UCLA ENGINEERING
Henry Samueli School of Engineering and Applied Science
Birthplace of the Internet

ELFIN

Developing a Thermal Analysis Program for a Nanosatellite

Kyle Colton (ky.colton@gmail.com) and Stephen Sundin (stephensundin@sbcglobal.net)

Electron Losses and Fields Investigation (ELFIN)

Engineering Goal

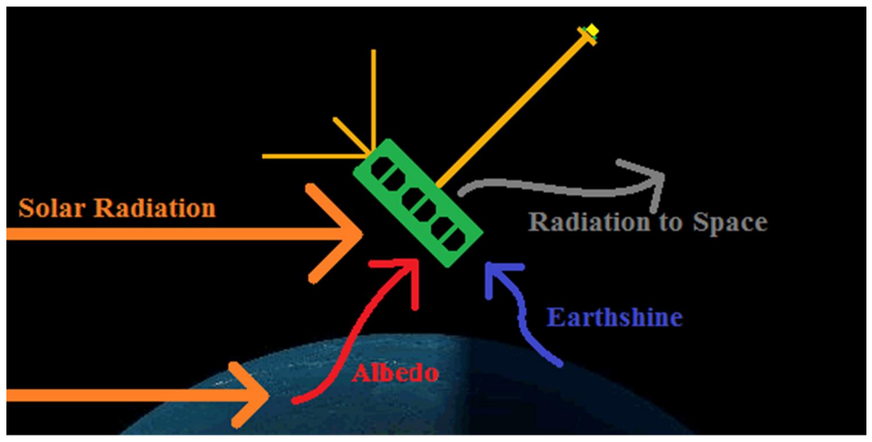
The primary engineering goal of this project was to design an accurate finite difference method analysis program capable of analyzing the thermal interactions and temperatures for the Electron Losses and Fields Investigation (ELFIN) nanosatellite in a low Earth orbit (LEO).

Development Decisions

1.) The program was written in MATLAB due to the availability of differential equation solvers
2.) ELFIN was modeled using an easily expanded network of nodes
3.) Special attention was spent on particularly sensitive components, such as the scientific instruments and batteries by adding more nodes
4.) The program was given the name Analysis of Thermal Interactions on ELFIN (ARIEN)
5.) ARIEN was to be capable of analyzing a rotating spacecraft in earth orbit at any altitude and inclination as well as model internal heat generation.

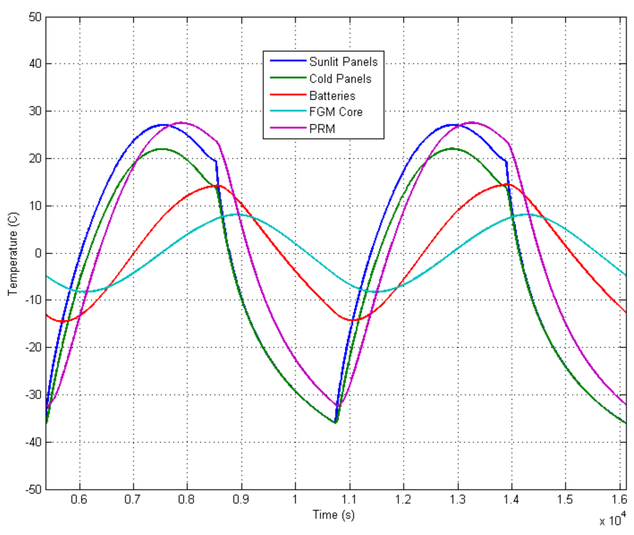
Background

ELFIN is a CubeSat standard nanosatellite intended to go into a polar or near polar LEO. Since ELFIN's orbit requires this high inclination, it will experience greatly varying temperature environments. Due to this, there is a real risk of onboard components failing, jeopardizing the mission. In order to ensure that all of the components on ELFIN survive over the entire mission lifetime, it is necessary to develop an in depth thermal protection plan. Accurate thermal modeling is essential to creating such a plan

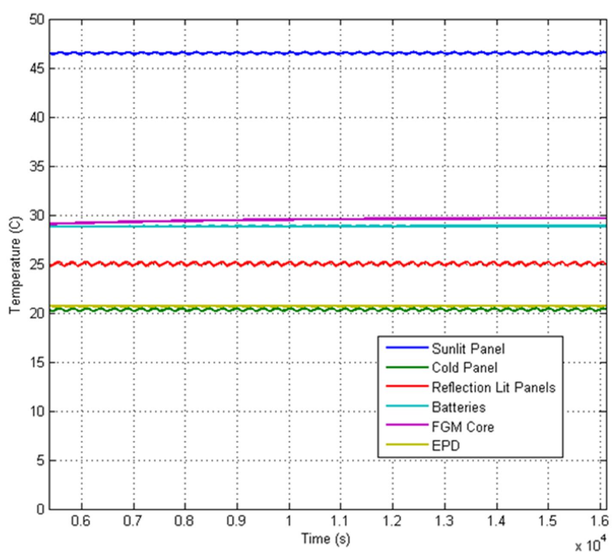


Thermal Environmental Interactions in LEO

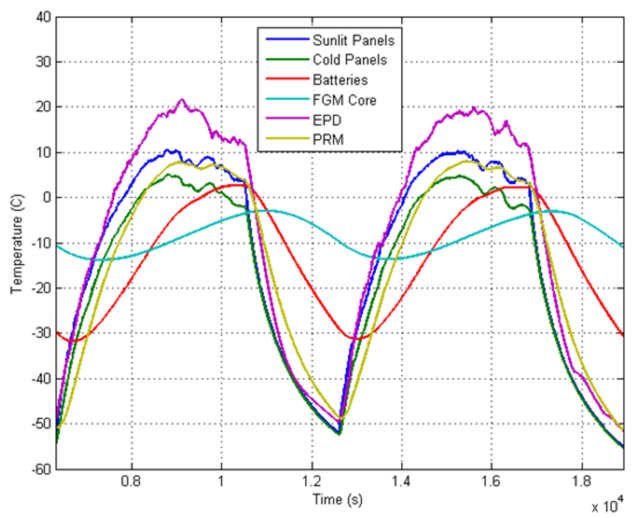
Example Results



250 km altitude, 0° Inclination
No heat generation



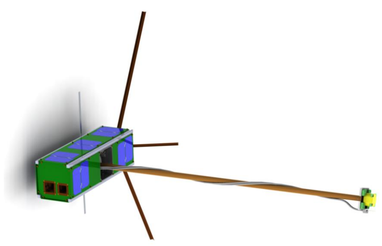
250km altitude, 90° Inclination
Heat generation



1000 km altitude, 0° Inclination
No heat generation

Program Operation

1.) The user inputs desired orbital values, such as altitude
2.) ARIEN establishes a nodal network based on a easily editable master matrix and a time vector based on orbital parameters
3.) ARIEN calculated the heat exchange between the connected nodes at each time step
4.) The heat fluxes are used to determine component temperatures, which are then displayed



The ELFIN satellite

Conclusion

The goal of this project of designing an accurate finite difference method analysis program capable of analyzing ELFIN's thermal interactions was met. The accuracy was determined by comparing the results to theoretical models of satellites in LEO. According to SMAD, the maximum temperature of a satellite in LEO is approximately 23°C, which is quite similar to the maximum temperatures ELFIN's interior components. The program provides easily understandable graphs detailing the temperature profile, allowing thermal control methods to be analyzed. Due to this, a viable thermal protection plan for ELFIN can be created.

Credits

-Chris Shaffer, the ELFIN Project Manager
-Prof. Vassilis Angelopoulos, the ELFIN Principle Investigator
-Institute of Geophysics and Planetary Physics Staff
-Air Force Research Laboratory

Selected Bibliography

.) Angelopoulos, V. "Cubesat: Electron Losses and Fields Investigation" University of California, Los Angeles. 7 May 2012
2.)Gilmore, David G. Spacecraft Thermal Control Handbook, Volume 1: Fundamental Technologies. 2nd ed. El Segundo: The Aerospace Press, 2002. Print.
3.) Williams, Andrew. "An Introduction to Satellite Thermal Management." Powerpoint Presentation. Air Force Research Laboratory/VSSV. 16 May 2006