

This summer, one of my projects was improving the control algorithm for continuous adiabatic demagnetization refrigerators (CADR) used for x-ray astronomy. ADRs use magnetism instead of pressure to pump heat from the salt pill to the heat dump. By linking four ADRs together, the total mass can be smaller, and you can avoid using a liquid helium bath to cool to 4 Kelvin, which can be tricky to use in space. Additionally, the temperature of the first salt pill can stay constant, allowing the detector to be read continuously, rather than having to wait for the ADR to warm up by increasing the magnetic field, bleed off heat, and the cool back down to temperature. However, making sure the individual ADRs are applying the correct current is a complex problem. While the relationship between temperature, entropy, and magnetic field through the salt pill is a well defined relationship, there are also heatflows between stages depending on their relative temperatures. Working in a team of four students, I helped refine the control algorithm so that it will be able to maintain greater temperature stability. For the CADR to be useful for keeping the x-ray detector cold, it needs to be kept at 50 milliKelvin with a root mean squared error of one microKelvin, while the current system only provides stability to around 10 microKelvin. Working in LabVIEW, we improved the algorithms used to predict how temperature should relate to the current through the electromagnets, and made the simulation more physically accurate. We did this by adding appropriate noise to the system, and implementing a model of a spatially distributed salt pill. Since the temperature is related to changes in magnetic field, a non-uniform magnetic field means there will be internal heat flow, which should be modeled. This should help future developments to be more usefully tested without needing access to a physical ADR.

For my other project, we developed an attitude control system designed for a CubeSat taking vertical snap shots of clouds, to help with studying the composition and development of cloud structures. The satellite was to use only magnetorquers and keep one face towards the sun and another away from the earth to allow efficient power generation and radiation of heat. Additionally, this ensures the lighting should be good for taking pictures, and the camera should be properly aimed and stable. Most satellites also have a flywheel since magnetorquers can never provide a torque perpendicular to the magnetic field, which makes control more difficult. However, this adds mass and periodically needs to be unloaded. To approach this problem, we primarily used Simulink to implement a control system as well as a model of the satellite in orbit to test its effectiveness. The Satellite Toolkit from AGI allowed us to use realistic values for magnetic field and sun. Our control system implemented PID control supplemented with simple logic systems.