

Thermal modeling for a CubeSat [Nano-satellite]

Aim: Calculate the temperature of a satellite in low-Earth orbit

Physics: Thermal diffusion, radiative processes

Mathematical methods: Order of magnitude estimates, ODEs, Finite Element Methods.

Background and setup:

Thermal modeling is a fundamental aspect of satellite mission design, as spacecraft operations are sensitive to internal temperature levels and changes. Estimating them is thus an early critical step during feasibility concept studies. Here we are considering a CubeSat (nano-satellite of standardized dimensions). A 1U CubeSat is a cube of 10cm edge.

With a physical approach to the problem, first consider what is the simplest meaningful model to consider for an order-of-magnitude calculation of the expected average temperature of the 1U CubeSat, if the satellite is in a static configuration along the Earth-Sun line with one face perpendicular to Earth (and the opposite face perpendicular to the Sun). Identify the key physical parameters that are influencing the answer, in particular address how the answer changes if the CubeSat is made of Aluminum vs. a piece of coal. Also, calculate the order-of-magnitude change in the equilibrium temperature derived if the effect of the Moon is taken into account.

Next assume a hollow CubeSat model with a single temperature for each face (each face can be assumed to be infinitely thin, but have finite mass, and conductance with neighboring faces proportional to the linear length of the edge). Write the equation that describes the thermal model under these assumptions, and solve it numerically discussing characteristic timescales for the problem.

Relax the assumption of a single temperature for each face and solve it using a Finite Element Method, still keeping the infinitely thin approximation.

Relax the infinitely thin approximation and consider finite thickness.

Resolve the model with the satellite in orbit around Earth and discuss the difference of equatorial vs. Polar Sun-Synchronous orbits.