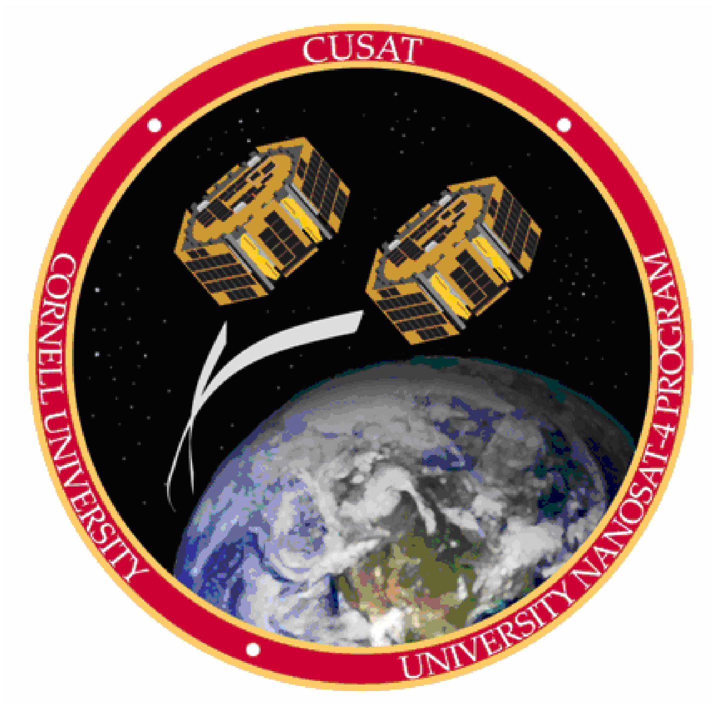
CORNELL UNIVERSITY

SPACE SYSTEMS LABS



SPONSORSHIP AND INFORMATION PACKET

Project Summary

The Cornell University Satellite (CUSat) project is a multi-year effort to design, build, and launch an end-to-end autonomous on orbit inspection system. The CUSat system will demonstrate a process through which one satellite can diagnose the structural health and configuration of another; a capability that will benefit commercial, government, and manned space missions envisioned for the coming decades. The space segment consists of two functionally identical satellites that will launch together and separate on orbit in a target-inspector configuration. Once in orbit, CUSat will use micro-thrust Pulsed Plasma Thrusters (PPTs) and sub-centimeter level accurate Carrier-phase Differential GPS (CDGPS) to navigate the satellites to within ten meters of each other. The inspector satellite will use cameras to gather imagery of the target satellite while performing relative navigation. Target satellite imagery will be transferred to the ground segment where they will be used to reconstruct a three dimensional model for the end user.

Competition Summary

The University Nanosat-4 Program (UNP-4) is a joint program between the Air Force Research Laboratory Space Vehicles Directorate (AFRL/VS), the Air Force Office of Scientific Research (AFOSR), the American Institute of Aeronautics and Astronautics (AIAA), and the National Aeronautics and Space Administration (NASA). The primary objectives of the program are to educate and train the future workforce through a national student satellite design and fabrication competition to enable small satellite research and development, payload development, integration, and flight test.

As finalists, eleven universities construct a protoflight Nanosatellite — a flight unit with full hardware traceability, that is subject to accelerated flight upgrades at the AFRL. This occurs over a two year period and culminates in an AIAA sponsored Flight Competition Review (FCR) in March 2007, during which one of the Nanosatellites will be selected for flight. The chosen satellite will undergo an accelerated integration and testing process, with aid from the AFRL, after which they will receive a free launch opportunity.

Professor Mason Peck

After leaving the Ph.D. program in English at the University of Chicago, Peck earned a B.S. in Aerospace Engineering from the University of Texas at Austin, where he also taught technical writing part time. He worked at Bell Helicopter in Fort Worth, Texas from 1993 to 1994 on structural dynamics for the BellAgusta Tiltrotor. From 1994 to 2001, he was an attitude dynamics specialist and systems engineer at Hughes Space and Communications (now known as Boeing Satellite Systems) in El Segundo, California. At Hughes he led the attitude dynamics development for the 702 spacecraft product line and worked on the GOES, ICO, TDRS, and Thuraya spacecraft in various capacities. While at Hughes/Boeing he conducted applied research in attitude control, multibody dynamics, fluid/structure interaction, launch-vehicle integration, and gyrostat dynamics. He has also contributed to classified spacecraft efforts and currently holds several U.S. government clearances. During his years at Boeing he served as attitude dynamics lead in the Boeing mission control center, participating in real-time spacecraft operations and helping to resolve spacecraft performance anomalies.

He earned his M.S. and his Ph.D. at UCLA as a Howard Hughes Fellow from 1998 to 2001. In 2001 he joined Honeywell Defense and Space Systems in Phoenix, Arizona, and in 2003 was named Principal Fellow. In that capacity, Peck led several research efforts, including the development of the momentum-control and line-of-sight test bed—a full-scale spacecraft dynamics and control simulator for agile spacecraft actuated by control-moment gyroscopes. He also led or contributed to efforts in areas such as gyroelastic structures, launch-vehicle stabilization, precision inertial-reference development, and the Space Tracking and Surveillance System payload dynamics and control. He has been issued several patents based on his work at Boeing and Honeywell.

ADVISORS

Professor Mark Campbell

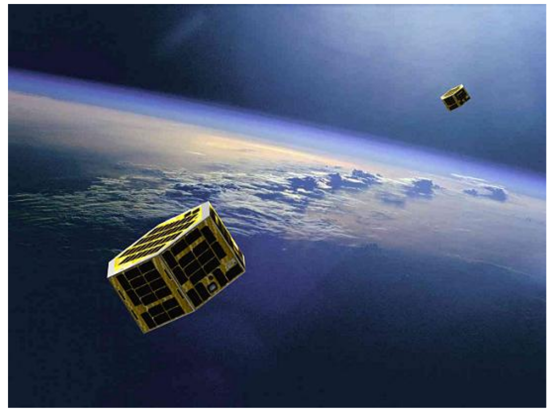
A graduate of Carnegie Mellon University (B.S.) and MIT (M.S., Ph.D.), Professor Campbell's doctoral work focused on the prediction of parameter uncertainties in 0-g. This work enabled the on-orbit implementation of MACE, a dynamics and control laboratory flown on the space shuttle Endeavour in 1995. Campbell was an Assistant Professor at the University of Washington from 1997 to 2001, and joined the Cornell University faculty as Associate Professor in 2001.

Professor Mark Psiaki

While a graduate student at Princeton, Dr. Psiaki was a National Science Foundation Fellow, a Guggenheim Honorary Fellow, and a Lothrop Honorific Fellow. Psiaki joined the Cornell University faculty in 1986. In 1994 he received a Lady Davis fellowship, and under this award he spent a sabbatical leave with the aerospace engineering faculty at the Technician in Haifa, Israel. He is an associate fellow of the American Institute of Aeronautics and Astronautics and served on its Guidance, Navigation, and Control technical committee from 1992 through 1995.

Dr. JinWoo Lee

Dr. Lee received his undergraduate degree in Mechanical Design and Production Engineering from Seoul National University in South Korea. Lee's doctoral work focused on a way to design the optimal controller for the stochastic linear MIMO systems specified by a multivariate sampling system. After completing his Ph.D. in Mechanical Engineering, Dr. Lee joined the Cornell faculty in 1998 as a research associate.

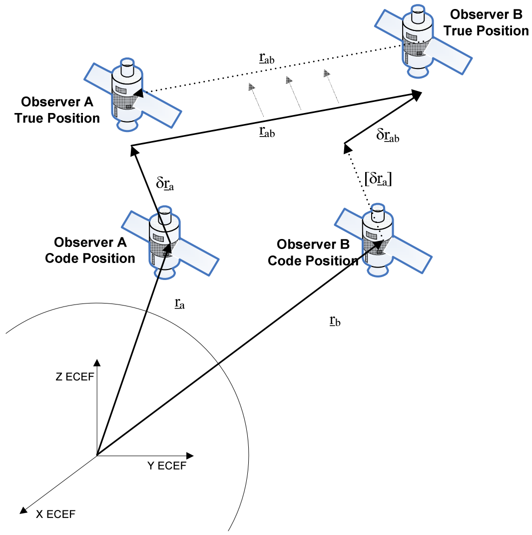


The nanosatellite CUSat is developing serves as an on orbit inspection system that can be applied to verify the condition of the surface of another spacecraft. This is one of the first steps that must be taken in the quest to create satellites that can then be used to repair and service themselves as well as other satellites while still in orbit. Having an autonomous method of servicing satellites would increase the lifetime of expensive satellites, greatly decreasing the expenditures that come with the alternative of building an entirely new satellite to replace the one in need of repair. Along with this ability, the autonomous service satellite would allow for modification of reliability and platform autonomy, and even the eventual exchange of the larger vehicle's payload. Once the servicing of satellites is mastered, the applications can be extended to even building completely new objects in space. At this point however, CUSat aims to provide a stepping stone to these achievements by demonstrating a system through which one spacecraft can diagnose the structural health and configuration of another.

Aside from the technological opportunities, CUSat offers a valuable learning experience for both undergraduate and graduate students. Students from a wide variety of disciplines work together on all levels of the project, including management, engineering, test and hardware assembly, to create a complete system. Students work together in a professional environment to design, build, and test a small satellite. In addition, CUSat incorporates a community outreach program where members of the team present the project to local children, talk to them about the process of building a spacecraft and give tours of the facilities.

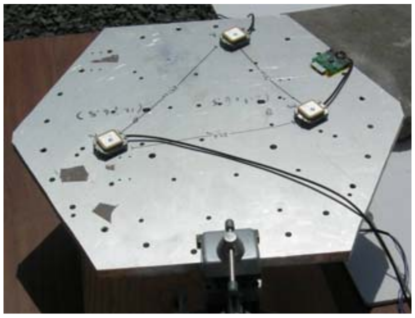
TECHNOLOGIES

CUSat's mission implements several key technologies that cannot be verified through simulation and terrestrial testing. Among these technologies are PPTs and closed-loop, autonomous inspection and navigation. CUSat will demonstrate these breakthrough technologies in a low-cost, orbital package, allowing future incorporation into more critical missions with confidence. CUSat will increase the Technology Readiness Level (TRL) of each with a lower total investment and at lower risk than otherwise available. Reliability and performance can be tested and studied on orbit, decreasing the cost and risk involved in future,



large-scale missions that will benefit from these technologies.

The primary aim of CUSat is to demonstrate CDGPS, providing a complete and cost-effective navigation solution with a high TRL. CDGPS has a high performance to cost ratio and has been designed to maximize adaptability. Combined with relatively low implementation complexity, CDGPS based GNC is ideally suited for a wide spectrum of missions.



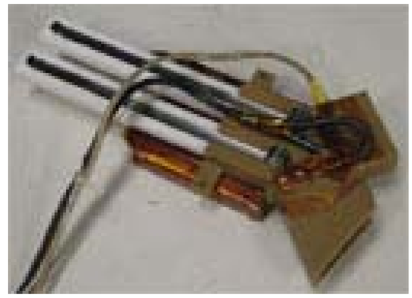
Each satellite half employs three GPS antennas, which when accompanied with a Geometric Dilution of Precision (GDOP) of less than two, provides absolute navigation solutions accurate to within ten meters. Under these conditions, CDGPS also makes possible relative positioning with centimeter-level accuracy when at least five satellites are visible to each antenna. Both simulation data and terrestrial field test data suggest positioning accurate to within centimeters and pointing accurate to magentometer levels—approximately two degrees of instantaneous pointing accuracy.

CDGPS requires minimal calibration, a simple interface and has a modular design. The centimeter level accuracy of CDGPS enables precise attitude determination for satellites that involve close-proximity operations. This high precision enables numerous attitude sensitive technologies, such as in-orbit inspection, construction, repair, or any application that requires high pointing accuracy.

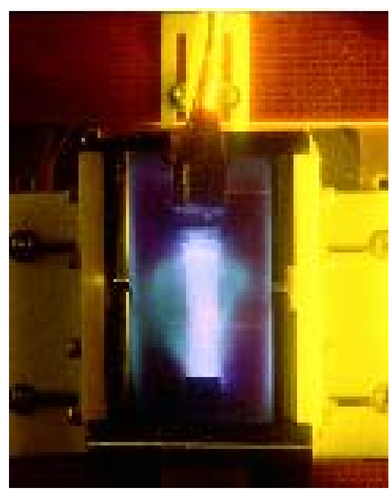
A general pulsed plasma thruster and power processing unit (PPT/PPU) system has been used to control numerous spacecraft in the last 30 years. The CUSat satellites will be propelled by a

PPT/PPU system developed by Christopher Rayburn and Professor Mark Campbell in conjunction with the University of Washington. This system was designed for light space vehicles in the nano or micro satellite class. PPTs are much less complex than gas systems, using solid fuel rather than high pressure gas. Additionally, their low thrust is better for controlling light-weight spacecraft such as CUSat, where precision formation flying is required. The pulsed plasma thruster operates by rapidly discharging the energy stored in a capacitor — powered by the PPU — across the face of a solid Teflon fuel bar, converting a small amount of solid Teflon to plasma. The plasma is a partially ionized vapor. This rapid change of the electric field between the electrodes that surround the fuel creates a strong magnetic field that accelerates the ionized portion of the gas. The use of solid Teflon fuel eliminates the mechanical complexity of a using a gaseous propellant since only a simple spring is needed to feed the Teflon fuel bar.

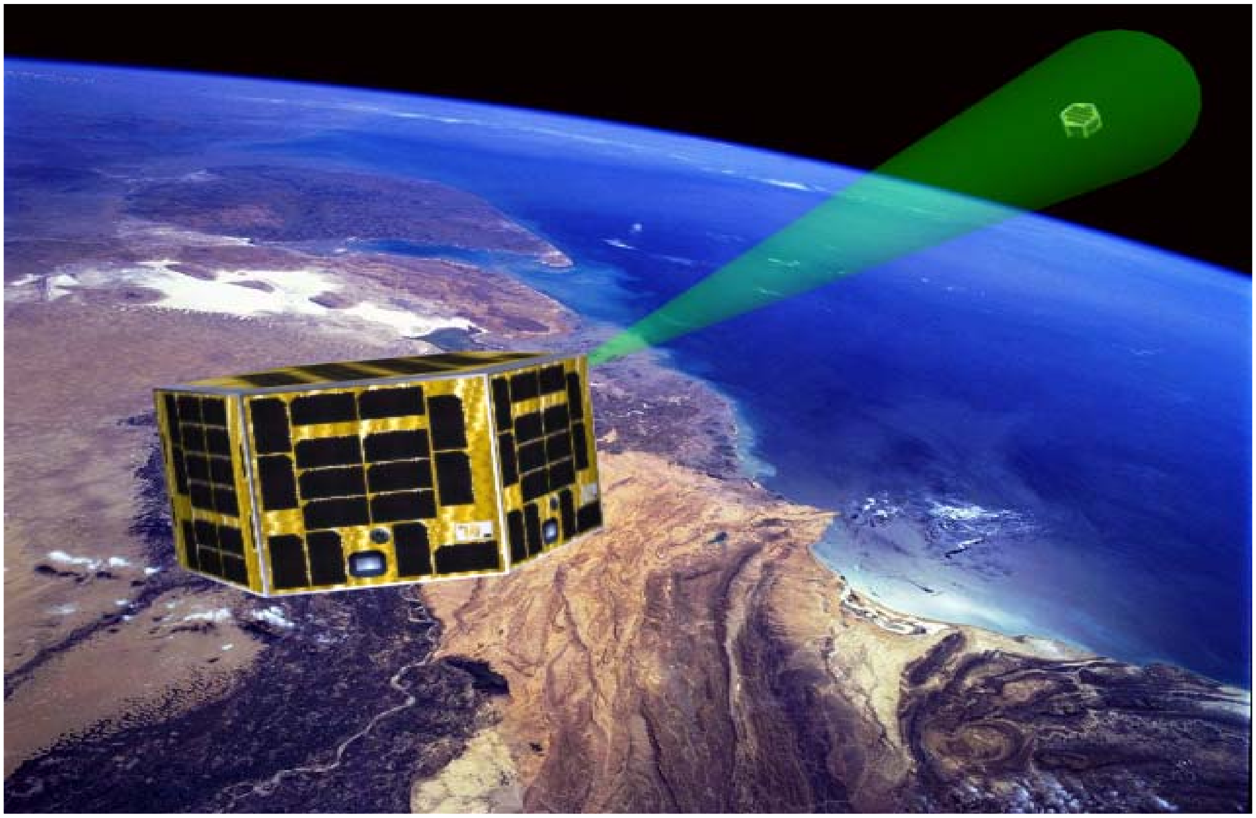
CUSat is an end-to-end system that autonomously inspects objects on orbit and transmits, processes, and formats this inspection data. Such as system, provides the option of in-space surface failure detection and diagnosis. With the ability to detect and diagnose surface failure, it becomes easier to monitor the system health of any satellite that has been outfitted with the necessary equipment. CUSat offers a complete turnkey system that provides an inspector, a ground segment, and a CU-RelNav target module. The CU-RelNav kit is composed of three GPS receivers, three GPS antennas, a computing board, and a data crosslink. This integrated system provides enough information for an inspector to determine the relative attitude and relative position of a target. The technology demonstration package being flown on board CUSat can be further modularized yielding a solution, enabling future programs to build-in robustness while buying down risk. Becuase CUSat is an end-to-end system, it can be adapted directly for use with other spacecraft that carry the CU-RelNav kit. CDGPS makes centimeter-accurate relative position and relative attitude determination possible, enabling close-proximity navigation, on orbit construction and on orbit inspection.

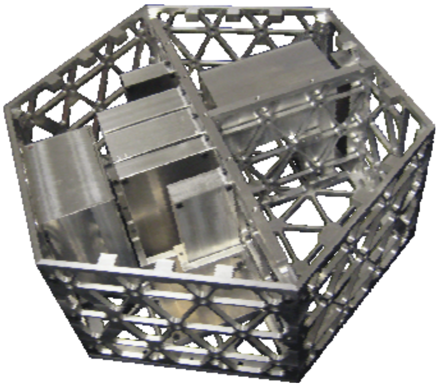


The satellites provide a method for demonstrating self reliant control and through this a solution for autonomous inspection. CUSat's mission objectives contribute towards further developing several technological areas of interest.



Such capabilities further provide a platform for development of on orbit servicing, by demonstrating the technologies necessary to make this possible. CUSat implements advanced science instrumentation and detector technologies to demonstrate the possibilities of survey grade GPS receivers in real time.



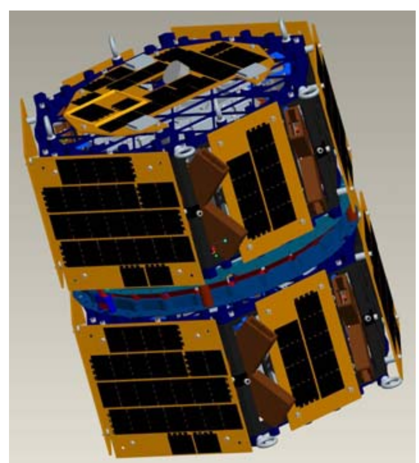


The CUSat team is a group of exceptional and diverse students and researchers. The team consists of nearly 90 members ranging from freshmen to post doctorate researchers and faculty members. Team members are pursuing degrees in Mechanical and Aerospace Engineering, Electrical and Computer Engineering, Applied and Engineering Physics, Computer Science, Applied Economics and Management, and Architecture.

The CUSat Satellite project extensively employs Systems Engineering. The Systems group, lead by the project manager, is largely responsible for providing the project with direction by defining top-level system requirements, establishing best practices, maintaining communications, and facilitating design choices. Reporting to the Systems group are over a dozen subsystems that focus on various components and technologies of the satellite. Each of the subsystem leads participates as a member of the Systems group, which allows the project to maintain consistency, open communication, and focus.

CUSat is comprised of eleven subsystems, each responsible for different aspects of the mission. For orbit control, CUSat will be using PPTs, torque coils, and a miniature reaction wheel assembly. The PPTs give each satellite three degrees of translational freedom and three degrees of rotational freedom. Through the use of GPS antennas, CDGPS will be used to ascertain attitude determination and navigate the spacecrafts. Due to the small external surface of the nanosatellite, a high-efficiency solar array must be incorporated to harness solar energy to power the spacecraft systems. Using a commercial off the shelf (COTS) single board computer running Windows CE and C++, CUSat will execute relative navigation algorithms and flight code. CUSat will acquire images while in orbit, compressing them in a modified JPEG format, and relaying them to the onboard computer.

The images are then transmitted to the ground segment through radios operating in amateur frequency bands for construction of a three dimensional model that can be used for surface inspection and verification of CDGPS.

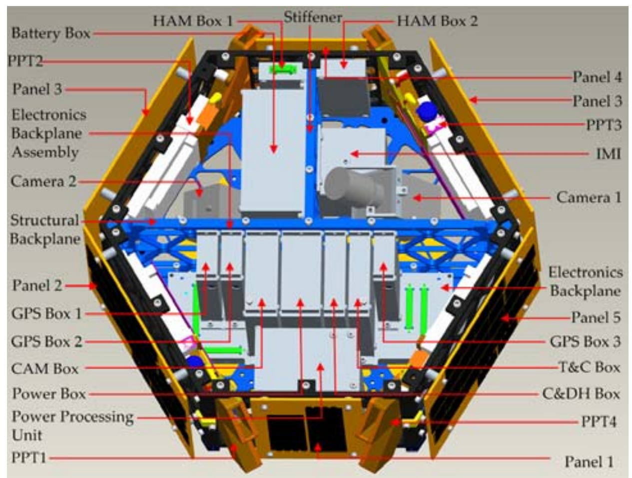


CUSat is partnering with Northrop Grumman Mission Systems, who have offered access to ground stations in Redondo Beach, California and Colorado Springs, Colorado.

Yet before these exciting technologies can be demonstrated on orbit, the entire system

integration of CUSat will consist of a three phase process. The first phase consists of integrating subsystems and verifying the system design by completing an engineering design unit. This phase also incorporates design rework and finalization. As the engineering design unit finishes, the second phase – flight electrical integration – begins, which consists of procuring all flight electronics in time to begin the flight electronics build, test and integration.

Following verification of the flight electronics, the program will enter its final phase: mechanical integration. In this phase, the two flight units will be integrated and tested separately, followed by full systems integration. Following full integration, system checkout tests will be performed. Once all checkouts have been completed, CUSat will be ready for integration into a launch vehicle and mission operations.



Though CUSat has received a generous seed grant from the Air Force Office of Scientific Research (AFOSR), a great deal of funding is still necessary. And while CUSat is significantly cutting cost by effectively implementing commercial off-the-shelf hardware and software such as Microsoft® Windows and amateur radios, other novel technologies require significant in kind and monetary sponsorships. To date approximately 60,000 man-hours have been invested in the program, representing the equivalent of several million dollars in engineering time. Discounting several high-price items, CUSat is facing a projected cost balance of $221,250.

Sponsorship of the CUSat team — financial or otherwise — would provide national media xposure of relations with Cornell University as well as a direct exposure to an elite pool of student knowledge for employer recruiting. It would also clearly demonstrate a dedication to education and research. Any hardware donations would exhibit the capabilities of you/your company's products to potential customers including the United States Air Force, and NASA, as well as detailed reviews of donated hardware by CUSat engineers. Tax-deductible charitable donations and personal donations are eligible for most corporate matching funds programs. Many of the components have already been designed or chosen, such as printed circuit boards, connectors and cabling, cameras, mechanical tools and fasteners. However, any financial contribution would be subject to established procurement processes that are already in place to ensure the responsible disbursement of all CUSat funds.

We invite you to join us, and the following sponsors, as we design, build, and launch an autonomous in-orbit satellite inspection system that will not only provide an unparalleled educational opportunity for nearly 90 Cornell Engineers, but make a significant contribution to the development of space sciences and mankind's role in space exploration.

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- Logo and link on sponsor page of team website.
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