USER STORY

University of Toronto Students Work with Space Flight Laboratory Engineers to Design and Simulate Nanosatellite Control Systems

Typically weighing less than 10 pounds (4.5 kilograms), nanosatellites are more than 100 times lighter than traditional satellites and can be produced at about 1% of the cost. To meet size and budgetary constraints, most nanosatellites are built either without attitude control systems or with rudimentary systems that make them unsuitable for applications that require precise orientation.

Graduate students and engineers at the Space Flight Laboratory (SFL) at the University of Toronto Institute for Aerospace Studies (UTIAS) design, analyze, and simulate attitude control systems that precisely control nanosatellites on orbit, including Canadian Advanced Nanospace eXperiment 2 (CanX-2) and CanX-6.

MathWorks tools are integral to SFL's control system design process. They also enable graduate students to gain practical experience on real-world space missions.

"We rely on these products to build high-fidelity models of sensors, actuators, and satellite mass properties; develop control algorithms; and simulate the overall control system to predict performance," says Dr. Robert Zee, director of the Space Flight Laboratory. "Our nanosatellites are among the first in the world that can maintain a precise orientation to within 1 degree. With this level of precision, the satellites can be used on real earth observation and astronomical missions."

THE CHALLENGE

Develop precise controls for nanosatellites while providing graduate students with experience in developing satellite technology and managing actual missions

THE SOLUTION

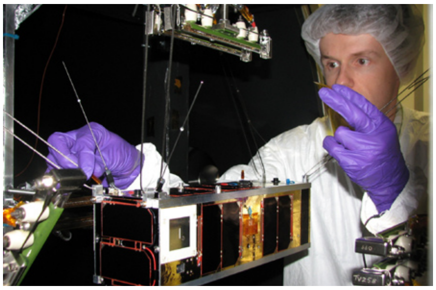
Use MATLAB and Simulink to design, model, and simulate nanosatellite attitude control systems

THE RESULTS

- Students prepared for successful engineering careers
- Control requirements met or exceeded
- Collaboration with other specialists and universities extended

THE CHALLENGE

In addition to mass and volume constraints, nanosatellites have a limited ability to generate power. SFL's tight budget



The CanX-2 nanosatellite before launch.

and accelerated launch schedule led the engineers to use readily available, lower-cost commercial electronics instead of radiation-hardened components. "To ensure that these parts will work reliably in space, we need to be very careful in how we design around them," says Zee.

Because the effects of gravity and air currents make it impossible to fully test a precision attitude control system in the lab, SFL had to rely on simulation to predict on-orbit performance.

To train graduate students in space systems engineering, SFL required development tools that students already knew or could learn quickly. The tools needed to facilitate collaboration between engineering teams and enable the students to acquire practical experience that they could leverage in their careers.

THE SOLUTION

Graduate students and space systems engineers at SFL used MathWorks tools to design, simulate, and build the attitude control systems for CanX-2 and other nanosatellites.

Before working at SFL, the graduate students completed Microsatellite Design I

> With the control systems that we developed with MATLAB and Simulink, our next-generation nanosatellites will have an unprecedented level of stability. By working side-by-side with space system engineers, our graduate students gained practical experience on a system that will actually fly in space.
>
> **Dr. Robert Zee, Space Flight Laboratory**

and II, courses taught by Zee, in which they used MATLAB® and Simulink® to build a preliminary design of a satellite system.

In Simulink, the SFL team modeled the sensors used to determine the nanosatellite's position and orientation, including sun sensors, magnetometers, star trackers, and GPS receivers. They also modeled the components used to control the satellite, including reaction wheels, cold gas propulsion systems, and magnetorquers. The component models reflected the actual satellite's interface and sampling period.

SFL used MATLAB and Control System Toolbox™ to develop control algorithms for the attitude control system. Using Simulink they combined the sensor, actuator, and controller models with a model of the satellite's mass, and then simulated the system to assess its performance in a zero-gravity environment.

Aerospace Toolbox enabled the team to estimate atmospheric drag and perform re-entry analysis for de-orbiting scenarios.

SFL used a thermal chamber to test the electronic components in temperature ranges encountered in space. Using Data Acquisition Toolbox™ they collected the test data for analysis in MATLAB. MATLAB was also used to model power systems and perform transient power condition analysis of the nanosatellites' batteries.

The team is using MATLAB to analyze telemetry data downloaded from CanX-2 and CanX-6, which are now on orbit.

Currently, SFL is working on CanX-4 and CanX-5, two nanosatellites that will demonstrate precise autonomous formation flying in low earth orbit, as well as CanX-3, a group of four nanosatellites that will be used for space astronomy.

THE RESULTS

- **Students prepared for successful engineering careers.** "Using MATLAB and Simulink on SFL projects provides our students with invaluable practical space systems engineering experience," says Zee. "Our graduates have gained a reputation for being highly competent, and many of them go on to great careers in the space industry or other technology fields."

- **Control requirements met or exceeded.** "CanX-2 is performing extremely well, pointing accurately to within 1 degree," says Zee. "CanX-3 is designed to be stable to within 1/60th of a degree, which is unprecedented for nanosatellites. This level of control would not be possible without MATLAB and Simulink."

- **Collaboration with other specialists and universities extended.** "When we work with other professors within University of Toronto on various algorithms, being able to share MATLAB models is a great benefit," says Zee. "We also collaborate with other universities in Canada, and it really helps to speak a common language via MATLAB and Simulink."

Learn more about the Space Flight Laboratory at the University of Toronto: *www.utias-sfl.net*

INDUSTRY

- Academia
- Aerospace and defense

APPLICATION AREAS

- Model-Based Design
- Control systems
- Test and measurement
- Data acquisition
- Data analysis
- System design and simulation

PRODUCTS USED

- MATLAB®
- Simulink®
- Aerospace Toolbox
- Control System Toolbox™
- Data Acquisition Toolbox™

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