

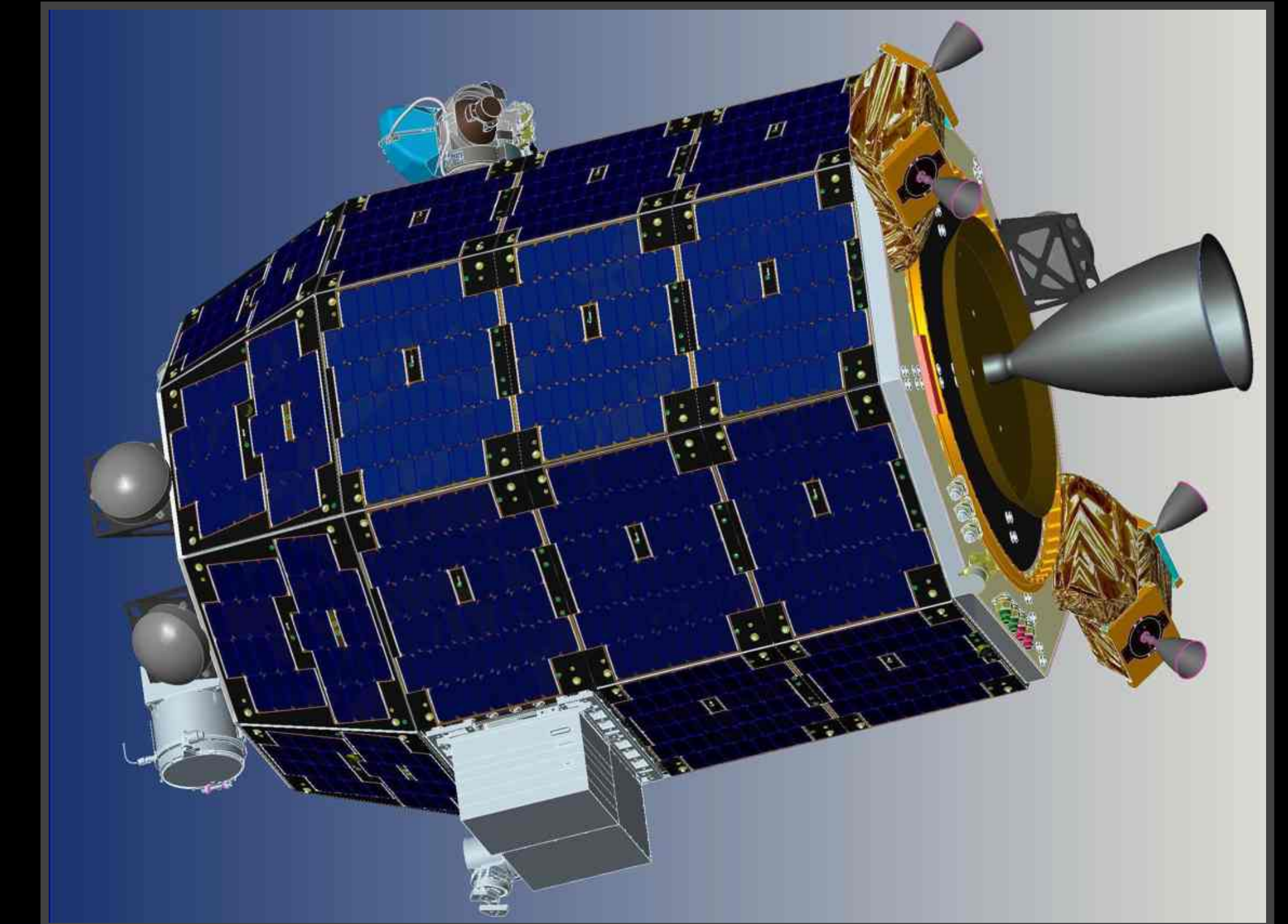
# LADEE Satellite Modeling and Simulation Development

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## Abstract

As human activity on and around the Moon increases, so does the likelihood that our actions will have an impact on its atmosphere. The Lunar Atmosphere and Dust Environment Explorer (LADEE), a NASA satellite scheduled to launch in 2013, will orbit the Moon collecting composition, density, and time variability data to characterize the current state of the lunar atmosphere. LADEE will also test the concept of the "Modular Common Bus" spacecraft architecture, an effort to reduce both development time and cost by designing reusable, modular components for use in multiple missions with similar requirements. An important aspect of this design strategy is to both simulate the spacecraft and develop the flight code in Simulink, a block diagram-style programming language that allows easy algorithm visualization and performance testing. Before flight code can be tested, however, a realistic simulation of the satellite and its dynamics must be generated and validated. This includes all of the satellite control system components such as actuators used for force and torque generation and sensors used for inertial orientation reference. My primary responsibilities have included designing, integrating, and testing models for the LADEE thrusters, reaction wheels, star trackers, and rate gyroscopes.



## The LADEE Mission

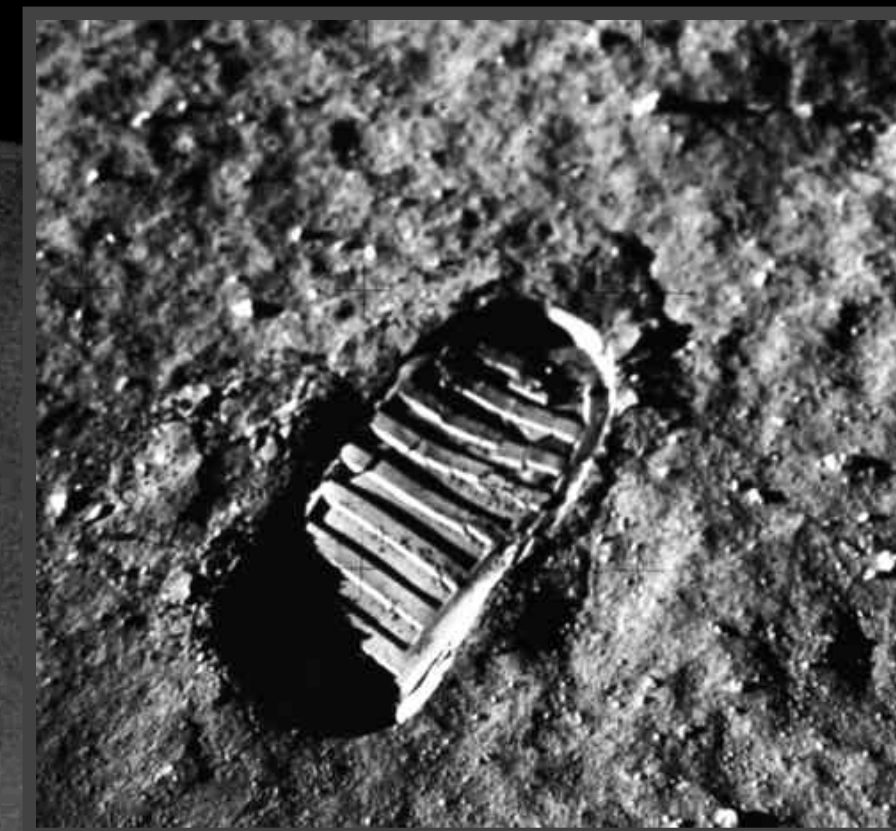
The science objective of LADEE is to characterize the environment surrounding the moon before it is altered by human activity. The specific objectives include:

- 1) Determine the composition of the lunar atmosphere and investigate the physics behind its distribution and variability
- 2) Characterize the exospheric dust environment and measure its variability

Knowledge of the lunar environment will play a key role in planning for extended human habitation on the moon. Characterizing the lunar atmosphere is also significant, because the moon has a Surface Boundary Exosphere, which means that particles in the atmosphere are considered collisionless until impacting the surface of the moon. This type of atmosphere is common in our solar system and surrounds other objects such as Mercury, Europa, and large asteroids. Studying the physics of the lunar Surface Boundary Exosphere will give insight to the environment on many other similar bodies.

To measure the atmospheric content, LADEE will carry a neutral mass spectrometer (NMS) and a UV spectrometer (UVS) to identify the present elements. For dust measurements, LADEE will use a Lunar Dust EXperiment (LDEX) instrument capable of measuring submicron particles.

In addition to the primary science measurements, LADEE will also carry the Lunar Laser Com Demo (LLCD) technology demonstration. If successful, the LLCD system will transmit telemetry via an optical laser communication link to the surface of the Earth.

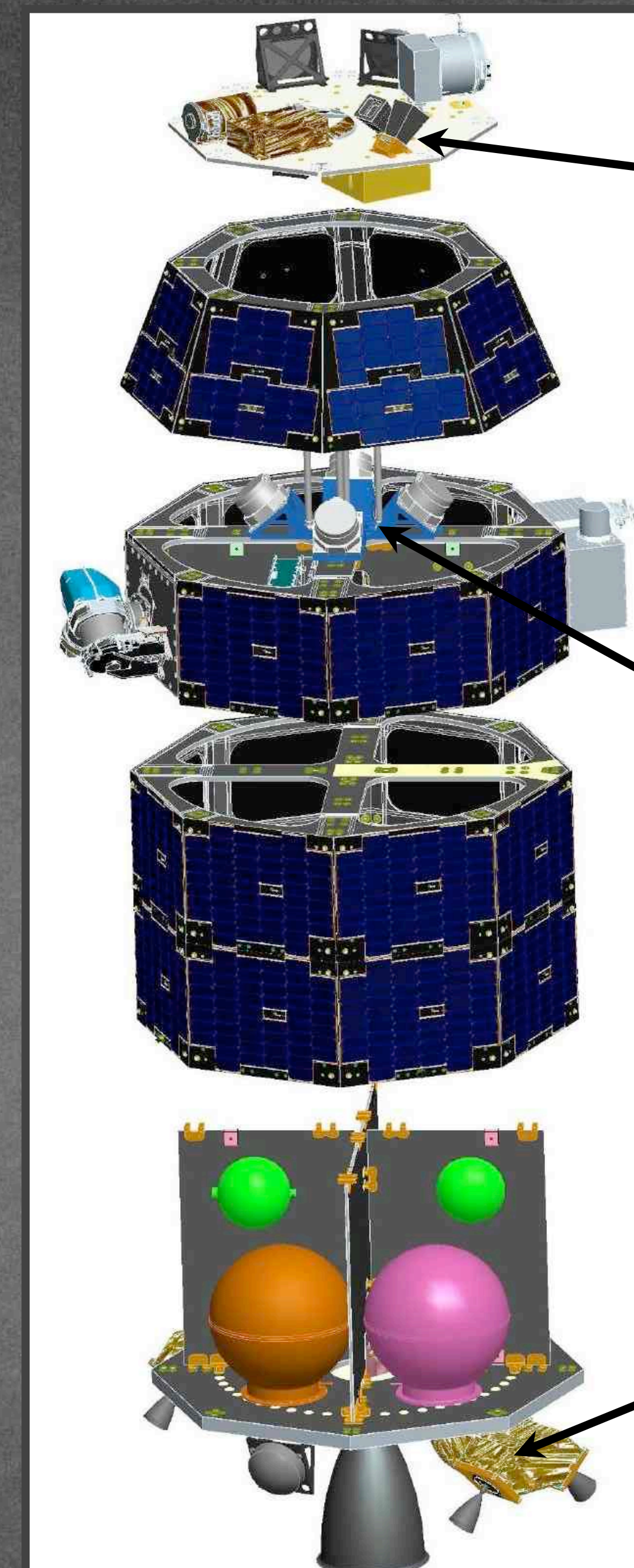


## LADEE Simulation

The flight software for the LADEE satellite is developed using Simulink, a visual programming language. Matlab's code generation tools are then used to automatically generate flight code from the Simulink model that runs on the actual satellite computer.

In order to test the flight code, the spacecraft and space environment are modeled and simulated. My modeling efforts have been focused on the control system hardware components. These are used by the LADEE simulation to test the physical response of the satellite to the control system software and verify that the control system meets performance requirements.

The integrated simulation package is also used to test other systems such as power, anomaly handling, and ground operations interaction with the spacecraft. All important activities that will occur during the mission are designed and tested with the LADEE simulation environment prior to launch.



Star Trackers

Reaction Wheels

Thrusters

## Sensors

LADEE will use star trackers for inertial reference measurements. Star trackers are cameras that measure their orientation with respect to the distant inertial star field by matching observed star patterns to the known star field stored in an onboard catalog. The LADEE control system will also use a set of control gyroscopes to improve the accuracy of the star tracker orientation measurements while also measuring the slew rate of the spacecraft.

## Actuators

The actuators used in the LADEE satellite control system are reaction wheels and thrusters. The reaction wheels are used to generate torques on the satellite to control its inertial orientation. The wheels spin in a direction opposite to the desired satellite rotation. The equal and opposite reaction, according to Newton's Third Law, rotates the satellite to its commanded attitude. The thrusters are used both to correct the satellite orientation and to propel it to its desired orbit around the moon.