XSAS

eXtendable Solar Array System

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Michigan Space Grant Consortium NASA

MichiganEngineering

University of Michigan Engineering Council UMEC 1927

Overview

- Background
  - CubeSat technology
  - XSAS concept / history
  - Michigan NanoSat Pipeline
- Current XSAS Development
  - Mechanisms
  - Solar panels
  - Electrical Power System
- Future Work

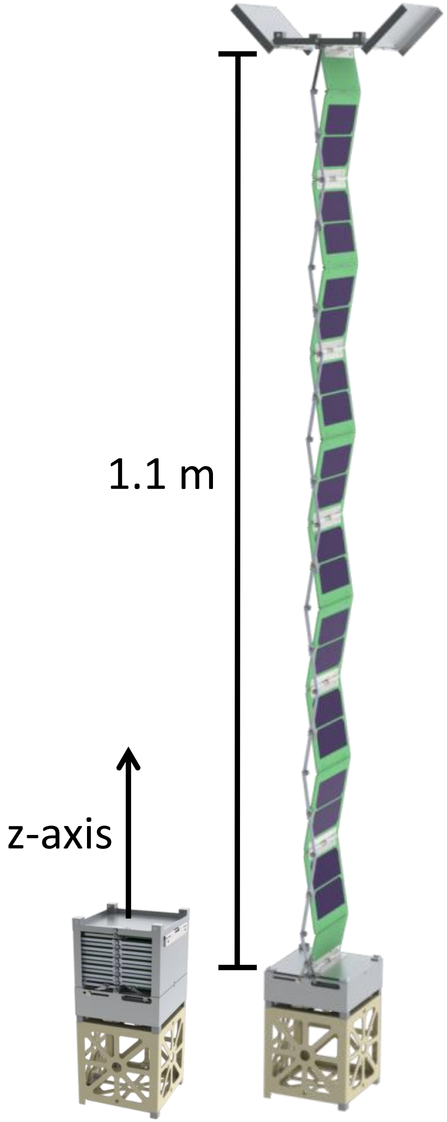
CubeSat Background

- Standardized form of NanoSat
- CubeSat Specifications
  - Size: 1U = 10 cm x 10 cm x 10 cm
  - Mass: 1.33 kg per U
- Growing interest in CubeSats
  - Mostly on a university level
  - Some industry or government interest
  - Relatively low development & launch costs
- Major Problem: limited power generation restricts mission capabilities
  - Methods to increase power generation of major concern

Cal Poly CP-1 CubeSat

XSAS - Concept

- Solution: use of deployable structures
  - 1U stowed array extends ≈1 meter
  - Increase power generation surface area
  - Provides gravity gradient stabilization
  - Capability for high gain antenna
- "Independent" of CubeSat
  - Well defined interface
- Capabilities
  - 20 Watt-hours average power
  - Typical 3U: 7 Watt-hours



XSAS - Past Development

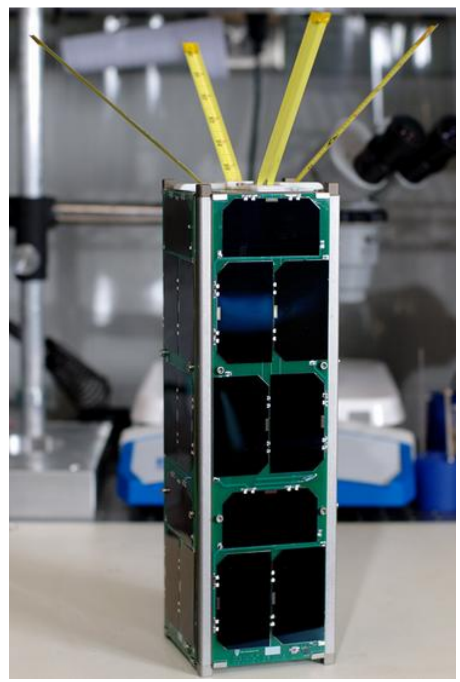
- Conceptualized in MEng Program (2008-2009)
- Prototypes designed and fabricated for proof-of-concept demonstrations
- Small scale version tested in microgravity (2010)

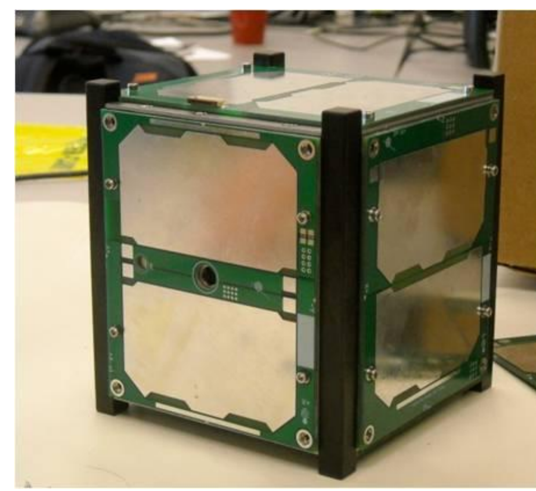
XSAS - Microgravity Testing

- Tested a scaled down array due to safety restrictions by NASA
- Reliable deployment verified, XSAS extension characterized

Michigan NanoSat Pipeline

- Program established to sustain growth of small satellite projects within the University of Michigan
  - Heritage for XSAS
  - Mission prospects



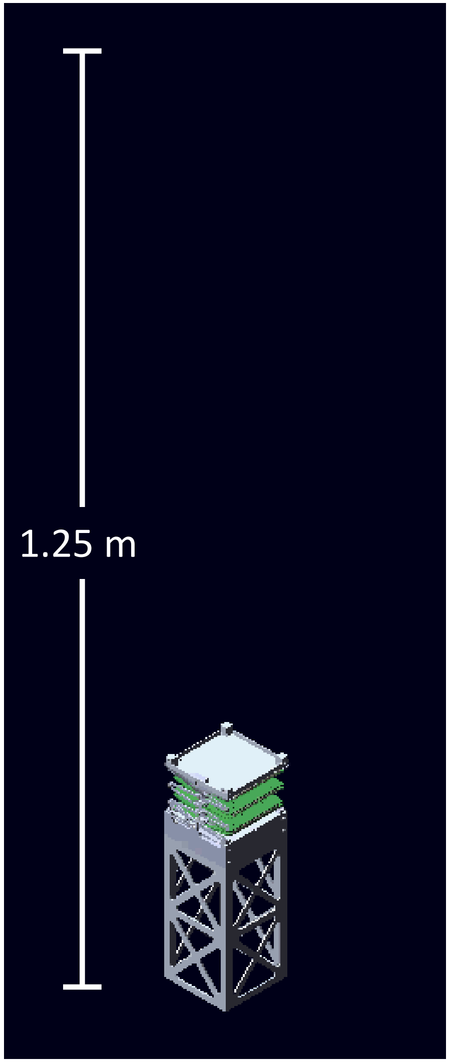


Current Development

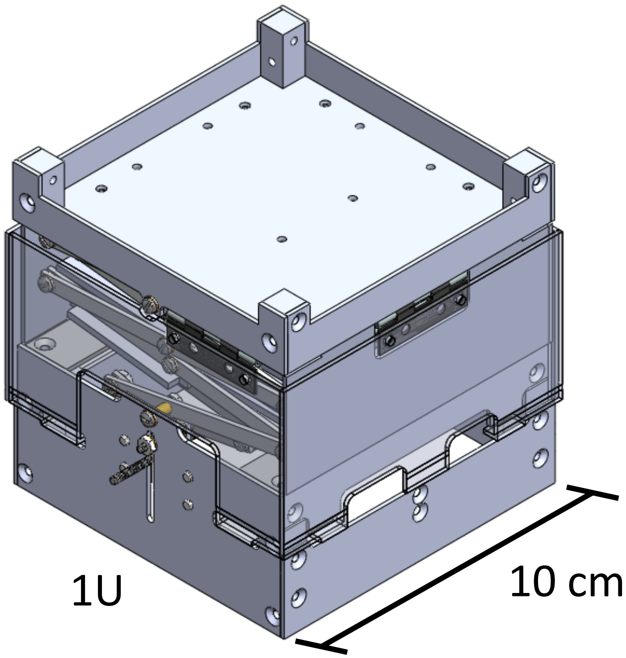
- Third design iteration of extending array complete
  - Mechanisms redesigned based on lessons learned
  - Improved design stows to size of 1U
  - New design considerations: solar cell wiring, launch survival
- Preliminary design of electrical power system (EPS)
  - Power regulation and distribution
  - Maximum Power Point Tracking (MPPT)
  - Interfacing with CubeSat
  - Housekeeping data

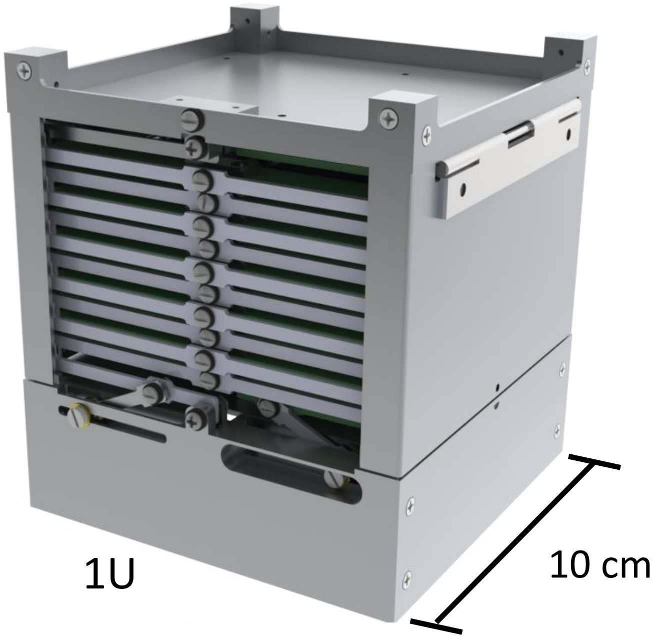
Mechanisms

- Design must satisfy top level requirements/objectives and customer needs
- Stowed configuration must be no larger than 1U
  - Any larger and it will be unpractical for CubeSat mission
- Must provide EPS with ≈ 500 cm^3 volume in lower assembly
- Springe hinges between panels drive extension
- Extended panels angle 10 degrees with z-axis
- Currently focusing on optimizing the XSAS baseline design
- Dynamic modeling using ADAMS to identify problematic areas for ground testing



Design Heritage

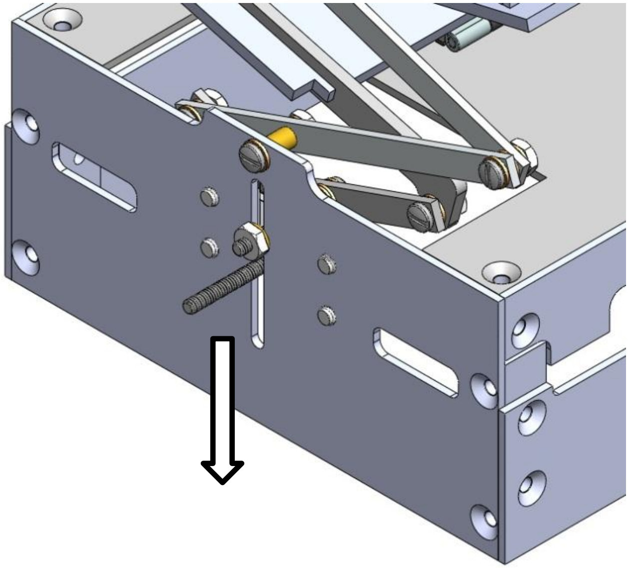


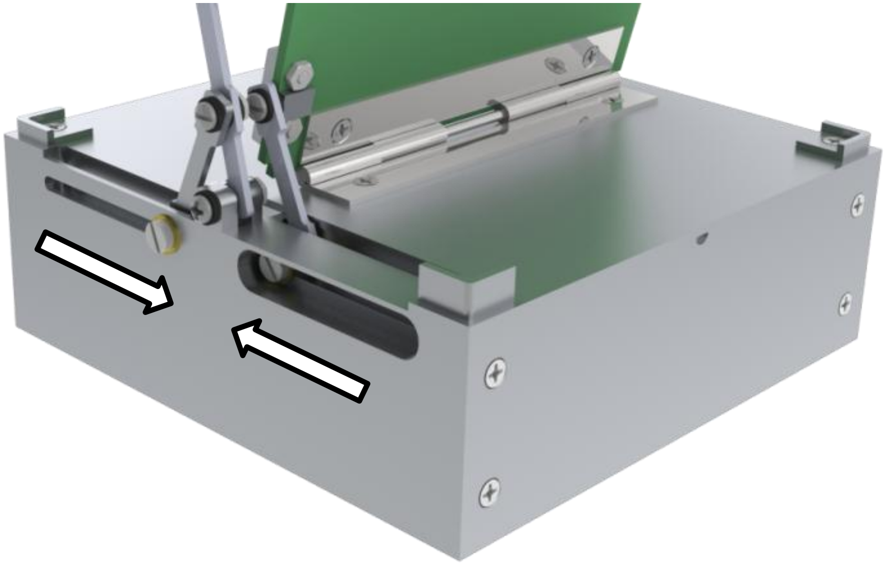


- 4 point release
- Assembly not rigid in stowed configuration
- Angular displacement during deployment

- 1 U includes EPS
- Similar Dyneema burn release (experimentally validated)
- Reduced complexity
- Higher tolerances

Scissor Constrain





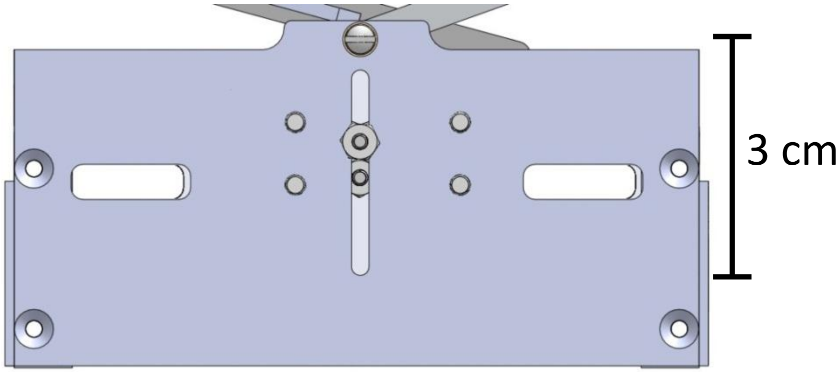
<u>Vertical constraint (1 DOF)</u>

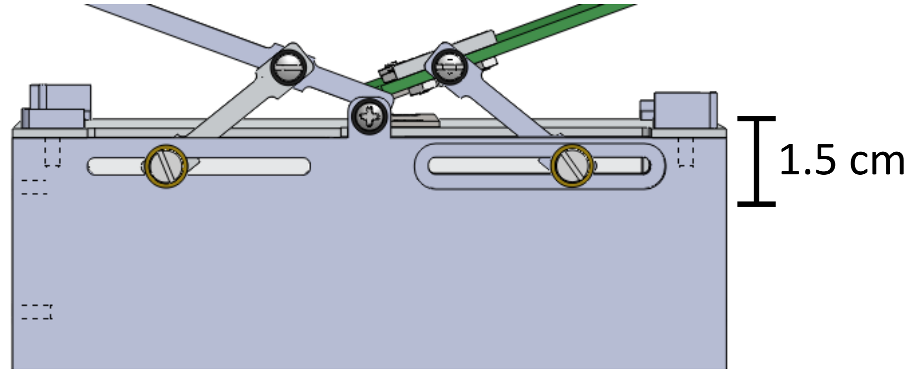
- Cantilevered support of constraint mechanism
- Lots of flex “bounce back”
- Torques in scissor pieces

<u>Horizontal constraint (1 DOF)</u>

- Fully supported scissor constraint mechanism
- Increased rigidity
- Offset scissor components to avoid interference

Lower Assembly

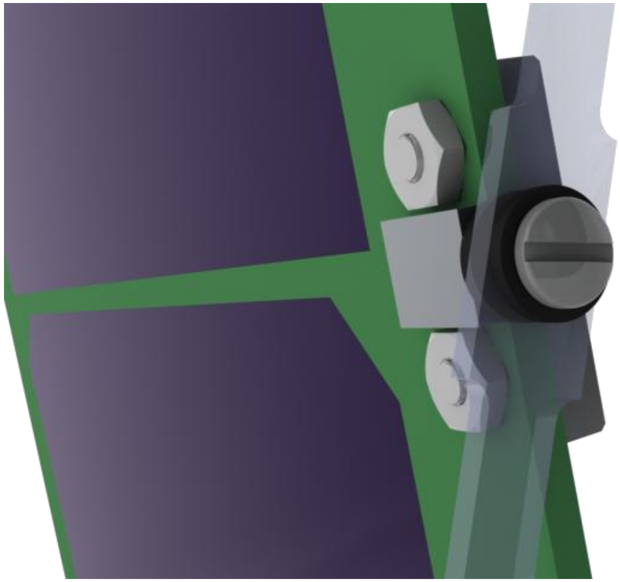




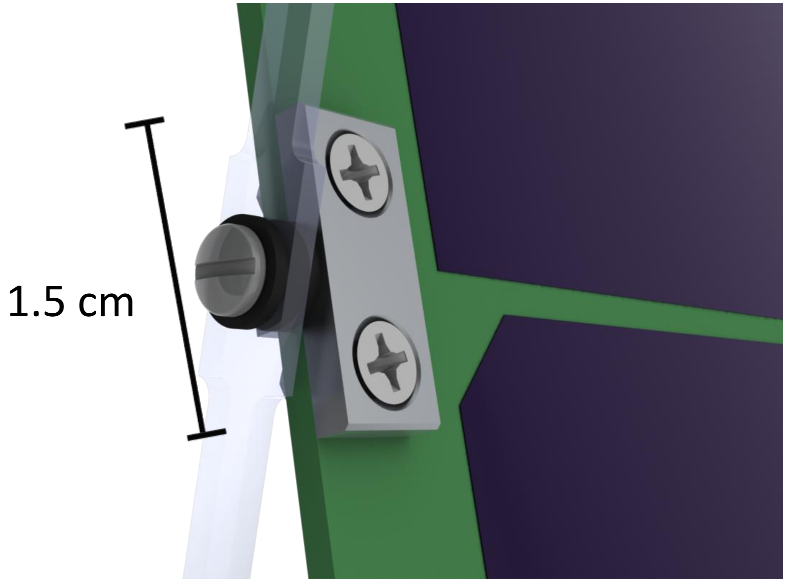
- Vertical scissor constraint requires tall lower assembly
- Increased internal complexity
- Requires an additional 0.5 U for EPS

- Horizontal scissor constraint saves valuable vertical space
- More room for panels (>200cm^3 increase)
- Leaves enough space for EPS

Scissor to Panel Interface

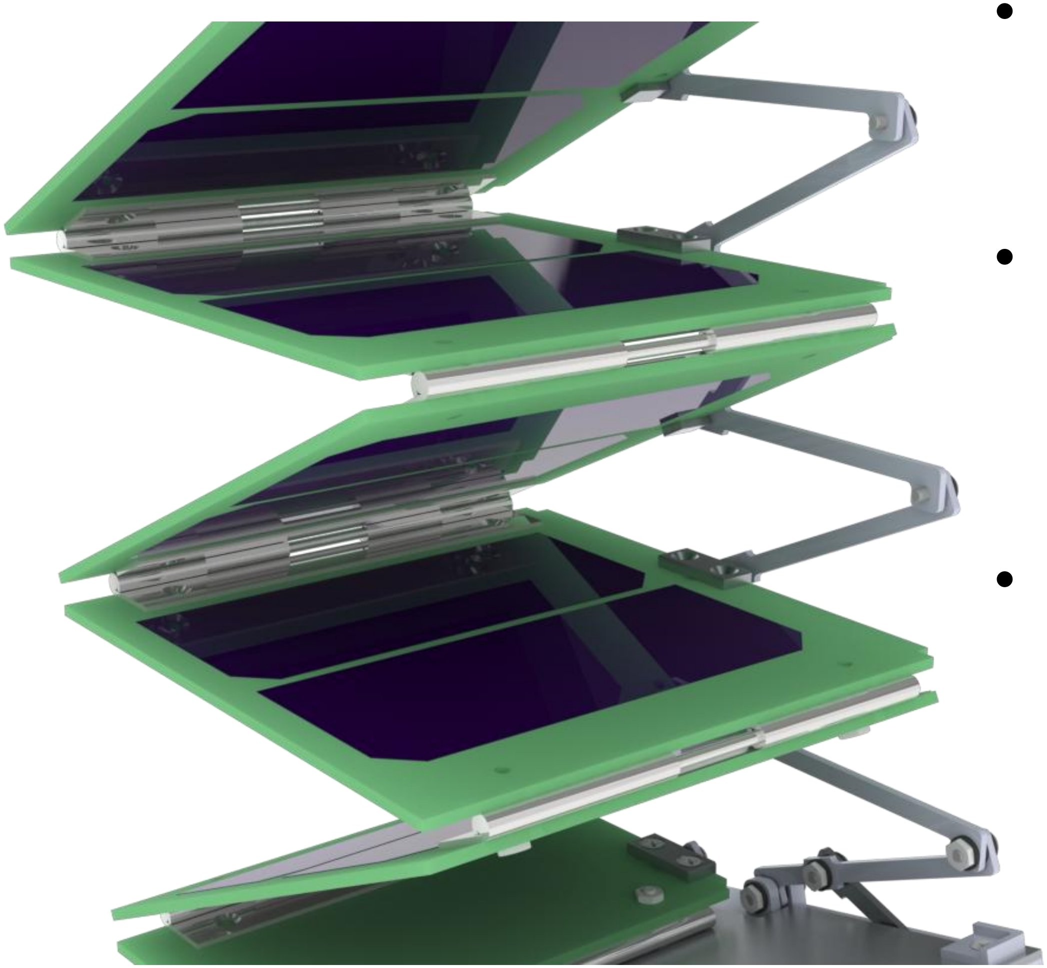


- New T-shaped bracket attaches scissor arm to panel
- Mechanical attachment is an improvement over epoxy press fit method



- Predict stresses and safety factors at such small scales

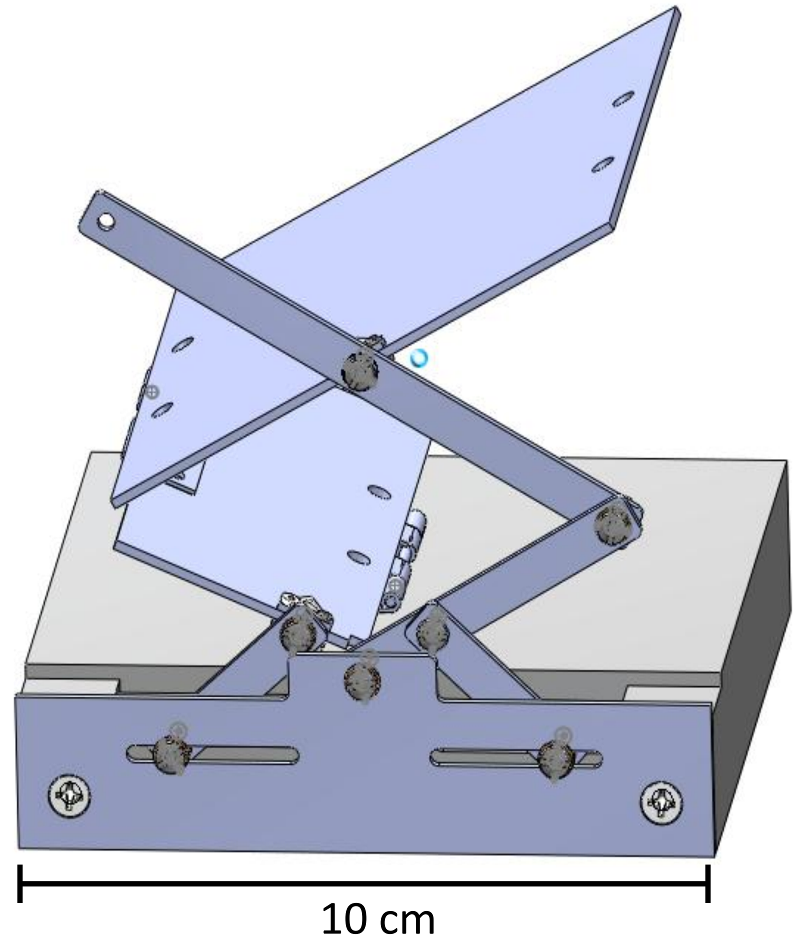
Increasing Hinge Precision



- Old hinges introduced small displacement within hinge point
- Created angular displacement in scissor structure during extension
- New hinges wider, higher precision to prevent unwanted play and improve linearity of extension

Testing Rig Validation

- Understand the dynamics of extension before proceeding in design
- Machined from a solid block for rapid prototype
- Focus on exploring the degrees of motion
- Prove feasibility of front panel horizontal constraints

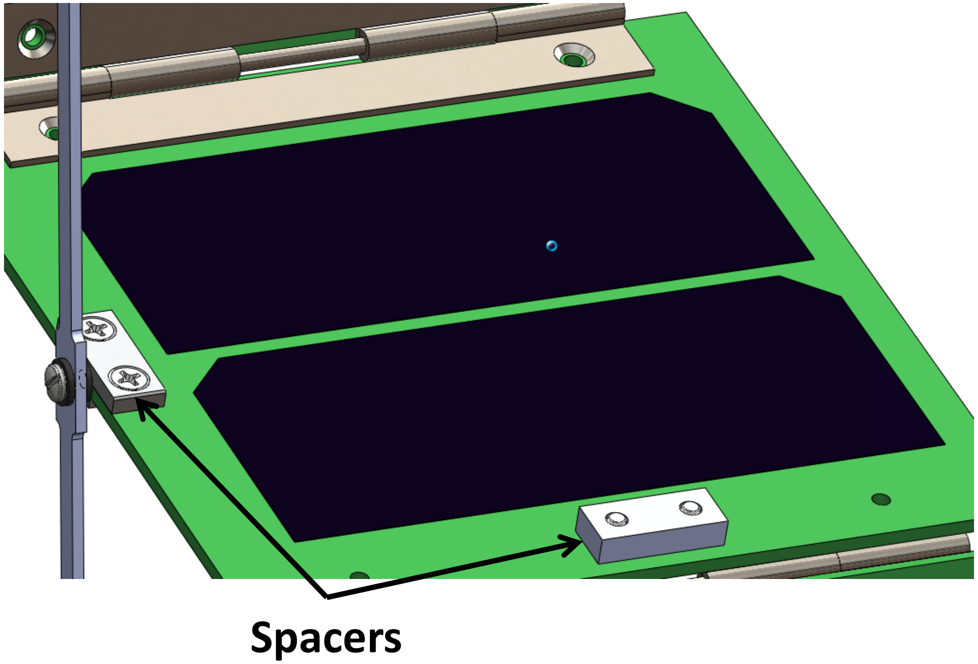


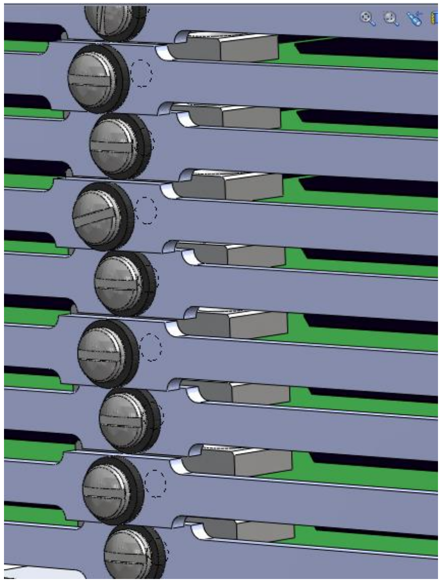
Trials and Analysis

- Varied number of springs
- Achieved better linear deployment with bottom spring removed
- Identified geometric incompatibility

Panel Design

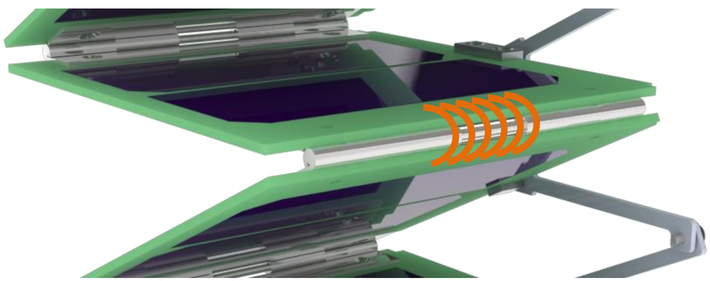
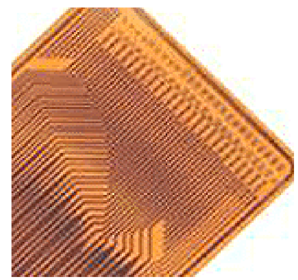
- Spacers between panels support panels during launch
- Current scissor attachment bracket doubles as a spacer
- Additional spacers placed around the panel
- Made from same material as bracket (Aluminum)



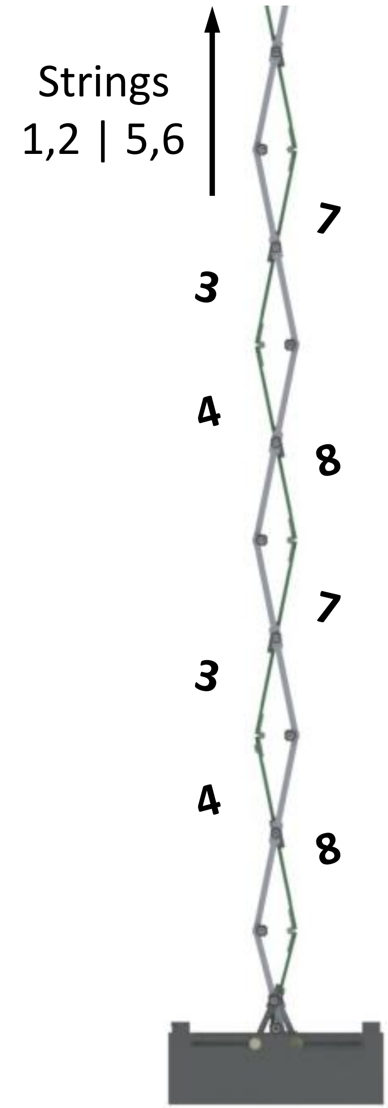


Solar Array Wiring

- Wires integrated into PCB panels
- Flexible wiring between adjacent panels

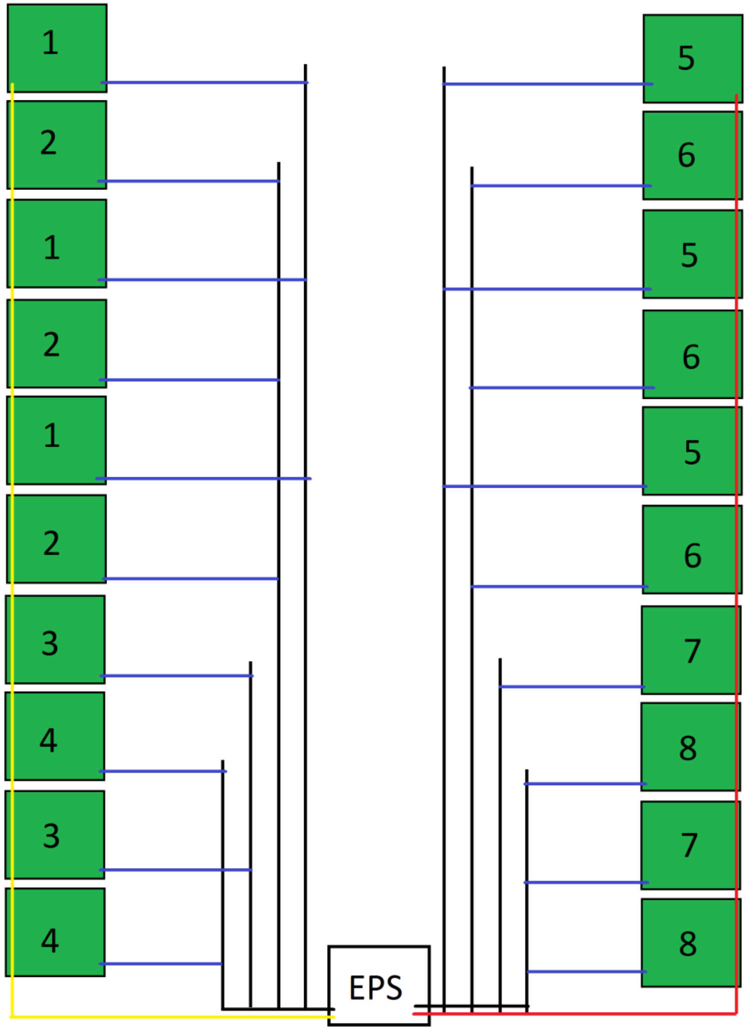



- 8 “Strings” of solar panels wired in series
- Tradeoffs:
  - Complexity vs. reliability
  - Power generation vs. reliability
- Strings vary by panel angle and location



Solar Array Wiring

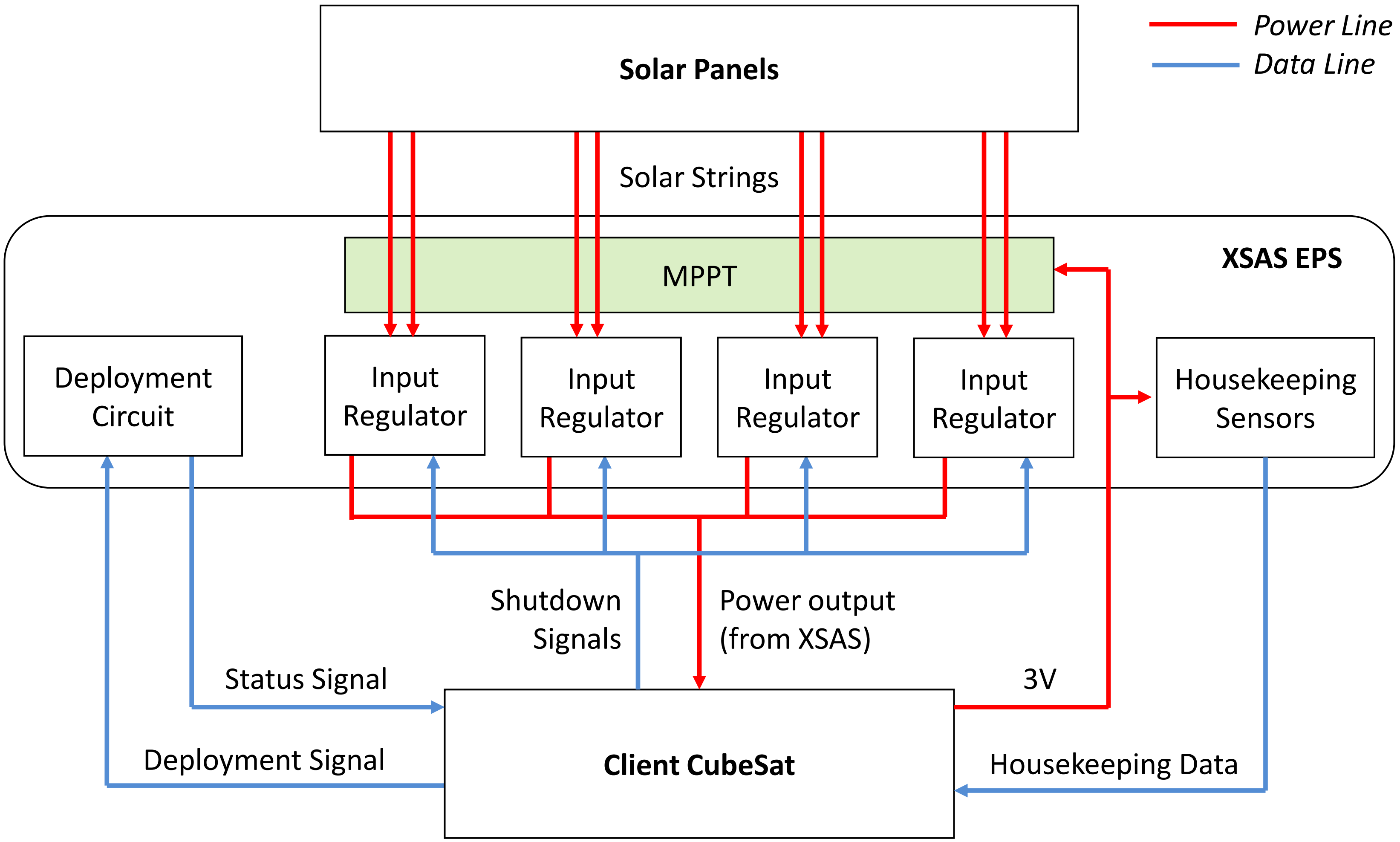
- 16 Power lines transferring unregulated power from solar cells to EPS
- 1 Signal wire supporting temperature sensors
- 1 Regulated 3.3V power line coming from the EPS and feeding the power to the temperature sensors
- 1 Common ground line



Electrical Power System

- Interface between solar cells and power bus of CubeSat
- Primary objectives:
  - Regulate power from solar panels
  - Distribute power to CubeSat
  - Collect basic telemetry data (voltage, current)
  - Deployment of XSAS
- Secondary objectives:
  - Convert power efficiently (MPPT)
  - Provide additional telemetry data (temperature)
- Utilize Michigan NanoSat Pipeline heritage

EPS – Block Diagram

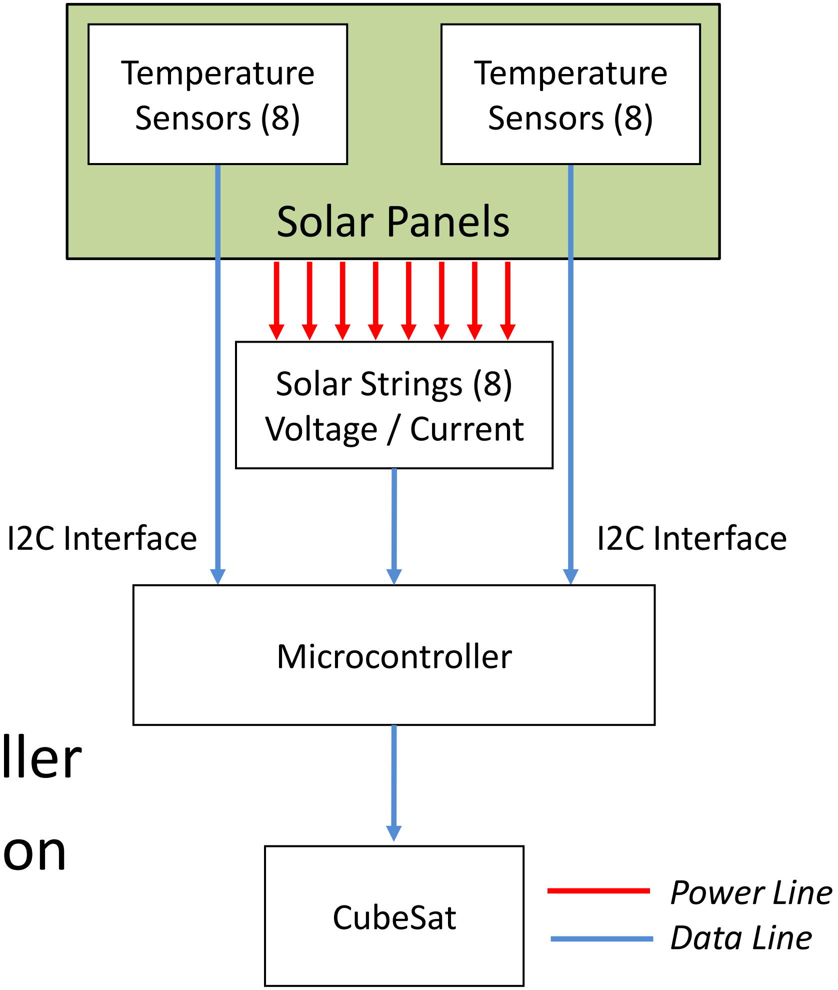


EPS – Power Regulation

- Input Regulation
  - Converts voltage output of cells to provide steady voltage to power bus
  - Only 4 regulators needed for 8 strings, due to shadowing
- MPPT
  - Adjusts reference voltage of regulator, regulators stop converting below reference voltage, more efficient
  - Use microcontroller, saves space
  - Backup analog set point tracker
  - Under development in Michigan NanoSat Pipeline

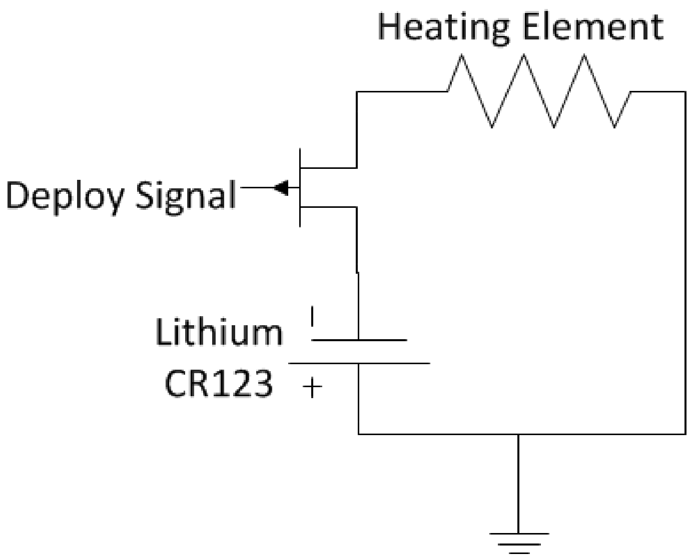
EPS – Housekeeping Data

- Measurements
  - Panel temperature
  - Solar string output voltage
  - Solar string output current
- Measurements useful
  - MPPT architectures
  - Health monitoring
- Packages data for CubeSat
  - Dual purpose of microcontroller
  - Transmit data to ground station

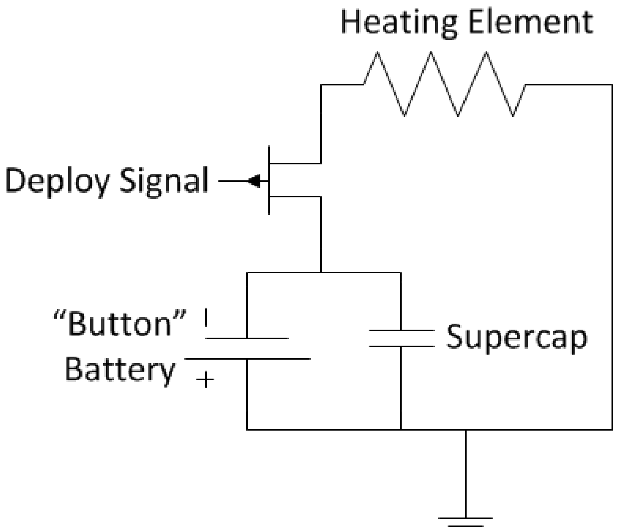


EPS – Deployment Circuit

- Heat Nichrome wire to melt Dyneema and deploy XSAS
  - Dyneema burn via resistor commonly used to release NanoSat deployable structures
- 2 possible configuration:



Turn on nMOSFET to heat Nichrome



Turn on nMOSFET to charge capacitor
Turn off nMOSFET to heat Nichrome

Future Work

- Build full scale prototype of 3rd design iteration
- Perform integrated testing to validate design
  - Ground deployment testing
  - Thermal vacuum testing of mechanisms
- Prototype EPS components for testing
  - Input regulation
  - Basic MPPT architecture
  - Data management system

Questions?