Department of Aeronautics and Astronautics

Undergraduate Enrollment over the Last Ten Years

	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01	01–02	02–03	03–04[a]
Sophomores	36	36	30	46	40	48	59	68	56	64	72
Juniors	31	37	31	23	33	37	40	53	69	51	59
Seniors	66	38	37	29	24	35	37	45	53	70	61
Total	**133**	**111**	**98**	**98**	**97**	**120**	**136**	**166**	**178**	**185**	**192**
Women	32%	31%	29%	26%	30%	33%	30%	32%	33%	35%	34%
Minorities	23%	19%	16%	18%	22%	15%	12%	21%	22%	30%	30%

[a] 2003–2004 data are based on fifth-week enrollment.

Graduate Program Enrollment Statistics, Academic Year 2003–2004

	February '04	June '04	September '04	Total
Applications	14	0	250	264
Admitted	6	0	136	142
Accepted Admission	5	0	76	81
SM	5	0	65	70
PhD	0	0	11	11
Minority	0	0	3	3
SM	0	0	2	2
PhD	0	0	1	1
Female	0	0	15	15
SM	0	0	14	14
PhD	0	0	1	1
Funding Accepted				
Fellowship (MIT)	0	0	5	5
Fellowship (other)	2	0	6	8
RA & Draper	2	0	26	28
TA	0	0	2	2
Other	1	0	0	1

Undergraduate Awards

The following awards were presented at the Aeronautics and Astronautics Department Senior Recognition Dinner on Monday, May 10, at the University Park Hotel, Cambridge, MA.

The Andrew Morsa Prize for demonstration of ingenuity and initiative in the application of computers to the field of aeronautics and astronautics was presented to Chinwe P. Nyenke and Shen Qu for the design and development of a display evaluation procedure for an advanced terrain warning system; and to Michael S. Fritts and Robert W. Grimes for the design and development of a UAV autonomous airspeed control system.

The Yngve Raustein Award, given to a student in unified engineering who best exemplifies the spirit of Yngve Raustein and to recognize significant achievement in this area, was presented to Lauri O. Kauppila for the spirit of community he has brought it and for his achievements in design optimization and piloting proficiency in the unified engineering design contest.

The David Shapiro Award to pursue special aeronautical projects that are student-initiated and/or to support foreign travel for the enhancement of scientific/technical studies and research opportunities was presented to David A. Broniatowski to attend the International Space University summer program; to Thomas M. Coffee for the study of an integrated organizational and analytical tool for systems engineering; to William K. Chen, Jordan J. McRae, and Allen D. Wu for the study of “The Basilisk: A Versatile Robotic Air Cushion Vehicle”; and to Carl Engel and Adam Woodworth to enter the 2005 International Micro Air Vehicle Competition.

The Apollo Award for best undergraduate research project on the topic of humans in space or for successful participation in a Course 16 design project was presented to Laura R. Messeri and Dominic A. Rizzo for the development of a haptic feedback glove for remote grasping.

The Thomas Sheridan Award, given to an Aero-Astro or Mechanical Engineering undergraduate student whose research or design project best exemplifies creativity or improvement in human-machine integration or cooperation, was presented to Chinwe P. Nyenke and Shen Qu for outstanding work on display evaluation of an advanced terrain warning system.

The Leaders for Manufacturing Prize, awarded to 16.622 students who have used their project to directly deal with issues that are related to the interaction between manufacturing and engineering, was presented to Miguel Macias and Melanie A. Miller for outstanding work in the exploration of reliability and cost reduction of using shear pins to control the launch of rockets.

The United Technologies Corp. Prize for outstanding achievement in the design, construction, execution, and reporting of an undergraduate experimental project was presented to Julie A. Arnold and Paula Echeverri for outstanding performance in the development of a method for protecting payloads during parachute drops.

The Admiral Luis De Florez Prize for original thinking or ingenuity as demonstrated by the individual effort of the student, not the ideas and suggestions of his advisor, instructors, or an advisory team, was presented to Emily Schwartz and Christopher J. Sequeira for original thinking and ingenuity in the design and construction of an apparatus to measure the propulsive efficiency of a flapping wing; and to Kathleen M. McCoy and Darlene A. Utter for demonstrated ingenuity and perseverance in the execution and completion of their project on long-range visibility and driver braking reaction.

The James Means Award for Excellence in Space Systems Engineering was presented to Philip N. Springmann for outstanding analysis of low earth orbit communications satellite systems with subsequent publication in the *21st AIAA International Communications Satellite Systems Conference* and in the *Journal of Spacecraft and Rockets*.

The James Means Award for Excellence in Flight Vehicle Engineering was presented to Charles T. Wesley for outstanding engineering analyses, systems testing, and systems integration of the propulsion system in the 16.82x Phaeton quad-rotor Aero capstone project.

The Henry Webb Salisbury Award for outstanding academic achievement was presented to Glenn P. Tournier for outstanding academic performance in pursuing two rigorous undergraduate programs—aeronautics and astronautics and electrical science and engineering.

The Aero & Astro Teaching Assistantship Award, given to a teaching assistant who has demonstrated conspicuous dedication and skill in helping fulfill a departmental undergraduate or graduate subject's educational objectives, was presented to Farmey A. Joseph.

The AIAA Undergraduate Advising Award, given by the AIAA Student Chapter to a faculty or staff member who has demonstrated excellence in serving as an academic or 16.62x advisor, was presented to Col. John E. Keesee.

The AIAA Undergraduate Teaching Award, given by the AIAA Student Chapter to a faculty or staff member who has exemplified the role of a "great teacher," was presented to Professor Karen E. Willcox.

The Sigma Gamma Tau Society Graduate Teaching Award, given by the MIT Student Chapter of the Aero-Astro Honors Society to a faculty or staff member who has exemplified what graduate students consider to be a "great teacher," was presented to Professor Dava J. Newman.

Faculty Awards

Professor Olivier de Weck was given the Robert N. Noyce career development professor, a three-year appointment retroactive to September 2002 (http://esd.mit.edu/HeadLine/deweck_appointed.html). He won the best paper award in the modeling and tools category at the 2004 INCOSE International Systems Engineering Conference in June 2004 for a paper coauthored with M. B. Jones, "Isoperformance: Analysis and Design of Complex Systems with Known or Desired Outcomes." With Professor Chris Magee, he won a second-best paper award at the same conference in the education and research category for a paper entitled "Complex Systems Classification."

Professor Edward M. Greitzer's book entitled *Internal Flow: Concepts and Applications* was published earlier this year. The coauthors are C. S. Tan (principal research engineer) and M. B. Graf. The prospective audience spans from first-year graduate students to practicing engineers. While a number of excellent texts focus on the external flow around aircraft, ships, and automobiles, for many engineering fluid devices (jet engines or other propulsion systems, fluid machinery) the motion is appropriately characterized as an internal flow and there is no unified treatment of these situations. The aim of the text is to provide such a treatment.

Professor John Hansman was nominated and selected to give the AIAA Dryden Lecture in Aeronautics Research.

Col. John Keesee won the AIAA Undergraduate Advisor Award at the May Senior Recognition Dinner.

Professor Nancy Leveson received the ACM Sigsoft Outstanding Research Award; the Nico A. Habermann Award; and four best paper awards. In addition, she received the title of distinguished professor by the Computing Research Association and presented the Robert T. Chien Distinguished Lecture at the University of Illinois, Urbana-Champaign.

A paper coauthored in 1971 by Professor Earll Murman was one of 36 papers republished in a special July 2003 issue of the *AIAA Journal* titled "Centennial of Powered Flight: A Retrospective of Aerospace Research." The paper, titled "Calculation of Plane Transonic Flows," was selected from amongst all the papers published between 1934 and 1982 in the *AIAA Journal* and its predecessors.

A book entitled *Lean Enterprise Value: Insights from MIT's Lean Aerospace Initiative* (Palgrave, 2002) was awarded the 2003 Engineering Sciences Book Award by the International Academy of Astronautics (http://www.iaanet.org/). Professor Earll Murman, the book's lead author, received the award in a ceremony in Bremen, Germany, on September 28, 2003. The book was written by a team of MIT scholars affiliated with the Engineering Systems Division (http://web.mit.edu/org/c/ctpid/www/index.html) and its Center for Technology, Policy, and Industrial Development, which is home to the Lean Aerospace Initiative (http://web.mit.edu/lean/). The coauthors were Kirk or Bodega, CTPID principal research associate; Earll M. Murman, Ford professor of engineering and professor of aeronautics, astronautics, and engineering systems; Deborah Nightingale, professor of the practice of aeronautics and astronautics and engineering systems (http://esd.mit.edu/Faculty_Pages/nightingale/nightingale.htm); Eric Reenlist, CTPID research associate; Tom Shields, CTPID research associate; and Sheila Windfall, Institute Professor and professor of aeronautics, astronautics, and engineering systems (http://esd.mit.edu/Faculty_Pages/widnall/widnall.htm). Other coauthors formerly affiliated with MIT are Hugh McManus, Fred Stahl, Myles Walton, Joyce Warmness, and Stanley Weiss.

Professor Dava Newman received the Sigma Gamma Tau Society (Aerospace Honor Society) Graduate Teaching Award for "exemplifying the qualities of a Great Teacher including not only her ability to present information clearly and well, but also for her dedication to individual students in and out of class."

Professor Newman was promoted to full professor.

Professor Moe Win has been involved actively in organizing and chairing sessions and has served as a member of the Technical Program Committee in a number of international conferences. He served as the technical program chair for the IEEE Communication Theory Symposium of ICC–2004. He is the secretary for the Radio Communications Technical Committee of the IEEE Communications Society and the current area editor for *Modulation and Signal Design* and editor for *Wideband Wireless and Diversity,* both for IEEE *Transactions on Communications.*

In 2003, Professor Win received an MIT School of Engineering Educational Innovation Award, Young Investigator Award from the Office of Naval Research, and the IEEE Antennas and Propagation Society's Serge A. Schelkunoff Transactions Prize Paper Award. In 2004, he was named Young Aerospace Engineer of the Year by AIAA, awarded the Fulbright Foundation Senior Scholar Lecturing and Research Fellowship, and elected fellow of the IEEE, cited "for contributions to wideband wireless transmission."

Professor Moe Win was invited to serve on a panel of the National Research Council's Forum on Spectrum Management Policy Reform, sponsored by the National Academies and the National Telecommunications & Information Administration, Washington, DC, February 2004. He delivered an invited plenary presentation at the WNCG Wireless Networking Symposium, Austin, TX, October 2003. He also gave invited talks at the NSF Wireless Networking PI Meeting, National Science Foundation, Charleston, SC, January 2004, IdeaStream Symposium, Massachusetts Institute of Technology, Cambridge, MA, April 2004, and Aerospace and Defense Symposium, Massachusetts Institute of Technology, Cambridge, MA, September 2003.

Staff Awards

Fred Donovan received the Infinite Mile Award for Excellence from the School of Engineering.

Col. Pete Young received the Infinite Mile Award for Excellence from the School of Engineering.

Communication for Challenging Environments

Professor Win and his graduate students are working on the application of mathematical and statistical theories to communication, detection, and estimation problems. Specific current research topics include measurement and modeling of time-varying channels, design and analysis of multiple antenna systems, ultrawide bandwidth (UWB) communications systems, optical communications systems, and space communications systems. Their accomplishments include the following:

Transmitted-Reference Signaling for UWB Communications: Professor Win and his students developed an analytical framework, based on a sampling expansion approach, to evaluate the exact SEP of the autocorrelation receiver in a transmitted-reference UWB system. They obtained a rule of thumb for the asymptotic SNR penalty that is useful for comparing a simple transmitted-reference system to an ideal Rake receiver.

Diversity with Practical Channel Estimation: The group developed an analytical framework for evaluating the performance of practical diversity systems with nonideal channel estimates. This framework is simple and applicable to channels with arbitrary distribution, including correlated fading. Their analysis showed that the SNR penalty, due to estimation error, has a surprising lack of dependence on the number of diversity branches. They proved that the practical estimator preserves the full diversity order, in contrast to results in the literature, which state that, even with an arbitrarily good estimate, the diversity order is that of a single-branch system.

Slow Adaptive Modulation (SAM) and Diversity Reception: The researchers derived tight upper and lower bounds on the inverse bit error probability (BEP) for diversity reception in fading. The new bounds enable the derivation of the bit error outage (BEO) and normalized throughput for slow adaptive M-ary quadrature amplitude modulation with diversity reception. Their results show that the SAM technique can provide substantial increase in throughput with respect to fixed schemes while maintaining an acceptable low BEO. They also compare SAM and fast adaptive modulation (FAM) techniques showing that the throughput of SAM is quite close to that of FAM despite the fact that SAM is less complex and requires a lower feedback rate to the transmitter.

Complex Systems Research Lab

Increasing complexity and coupling as well as the introduction of new digital technology are introducing new challenges for engineering, operations, and sustainment. We are designing system modeling, analysis, and visualization theory and tools to assist in the design and operation of safer systems with greater capability. To accomplish these goals, we apply a system's approach to engineering that includes building technical foundations and knowledge and integrating these with the organizational, political, and cultural aspects of system construction and operation.

While our main emphasis is aerospace systems and applications, our research results are applicable to complex systems in such domains as transportation, energy, and health. Current research projects include accident modeling and design for safety; model-based system and software engineering; reusable, component-based system architectures; interactive visualization; human-centered system design; system diagnosis and fault tolerance; system sustainment; and organizational factors in engineering and project management.

Participating faculty are Nancy Leveson (director, AA/ESD), Paul Lagace (AA/ESD), Wes Harris (AA), Missy Cummings (AA), Joel Cutcher-Gershenfeld (Engineering Systems Division/Sloan), John Carroll (Sloan), and David Mindell (PSTS/ESD).

Embedded Systems Laboratory

The Embedded Systems Laboratory (ESL) was founded in 2003 with the mission of providing tools and methodologies to support the design, development, verification, and sustainment of mission-critical embedded systems by leveraging formal methods and system-on-chip methodologies, thereby shaping academic thought and industry outlook through collaborative efforts, technical publications, and education. Professor Lundqvist and her students are working on three primary research areas: system-on-chip design approaches, verification and validation of mission critical software systems, and operating systems. The laboratory collaborates extensively with industry, including NASA, Ford, and Draper Laboratories.

System-on-Chip Design Approaches

System-on-chip designs provide compact implementations that integrate multiple heterogeneous components on a single chip. Given that the capacity of programmable hardware is governed by Moore’s law, new design techniques are needed to translate these quantum increases in capacity into capability. The research approach integrates facets of specification theory, programming language theory, and software engineering to provide a design-level tool-supported process for determining the partitioning between hardware and software.

Verification and Validation

The amount of software on airborne platforms is set to reach a level that challenges the developer’s ability to deliver the program code itself, let alone support the code with safety arguments and maintain it over the life cycle of an operational system. Research is currently underway to integrate formal methods into the conventional verification and validation processes. The approach includes model-based testing, automatic code generation, and generating safety case arguments from a hybrid set of specifications and code.

Operating System Design

The operating system forms the backbone around which embedded systems are built. Conventional systems rely on static cyclic schedules in order to maintain determinism and robustness. The approach, however, fails to meet the requirements of interoperability and upgradeability. Research is currently underway to design, implement, and analyze real-time operating systems that provide dynamic schedulability. RavenHaRT is a formally verified, deterministic, hardware implemented run-time kernel developed by ESL for use in mission-critical automotive systems. It is currently in beta testing, with version 1.0 expected later this year.

More information about the Embedded Systems Laboratory can be found at http://esl.mit.edu.

Man-Vehicle Laboratory

The group led by Professor Laurence Young in the Man-Vehicle Laboratory continued to develop methods for using artificial gravity as a countermeasure to the debilitating effects of weightlessness during long-duration human spaceflights. With the able assistance of Dr. Thomas Jarchow, a new post-doc from Zurich, and the continuing help of Dr. Heiko Hecht, who was appointed professor of psychology in Mainz, we published several papers in the *Journal of Vestibular Research* demonstrating the practicality short radius high-speed centrifugation. Together with the Johnson Space Center we began a pilot study of bed-rest subjects, simulating the effects of weightlessness and the influence of periodic centrifugation.

Massachusetts Space Grant Consortium

The Massachusetts Space Grant Consortium (MASGC) includes MIT (lead), Tufts University, Wellesley College, Harvard University, Boston University, the University of Massachusetts, Worcester Polytechnic Institute, the Marine Biological Laboratory, the Five College Astronomy Department, Northeastern University, Williams College, College of the Holy Cross, Boston Museum of Science, the Christa McAuliffe Center/Framingham State College, and Olin College of Engineering. MASGC continues to support a wide variety of programs aimed at education/public outreach and aerospace workforce development. MASGC contributes to the education of precollege teachers in space science and engineering through summer workshops run by the Wright Center at Tufts. MASGC continues to support undergraduate research through the MIT Undergraduate Research Opportunities Program (UROP) and similar programs at affiliate institutions. It also provided graduate fellowships last year for three students. MASGC supported several students at the summer Space Academies at NASA's Goddard and Ames Research Centers. It increased the number of companies involved in placing students for summer employment in the aerospace industry. Last November, in cooperation with the Boston Museum of Science, MASCG hosted the annual Space Day, inviting students supported by MASGC to present the results of their research to an assembly of Boston area high school students. The students then heard a lecture by NASA astronaut Scott Horowitz. During the spring semester at MIT, MASGC sponsored a popular undergraduate seminar on "Modern Space Science and Engineering," with guest speakers from our industrial and academic affiliates. The annual Space Grant public lecture this year was given by Riccardo Giacconi, professor at Johns Hopkins University and president of Associated Universities, Inc., and winner of the 2002 Nobel Prize in physics on "Progress in the Study of the X-Ray Background."

Space Systems Laboratory

The Space Systems Laboratory (SSL), affiliated with the Department of Aeronautics and Astronautics at MIT, was founded in 1995 and is under the direction of Professor David Miller. The SSL has the mission of developing the technology and systems analysis associated with small spacecraft, precision optical systems, and International Space Station technology research and development. The laboratory encompasses expertise in structural dynamics, control, thermal, autonomy, space power, propulsion, software development, and systems. A major activity in this laboratory is the development of ground and space test beds for validation and maturation of spaceflight technologies. Much of this work is in support of the next generation of space telescope missions, which exploit the physics of interferometry to achieve dramatic breakthroughs in angular resolution. The objective of the laboratory is to explore innovative concepts for the integration of future space systems and to train a generation of researchers and engineers conversant in this field.

Systems Analysis Tools (Professor David Miller)

The objective of the SSL's research into systems analysis is to provide tools for system design that will yield greater performance at lower cost. To this end, the SSL has developed the Generalized Information Network Analysis (GINA) systems architecting methodology for conducting quantitative design trades at the mission concept level. In addition, several enabling technologies are being developed to support such mission concepts.

Generalized Information Network Analysis

The fundamental assumption that MIT's GINA methodology makes is that almost all envisioned satellite systems are information disseminators that can be represented as information transfer networks. Whether the network allows one to obtain a navigational fix, communicate with a colleague, send data files around the globe, or provide an image of a stellar nursery to a scientist, all of these networks fundamentally transfer information between well-defined origin-destination pairs. Furthermore, satellite networks must be seen as a part of the wider information network in which they are imbedded or else unbiased comparative analyses cannot be made (e.g., terrestrial fiber optic vs. satellite link).

GINA is currently an extensive modeling framework that is used to quantify a mission's life cycle productivity and cost, the ratio of which corresponds to the efficiency of the mission. This framework is currently being used extensively to architect the US Air Force's TechSat21 mission as well as NASA's Terrestrial Planet Finder mission.

Dynamics, Optics, Controls, and Structures

The Dynamics, Optics, Controls, and Structures (DOCS) team is researching methods and tools in the design of large, dynamically flexible space structures. These structures, including space-based observatories such as the Terrestrial Planet Finder, have very tight dynamic performance requirements. However, testing these structures before launch is not practical because of the difficulty in recreating the environmental factors of orbit on such a large scale. In place of full system-level tests, then, analysis of integrated models coupled with test-bed and component tests must be used to validate the designs. The DOCS team is based around the DOCS software framework developed in the SSL, which creates an integrated model of the system from the individual subsystem models (optics, controls, etc.) and has a suite of tools to analyze the model, including computing the performance due to dynamic disturbances, the sensitivities to specific design parameters, and isoperformance trades of select design parameters. Current research is focused on including uncertainty and robustness in the models. The team supports efforts underway by Mide Technology Corporation to turn DOCS into commercial software, and it has most recently used the software to build and analyze models of the Terrestrial Planet Finder and the ground-based Thirty-Meter Telescope.

Uncertainty Propagation in System Modeling

There is a clear need to conduct architectural trades early in the lifetime of a mission to identify those designs that best meet the needs of stakeholders. Typically, these trades evaluate mission performance as a function of a set of design parameters that are assumed to be invariant over the lifetime of a mission. In reality, degrading failures and emergent properties alter system parameters during the course of a mission, thus impacting overall system performance and efficiency. Consequently, the capability to model the probabilistic nature of the expected productivity of a system, accounting for the possibility of failures, is needed. In previous expected productivity modeling efforts, the instantaneous productivity of the system depended on the failure state of the instrument alone. While an instrument can still be modeled as a Markov system, since the instantaneous failure state depends only on the previous state, overall system productivity is really time and path dependent. This dependency greatly complicates the computation of expected productivity. A new approach to modeling the overall expected productivity of a system with path-dependent productivity is being explored.

Spaceflight Dynamics and Control Technologies

In addition to systems studies, the Space Systems Lab is active in the development of hardware and software technologies that support spaceflight. A major component of this is in the area of dynamics and control.

Electromagnetic Formation Flight (Professor Miller, Dr. Raymond Sedwick)

The SSL has developed an innovative method for maneuvering satellites in close proximity relative to each other without the need for propellant. Elimination of the need for a consumable, such as propellant, significantly extends the lifetime of satellite formation flight missions. Electromagnets, composed of high-temperature superconductors, are used to control attitude and relative spacing and to rotate the array on the sky. Electromagnetic Formation Flight is receiving serious consideration from space telescope missions such as NASA's Terrestrial Planet Finder mission.

Formation Flight and Sparse Aperture Synthesis (Professor Miller, Dr. Sedwick)

The use of distributed spacecraft enables large space telescopes to be developed, using principles of sparse apertures that are a fraction of the cost of monolithic systems. Technical challenges that arise, however, originate from the need to form favorable sub-aperture geometry through spacecraft formation flight while in the presence of environmental constraints such as orbital dynamics, collision avoidance, and so on. The SSL has developed sophisticated dynamics models and control schemes for optimally controlling formations of spacecraft, both with the earth's gravitational field as well as in deep space. One such model is a formulation of the effect of the earth's nonspherical geopotential on spacecraft clusters and how control of these perturbative effects can be achieved with minimum propellant or power.

Nonlinear Control and Trajectory Optimization (Dr. Sedwick)

Interplanetary missions often rely on complex maneuver plans to minimize the propellant mass that must be included. An example is the use of gravity assist. Optimizations of this type fall firmly into the area of nonlinear control, and there are many approaches to addressing such problems. However, a major issue is that of the robustness of various control approaches and the amount of "tweaking" that must be done by expert users. The SSL is currently researching an old but somewhat underutilized approach to nonlinear optimal control called differential dynamic programming, which has certain characteristics that may lend themselves to a more robust approach to these problems.

Technology, Test Beds, and Education (Professor Miller)

An important component of the philosophy of the SSL is educating the next generation of engineers through hands-on and real-world experience. To this end, a senior capstone design course within the Department of Aeronautics and Astronautics has been tied to the development of test beds for demonstrating state of the art technologies being developed within the SSL. The projects are funded through relevant end users of the technology (NASA, DoD), bringing considerable funding and requirements to technologies being developed. The class is currently on its fourth project.

SPHERES

The SPHERES satellite formation flight test bed was the first built collaboratively between the SSL and the MIT Department of Aeronautics and Astronautics as a part of an undergraduate educational experiment in Conceive, Design, Implement, Operate (CDIO). The test bed consists of multiple microsatellites, or spheres, which can autonomously control their position and attitude. The test bed can be operated on an air table in 1-g laboratory environment, in NASA's KC-135 reduced gravity research aircraft, and inside the International Space Station (ISS). It is capable of formation flight, rendezvous, and docking up to three soccer ball–sized nanosatellites operating within the US Lab module. Each sphere has an expansion port to which future payloads can be attached. This port contains mechanical mounting locations, power, and a high-speed parallel data port. Since SPHERES operates inside ISS, it can access ISS communications, receives full video coverage, is serviced by the crew, and does not need to worry about satellite safe modes or thermal and radiation hardened components. This makes SPHERES a low-cost flight facility that can be upgraded on reflights to conduct additional technology development. SPHERES is currently manifested to launch to the ISS on STS 116, the return-to-flight shuttle mission. Original funding for SPHERES was through the Air Force Research Laboratory, but it was then supported through development of a flight system by the Defense Advanced Research Projects Agency (DARPA), as well as NASA's Jet Propulsion Lab (JPL), and the Goddard and Ames Research Centers.

ARGOS

The ARGOS test bed was the second project under the CDIO capstone course. This test bed is a modular Golay-3 telescope, designed primarily to compare the cost and effort in this technology to that of building a conventional telescope of the same effective aperture. Today, the test bed is still used for research in optical alignment and processing techniques. The project was initially funded by the NRO Director's Innovation Initiative (DII) program.

EMFFORCE (Dr. Sedwick)

EMFFORCE, the third capstone project, was developed for the purpose of validating the Electromagnetic Formation Flight technology invented within the SSL. This test bed uses high-temperature superconducting wire bathed in liquid nitrogen to generate magnetic fields. The interaction of these fields, when coupled with reaction wheels, provides the capacity to control all of the relative degrees of freedom within the system without expending propellant. This project was funded originally through the NRO DII program and has since received funding through the NASA Institute for Advanced Concepts, NASA JPL, and DARPA.

SWARM

SWARM is the current project under the CDIO capstone. This project is to develop a modular spacecraft bus, with common physical interfaces and wireless data connections. The purpose of this technology is to greatly reduce the development costs of new spacecraft bus design by allowing "off-the-shelf" selection of components. In addition, upgrade and repair of orbiting systems is enabled by providing a common modular interface. This project is currently supported internally, but it is looking likely that DARPA funding will soon be provided to support the effort.

Imaging Systems (Dr. Sedwick)

In the past years, the SSL has begun research in compact imaging systems with application to space missions.

Lightweight Inexpensive Star Tracker

The Lightweight Inexpensive Star Tracker system is being developed collaboratively with AeroAstro, Inc. under a DOD Small Business Technology Transfer contract. This star tracker focuses less on the ultrahigh-precision tracking required by advanced space telescope missions and more on being a small, low-power, low-mass, and low-cost solution available to the small spacecraft community. The current manifestation is primarily for rate sensing, but a more advanced model, FARMST, would also have the ability to provide absolute attitude information or, in the parlance of the industry, provide “lost in space” capability.

High-Resolution Omnidirectional Stereographic Imager

The cost and risk of doing robotic exploration is favorable to sending humans, but it is difficult to match the data gathering capabilities of the human mind. The High-Resolution Omnidirectional Stereographic Imager (HRODSI), in addition to having a very poor acronym, provides an imaging system that gathers sufficient observational data to allow a person wearing a head-mounted display to be embedded into the scene at nearly the same fidelity as actually being there. With this technology, future rover missions would gather data that could be used in near real-time by scientists to guide the rover to the most interesting locations, and it could be archived and distributed to schools for students to experience firsthand what it would be like to stand on the surface of another planet. This technology is being developed in cooperation with Axis Engineering Technologies through a NASA Small Business Technology Transfer contract.

Nuclear Space Power and Propulsion (Dr. Sedwick)

Although most space propulsion within the Department of Aeronautics and Astronautics is done within other labs (Space Propulsion Lab and Gas Turbine Lab), advanced power and propulsion techniques based on nuclear energy are being investigated within the Propulsion Group of the Space Systems Laboratory.

Inertial Electrostatic Confinement Fusion Power

The rigors of future human interplanetary space travel will necessitate the development of advanced power and propulsion systems. The SSL propulsion group is exploring methods to increase the confinement properties of inertial electrostatic confinement (IEC) devices in order to improve system efficiencies toward the break-even fusion conditions required for practical usage. IEC confinement offers a much lower mass system than the magnetic confinement systems under development for terrestrial power generation and is therefore much more attractive for space missions. Under the guidance of Dr. Raymond Sedwick, doctoral candidates Tom McGuire and Carl Dietrich have been pursuing theoretical development of these new devices. An experiment is under construction to show improved IEC performance with multiple cathode grids and to test synchronization effects predicted by numerical modeling of IEC systems with improved confinement. Further numerical analysis seeks to explain synchronization phenomena within confined IEC beams and between multiple beams.

TELAC AY2004

Some 20 students were involved in TELAC and with the associated faculty (Lagace, Radovitzky, Spearing, Wardle) during AY2004, including 11 graduate students and several UROPers. No students in 16.621/2 performed their projects in TELAC during this year. Four students finished their master's theses in the laboratory during this period and four doctorates were completed. In addition, the laboratory was host to occasional visits from international scholars through the year. The laboratory issued over 40 reports during this period, including over 30 accepted for publication in journals and proceedings. Laboratory personnel participated in conferences at the national and international level, giving more than a dozen presentations. Two items were of particular note during the past year. One is that Paul Lagace returned with a fuller commitment after a five-year hiatus as codirector of Leaders for Manufacturing–System Design and Management. The second is that Mark Spearing announced his departure, toward year's end, to take a position at the University of Southampton.

The laboratory personnel continue to have a diverse set of research interests, and these are manifested in the work that is pursued, the variety of sources from which funding is acquired, and the range of organizations and personnel with whom they pursue their work. Important progress was made in a number of research areas throughout the year. These include high-performance simulation of the effects of blasts on soldiers; direct numerical simulation of surface roughening in plastically deformed aluminum sheets; continuum modeling of the anomalous size dependence of strength in nanocrystals; composite tubular structural and laminate failures; MEMS–scale mechanical energy harvesting; fundamental work on the mechanics and materials science of the wafer bonding process, including direct bonding, anodic bonding, and thermal compression bonding; work on the use of piezo-actuation to induce fatigue in solders and adhesives; supporting work on the microengine, microrocket, and microchemical power projects; developing and characterizing new materials and performing structural design and analysis; development of mechanism-based models for the delamination fatigue processes in polymer matrix composites that account for the influence of low-angle fiber bridging; and a reengagement in the overall issues of the design of composite structures with a focus on failure and durability. In performing this work, the laboratory and its members continued to have extensive collaborations with industry (Rockwell Scientific, Boeing, Draper Labs, Schlumberger), government organizations (ONR, NSF, AFOSR, ARO, DARPA, FAA, NASA), other academic institutions (California Institute of Technology, Rutgers University, Princeton Plasma Physics Laboratory, Cambridge University, Clark Atlanta University, Georgia Tech, McGill University, the University of Southampton, Imperial College London), and other groups and faculty within the Institute (Singapore–MIT Alliance, Institute for Soldier Nanotechnologies, Aerospace

Computational Design Laboratory, Gas Turbine Laboratory, Chemical Engineering, Department of Materials Science and Engineering, and Mechanical Engineering).

Professor Wesley Harris
Department Head
Charles Stark Draper Professor of Aeronautics and Astronautics

More information about the Department of Aeronautics and Astronautics can be found on the web at http://web.mit.edu/aeroastro/www/index.html