Design and validation of an articulated solar panel for CubeSats

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Abstract

- CubeSats mission more and more demanding
- Current designs mostly limited to surface mounted solar cells
- Additional potential by deployable solar panels like in large satellites
- Further enhancements possible by proposed articulated solar panels
- Successfully validated prototypes to vibrational loads during launch phase

Environmental Challenges

- Large vibrational load during rocket launch
  - Risk of physical destruction / missing of mechanical parts (e.g., screw connections)
  - Risk of physical destruction by not appropriate bolting of the solar panel and mechanical
    connections
- Orbital Environment
  - Cycle changes of temperature during one orbit
  - Induced stress on mechanical components by difference in thermal expansion
  - Various environment
  - Outgassing of mechanical components
  - Particle radiation
  - Degradation of applied materials

Motivation

- Increasing power demands on small satellites
- Currently increase of solar cell area by deployable solar panels with fixed angle
- Proposed further improvements by adjusting solar panels for an optimized sun-incident angle

Conceptual Design

- Hinge design with stepper motor enhanced by planetary gears for larger available torque and higher precision of sun-incident angle
- Attachment of solar panel by wire which is cut by heat winding
- Ultra Triple-Junction solar cells for highest efficiency
- Electronic controller for validation of control signal to stepper motor
- CAD-drawing of proposed mechanism:
  - First prototype with mock-up solar panel
  - First mode found in model test at approximately 110 Hz
  - Second step: classical analysis with constant rotation
  - Resulting deflections:
  - Resulting stress in whole panel:

Subsystems

- Release Mechanism
  - Required for releasing panel from locked configuration during launch
  - Simple, light, small and reliable mechanism required
- Articulation Mechanism
  - Proposed to increase efficiency of solar cells
  - Rotation of deployable solar panels to achieve near one degree of freedom
  - Simple, light and reliable mechanism required
- Type of solar Cells
  - Comparison of solar cells regarding costs, availability and external efficacy
- Control Mechanism
  - To adjust the attitude of the solar panels to achieve optimal sun-incident angle
  - Electronic controller embedded in an board data handling system preferably

Refined Specification

- Estimated Solar Cell Area: 0.058 m²
- Improvements by articulated Solar Panels
  - Fixed mounting parallel to +x panel: average of 486 W/m² per year
  - Additional rotation around x axis: average of 496 W/m² per year
  - Combined rotation: average of 488 W/m² per year
- Additional rotation around y axis: average of 486 W/m² per year

Problem Statement

- Additional available energy: 12 Wh at 1.3 V by articulated solar panels
- Output voltage between 10 and 20 volts
- Embodied torque coil including interface
- Temperature sensor at back side of panel
- Possibility to print antenna circuit on or within the array substrate without degradation of antenna performance
- Electrical interfaces for antenna, torque coil, power and temperature sensor
- Hz

Evaluation and Testing of the proposed Solution

- First two calculated fundamental modes:
  - First mode found in model test at approximately 110 Hz
  - Second step: classical analysis with constant rotation
  - Resulting deflections:
  - Resulting stress in whole panel:

Conclusion and Future Work

- Large improvements by adding one degree of articulated freedom
- Validated feasibility of proposed design
- Consistent results from numerical and experimental vibrational analysis
- Further tests for outgassing, particle radiation

Acknowledgments

- SpaceMaster Consortium for funding the work at Utah State University
- Utah State University and Space Dynamics Lab for opportunity to design and validate design
- Dr. Ross Palmer and band at Space Dynamics Lab for sharing their practical experience and continued support throughout the whole project
- Dwarf Planet Project for the funding the opportunity to attend the conference

References