Department of Aeronautics and Astronautics

MIT's Department of Aeronautics and Astronautics (AeroAstro) has long been one of the world's leading centers of aerospace research and education. With 225 graduate students, 180 undergraduate students, 35 faculty members, and top-ranked graduate and undergraduate educational programs, our community includes a former space shuttle astronaut, a former fighter pilot, former leaders of industry, a former secretary and three former chief scientists of the Air Force, two former NASA associate administrators, 16 National Academy of Engineering members, 15 American Institute of Aeronautics and Astronautics fellows, and two Guggenheim Medal recipients.

AeroAstro is a vibrant department with a strong sense of community. We value collaboration—within the department, across MIT, and with colleagues around the world. Our environment is connected, busy, global, hectic, open, collegial, and fun.

In 2007 we completed a strategic report, *Aero-Astro: Our Future*. It defines our mission and values, and identifies eight areas that represent grand challenges and grand opportunities for the department and for aerospace. Those areas are:

- space exploration
- autonomous, real-time humans-in-the-loop systems
- aviation environment and energy
- aerospace communications and networks
- aerospace computation, design, and simulation
- air transportation
- fielding large-scale complex systems
- advancing engineering education

Through making advances in these and related areas, MIT AeroAstro is shaping the future of air and space transportation, exploration, communication, and national security.

Mission and Strategy

As defined in our strategic report, AeroAstro's mission is to prepare engineers for success and leadership in the conception, design, implementation, and operation of high-performance aerospace and related engineering systems. The department is committed to excellence and to the creation, development, and application of the technologies critical to aerospace vehicle and information engineering, and to the architecture and engineering of complex high-performance systems.

Our strategy has four elements:

1. We are building a stronger faculty by hiring for excellence, mentoring, and promoting collaboration.

2. We are attracting more top-quality graduate students (not more students) through increasing our graduate student fellowship endowment and improving our financial structure.
3. We are improving the short-term and lifelong value of the graduate student experience to both the student and the Institute research enterprise by pursuing an initiative to advance graduate education, graduate student mentoring, and graduate student professional development.
4. We are enhancing excellence in undergraduate education by reinvigorating our commitment to the development, assessment, and continuous improvement of our pedagogy and of our student learning.

Progress in 2009–2010

Promoting Faculty Excellence

- The department saw a 26% increase in research funding over last year primarily in the areas of autonomous humans-in-the-loop systems, energy and environmental issues related to air transportation, computational engineering and space systems engineering. We furthered our strategic relationships with Boeing, Draper Labs, Lincoln Labs and Aurora Flight Sciences.
- Paulo Lozano was promoted to associate professor without tenure. Brian Wardle was promoted to associate professor with tenure and David Darmofal was promoted to full professor following rigorous faculty promotion and performance review processes.
- The department head and associate head continued to meet regularly throughout the year with junior faculty members as part of an expanded mentoring program and professional development.
- Frequent faculty research talks were used to build connections among faculty.
- The AeroAstro faculty awards and recognition committee remained very active.
- Our hiring process was successful, leading to two new faculty members from our department general search. Dr. *Kerry Cahoy* joins AeroAstro as a Boeing Assistant Professor in July 2011. She uses spacecraft radio systems to study the atmospheres and ionospheres of solar system planets. She also is interested in using space-based instrumentation, including cameras, telescopes, and coronagraphs, to search for and characterize planets outside our solar system. *Julie Shah* also comes to AeroAstro as a Boeing Assistant Professor in July 2011. Her research interests include multi-agent coordination, dynamic plan execution under uncertainty, and temporal reasoning.
- From our prior year search, Professor Qiqi Wang joined the faculty on September 1 and Professor Steven R. H. Barrett joined the faculty on June 1. Professor Wang works in the area of computational engineering and was hired as a result of a school-wide search. Professor Barrett's primary research interest is in aviation environmental impacts.

- We contributed to major School and Institute initiatives (Computation for Design and Optimization Program, MIT Energy Initiative, Transportation@MIT, SOE Education Committee and the Institute-wide Planning Task Force).

Promoting Excellence in Graduate Education

- In our second year of a reformed admissions process, our graduate admissions rate was 18% of 450 applications, with 67% of these students accepting admission. At the time of admission notification, 89% of students had funding offers, and by May all students accepting admissions were funded. When we cross-competed for the graduate students with our top competitors (Caltech and Stanford), the students selected our department 85% of the time.
- We continued to require formal end-of-semester progress reviews for all graduate students whereby graduate students and faculty meet at the end of each semester to enhance professional development, feedback, and mentoring. In a recent internal survey, 80% of our graduate students found the review process valuable.
- We held the second Women in Aerospace Symposium (with Department of Earth, Atmospheric, and Planetary Sciences) to foster a network among top women doctoral students in aerospace from around the United States. Of the attendees in the last two years we have interviewed three and hired one.
- The department head and associate head met with the graduate students every other week throughout the year to promote feedback and stronger involvement in department business.

Promoting Excellence in Undergraduate Education

- We proposed a new flexible undergraduate engineering degree, Course 16-ENG, designed to allow students to pursue interdisciplinary and multidisciplinary studies through a six-subject concentration, while still retaining technical rigor and a context of aerospace engineering. Concentrations in the program currently include: autonomous systems; computation; energy; engineering management; environment; space exploration.
- The department enrollment was 180 students composed of 34% women and 40% underrepresented minorities.
- We continue to require reflective memos of all undergraduate instructors as a means for promoting continuous improvement in faculty teaching performance.
- The department head and associate head met with the undergraduates every other week throughout the year to promote feedback and a stronger sense of community.

Flexible Engineering Degree Program, 16-ENG

On April 22, MIT faculty voted to approve AeroAstro's new flexible engineering degree program, Course 16-ENG. This degree provides students the opportunity to develop understanding and skill in addressing multidisciplinary and interdisciplinary problems while maintaining technical rigor and a context of aerospace engineering. The 16-ENG degree path includes Unified Engineering and two second-level core subjects as a foundation, followed by a heavily technical six-subject concentration drawn from subject across the Institute, capped off by AeroAstro's multi-semester, hands-on laboratory and capstone Conceive-Design-Implement-Operation subject sequences. Concentrations include autonomous systems, computational engineering, energy, engineering management, environment, and space exploration; other concentration areas are anticipated in the near future. Launching in September of 2010, the 16-ENG program leads to the degree Bachelor of Science in Engineering as recommended by the Department of Aeronautics and Astronautics.

2009–2010 Personnel Achievement

Faculty Highlights

- The American Institute for Aeronautics and Astronautics announced that AeroAstro Professor Emeritus Eugene Covert is the recipient of the 2010 Reed Aeronautics Award. He was cited for "lifelong contributions to aeronautics teaching; research through advancements in state-of-the-art wind tunnel testing at subsonic, supersonic, and hypersonic speeds; and public service."
- Professor of the Practice Robert Liebeck received one of the most prestigious awards in aviation: the Daniel Guggenheim Medal. The medal recognizes individuals who make profound contributions to advancing aeronautics. Liebeck's award cites him for "distinguished engineering as evidenced by the conception and development of Liebeck airfoils and blended wing body aircraft."
- Professor Sheila Widnall received the National Academy of Engineering's "Arthur M. Bueche Award for "a remarkable academic career in fluid dynamics combined with the highest levels of public service, and for championing the role of women in engineering."
- The American Astronautical Society awarded its Eugene M. Emme Astronautical Literature Award to Professor David Mindell's book "Digital Apollo." The book explores the relationships between humans and computers associated with the Apollo program. The Emme Award is the society's award for a work of space history.
- Professor Karen Willcox received the Sir Peter Blake Emerging Young Leaders Award, sponsored by the Sir Peter Blake Trust in New Zealand. The Trust, which memorializes the late Sir Peter Blake, a world-famous environmentalist, celebrates leadership capabilities in shaping New Zealand's future.
- Professor Emilio Frazzoli and EECS grad student Sertac Karaman received Willow Garage's Best Open Source Code Award for their development of RRT(*), which is a software library implementing algorithms introduced in their paper "incremental Sampling-based Algorithms for Optimal Motion Planning."

- Professor Dave Miller reports that the SPHERES facility on the International Space Station is transitioning to ISS National Laboratory status. In the fall of 2009, using privately donated funds, two high school teams from Idaho (Bonners Ferry High School and the Coeur d'Alene School District), were given the tools to program the SPHERES satellites. Over the course of three months, with the help of their teachers and MIT mentors, the students wrote and tested actual spaceflight software to carry out a competitive task using SPHERES. Their programs were run first in simulation, and then on the MIT flat floor. On December 9, 2009, the two teams flew to MIT and were able to participate in the operation of their software aboard the International Space Station.
- Professor Oliver de Weck was named recipient of the Capers and Marion McDonald Award for 2010. Established by Capers '76 SM, and Marion McDonald, this award is presented to a School of Engineering faculty member who, "through tireless efforts to engage minds, elevate spirits, and stimulate high quality work, has advanced the professional and personal development of students and colleagues." In announcing the award, Dean Subra Suresh wrote, "Oli's commitment to advising and mentoring of MIT students is extraordinary."
- The AeroAstro Vickie Kerrebrock Award was presented to Professor Jeff Hoffman for all he has done to inspire, connect, lead, mentor and educate our students, staff and faculty. "From the big to the small and everything in between, he has contributed significantly to stronger sense of community in AeroAstro."
- Several new appointments for Professor Dava Newman: she was appointed to the NASA Advisory Council's Committee on Technology and Innovation where she will provide advice to NASA and help shape the agency's new direction; and she accepted a position on the International Advisory Board of the Politecnico de Torino where she will offer advice primarily on their new Human Space Robotics Initiative
- The MIT Undergraduate Research Opportunities Program presented Professor Paulo Lozano with its 2010 Outstanding UROP Faculty Mentor Award. The award is presented to mentors who have demonstrated exceptional guidance and teaching in a research setting.
- Professor Youssef Marzouk has received a U.S. Department of Energy grant under the Department of Education's Early Career Research Program. Marzouk's project, "predictive Modeling of Complex Physical Systems: New Tools for Uncertainty Quantification, Statistical Inference, and Experimental design, " was one of 69 selected from among 1,750 applications.
- Professor Eytan Modiano received the AIAA Undergraduate Teaching Award at the Senior Awards Dinner on May 5.
- Engineering Dean Subra Suresh appointed Professor Amedeo Odoni as the Singapore Research Professor of Transportation Systems.

Other Accomplishments

- AeroAstro seniors Jennifer L. Allen, Isaac M. Asher, Kevin S. Lim, and Eric Timmons were elected to the MIT Phi Beta Kappa chapter. A faculty committee conducts the election, reviewing the students' academic records to identify those with superlative records and clear evidence of breadth in the liberal arts.
- Kristen Anderson, Garrett Fritz, Adam Fuhrmann, Jillian James, and Ryan McLinko of Professor Dave Miller's 16.83 Cathode/Anode Satellite Thruster for Orbital Repositioning (CASTOR) class project captured first place in a NASA Space Grant Systems Engineering paper competition. The team received a $3,500 scholarship and an invitation to view a future launch at Kennedy Space Center.
- The AeroAstro Spirit of XVI Team Award was presented to technical instructors Todd Billings, Dick Perdichizzi and Dave Robertson for their outstanding work to educate our students through helping hands, critical eyes and encouraging words.
- Grad student Dan Buckland received the Society of NASA Flight Surgeons Outstanding Student Award. Dan is involved with the Man Vehicle Lab.
- Through Women in Aviation International, Abhizina Butchibabu was named recipient of the American Airlines/American Eagle Engineering Scholarship. Candidates for the $5,000 award are evaluated on academic standing, personal accomplishments, teamwork, leadership skills, and community service involvement. Butchibabu is an AeroAstro grad student working with MIT's International Center for Air Transportation.
- Air Force Chief of Staff Gen. Norton A. Schwartz named Cadet Col. Ryan W. Castonia the 2009 United States Air Force Cadet of the Year. Castonia is a member of the Air Force Reserve Officers' Training Corps Detachment 365 in Cambridge, MA. The award recognizes the most outstanding cadet in one of the three Air Force commissioning programs: Officer Training School, the Air Force Academy, and Air Force ROTC.
- Students working on the TALARIS planetary hopper vehicle took first place in the NASA-sponsored Revolutionary Aerospace Systems Concepts – Academic Linkage contest designed to help the space agency with new space exploration concepts. The winners included grad students Ben Corbin, Chris Han, Bobby Cohanim, Eph Lanford, Howard Yue, and Philip Cunio; and undergrads, Nana Essilfie-Condulah, Garrett Fritz, and Sarah Vega.
- Astronauts4Hire selected AeroAstro Ph.D. candidate Ben Corbin as one of six new commercial astronaut candidates. Astronauts4Hire is a non-profit organization whose mission is to increase the competitiveness of commercial astronaut candidates by providing skills training, facilitating forums for candidate communication, engaging with potential employers and inspiriting the next generation. The fist step in Ben's training will be participating in the NASTAR Suborbital Scientist Training Program.

- Grad student Fabio Fachin was awarded the Whitaker Health Sciences & Technology Fellowship for next year by MIT Office of the Dean for Graduate Education.
- Doctoral candidate Stephanie Gil has received the General Chairs' Recognition Award for Interactive papers at the IEEE Conference on Decision and Control and 28th Chinese Control Conference.
- AeroAstro principal research engineer and Partnership for AiR Transportation Noise and Emissions Reduction associate director Jim Hileman was named FAA Centers of Excellence Faculty of the Year.
- AeroAstro PhD candidate Paul Grogan was selected from more than 2,600 applicants to receive a 2010 National Defense Science and Engineering Graduate Fellowship. The Department of Defense awards these fellowships to people "who have demonstrated ability and special aptitude for advanced training in sciences and engineering."
- The MIT AIAA Undergraduate Advising Award was presented to Barbara Lechner.
- Grad student Chad Lieberman has been awarded the Kambourides Fellowship in Computational Engineering.
- Senior Administrative Assistant Carol Niemi was presented the AeroAstro Wings Award in recognition of her outstanding work keeping the department running smoothly while maintaining a smile and a caring attitude.
- 62x alums Jonathan Brent Parham and Matt Fitzgerald captured first place in the NE Regional ASEE student conference award for their paper and presentation, "Flow Control for Boundary Layer Ingestion in an S-duct Diffuser." Their advisor was AeroAstro research engineer Elena de la Rosa Blanco.
- The AeroAstro Spirit of XVI Individual Award went to Liz Zotos for going above and beyond to assist students, offer advice, organize extra help, and share her wisdom as a member of the Man Vehicle Laboratory and the AeroAstro Department.

Research

AeroAstro faculty and students are engaged in hundreds of research projects under the auspices of our department's laboratories and centers. Many of the department's research projects are open to undergraduates through the Undergraduate Research Opportunities Program. In addition, research activities in other MIT laboratories and centers are open to students registered in aeronautics and astronautics.

Aerospace Computational Design Laboratory

The Aerospace Computational Design Laboratory's mission is the advancement and application of computational engineering for aerospace system design and optimization. ACDL researches topics in advanced computational fluid dynamics and reacting flow, methods for uncertainty quantification and control, and simulation-based design techniques.

The use of advanced computational fluid dynamics for complex 3D configurations allows for significant reductions in time from geometry-to-solution. Specific research interests include aerodynamics, aeroacoustics, flow and process control, fluid structure interactions, hypersonic flows, high-order methods, multi-level solution techniques, large eddy simulation, and scientific visualization. Research interests also extend to chemical kinetics, transport-chemistry interactions, and other reacting flow phenomena.

Uncertainty quantification and control is aimed at improving the efficiency and reliability of simulation-based analysis as well as supporting decision under uncertainty. Research is focused on error estimation, adaptive methods, ODEs/PDEs with random inputs, certification of computer simulations, and robust statistical frameworks for estimating and improving physical models from observational data.

The creation of computational decision-aiding tools in support of the design process is the objective of a number of methodologies the lab pursues. These include PDE-constrained optimization, real time simulation and optimization of systems governed by PDEs, multiscale optimization, model order reduction, geometry management, and fidelity management. ACDL applies these methodologies to aircraft design and to the development of tools for assessing aviation environmental impact.

ACDL faculty and staff include: Jaime Peraire (director), Doug Allaire, Marcelo Buffoni, David Darmofal, Mark Drela, Robert Haimes, Youssef Marzouk, Cuong Nguyen, QiQi Wang, and Karen Willcox.

Aerospace Controls Laboratory

The Aerospace Controls Laboratory researches autonomous systems and control design for aircraft, spacecraft, and ground vehicles. Theoretical research is pursued in areas such as decision making under uncertainty; path planning, activity and task assignment; estimation and navigation; sensor network design; and robust, adaptive, and nonlinear control. A key part of ACL is RAVEN (Real-time indoor Autonomous Vehicle test ENvironment), a unique experimental facility that uses a motion capture system to enable rapid prototyping of aerobatic flight controllers for helicopters and aircraft, robust coordination algorithms for multiple helicopters, and vision-based sensing algorithms for indoor flight. Recent research includes the following:

Robust Planning: ACL developed a distributed task-planning algorithm that provides provably good conflict-free task allocations that are robust to poor network connectivity and inconsistencies in the situational awareness over the team. Recent work demonstrated key theoretical properties of this consensus-based bundle algorithm and extended the algorithm to enable tight linkages with a human operator.

Sensor Networks: ACL also addressed planning of mobile sensor networks (e.g., UAVs) to extract the maximal information from a complex dynamic environment such as a weather system. The primary challenge in this planning is the significant computational complexity due to the large size of the decision space and the cost of propagating the influence of sensing into the future. ACL developed a new set of methodologies that correctly and efficiently quantify the value of information in large information spaces, thus leading to a systematic architecture for planning information-gathering paths for mobile sensors in a dynamic environment.

Approximate Dynamic Programming: Markov Decision Processes are a natural framework for formulating many of the decision problems of interest to ACL, but the curse of dimensionality prevents the exact solution of problems of practical size. ACL has developed new approximate policy iteration algorithms that exploit flexible, kernel-based cost approximation architectures to quickly compute an approximate policy by minimizing the error incurred in solving Bellman's equation over a set of sample states. Experimental results demonstrating the applicability of this approach to several applications, including a multi-UAV coordination and planning problem.

Autonomous Vehicles: Working with Professor Emilio Frazzoli and team as part of the Agile Robotics for Logistics program, ACL has developed a planning and control framework capable of autonomous forklift operations in an unstructured, outdoor warehouse setting. The framework implemented uses closed-loop rapidly exploring random trees for navigation, and a steering controller coupled with pallet and truck perception filters for manipulation of pallet loads. In a presentation at Fort Belvoir, VA in June 2009, the team's robotic forklift demonstrated robust path planning capabilities in a complex environment with uncertain terrain, dynamic obstacles (including humans), and unreliable GPS data.

ACL faculty include Jonathan How and Steven Hall.

Communications and Networking Research Group

The Communications and Networking Research Group's primary goal is the design of network architectures that are cost effective, scalable, and meet emerging needs for high data-rate and reliable communications. To meet emerging critical needs for military communications, space exploration, and internet access for remote and mobile users, future aerospace networks will depend upon satellite, wireless and optical components. Satellite networks are essential for providing access to remote locations lacking in communications infrastructure, wireless networks are needed for communication between untethered nodes (such as autonomous air vehicles), and optical networks are critical to the network backbone and in high performance local area networks.

The group is working on a wide range of projects in the area of data communication and networks with application to satellite, wireless, and optical networks. Over the past year, the group continued to work on a Department of Defense-funded project toward the design of highly robust telecommunication networks that can survive a massive disruption that may result from natural disasters or intentional attack. The project examines the impact of large scale, geographically correlated failures, on network survivability and design. In a related project, recently funded by the National Science Foundation, the group is studying survivability in layered networks; with the goal of preventing failures from propagating across layers.

The group also started work on a new Army MURI (Multidisciplinary University Research Initiative) project titled "MAASCOM : Modeling, Analysis, and Algorithms for Stochastic Control of Multi-Scale Networks." The project deals with control of communication networks at multiple time-scales; and is a collaboration among MIT, Ohio State University, University of Maryland, University of Illinois, Purdue University, and Cornell University.

CNRG's research crosses disciplinary boundaries by combining techniques from network optimization, queueing theory, graph theory, network protocols and algorithms, hardware design, and physical layer communications.

Eytan Modiano directs the Communications and Networking Research Group.

Complex Systems Research Laboratory

Increasing complexity and coupling as well as the introduction of new digital technology are introducing new challenges for engineering, operations, and sustainment. The Complex Systems Research Lab designs 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, the lab applies 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 CSRL's main emphasis is aerospace systems and applications, its 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.

Nancy Leveson directs the Complex Systems Research Laboratory.

Gas Turbine Laboratory

The MIT Gas Turbine Laboratory has had a worldwide reputation for research and teaching at the forefront of gas turbine technology for more than 60 years. GTL's mission is to advance the state-of-the-art in fluid machinery for power and propulsion. The research is focused on advanced propulsion systems, energy conversion and power, with activities in computational, theoretical, and experimental study of: loss mechanisms and unsteady flows in fluid machinery; dynamic behavior and stability of compression systems; instrumentation and diagnostics; advanced centrifugal compressors and pumps for energy conversion; gas turbine engine and fluid machinery noise reduction and aero-acoustics; novel aircraft and propulsion system concepts for reduced environmental impact.

Examples of current and past research projects include: engine diagnostics and smart engines, aerodynamically induced compressor rotor whirl, a criterion for axial compressor hub-corner separation, axial and centrifugal compressor stability prediction, losses in centrifugal pumps, loss generation mechanisms in axial turbomachinery, the Silent Aircraft Initiative (a collaborative project with Cambridge University, Boeing, Rolls Royce, and other industrial partners), hybrid-wing-body airframe design and propulsion system integration for reduced environmental impact (NASA N+2), counter-rotating propfan aerodynamics and acoustics, an engine air-brake for quiet aircraft, inlet distortion noise prediction for embedded propulsion systems, novel aircraft concepts for 2035 (NASA N+3), high-speed micro gas bearings for MEMS turbomachinery, small gas turbines and energy concepts for portable power, and carbon-nano-tube bearings.

Zoltan Spakovszky is the GTL director. Faculty, research staff and frequent visitors include John Adamczyk, Nick Cumpsty, Elena de la Rosa Blanco, Mark Drela, Fredric Ehrich, Alan Epstein, Edward Greitzer, Gerald Guenette, Jim Hileman, Bob Liebeck, Jack Kerrebrock, Jürg Schiffmann, Choon Tan, and Ian Waitz.

Humans and Automation Laboratory

Research in the Humans and Automation Laboratory focuses on the multifaceted interactions of human and computer decision-making in complex socio-technical systems. With the explosion of automated technology, the need for humans as supervisors of complex automatic control systems has replaced the need for humans in direct manual control. A consequence of complex, highly-automated domains in which the human decision-maker is more on-the-loop than in-the-loop is that the level of required cognition has moved from that of well-rehearsed skill execution and rule following to higher, more abstract levels of knowledge synthesis, judgment, and reasoning. Employing human-centered design principles to human supervisory control problems, and identifying ways in which humans and computers can leverage the strengths of the other to achieve superior decisions together is HAL's central focus.

Current research projects include investigation of human understanding of complex optimization algorithms and visualization of cost functions, human performance modeling with hidden markov models, collaborative human-computer decision making in time-pressured scenarios (for both individuals and teams), human supervisory control of multiple unmanned vehicles, and designing displays that reduce training time. Lab equipment includes an experimental testbed for future command and control decision support systems, intended to aid in the development of human-computer interface design recommendations for future unmanned vehicle systems. In addition, the lab hosts a state-of-the-art multi-workstation collaborative teaming operations center, as well as a mobile command and control experimental test bed mounted in a Dodge Sprint van awarded through the Office of Naval Research. Current research sponsors include the Office of Naval Research, the U.S. Army, Lincoln Laboratory, Boeing, the Air Force Research Laboratory, the Air Force Office of Scientific Research, Alstom, and the Nuclear Regulatory Commission.

HAL faculty include Mary L. Cummings (director), Nicholas Roy, and Thomas Sheridan.

International Center for Air Transportation

The International Center for Air Transportation undertakes research and educational programs that discover and disseminate the knowledge and tools underlying a global air transportation industry driven by technologies. Global information systems are central to the future operation of international air transportation. Modern information technology systems of interest to ICAT include global communication and positioning; international air traffic management; scheduling, dispatch, and maintenance support; vehicle management; passenger information and communication; and real-time vehicle diagnostics.

Airline operations are also undergoing major transformations. Airline management, airport security, air transportation economics, fleet scheduling, traffic flow management, and airport facilities development, represent areas of great interest to the MIT faculty and are of vital importance to international air transportation. ICAT is a physical and intellectual home for these activities. ICAT, and its predecessors, the Aeronautical Systems Laboratory and Flight Transportation Laboratory, pioneered concepts in air traffic management and flight deck automation and displays that are now in common use.

ICAT faculty include R. John Hansman (director), Hamsa Balakrishnan, Cynthia Barnhart, Peter Belobaba, and Amedeo Odoni.

Laboratory for Information and Decision Systems

The Laboratory for Information and Decision Systems is an interdepartmental research laboratory that began in 1939 as the Servomechanisms Laboratory, focusing on guided missile control, radar, and flight trainer technology. Today, LIDS conducts theoretical studies in communication and control, and is committed to advancing the state of knowledge of technologically important areas such as atmospheric optical communications, and multivariable robust control. LIDS continues to host events, notably weekly colloquia that feature leading scholars from the laboratory's research areas. In addition to a fulltime staff of faculty, support personnel, and graduate assistants, scientists from around the globe visit LIDS to participate in its research program.

AeroAstro/LIDS faculty includes Emilio Frazzoli, Jon How, Eytan Modiano, and Moe Win.

Lean Advancement Initiative

The Lean Advancement Initiative is a learning and research consortium focused on enterprise transformation; its members include key stakeholders from industry, government, and academia. LAI is headquartered in AeroAstro, works in collaboration with the Sloan School of Management, and is managed under the auspices of the Center for Technology, Policy and Industrial Development, an MIT-wide interdisciplinary research center.

LAI began in 1993 as the Lean Aircraft Initiative when leaders from the U.S. Air Force, MIT, labor unions, and defense aerospace businesses created a partnership to transform the U.S. aerospace industry using an operational philosophy known as "lean." LAI is now in its sixth phase and focuses on a holistic approach to transforming entire enterprises across a variety of industries. Through collaborative stakeholder engagement, along with the development and promulgation of knowledge, practices, and tools, LAI enables enterprises to effectively, efficiently, and reliably create value in complex and rapidly changing environments. Consortium members work collaboratively through the neutral LAI forum toward enterprise excellence, and the results are radical improvements, lifecycle cost savings, and increased stakeholder value. LAI's Educational Network, which provides LAI members with unmatched educational outreach and training capabilities, includes more than 50 educational institutions on five continents.

AeroAstro LAI participants include Deborah Nightingale (co-director), Earll Murman, Dan Hastings, Annalisa Weigel, and Sheila Widnall. John Carroll (co-director) joins LAI from the Sloan School of Management, and Warren Seering and Joe Sussman represent the Engineering Systems Division.

Man Vehicle Laboratory

The Man Vehicle Laboratory addresses human-vehicle system safety and effectiveness by improving understanding of human physiological and cognitive capabilities. MVL develops countermeasures and display designs to aid pilots, astronauts, and others. Research is interdisciplinary, and uses techniques from manual and supervisory control, signal processing, estimation, sensory-motor physiology, sensory and cognitive psychology, biomechanics, human factors engineering, artificial intelligence, and biostatistics. MVL has flown experiments on Space Shuttle missions, the Mir Space Station, on many parabolic flights, and developed experiments for the International Space Station.

MVL has four faculty and 20 affiliated graduate students. Research sponsors include NASA, the National Space Biomedical Research Institute, the Office of Naval Research, the Department of Transportation's FAA and FRA, the Center for Integration of Medicine and Innovative Technology, the Deshpande Center, and the MIT Portugal Program. Space projects focus on advanced space suit design and dynamics of astronaut motion, adaptation to rotating artificial gravity, development of mathematical models of spatial disorientation accident analysis, and space telerobotics training. New major projects include a collaborative study with Draper laboratory on manual and supervisory control of lunar/planetary landings, and a study of fatigue effects on space teleoperation performance, in collaboration with colleagues at the Brigham and Women's Hospital. Non-aerospace projects include fatigue detection in locomotive engineers, and advanced helmet designs for brain protection in sports and against explosive blasts. The laboratory also collaborates with the Volpe Transportation Research Center, and the Jenks Vestibular Physiology Laboratory of the Massachusetts Eye and Ear Infirmary.

The laboratory's "Bioastronautics Journal Seminar" enrolled 18 graduate students. For the seventh year, MVL MIT Independent Activities Period activities included a popular course on Boeing 767 Systems and Automation and Aircraft Accident Investigation, co-taught with B N. Nield, Boeing's chief engineer for the 777.

MVL faculty members include Charles Oman (director), Jeffrey Hoffman, Dava Newman, and Laurence Young. They teach subjects in human factors engineering, space systems engineering, space policy, flight simulation, space physiology, aerospace biomedical engineering, the physiology of human spatial orientation, and leadership.

The MVL also serves as the office of the Director for the NSBRI-sponsored HST Graduate Program in Bioastronautics (Young), the Massachusetts Space Grant Consortium (Hoffman), NSBRI Sensory-Motor Adaptation Team (Oman), the MIT-Volpe Program in Transportation Human Factors (Oman), and the MIT Portugal Program's Bioengineering Systems focus area (Newman).

The Partnership for AiR Transportation Noise and Emissions Reduction

The Partnership for AiR Transportation Noise and Emissions Reduction is an MIT-led FAA/NASA/Transport Canada-sponsored Center of Excellence. PARTNER research addresses environmental challenges facing aviation through analyzing community noise and emission impacts on climate and air quality. PARTNER also studies a range of environmental impact potential mitigation options including aircraft technologies, fuels, operational procedures, and policies. PARTNER combines the talents of nine universities, three federal agencies, and more than 50 advisory board members, the latter spanning a range of interests from local government, to industry, to citizens' community groups.

MIT's most prominent research role within PARTNER is in analyzing environmental impacts and developing research tools that provide rigorous guidance to policy-makers who must decide among alternatives to address aviation's environmental impact. The MIT researchers collaborate with an international team in developing aircraft-level and aviation system level tools to assess the costs and benefits of different policies and mitigation options.

Other PARTNER initiatives in which MIT participates include estimating the lifecycle impacts of alternative fuels for aircraft; studies of aircraft particulate matter microphysics and chemistry; and economic analysis of policies. PARTNER's most recent reports emanating from MIT research are "Near-Term Feasibility of Alternative Jet Fuels" (with the RAND Corp.) "Aircraft Impacts on Local and Regional Air Quality in the United States," and "Life Cycle Greenhouse Gas Emissions from Alternative Jet Fuels." These may be downloaded at http://web.mit.edu/aeroastro/partner/reports.

PARTNER MIT personnel include Ian Waitz (director), James Hileman (associate director), Hamsa Balakrishnan, Steven Barrett, John Hansman, Thomas Reynolds, Karen Willcox, Malcolm Weiss, William Litant (communications director), Jennifer Leith (program coordinator), and 15-20 graduate students and postdocs.

Space Propulsion Laboratory

The Space Propulsion Laboratory, part of the Space Systems Lab, studies and develops systems for increasing performance and reducing costs of space propulsion. A major area of interest to the lab is electric propulsion in which electrical, rather than chemical energy propels spacecraft. The benefits are numerous; hence the reason electric propulsion systems are increasingly applied to communication satellites and scientific space missions. In the future, these efficient engines will allow exploration in more detail of the structure of the universe, increase the lifetime of commercial payloads, and look for signs of life in far away places. Areas of research include Hall thrusters; plasma plumes and their interaction with spacecraft; electrospray physics, mainly as it relates to propulsion; microfabrication of electrospray thruster arrays; Helicon and other radio frequency plasma devices; and space electrodynamic tethers.

Manuel Martinez-Sanchez directs the SPL research group. Paulo Lozano is the associate director.

Space Systems Laboratoy

Space Systems Laboratory research contributes to the exploration and development of space. SSL's mission is to explore innovative space systems concepts while training researchers to be conversant in this field. The major programs include systems analysis studies and tool development, precision optical systems for space telescopes, microgravity experiments operated aboard the International Space Station, and leading the AeroAstro efforts on student-built small satellites. Research encompasses an array of topics that comprise a majority of space systems: systems architecting, dynamics and control, active structural control, thermal analysis, space power and propulsion, microelectromechanical systems, modular space systems design, micro-satellite design, real-time embedded systems, and software development.

Major SSL initiatives study the development of formation flight technology. Significant research has been conducted using the Synchronized Position Hold Engage and Reorient Experimental Satellites (SPHERES) facility, in the areas of distributed satellites systems, including telescope formation flight, docking, and reconfiguration. The SPHERES facility consists of three small satellites 20 centimeters in diameter that have flown inside the International Space Station since May 2006. They are used to test advanced control software in support of future space missions that require autonomous inspection, docking, assembly and precision formation flight. Over the past four years SSL hassuccessfully completed 21 test sessions with eight astronauts. In 2009 we expanded the uses of SPHERES to include STEM outreach. In the fall of 2009 we began an exciting program called "Zero Robotics" to engage High School students in a competition aboard the ISS using SPHERES. In December 2010 ten students from two Idaho schools came to MIT and saw their algorithms compete against each other in a live feed from the ISS. We look forward to expanding this competition to a national scale.

SSL is in the third year of the SEA program; the Space Engineering Academy immerses junior Air Force officers in the actual development of flight hardware providing first hand experience in implementing best (and avoiding worst) practices in space system procurement. It is a two year, end-to-end, flight-worthy satellite conceive, design, build, integrate, test, and operate program. The SEA students, together with several other SSL graduate assistants, formed a robust group of teaching assistants for the 16.83 capstone satellite design-build course. This year the course tackled two projects: the MIT Satellite team entry to the University Nanosatellite Program and conceptual design of the Exo-Planet cubesat to detect planets in other solar systems. The UNP entry, named CASTOR, is being developed jointly with the Space Propulsion Laboratory to demonstrate an innovative electric thruster. The propulsion system will be demonstrated in LEO with up to 1 km/s delta-V; if successful a 2 km/s delta-V spacecraft could be built to reach the moon! The Exo-Planet spacecraft is a cooperation between the SSL and faculty in EAPS and the Kavli Institute; it uses an innovative sensor with staged control to detect the presence of planets as they orbit around their stars.

The Electromagnetic Formation Flight testbed is a proof-of-concept demonstration for a formation flight system that has no consumables; a space-qualified version is under study. The MOST project completed architectural studies for lightweight segmented mirror space telescopes using active structural control. Multiple programs research the synthesis and analysis of architectural options for future manned and robotic exploration of the Earth-Moon-Mars system.

SSL continues to lead the development of methodologies and tools for space logistics. Jointly with Aurora Flight Sciences, SSL is developing prototypes for automated asset tracking and management systems for ISS based on radio frequency identification technology. Together with the Jet Propulsion Laboratory, SSL is editing a new AIAA Progress in Aeronautics and Astronautics Volume on Space Logistics that summarizes the current state of the art and future directions in the field.

SSL personnel include David W. Miller (director), John Keesee, Olivier de Weck, Jeffrey Hoffman, Edward F. Crawley, Daniel Hastings, Annalisa Weigel, Manuel Martinez-Sanchez, Paulo Lozano, Alvar Saenz-Otero, Paul Bauer (research specialist), SharonLeah Brown (administrator and outreach coordinator), Brían O'Conaill (fiscal officer), Marilyn E. Good (administrative assistant), and Deatrice Moore (financial assistant)

Technology Laboratory for Advanced Materials and Structures

A dedicated and multidisciplinary group of researchers constitute the Technology Laboratory for Advanced Materials and Structures. They work cooperatively to advance the knowledge base and understanding that will help facilitate and accelerate advanced materials systems development and use in various advanced structural applications and devices.

TELAMS has broadened its interests from a strong historical background in composite materials, and this is reflected in the name change from the former Technology Laboratory for Advanced Composites. A significant initiative involves engineering materials systems at the nanoscale, particularly focusing on aligned carbon nanotubes as a constituent in new materials and structures. This initiative is in partnership with industry through the Nano-Engineered Composite aerospace STructures (NECST) Consortium founded at MIT in 2007. Thus, the research interests and ongoing work in the laboratory represent a diverse and growing set of areas and associations. Areas of interest include:

- nano-engineered hybrid advanced composite design, fabrication, and testing
- fundamental investigations of mechanical and transport properties of polymer nanocomposites
- characterization of carbon nanotube bulk engineering properties
- carbon nanotube synthesis and catalyst development
- composite tubular structural and laminate failures
- MEMS-scale mechanical energy harvesting modeling, design, and testing
- MEMS device modeling and testing, including bioNEMS/MEMS

- structural health monitoring system development and durability assessment
- thermostructural design, manufacture, and testing of composite thin films and associated fundamental mechanical and microstructural characterization
- continued efforts on addressing the roles of length scale in the failure of composite structures
- numerical and analytical solid modeling to inform, and be informed by, experiments
- continued engagement in the overall issues of the design of composite structures with a focus on failure and durability, particularly within the context of safety

In supporting this work, TELAMS has complete facilities for the fabrication of structural specimens such as coupons, shells, shafts, stiffened panels, and pressurized cylinders, made of composites, active, and other materials. A recent addition includes several reactors for synthesizing carbon nanotubes. TELAMS testing capabilities include a battery of servohydraulic machines for cyclic and static testing, a unit for the catastrophic burst testing of pressure vessels, and an impact testing facility. TELAMS maintains capabilities for environmental conditioning, testing at low and high temperature, and in hostile and other controlled environments. There are facilities for nano and microscopic inspection, nondestructive inspection, high-fidelity characterization of MEMS materials and devices, and a laser vibrometer for dynamic device and structural characterization.

With its linked and coordinated efforts, both internal and external, the laboratory continues its commitment to leadership in the advancement of the knowledge and capabilities of the materials and structures community through education of students, original research, and interactions with the community. There has been a broadening of this commitment consistent with the broadening of the interest areas in the laboratory. This commitment is exemplified in the newly formed NECST Consortium, an industry-supported center for developing hybrid advanced polymeric composites. In all these efforts, the laboratory and its members continue their extensive collaborations with industry, government organizations, other academic institutions, and other groups and faculty within the MIT community.

TELAMS faculty include Paul A. Lagacé (director), Brian L. Wardle, John Dugundji (Emeritus), and visitors Antonio Miravete, Desiree Plata, Luis Rocha, and Junichiro Shiomi.

Wireless Communication and Network Sciences Group

The Wireless Communication and Network Sciences Group is involved in multidisciplinary research that encompasses developing fundamental theories, designing algorithms, and conducting experiments for a broad range of real-world problems. Its current research topics include location-aware networks, network synchronization, aggregate interference, intrinsically-secure networks, time-varying channels, multiple antenna systems, ultra-wide bandwidth systems, optical transmission systems, and space communications systems. Details of a few specific projects are given below.

The group is working on location-aware networks in GPS-denied environments, which provide highly accurate and robust positioning capabilities for military and commercial aerospace networks. It has developed a foundation for the design and analysis of large-scale location-aware networks from the perspective of theory, algorithms, and experimentation. This includes derivation of performance bounds for cooperative localization, development of a geometric interpretation for these bounds, and the design of practical, near-optimal cooperative localization algorithms. It is currently validating the algorithms in a realistic network environment through experimentation in the lab.

The lab has been engaged in the development of a state-of-the-art apparatus that enables automated channel measurements. The apparatus makes use of a vector network analyzer and two vertically polarized, omni-directional wideband antennas to measure wireless channels over a range of 2–18 GHz. It is unique in that extremely wide bandwidth data, more than twice the bandwidth of conventional ultra-wideband systems, can be captured with high-precision positioning capabilities. Data collected with this apparatus facilitates the efficient and accurate experimental validation of proposed theories and enables the development of realistic wideband channel models. Work is underway to analyze the vast amounts of data collected during an extensive measurement campaign that was completed in early 2009.

Lab students are also investigating physical-layer security in large-scale wireless networks. Such security schemes will play increasingly important roles in new paradigms for guidance, navigation, and control of unmanned aerial vehicle networks. The framework they have developed introduces the notion of a secure communications graph, which captures the information-theoretically secure links that can be established in a wireless network. They have characterized the s-graph in terms of local and global connectivity, as well as the secrecy capacity of connections. They also proposed various strategies for improving secure connectivity, such as eavesdropper neutralization and sectorized transmission. Lastly, they analyzed the capability for secure communication in the presence of colluding eavesdroppers.

Lab director Moe Win and a team of undergraduate and graduate students competed in the Institute of Soldier Nanotechnologies Soldier Design Competition. In this contest they demonstrated the first cooperative location-aware network for GPS-denied environments, using ultra-wideband technology, leading to the team winning the L3 Communications Prize. They are now advancing the localization algorithms in terms of scalability, robustness to failure, and tracking accuracy.

To advocate outreach and diversity, the group is committed to attracting undergraduates and underrepresented minorities, giving them exposure to theoretical and experimental research at all levels. For example, the group has a strong track record for hosting students from both the Undergraduate Research Opportunities Program and the MIT Summer Research Program (MSRP). Professor Win maintains dynamic collaborations and partnerships with academia and industry, including the University of Bologna and Ferrara in Italy, University of Lund in Sweden, University of Oulu in Finland, National University of Singapore, Nanyang Technological University in Singapore, Draper Laboratory, the Jet Propulsion Laboratory, and Mitsubishi Electric Research Laboratories.

Moe Win directs the Wireless Communication and Network Sciences Group.

Wright Brothers Wind Tunnel

Since its opening in September 1938, the Wright Brothers Wind Tunnel has played a major role in the development of aerospace, civil engineering and architectural systems. In recent years, faculty research interests generated long-range studies of unsteady airfoil flow fields, jet engine inlet-vortex behavior, aeroelastic tests of unducted propeller fans, and panel methods for tunnel wall interaction effects. Industrial testing has ranged over auxiliary propulsion burner units, helicopter antenna pods, and in-flight trailing cables, as well as concepts for roofing attachments, a variety of stationary and vehicle mounted ground antenna configurations, the aeroelastic dynamics of airport control tower configurations for the Federal Aviation Authority, and the less anticipated live tests in Olympic ski gear, space suits for tare evaluations related to underwater simulations of weightless space activity, racing bicycles, subway station entrances, and Olympic rowing shells for oarlock system drag comparisons.

In its more than 70 years of operations, Wright Brothers Wind Tunnel work has been recorded in hundreds of theses and more than 1,000 technical reports.

WBWT faculty and staff include Mark Drela and Richard Perdichizzi.

Education

Undergraduate Program

Several years ago, working closely with student, alumni, industry, government, and academic stakeholders around the world, the AeroAstro Department developed and implemented a landmark educational initiative for our degree programs. It was determined that graduates must be knowledgeable in all phases of the aerospace system life cycle: conceiving, designing, implementing, and operating (CDIO). A new form of undergraduate engineering education was adopted, motivating students to master a deep working knowledge of the technical fundamentals while giving them the skills, knowledge, and attitudes necessary to lead in the creation and operation of products, processes, and systems. The department reformed the way it teaches, redesigned its curriculum, and performed a $20 million state-of-the-art reconstruction of its teaching laboratories. The academic program and its facilities now serve as models for 33 engineering schools on four continents.

This year, the Department developed the new Course 16-ENG degree to complement our existing aerospace engineering degrees (Course 16-1 and 16-2). The 16-ENG curriculum is designed to offer flexibility within the context of aerospace engineering. This aerospace context is achieved in two ways:

- The inclusion of Unified Engineering, our integrative, foundational subject in aerospace disciplines
- The use of our existing aerospace laboratory and capstone subject sequences, which emphasize authentic project-based learning within the aerospace context, in multi-semester team environments with integral communications education

These are essential elements of our MIT AeroAstro educational program. They also combine well with any number of aerospace-related concentration areas. The technical depth of the concentration areas is ensured in part by a requirement that of the 72 units in the concentration, 42 must be engineering and 12 must be math/science. We are excited about the educational opportunities brought by this new degree. Undergraduate students who pursue 16-ENG will receive a more multi-disciplinary or interdisciplinary engineering education, but one that still features the rigor and technical depth of the department's traditional aerospace engineering degrees.

Learning Lab

The AeroAstro Learning Laboratory, located in Building 33, is a world-class facility developed to promote student learning by providing an environment for hands-on activities that span our conceive-design-implement-operate educational paradigm.

The Learning Lab comprises four main areas:

Robert C. Seamans Jr. Laboratory. The Seamans Laboratory occupies the first floor. It includes:

- The Concept Forum—a multipurpose room for meetings, presentations, lectures, videoconferences and collaboration, distance learning, and informal social functions. In the Forum, students work together to develop multidisciplinary concepts, and learn about program reviews and management.
- Two Project Offices—team-focused work and meeting spaces, which may be assigned to teams for weeks or months, or kept available as needed. These rooms support individual study, group design work, online work, and telecommunication.
- Al Shaw Student Lounge—a large, open space for social interaction and operations.

Arthur and Linda Gelb Laboratory. Located in the building's lower level, the Gelb Laboratory includes the Gelb Machine Shop, Instrumentation Laboratory, Mechanical Projects Area, Projects Space, and the Composite Fabrication-Design Shop. The Gelb Laboratory provides facilities for students to conduct hands-on experiential learning through diverse engineering projects starting as first-year students and continuing through the last year. The Gelb facilities are designed to foster teamwork with a variety of resources to meet the needs of curricular and extra-curricular projects.

Gerhard Neumann Hangar. The Gerhard Neumann Hangar is a high bay space with an arching roof. This space lets students work on large-scale projects that take considerable floor and table space. Typical of these projects are planetary rovers, autonomous vehicles, and re-entry impact experiments. The structure also houses low-speed and supersonic wind tunnels. A balcony-like mezzanine level is used for multi-semester engineering projects, such as the experimental three-term senior capstone course, and is outfitted with a number of flight simulator computer stations.

Digital Design Studio. The Digital Design Studio, located on the second floor, is a large room with multiple computer stations arranged around reconfigurable conference tables. Here, students conduct engineering evaluations and design work, and exchange computerized databases as system and subsystem trades are conducted during the development cycle. The room is equipped with information technologies that facilitate teaching and learning in a team-based environment. Adjacent and networked to the main Design Studio are two smaller design rooms: the AA Department Design Room, and the Arthur W. Vogeley Design Room. These rooms are reserved for the use of individual design teams and for record storage. The department's IT systems administrator is positioned for convenient assistance in an office adjacent to the Design Center, positioning him for convenient assistance.

Some of the projects undertaken by students in the Learning Lab during the past year include research into landing impact cushioning devices for re-entering manned spacecraft, design and construction of an aircraft for the AIAA Design/Build/Fly competition, construction of a D-8 aircraft wind tunnel model, development work on the TALARIS planetary hopper, construction and testing of an autonomous robotic forklift, and design and construction of an aircraft for the Air Force to use in testing ground-based sensor systems.

The Experimental Projects course (Course 16.62X) is a major user of the teaching labs, from experiments using the Neumann Hangar's low-speed wind tunnel to the workspaces in the Gelb laboratory, with a number of excellent projects as outcomes. The motivation for these projects come from a variety of sources including faculty research interests, interactions with companies (e.g. Aurora Flight Sciences), and student-generated ideas.

Another major use of the Learning Lab is in our capstone design sequences: on the aeronautics side 16.82-16.821, and on the space side 16.83-16.832. These multi-semester capstone subjects take students through an entire life cycle of a product from conception to design to implementation and operation.

For 16.82x, a new collaboration was initiated between the department and Lincoln Lab in real world design build projects for students. Lincoln Lab and the U.S. Air Force commissioned and provided funding for the design, construction, and testing of an Unmanned Air Vehicle to calibrate sensor systems in Air Force test ranges. The students were highly motivated by the opportunity to develop a vehicle with a real customer. In the fall semester, 16.82 and our graduate aircraft system engineering course (16.885) were combined into a team that developed an initial design for the aircraft working in collaboration with Lincoln staff. Construction was begun by a group of students during IAP and continued in the spring semester in the follow-on laboratory course (16.821 and a special graduate course). The aircraft was successfully flown during the spring semester in a series of flight tests designed and executed by the students. The students presented the results at an Air Force testing conference with extremely favorable reviews. During the summer, two aircraft were delivered to Lincoln Lab who plan to use them as part of their flight test fleet. Based on the successful results of this pilot project, additional aircraft and spacecraft collaboration projects have been initiated for the current academic year.

The follow-on to the Space Systems Engineering capstone class (Course 16.83X) is using the Gelb lab to build a high delta V (~1-2 km/s) microsatellite. The motivation is to provide a low-cost orbital transfer vehicle capability for maneuvering throughout the Earth–moon system. The goal is to deliver to the Air Force in January 2011 a flight-qualified vehicle for launch as an ESPA-Ring (a device that permits up to six small satellites to be carried along with a larger satellite) secondary payload. The project offers approximately 35 undergraduates and 10 graduates from multiple departments hands-on experience in designing, building, and testing actual flight hardware.

Graduate Program

Over the past three years, we have made significant revisions to enhance the excellence of our already top-ranked graduate program. These changes occurred throughout the program from graduate admissions to improved mentoring to the requirements of the doctoral program. Some highlights from the past year include:

- In our second year of a reformed admissions process, our graduate admissions rate was our most selective ever at 18%. Of the admits, 67% of these students accepting admission, also an all-time AeroAstro high.
- At the time of admission notification in mid-April, 89% of students had funding offers and by June all students accepting admissions were funded. Further, through increased fund-raising for graduate student fellowships, careful use of Department fellowship resources to back funding offers based on in-review research proposals, and close coupling of our admissions size to anticipated funding levels, we believe our system will allow us to ensure funding for all admitted students.
- When we competed for graduate students with our top competitors (Caltech and Stanford), the students selected our department 85% of the time.
- Our department continues to have formal fall and spring end-of-semester research progress reviews required of all graduate students. These reviews are between the student and advisor and are an opportunity to set goals, consider progress first past goals, clarify funding needs and availability, and discuss career plans. A recent survey of our students showed that 80% of the respondents believe the review process is a valuable part of their education.

Degrees

The Bachelor of Science (SB) degree is a four-year program preparing the graduate for an entry-level position in the aerospace field and for further education at the master's level. Three degrees are available, one that emphasizes the disciplines that relate to the engineering of aerospace vehicles (Course 16-1), a second that defines a specialization in aerospace information technology (Course 16-2), and our new flexible engineering program described above (Course 16-ENG). All three degrees retain an emphasis on the fundamentals and provide strong integration with the overarching CDIO context.

The Master of Science (SM) degree is a one- to two-year graduate program with a beginning research or design experience represented by the S.M. thesis. This degree prepares the graduate for an advanced position in the aerospace field, and it forms a solid foundation for future doctoral study.

AeroAstro offers doctoral degrees (PhD and ScD) that emphasize in-depth study with a significant research project in a focused area. Entrance to the doctoral program requires students to pass a graduate-level examination in a field of aerospace engineering as well as to demonstrate an ability to conduct research in the field. The doctoral degree is awarded after completion of an individual course of study, submission and defense of a thesis proposal, and submission and defense of a thesis embodying an original research contribution.

In addition, the department participates in a variety of interdisciplinary graduate programs.

Graduate Enrollment*

	04-05	05-06	06-07	07-08	08-09	09-10
Total graduate student body	231	223	223	226	236	226
SM**	137	124	135	146	148	130
PhD***	94	99	88	80	88	96
Minority						
SM	7	7	9	8	8	9
PhD	6	4	3	5	6	4
Female						
SM	34	31	26	29	32	30
PhD	19	25	19	19	23	17

*Numbers based on fifth-week enrollment data.

** Includes students pursuing only the master's degree and students who have not yet passed the doctoral qualifying exam.

***Students who have passed the doctoral qualifying exam.

Undergraduate Student Prizes

Awards presented at the AeroAstro Class of 2009 Recognition Dinner on Wednesday, May 5, 2010:

The Andrew Morsa Prize—awarded for demonstration of ingenuity and initiative in the application of computers to the field of aeronautics and astronautics: Eli A. Cohen, Jacob L. Rosenbluth, and Jameson W. Nash

The Yngve Raustein Award—given to a unified engineering student who best exemplifies the spirit of Yngve Raustein and to recognize significant achievement in unified engineering: Victoria (Vicky) M. Thomas

Undergraduate Enrollment*

	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10
Sophomores	68	56	64	72	64	65	65	65	74	57
Juniors	53	69	51	59	59	52	60	66	55	65
Seniors	45	53	70	61	65	76	56	66	62	58
Totals	**166**	**178**	**185**	**192**	**188**	**196**	**181**	**189**	**191**	**180**
Women	32%	33%	35%	34%	30%	26%	31%	30%	30%	34%
Underrepresented minorities	21%	22%	30%	30%	27%	25%	26%	24%	32%	40%

*Data based on the fall fifth-week enrollment.

The Apollo Award—given to an AeroAstro student who conducts the best undergraduate research project on the topic of humans in space: Dustin P. Kendrick

The Leaders for Manufacturing Prize—awarded to a team that uses its project to directly deal with issues related to the interaction between manufacturing and engineering through demonstration of modern manufacturing processes: Andres M. Camarena, Lindsey M. Holland, Evelyn Garcia Gomez, Yodit Tewelde, and Carolina D. Vargas

The United Technologies Corp. Prize—awarded to an AeroAstro student for outstanding achievement in the design, construction, execution, and reporting of an undergraduate experimental project: Julie C. Andren, Marie S. Heglund, Emily J. Dykgraaf and Jeffrey S. Mekler

The Admiral Luis De Florez Prize—awarded for "original thinking or ingenuity" as demonstrated by the individual effort of the student, not the ideas and suggestions of an advisor, instructors, or an advisory team: Kimberly F. Jackson and Eric M. Timmons

The James Means Award for Excellence in Flight Vehicle Engineering: Kelly A. Strominger, Damon C. Henry and Brent E. McLaughlin

The Henry Webb Salisbury Award—given in memory of Henry Salisbury to a graduating senior who has achieved superior academic performance in the Course 16 undergraduate program: Ryan W. Castonia and Kevin S. Lim

Ian A. Waitz
Department Head
Jerome C. Hunsaker Professor of Aeronautics and Astronautics