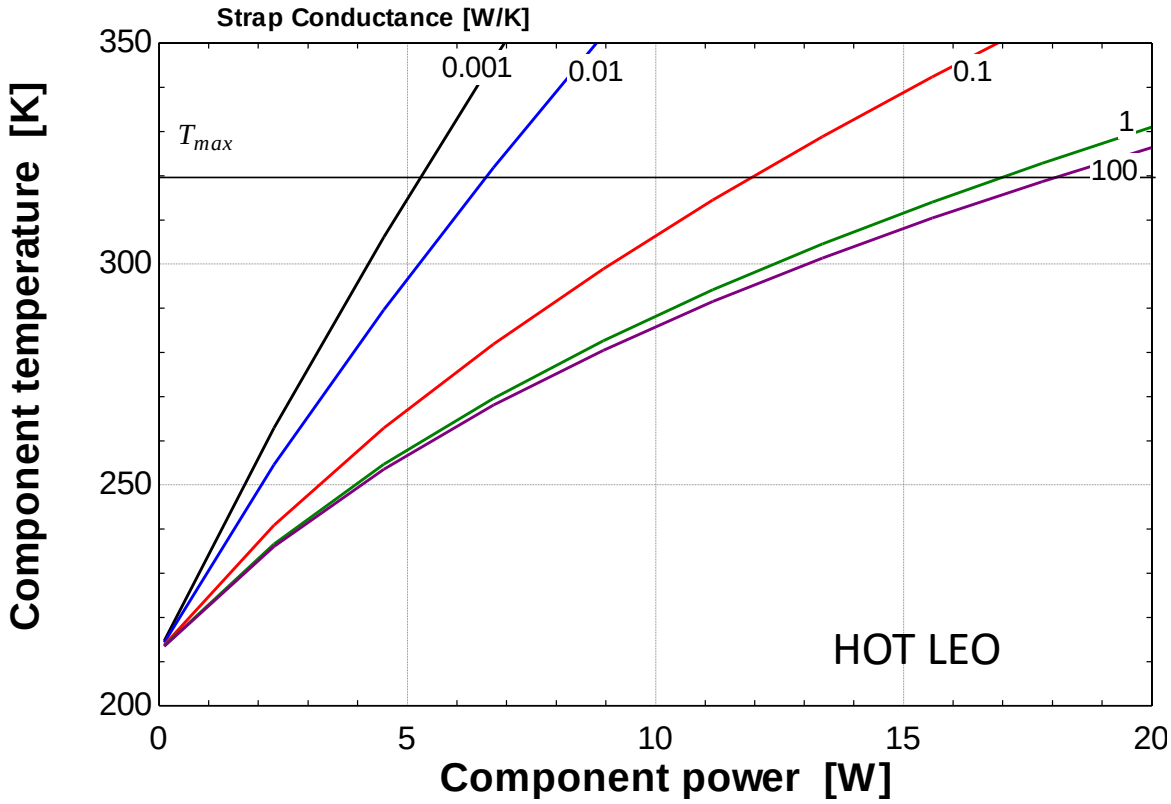
$\tau_{orbit} = 24$ h



Hengeveld, D., 2009, Hot- and Cold-Case Orbits for Robust Thermal Control, *J. Spacecrafts and Rockets*

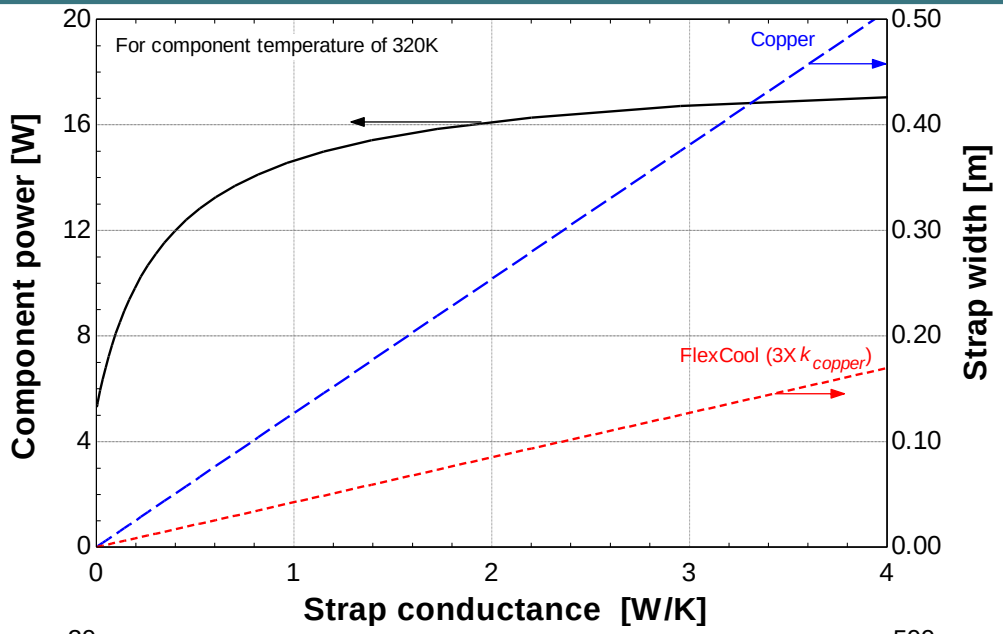
Thermal Model

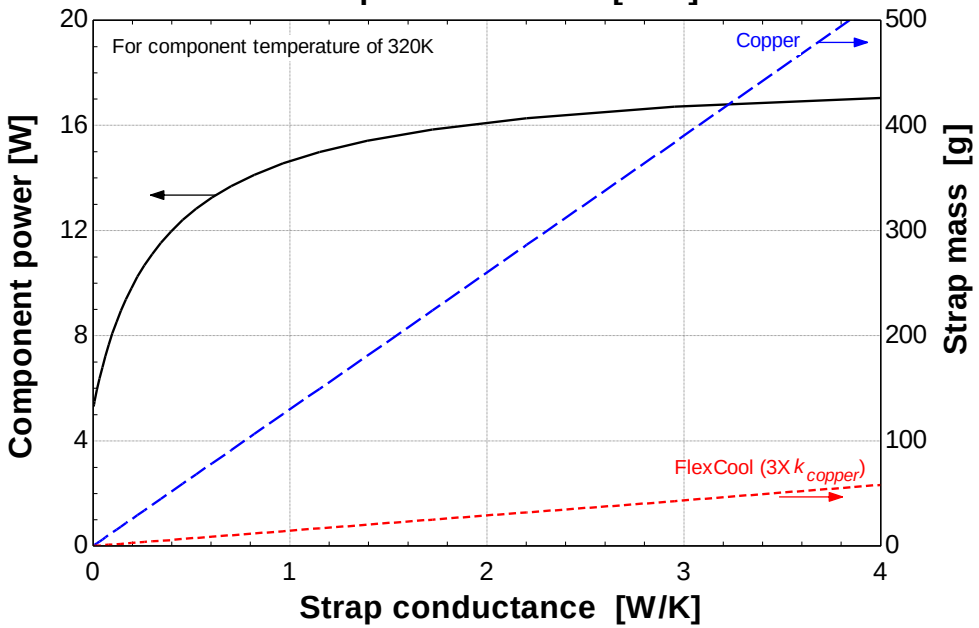




- Design chart for hot-bounding case:
  - Dependent on environment (orbital conditions) and overall geometry (board and radiator)
  - **Any component above 5W would overheat without thermal strap**

Benefits





FlexCool™ saves 66% in volume and 90% in weight of equivalent copper strap

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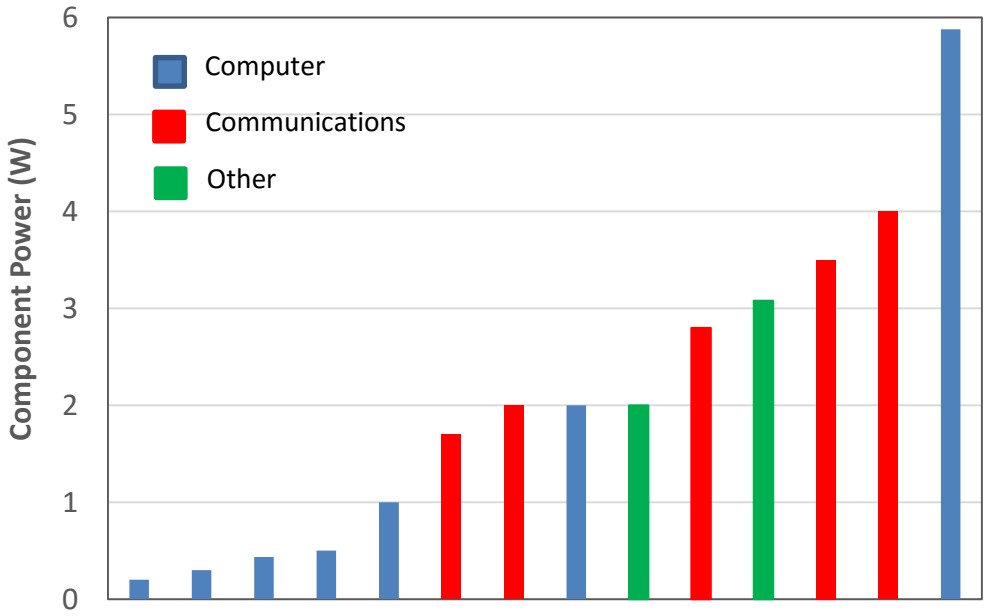
Backup - Survey of CubeSat components

- Off-the-shelf components have reached 5W of power dissipation
- Candidate components include flight computers, communication equipment and power controllers



Based on Cybesatshop.com, Tyvak.com, Andrews Space

MicroSat Boom