Naval Postgraduate School

The mission of the Naval Postgraduate School is to enhance the security of the United States of America through graduate and professional education programs focusing on the unique needs of the military officers. These programs are sustained by research and advanced studies directed towards the needs of the Navy and DoD. Our goals are to increase the combat effectiveness of the armed forces of the U.S. and its allies and to contribute to fundamental scientific, engineering, policy, and operational advances that support the Navy, DoD, and other national security establishments.

(591) Space Systems Engineering Matrix, ASTRO

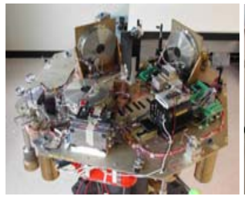
Engineering Science Refresher Quarter – 460

0 Su	NW3230 (4-0) Strategy & Policy *(All)*	MA1043 (2-0) Matrix Algebra *(Su)*	MA1118 (5-2) Multi Variable Calc *(All)*	PH1001 (4-2)& PH1002 (4-2) Physics I & II *(Su)*

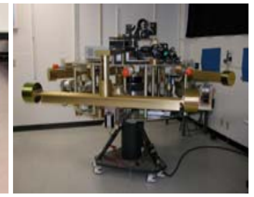
Core Curriculum

1 F	AA2440 (3-2) Introduction to Digital Computation (Sp/F)	AA2820 (3-2) Structures *(F)*	MA2121 (4-0) Differential Equations (All)	EC2820 (3-2) Digital Logic Circuits *(Sp/F)*
2 W	SS2500 (4-0) Orbital Mechanics (or MA 4362) *(W)*	PH2514 (4-0) Space Environment *(W)*	MA3046 (4-1) Matrix Analysis *(W/Su)*	EC2300 (3-2) Controls *(W/Su)*
3 Sp	AA3815 (3-2) Spacecraft Dynamics *(Sp)*	EO2525 (4-1) Analysis of Signals for Comms *(Sp)*	SS3525 (3-2) Remote Sensing *(W/Sp)*	AA 3830 (3-2)* Guidance & Control AA 3811(2-2)* Space Lab (Sp)
4 Su	AA3851 (3-2) Spacecraft Propulsion *(Su)*	EO3525 (4-1) Communications Engineering (Su)	AA3804 (3-0) Thermal Control of Spacecraft (Sp)	ME 3521 (3-2)* Mechanical Vibrations (Su)
5 F	AA3818 (3-2) S/C Attitude Dynamics & Control *(F)*	PH3360 (4-1) EM Waves (or PH 2351 & 3352) *(F)*	SS3035 (3-2) Microprocessors (or EC2840 & 3800) *(F)*	AA 3820 (3-2)* Space Systems Dynamics *(F)*
6 W	AA3870 (2-2) (Acc) Spacecraft Design Tools *(W)*	EC3230 (3-1) (Acc) Space Power *(W)*	SS3001 (3-2) (Acc) Military Appl of Space *(W)*	SS0810 (0-8) Thesis Experience Tour *(W)*
7 Sp	AA4870 (4-0) Spacecraft Design I *(Sp)*	EO3535 (3-2) Spacecraft Communications *(Sp)*	AA 4850 (3-2)* Astrodynamic Optimization *(F)*	AA 4816 (4-0)* Dynamics & Control of Structures *(Sp)*
8 Su	AA4871 (2-2) Spacecraft Design II *(Su)*	Elective* AA 4XXX	Elective	SS0810 (0-8) Thesis Research *(All)*
9 F	MN3331 (5-1) or MN3321&3322 Systems Acquisition & Program Mgmt *(All)*	SS0810 (0-8) Thesis Research *(All)*	SS0810 (0-8) Thesis Research *(All)*	Elective * AA XXXX

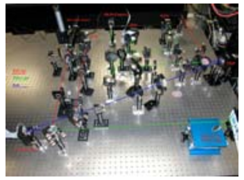
*** Core courses for MS Astronautical Engineering**



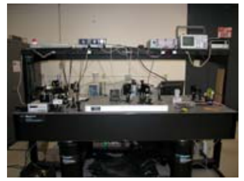
Three-Axis Simulator 1



Three-Axis Simulator 2



Adaptive Optics Test-bed



Laser Jitter Control Test-bed

Spacecraft Research and Design Center

Fltsatcom Laboratory

HEL Beam Control Testbed

Flexible Spacecraft Simulator

Spacecraft Design Laboratory

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NAVAL POSTGRADUATE SCHOOL

Spacecraft Research & Design Center

The Spacecraft Research and Design Center at the Naval Postgraduate School consists of six state-of-the art laboratories: Fltsatcom Laboratory, Spacecraft Attitude Dynamics and Control Laboratory, Smart Structures laboratory, Spacecraft Design Center, NPS-AFRL Optical Relay Mirror Spacecraft Laboratory, and Satellite Servicing Laboratory. These laboratories are used for instruction and research in space system engineering and space operations curricula. The emphasis has been on providing students with hands-on experience in the design, analysis, and testing of space systems and systems and to provide students facilities for experimental research. The emphasis in the research h areas is on acquisition, tracking and pointing of flexible spacecraft with optical payloads; active vibration control, Isolation, and suppression using smart structures; space robotics, satellite servicing, space system design, and computer aided design tools. These laboratories have been used in joint projects with Naval Satellite Operational Center, NRL, AFRL, Columbia University, and Boeing.

Distinguished Professor Brij N. Agrawal

Dr. Brij Agrawal is currently Distinguished Professor in the Department of Mechanical and Astronautical Engineering and Director of Spacecraft Research and Design Center at the Naval Postgraduate School (NPS). He has developed research programs in acquisition, tracking and pointing of flexible spacecraft with optical payloads; active vibration control, Isolation, and suppression using smart structures; space robotics, satellite servicing, space system design, and computer aided design tools. Prior to joining NPS in 1989, he worked for twenty years for Communications Satellite Corporation (COMSAT) and International Telecommunications Satellite Organization (INTELSAT) where he conducted research in spacecraft attitude control, spacecraft structures, spacecraft system designs, and spacecraft testing. He participated in the development of INTELSAT IV, IV-A, V, VI, and VII, COMSTAR, and MARISAT satellites. Professor Agrawal has written first text book on spacecraft design "Design of Geosynchronous Spacecraft", has over 70 technical paper publication and has a patent for an attitude pointing error correction system for geosynchronous satellites. He received Ph. D. in Mechanical Engineering in 1970 from Syracuse University and MS in Mechanical Engineering in 1968 from McMaster University, MS in Mechanical in 1966 from Roorkee University and BS in Mechanical Engineering in 1964 from Banares Hindu University. He has received NPS Outstanding Teacher Award, NPS Outstanding Researcher Award, an AIAA Space System Design Award, and INTELSAT Award for Inventiveness and Technological Contribution. Professor Agrawal is an Associate Fellow of AIAA and a registered P. E. in the state of Maryland.

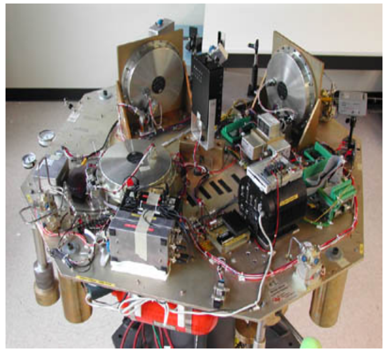
Thesis/Research Opportunities

Analytical and experimental investigation are performed to develop technologies for acquisition, tracking and pointing of flexible spacecraft with optical payloads; active vibration control, Isolation, and suppression using smart structures; space robotics, satellite servicing, space system design, and computer aided design tools.

- Slew maneuver torque profile to minimize settling time.
- Active vibration isolation/suppression using smart sensors and actuators
- Fast steering mirror pointing/jitter control
- Improved multi-body flexible dynamics and control models
- Adaptive Optics Control
- On-orbit system identification of spacecraft inertia and structural natural frequencies
- Ground test beds to validate spacecraft pointing performance.
- Satellite servicing dynamics and control
- Computer-aided spacecraft design optimization
- Fltsatcom ground telemetry and command systems.

Publications

- Watkins, R. and Agrawal, B. "The use of an LMS Filter in the Control of Optical Beam Jitter", AIAA Journal of Guidance, Control, and Dynamics. Vol. 30, Number 4, July-August 2007.
- Sugathevan, S. and Agrawal, B. "Optical Laser Pointing and Jitter Suppression using Adaptive and Feedback Control Methods," Proceedings of Beam Control Conference, Directed Energy Professional Society, Monterey, CA, March 21-24, 2006.
- Kim, J. and Agrawal, B. "Experiments on Jerk-Limited Slew Maneuvers of a Flexible Spacecraft", AIAA Guidance, Navigation, and Control Conference and Exhibit, August 21-24, 2006.
- Kim, J. and Agrawal, B., "Acquisition, Tracking, and Pointing of Bifocal Relay Mirror Spacecraft," Proceedings of Beam Control Conference, Directed Energy Professional Society, Monterey, CA, March 21-24, 2006.
- Agrawal, B. N., Kim, J.-W., Romano, M., "Attitude Control and Determination of the NPS Bifocal Mirror Testbed," 55th International Astronautical Conference, Vancouver, Canada, 2004.
- Romano, M., Agrawal, B. N., "Attitude Dynamics/Control of Dual-Body Spacecraft with Variable-Speed Control Moment Gyros", AIAA Journal of Guidance, Control, and Dynamics, vol. 27, No. 4, pp. 513-525, July-August 2004.
- Agrawal, B. N., and Chen, H., "Algorithms for Active Vibration Isolation on Spacecraft," Journal of Smart Materials and Structures, Vol 13, pp 873-8880, 2004.
- Watkins, R. J., Agrawal, B.N., Shin, Y.S., and Chen, C., "Jitter Control of Space and Airborne Laser Beams",22nd AIAA International Communications Satellite Systems Conference, Monterey, CA, 9-12 May, 2004.
- Chen H., Hospodar Jr., E., and Agrawal, B. N., "Development of a Hexapod Laser –based Metrology Systems for a Finer Optical Beam Control ",AIAA International Communications Satellite Systems Conference, Monterey, CA, 9-12 May, 2004.

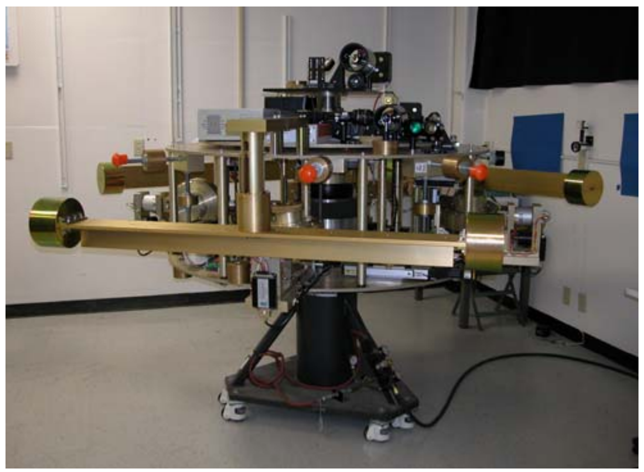


Optical Relay Mirror Laboratory

Three-Axis Simulator 1

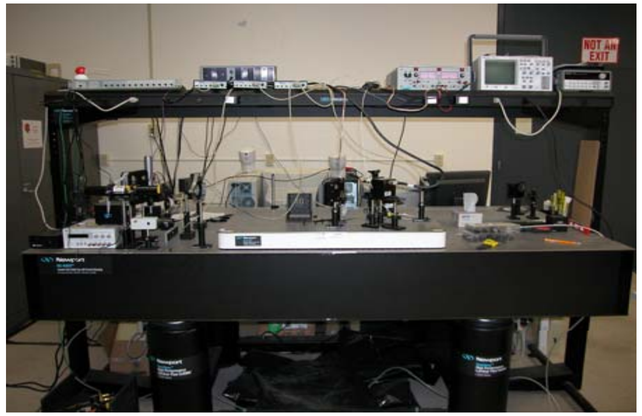
A new joint NPS and AFRL laboratory, NPS-AFRL Optical Relay Spacecraft Laboratory, was dedicated on June 5, 2002. This laboratory is used for both instruction and research on acquisition, tracking, and pointing of flexible military spacecraft. Three-axis simulator 1 can simulate spacecraft three-axis motion as well as the optical system of a space telescope. The spacecraft simulator has three reaction wheels and thrusters as actuators; rate gyros and sun sensors as sensors; on-board processor; batteries; and supported on a spherical air bearing. The optical system consists of laser source, a fast steering mirror, jitter sensor, and a video camera as a tracking sensor.

Three-Axis Simulator 2



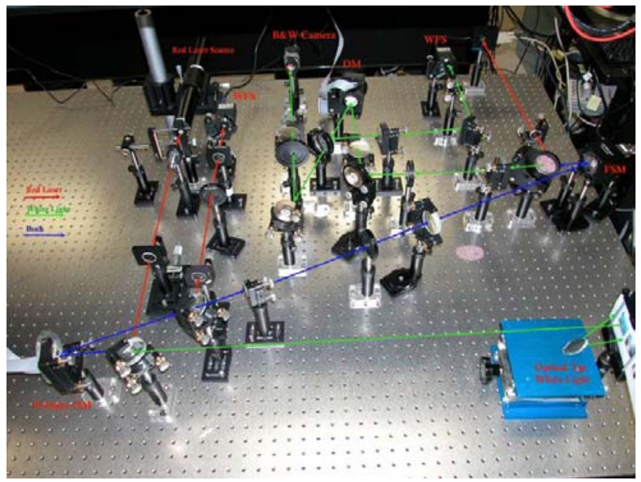
The three-axis simulator 2 can be divided into three modules: spherical air bearing, spacecraft bus module and optical payload module. The spacecraft bus has three variable speed control moment gyros (CMGs), Northrop Grumman Litton LN-200 IMU consisting of three fiber optics rate gyroscopes, sun sensors, magnetometers, inclinometer, fine sensor, batteries, power switching and control electronics, and automatic balancing system. The optical payload consists of receive telescope and associated optical equipment on the upper platform and transmit telescope and associated optical equipment on the lower platform.

Laser Jitter Control Test-bed



The purpose of the test-bed is to Investigate control methods to reduce optical jitter and mitigate disturbances to optical beams and structures. Emphases are made on Adaptive Control methods due to the expected changing environment.

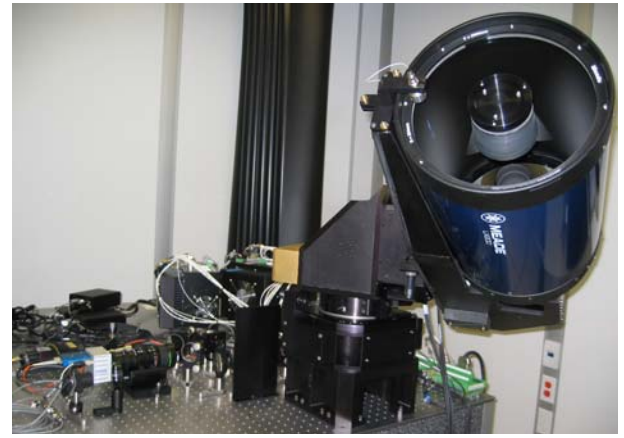
Adaptive Optics Test Bed



The purpose of this test-bed is to develop improve control techniques for adaptive optics. The current application is controlling surface of large flexible mirrors in space. The test bed has two adaptive optics systems (two deformable mirrors and two wave front sensors). One system corrects the surface of flexible mirror and the other system correct the aberration in imaging object beam. The test bed also has fast steering mirror for correcting jitter. The test bed has two beams: reference beam and object beam. The reference beam is used by the sensors and actuators to correct flexible mirror surface and beam jitter introduced in the spacecraft.

Adaptive Optics Beam Control Laboratory

High Energy Laser (HEL) Beam Control Testbed



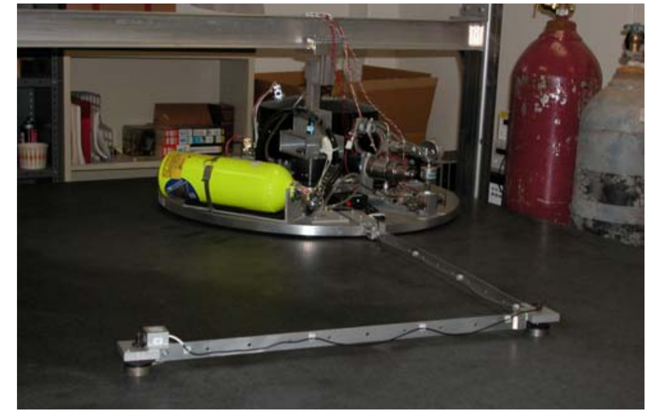
High Energy Laser (HEL) Beam Control Testbed is used to test and evaluate beam control techniques such as adaptive optics, jitter control, and structure/optics optimization required for directed energy systems. The HEL Testbed is housed in a class 10,000 clean room facility

FLTSATCOM Laboratory

This laboratory, as shown in the figure, consists of a qualification model of the Navy communications satellite, FLTSATCOM, the associated ground support equipment for testing the satellite, and the FLTSATCOM Attitude Control Simulator, which provides a graphical display of the spacecraft's attitude and rotational motion in response to commands similar to the commands required for flight model FLTSATCOM spacecraft.

Spacecraft Attitude Dynamics and Control Laboratory

Flexible Spacecraft Simulator (FSS)



FSS, as shown in the figure, simulates attitude motion in the pitch axis of a flexible spacecraft. It consists of a central rigid body representing the spacecraft central body and a flexible appendage representing a reflector with a flexible support structure. This system is floated on air pads over a granite table to simulate a micro-gravity environment. The actuators are thrusters with air supplied by a compressed air bottle and a momentum wheel

Spacecraft Design Laboratory

This laboratory houses computer–aided design tools for spacecraft design and a spacecraft design library. It has GENSAT, a general-purpose software application for the satellite design, and Conceptual Design Center (CDC) software from Aerospace. In addition, it has several subsystem design software, such as STK, NASTRAN, IDEAS, Matlab/Simulink. Using these unique design tools, students can do collaborative spacecraft design