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Transient Thermal Circuit Model of the Northern SPIRIT Cube Satellites

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ABSTRACT

A transient thermal circuit model was developed by the AlbertaSat Student Team for the Northern SPIRIT cube satellites: Ex-Alta 2 (3U), YukonSat (2U) and AuroraSat (2U), which are to be launched into Low Earth Orbit. The model was used to study heat transfer and determine temperature profiles over time in each CubeSat. The thermal resistance analogy for conductive heat transfer was utilized, assuming convection as negligible under vacuum conditions.

The thermal circuit model was used because of its greater modularity and computational efficiency, when compared to finite element analysis simulations, particularly for preliminary analysis when internal stack configuration is subject to change. The approach has also shown adaptability and modularity between different sizes of CubeSat structures. Thermal circuits were created for each face of the satellite, which allows for varying inputs to each side based on thermal loading. The simulations will aid in determining whether modifications to the CubeSats need to be made to ensure all on-board components remain within their predefined thermal operating ranges during orbit.

The transient thermal models for the Northern SPIRIT constellation are simulated with LTSpice XVII, a circuit simulator written by Linear Technologies Inc. The thermal circuit simulations use electrical properties to represent thermal properties; where current sources represent heat sources, electrical resistances represent thermal resistances, capacitors represent heat capacity, and voltage differences represent temperature differences. LTSpice allows for accurate representation for all components within the satellites, as long as an association with thermal resistance or capacitance can be made. The thermal equivalent of each printed circuit board (PCB), the solar panels, the deployable components, and satellite bus for all three CubeSats has been created in LTSpice. The heat transfer on the outer surfaces and heat generation sources on PCBs have also been implemented to account for the transient nature of thermal loading during orbit.

The individual CubeSat models will be validated through tests in the thermal vacuum chamber prior to assembly and launch, with the goal of the thermal simulations being the accurate prediction of temperature fluctuations. Also, the simulations will aid calculation of operational temperatures for all on-board components of the three satellites and support in-orbit operations following launch.

The end goal of utilizing LTSpice to execute thermal simulations is to provide an open-source model that is computationally inexpensive, efficient, and accurate in execution, and reconfigurable for other CubeSat projects and future AlbertaSat missions.