# Advanced Electrical Bus (ALBus) CubeSat Technology Demonstration Mission

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David Avanesian, EPS Lead
Tyler Burba, Software Lead

# Outline

- Introduction
- Systems Engineering
- Electrical Power System
- SMA Technology
- Future Work
- Questions

# INTRODUCTION

# Introduction

- Initiated as a developmental opportunity
  - 11 early career employees
  - Emphasize hands-on flight project experience and flight hardware development
    - Scope project appropriately to allow hands-on development of flight hardware
    - Document lessons learned
- Stakeholder Requirements
  - Provide flight project and flight hardware development
  - Work towards a Ship Sat Demonstration mission
- Started Pre-Phase A work in Aug/Sept 2013
  - Informally surveyed GRC community for interest in flying CubeSat missions
  - Compiled potential mission and payload concepts and high level needs
- Address CubeSat capability needs required for advanced payload/mission concepts, including ShipSat
  - Phased approach to address capability needs in a series of developmental flights
  - First flight demonstration of power management capability

# Project Needs, Goals and Objectives

**Needs Statement(s)**

1. **Early career employees in technical fields need an opportunity for a hands-on flight project experience.**
2. **CubeSats need an advanced power system capability with standardized interfaces and regulated bus voltage in order to reduce development time and costs by reducing the need to design payload/mission specific power systems.**

| Goals | Objectives |
|---|---|
| **Maximize hands-on flight hardware development and integration.** | Use COTS parts for component level only. Team members perform all subsystem and system level design, integration and test. |
| **Develop a standardized electrical power system to meet CubeSat payload/mission needs.** | Provide an EPS with standard, simplified interfaces to CubeSat payloads and subsystems. |
| | Develop an EPS that fits in 1 U volume. |
| **Advance the state of CubeSat power management capability.** | Provide a 100 W capable power management system. |
| | Demonstrate regulated high power bus. |
| | On-orbit demonstration of technologies required for a 100 W system. |
| **Utilize NASA GRC core competency expertise and technologies.** | Demonstrate deployable solar array mechanisms utilizing GRC shape memory alloy (SMA) materials. |

# SYSTEMS ENGINEERING

# Requirements

- Requirements obtained from several sources:
  - Self-generated (from project needs, goals, and objectives)
  - NASA launch service providers (LSP) per CubeSat Launch Initiative (CSLI)
  - Cubesat deployers:
    - P-POD (as launch vehicle secondary payload)
    - Nanoracks (from ISS)
  - In case of requirement overlap, more stringent req't adopted to maximize launch opportunities and mission flexibility
- 61 total top level requirements identified
  - Additional requirements for small payloads and battery safety aboard ISS for Nanoracks deployment opportunity
  - Two TBXs remain, both related to EPS capability

# Key Performance Parameters

| Title | Requirement |
|---|---|
| Power Output | System shall provide no less than 100W power to a target load for no less than TBD minutes |
| EPS Efficiency | Power system efficiency shall be no less than 85% |
| Voltage Regulation | The EPS shall regulate voltage to ±1% of the nominal main bus voltage output |
| EPS Volume | The EPS shall not exceed a volume of 1U (10x10x10cm) |
| Mass | Each triple (3U) CubeSat shall not exceed 4.0 kg mass |

- Design expected to meet all key performance parameters

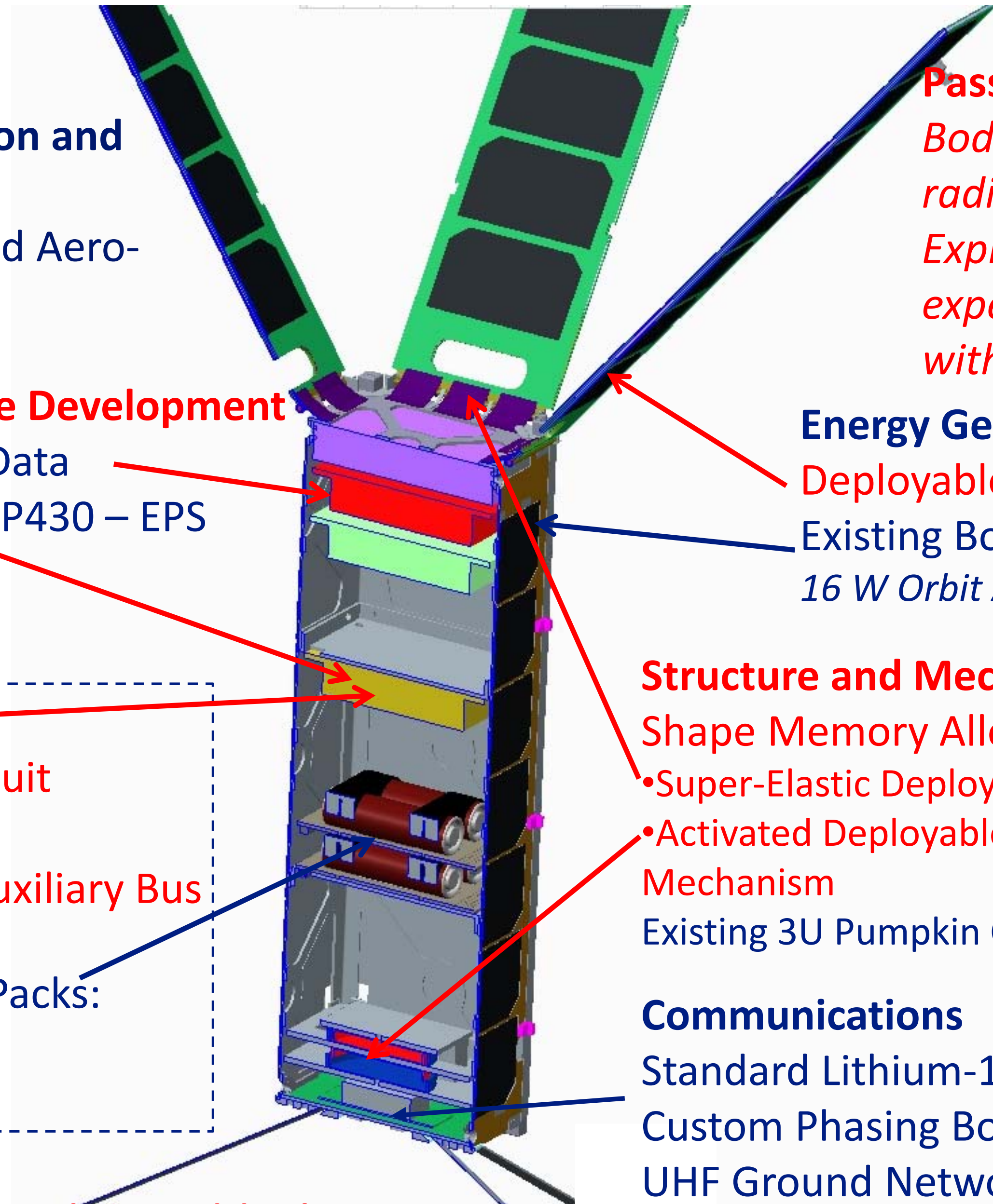
# System Definition

**Attitude Determination and Control**
Velocity Vector Aligned Aero-stabilization

**Avionics and Software Development**
Edison uController – Data
Texas Instruments MSP430 – EPS
Tasking and Control

1-U Volume

**PMAD**
Battery Charging Circuit
14.8 V, 6.8 A Bus
3.3V, 5V and 10 W Auxiliary Bus
**Energy Storage**
GOM Space Battery Packs:
80 W-hr
ISS Qualified



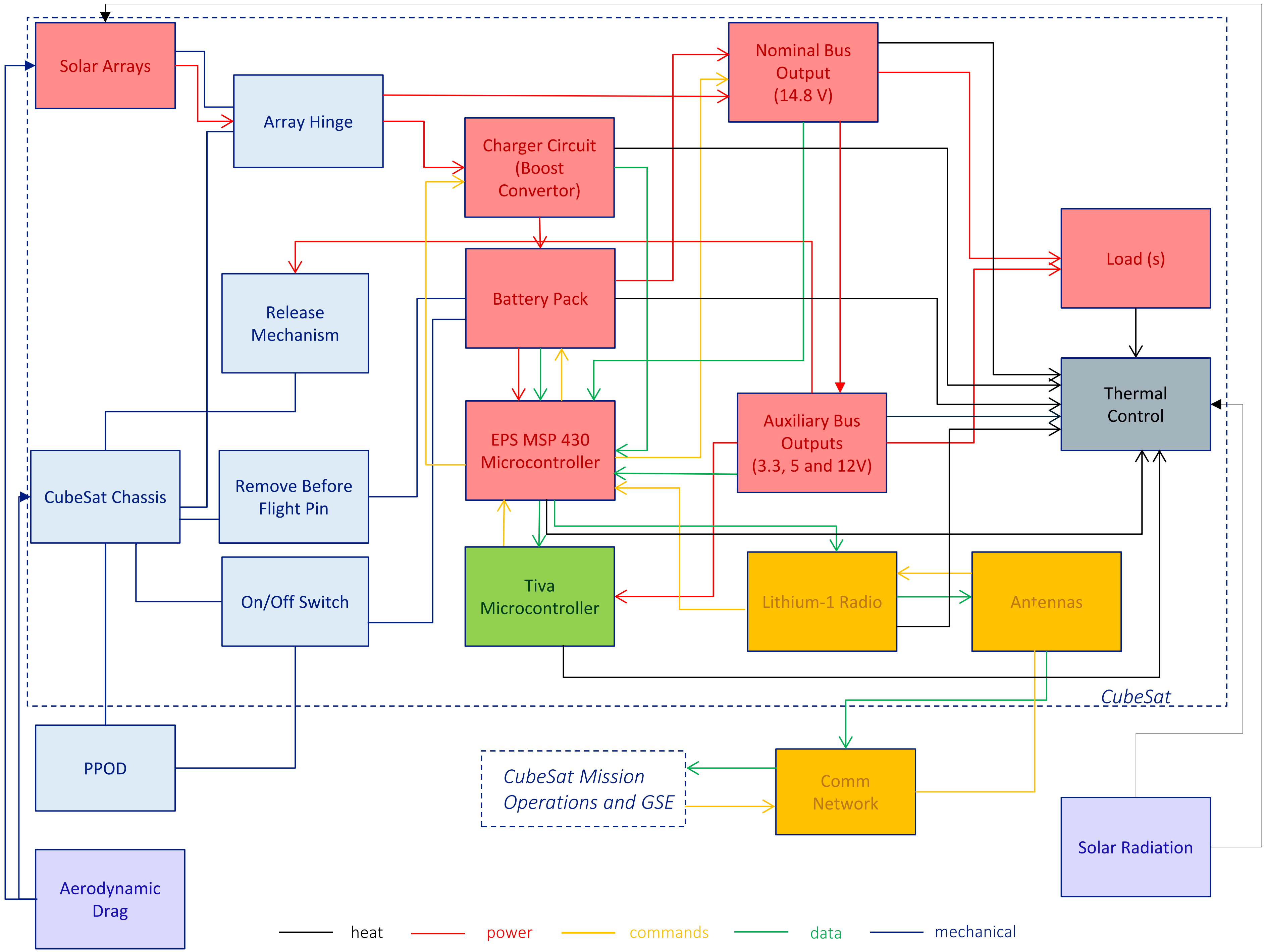
**Passive Thermal Control**
*Body Mounted Arrays – radiative surface*
*Exploring dedicated experimental radiator with YSU*

**Energy Generation**
Deployable Solar Arrays
Existing Body Mounted Arrays
*16 W Orbit Avg Generation*

**Structure and Mechanisms**
Shape Memory Alloy Mechanisms
•Super-Elastic Deployable Array Hinge
•Activated Deployable Array Release Mechanism
Existing 3U Pumpkin Chassis

**Communications**
Standard Lithium-1 UHF Radio
Custom Phasing Board and Antennas
UHF Ground Network

***Red text indicates in-house GRC design and development***

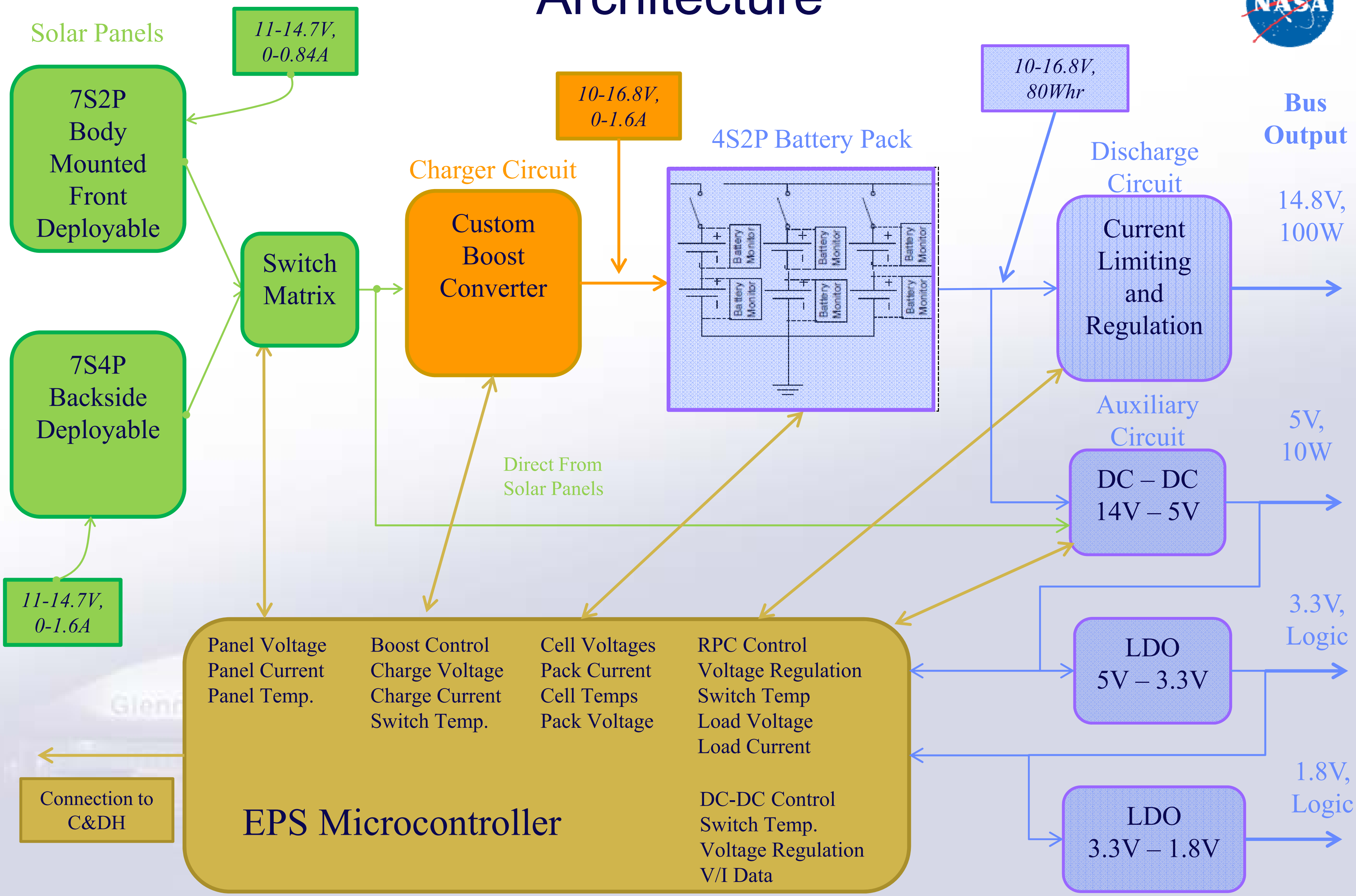

Solar Arrays
Array Hinge
Nominal Bus Output (14.8 V)
Charger Circuit (Boost Convertor)
Load (s)
Release Mechanism
Battery Pack
Thermal Control
EPS MSP 430 Microcontroller
Auxiliary Bus Outputs (3.3, 5 and 12V)
CubeSat Chassis
Remove Before Flight Pin
On/Off Switch
Tiva Microcontroller
Lithium-1 Radio
Antennas
CubeSat
PPOD
CubeSat Mission Operations and GSE
Comm Network
Solar Radiation
Aerodynamic Drag
heat
power
commands
data
mechanical

# 5.1 ELECTRICAL POWER SYSTEM

# Requirements

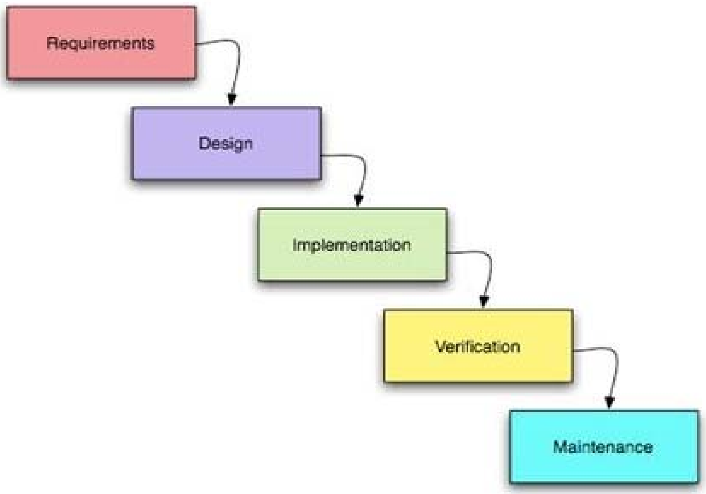
- System shall provide no less than 100W power to a target load for no less than TBD minutes.
- System shall have TBD ms/us transient performance with 100W continuous power output
- Power system efficiency shall be no less than 85%.
- System shall have a regulated main bus voltage of 14.8 V nominal.
- EPS shall regulate voltage to 1% of nominal main bus voltage output
- Main EPS shall be able to fit in 1U volume or less.
- EPS shall provide multiple auxiliary power busses (3.3V, 5V, 10W)
- Battery Temperature Range:
  - Charge: -5C to 45C
  - Discharge: -20C to 70C

# Architecture



National Aeronautics and Space Administration

# PMAD: Analysis/Development Plan

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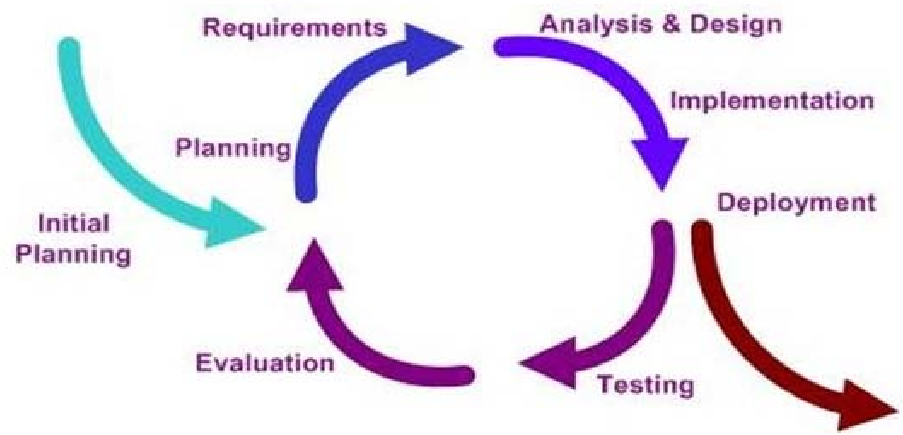
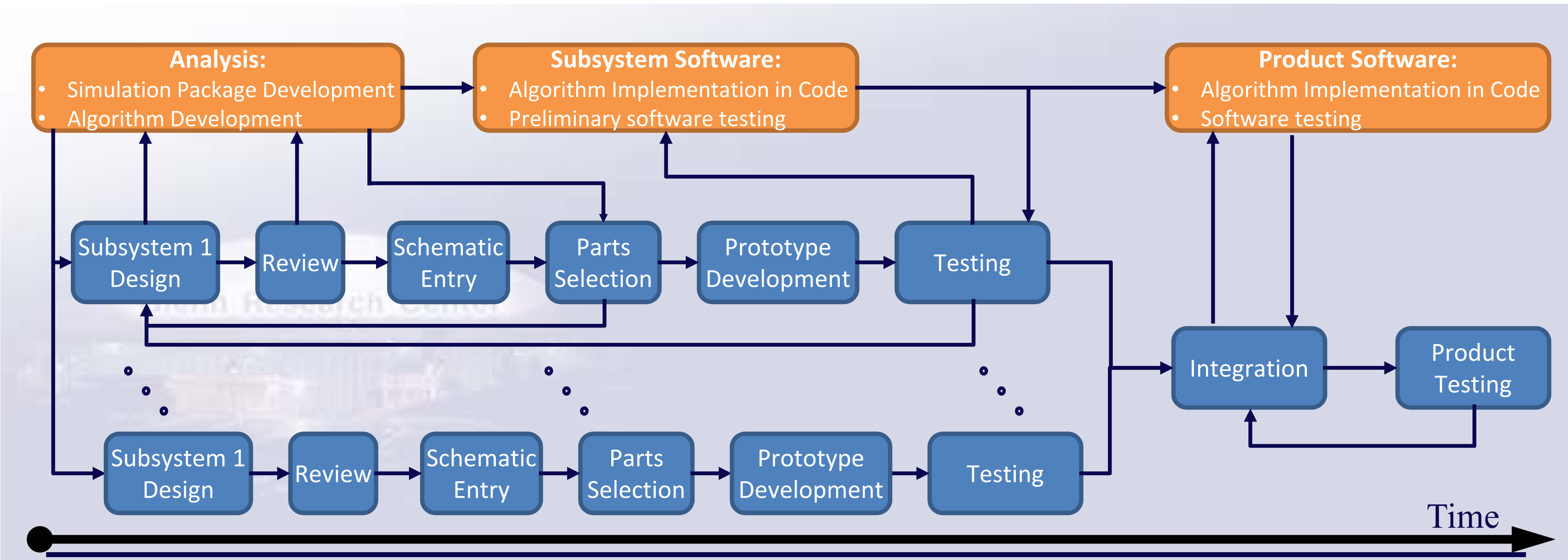
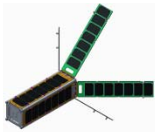


# 5.2 STRUCTURES AND MECHANISMS - SMA



# Technology Infusion - *Shape Memory Alloys*

- SIZE: Need for smaller, compact and cost effective mechanisms for deployment of solar arrays
- FUNCTIONS: Load capability, multifunctional use of mechanisms (hinging and structure support)
- MISSION SAFETY: Repeatable, and reproducible deployment, clean and debris-less

- As part of the CubeSat project, we are designing and developing new mechanisms based on SMAs that have added benefits than currently used technologies.

- Current methods:
  - Nichrome burn wire mechanism (Adam Thurn NRL) for deployment. This is a one time use and can't be ground tested (also a source of failure).
  - Conventional metallic spring hinge mechanism

# Mechanisms Design Overview - Hinge

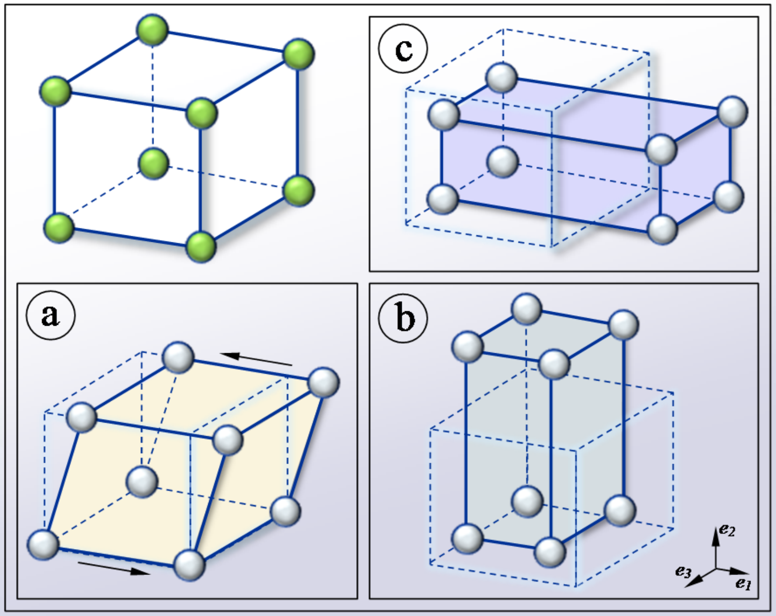
## Features

1. Utilizes Glenn Shape Memory Alloy (SMA) in a new application to advance technology
2. Three SMAs replace torsion springs, redundant so if one fails the other one can deploy the arrays (1-2 in-lbs moment each)
3. Hinge pin and hinge have dual rotating surfaces (pin can rotate and hinge can rotate).
4. SMAs transmit power from the solar arrays to the chassis eliminating a wiring harness.
5. Hard stop on hinge bracket keep the arrays at the desired deployment angle.
6. Two locking detent mechanisms per solar array for redundancy.

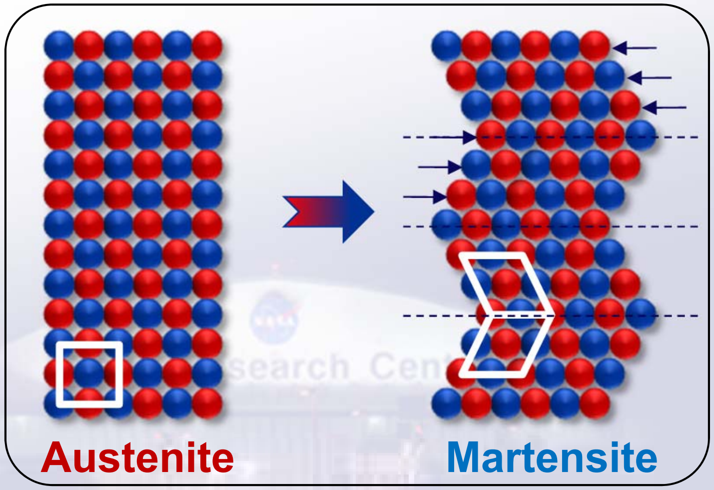
# Shape Memory Alloys (SMAs)

- **Shape memory alloys (SMAs) exhibit a solid-to-solid, reversible phase transformation**
- **Can accommodate large strains (e.g., 8% strain)**
- **Shape change can generate stresses (up to 500 MPa)**

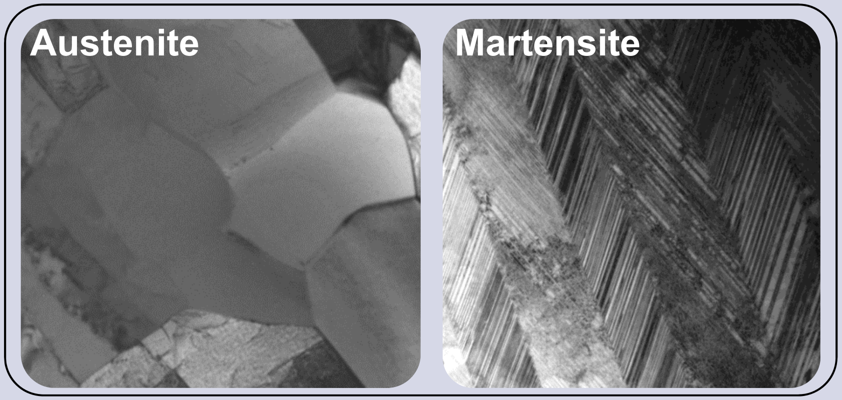
## Variant selection




## Simplified 2D




## Microstructure

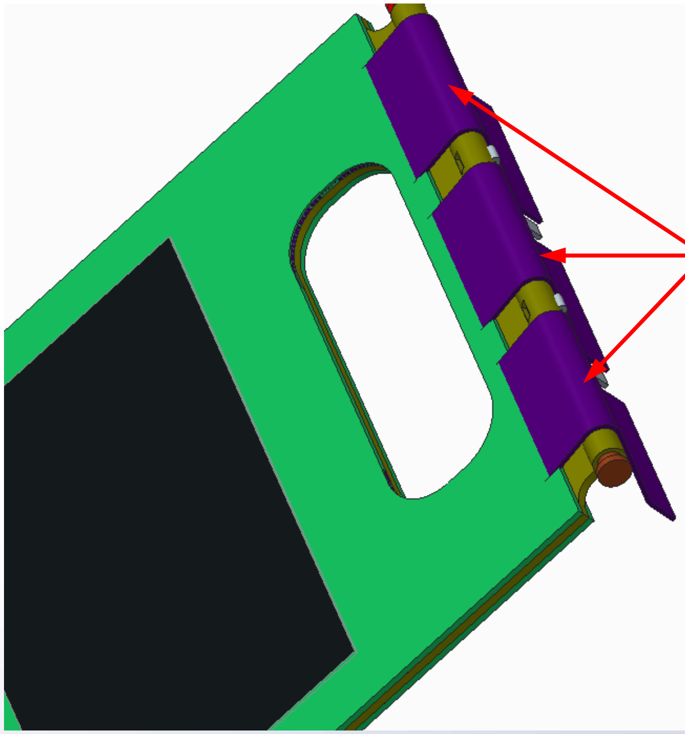



Courtesy of A. Garg

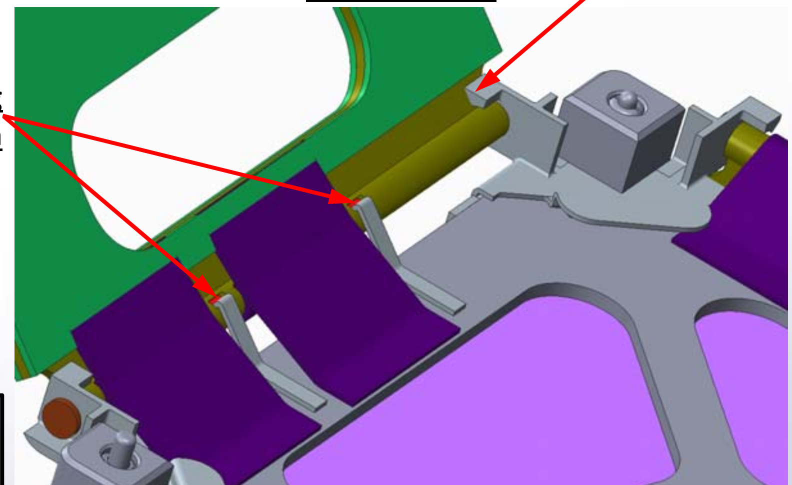
➢ **How?**
1. **Bain strain → (lattice deformation)**
2. **Lattice invariant shear → (accommodation)**

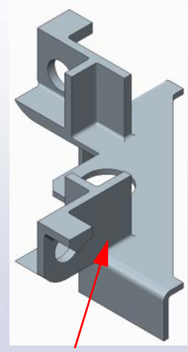
# Mechanisms Design Overview - Hinge

**Stowed**

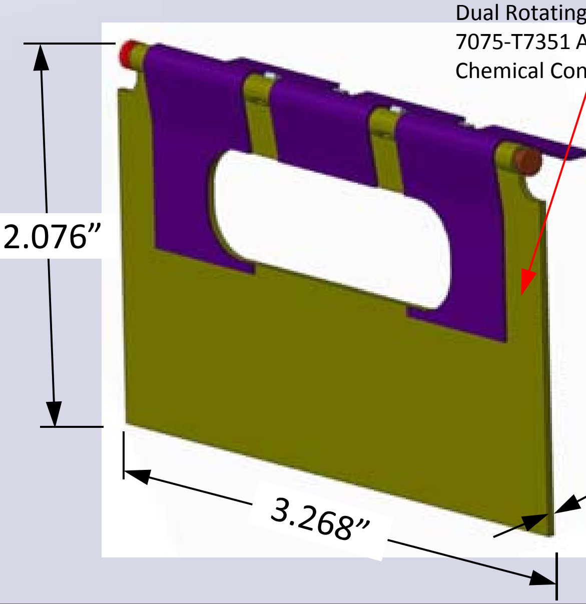


**Deployed**



**Hinge Bracket**
7075-T7351 AL
Chemical Conversion Coat

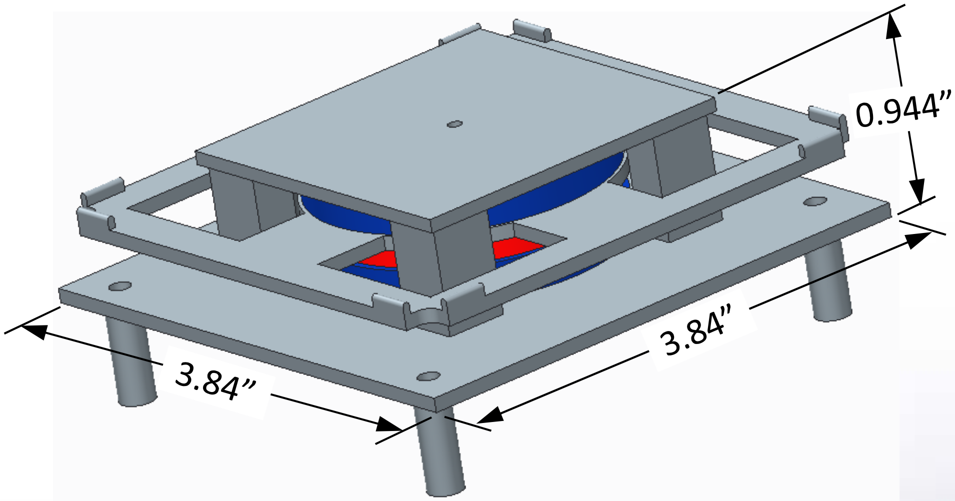


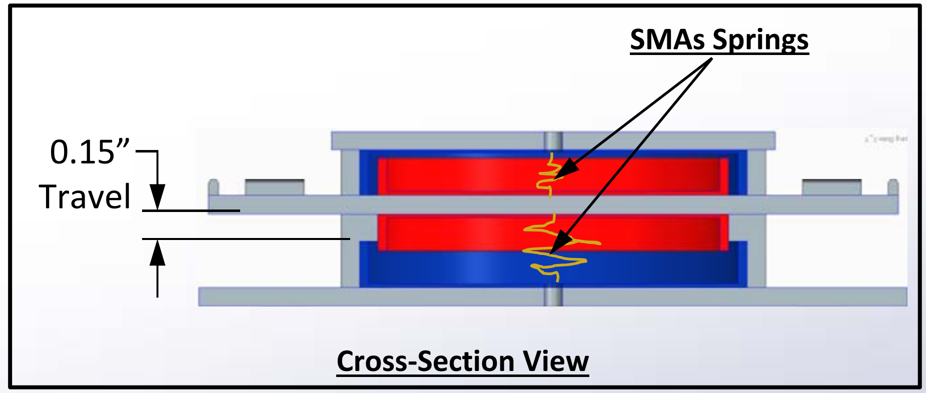

**Hinge**
Dual Rotating Surfaces
7075-T7351 AL
Chemical Conversion Coat

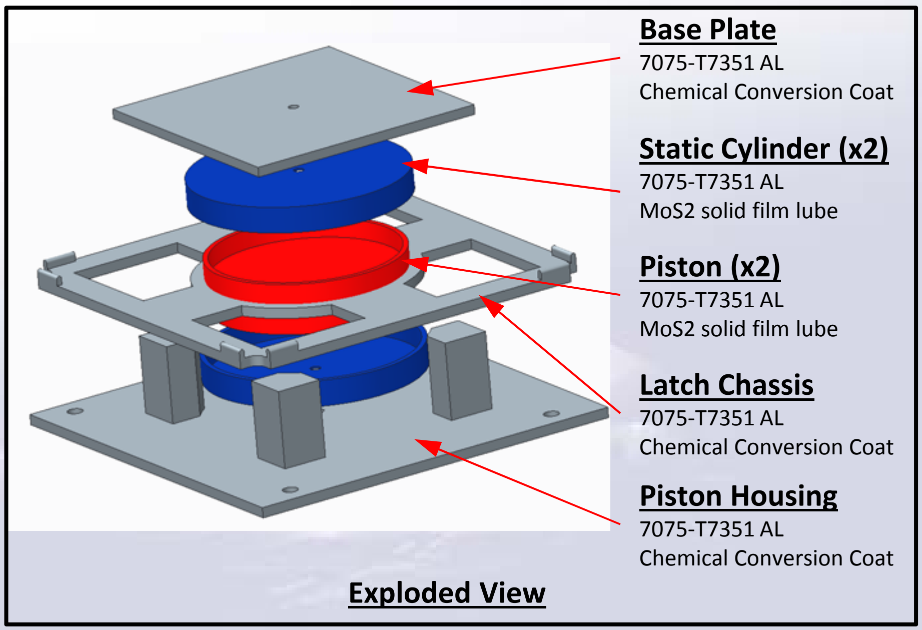


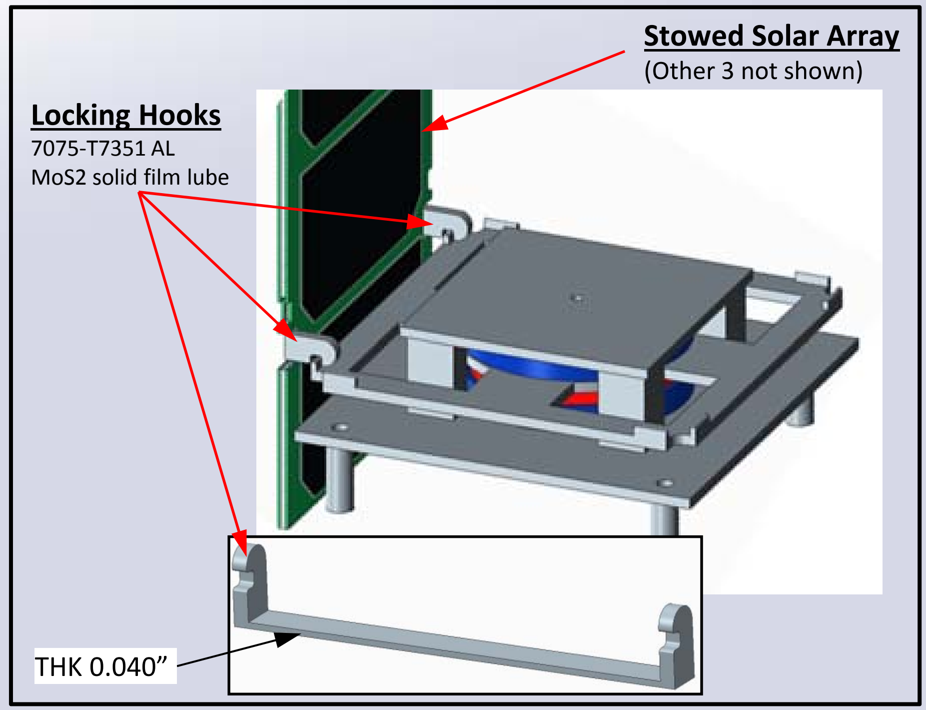
**Hinge Pin**
Two Piece Construction (press fit)
A286 CRES
MoS2 solid film lube

# Mechanisms Design Overview – R&R



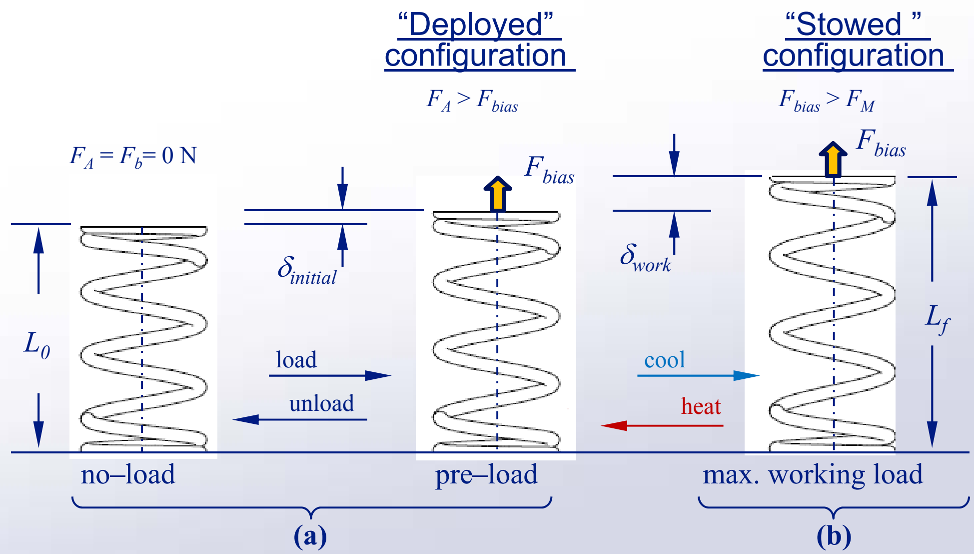



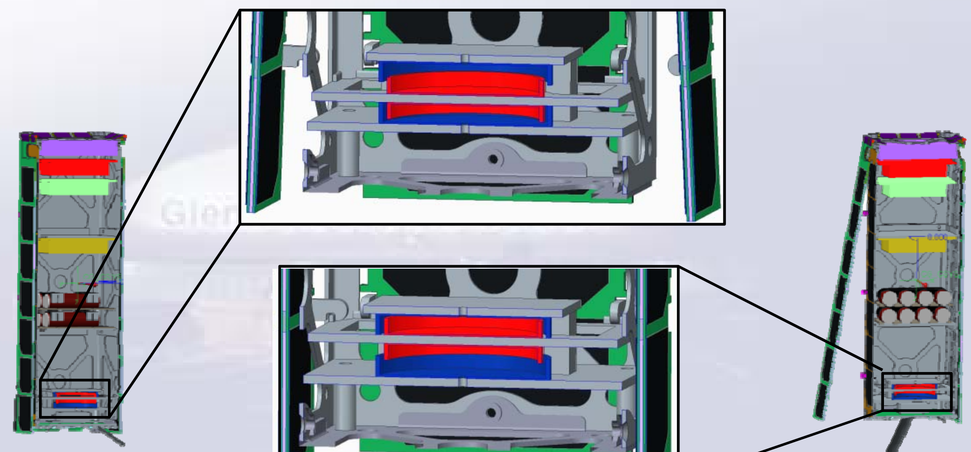



# Mechanisms Design/Analysis

- Deployable Array Retention and Release Mechanism (Shape Memory Alloys)

| NiTi thermo-elastic properties | | | |
|---|---|---|---|
| Shear modulus | $G_A$ | 20 | GPa |
| | $G_R$ | 8 | GPa |
| Poisson's ratio | $n$ | 0.413 | – |
| Transformation temperatures (± 2 ºC) | | | |
| Martensite start | $M_s$ | 71 | ºC |
| Martensite finish | $M_f$ | 55 | ºC |
| Austenite start | $A_s$ | 92 | ºC |
| Austenite finish | $A_f$ | 105 | ºC |



**Stowed** **Deployed**

- Need to provide 0.5″ travel
- Design for a redundant system
- Activation (deployment) above 95 °C)
- Release all 4 panel with one motion

# FUTURE WORK

# Current/Future Work

- Submitted a proposal to CubeSat Launch Initiative.
- Proposal was recommended for selection to participate in the program and is currently selected 3rd out of 14.
- PDR is scheduled for June 2015
- Procured solar cells for deployable arrays and identified the solar panel manufacturers
- Identified COTS subsystem manufacturers and lead times.
- In the process of prototyping both mechanical and electrical systems.

# QUESTIONS?