Engineering Systems Division

Academic year 2006 was one of significant accomplishment for the Engineering Systems Division (ESD) as we continued to move forward toward our goals of defining and evolving engineering systems as a new field of study and transforming engineering education and practice.

In December 2005 Institute Professor Joel Moses became ESD's acting director after Professor Daniel Hastings was named dean of undergraduate education. Professor Moses holds a dual appointment in the Department of Computer Science and Engineering and in ESD. He has served as MIT's provost, dean of engineering, head of the Department of Electrical Engineering and Computer Science (EECS), associate head of EECS, and associate director of the Laboratory for Computer Science. Professor Moses is a member of the National Academy of Engineering and a fellow of the American Academy of Arts and Sciences, the American Association for the Advancement of Science, and the IEEE. He led development of the Macsyma system for algebraic formula manipulation and is codeveloper of the knowledge-based systems concept in artificial intelligence. His current interests include the complexity and flexibility of engineering systems, algebraic formula manipulation, and knowledge-based systems. Dr. Moses was also named acting director of ESD's Center for Technology, Policy, and Industrial Development, effective July 1, 2006.

Two ESD faculty, Daniel Frey, Mechanical Engineering and Engineering Systems, and Olivier de Weck, Aeronautics and Astronautics and Engineering Systems, received promotions, effective July 1, 2006.

Professor Frey was promoted to associate professor without tenure. Currently Robert N. Noyce career development professor and assistant professor of mechanical engineering and engineering systems, Professor Frey has received numerous awards and honors, including the Junior Bose Award for Excellence in Teaching in 2006, a best paper award from the International Council on Systems Engineering (INCOSE) in 2005, a National Science Foundation Career award in 2004, the MIT Department of Aeronautics and Astronautics Teaching Award in 2000, the Everett Moore Baker Memorial Award for Outstanding Undergraduate Teaching at MIT in 1999, and an R&D 100 Award in 1997.

Professor Frey is a member of the American Society of Mechanical Engineers, the American Statistical Association, INCOSE, and the American Society of Engineering Education (ASEE). He holds a PhD in mechanical engineering from MIT, an MS in mechanical engineering from the University of Colorado, and a BS in aeronautical engineering from Rensselaer.

ESD faculty member Olivier L. de Weck was also promoted to the rank of associate professor without tenure. Professor de Weck received the 2006 Frank E. Perkins Award for excellence in advising and mentoring graduate students. He has also won two best paper awards at the 2004 Systems Engineering Conference of INCOSE for research on system classification and iso-performance. His research has been funded by General

Motors, NASA, British Petroleum, Jet Propulsion Laboratory, ArvinMeritor, DARPA/AFRL, and the Alfred P. Sloan Foundation.

Professor de Weck is a senior member of American Institute of Aeronautics and Astronautics (AIAA) as well as a member of INCOSE, the Institute for Operations Research and Management Sciences (INFORMS), ASEE, and Sigma Xi. He was the general chair for the 2nd AIAA MDO Specialist Conference in May 2006. He holds degrees in industrial engineering from ETH Zurich (1993) and in aerospace systems engineering from MIT (SM 1999, PhD 2001).

We are delighted to announce that the following individuals have joined our faculty and teaching staff:

—Eric von Hippel, professor of management and of innovation and entrepreneurship in the Sloan School of Management, joined ESD as a joint professor. Professor von Hippel received a PhD from Carnegie Mellon University, an SM from MIT, and a BA from Harvard College. He also holds an honorary PhD from Ludwig-Maximilians Universität München.

Professor von Hippel is a cofounder of the MIT Entrepreneurship Program and has served as the Sir Walter Scott distinguished professor in the Australian Graduate School of Management, UNSW (1997–1998), and as a fellow in the Canadian Institute of Advanced Research (1995–1997). He has also worked as a consultant at McKinsey and Company.

Professor von Hippel has published extensively. His books include *Democraticizing Innovation* (MIT Press, 2005) and *The Sources of Innovation* (Oxford University Press, 1988). He has coauthored articles that have appeared in *R&D Management*, *Pharmacotherapy*, *Research Policy*, *The Journal of Technology Transfer*, and others. He sits on several journal editorial boards, including *Research Policy*, *Organization Science*, *British Journal of Management*, *International Journal of Entrepreneurship Education*, *International Journal of Management of Innovation and Technology*, and *Journal für Betriebswirtschaft*. Professor von Hippel also holds several patents.

—Hamsa Balakrishman accepted a dual appointment as assistant professor in air transportation/critical networked infrastructure systems and will join ESD and the Aeronautics and Astronautics Department in early 2007. Dr. Balakrishman received a PhD in aeronautics and astronautics from Stanford University, with a minor in electrical engineering, in May 2006, as well as an MS in aeronuatics and astronautics from Stanford University and a BTech in aerospace engineering from Indian Institute of Technology (Madras).

Dr. Balakrishman's research interests include systems and control theory (estimation, model identification, and stability analysis of hybrid systems), target tracking and identity management (applications to sensor networks and air traffic surveillance), and market-based mechanisms (applications to airport and airspace resource allocation.

She is interested in developing tools aimed at improving the efficiency of the National Airspace System.

—Stan N. Finkelstein joined ESD as a senior research scientist in ESD and in the Harvard–MIT Division of Health Sciences and Technology. Dr. Finkelstein is also codirector of the Program on the Pharmaceutical Industry and serves as a senior lecturer in the Department of Health Care Policy at Harvard Medical School. He received his MS and BS in chemical engineering from MIT in 1971 and an MD from Harvard Medical School in 1975.

Since 1975, he has worked actively in the field of medical technology assessment and transfer at MIT. He conducts research and teaches classes in the development and evaluation of medical practice and technology and in health economics and policy at both MIT and Harvard Medical School.

An active consultant to US and international pharmaceutical, biotechnology, and medical device firms, as well as to health services organizations and government agencies, Dr. Finkelstein is an expert in outcomes research. His areas of specialization extend to the business–government interface related to medical technology, especially product development, clinical research design, and third-party reimbursement. Dr. Finkelstein is author, editor, or contributor to several books and numerous articles on those subjects and other issues in health economics.

Dr. Finkelstein's current research interests include analyses relating to the economics of illness and pharmaceutical treatment. His publications include studies of cost of illness and cost-effectiveness of treatment. He is coauthor of several recent articles addressing the link between treatment of illness and productivity at work, and the role of advancing science and technology in changing patterns of medical treatment.

Dr. Peter P. Chen joined ESD as a visiting professor of engineering systems. Dr. Chen is M. J. Foster distinguished chair professor in the Computer Science Department of Louisiana State University. He holds a PhD and an MS in computer science/applied mathematics from Harvard University and a BS in electrical engineering from National Taiwan University. He developed the entity relation model for databases while he was a faculty member at the MIT Sloan School in the 1970s. His research at MIT/ESD focuses on system architecture.

—Kourosh Eshghi joined ESD as a visiting professor. Dr. Eshghi is an associate professor in the Industrial Engineering Department at Sharif University of Technology, Tehran, Iran. He received his PhD in operations research from the University of Toronto in 1997 and his MS in industrial engineering from Sharif University of Technology in 1992.

Dr. Eshghi has taught undergraduate and graduate courses in industrial engineering, focusing on mathematical programming. His research interests are graph theory, integer programming, and combinatorial optimization. He is the author of two books and more than 30 journal papers.

Dr. Eshghi has received numerous awards for outstanding teaching and research. He has also served in editorial capacities on several professional and academic journals.

Dr. Eshghi is currently a visiting scientist at the Operations Research Center for academic year 2005–2006. His most recent work involves developing a model to optimize the volunteer efforts before, during, and after a major disaster.

—David Hartzband, ScD, joined ESD as a visiting scholar. Dr. Hartzband has been exploring and integrating emerging technologies into new and existing product streams for over two decades. He has developed advanced database and metadata technologies, including knowledge base, similarity-based reasoning systems, and model- and ontology-based systems. He has also developed products in the distributed middleware, content management, and collaboration areas as well as developing architectures for very large-scale data and information management systems. He has done considerable consulting on the use of emerging technologies in conventional products and product strategies and has also consulted on business and technology strategies for early stage and established companies.

Dr. Hartzband has worked at companies such as EMC, Documentum, eRoom Technology, Agile Software, General Motors, Boeing (Commercial Airplane Company), and the Digital Equipment Corporation, where he was chief scientist for artificial intelligence and database architect for the corporation. He has previously held faculty positions at Stanford University (Computer Science Division) and The College of William and Mary (Mathematics and Marine Science) and was last a visiting scholar at MIT in the Leaders for Manufacturing Program in 1991–1992.

Dr. Hartzband's current research is focused on the coevolution of organizations in technology and engineering companies and the technology those organizations develop, adopt, and use. He is writing a book on this topic with the working title *Technology, Organizations and the Future of Work.*

—Dr. Farid Kaymaram joined ESD as a visiting scholar. Dr. Kaymaram holds a PhD in mechanical engineering with a minor in expository writing and rhetoric from MIT. He spent four years with MIT's International Science and Technology Initiative Program, including three years in Toshiba's R & D Center in Kawasaki (Japan). He has had more than 10 years of industrial experience in the United States and Japan. He is a tenured faculty member at the School of Management and Economics at Sharif University of Technology in Iran.

Dr. Kaymaram has taught graduate and undergraduate courses for various international programs, including engineering systems and engineering context for the Engineering Program of Monash University in Australia and business cross-cultural communication for the Executive MBA Program of the University of Calgary in Canada. He taught industrial management and economics, as well as production methods, at Sharif University of Technology in Iran.

Dr. Kaymaram's recent research and publications have focused on industrialization strategy, research and development policy, and transfer and development of technology. He is also interested in the role of small and medium enterprises in industrialization and economic development, as well as the effects of environmental (cultural, social, political, and economic) parameters on entrepreneurship in developing countries.

—Dr. Nitin Patel joined ESD as a visiting scholar. Dr. Patel served for 18 years on the faculty of the Indian Institute of Management in Ahmedabad. His research involves the practical applications of operations research and statistical analysis for small samples.

Dr. Patel won India's Vikram Sarabhai Medal for systems analysis research in 1985 and the American Statistical Association's Snedecor Award in 1988. Formerly president of the Operations Research Society of India, Dr. Patel has also served as vice president of the International Federation of Operational Research Societies. He helped create Tata Consultancy Services, a leading Indian software company, and cofounded Cytel Software, a Cambridge-based firm that develops state-of-the-art statistical software.

—Dr. Irving Wladawsky-Berger, vice president of innovation and technology, IBM, joined ESD as a visiting professor. Dr. Wladawsky-Berger is responsible for identifying emerging technologies and marketplace developments critical to the future of the information technology industry and organizing appropriate activities inside and outside IBM to capitalize on them. In conjunction with that, he leads a number of key innovation-oriented activities and formulates technology strategy and public policy positions in support of them. As part of this effort, he is also responsible for the IBM Academy of Technology and the company's university relations office.

Dr. Wladawsky-Berger's role in IBM's response to emerging technologies began in December 1995 when he was charged with formulating IBM's strategy in the then-emerging internet opportunity and developing and bringing to market leading-edge internet technologies that could be integrated into IBM's mainstream business. He has led a number of IBM's companywide initiatives including Linux, IBM's Next Generation Internet efforts, and its work on grid computing. Most recently, he led IBM's On Demand business initiative.

He began his IBM career in 1970 at the company's Thomas J. Watson Research Center, where he started technology transfer programs to move the innovations of computer science from IBM's research labs into its product divisions. After joining IBM's product development organization in 1985, he continued his efforts to bring advanced technologies to the marketplace, leading IBM's initiatives in supercomputing and parallel computing, including the transformation of IBM's large commercial systems to parallel architectures. He has managed a number of IBM's businesses, including the large systems software and the UNIX systems divisions.

Dr. Wladawsky-Berger is a member of the University of Chicago Board of Governors for Argonne National Laboratories and of the Technology Advisory Council for BP International. He was cochair of the President's Information Technology Advisory Committee as well as a founding member of the Computer Sciences and

Telecommunications Board of the National Research Council. He is a fellow of the American Academy of Arts and Sciences. A native of Cuba, he was named the 2001 Hispanic Engineer of the Year. Dr. Wladawsky-Berger holds an MS and a PhD in physics from the University of Chicago.

—Dr. Taft Broome joined ESD as a Martin Luther King, Jr., visiting professor for academic year 2006. A faculty member at Howard University in Washington, DC, for more than 30 years, Broome is a civil engineer with expertise in dynamic structural systems. He also specializes in engineering ethics and the use of personal narrative to find and fulfill one's destiny.

Dr. Broome taught an ESD seminar on engineering ethics (ESD.932) during the spring semester. The purpose of the seminar was to initiate a systematic approach to the problems of identifying cross-cultural issues in the ethical education of science and engineering students and extract from these issues lessons that may enhance the research experience in the globalization process. Dr. Broome conducted a special session on narrative ethics on May 11 with Segun Gbadegesin of Howard University and a session on ethics in academia on November 16, 2005. He also spent time at MIT working on his book on the philosophy of engineering.

There are 46 ESD faculty members: 33 in engineering, 10 in management, 1 in science, and 2 in humanities, arts, and social sciences. Twenty-six hold dual appointments and 20 hold joint appointments. There are 5 other members of the teaching staff.

As a division, ESD establishes an intellectual home for key programs and centers, engages faculty across departments and disciplines, and fosters discourse about engineering innovation, all oriented around the issues of engineering systems. The division coordinates academic programs with more than 300 graduate students. Now in their third year, the Engineering Systems PhD and Engineering Systems SM programs admitted the third full classes of 14 ESD PhD and 4 ESD SM students, respectively. An additional 22 ESD SMs entered Leaders for Manufacturing (LFM) in June 2006 (class of 2008). Also, 10 ESD PhDs and 2 ESD SMs, plus 10 LFM ESD SMs, graduated in this academic year.

In addition to the ESD SM, master's-level programs include LFM, the master of engineering in logistics (MLOG), system design and management (SDM), and the technology and policy program (TPP). A PhD is offered in engineering systems.

Two ESD programs celebrated their anniversaries: TPP (30 years) and SDM (10 years).

ESD has three affiliated research centers: the Center for Engineering Systems Fundamentals; the Center for Technology, Policy, and Industrial Development; and the Center for Transportation Studies and Logistics. The Center for Innovation in Product Development ceased operating in fall 2005.

ESD Postdoc

Dr. Adam Ross was appointed postdoctoral associate by the Center for Technology, Policy, and Industrial Development. His research will extend his doctoral research on dynamic trade space exploration for complex aerospace systems. Dr. Ross received his PhD from ESD in June 2006, and he was previously a research assistant with the Lean Aerospace Initiative at MIT.

Ongoing Initiatives

Undergraduate Education

ESD launched a new undergraduate course, ESD.04 Frameworks and Models in Engineering Systems (FAMES), in the spring semester. FAMES approached systems thinking through a classwide system design project concerned with transportation of spent nuclear fuel to Yucca Mountain, NV, a complex technical problem within a challenging societal context. The class was taught in conjunction with Course 1.041J, Engineering System Design, The instructor, Professor Joseph Sussman, is a dual faculty member in ESD and Civil and Environmental Engineering.

MIT–Portugal Assessment

During a five-month assessment period from February 15 to July 15, 2006, faculty and representatives of MIT had discussions and visits with various Portuguese researchers, higher education institutions, industrial companies, and government agencies to exchange information and ideas with the goal of determining mutually desirable focus areas and the necessary requirements for framing successful projects and identifying key institutional, operational, financial, legal, and technical issues to be resolved.

With Professor Daniel Roos of Engineering Systems and Civil and Environmental Engineering as assessment director, assisted by Renee Robins, director of special projects at TPP, ESD has served as the lead unit at MIT in coordinating the assessment. This included exploring basic research initiatives focusing on system thinking in intellectual areas relevant to problems in Portugal and of interest to MIT and education programs, including the PhD, one-year professional master's degrees, and short courses.

The following specific fields were identified as the initial focus areas for the MIT–Portugal relationship. Leaders' names are indicated for each focus area:

Engineering Design and Advanced Manufacturing. MIT leaders: Joel Clark, professor of materials science and engineering and engineering systems (Manufacturing), and Christopher Magee, professor of the practice of mechanical engineering and engineering systems (Design). Portugal leader: Antonio Cunha, full professor, dean of the School of Engineering at the University of Minho, and codirector of the Center for Excellence and Innovation in the Auto Industry (CEIA).

Transportation Systems. MIT leader: Joseph Sussman, professor of civil and environmental engineering and engineering systems. Portugal leader: João Bento, member of the board,

Brisa-Auto-Estradas de Portugal and president, ASECAP. Also, invited professor at Instituto Superior Tecnico.

Energy Systems. MIT leader: David Marks, professor of civil and environmental engineering and engineering systems and director, Laboratory for Energy and the Environment. Portugal leader: Paulo Manuel Cadete Ferrao, associate professor at Instituto Superior Tecnico, Technical University of Lisbon, and director, Center for Innovation, Technology, and Policy Research.

Bio-Engineering Systems. MIT leader: Dava Newman, professor of aeronautics and astronautics and engineering systems, and director, Technology and Policy Program. Portugal leader: Manuel Nunes da Ponte, full professor, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, and former director of ITQB.

Management. MIT leader: Paul Osterman, professor and deputy dean, Sloan School of Management. Portugal leader: Contacts were made with four other schools.

Engineering Systems Learning Center

In 2006 the Engineering Systems Learning Center (ESLC) centered its efforts on continued partnership with the Knowledge Resource Network (KRN) involving Cambridge University, UK Open University, and Delft as well as work on the Sloan Foundation–sponsored "Engineering Systems Studies." The partnership with KRN included cohosting our third annual conference, held at the UK Open University. The conference focused on communities of practice and electronic learning materials and was cohosted with Cambridge University, TU Delft University, and UK Open University.

A signature product of the ESLC, Engineering Systems Industry Studies, has been promoted through presentations at meetings of the Sloan Foundation Industry Center directors, the International Motor Vehicle Program, the Labor and Employment Relations Association, and other venues. Possible marketing of these studies through the Harvard Business School Press is under exploration.

Cambridge–MIT Initiative

A number of ESD faculty and staff are involved in activities of the Cambridge MIT Institute (CMI). In particular, CMI graduate education, for which Renee Robins has been associate program director on the MIT side, has a number of initiatives with strong links to ESD. TPP has continued to work with Cambridge University with support and funding from the Cambridge–MIT Initiative. Several faculty members traveled to Cambridge University this past year to participate in teaching in the MPhil program in technology policy, established in 2002 with significant assistance and involvement provided by TPP staff and faculty. There is also significant collaboration over curriculum development, and curriculum developed for Cambridge University is also being used in new courses offered at MIT. Enrollment in the Cambridge University program has increased each year, with a goal of 35 in next year's class. TPP and technology policy students are eligible for summer internships doing research and curriculum development with faculty in the partner program. This summer, TPP is hosting one

student from Cambridge University, and two TPP students are currently working with faculty in the UK.

Program on Emerging Technologies

The Program on Emerging Technologies (PoET) was formed and is led by four principal investigators: Daniel Hastings, dean of undergraduate education; Dava Newman, director of TPP within ESD; Kenneth Oye of the Department of Political Science, ESD, and the Center for International Studies; and Merritt Roe Smith of the Program in Science, Technology and Society (STS). Funded by a recently awarded five-year $2.97 million grant from the National Science Foundation's IGERT program and a grant from the Cambridge–MIT Institute, PoET aims to improve responses to emerging technologies by increasing understanding of the economic, security, environmental, and cultural implications of technological advances and the uncertainties surrounding them. This year's work saw continuation of the research in emerging computing technologies, including a workshop conducted at the Oxford Internet Institute. In addition, the program has been working with Professor Andrew Endy in the Department of Biological Engineering on topics emerging in the area of synthetic biology, with several research collaborations developing. There are now 11 PhD students from ESD, CIS, and STS funded by PoET IGERT traineeships. Four other students without direct financial ties to PoET will be joining the research effort in the fall, reflecting the growing interest in the research efforts of the program among our colleagues. Visit http://poet.mit.edu/ for more information.

MIT ESD–MITRE Workshops

The MIT ESD–MITRE workshops are designed to foster research collaboration. The long-term objective is to perform joint research related to many aspects of the engineering of complex systems. The second annual workshop was held at MITRE on November 4, 2005. Participants included leading professionals from MITRE; MIT faculty, researchers, and ESD PhD students; and several invited attendees.

MIT ESD–MITRE Seminars

As part of the ongoing collaboration between MIT ESD and MITRE Corporation, the first seminar in a planned series was held on June 6, 2006. The topic was "Research to Reduce Spread of Pandemic Influenza." The purpose of the seminar was to provide research highlights from each organization and discuss areas of potential collaboration.

MIT ESD Professor Richard Larson presented "Social Distancing Models to Reduce the Spread of Pandemic Influenza." MITRE presentations included Dr. James Dunyak on "Consequence and Response Analysis for Biosecurity," Dr. Brian Tivan on "Agent Based Modeling of Disease Spread and Control," and Dr. Grace Hwang on "Bio-Threat Aircraft Warning Systems."

MIT participants included MIT ESD Professor Larson, MIT ESD senior researcher Stan Finkelstein, MIT ESD senior lecturer Dr. Donna Rhodes; and MIT graduate student Katsunobu Sasanuma.

Interplanetary Supply-Chain Management and Logistics Architectures Project

This interdisciplinary project is sponsored by NASA with a $2.5 million budget over two years. The objective is to develop methods and tools for optimizing the flow of vehicles, crew, and cargo for future space exploration.

Two main achievements characterize the research in the 2005–2006 timeframe. First, an expedition was conducted to the Haughton-Mars research station on Devon Island (Canadian Arctic) to study and characterize the logistics for a remote analogue research station on Earth. Second, a software tool, SpaceNet, was developed to simulate and optimize future human exploration missions and campaigns. This tool has been adopted by NASA and is currently being used to conduct trade studies and refine requirements for the Constellation Program that will return human explorers to the Moon by 2015. The research combines principles and methods from spacecraft systems engineering with advances in terrestrial supply-chain management and is enabled by the interdisciplinary approach spearheaded by the School of Engineering ESD.

The project website is http://spacelogistics.mit.edu/, and the principal investigators are Professor Olivier de Weck (deweck@mit.edu) and Professor David Simchi-Levi (dslevi@mit.edu).

Faculty Notes

Cynthia Barnhart, professor of civil and environmental engineering and engineering systems received the 2005 WORMS Award for the Advancement of Women in OR/MS, at the INFORMS Annual Meeting in San Francisco, CA, on November 13–16, 2005.

Joel Cutcher-Gershenfeld, PhD, senior research scientist, MIT Sloan School of Management, and executive director, Engineering Systems Learning Center, has updated and provided new commentary on *The Human Side of Enterprise, Annotated Edition*, Douglas McGregor, McGraw-Hill, 2006.

Steven D. Eppinger, General Motors LFM professor of management science and professor of engineering systems and deputy dean, MIT Sloan School of Management, was named a distinguished fellow of Product Innovation & Technology Management, College of the Production and Operations Management Society.

Daniel D. Frey, Robert N. Noyce Career Development professor and assistant professor of mechanical engineering and engineering systems, received the 2005–2006 Junior Bose Award for Excellence in Teaching.

Professor Frey and Professor David Wallace, Esther and Harold E. Edgerton associate professor of mechanical engineering and engineering systems, and codirector of the MIT CADlab, jointly serve as content directors of a new educational television program to be broadcast nationally on public television. The show (titled "Design Squad") features children designing and building a variety of devices such as vehicles, sports equipment, and household appliances. The show is being filmed on the MIT campus in summer 2006 and will be launched during National Engineer's week in February 2007.

Patrick Hale, senior lecturer and director of the System Design and Management Fellows Program, was named president-elect of INCOSE.

Daniel E. Hastings, professor of aeronautics and astronautics and engineering systems and director of ESD, was named dean for undergraduate education in November 2005.

Professor Thomas A. Kochan, George Maverick Bunker professor of management, professor of engineering systems, co-director, Institute for Work and Employment Research at MIT Sloan School of Management, and codirector, MIT Workplace Center, published a new book, *Restoring the American Dream—A Working Families' Agenda for America.*

Professor Richard C. Larson, professor of civil and environmental engineering and engineering systems, was appointed director of ESD's Center for Engineering Systems Fundamentals (CESF).

Christopher L. Magee, professor of the practice of mechanical engineering and engineering systems, engineering systems, received the Joseph A. Martore (1975) ESD Educational Excellence Award. The award was established to recognize and honor a fulltime ESD faculty member who has made outstanding contributions to one of ESD's academic programs in the area of education and program development.

David Hunter Marks, director of the Laboratory for Energy and the Environment and Martin and Claire Goulder family professor of civil and environmental engineering and engineering systems, received the TPP Faculty Appreciation Award.

David Mindell, Frances and David Dibner professor of the history of engineering and manufacturing and engineering systems and Margaret MacVicar faculty fellow, was named director of the Program in Science, Technology, and Society.

Earll Murman retired and is now professor emeritus of aeronautics and astronautics and engineering systems.

Devavrat Shah, assistant professor of electrical engineering and computer science and engineering systems, received the National Science Foundation's Division of Computer and Network Systems Early Career Development Award.

Yossi Sheffi, professor of civil and environmental engineering and engineering systems and director of the MIT Center for Transportation & Logistics, had his book *The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage* published by MIT Press in October 2005. The book received rave reviews from the *Wall Street Journal*, the *New York Times*, *The Economist*, and dozens of other publications. It was named one of the best business books of 2005 by the *Financial Times*, and *Foreword Magazine* named it the "2005 Book of the Year" in the category of business and economics.

John Sterman, Jay W. Forrester professor of management and engineering systems and director of the Systems Dynamics Group, received the 2005 IBM Faculty Award.

Joseph Sussman, professor of engineering systems and civil and environmental engineering, chaired a National Research Council/Transportation Research Board committee charged with reviewing the US Department of Transportation Strategic Plan for Research, Development, and Technology.

Olivier de Weck, associate professor of aeronautics and astronautics and engineering systems, was honored with the Frank E. Perkins Award for "a professor who has served as an excellent advisor and mentor for graduate students." He also served as technical general chair for the 2006 AIAA Multidisciplinary Design Optimization Conference.

David Simchi-Levi, professor of civil and environmental engineering and engineering systems, became editor-in-chief of *Operations Research*, the flagship journal of INFORMS, effective January 1, 2006.

Several ESD professors participated in MIT's four-part series of symposia, "Big Questions after Big Hurricanes," including Daniel Hastings, Thomas Kochan, Richard C. Larson, David Mindell, Kenneth Oye, and Yossi Sheffi.

Student Honors

Two TPP 2006 students were among those honored by the Office for Science and Technology of the French Embassy in the United States for their entrepreneurial creativity. François de Laigue and Hironori Matsunaga were on the third-place team in the embassy's Young Entrepreneurs' Initiative.

MLOG 2006 graduate Anne Davidson was awarded a $1,000 scholarship from the New England Roundtable of the Council of Supply Chain Management Professionals.

LFM 2007 students Subhrangshu Datta and Aamir Sundrani were part of a team that won the runner-up award in the development track of the MIT 100K Entrepreneurship competition that concluded on May 18, 2006.

LFM 2007 Marshall Einhorn received the seventh annual Charles "Harrison" Smith III Memorial Award.

LFM 2006 Scott Hiroshige was part of the MIT Sloan/LFM team, which placed third in Boston University's First Annual International Tech Strategy Business Case Competition.

SDM 2005 Massimo Usan won SDM's first Best Thesis award. His thesis is titled "Automotive Component Product Development Enhancement through Multi-Attribute System Design Optimization in an Integrated Concurrent Engineering Framework."

SDM 2006 Vineet Thuvara is the first SDM graduate to win the prestigious Patrick J. McGovern, Jr., 1959 Entrepreneurship Award.

Leticia Soto who entered ESD's SDM program in January 2006, received the Society of Hispanic Professional Engineers' "Hispanic in Technology Government Award."

An SDM team advanced to the final round of the 2005 Thunderbird Global Innovation Challenge in Arizona in October. Members included Jeanne Kesapradist, Dave Schiller, Christian LaFon, and Matt LaMantia, all from the SDM class entering in 2005.

Program Honors

For the fifth year in a row, MIT has been ranked first among graduate business programs in the area of logistics and supply-chain management, according to a recent survey by *US News & World Report*.

INCOSE

On April 6, 2006, INCOSE hosted the first workshop for doctoral students working on systems engineering research topics. The workshop is part of an ongoing effort called SEANET (systems engineering and architecting network), led by MIT ESD senior lecturer Dr. Donna Rhodes, to establish a collaborative network of doctoral students for the purpose of creating dialogue to enable synergistic research outcomes.

The workshop was cochaired by Dr. Rhodes and MIT Center for Technology, Policy, and Industrial Development/Lean Aerospace Initiative (CTPID/LAI) researcher Dr. Ricardo Valerdi. Attended by more than 30 students from 14 universities in six countries, it featured speakers, panels, a poster session, and roundtable discussions. MIT ESD Professor Annalisa Weigel was a keynote speaker for the event. A doctoral research perspectives panel included Dr. Heidi Davidz, a recent MIT ESD doctoral graduate, and MIT ESD doctoral candidate Adam Ross. MIT graduate students Matthew Richards and Nirav Shah also participated in the event.

Several ESD faculty, teaching, and research staff and students participated in the 2005 INCOSE International Systems Engineering Conference in July. Papers or presentations were delivered by ESD professors Daniel Hastings, Daniel Frey (with Don Clausing), Olivier de Weck, and Ed Crawley, senior lecturer Dr. Donna Rhodes, senior lecturer Pat Hale (also director of Fellows for the SDM Program), and ESD PhD candidates Heidi Davidz and Adam Ross. Professor Daniel Roos convened a meeting of the heads of leading academic programs in engineering systems. ESD staged an exhibit that showcased its graduate programs, focusing on the SDM program and on ESD PhD research. ESD PhD candidate Jason Bartolomei demonstrated a simulation of his research. Professor Hastings also chaired INCOSE's academic council.

ESD at Conference on Systems Engineering Research

The Fourth Annual Conference on Systems Engineering Research (CSER) was held April 7 and 8 in Los Angeles. MIT ESD senior lecturer Dr. Donna Rhodes was a plenary speaker on the future of systems engineering research.

Papers were presented by MIT CTPID/LAI researcher Dr. Ricardo Valerdi, and MIT ESD graduate students Adam Ross and Matthew Richards. The research projects of MIT ESD students Adam Ross and Jason Bartolomei were featured in a doctoral research poster session at the conference. MIT coauthors included Professor Daniel Hastings, Professor Richard de Neufville, Donna Rhodes, Ricardo Valerdi, Tao Wang, Jason Bartolomei,

Matthew Richards, and Nirav Shah. Dr. Rhodes and Dr. Valerdi also participated in a postconference workshop to further refine the vision for systems engineering research.

Events

ESD–National Science Board Workshop

ESD hosted a one-day workshop at MIT on October 20 that grew from issues discussed in the recent National Academy of Engineering report, "The Engineer of 2020: Visions of Engineering in the New Century," as well as National Science Board reports that identified troubling trends such as the small number of domestic engineering students.

Top scientists, engineers, and educators from around the country gathered to push forward a national conversation on engineering education in the 21st century and the challenges, both here and abroad, that will affect it. President Susan Hockfield addressed attendees at a luncheon. Other speakers included John H. Marburger, science advisor to the president and director of the Office of Science and Technology Policy, and Arden L. Bement, head of the National Science Foundation.

Brunel Lecture on Complex Systems

On October 14, 2005, Dr. A. Richard Newton delivered the 5th annual Brunel Lecture on Complex Systems. The title of his presentation was "The 21st Century Is about Engineering, Systems, and Society." Dr. Newton is dean of the College of Engineering and Roy W. Carlson professor of engineering, University of California, Berkeley. Dr. Newton's lecture can be viewed on MIT World at http://mitworld.mit.edu/video/310/.

Charles L. Miller Lecture

Noted economist Mr. Clyde Prestowitz, Jr., delivered the annual Charles L. Miller Lecture on April 4, 2006. The title of his lecture was "The World Turned Upside Down: The Impact of the Return of India and China to Their Historical Global Weight." Mr. Prestowitz's 's lecture can be viewed on MIT World at http://mitworld.mit.edu/video/358/.

CTPID-ESD Seminar Series

CTPID and ESD cosponsored the Perspectives on Critical Infrastructure series, which included the following:

- *Infrastructure in the 21st Century*, by Cordell W. Hull, venture investor and developer, former chairman of Bechtel Enterprises, and executive vice president of the Bechtel Group (November 28, 2005).
- *Regulatory Perspectives on U.S. Nuclear Power Infrastructure—Current or Future*, by Peter Lyons, commissioner, Nuclear Regulatory Commission (February 28, 2006).
- *Critical Infrastructure Challenges: Impacts of Global and Cross-Sector Trends and Driving Forces*, by Ralph Peterson, CH2M (March 15, 2006).

- *Critical Infrastructure Challenges: Managing the Electricity Enterprise*, by Ted Marston, Electric Power Research Institute (April 6, 2006).

ESD Five Year Review

When ESD was created, the MIT faculty vote mandated a review of the intellectual, educational, and organizational progress of the unit after five to seven years. The previous provost, Bob Brown, set up a review committee of non-ESD faculty in the last academic year. ESD supported the review by providing all information requested. The results of the review were made available spring of this academic year and were discussed with MIT leadership and ESD faculty. This will be further discussed at an MIT faculty meeting in the fall.

Major Meetings

ESD Faculty Offsite Meetings

ESD held two offsite meetings in AY2006.

ESD's winter offsite meeting was held January 17, 2006, at MIT's Endicott House Brooks Conference Center. Presentations included a review of the ESD PhD program by Professor Warren Seering and offsite committee members; key issues raised in the review, led by Professor John Carroll; and the status of track development in technology, management, and policy, enterprises, and model-based analysis. Group reports were made on a process for moving forward with track definition. Professor Richard Larson's presentation was on a straw core methods class; Professor John Carroll's presentation was on issues in the design of a "behavioral methods" class; Professor Steve Eppinger presented on Sloan as a supplier of content; Professor Warren Seering covered issues of depth and breadth and requirement specifications; and Professor Sanjoy Mitter's presentation was on engineering systems theory. ESD's five year review was also discussed.

ESD's spring offsite meeting was held on May 30, 2006, also at MIT's Endicott House. The following presentations were made: an overview of spring semester activities by Professor Joel Moses, probability/statistics methods subject by Professor Richard Larson, social science methods subject by Professor John Carroll, Sanjoy Mitter's seminar activities, the ESD director search by Professor Sheila Widnall, and an overview of the five year review committee's recommendations and ESD's response. ESD faculty worked in breakout groups in the afternoon, convening later to report and discuss conclusions and plans for ESD's draft report.

ESD Alumni Advisory Council

The ESD Alumni Advisory Council convened two meetings. On October 14, topics included an update on implementation of ESD's strategic plan by (then) ESD director Professor Daniel Hastings, leadership programs across ESD by senior lecturer Janice Klein of the Sloan School of Management, ESD PhD students' perspectives by Robb Wirthlin, fundraising and industrial council by Professor Daniel Roos, and communications and response to ESD branding by ESD communications director Lois

Slavin. Members of the ESD Advisory Council attended the leadership seminar before the meeting and the Brunel Lecture afterward.

On April 6, 2006, the ESD Alumni Advisory Council met to hear the following presentations: an ESD overview by ESD acting director Joel Moses, ESD director search by Institute Professor Sheila Widnall, ESD's international activities by Professor Daniel Roos, and ESD research by Professors Olivier de Weck and Richard Larson.

Members of ESD's Advisory Council include Paul B. Adamsen II, Vernon Altman, Jason Amaral, Thomas Clark Davis, Moises Goldman, Joseph Harrington, Benjamin R. Jurewicz, James Kim, Henry Lichstein, William McIntyre Layson, Joseph Albert Martore, John Edward Shephard, Jr., James Donald Shields, Dr. Donald E. Shobrys (chair), Matthew Siegel, Martin Ayers Taylor, Jay M. (Marty) Tenenbaum, Leif Christian Ulstrup, and Peter Yanev.

ESD Leadership Seminar

The ESD Leadership Seminar was held on October 14. A presentation was made by Matthew Siegel, managing director and chief marketing officer of GE Commercial Finance, Energy Financial Services, titled "Can System Understanding Differentiate Capital? The Art and Science of Selling Financing Products in the Energy Sector."

ESD Seminar Series

This ESD Seminar Series, created by ESD Professor Randolph Kirchain with ESD Professors Richard Larson, Christopher Magee, and Warren Seering, included the following:

- "Counterterrorism: Unconventional Solutions to Unconventional Problems in an Unconventional World" by Jeffrey Baxter, National Security Counterterrorism Expert (December 9, 2005).
- "Air Force Transformation and Technology—A Systems Challenge" by General Lester Lyle, USAF (November 28, 2005).
- "The Dynamic Role of Knowledge Relatedness at Industry Birth: The Evolution of the Automotive Airbag Industry," by Professor Sebastian Fixson, assistant professor, Industrial & Operations Engineering, University of Michigan (May 1, 2006).

ESD Courses at Independent Activities Period

ESD and its affiliated academic programs and research centers offered the following during MIT's 2006 Independent Activities Period (IAP):

ESD Seminar

Uncovering the Leader in You by Partha Gosh (January 9–12, 2006)

Operations Research Center/ESD Seminar Series

Adaptive Experimentation, Expected Value of Improvement, and Robust Design (January 10, 2006)

An OR Approach to Financial Planning (January 17, 2006)

Strategic Engineering: Designing Systems for an Uncertain Future (January 24, 2006)

The Weakest Link (January 31, 2006)

TPP Seminar Series

An Introduction to Complexity (January 10–11, 2006)

Electric Power Networks: Challenges and Opportunities (January 18, 2006)

International Space Cooperation? Visions of the Future (January 25, 2006)

MyAmazon.Com? Personalization and Privacy in the Marketplace (January 31, 2006)

MLOG Seminar Series

Creating and Evolving a Corporate Culture (January 11, 2006)

Leadership versus Management (January 11, 2006)

The Resilient Enterprise (January 18, 2006)

Sloan School of Management Seminar

Sports as a Vehicle for Change and Opportunity (January 18–19, 2006)

LFM Seminar

The Role of Operations in Corporate and National Competitiveness (January 23, 2006)

Diversity Outreach

As part of ESD's plan to increase enrollment of women and underrepresented minorities in its programs, ESD staged exhibits at the national conferences of the Society of Women Engineers, the Society of Hispanic Professional Engineers, and the National Society of Black Engineers. ESD students, faculty and staff participated in these events. ESD's diversity recruitment conference efforts are led by communications director Lois Slavin.

ESD Reports

In AY2006, ESD published two editions of its online newsletter, *ESD Reports*. The theme of the summer 2005 edition was ESD research, and the theme of the fall issue was diversity. They can be viewed at http://esd.mit.edu/esd_reports/esd_reports.html.

Employee Recognition

Two ESD employees were honored for excellence: Susan Cass, communications manager, CTPID, received MIT's Infinite Mile Award for Sustained Excellence, and Tara Eisner, administrative assistant for CTPID/LAI, received the Infinite Mile Award for Excellence.

Space Changes

The Committee for Review of Space Policy arranged for ESD to acquire space in NE20 (3 Cambridge Center) for research-related projects. This new space replaces approximately 3,200 sq ft of space the Center for Innovation and Product Development (CIPD) vacated in E60. ESD plans to relocate faculty from the now disbanded CIPD in NE20 who will be involved on various independent research endeavors. In addition, a section of LAI will be located in NE20.

Personnel Changes

Elizabeth Milnes became ESD's academic administrator.

Joel Moses
Acting Director
Institute Professor

More information about the Engineering Systems Division can be found at http://esd.mit.edu/.

Leaders for Manufacturing

The Leaders for Manufacturing (LFM) program is a partnership between MIT and more than 25 global manufacturing firms to discover and translate into teaching and practice the principles that produce world-class manufacturing and manufacturing leaders. This partnership is motivated by a shared belief that excellence in manufacturing is critical to meeting the economic and social needs of individuals, firms, and society and that the health of companies operating in global markets is essential to the world's well-being.

Now in its 18th year of operation, LFM is a partnership between the School of Engineering, the MIT Sloan School of Management, and leading manufacturers. Launched in 1988 with significant industry funding, the program emphasizes collaboration and knowledge sharing with its partner companies across the entire spectrum of "Big M" manufacturing enterprise issues. LFM supports students as fellows with a generous fellowship. The program is a 24-month dual master's degree (SM in engineering and MBA or SM in management) experience, involving a single integrative research project carried out on site in partner firms. With regard to the School of Engineering, LFM students can get degrees in eight School of Engineering master's programs.

On the administrative level, LFM and System Design and Management (SDM) are managed by common staff, enabling conservation of resources.

Academic Program

Forty-eight students in the class of 2006 completed the LFM Fellows Program. Each completed an internship at a partner company during summer and fall 2005. Internships are focused projects of concern to the partners, accomplished by interns with company support and MIT faculty guidance. Representative projects this past year

included process improvement design, supply-chain management, and various lean manufacturing initiatives.

Another 46 students (class of 2007) completed their first year of on-campus studies and started their six-month internships. Applications increased by 20 percent for the class of 2008; 47 new students were admitted and began an intensive summer session in June 2006. The class of 2008 has an average of 5.2 years of work experience.

Donald Rosenfield continues to serve as the director of the LFM Fellows Program. Codirectors for the LFM and SDM programs are David Simchi-Levi and Thomas Allen. Ronald Slahetka continues as industry codirector.

In terms of new endeavors, ESD created two new courses in 2004 for LFM: ESD.60 Lean/Six Sigma Processes is taught by Steven Spear and ESD.730 Materials Selection, Design, and Economics is taught by Joel Clark and Thomas Eagar. The leadership seminar was taught by Don Davis, retired CEO of Stanley, and Bill Hanson, former LFM-SDM codirector.

Marketing Efforts

In 2005, LFM applications had been decreasing for a number of years. LFM increased its marketing efforts and secured and implemented its first significant marketing budget. New marketing efforts for the class of 2008 included two information nights (Detroit and Boston), rewriting the LFM website, improved Admit packets, new self-mailing postcards, an interview fest, virtual visits, and the year-round purchase of GMASS names. LFM met its goal of 200 applications this year.

China LFM

Major studies on competitiveness in China indicate a critical imperative—the need for manufacturing enterprises to recruit, develop, and retain mid- and top-level leaders over the short and long term. The China Leaders for Manufacturing program (CLFM) was developed to address this issue.

The CLFM program is an educational and research partnership among global firms and Shanghai Jiaotong University's (SJTU) Antai College of Economics and Management, School of Mechanical Engineering and School of Electronics and Electric Engineering. Its mission is to educate the next generation of manufacturing and operations leaders in China.

Modeled after MIT's LFM program and created with MIT's authorization and educational support, CLFM is the country's first-ever dual degree graduate program focused on educating China's next generation of manufacturing and operations leaders. A partnership of SJTU and industry, CLFM offers a 24-month, dual master's degree program that combines the disciplines of engineering and management. Students will work an additional six months at a partner company site during the required internship experience. Each graduate will receive an MS in engineering from SJTU's School of Mechanical Engineering or School of Electronic, Information and Electrical Engineering, and an MBA from SJTU's Antai College of Economics and Management.

Nine companies have now signed up for CLFM, and MIT will sign a memorandum of understanding with SJTU in Shanghai on August 29, 2006.

Research and Knowledge Transfer Program

As part of LFM and SDM's commitment to lifelong learning, an initiative begun in FY2002 was continued to encourage LFM and SDM alumni to stay connected with MIT by sharing relevant information. LFM and SDM continued to schedule monthly webcasts presented by MIT faculty and various LFM and SDM alumni. The content of each webcast, also called a "webinar," provides valuable information on the latest trends, cutting-edge developments, and innovative strategies, all of which pertain to manufacturing and/or systems design. The presentations are given in real time, via the Internet and telephone, which allows participants to follow along visually and audibly as well as to ask questions. Alumni continue to express a high degree of interest in these virtual knowledge-sharing events, and webinars have evolved into a key tool for alumni engagement.

LFM Alumni

The LFM Alumni Council is in its fourth year. It meets the second Friday of each month in a virtual meeting to improve the LFM network and the LFM program and to enrich the lives of the alumni. All alumni are welcome. Jay Burkholder, LFM 1998, took office as the official voice of the alumni at the LFM Operating Committee. The LFM 2005 Conference took place in Santa Clara, CA, where 88 alumni gathered to see presentations by Cisco and Novellus executives and panel discussions with prominent LFM alumni. The theme was "Innovation in Manufacturing."

Pro Seminar Speakers

On campus, LFM students attend weekly seminars with faculty and industry experts, enriching their formal education with learning about current manufacturing leadership and business issues that are local, national, or international in scope. Speakers in fall 2004 and spring 2005 included Len Baxter of GM, Doug Busch of Intel, Tim Crawley of Motorola, Taiyu Chou of Foxconn, Clay Christensen of Harvard Business School, Tim Copes of Boeing, Rafael O. de Jesus of ABB, John Deutch of MIT, Doug Field of Segway, Ben Goss of BAE Systems, LFM founders Bill Hanson and Kent Bowen, Bill Hetzel of Tom's of Maine, Sean Hilbert of Cobra Motorcycles, Tom Hutton of Sikorsky, Laura Kennedy of ABB, Chip MacDonald of Segway, Jim Miller of Cisco, Dev Pillai of Intel, Randal Pinkett of BCT Partners, Mike Rion of Cummins Engine Company, Yossi Sheffi of MIT, and Jeff Wilke of Amazon.com.

Plant Tours

The LFM plant tours expand students' understanding of manufacturing complexity by introducing them to LFM partner companies' diverse operations, plant floor workers, executives, and LFM alumni. In the summer term and during the academic year, students see an average of 15 companies during local visits and a two-week national plant tour. This past year, plant tours were held at The Broad Institute, Cambridge, MA; Raytheon, Andover, MA; AAC, Detroit, MI; Amazon.com, Reno, NV; The Boeing Co., Seattle, WA; Dell, Austin, TX; Ford, Detroit, MI; GM, Detroit, MI; Honeywell, Phoenix,

AZ; Intel, Phoenix, AZ; UTC, Phoenix, AZ. (In addition, several students visited Habitat for Humanity, New Orleans, to assist in post-Katrina efforts.)

The International Plant Tour to China included ABB, Shanghai; ITI Holdings, Beijing; Jetta Pan Yu, Shenzen; Li & Fung Ltd., Hong Kong; and Motorola, Tianjin.

Career Development

LFM students, sponsored and nonsponsored, continue to be highly sought after once they have completed the program. Partner companies as well as other organizations take a special interest in LFM students, as proven by their commitment to speak to the class on various issues during the Pro Seminar session. Seventy-two percent of the class of 2005 accepted positions within manufacturing and operations companies, and 40 percent accepted positions within partner companies.

Governance

LFM is run by a governing board consisting of the partner companies' senior officers, program codirectors, and MIT deans. It is cochaired by Bill Ramsey of Honeywell and Larry Loftis of Boeing. The operating committee handles ongoing management of the program and includes company representatives, faculty, and directors. The Operating Committee is chaired by Ron Slahetka. The Operating Committee's focus is a series of standing committees that include companies, faculty, and students.

New internship participants included ATI Technologies, Inc., Building Materials Holding Corporation, Inditex, iRobot, and Siemens. New partner companies are American Axle & Manufacturing, Cisco Systems, Inc., Flextronics International Ltd., and Novartis, AG.

Tom Allen, Codirector, Howard W. Johnson Professor of Management, and Professor of Engineering Systems
David Simchi-Levi, Codirector and Professor of Civil and Environmental Engineering and Engineering Systems
Ron Slahetka, Industry Codirector
Don Rosenfield, Director, LFM Fellows Program

More information about the Leaders for Manufacturing Program can be found at http://lfm.mit.edu/.

System Design and Management

The mission of the System Design and Management (SDM) program is to educate future technical leaders in the architecture, engineering, and design of complex products and systems, preparing them for careers as the technically grounded senior managers of their enterprises. SDM intends to set the standards for delivering career-compatible professional education using advanced information and communication technologies. SDM was one of MIT's early entries into the field of distance education and remains the only degree at MIT that can be earned primarily from a remote location.

The SDM program, in its 10th year with the 2006 cohort, is a joint offering of the School of Engineering and the MIT Sloan School of Management, leading to a master of science degree in engineering and management. Targeted to professional engineers with three or more years of experience, SDM centers on a 13-course curriculum in systems, engineering, and management, including a project-based thesis. It offers three curriculum options: a 13-month in-residence format; a 24-month distance education for company-sponsored students, requiring one academic semester in residence at MIT; and a 24-month commuter program for local students. The program was conceived as an alternative to the MBA for professional engineers, allowing working professionals to pursue a degree without interrupting their careers and relocating themselves and their families.

Pat Hale continues as director for his second year. Codirectors for the program are David Simchi-Levi and Tom Allen. John Grace is the industry codirector.

Student Statistics

In January 2006, SDM admitted its 10th class, enrolling 58 students, including seven Navy students from Course 2N who selected SDM as a second master's program. As was done in FY2005, SDM put on informational evenings in July, September, October, April, May, and June for local MIT alumni and others interested in SDM as a way to recruit prospective students for SDM 2006. These successful events brought more than 100 prospective students to campus or suburban locations, where they heard presentations from faculty, students, and alumni.

System Design and Management Admissions Statistics

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Admitted	35	58	47	50	37	27	36	37	62	58
On campus	8	16	6	14	8	7	18	27	44	44
Self-supported	3	1	2	5	2	1	6	25	42	34
Research assistant	3	12	2	4	3	1	10	0	0	0
Distance education	27	42	41	36	29	18	17	10	18	14
Company-sponsored	29	45	43	41	32	25	20	12	20	24

MIT–Industry Partners System Engineering Program

This past year, SDM and its partner program LFM, along with United Technologies Corporation (UTC), continued with a third year of the MIT–Industry Partners Systems Engineering Program. This year, program involvement included additional partner companies—Boeing and Nortel—for the second consecutive year.

To build a systems engineering core competency, this unique program targets three key populations: experts enrolled in the SDM program, experts enrolled in the Systems Engineering Certificate Program, and the organizational leaders of those experts. The program has been very successful, with 106 students completing the Certificate Program and more than 100 organizational leaders completing the six days of content in the Organizational Leaders Workshop. With its active participation in all levels of the

program, UTC now has more than 220 employees touched by SDM. The next cohort of certificate students for FY2007 is expected to reach 25, with students from UTC, Boeing, and John Deere.

Distance Education Delivery

As MIT's premier degree program offered at a distance, SDM has recognized its leadership role at the Institute regarding the practice of distance education. SDM continues to evaluate its delivery with the goal of increasing the quality of the remote-learning experience while reducing costs, both for MIT and for sponsoring companies.

Tom Allen, Codirector, Howard W. Johnson Professor of Management, and Professor of Engineering Systems
David Simchi-Levi, Codirector, Professor of Civil and Environmental Engineering and Engineering Systems
Jack Grace, Industry Codirector
Pat Hale, Director, SDM Fellows Program

More information about the System Design and Management Program can be found at http://sdm.mit.edu/.

Technology and Policy Program

The MIT Technology and Policy Program (TPP) provides an integrative education to engineers, scientists, and humanists who want to lead technological development by implementing responsible policies for the benefit of humankind. TPP's guiding vision is the education of "Leaders Who Are Engineers and Scientists."

Within the intellectual and educational ambit of the School of Engineering's Engineering Systems Division (ESD), the TPP graduate educational program focuses on the development of skills in policy development and analysis and requires a significant research thesis as a fundamental component of engineering systems studies. The program provides a high-impact, high-quality education. Its goals are to make TPP the most prestigious and sought-after technology policy program in the world and to produce the technological decision makers of the future.

TPP sponsors a master of science program and the technology, management, and policy (TMP) doctoral program, constituted as a track within the ESD doctoral program. TPP receives most of its applications from outside MIT, but it also has several internal admits each year, with many students pursuing a master's or doctoral degree in another program concurrent with their TPP SM degree. Each entering class is around 40 students (39 this coming fall), with approximately 35 percent of them pursuing dual degrees, which may require an additional semester or two to complete. This year, 35 students graduated with master's degrees in technology and policy, and four master's students were accepted to continue their studies at the doctoral level. This year's Best Thesis in Technology and Policy was awarded jointly to Meghan Sweeney and Nicole Jordan, supervised, respectively, by Professor Nicholas Ashford and by Professor Dava Newman.

The TMP track within the ESD PhD program has a current enrollment of 24 students, reflecting a steady-state admission rate of about five students per year. Five students received their technology, management, and policy PhD in this past academic year. The fourth annual Technology, Management and Policy Doctoral Consortium was hosted by TPP at MIT in June 2005, and attendees came from North American, European, and Asian universities working in this area. TMP and TPP students presented their research in the form of talks and posters, and TMP presenter Erica Fuchs won the award for best presentation. The consortium meeting has been an unmatched opportunity for our students to build relations among the burgeoning international academic community of technology and policy scholars. Previous meetings were held in the Netherlands, in Washington DC and in Cambridge, UK. We look forward to next year's meeting at Instituto Superior Téchnico in Lisbon, Portugal.

Fellowship funding was provided to several incoming students to attract the top TPP candidates to MIT. This year the funds came from the Rabinowitz and de Neufville funds, as well as a tuition-only Keil Fellowship. The Office of the Dean of the Graduate School also provided fellowship funding to TPP students this year. These funds have been generously provided by TPP alumni and donors who also make possible several other student benefits, including funding for TPP women student events and some of the costs associated with the TPP visiting speaker series and alumni relations. TPP maintains ties to its roughly 900 alumni, and works to foster a strong alumni community through biannual publication of the *Alumni Directory* and regional gatherings in Washington and Boston. This January's gathering in Washington, DC, was held at ICF Consulting's DC offices and more than 50 people attended, including 30 local alumni. Professor Newman also conducted alumni activities in Japan and Singapore this fall. TPP alumni receive e-newsletters several times a year, including articles written by current and former TPP students as well as faculty and staff.

The year 2006 marked the 30th anniversary of the founding of the program, which was celebrated over the course of the spring semester. A lecture series on current and future Internet policy issues was held during the spring term. On June 8, during alumni week, a half-day symposium was held that comprised two panel discussions: one by TPP alumni and one by educators in technology and policy from MIT and Carnegie Mellon. A gala dinner was held on June 9, featuring TPP alumnus and NASA astronaut Michael Massimino as the keynote speaker. (See http://alum.mit.edu/ne/noteworthy/news-features/tpp.html.)

TPP greatly values practical experience and actively encourages students to take summer internships between their first and second years of study. In January 2006, 19 students traveled to Washington, DC, to attend meetings with prospective internship employers, including government agencies such as the Office of Management and Budget and private consulting companies and think tanks such as ICF and CSIS. Many students found internships in Washington this summer, while others are working elsewhere in the United States or abroad. Students whose internships were unfunded were able to earn valuable experience by taking advantage of living-cost funding provided by TPP alumni and donors—including Larry Linden, Phillip Ng, Francis Chin, and Donald Cooke—to make their internship experiences possible.

The Technology and Policy Student Society (TPSS) is one of the most active student groups on campus. Generous donors have made it possible for TPP to recognize TPP students for leadership. In addition to recognizing the student board of TPSS, this year's leadership prizes also went to the officers and members of the TPP Student Society, whose many contributions to the TPP community were recognized and honored. In many respects, this award was a recognition of the all the very dedicated students in the program who make so many TPP initiatives possible.

This past year, Course ESD.10 Introduction to Technology and Policy was team taught by Professors Annalisa Weigel, David Mindell, and Daniel Roos. Professor Weigel has been leading this course, which is the core introductory course for the program. Professor Weigel leads the continuous refinement of this course through the availability of curriculum development funds from the Lord Foundation, which also supports other course changes at TPP. Another notable TPP curriculum development is the addition of a course from the Department of Economics (Course 14.003 Microeconomic Theory and Public Policy) as an alternative to the course from the Department of Management (Course 15.011 Economic Analysis for Business Decisions) that has been a part of the core since the program's inception. Course 15.011's instructor this fall, Professor Ernst Berndt, was awarded a faculty appreciation award by the TPP students.

With support from the Cambridge–MIT Institute, TPP has maintained its close collaboration with the Technology Policy Master of Philosophy (MPhil) program at Cambridge University, which has just completed its fourth year. Collaborative curriculum development efforts continue, with some of the new educational material developed for Cambridge University being incorporated into TPP teaching at MIT. More than half dozen faculty members traveled to Cambridge University this past year to participate in teaching in the program's core curriculum and other newly developed elective modules. Over the past four summers, TPP has sent nine students to Cambridge University for summer internships to support the new curriculum there. For the fourth year, TPP has welcomed Cambridge students to MIT to pursue summer internships in research. In AY2004–2005, TPP imported a course in telecommunications that had been developed for the CMI-developed MPhil in technology policy. The telecommunications policy course was again taught this spring, led by David Clark, Sharon Gillett, Frank Field, and William Lehr. At the encouragement of and with the support of the Department of Electrical Engineering and Computer Science (EECS), the course was expanded to a full semester course this year.

TPP has continued its participation in the collaborative and interdisciplinary Program on Emerging Technologies (PoET), along with ESD, STS, CIS, and Political Science. Funded by a recently awarded five-year $2.97 million grant from the National Science Foundation's IGERT program and a grant from the Cambridge-MIT Institute, PoET aims to improve responses to emerging technologies by increasing understanding of the economic, security, environmental, and cultural implications of technological advances and the uncertainties surrounding them. This year's work saw the continuation of the research in emerging computing technologies, including a workshop conducted at the Oxford Internet Institute. In addition, the program has been working with Professor Drew Endy in the Department of Biological Engineering on topics emerging in the area

of synthetic biology, with several research collaborations developing. There are now 11 PhD students from ESD, CIS, and STS funded by PoET IGERT traineeships. Four other students without direct financial ties to PoET will be joining the research effort in the fall, reflecting the growing interest in the research efforts of the program among our colleagues. Visit http://poet.mit.edu/ for more information.

With the completion of our third year in the academic space on the third floor of E40, the Muckley Building, TPP has continued to find extraordinary value in having a "home" for its educational and research efforts. Having a physical focal point for TPP activities and student events (formal and otherwise) gives the otherwise far-flung TPP students (whose research activities take place across the entire MIT campus) a common base from which to develop their skills, scholarship, and community.

Dava Newman
Director
Professor of Aeronautics and Astronautics and Engineering Systems

More information about the Technology and Policy Program can be found online at http://tppserver.mit.edu/.

Center for Engineering Systems Fundamentals

On August 25, 2005, Professor Dan Hastings, then-director of MIT's ESD, announced a new center within ESD, the Center for Engineering Systems Fundamentals (CESF):

I am pleased to announce the formation of the Center for Engineering Systems Fundamentals (CESF) as of September 1, 2005. The Center will have as its major focus research on the fundamentals and cross cutting issues in engineering systems. The Center will be led by Professor Dick Larson and report to the Engineering Systems Division in the School of Engineering. The Center will be responsible for the following activities:

a) developing a climate to discuss Engineering Systems fundamentals (seminars, etc.)
b) developing and deepening relations with the Operations Research Center
c) working with faculty to bring in resources for the CESF
d) sponsoring a book series
e) sponsoring a biannual international symposium on ES fundamentals.

The Center will be housed in E40 and nearby buildings. The need for such a center was identified in the ESD Strategic Plan and endorsed by the ESD faculty.

This being the end of the first academic year for the CESF, it is time for a brief annual report to the ESD community. Additional details will be provided on request. Documents and presentations referred to here are summarized in the appendix and are available on request.

Progress on Points in Initial Charge

First we discuss CESF activities associated with those delineated in the announcement above.

Developing a New Climate

In developing a climate to discuss Engineering Systems Fundamentals, we held open meetings with the faculty, made two ESD faculty lunch presentations on engineering fundamentals, made a presentation to the Alumni Advisory Council Meeting, and invited one-on-one talks with interested faculty members. As a result, new relationships have been forged that will aid in the teaching and research devoted to fundamentals. There was an active discussion about whether fundamentals could be derived in a context-free environment or as a result of generalizing results discovered doing contextually motivated research. CESF has been emphasizing research on complex systems that exist or may exist, with the model that generalized fundamentals may be drawn from contextually motivated results. This has been the dominant history of fundamentals discovery in related fields such as operations research and optimal control theory.

A prototype seminar/dialogue process was established with the Mitter Seminar. It is planned to enlarge that effort next year and to open it to the entire ESD community. Also, we plan to invite outside speakers and advertise their talks to the MIT community.

Finally, ESD faculty members were asked to list their most important research journals and daily news media. The results were displayed as a social distancing network map (available on request), which dramatically showed that ESD is very diverse, containing "islands" not connected to the remainder of the network.

Relationship with the Operations Research Center

With regard to the Operations Research Center (ORC), CESF has cultivated a close and strong relationship with ORC codirector Professor James (Jim) Orlin, who is stepping down from this position on June 30. Jim and Dick Larson worked together on TA, RA, and UROP student support and related activities.

Dick also leads a team to produce this year a book celebrating the first 50 years of the ORC. This book is based on the presentations made by invited speakers at the ORC 50th celebration and on the remarks of MIT faculty and friends at the celebration of life service at the MIT chapel for Professor Al Drake, who passed away in 2005. Ingrid Larson is the editor of the book, and had extensive assistance from ORC's Laura Rose.

At the request of Professor Alice Gast, MIT's vice president for research, Dick Larson led a faculty committee charged with recommending the next two codirectors of ORC. After extensive discussions with ORC and in some cases ESD-related faculty members, the search committee submitted its report to Professor Gast. As a result, Professors Cynthia Barnhart and Dimitris Bertsimas will take leadership as ORC codirectors on July 1, 2006. Dimitris and Dick have discussed building collaborations between ORC and ESD and have agreed in principle to find one large contextually motivated project to work on jointly, writing a joint research proposal some time during AY2006–2007.

To build stronger ties between the national communities representing Engineering Systems and Operations Research, Dick Larson has agreed to serve as official liaison between INFORMS (Institute for Operations Research and the Management Sciences,

http://www.informs.org/) and CESUN (Council for Engineering System Universities, http://cipd2.mit.edu/).

Finally, Operations Research was brought into the spring edition of the ESD Doctoral Seminar (cotaught by Professor David Marks and Dick Larson), as David and Dick invited Operations Research historian and luminary Professor Saul Gass to fly to Boston to present the history of Operations Research to the seminar students. Of particular interest, the ESD seminar students suggested that Operations Research—as originally envisaged by Philip M. Morse and his colleagues in the 1940s and early 1950s—was remarkably close to our collective vision of Engineering Systems today.

Research Initiatives

We have worked with many faculty members and researchers in the direction of bringing research support resources into the CESF. As discussed below, several white papers and proposals have been submitted during this period, but no definitive commitments have yet been made. The one exception is a $50,000 award from Cordell Hull to undertake fundamentals research on peak load shedding on critical infrastructure systems. A draft report on that effort should be available in midsummer.

Book Series

The idea of a book series has been discussed with ESD faculty. Also, Dick Larson met with MIT Press, and that publisher would welcome the opportunity to publish such a series. There is a commitment by Professors Dan Frey and Dick Larson to write a first book in this series, a textbook that will be used to support the teaching of a required ESD doctoral subject on quantitative research methods. At the present time, there have been no additional commitments by ESD faculty members to author or coauthor a book in this series.

Biannual Meeting

With regard to sponsoring a biannual meeting on engineering systems fundamentals, no progress has been made on this topic. With the change in ESD directorship in January 2006, the topic of ESD-sponsored professional meetings and symposia has been placed on hold, most likely awaiting appointment of a permanent ESD director.

A New MIT Subject on Fundamentals

At the ESD off-site retreat in January, it was decided that a new required subject was needed for ESD doctoral students. This subject would cover engineering systems fundamentals that focus on quantitative modeling and research methods. As a result, Professors Dan Frey and Dick Larson have agreed to codevelop such a subject and offer it for the first time in spring 2007. This aggressive schedule relies on support for a full-time teaching assistant for both the fall and spring semesters for the coming academic year. Fall support is to help organize and put together the content of the subject and spring semester is to help teach the subject. As this support has just been received, we are committing to give this subject in spring 2007. Professors Frey and Larson believe they can write a textbook covering the fundamentals subject and publish it as one of the first in the desired series of books from the CESF.

The proposed new quantitative methods subject will contain aspects of each of three ESD disciplinary areas: engineering, management, and social science. It will be required of first-year ESD PhD students in the spring semester. There will be another new subject on qualitative methods, currently under development by others in ESD. In ESD tradition, the math part would be augmented with reading assignments and discussions tracing the history and application of each of the major concepts discussed and developed. There would be a term project for each student, and there would be computer-based as well as paper-based homework assignments. The subject would be rigorous.

While a byproduct would be continued class bonding of the first-year doctoral students, the primary focus is on intellectual content. For students whose academic plan is to take MIT subjects that go much deeper than this subject (in statistics, probability, quantitative research methods), the requirement for taking this subject can be waived.

This subject represents a "knowledge requirement" that will be assumed on doctoral general exams. The subject will have an enforceable prerequisite: Course 6.041 Probabilistic Systems Analysis/Course 6.431 Applied Probability, or equivalent.

This new subject will leverage all the fine work that Dan Frey has done with School of Engineering curriculum development grant support—funded in response to the oft-cited Odoni report on the lack of a good solid engineering-focused statistics subject in the School of Engineering. However, our planned new subject is not a statistics subject. If we are successful, we should attract students from elsewhere in the School of Engineering who are not associated with ESD. This could be ESD's first "service subject."

Model building, based on empirical evidence and axiomatic conjectures, should be the emphasis for the new subject. We are not creating a new subject in applied probability, nor are we creating one in statistics, but we use both to obtain our objectives. The focus is more on model synthesis, not data analysis per se. It will have an active model creating focus, not a passive critical social science focus. Axiomatic models would be emphasized more than data-inferred models, inferred from curve fitting—where causation and correlation can become confused.

CESF Research Initiatives

We have had an active year pursuing CESF research initiatives, involving numerous MIT faculty members, both within ESD and outside. In selecting promising targets of research opportunity, we were guided by the ESD mission that our work is focused at the intersection of traditional engineering, management (broadly defined), and social sciences.

Critical Infrastructures

On October 30, 2005, a CESF white paper was submitted to the MIT Energy Research Council, *The 3 R's of Critical Energy Networks: Reliability, Robustness, and Resiliency*. The paper states:

We seek to undertake research that leads to improvements in each of the 3 R's for critical energy networks. We propose (1) to develop system models with sufficient fidelity to identify weaknesses in energy networks as well as potential for cascading failures; (2) to design and analyze new methods for improving infrastructure, taking into account the interactions with legacy systems; (3) to improve real-time monitoring and control of energy networks; (4) to develop new technologies for transmitting and storing energy; (5) to determine how economic and regulatory incentives can be used to direct investment for improving the network infrastructure; and (6) to reduce needed network capacity by decreasing peak energy demands via incentives and technologies for time-shifting the demand to off-peak hours.

Participating MIT faculty members are David Marks, Munther Dahleh, Marija Ilic, and Richard Larson, with Stephen Connors, John Hansman, James Kirtley, Steven Leeb, Sanjoy Mitter, Alexandre Megretski, James Orlin, Asuman Ozdaglar, Pablo Parrilo, Devarat Shah, John Tsitsiklis, and others in the Laboratory for Information and Decision Systems, the ORC, and EECS. At the time of writing, this white paper is still in contention for high-priority support by MIT's broader energy initiative, supported by MIT President Susan Hockfield.

Water Systems

On March 19, 2006, a CESF white paper was submitted to MIT's new Singapore research initiative, *Water: East Meets West, The Need for Appropriate Technologies and Systems*, written by Dennis McLaughlin and Richard C. Larson, with Oral Buyukozturk, Joel Cutcher-Gershenfeld, Herbert Einstein, Charles Harvey, Robert Jaffe, John Kassakian, Stuart Madnick, and David Marks. The white paper, representing a joint effort between CESF and the Department of Civil and Environmental Engineering, describes the proposed research as follows:

With a world-class team of researchers from MIT, Singapore and LUMS, we plan to embark on a major multi-year research effort that examines water systems in all-important aspects, with special emphasis on applications in Asian countries. Our interests are water distribution systems, water origination systems (e.g., desalinization, rain fall collectors), irrigation systems, wastewater treatment systems, water reuse, water systems in poor rural regions without modern support networks, use of water in the design and operations of homes and other buildings, and more. The end product would be new research results in this area, hopefully much of it finding its way to the marketplace seeking solutions to the myriad water-related problems of Asia. To maximize market size, rural Asia is a special focus of this work.

Our work must be contextualized within constraints and traditions of Asian culture. Asian countries have well-developed traditional cultures that are, for various reasons, not always compatible with 21st century Western approaches to decision-making. The institutional issues are tied up with the local culture, and westerners often have relatively little credibility in this area. Naïve application of western 'scientific methods' can backfire, as in Bali. Our team has social science expertise and much practical experience in various countries of Asia, so we plan to be cognizant of cultural issues and utilize centuries-learned knowledge when appropriate.

At the time of this writing, this CESF white paper is still under review by the committee creating the Singapore research initiative.

Voting in US Presidential Elections

Along with ESD research affiliate and long-time friend of MIT Dr. Alex Belenky, Dick Larson has been studying queueing at election precincts during US presidential elections. There are those who argue that potential voters were discouraged from voting in both the 2000 and 2004 presidential elections because there were too few voting machines and support personnel in certain voting places. Belenky and Larson have written a paper about this topic, "To Queue or Not To Queue? In a U.S. Presidential Election, that should NOT be a question!" The paper was published in the June 2006 issue of *OR/MS Today* (available online at http://www.lionhrtpub.com/orms/orms-6-06/frqueues.html).

Belenky and Larson are currently in discussions with two private foundations about supporting fundamental research in this area, leading to a new "services science" method of deploying voting machines and support personnel that would guarantee voter parity for voters of all political parties.

Social Distancing in an Influenza Pandemic

CESF has arranged a team of students, faculty members, and senior research staff to examine preparedness and response to a potential influenza pandemic, along the lines of the 1918–1919 "Spanish Flu," for which Boston was the urban epicenter. Participating students have ranged from a freshman UROP to ORC doctoral students. We have made ties to the Harvard School of Public Health and we are coordinating our work with MIT's plans for response to an influenza pandemic with MIT's William Van Schalkwyk. Dick Larson published (in October 2005) an op-ed piece on this topic in a major Boston newspaper.

Our focus is on social distancing as a control strategy for containing the spread of the influenza virus. Our students and faculty have drafted preliminary research papers on this topic, often examining social distancing historically used in 1918 and in 2003 to combat the SARS epidemic (Hong Kong and Toronto, Canada). We submitted an invited fast-track research proposal on this topic to the Sloan Foundation in early spring 2006. The proposal team included Dick Larson (principal investigator) and Stan Finkelstein (co-principal investigator), with Joel Cutcher-Gershenfeld, Steven H. Hinrichs, MD., Thomas P. Hughes, Salal Humair, David Marks, Karima Robert Nigmatulina, Robert H. Rubin, MD., Katsunobu Sasanuma, and Adam Sonnenschein. The reviews asked for more specific details and we are planning to submit a revised proposal—with Sloan Foundation backing—for their October review cycle.

We view this topic as one of extreme national and international importance, as hundreds of millions of lives could be at stake, depending on how we respond individually and collectively to a pandemic should one occur. Also, we see this research as an exemplar of the type of new research area that ESD wants to enter, health care with a need to examine all three parts of the Venn diagram: engineering, management, and social science. We thank ESD Professor Yossi Sheffi and the project he directs, the Zaragoza program, for supporting a full-time research assistantship on this topic for the past academic year.

Hurricane Decision Making: Example of Disaster Preparedness and Response

PhD student Michael Metzger has been working with Dick Larson, creating a quantitative planning model to frame and formulate rational policies for preparedness and response to hurricanes. This is a specific example of a broader interest and expertise at MIT, preparedness and response models for disasters of all types. Metzger has identified aspects of all three parts of the Venn diagram: engineering in the form of operations research, management (in the form *not* demonstrated in the response to Hurricane Katrina), and social science, all as important in this work.

For example, one social science component involves a local population's propensity to evacuate, given a governmental evacuation order. There is a "boy-who-cried-wolf" syndrome here. If a recent hurricane evacuation order elsewhere in the United States proved to be unnecessary (in retrospect), then local people are less prone to follow a new governmental evacuation order. If, on the other hand, as with Hurricane Katrina, an order is given and people do not evacuate and as a result there are numerous deaths and injuries, then the local population in another jurisdiction is much more likely to follow an evacuation order. The latter propensity was shown in Houston, TX, during Hurricane Rita, when the entire city was eager to evacuate. Metzger is now quantifying this and incorporating it into his stochastic dynamic programming decision model.

We thank Professor Fred Moavenzadeh and the center he directs, CTPID, for supporting a full-time Charles A. and Constance C. Stokes fellowship on this topic for the spring semester. We plan to seek outside research support for this work in fall 2006.

MIT LINC Teaching Initiative in the Middle East

MIT LINC is the Learning International Networks Consortium (http://linc.mit.edu/). LINC, a volunteer effort housed in CESF, is a quasi-professional society of leaders worldwide who believe in the transformative nature of technology as it pertains to education: "With today's computer and telecommunications technologies, every young person can have a quality education regardless of his or her place of birth." Until recently, the assets of a country lay buried underground, such as oil, gas, gold, silver, and diamonds. Today, the key assets of a country lie "buried between the ears of its citizens!" Educating the mind—that is the key to a better tomorrow for all.

In addition to Dick Larson, LINC's 15-member MIT Faculty Advisory Board includes ESD's Professor Dan Roos, who has been very supportive of LINC's goals and directions. The Faculty Advisory Board spans all five schools of MIT.

In June 2006, LINC submitted a major proposal to USAID: "Blended Learning for High School Math Classes: A Partnership Between MIT and Arab Universities to Foster Creative Critical Thinking in High School Math Classes." The extended abstract starts with this overview:

Our focus will be on high school teachers of mathematics, with the idea of inspiring high school students to study math-oriented careers in engineering and science. Recognizing that each country in the Middle East region has its own approved national educational curriculum, we propose to create a set of short "Learning Modules," offered by volunteer professors from

MIT and from participating colleges and universities in the Greater Middle East. Each learning module would be available either on line (via the Internet) or on CD, DVD or videotape. Each would be configured to be compatible with any given national curriculum as an interesting, informative and insightful addition to the usual mathematics curriculum. A learning module might, for instance, be a short video lecture followed in class by some exercise building from the usual curriculum content plus the new "challenge content" of the module. The usual in-class teacher would of course direct the in-class activity. This type of learning module is an example of "Blended Learning," a new and growing pedagogical model in which the content expert enlightens the class with some new ideas and mind-extending challenges, and the class with its regular teacher follows up, climbing new exciting learning heights. Another type of learning module could be an on-line (Internet-based) interactive experiment or project, perhaps as collaborative on-line student projects with the students working in teams.

We believe that proposals such as this one are vitally important to MIT and ESD for a variety of reasons. First, ESD wants to extend its research strongly into the services area. After health care, education is the second largest services component of the gross domestic product of most developed countries. Perhaps more importantly, this proposal engages a troubled part of the world, with friends and colleagues in that area, who want to work with MIT to leverage education as a transformative mechanism for improving lives and helping peace and prosperity. Again, all three parts of the ESD Venn diagram are vital to understanding and improving education in the emerging world. ESD must become involved with education.

A summary of the major research initiatives of CESF are shown in the table below, with examples of how each of the Venn diagram components—engineering, management, and social sciences—is important in undertaking that research.

CESF Research Initiatives

Research Topic Area	Engineering	Management	Social Sciences
Flu Pandemic	Modeling the physics of disease progression	Planning responses of government, businesses, and families	Understanding and managing human behavior in the presence of a pandemic
Hurricane Response	Modeling the physics of hurricane progression	Managing evacuations and related responses	Understanding people's propensity to follow evacuation orders
Water Systems	Traditional civil engineering plus operations research	Planning large capital investment projects; maintaining systems	Understanding people's need for and use of water
Critical Energy Infrastructures	Electrical and systems engineering	Planning large capital investment projects; maintaining systems	Understanding cost/benefit relationships for users to shave peak demands
Election Queues	Operations research of queueing physics	Managing pre-election day deployment and real-time redeployment of resources	Understanding voters' choices to balk or renege from voting lines
e-Learning in Developing Countries	Computer science, electrical engineering, and operations research	Managing deployment of technology and human assets and maintaining the system	Understanding learners' responses to pedagogy by culture, gender, age, and related measures

Lateral alignment of interests and behaviors of key stakeholders is important in all these research areas, covering issues of both management and social science. Research on lateral alignment is active at ESD, headed by Joel Cutcher-Gershenfeld and Joel Moses, with at least six doctoral students now involved. We look forward to their results to help CESF in its research initiatives.

Outreach to Other Organizations

CESF has been actively reaching out to other organizations that could be collaborators and/or supporters of CESF research.

One example is the first MITRE-CESF-ESD Joint Seminar at MITRE Headquarters in Bedford, MA, on June 6, 2006. The focus was on quantitative research of an influenza pandemic. Preliminary results of the CESF team (Stan Finkelstein, Katsunobu Sasanuma, Karima Robert Nigmatulina, Kelley M. Bailey, Salal Humair, and Dick Larson) were presented and discussed. Also presented were research summaries by several MITRE professionals.

CESF is also partnering with Professor Barry Horowitz of the University of Virginia on a National Science Foundation ERC proposal. The tentative title of the proposal is "Revolutionary Advancement in the Design and Development of Large Scale Systems, 'Systems Engineering of the First Derivative.'" The CESF contribution would be in the design and analysis of a national response to a flu pandemic, focusing primarily on use of social distancing as a control mechanism. Also partnering in this effort are researchers from Georgia Tech and the University of Southern California.

In January, CESF made a presentation to the Volpe Center to explore ways CESF and ESD more broadly may jointly undertake research.

Pfizer Corporation supported portions of the October 2005 LINC International Symposium. This extends a remarkable period of several years in which Pfizer has supported our technology-enabled education research and professional practice, with total support of nearly $1 million.

CESF has spent considerable time with potential collaborators from IBM, focusing on various aspects of the services sciences. This includes Dick Larson serving as invited keynote plenary presenter at an IEEE-sponsored symposium at Shanghai Jiao Tong University, Shanghai, China, June 21–23, 2006; 2006 IEEE International Conference on Service Operations and Logistics; and Informatics, SOLI 2006. The title of his presentation was "Services: The Other 75% of the Economy." In July, Dick will travel to IBM to seek a collaborative partnership on flu pandemic research, an active area for IBM researchers. In October, CESF will present a general services systems paper at IBM's conference on services sciences.

Finally, reflecting the importance of disaster preparedness and response and the need for MIT to build stronger capabilities in this domain, Dick Larson has arranged a cluster of six sessions at the November 5–8 national research meeting of INFORMS. The cluster is

entitled, "Planning for and Responding to Disasters." The sessions within the cluster are as follows:

- Planning for and Responding to Hurricanes
- Planning for and Responding to a Flu Pandemic
- Planning for and Responding to Explosive Terrorist Attacks
- Planning for and Responding to Biological or Chemical Terrorist Attacks
- OR and Disaster Planning
- Panel on Humanitarian Supply Chain Management

LINC International Symposium

On October 27 and 28, 2005, LINC ran its Third Annual International Symposium at MIT. With more than 80 participants from more than 20 countries, approximately 30 papers were presented, with the opening MIT welcome by Chancellor Phil Clay. The LINC website will soon contain the edited proceedings. The proceedings of LINC 2003 and LINC 2004 are already on the website as downloadable PDF files. As with previous LINC symposia, best practices were shared, thereby reducing the risks that those just starting in various countries will repeat mistakes made by others. Support of the US State Department for LINC was shown by the presentation, "ICT-Based Mentorship in Science, Technology, and Engineering in the Middle East," by Dr. George Atkinson, science and technology adviser to the Secretary of State.

Many social networking connections were made at LINC 2006, and as a result new initiatives have started between collaborating leadership in emerging countries. Of particular interest is a new collaboration between China and Mexico, dealing with the use of e-learning for poverty reduction and economic development.

Arrangements are under way to hold the next LINC international symposium at the University of Jordan in Amman in March 2007. Private sources in Dubai have pledged $100,000 to underwrite the symposium. Top levels of the Jordanian government also have pledged their support to this effort. One key theme will be on the high school blended learning project described above.

Other International Outreach

CESF undertook additional activities leading to international outreach related to complex systems. These include publication (on the ESD website) of a working paper by Dick Larson and M. Elizabeth Murray titled "Distance Learning as a Tool for Poverty Reduction and Economic Development: A Focus on Two Countries, China and Mexico." From the introduction to the paper:

In this paper, we focus on two remarkable programs aimed at reducing poverty and accelerating economic development in two countries–China and Mexico, both programs leveraging modern Information and Communication Technologies (ICTs) to deliver quality education to underserved communities. The programs are new and growing, and thus still in formative stages. At this time, we feel it is appropriate to describe these programs and to offer a framework for continuous

assessment and evaluation. This will facilitate ongoing self-improvement, as each program can utilize continuing data and qualitative experience as a self-learning, self-improving organization. To the best of our knowledge, these two programs are the largest in the world that utilize the concept of technology-equipped "Community Learning Centers," networked throughout the country, and with educational content delivered by a highly respected university. Each is unique in its detailed implementation, but each has very similar goals—reducing poverty and improving economic development by educating local citizens, young and old.

The paper has been circulated in The World Bank and delivered in Singapore to a group of university rectors from Sub-Saharan Africa who have been touring Asia under World Bank guidance. The work has also led to new prospects for funded research in this area with the World Bank in Africa and in Latin America. We should know more about these possibilities in the months ahead.

Finally, Dick Larson and two other senior MIT faculty members have been invited to join the senior advisory team of LUMS (Lahore University of Management Science), a major private university in Pakistan that is now opening a new School of Science and Engineering—patterned after MIT and the India "IIT's." The first trip to Lahore occurred in February, and it is expected that there will be annual trips in the years ahead. The relationship has already helped ESD and CESF, as LUMS has partnered with CESF on the white paper water proposal ("Water: East Meets West") to the MIT Singapore research initiative.

Reflections and Future Directions

If we were to characterize the activities of Year 1 of CESF, they may be listed with the following attributes:

- Services and services sciences, with special emphasis on the largest two services: health care and education;
- Problems requiring analysis at the intersection of the ESD Venn diagram: traditional engineering, management, and social sciences;
- Derived of engineering systems fundamentals from real rather than imagined complex systems;
- International as well as domestically focused;
- MIT faculty are included from outside as well as from inside ESD;
- Responsive to MIT-wide initiatives;
- Problems of urgent priority, both domestically and internationally;
- Still at the beginning.

There are at least two types of research that CESF and, more broadly, ESD can pursue: opportunistically selected and strategically selected. Opportunistic research is responsive to potential projects that arrive at one's door exogenously over time, in a sense as a random process from outside ESD. These are relatively easy and convenient, as one does not need to search for funding advocates and sources to undertake the research. And there are many success stories associated with opportunistic research.

But we must consider a balanced portfolio of research endeavors, in which a significant portion is selected strategically to advance ESD, CESF, and the fundamental knowledge and impact of complex systems. Our CESF white papers in response to MIT-wide initiatives may be called opportunistic responses. Our attempts to launch major research in technology-enabled education, pandemic flu modeling, and disaster preparedness and response may be called strategic selections. They are more difficult because funding sources are not known at the beginning and may never be found. But, in our minds, we need to decide certain strategic directions for ESD and CESF and make a commitment to pursue research in those directions to advance our fundamental knowledge of the field and to have substantial impact. The year-over-year cumulative impact of such a balanced portfolio approach could be considerable.

Let us not forget the ESD Venn diagram. Engineering systems is different from systems engineering because the former explores complex systems using the three components of the Venn diagram intersection: traditional engineering, management, and social sciences. Systems engineering does not. Each research initiative described above involves all three components. In fact, for some initiatives, the social sciences component is the most difficult from a research perspective (e.g., societal response to a flu pandemic). Although the social science and/or management component may be difficult and interesting research, we must also recall that engineering systems *is* engineering. So, of the three components, engineering must be dominant, in that ultimately we want to design and create a system. We want to build and operate something, in the finest tradition of engineering. We will be *engineering* systems. We include social sciences and management to design, build, and operate systems intelligently, with full awareness of all essential aspects of the problem. If we are successful, engineering systems may become a transformative way of approaching design and operation of complex systems.

Finally, what is in store for Year 2 of CESF? In addition to, and as part of, pursuing new research initiatives, we need to build a more cohesive and collaborative community of scholarship at ESD. This community should include students as well as faculty and research professionals. Building ESD in a way is similar to the research initiatives we have discussed. It involves each of the three components of the Venn diagram: engineering, management, and social sciences. And, as with avian flu, the social science component may be the most difficult, as suggested by the diffuse and unconnected social network of our daily readings and research journals. We propose to launch a weekly seminar series in the fall, alternating between inhouse (i.e., MIT) speakers and invited guests from outside. The idea would be not only to learn of new and exciting research possibilities in engineering systems but also to start building that ESD community of scholarship, identifying research synergies, and perhaps even connecting our social network.

We look forward to engaging more ESD as well as MIT-wide faculty in Year 2, with the hope of building consensus on important strategic directions.

Richard Larson
Director
Professor of Civil and Environmental Engineering and Engineering Systems

More information about the Center for Engineering Systems Fundamentals can be found at http://esd.mit.edu/.

CESF Documents and Presentations Available Upon Request

Documents

The 3 R's of Critical Energy Networks: Reliability, Robustness and Resiliency
A White Paper Submitted to the MIT Energy Research Council, October 30, 2005. David Marks, Munther Dahleh, Marija Ilic, Richard Larson, with Stephen Connors, John Hansman, James Kirtley, Steven Leeb, Sanjoy Mitter, Alexandre Megretski, James Orlin, Asuman Ozdaglar, Pablo Parrilo, Devarat Shah, John Tsitsiklis, and others in LIDS, the ORC, and EECS.

Social Networks Modeling of The Dynamics of an Influenza Pandemic: Seeking Social Distancing Policies to Deter Its Progression
Proposal submitted to the Alfred P. Sloan Foundation, March 1, 2006. Richard C. Larson, principal investigator, and Stan N. Finkelstein, co-principal investigator (with Joel Cutcher-Gershenfeld, Steven H. Hinrichs, MD, Thomas P. Hughes, Salal Humair, David Marks, Karima Robert Nigmatulina, Robert H. Rubin, MD, Katsunobu Sasanuma, and Adam Sonnenschein).

Water: East Meets West, the Need for Appropriate Technologies and Systems.
A white paper submitted to the Singapore Research Initiative, March 19, 2006. Dennis McLaughlin and Richard C. Larson, with Oral Buyukozturk, Joel Cutcher-Gershenfeld, Herbert Einstein, Charles Harvey, Robert Jaffe, John Kassakian, Stuart Madnick, David Marks.

Distance Learning as a Tool for Poverty Reduction and Economic Development: A Focus on Two Countries, China and Mexico
ESD-Working-Paper-2006-09, May 2006. http://esd.mit.edu/WPS/esd-wp-2006-09.pdf. Richard C. Larson and M. Elizabeth Murray.

Blended Learning for High School Math Classes: A Partnership Between MIT and Arab Universities to Foster Creative Critical Thinking in High School Math Classes.
MIT LINC Proposal submitted to USAID, June, 2006.

To Queue or Not To Queue? In a U.S. Presidential Election, that should NOT be a question!, Published in OR/MS Today, June 2006. http://www.lionhrtpub.com/orms/orms-6-06/frqueues.html. Alexander S. Belenky and Richard C. Larson.

PowerPoint Presentations

Center for Engineering Systems Fundamentals (CESF): The Beginnings. ESD Faculty Lunch, September 20, 2005.

Operations Research: The Value Proposition. November 18, 2005, invited Plenary Presentation, 30th Anniversary Celebration of EURO, The Association of European Operational Research Societies, Paris, France.

Center for Engineering Systems Fundamentals (CESF): Status Report and Planning Meeting. Open Meeting with ESD and other interested MIT faculty, January 18, 2006.

Center for Engineering Systems Fundamentals (CESF): The Research Beginnings. ESD Faculty Lunch, April 4, 2006.

MIT: E-Reaching Out via LINC, OCW and I-Labs. Invited Keynote Plenary Presentation, Princess Sumaya University for Technology, Amman, Jordan, April 19, 2006. International Conference on Interactive Mobile and Computer aided Learning (IMCL), in cooperation with the IEEE Education Society.

Center for Engineering Systems Fundamentals (CESF): The Beginnings of Flu Pandemic Research; 1st MITRE–CESF-ESD Joint Seminar at MITRE Headquarters in

Bedford, MA. June 6, 2006. (Stan Finkelstein, Katsunobu Sasanuma, Karima Robert Nigmatulina, Kelley M. Bailey, Salal Humair, and Richard C. Larson.)

Services: The Other 75% of the Economy. Invited Keynote Plenary Presentation. IEEE-sponsored symposium at Shanghai Jiao Tong University, Shanghai, China, June 21, 2006, IEEE International Conference on Service Operations and Logistics, and Informatics, SOLI 2006.

Center for Innovation in Product Development

In 2005, the Center for Innovation in Product Development (CIPD) completed work and a publication on resource prediction in product development. Student and staff work continued on robust decision making, distributed object-based modeling environment (DOME), technological dynamics in information technology, and the network structure associated with the internet protocols.

At the end of FY05, CIPD closed down. Former CIPD director Professor Chris Magee continues to teach in ESD and is involved in other research activities. The staff, postdocs, and students have moved to 3 Cambridge Center.

Center for Technology, Policy, and Industrial Development

Research at the Center for Technology, Policy, and Industrial Development (CTPID) focuses on contemporary industrial problems that span social, natural, and technological interests. Founded in 1985, CTPID brings together more than 80 faculty, researchers, and staff from engineering, management, and social sciences to approach the complex issues that shape modern economies.

The vision guiding CTPID focuses on challenges at the nexus of social, natural, and technological systems. CTPID addresses critical dilemmas that emerge from interactions among these systems—in terms of opportunities and challenges they offer our industrial enterprises as well as constraints they impose on the scope and extent of their activities. CTPID strives to develop research programs that bring together industry and government participants with those of academia. Among the sectors of current focus are aerospace, automotive, telecommunications, information management, and environmental law.

ESD aims to unite interdisciplinary faculty and students to study large-scale, complex engineering systems. As a major research center within ESD, CTPID expands the intellectual scope of the division by forming collaborative research projects with industrial and government stakeholders outside the Institute, whereas ESD provides academic opportunities for CTPID faculty, students, and staff.

CTPID is funded by 50 industry sponsors and 15 government agencies for a research volume of about $8 million. Current projects include the Communications Futures Program (CFP), the Ford–MIT Alliance (administered by CTPID), the International Motor Vehicle Program (IMVP), the Labor Aerospace Research Agenda, the Lean Aerospace Initiative (LAI), the Materials Systems Laboratory (MSL), the MIT Information Quality Program (MITIQ), and the Technology and Law Program.

The director of CTPID is Professor Fred Moavenzadeh, the James Mason Crafts professor of engineering systems and civil and environmental engineering, who also directs the Technology and Development Program. Su Chung serves as CTPID's administrative officer, and Susan Cass is CTPID's communications manager. CTPID's administrative offices are located in MIT's room E40-227. Professor Moavenzadeh will be stepping down as director in FY2007.

Highlights of the Year

Sharon Gillett has been serving since February 2006 on Mayor Menino's Boston's Wireless Task Force, charged with developing recommendations for making Boston a world leader in wireless broadband activity.

LAI stakeholders approved a $24.4 million extension of the LAI consortium, funding a fifth five-year phase that began September 1, 2005.

MITIQ established a consortium to study long-term impacts of information quality on organizations, how information quality is related to organizational performance, and what kind of processes, techniques, and models are used in different organizational settings. One outcome of this research was an index that measures the distance of different transactions related to an entity. The entity resolution technique is important beyond the simple application of assigning transactions associated with an entity. In the homeland security area, one could conceive that the same technique could be applied to identify various sources of information that may be related to a potential threat.

In another initiative, MITIQ helped the University of Arkansas at Little Rock to successfully establish the first-of-its-kind master of science degree in information quality (MSIQ) program. The MSIQ program secured final approval from the state in April 2006 and the first MSIQ class will begin in fall 2006.

In December 2005, IMVP welcomed back the Nissan Motor Company with a three-year sponsorship agreement.

Awards and Recognition

LAI researcher Dr. Donna Rhodes was awarded the INCOSE Founder's Award in July 2005 for her 15 years of service including technical board chair, fellow, director of strategic planning, and president of the organization.

LAI administrative assistant Tara Eisner was awarded the School of Engineering's Infinite Mile Award for Excellence at a ceremony on May 10. CTPID's communications manager, Susan Cass, received an Infinite Mile Award for Sustained Excellence at the same ceremony.

MSL was recognized by the Portuguese government for its contributions to the development of an advanced automotive design and engineering center. This was the result of nearly 10 years of research collaboration with Portuguese universities, research centers, and automotive industry partners. Joel Clark was invited to speak at the

opening ceremonies for the Engineering Center along with high-ranking government and industry figures from Portugal and the European Union.

Selected Publications

Books

Joel Cutcher-Gershenfeld updated and provided new commentary on *The Human Side of Enterprise, Annotated Edition*, Douglas McGregor, McGraw-Hill, 2006

Craig Fisher, Eitel Laura, Shobha Chengalur-Smith, and Richard Wang, *Introduction to Information Quality*, http://mitiq.mit.edu/Books.htm.

Articles and Book Chapters

Nicholas A. Ashford "The Legacy Of The Precautionary Principle in U.S. Law: The Rise of Cost-Benefit Analysis and Risk Assessment as Undermining Factors in Health, Safety and Environmental Protection" in Sadeleer, Nicolas (ed.), *Implementation of the Precautionary Principle in the Nordic Countries: Lessons from the EU and the United States*, Earthscan, 2006.

Nicolas A. Ashford, "Scientific, Ethical and Legal Challenges in Work-Related Genetic Testing in the United States," *European Journal of Oncology* Library, 4: 33–59, 2005.

Nicholas A. Ashford and Charles C. Caldart, "Government Regulation of Occupational and Environmental Health and Safety" in *Occupational and Environmental Health: Recognizing and Preventing Disease and Injury*, 5th ed. Barry S. Levy and David H. Wegman (eds.), Lippincott Williams & Wilkins, Philadelphia 2005, pp. 39–73.

William H. Lehr, Marvin A. Sirbu, and Sharon E. Gillett, "Wireless Is Changing the Policy Calculus for Municipal Broadband," *Government Information Quarterly*, Vol. 23, No. 3, 2006.

Sharon Eisner Gillett, "Municipal Wireless Broadband: Hype or Harbinger?" 79 *Southern California Law Review* 561, 2006.

Lars Koch and Nicholas A. Ashford, "Rethinking the Role of Information in Chemicals Policy: Implications for TSCA and REACH," *Journal of Cleaner Production* 14(1): 31–46 2006.

Marvin A. Sirbu, William H. Lehr, and Sharon E. Gillett, "Evolving Wireless Access Technologies for Municipal Broadband," *Government Information Quarterly*, Vol. 23, No. 3, 2006.

Personnel Changes

Susan Cass joined CTPID as communications manager in August 2005. LAI welcomed several new staff members. Ricardo Valerdi, PhD, joined LAI as a research associate in early fall 2005; Emily Kearney BaThan, CTPID administrative assistant II, moved to LAI as operations manager in February 2006; Michelle Gaseau joined LAI in March 2006 as

communications coordinator; and Adam Ross joined LAI in June 2006 as a postdoctoral associate.

Geoffrey Grosbeck, LAI communications manager, left LAI in January 2006. Juliet Perdichizzi, LAI services manager, left LAI for a position in the MIT president's office in early 2006.

Communications Futures Program

The Communications Futures Program is a joint venture across several parts of MIT, led by David Clark of the Computer Science and Artificial Intelligence Laboratory (CSAIL) and CTPID, Charles Fine of the Sloan School, and Andrew Lippman of the Media Lab. CFP's objective is to promote growth and innovation across the communications value chain by conducting research and facilitating cross-industry interactions through industry-academic working groups focused on issues requiring cross-industry coordination. CFP also partners with Cambridge University through a seed grant from the Cambridge–MIT Institute (CMI).

Within CTPID, Sharon Gillett and William Lehr lead several of CFP's working groups.

Key CFP Accomplishments

In the past year, CFP continued to lead industry–academic working groups focused on the following topics:

- Broadband access technology, economics, and public policy, led by Sharon Gillett of CTPID;
- Interprovider quality of service, led by William Lehr of CTPID;
- Value chain dynamics, led by Charlie Fine of Sloan and CTPID;
- Viral communications, led by Andy Lippman and David Reed of the Media Lab.

In addition, CFP launched three new working groups:

- Next-generation spectrum policy, led by William Lehr of CTPID, in partnership with Cambridge University;
- Interconnection, led by William Lehr of CTPID and David Clark of CSAIL and CTPID; and
- Privacy and security, led by Karen Sollins of CSAIL.

CFP held two 3-day plenary meetings for sponsoring companies, one in January, hosted by Nortel Networks at their facility in Richardson, TX; and one in June, hosted by Cambridge University in Cambridge, UK.

In addition, numerous single-day workshops were held for specific working groups throughout the year.

Working group deliverables prepared for CFP during the year included the following:

- The Broadband Incentive Problem, final white paper, released September 2005, articulates the Broadband Working Group's consensus view that "The broadband locomotive left the station with a critical missing piece: the incentive for network operators to support many of the bandwidth-intensive innovations planned by upstream industries and users."
- Interprovider QoS for VPNs, draft white paper, released October 2005 for the Interprovider Quality of Service Working Group.
- Vision of Personal Broadband, final white paper, released January 2006, outlines the Broadband Working Group's consensus vision of what a personalized broadband experience should look like for users, first by examining the inconsistencies users commonly experience today, and later by exploring a set of "use cases" describing the more consistent experience that truly personal broadband could offer users.
- Value Chain Dynamics in the Communication Industry, final white paper, released January 2006 for the Value Chain Dynamics Working Group.

CFP's roster of sponsoring companies expanded from 9 companies (BT, France Telecom, Cisco, Comcast, Deutsche Telekom/T-Mobile, Intel, Motorola, Nokia, and Nortel) to 10 (adding Telecom Italia).

Other Key Accomplishments

CTPID researchers Sharon Gillett and William Lehr continued their research, writing, and outreach activities related to broadband's economic impact and to municipal broadband.

In collaboration with ESD doctoral student Carlos Osorio, and Professor Marvin Sirbu of Carnegie Mellon University, Gillett and Lehr completed their statistical study estimating broadband's economic impact in the United States, commissioned by the Department of Commerce's Economic Development Administration (EDA). They presented their results at the 33rd Annual Research Conference on Communication, Information, and Internet Policy in September 2005 as well as at an Organisation for Economic Co-operation and Development meeting in May 2006. They have been featured in numerous industry publications and conferences as well as on the EDA website.

As an outgrowth of this work, Sharon Gillett collaborated with Kenneth Flamm of the University of Texas (LBJ School of Public Policy) and John Horrigan of the Pew Internet & American Life project to develop and run a workshop in Washington, DC, in June 2006 focused on improving the state of data collection about the broadband economy. The workshop proved to be a successful venue for knowledge exchange among leading academics researching broadband's economic and social impact, government statistical agencies responsible for collecting the necessary data, and government and industry users of data on broadband technologies and applications.

The emergence of wireless technologies provided a focus to Gillett and Lehr's municipal broadband research during the year, with three publications completed on the topic

of municipal wireless (see "Research Publications" section below). In addition to disseminating their work in scholarly venues, Gillett and Lehr performed outreach service to several local governments, including MIT's neighboring cities of Cambridge and Boston. In particular, since February 2006, Sharon Gillett has been serving on Mayor Menino's Boston's Wireless Task Force, charged with developing recommendations for making Boston a world leader in wireless broadband activity.

Building on the work on spectrum policy that led to the launch of the new CFP working group, next generation spectrum policy, in November 2005 Lehr served as the policy program cochair of the IEEE DySPAN conference (http://www.ieee-dyspan.org/2005/) in Baltimore, MD, which was the first conference focusing on multidisciplinary research on dynamic spectrum access markets that actively sought to initiate research collaborations between policy and engineering analysts engaged in the design of new wireless architectures. At that conference, Lehr organized a panel with David Reed of the Media Lab and Jon Crowcroft of Cambridge University and presented a paper on managing RF spectrum. Following up on this success, Lehr is co-organizing the TAPAS2006 workshop in Boston in August 2006 (http://www.wtapas.org/) and the second DySPAN conference, which is planned for Dublin in 2007 (http://www.ieee-dyspan.org/2007/).

Academic Activities (Teaching and Supervisory)

Sharon Gillett, William Lehr, and Frank Field of CTPID continued their CMI-funded collaboration with Tim Wilkinson of Cambridge University to teach 5CMI2, "Telecommunications: Technologies and Policies in the Networked Digital World," for the third time in the 2005 Michaelmas term. This course is offered in the MPhil in Technology Policy Program.

In the spring term, with funding from the EECS department, Sharon Gillett, David Clark, Frank Field, and William Lehr expanded the previous year's half-semester course, Communications and Information Policy," into a full-semester course of the same name (Course 6.978/Course ESD.68 Communications and Information Policy). This course used lectures, readings, discussion, and individual and team projects to engage students in critical thinking around selected technology policy issues arising from advancing telecommunications and Internet technologies. Graduate and undergraduate students from EECS, TPP, and Sloan enrolled in the course.

CFP funded ESD doctoral student Carlos Osorio to complete his dissertation on the economic impact of municipal electric utilities' entry into broadband markets and TPP MS student Elisabeth Maida to serve as a research assistant for the Broadband Working Group, with particular focus on the "Personal Broadband" topic. Sharon Gillett directly supervised both students.

Sharon Gillett served on the admissions committee for TPP, evaluating applicants in fields related to information and communications technologies.

Research Publications

William H. Lehr, Marvin A. Sirbu, and Sharon E. Gillett, "Wireless is Changing the Policy Calculus for Municipal Broadband," *Government Information Quarterly*, Vol. 23, No. 3, 2006.

Marvin A. Sirbu, William H. Lehr, and Sharon E. Gillett, "Evolving Wireless Access Technologies for Municipal Broadband," *Government Information Quarterly*, Vol. 23, No. 3, 2006.

Sharon Eisner Gillett, "Municipal Wireless Broadband: Hype or Harbinger?" 79 *Southern California Law Review* 561, 2006.

William H. Lehr, Carlos A. Osorio, Sharon E. Gillett, Marvin A. Sirbu, "Measuring Broadband's Economic Impact," presented at the 33rd Research Conference on Communication, Information, and Internet Policy (TPRC), September 23–25, 2005, Arlington, VA.

William H. Lehr and Jon Crowcroft, "Managing Shared Access to a Spectrum Commons," IEEE DySPAN2005, November 2005, Baltimore, MD (http://www.ieee-dyspan.org/2005/. A copy of the paper is available at http://cfp.mit.edu/resources/papers/Lehr_Crowcroft_SCD.pdf).

David Clark, William Lehr, Steve Bauer, Peyman Faratin, Rahul Sami, and John Wroclawski, "The Growth of Internet Overlay Networks: Implications for Architecture, Industry Structure and Policy," presented at the 33rd Research Conference on Communication, Information, and Internet Policy (TPRC), September 23–25, 2005, Arlington, VA.

Ford–MIT Alliance

The Ford–MIT Alliance is an institute-wide program, established to develop and implement a research agenda of real value to Ford, as well as to MIT faculty and students. This $15 million, five-year program will run through 2007. Since its initiation in 1997, the program has funded approximately 100 projects, with budgets ranging from $200 thousand to $1.3 million.

In addition to the research projects the Alliance identifies, develops, and funds in close partnership with Ford, the Alliance also brings the vice presidents involved on campus three times a year, providing them a key window to new, relevant knowledge development and research at MIT.

Ford–MIT Alliance Research Activities

Ford–MIT Alliance research continues to focus on four explicit areas: environment, product development, active safety, and powertrain. At the same time, the Alliance aggressively explores emerging opportunities, creating a research portfolio that is more diverse than it has ever been. In addition to continuing work in the four thrust areas, the Alliance has initiated its first two projects in nanotechnology, a potentially revolutionary

mathematical modeling approach to vehicle incentive pricing, and an ambitious survey of the trajectory of embedded systems and software development. Alliance projects have begun to transfer into Ford's product development pipeline.

The projects within the environmental thrust area continue the transition from more exploratory to more application-oriented. Work continues assessing the impact of diesel emissions on climate and new projects have begun in nanofluids with superior heat transfer properties and a cap-and-trade study that might produce a more industry-friendly mechanism than increased CAFE standards for controlling carbon emissions. We also funded a project utilizing nanotechnology to increase the storage capacity of ultracapacitors to replace or augment batteries in hybrids and perhaps to ultimately compete with fuel cells.

The product development area will continue supporting the closure systems project, helping Ford engineer vehicle doors as a system. Additionally, two projects on noise, vibration, and harshness (NVH) have been initiated, one on applying aerospace modeling techniques to wind noise and the other specifically targeting driveline NVH solutions.

The active safety focus will continue funding pedestrian detection, enhanced vehicle stability, and complex alerting systems development while initiating a broad study of driver wellness and impairment detection with the MIT Age Lab.

Most Powertrain work is ongoing in homogeneous charge compression ignition, oil aeration, and control software, and a new project on self-calibrating controls has been initiated with the goal of reducing calibration complexity.

Dialogue between Ford and MIT

The Ford–MIT Alliance creates venues for in-depth dialogue between Ford and MIT, both at the Alliance management level and at the individual projects level. For example:

- Three annual executive committee meetings bring Ford vice presidents and senior directors on campus
- One annual Alliance Technology Day at Ford. Last year, eight MIT faculty members presented their alliance results on May 25–26. Technology Day is widely advertised within Ford, open to all, and draws between 30 and 50 people to each presentation. This year, the event will take place on October 13–14.
- Periodic topic-focused meetings bring together senior Ford executives and MIT faculty, such as the sustainable mobility meeting at Ford.
- Four to six times per year, the Ford–MIT Alliance invites an MIT faculty member not involved with the alliance whose work is relevant to Ford to present his or her work with the Ford technical community in Dearborn, MI.

The Alliance agreement runs through December 2007, and we are preparing for the renewal discussion with Ford. The Alliance operating committee has prepared an assessment and renewal document of the Alliance to serve as the basis for the renewal

discussion with Ford. A letter from the chancellor will be sent to the Ford vice president of research and development in July, informing him of MIT's strong interest in pursuing this research collaboration and initiating the renewal process.

Leadership for the Ford–MIT Alliance includes MIT chancellor Phillip Clay (director), John Heywood (codirector), Sun Jae, (professor of mechanical engineering and director, Sloan Autolab), Joseph Saleh (executive director, MIT), and Simon Pitts (executive director, Ford).

International Motor Vehicle Program

IMVP is the oldest and largest international research consortium aimed at understanding the challenges facing the global automotive industry. Founded at MIT in 1979 and headquartered at MIT, IMVP has evolved to become a network of professors and researchers engaging with managers and executives in the global automotive industry. IMVP researchers are based at universities around the world, including MIT, the Wharton School at the University of Pennsylvania, University of Michigan, Carnegie Mellon University, Oxford University, University of Cambridge, INSEAD, École Polytechnique, Catholic University of Korea, and University of Tokyo.

The IMVP research framework includes six broad areas of study:

- Innovation in the automobile industry
- Next-generation product development
- Lean value chains: The evolving supply base
- Lean production revisited
- Next-generation distribution
- Sustainability: Environmental and social impacts of the automobile

IMVP organized its research agenda into six primary research projects during FY06:

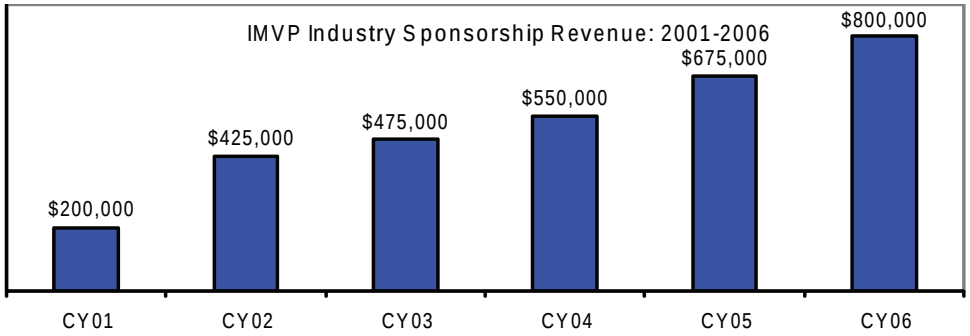
- Research and advanced engineering benchmarking study
- Product development benchmarking (round 4)
- Strategic priorities for global manufacturing systems
- Comparative analysis of global supply chains
- Lean location logic project
- Evaluation framework for automotive materials

Leadership

IMVP maintained the same leadership structure as in the previous fiscal year. Professor Michael Cusumano, Sloan School, continued to serve in his role as IMVP codirector, sharing that responsibility with Professor John Paul MacDuffie, Wharton School, University of Pennsylvania. Professor Daniel Roos continued to serve as chairman of the IMVP Advisory Board. John Moavenzadeh serves as executive director of IMVP.

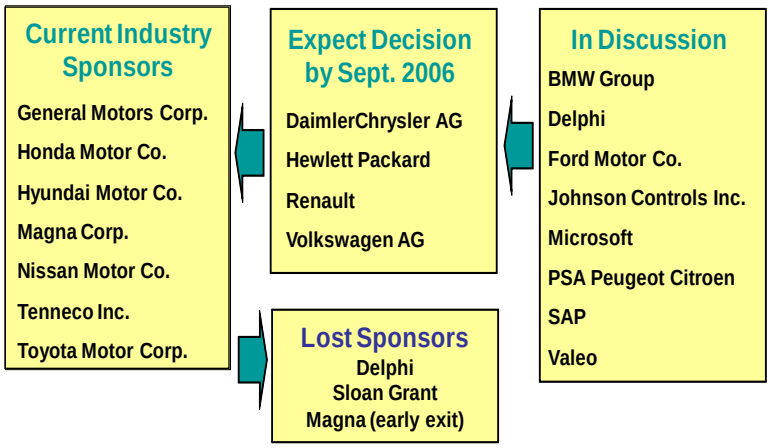
New Funding

In December 2005, IMVP secured a standard three-year sponsorship agreement with Nissan Motor Company. IMVP is almost fully funded from industry sponsors ($800,000 of the current $850,000 funding is from industry sponsors). The recent funding history for the program is shown below.



Despite a difficult business environment for securing research funding from the global automotive industry, IMVP continues to pursue a number of new sponsorship agreements, as shown below.

IMVP is supported primarily by industry sponsors



IMVP Continues Relationship with World Economic Forum

IMVP continues a partnership with the World Economic Forum's Automotive Program. Based in Geneva, Switzerland, the World Economic Forum is an independent international organization committed to improving the state of the world by engaging leaders in partnerships to shape global, regional, and industry agendas. IMVP provides intellectual content and research findings to support the Forum's program of events and initiatives for its partners and member companies in the global automotive industry.

On September 15, 2005, 17 executives from vehicle manufacturers and suppliers from seven countries participated in the Forum's Automotive Industry Agenda Meeting in Frankfurt, Germany. The program focused on an array of high-level strategic issues confronting the global automotive industry. IMVP principal investigator Eric Thun of

Oxford University, presented findings on his research on the automotive industry in China.

On January 26, 2006, John Paul MacDuffie, IMVP codirector, participated in the full program for the Governors' Meeting of the Automotive Industry, a CEO-level meeting held during the Forum's Annual Meeting in Davos, Switzerland. Charlie Fine, MIT Sloan School professor and IMVP principal investigator, was invited to provide commentary during the governors' session with Bill Gates.

IMVP Advisory Committee Continues to Grow

MIT Professor Daniel Roos continues his role as chairman of the IMVP Advisory Committee. The objective of the committee is to help shape the IMVP research agenda to ensure that topics are valuable for senior executives within the industry. The program is targeting 8 to 10 members for the committee, balanced among North America, Europe, and Asia. To date, the following individuals have agreed to serve on the IMVP Advisory Committee:

- Paul Anderson, former head of Booz Allen Hamilton's automotive practice
- Dana Mead, chairman of the MIT Corporation, former CEO of Tenneco
- Louis Schweitzer, chairman of Renault, former CEO of Renault
- Jack Smith, former CEO of General Motors
- Shoichiro Toyoda, honorary chairman, Toyota Motor Corporation

The first meeting of the IMVP Advisory Committee is expected to take place October 2006 at MIT.

IMVP Research Impact

IMVP funded research projects across all elements of the automotive value chain, including the following:

- Lean locational logic: Developing a better framework for location decisions
- Product development and architecture in emerging countries
- Successful strategies of multinational enterprises in the Chinese market
- Understanding seemingly contradictory supply relationships
- The influence of relationship stress factors on the governance strategies of automotive OEM-supplier relationships
- Dynamic evolution path at the 3-dimensional double helix model: Case of Hyundai, Toyota, GM and their performance
- Innovation design process and advanced engineering in the auto industry
- The economic value of supplier working relations with automotive OEMs
- Automobiles, sustainability, and the emergence of China

- Outsourcing of business services and contingent labor
- Innovation capability under collaborative concept development
- Deverticalization of the Japanese supplier structure
- Capability development in the supplier base of the Chinese auto industry
- Dominant design and locus of innovation for complex technological systems: The case of auto emission control

On October 10–14, 2005, IMVP researchers traveled to Korea and Japan for the 2005 IMVP Asia Pacific Forum. They were joined by researchers from GERPISA as well as a number of respected academics from universities in Korea and Japan. The visit opened with the IMVP-IPS Seoul Forum meeting on October 10, hosted by IMVP researcher Professor Ki-Chan Kim and his colleagues at the Institute for Industrial Policy Studies (IPS). The Seoul Forum audience included guests from IMVP, IPS, GERPISA, Hyundai/Mobis, and a number of other Korean business, government, and research organizations. The second half of the IMVP Asia–Pacific Forum was held on October 13 at Hosei University in Tokyo, Japan. This portion of the Forum was hosted by University of Tokyo's Manufacturing Management Research Center and also received funding from Hosei University's Research Institute of Innovation Management. In addition to participating in the Seoul and Tokyo Forum meetings, IMVP attendees took advantage of their time in the region to also meet with executives and take plant tours at Hyundai and Mobis in Korea and at Toyota and Nissan in Japan.

On March 28, 2006, IMVP and WZB (Social Science Research Center) hosted a workshop in Berlin, Germany, entitled "Navigating an Uncertain Business Environment: International Perspectives on the Rapidly Changing Automotive Industry." This workshop brought together an international team of researchers with managers from leading German automotive firms. The objective was to explore several key issues confronting the global automotive industry, including the impact of globalization on location decisions, key capabilities required for profitable innovation, supplier relations, the spread of lean production practices, and competitive advantage in the industry. In particular, the workshop sought to contrast how many of these issues are playing out in Germany versus the rest of the world. IMVP thanks WZB Professor Ulrich Jürgens for his cooperation in organizing and hosting this event.

MIT hosted the annual IMVP Researchers Meeting June 5–7, 2006, in Cambridge, MA. Nearly 45 professors and graduate students shared their research findings on an array of topics related to the global automotive industry. Participants were based at universities in France, Spain, Italy, Switzerland, the United Kingdom, Japan, South Korea, Canada, and the United States. This year's meeting also saw the addition of the inaugural IMVP Automotive Mini-Conference (AMC), a one-day event developed to provide an opportunity for more in-depth discussion around a selected set of papers. The AMC attracted 16 submissions for 8 presentation slots and involved several academics from outside the IMVP network.

IMVP researchers were quoted in a variety of publications, including *Business Week* and *The New York Times*. IMVP researchers Susan Helper, Case Western Reserve University, and John Paul MacDuffie, Wharton School, along with IMVP executive director John Moavenzadeh, were quoted in an article in *Knowledge@Wharton*, a biweekly online resource that offers the latest business insights, information, and research from a variety of sources. John Paul MacDuffie was also quoted in another *Knowledge@Wharton* article and completed a podcast interview about the current troubles of the automobile industry. IMVP affiliated researcher James Womack, Lean Enterprise Institute, authored an editorial in the *Wall Street Journal*.

Several IMVP researchers contributed notable academic achievements during the fiscal year.

Professor Mari Sako, Oxford University, received an IBM Faculty Award in the area of services science.

Professor Susan Helper, Case Western Reserve University, was named SBC professor of regional economic development.

Professor Frits Pil, University of Pittsburgh, was designated as international fellow, Advanced Institute of Management, Economic and Social Science Research Council.

Professor Matthias Holweg of the Judge Business School at the University of Cambridge received tenure and promotion to University senior lecturer as of October 2005. Professor Holweg also received the Emerald Literati Network "Highly Commended Award" in 2006 for his paper on supplier responsiveness in the *International Journal of Logistics Management* as well as the Emerald Management Review Board's "Citation of Excellence" award in 2005 for his paper on supply-chain collaboration in the *European Management Journal*.

Professor Ki-Chan Kim, Catholic University of Korea, was elected to the Hyundai Mobis board of directors and received the best paper award from The Korean Academic Society of Business Administration.

Professor Christophe Midler, Ecole Polytechnique (France), was appointed to the chair on innovation management, based at the Centre de Recherche en Gestion.

Professor Eric Thun, Oxford University, published a book titled *Changing Lanes in China: Foreign Direct Investment, Local Governments, and Auto Sector Development*.

Jianxi Luo was admitted to MIT's PhD program in technology, management, and policy in ESD.

Professor Francisco Veloso and doctoral student Jaegul Lee, Carnegie Mellon University, were awarded the best student paper award at PICMET (Portland International Conference on the Management of Engineering and Technology), July 2005. Professor Veloso also received a funding award from the National Science Foundation for his

project on "The Socio-Political Construction of Technologies under 'Technology-Forcing' Regulation: A Tale of Two Automotive Technologies, 'One' Government, and One Industry."

Professor Victor Seidel received the Christer Karlsson Best Paper Award, International Product Development Management Conference, for "Crafting Novel Product Concepts: Concept Shifting and the Radical Development Process," June 2006.

More information about IMVP can be found on the web at http://imvp.mit.edu/.

The Lean Aerospace Initiative

The Lean Aerospace Initiative (LAI) completed an exciting transition in the past year from its fourth phase of operations—the enterprise value phase (September 1, 2002, to August 31, 2005)—into a fifth phase focusing on lean transformation (September 1, 2005, to August 31, 2010).

Throughout its existence, LAI has accelerated lean deployment through identified best practices, shared communication, common goals, and strategic and implementation tools honed from collaborative experience. LAI has also promoted cooperation at all levels and facets of an aerospace enterprise, which eliminates traditional barriers to improving industry and government teamwork and helps organizations strive for across-the-board lean performance and total lean enterprise transformation.

In concluding its fourth enterprise value phase, LAI was deeply engaged in transforming aerospace entities into total lean enterprises and delivering more value to all stakeholders than is possible through conventional approaches.

LAI in Phase V, through research, collaboration, and knowledge sharing among the consortium members, underscores maturation of the lean transformation process within enterprises and its requisite need for appropriate tools and leadership.

LAI Strategic Imperatives

In developing the concept of operations for Phase V, LAI created a new set of strategic imperatives based on understanding the needed stakeholder value and supporting the overarching goal of accelerating transformation of the greater US aerospace enterprise. These goals are to:

- Provide value to all consortium stakeholders.
- Sustain the LAI consortium as a learning community among industry, government, the workforce, and academia to address enterprise excellence and take collective action for continuous improvement.
- Facilitate enterprise transformations within and between industry and government.
- Expand and diffuse enterprise transformation knowledge.

To accomplish these imperatives, LAI engages in a large number of activities. They can be characterized as (1) product/tool/process development, (2) fostering transformation, (3) expanding knowledge, (4) facilitating education and learning, (5) sharing knowledge, (6) facilitating communications, (7) governance, and (8) collaborative activities.

In all these activities, it is important that LAI consortium members receive value from these activities and that this value is evenly distributed among the different stakeholder groups within the consortium. This desire guides how the consortium is organized and the processes used by the consortium. This has been LAI's focus in the past year.

Transforming the US Aerospace Enterprise

One sign of LAI's impact in "leaning" the US aerospace enterprise was the announcement in November 2005 by the Secretary of the US Air Force of a new program, Air Force Smart Operations 21st Century—nicknamed AFSO21—that will lean the entire service. With LAI's fingerprints on several different lean initiatives throughout the Air Force—at the depot level, at the Air Force Air logistics centers, and through support from the Air Force's Materiel Command (AFMC), it is gratifying to see such a major government enterprise-level transformation effort.

Air Force General Bruce Carlson, AFMC, and Air Force Brigadier General Taco Gilbert spoke at the LAI annual conference in April 2006 about AFSO21 and the value of LAI to this major transformation effort.

Additionally, at the LAI annual conference, Rockwell Collins president and CEO Clayton Jones spoke of the lean transformation journey by his company and also credited LAI with the role it had played in that transformation process over the years.

These announcements and accolades signal that the hard work and the effective research and tools being developed through LAI have resonated with top-level executives in the aerospace industry and are paying major dividends in terms of lean transformation.

Many other successes in the past 12 months should be noted. Together they provide evidence that lean has and will continue to be diffused throughout the enterprises involved in LAI. As for specific successes within the past year, consider the following, all of which reflect LAI's commitment to enterprise-level transformation:

- In fall 2005, three LAI consortium members made outstanding placements in the annual Shingo Prize awards and three Air Force logistics centers were awarded public-sector recognition. Robins, Ogden, and Oklahoma Air Force logistics centers were honored for their lean efforts. Robins and Ogden had hosted LAI enterprise value stream mapping events in 2005. Three other LAI members took awards in the large business award section. They were BAE Systems' Fort Wayne Operations Plant, The Boeing Company's Mesa, AZ, and St. Charles, MO, manufacturing centers, and Lockheed Martin's Archbald, PA, plant. Recipients were required to produce "phenomenal statistics that highlight the value of using lean/world-class manufacturing practices to attain world-class status."

- LAI's EdNet began a collaboration with Microsoft, which hosted an EdNet meeting and workshops in July 2005 and will do so again in summer 2006.
- LAI's lean academy held its first open enrollment course at the University of Alabama, Huntsville, which was attended by seven different organizations including representatives from three Air Force bases. A second open enrollment is scheduled later in 2006.
- LAI researchers began a new collaboration with MITRE Corporation on enterprise dynamics and modeling in October 2005, bringing together integrated capabilities in enterprise architectures, system acquisition, and modeling and simulation. This is one of four collaborative research projects between MIT's ESD and MITRE Corporation that are funded as MITRE-sponsored projects.
- In spring 2006, the Defense Finance and Accounting Service (DFAS) held the first-ever training event that paired the lean enterprise value (LEV) simulation and enterprise value stream mapping and analysis (EVSMA) toolset. The objective of the event was to familiarize DFAS change agents with advanced lean enterprise concepts and with use of the EVSMA toolset for transformation activities at DFAS.
- Lean enterprise value simulation workshops were held at BAE Systems, Raytheon, Boeing, and DFAS, among others.
- LAI researchers and LAI students participated in an INCOSE workshop for doctoral students working on systems engineering research topics. The workshop is part of an ongoing effort called SEANET (Systems Engineering and Architecting Network), led by LAI researcher Dr. Donna Rhodes, to establish a collaborative network of doctoral students for the purpose of creating dialogue to enable synergistic research outcomes.
- The Lean Supply Chain Now concept demonstration continued with a meeting at Lockheed Martin in March 2006 where the LAI Supplier Networks Working Group decided to explore the idea of conducting a benchmarking survey of supply-chain design and management practices within the aerospace industry. It also agreed to continue the survey work being conducted at MIT in conjunction with a master's thesis concentrating on a comparative analysis of supply-chain management practices by Boeing and Airbus.

LAI Research and Knowledge Deployment

In the past year, LAI further increased efforts to help transform the US aerospace enterprise by reexamining its research goals and efforts in light of the new lean transformation Phase V and then centering its knowledge sharing and deployment events on these new focal points. The undeniable link between the research and the products and knowledge deployment through LAI has been emphasized and supported by the entire consortium.

LAI Research

The LAI Phase V research program continues to be driven by the key goals defined in Phase IV. These are (1) the need to accelerate lean enterprise transformation, (2) the need

to design future lean enterprises, and (3) the need to evolve adaptive lean enterprises. The LAI Phase V research program seeks to provide further knowledge, insight, and tools to enable true enterprise transformation. As such, the Phase V program is formulated around four core research questions and further structured around seven unique research threads that extend from consideration of these questions.

LAI Grand Questions

(A) How can I understand how my organization/enterprise currently operates within its larger context?

(B) How can I define and evaluate the future possibilities for a more efficient and effective enterprise?

(C) What are the most effective strategies and tactics to achieve these future possibilities for my enterprise?

(D) How can I best manage the enterprise change process?

LAI Research Clusters

The Phase V research agenda is formulated to address seven research clusters that are necessary for realizing the lean enterprise transformation vision in light of the four core questions. Each cluster has a lead LAI researcher and associated faculty advisor(s). Student researchers include those who are funded by LAI and affiliated students who are working on LAI research topics but are sponsored by other funding sources.

Concepts and Models for Designing Future Enterprises Research Lead, Kirkor Bozdogan

Today's enterprises must develop a sound capability to design and successfully execute their enterprise transformation efforts in an increasingly fast-paced, complex, and uncertain external environment. An overall goal of research in this area is to provide enterprises with such a capability by creating basic principles, conceptual frameworks, simulation models, and tools and techniques that can be used to define the current-state enterprise architecture, design and evaluate the future-state architecture options, and select an executable architecture for implementation.

Enterprise Lean Product Development Research Lead, Eric Rebentisch

Enterprises are faced with increasingly complex products and portfolios of products that are beginning to defy traditional notions of the product life cycle. As the complexity of these products and portfolios increases, there is even less room for poor product development performance with cost and schedule overruns. Research in this area seeks to characterize the elements and architectures of lean and effective enterprise product development systems that are capable of efficiently, consistently, and responsively producing streams of products that are valued by enterprise stakeholders.

Value-Based Methods of Architecting Systems Research Lead, Donna Rhodes

Enterprises are faced with the need to make decisions on very complex architectures under conditions of high uncertainty, including decisions required to architect the product system as well as decisions about the architecture of the enterprise. This area of research is developing methodologies that will provide mechanisms for performing the

complex trade space exploration and decision-making strategies to support system and enterprise architectural decisions.

Enterprise and Cost Metrics Research Lead, Ricardo Valerdi

Decision making in lean enterprises depends on the interaction of two systems: the system of metrics currently in place and the processes used for measurement. Non-lean behavior of the enterprise can often be traced to a mismatch internal to each of the systems or to the interactions between them. This research area focuses on both the metrics and the measurement systems critical to lean enterprise transformation at the system, enterprise, and interactions between them.

Strategies for High-Performance Enterprises Research Lead, Debbie Nightingale

Enterprises are discovering effective strategies for achieving and sustaining high performance in multiple dimensions. Research in this area is examining successful practices and looking to codify them into formal strategies and practices. Current research topics include how the enterprise is structured to achieve performance results, how policies and practices drive enterprise results, how effort can be distributed across large enterprises, and how knowledge integration can be enabled.

Enterprise Change Capability Research Lead, George Roth

An enterprise is only as robust, effective, and efficient as the sum of its constituent organizations. Approaches for improvement are largely organizational-based or have been developed within the social context of organizations. As organizations seek to operate as enterprises, how does this changing the social context affect the enterprise-level use of improvement methods and implementation of organizational changes? This research thread examines the changing social context of enterprises for effective implementation of lean tools and methods and organizational changes. The ongoing effort conducts case studies of successful lean transformations; these cases can used in the development of theory and set of practices for effective lean enterprise change.

Enterprise Integration Enabled by IT Research Lead, Jayakanth "JK" Srinivasan

Enterprise integration is a necessary but not sufficient step in transformation to a lean enterprise. Information technology (IT) enabled systems have become the nervous system of the enterprise, providing critical information to stakeholders across the enterprise, for strategic decision making as well as to enable efficient day-to-day operations. This area of research treats the enterprise IT architecture as being reflective of actual enterprise architecture and focuses on creating frameworks, tools, and techniques that enable effective integration at operational and strategic levels of the enterprise.

In communicating regular research updates and findings to the consortium, LAI has also created a research committee with membership by consortium representatives to focus specifically on transferring this information to the members. In the past several months, research cluster leads and students have given updates to this committee and the practice will continue.

LAI Knowledge Deployment

LAI deploys knowledge in several targeted ways, with LAI's EdNet and LAI Lean Academy® being crucial elements in this communication effort to consortium and EdNet members. Both activities support continuous learning throughout the US aerospace enterprise by sharing knowledge and curriculum developed by members and both programs have experienced steady growth. One example is the development this year of a LAI Lean Academy® open enrollment course held in conjunction with the University of Alabama, Huntsville.

EdNet's stated mission is to support continuous learning throughout the US aerospace enterprise by sharing knowledge and curriculum developed by EdNet members. More than two dozen institutions are members, among them the Air Force Institute of Technology, Defense Acquisition University, Loyola Marymount University, Purdue University, Stanford University, University of Southern California, University of Michigan, University of Texas at Arlington, and Worcester Polytechnic Institute.

In alignment with the start of LAI's Phase V, EdNet also created a strategic plan to follow the Phase V timeline. Included in the strategic plan are the following goals:

- Increase awareness of the value of EdNet for stakeholders.
- Create an effective learning community.
- Advance the deployment of EdNet curriculum and products.

In support of these goals, EdNet has already begun to create new alliances, such as with Microsoft and Lean Enterprise Institute, to further awareness and deployment of EdNet curriculum.

The LAI Lean Academy® is LAI's one-week course providing a hands-on introduction to lean fundamentals. It was initially targeted toward undergraduate students, but over the last year its reach has expanded beyond the original target audience. As stated earlier, the LAI Lean Academy® successfully held its first open enrollment course and another is planned for anyone interested in lean, regardless of their EdNet affiliation.

In addition, work continues on the goals to advance the capability of university faculty to teach lean, develop lean curriculum, stimulate the diffusion of lean principles into on-campus coursework, and build partnerships between industry and academia.

Another important setting for LAI's knowledge deployment is its annual LAI Plenary Conference, which continues to set attendance records annually and is considered one of the most important lean events of the year. In 2006, the LAI Plenary Conference featured several aerospace industry executives as keynote speakers who discussed distributed leadership in lean deployment. They included Clayton Jones of Rockwell Collins, Tom Farmer of Pratt & Whitney, General Bruce Carlson of the Air Force Materiel Command, Wright-Patterson Air Force Base, and others. These speakers gave examples of their successes and mistakes from military and corporate settings.

The conference also served as the setting for the LAI Lean Product Life Cycle Knowledge area meeting, the LAI executive board, and the LAI champions meetings.

At this year's conference, attendees of the general session heard examples from the keynote speakers about how they have led (and continue to lead) their organizations through the lean journey. In break-out sessions led by LAI researchers, attendees learned about topics such as lean culture transformation, leadership and processes for lean enterprise product realization, transforming a culture to support lean, creating the training and change infrastructure for lean leadership, leadership for lean in depots, and others. Attendees learned about the latest research from LAI and absorbed practical examples from those within the LAI consortium who have completed different levels of the lean journey.

LAI also continues to hone its specialized knowledge deployment activities with short courses, workshops, training sessions, on-site visits, conference collaborations, and other venues. A listing of current and upcoming events of this nature may be found on the LAI website, http://lean.mit.edu/.

Finally, LAI is in the process of redesigning its current website to improve browsers' access to the research, help them gain insight into the work of LAI at MIT, and promote the important efforts that are being made on behalf of the consortium to deploy lean concepts and principles.

LAI Publications

LAI consistently produces new research, papers, and presentations. Several recently published LAI research documents, in the form of reports, conference papers, and student theses, include detailed findings and recommendations in several key areas. All these works are available on the LAI website (http://lean.mit.edu/). A sampling of these publications includes:

Bresnahan, Steven M., "Understanding and Managing Uncertainty in Lean Aerospace Product Development" master's thesis, MIT, Feb 2006.

Davidz, Heidi Leoti, "Enabling Systems Thinking to Accelerate the Development of Senior Systems Engineers." PhD thesis, MIT, Jan 2006.

Hines, Erisa K., "Lifecycle Perspectives on Product Data Management" master's thesis, MIT, Sep 2005.

MacKenzie, Scott A., "Utilizing Value Stream Mapping in Air Force Acquisition Program Offices" master's thesis, MIT, Feb 2006.

Mahidhar, Vikram, "Designing the Lean Enterprise Performance Measurement System" master's thesis, MIT, Sep 2005.

McManus, Hugh, "Lean Engineering: Doing the Right Thing Right." Conference paper presented at the First International Conference on Innovation and Integration in Aerospace Sciences, Aug 4–5, 2005.

Rebentisch, Eric, "Value-Based System of System Development" AIAA Infotech Conference Sep 2005.

Richards, Matthew G., et al., "Managing Complexity with the Department of Defense Architecture Framework: Development of a Dynamic System Architecture Model", INCOSE 2006.

Richards, Matthew G., "On-Orbit Serviceability of Space System Architectures" master's thesis, MIT, May 2006.

Richards, Matthew G., et al., "Assessing the Challenges to a Geosynchronous Space Tug System" SPIE 2005.

Ross, Adam Michael, "Managing Unarticulated Value: Changeability in Multi-Attribute Tradespace Exploration" PhD thesis, MIT, Jun 2006.

Ross, Adam M., and Daniel E. Hastings, "The Tradespace Exploration Paradigm" INCOSE 2006.

Srinivasan, Jayakanth, and Erisa K. Hines, "IT Enabled Enterprise Transformation: Perspectives Using Product Data Management" LAI, MIT 2005.

Whitaker, Ryan Brent, "Value Stream Mapping and Earned Value Management: Two Perspectives on Value in Product Development" master's thesis, MIT, Sep 2005.

LAI Products

The LAI tool suite is regularly updated and revised to reflect the latest research and best practices. A comprehensive list of these tools is available online at the LAI website, http://lean.mit.edu/. A brief description of some of the most recently updated tools follows:

- Enterprise Value Stream Mapping and Analysis 1.0 (EVSMA) with Facilitator's Guide August 2005. This product presents a coherent method for analyzing and improving enterprise performance, integrating strategic objectives, stakeholder interests, and process performance. It is a decision aid for enterprise executives to identify barriers to the creation/delivery of value to each stakeholder, specify a vision of their future lean enterprise, determine significant gaps between current and future states, and prioritize opportunities.
- Product Development Value Stream Mapping 1.0 (PDVSM) and Manual September 2005. This is a practical guide tackling the application of lean to product development. It is focused at the "tactical level"—engineering process improvement—and is a summary and reference for more than four years of product development group experience facilitated through LAI. The manual

is intended for product development (PD) personnel working on improving their own processes and the lean change agents working with them. Its aim is to provide practical guidance for applying lean concepts to PD process improvement—specifically, PD value stream mapping (PDVSM).

- Manufacturing System Design Framework Manual. The current knowledge of manufacturing systems and the lack of a generally accepted scientific basis for relating the multiple variables needed for a successful manufacturing system design argues for the development of a framework to methodically approach the manufacturing system design process rather than attempt to create a definitive design methodology.
- Lean Now Facilitator Course July 2005.
- Lean Enterprise Value (LEV) Simulation (or "Game") Version 2.0 and Short Course. This unique tool for demonstrating the value and challenges of implementing lean principles and practices at the enterprise level was updated in June 2006. It was updated to include new enterprise functionality and to improve ease of adoption by LAI consortium members.

LAI People

LAI welcomed Dr. Ricardo Valerdi as the newest member of the LAI research staff in summer 2005. Previously, he worked as a member of the technical staff for Aerospace Corporation in El Segundo, CA. At LAI, he continues his work on cost modeling with the refinement of COSYSMO, a model for estimating systems engineering effort that has been calibrated with data by several major corporations. Valerdi received his PhD and MS from University of Southern California in systems engineering and his BS in electrical engineering at the University of San Diego.

LAI welcomed two new staff members in early 2006. Emily Kearney BaThan joined LAI as operations manager in Feb 2006. She previously worked at CTPID at MIT.

Michelle Gaseau joined LAI in Mar 2006 as communications coordinator. She has held positions previously as an editor, web manager, and journalist, most recently working for Screened Images Inc. in Quincy, MA.

LAI researcher Dr. Donna Rhodes was awarded the INCOSE Founder's Award in Jul 2005 for her 15 years of service including technical board chair, fellow, director of strategic planning, and president of the organization.

LAI Moving Forward

As LAI moves full force into Phase V, there is a major effort to continue to strengthen its innovative industry, government, and academic partnership and to assist its partners with enterprise transformation in light of major government and corporate lean initiatives, such as Air Force Smart Operations 21st Century. LAI plans to provide assistance where needed to ensure that its consortium members use the latest and greatest tools and practices backed by research.

The consortium looks to continue its goals of lean transformation through knowledge sharing, training, and modeling ways of continuous improvement to aerospace industry stakeholders. LAI will deploy this information through site visits, hands-on training, curriculum building, short courses and direct case studies with consortium members, and deployment of best practices through research.

The consortium also seeks to engage new aerospace industry members in the coming year as well as additional linkages with the US Navy, US Army, and international companies to broaden the perspectives within the forum that make LAI so unique.

LAI also plans to raise its profile among consortium membership and the general public and has already done so in several ways. In the last year, LAI sponsored a national Lean Enterprise Value Student Prize that awarded a monetary gift to the eligible student whose undergraduate or graduate coursework has contributed or has the potential to contribute to transformation of enterprises based on the concepts in LAI's book *Lean Enterprise Value*. The prize was funded by the Lean Enterprise Value Foundation Inc., which controls royalties from the book. LAI also hopes to raise awareness of its work and research through interconsortium communication collaborations through its communications group and through a website redesign that will engage website visitors and consortium members through a variety of media, including audio podcasts, web videos, and newsletters.

The LAI consortium is a powerful learning community with stakeholders from nearly 40 organizations including aerospace companies, US government offices and programs, and academia. The uniqueness of LAI lies in its creation of a neutral forum where consortium members have the ability to share new ideas, bridge cultural differences, enhance communication, understand differing perspectives, and respect competing interests, all with a common goal of lean transformation through research.

Throughout the coming year and the remainder of Phase V, LAI researchers, staff, and consortium stakeholders are committed to sustain the partnership, facilitate lean transformations within and between industry and government, expand knowledge of lean transformation, and foster collaboration within the greater learning community.

LAI Leadership

The cochairs of LAI, each representing LAI stakeholder groups, are General Bruce Carlson representing the US Air Force Material Command, Blaise Durante representing the Office of the Assistant Secretary of the Air Force, Chris Cool of Northrop Grumman representing industry, and Institute Professor Sheila Widnall representing MIT. LAI is managed by two codirectors, representing a multidisciplinary research approach: Professor Deborah Nightingale, Department of Aeronautics and Astronautics; and Professor John Carroll, MIT Sloan School of Management.

More information about LAI can be found at http://lean.mit.edu/.

Labor Aerospace Research Agenda

The Labor Aerospace Research Agenda (LARA) began in June 1998 with the belief that people are at the heart of new work systems—establishing stability and then driving continuous improvement. LARA was designed to further the understanding of this critical social dimension of lean principles in the aerospace industry.

LARA's funding cycle via the Manufacturing Technology Initiative of the US Air Force ended April 15, 2005. Nevertheless, the LARA team remains engaged in research with aerospace stakeholders with the Aerospace Industry Council as well as other projects including lateral alignment in complex systems and a network and social capital study.

Aerospace Industry Council

The LARA team was instrumental in putting together a new institutional initiative, the Aerospace Industry Council. This Council is an emerging forum for industry-level dialogue on labor and employment issues and is under the auspices of the Labor and Employment Relations Association's (LERA's) major new initiative to establish industry councils in many sectors of society, each of which will address labor and employment issues in that sector. The Aerospace Industry Councils met in January 2006 at the LERA meetings in Boston and at the National Federal Mediation and Conciliation Services national labor-management conference program in August 2005.

Lateral Alignment

Under the auspices of PARTNER and based in the Center for Technology, Policy, and Industrial Development, the LARA team is focusing on lateral alignment in aviation environmental issues. The specific focus is on alignment across stakeholders associated with the architecture and implementation of the Next Generation Air Transportation System. Sponsorship comes through the FAA's Office of Environment and Energy and NASA.

The project includes an "action research" component in which researchers provide technical assistance to the stakeholders in their alignment efforts. This is of tangible value to the parties and gives researchers insights into the dynamics of alignment that otherwise might not be visible.

The project also features a working group of leading scholars engaged in inductive and deductive theory development around the concept. Cochaired by Joel Cutcher-Gershenfeld and Joel Moses, the MIT Working Group on Lateral Alignment in Complex Systems is a sounding board for this research. Twenty-two people from six MIT departments are members of the working group and 10–15 participants attend each biweekly session. Participation has periodically included representatives from FAA, Ford, MITRE, and NASA, with opportunities for others to join in.

Network and Social Capital Study: Programme on Regional Innovation

This short-term project aims to evaluate and learn whether Cambridge–MIT Institute's funding has created greater capacity to leverage resources, innovate ideas, and direct the flow of information across a wider stream of people and groups.

LARA Accomplishments

"Building the Internal Organization to Support Lateral Alignment: A Case Study of the Office of Environment and Energy, Federal Aviation Administration," Joel Cutcher-Gershenfeld, Betty Barrett, and Christopher Lawson. Nov 2005.

Joel Cutcher-Gershenfeld updated and provided new commentary on *The Human Side of Enterprise, Annotated Edition*, Douglas McGregor, McGraw-Hill, 2006

More information about LARA can be found on the web at http://web.mit.edu/ctpid/lara/.

Materials Systems Laboratory

The Materials Systems Laboratory (MSL) is internationally recognized for innovative work analyzing the competitive position of materials and the strategic implications of material choice. For nearly two decades, MSL has addressed issues arising from materials choice in a range of applications in the automotive, electronic, and aerospace industries but with a recent emphasis on automotive applications. Most recently, MSL was recognized by the Portuguese government for its contributions to the development of an advanced automotive design and engineering center. This was the result of nearly 10 years of research collaboration with Portuguese universities, research centers, and automotive industry partners. Professor Joel Clark (Department of Materials Science & Engineering and Engineering Systems Division) was invited to speak at the opening ceremonies for the Engineering Center along with high-ranking government and industry figures from Portugal and the European Union.

MSL's research sponsors include major automakers and materials suppliers. A five-year agreement with General Motors established the Materials and Manufacturing Systems Analysis Collaborative Research Laboratory. This lab gives MSL a basis for conducting more in-depth research into the strategic implications of materials and processing developments for the automobile industry, particularly focusing on issues of the strategic position of new automotive technologies from economic and environmental standpoints. MSL has research projects in the areas of flexible automobile manufacturing, lightweight materials and automotive design, and the economics of the vehicle launch process.

MSL has recently begun an initiative with General Motors and a group of materials suppliers to add more depth to the research in the areas of lightweight materials and design. This new industrial consortium includes representatives of the steel, aluminum, and polymer composites industries.

MSL is also doing more in-depth research in the area of recycling. Historically, MSL has examined automotive industry recycling practices and material selection and substitution in the electronics industry, particularly in packaging. MSL has an ongoing project in the area of markets and electronics recycling. Researchers Randolph Kirchain (assistant professor, Department of Materials Science & Engineering and Engineering Systems Division), Frank Field (senior research associate, CTPID), and Jeremy Gregory (research associate, Laboratory for Energy and the Environment) have been working to understand current recycling practices and to develop an economic model for

improving product design and recycling technology. They have been working closely with a number of industrial partners including Hewlett-Packard, Microsoft, and Philips Electronics.

MSL has also been continuing its work in the area of microphotonics. Professor Randy Kirchain and Richard Roth (research associate, CTPID) have been working on a number of research activities aimed at gaining a better understanding of the materials and processes used to manufacture a variety of critical components for the microphotonics industry. They have recently expanded their work to address questions of network architecture and the influence of new component technology on network deployment strategies. MSL has worked closely with the Communications Futures Program, the Center for Integrated Photonics Systems, and the Communication Technology Roadmap within the Microphotonics Center.

The lab's work builds on a unique combination of materials-processing knowledge, engineering design practice, manufacturing process analysis, and environmental information to construct analytical tools for decision support and competitive analysis. To develop these tools, MSL has refined its extensions to classic engineering process modeling for the past two decades. Modeling elements have been married to elements of product design, material properties, and manufacturing assumptions to yield tools that can estimate the costs of product manufacture under a wide range of conditions. These tools analyze primary materials production, primary materials processing, component and subassembly manufacture, and end-of-life vehicle processing. In each case, these tools estimate the costs of production as a function of processing technology, material flows, operating conditions, and energy and capital requirements.

MSL has also developed techniques for understanding how markets respond to the different combinations of engineering and economic performance available by using different materials. MSL researchers also analyze the environmental consequences of materials and process choice, incorporating the emerging life-cycle analysis paradigm. These tools make it possible, when used with economic and engineering assessments, to develop robust, credible, and defendable product strategies that take life-cycle information into account.

Richard Roth, Director
Joel Clark, Principal Investigator

More information about MSL can be found on at http://web.mit.edu/ctpid/www/msl.html.

MIT Information Quality Program

The MIT Information Quality (MITIQ) program develops new knowledge in the information quality field and information quality benchmarking standards. MITIQ, launched in 2002, conducts research on all aspects of information quality, such as how to manage information as a product, how to develop an information product map, and how organizations adopt information quality over time. Additionally, MITIQ

equips professionals with the understanding and skills to significantly improve their organization's information and to use that information as a strategic tool. MITIQ is an outgrowth of MIT's Total Data Quality Management Program, founded in the 1990s by Sloan School of Management's then-Associate Professor Richard Wang and J. N. Maguire Information Technology Professor Stuart Madnick.

MITIQ Accomplishments

MITIQ hosted the 10th International Conference on Information Quality (ICIQ), a forum for researchers and practitioners to exchange IQ knowledge and ideas in November 2005 at MIT. More than 140 participants from academia and industry worldwide celebrated the 10th anniversary of this conference—the premier conference in the information quality field.

This year, Richard Wang, MITIQ director, was invited to participate in a working group sponsored by the Bureau of Justice Assistance, Office of Justice Programs, US Department of Justice, titled "Global Justice Information Sharing Initiative, Privacy and Information Quality Working Group." Dr. Wang gave presentations in March and June 2006 to federal, state, local, and tribal officials on the topic of information sharing post-September 11. The MITIQ endeavor is in keeping with CTPID's policy focus.

In a new initiative, MITIQ established a consortium to study long-term impacts of information quality on organizations, how information quality is related to organizational performance, and what kind of processes, techniques, and models are used in different organizational settings. One outcome from this research was an index that measures the distance of different transactions related to an entity (say a customer or a potential suspect). The entity resolution technique is important beyond the simple application of assigning transactions associated with an entity. In the homeland security area, one could conceive that the same technique could be applied to identify various sources of information that may be related to a potential threat.

In another initiative, MITIQ helped the University of Arkansas at Little Rock to successfully establish the first-of-its-kind master of science degree in information quality (MSIQ) program. The MSIQ program secured final approval from the state of Arkansas in April 2006 and the first MSIQ class will begin in fall 2006.

In yet another initiative, MITIQ is investigating the extent to which successful organizational outcomes are related to enterprise architecture through collaboration with the director of national intelligence (DNI). On June 8, 2006, MITIQ hosted a meeting for General Meyerrose (Retired), DNI's chief information officer at MIT to discuss issues such as leadership in enterprise architecture deployment, enterprise governance, and entity resolution research.

MITIQ offered a three-day (July 11–13, 2005) executive IQ course at MIT entitled "Information Quality: Principles and Implementation" through the MIT Professional Education Program. MITIQ also offered initial short courses leading to an IQ certification program for information quality professionals. In addition, MITIQ offered a

two-day (July 14–15, 2005) course with case study materials developed under the MITIQ program through the MIT Professional Education Program.

MITIQ continued to develop a body of knowledge in the field of IQ. For example, the MITIQ program has published the first textbook in the IQ field: *Introduction to Information Quality*, coauthored by Craig Fisher, Eitel Laura, Shobha Chengalur-Smith, and Richard Wang (http://mitiq.mit.edu/Books.htm). As another example, MITIQ was instrumental in the publication of a special volume in the *Advances in Management Information Systems* monograph series: *Information Quality*, coedited by Richard Wang, Elizabeth Pierce, Stuart Madnick, and Craig Fisher.

MITIQ Funding

Current MITIQ consortium members include Acxiom Corporation and Lockheed Martin Corporation. Other leading organizations and the ICIQ Conference are expected to join the consortium.

More information about MITIQ can be found on the web at http://mitiq.mit.edu/.

Technology and Law Program

The Technology and Law (T&L) program offers research opportunities and graduate-level courses focusing on the interface of law and technology. Research activities include the design and evaluation of policies that encourage technological change for preventing chemical pollution through regulation, liability, and economic incentives; promote environmental justice by involving communities in governmental decisions that affect their health, safety, and environment; and address the effects of globalization on sustainability.

T&L offers a two-semester sequence in environmental law and policy that is colisted with urban studies. Law, Technology, and Public Policy, a core subject in TPP and Sustainability, Trade, and Environment are listed jointly with Engineering and Sloan. As part of the Cambridge–MIT Institute, the latter course continues to be offered at Cambridge University as well as a course in European and international environmental law. A textbook, *Environmental Law, Policy, and Economics: Reclaiming the Environmental Agenda* by Nicholas Ashford and Charles Caldart, will be published by MIT Press next fall. A second textbook, *Globalization, Technology, and Sustainability*, is in preparation by Nicholas Ashford.

Technology and Law Publications

Nicholas A. Ashford, "The Legacy Of The Precautionary Principle In U.S. Law: The Rise of Cost-Benefit Analysis and Risk Assessment as Undermining Factors in Health, Safety and Environmental Protection" in Sadeleer, Nicolas (ed.), *Implementation of the Precautionary Principle in the Nordic Countries: Lessons from the EU and the United States*, Earthscan, 2006.
Nicholas A. Ashford, "Scientific, Ethical and Legal Challenges in Work-Related Genetic Testing in the United States," *European Journal of Oncology Library*, 4: 33–59, 2005.

Nicholas A. Ashford, "Government and Environmental Innovation in Europe and North America" in *Towards Environmental Innovation Systems*, Matthias Weber and Jens Hemmelskamp (eds.) Springer, Heidelberg, 2005, pp. 159—174.

Nicholas A. Ashford, "Pathways to Sustainability: Evolution or Revolution?" in *Innovation and Regional Development and Conditions for Innovation in the Network Society*, Marina van Geenhuizen, David V. Gibson, and Manuel V. Heitor (eds.), Purdue University Press, 2005, pp. 35–59.

Nicholas A. Ashford, "Implementing the Precautionary Principle: Incorporating Science, Technology, Fairness, and Accountability in Environmental, Health, and Safety Decisions." *International Journal of Risk Assessment and Management*, 5(2/3/4): 112–124, 2005.

Nicholas A. Ashford, "Scientific, Ethical and Legal Challenges in Work-Related Genetic Testing in the United States," *European Journal of Oncology Library*, 2005.

Nicholas A. Ashford and Charles C. Caldart, "Government Regulation of Occupational and Environmental Health and Safety" in *Occupational and Environmental Health: Recognizing and Preventing Disease and Injury*, 5th ed. Barry S. Levy and David H. Wegman (eds.), Lippincott Williams & Wilkins, Philadelphia 2005, pp. 39–73.

Nicholas A. Ashford and Charles C. Caldart, "Negotiated Regulation, Implementation and Compliance in the United States," *The Handbook of Environmental Voluntary Agreements*, Eduoardo Croci (ed.), Kluwer Academic Publisher, Environmental and Policy Series, 2005, pp. 135–159.

Lars Koch and Nicholas A. Ashford, "Rethinking the Role of Information in Chemicals Policy: Implications for TSCA and REACH," *Journal of Cleaner Production* 14(1): 31–46, 2006.

Technology and Policy professor Nicholas Ashford is director of the T&L Program. Charles Caldart participates as a lecturer in the course offerings.

More information about T&L can be found on the web at http://web.mit.edu/ctpid/www/tl/.

Professor Moavenzadeh resigned as director of CTPID as of June 30, 2006, after eight years of service. He remains director of the Technology and Development Program. Institute Professor Joel Moses was named the acting director of CTPID as of July 1, 2006.

Fred Moavenzadeh
Director
James Mason Crafts Professor
Professor of Civil and Environmental Engineering and Engineering Systems

More information about the Center for Technology, Policy, and Industrial Development can be found at http://web.mit.edu/ctpid/www/.

MIT Center for Transportation and Logistics

For more than 30 years, the MIT Center for Transportation & Logistics (CTL) has been a world leader in supply-chain management, logistics and transportation education, and research. The Center's world-renowned research programs directly involve more than 75 faculty and research staff from a wide range of academic disciplines as well as researchers in various affiliate organizations around the world. And in education, MIT is consistently ranked first among business programs in logistics and supply-chain management.

Our newly designed website has a wealth of information about the Center and its programs, including descriptions of current research projects, event listings, explanations of our corporate outreach program, a listing of MIT theses in transportation since 1980 and in logistics and supply-chain management since 1999, and details on our educational offerings, including master's and PhD programs as well as executive education.

Education

Twenty-seven new students arrived on campus in fall 2005 to enter the Center's master of engineering in logistics (MLOG) program as the class of 2006. MLOG is an intensive nine-month degree track preparing graduates for logistics management careers in manufacturing, distribution, retail, transportation, and logistics organizations.

The MLOG class of 2006 was geographically dispersed, with 60 percent coming from outside the United States, representing 12 countries. At graduation, 89 percent of the class had at least one job offer (with an average of 2.3 offers per student); within two weeks, 95 percent had job offers. The median outgoing salary for students was 40 percent higher than their incoming salary.

Expanded International Orientation Period

To better prepare the incoming international MLOG students, an additional one-week orientation was added to the existing two-week orientation at the beginning of the academic year. The objective is to better acclimatize students who have never lived in the United States with the language, culture, and general living practices.

Expanded Exchange with Zaragoza Logistics Center Students

In January 2006, during the Independent Activities Period (IAP), the MLOG class and the Zaragoza Logistics (ZLOG) students conducted a month-long exchange. First, the ZLOG students came to MIT for three weeks, where they participated in a number of trips, classes, and workshops. Then the MLOG class traveled to Zaragoza to visit a number of logistics facilities and partake in a competitive, team-based supply-chain design simulation. Additionally, more than 30 senior supply-chain executives came to the program to speak and recruit.

MLOG Alumni Interaction

In May, the first MLOG Re-Connect Days was held. Re-Connect Days will be held each spring. The two-day event is open to all MLOG alumni, current MLOG students, and incoming MLOG students; it features research presentations and professional

development talks from selected faculty. The objectives are threefold. First, it encourages networking among the classes. Second, it provides executive training to the alumni. Finally, it allows incoming students an advance look at thesis research projects. Approximately one-third of the entire alumni base attended the event along with half of the incoming class.

Supply-Chain Education Partners Program

This year, six companies participated in the Partners Program, in which a team of students is assigned a jointly scoped-out project that has practical and research aspects. Projects this year included the following:

- Analyzing the impact of product proliferation at Solutia
- Quantifying the benefits of vendor managed inventory at WR Grace
- Studying methods for merging multiple forecast systems for Albertsons
- Improving international inbound consolidation for Tyco
- Developing better transportation options for highly perishable products for Tyco Healthcare
- Studying the impact of different inventory practices in the health care supply chain at hospitals.

Established in 2002, the Partners Program promotes supply-chain knowledge sharing among leading executives and students in MIT's MLOG program.

Research

During the past academic year, many new research projects were posted on our website, along with many continuing projects carried over from previous years—a total of 80–90 efforts listed in various categories and cross-indexed with their principal researchers.

Corporate Outreach

In CY2004, CTL relaunched the corporate outreach program with the goal of significantly increasing both the number of our corporate partners and the quality of our interactions with them. During the fiscal year just ending, we passed our initial target of 40 active members of our MIT Supply Chain Exchange Program. New partners include Cordis (a Johnson & Johnson Company), DHL, EMC Corporation, LXP, Manhattan Associates, and Philips Lighting—bringing membership in the exchange program to 41 companies. As well as growing our partner base, we are deepening our relationships with partners by actively promoting ways they can engage with CTL and transfer CTL-created value into their organizations, including the following:

- Attending symposia and executive education courses
- Working with MLOG students by proposing business problems as thesis topics
- Recruiting MLOG students
- Presenting at symposia and to MLOG classes

- Distributing CTL newsletters, papers, and theses effectively within their organizations
- Participating on Supply Chain 2020 (SC2020) advisory councils and in other research projects
- Sharing strategies and key business problems at briefing sessions that convene senior sponsor and CTL staff.

Participation by our partners in all these aspects of their exchange membership has increased significantly. Additionally, we have initiated a number of high-visibility engagements at sponsor companies including Intel, CSX, and Procter & Gamble.

We conclude the year with a strong outreach program in place, including what we believe to be the largest and most active supply-chain management corporate participation program in academia. We plan continued growth in numbers of corporate partners, along with increased focus on making strategic contributions to partner companies by encouraging and enabling transfer of learnings from SC2020 and other CTL research projects.

Major Projects/Initiatives

The MIT–Zaragoza International Logistics Program

The MIT–Zaragoza International Logistics Program is part of a multiyear agreement with the government of Aragón, Spain, to help create an international education and research program in logistics and supply-chain management. The government of Aragón established the Zaragoza Logistics Center (ZLC) as a special research institute associated with the University of Zaragoza. A building for ZLC is being designed and will be located in the middle of PLAZA, the largest logistics park in Europe, which is being built near Zaragoza. In addition to conducting cutting-edge research, using PLAZA as a working laboratory for international logistics practice, ZLC offers graduate and executive education in logistics to students from around the world.

Two important faculty members were hired by ZLC to conduct research and deliver courses in the MIT–Zaragoza program. First, in May 2006, ZLC completed the international search for its new director by hiring Dr. Santiago Kraiselburd. Dr. Kraiselburd received his PhD from Harvard Business School and was recently a professor at the Instituto de Empresa in Madrid, where he retains a part-time appointment. Second, seven candidates were interviewed from more than 60 applications, and one was hired as an assistant professor: Dr. Mustafa Gurbuz, who received his PhD from the University of Washington Business School. Jarrod Goentzel continued in his role as executive director of the MIT–Zaragoza program and also continued his temporary assignment in Zaragoza to help establish the international education, research, and outreach programs. In addition, the MIT–Zaragoza program hosted visiting professors from Lund University (Sweden), London Business School, Instituto de Empresa (Madrid), and INCAE (Costa Rica).

This year saw the graduation of the second class in the Zaragoza master's degree program (ZLOG), which is modeled on MIT's MLOG. The ZLOG international exchange, occurring during MIT's IAP session in January, was extended from two to three weeks to enable more interaction with MIT's MLOG students and more exposure to executives visiting CTL. During IAP, MLOG and ZLOG students followed the same curriculum, which involved lectures on practical management skills, a series of seminars on leadership from supply-chain executives, and a four-week simulation exercise in which teams of students from both programs competed against each other in managing a virtual supply chain. The MIT–Zaragoza doctoral program was launched this past year, and the first PhD student from Zaragoza visited MIT in the fall.

The MIT–Zaragoza program initiated a partnership with the Instituto de Empresa (IE) Business School, a leading European business school, to launch a dual master's degree program. Students in the dual degree program will earn an international MBA at IE Business School in Madrid and either the MLOG or the ZLOG degree. Students must pass through the admissions process for each program and satisfy the requirements for each of the two degrees. The MBA/MLOG (or MBA/ZLOG) program requires students to spend nine months at CTL (or ZLC) and ten months at IE.

In addition to being named a lead institute for the National Center of Excellence on Integrated Logistics, the MIT–Zaragoza program began coordination with the Next Generation Innovative Logistics Center led by Lund University, the only logistics and supply-chain center of excellence funded by the Swedish government.

Research projects were conducted this year with the following organizations: AENA (the airport authority of Spain), AECOC (the retail standards body for Spain), Prosegur, Lucent, Nokia, i2, PepsiCo, Mondi, First Advantage Corporation, Fritz Institute, Oxfam, Save the Children, and the PLAZA logistics park. In April, the MIT–Zaragoza program hosted an industry event with more than 50 executives that featured research from the Supply Chain 2020 project. Outreach efforts focused on planning for the Zaragoza Supply Chain Summit in March 2007, where MIT President Susan Hockfield will give the keynote address.

Supply Chain 2020

The SC2020 project is a multiyear research effort to identify and analyze factors critical to the success of future supply chains. This pioneering project will map out the innovations that underpin successful supply chains up to the year 2020. By looking further into the future than most business research initiatives, the project hopes to deliver practical breakthroughs on the design and management of future supply chains. The project also aims to help companies understand the forces that are changing supply chains, so they can be better prepared for the future. This work can create value in society through improvements in transportation, logistics, and supply-chain management practices.

Initiated by the MIT–Zaragoza International Logistics Program, the global research project involves dozens of faculty, research staff, and students at MIT and other institutions around the world. Two advisory councils composed of 44 supply-chain executives from more than 40 leading companies—the Industry Advisory Council and

the European Advisory Council—routinely meet to play a crucial role in helping to shape the work and generate new ideas. To date, seven advisory council meetings have been conducted and their proceedings are available online.

SC2020 research is broad, far-reaching, and designed to meet a series of objectives in two phases. The major objective of Phase I (research completed in FY2005) was to understand excellent supply chains and the underlying strategies, practices, and macro forces that drive them. Leveraging what was learned during the first phase, the objective of Phase II of the research was to project the future by using scenario generation and planning methodologies.

Phase I research was conducted by a postdoctoral fellow and 14 MIT graduate students from MLOG, TPP, and MST (master of science in transportation) and supervised by five MIT faculty advisors from Sloan, CTL, Materials Science and Engineering, and the LAI project. The SC2020 project funded seven of these students with research assistantships. In addition, six Zaragoza-based graduate students were supervised by two faculty advisors from ZLC. In total, 12 master's theses, 5 working papers, and 1 PhD thesis have been written under the aegis of Phase I.

Phase II was completed June 2006. The objectives of this phase were to develop a set of 2020 macro factor scenarios, including natural resource-related issues such as energy and material availabilities, as well as environmental pressures. Three working scenarios were developed. In addition, six MLOG students researched different functions spanning supply chains to cover order fulfillment, customer collaboration, supplier collaboration, demand supply matching, after market service, and new product introduction by comparing prominent companies in nine industries. The underlying idea of this research was to identify practices in various functions that cut across industries and practices that are unique.

In November, CTL ran a symposium titled "Building the Future Supply Chain Now" that brought together MIT faculty and staff, Industry Advisory Council members, and CTL sponsors to discuss visions of the future and how supply chains might be reshaped by them. Another event was run in Zaragoza, Spain, in early April to solicit European input on similar issues.

Phase II research was conducted by a postdoctoral fellow and 11 MIT graduate students from MLOG, TPP, and CEE, supervised by MIT faculty advisors from CTL, Materials Science and Engineering, and the LAI project. The SC2020 project funded five of these students with full or partial research assistantships along with one postdoctoral fellow. So far, six masters' theses and two working papers have been written based on the work carried out in this phase.

MIT Supply-Chain Frontiers Newsletter

Frontiers is an electronic newsletter created by the Center to disseminate information to industry and media contacts. Published eight times a year, *Frontiers* includes feature articles on Center research projects and other subjects of interest to supply-chain

professionals. It also includes news on Center events, educational activities, papers, and presentations given by Center representatives and staff appointments.

Supply Chain Strategy Newsletter

The Center has partnered with Larstan Business Reports to produce *Supply Chain Strategy,* a monthly newsletter available in electronic and hard-copy formats. Published 10 times a year, the newsletter's mission is bridge the gap between supply-chain and corporate strategy, with articles that help companies to manage supply chains strategically. It is read by senior executives and was launched on March 1, 2005.

Major Events

Creating a Resilient & Secure Supply Chain

Businesses are more vulnerable than ever to sudden disruptions such as natural disasters, terrorist attacks, supplier failures, and labor actions. So how can companies successfully operate through disruptions like these? The MIT CTL focused on that question at its annual symposium entitled "The Resilient and Secure Supply Chain" held in Cambridge, MA, on September 29, 2005. Leaders from industry, government, and academia came together to explore ways to make companies more resilient and secure—and therefore less vulnerable to disruption. Commissioner Robert C. Bonner of the Department of Homeland Security's US Customs and Border Patrol delivered the event's keynote address. Other speakers included CTL Director Yossi Sheffi, Theo Fletcher, IBM vice president of supply chain security, and Stephen Flynn, Council of Foreign Relations and author of *America the Vulnerable*.

CTL Simulates Disaster

More than 150 executives from companies nationwide attended MIT CTL's second annual Crossroads symposium entitled "At the Crossroads of Supply Chain and Strategy: Simulating Disruption to Business Recovery." The one-day event held on April 11, 2006, in Cambridge, MA, focused on the strategic impact of supply chains in the face of global disruptions. It featured a real-time simulation of a fictional company's supply chain being crippled by an avian flu outbreak. The Center invited executives from several companies to participate as members of the fictional company's corporate emergency response team (CERT) and deal with the disruption as it unfolded in front of a live audience. This year's Crossroads symposium also featured presentations by Cath Malseed from Procter & Gamble, who was part of the team charged with getting its New Orleans facility up and running after Hurricane Katrina, and Edward Erickson, senior manager of supply chain risk management at Cisco Systems.

Smaller Functions

Effective Disruption Management

Emergency relief agencies and industrial manufacturers are very different organizations, but when disaster strikes they face similar supply-chain challenges. On September 8, 2005, they came together in Stanford, CA, to share best practices and learn some important lessons about disruption management. The event, "Effective Disruption

Management," was cosponsored by the MIT CTL, the Global Supply Chain Management Forum, the Center for Social Innovation at Stanford Business School, and the Fritz Institute. The key issues covered were supply-chain agility, management and planning, performance measurement, visibility, and public–private partnerships.

SC2020: Building the Future Supply Chain Now

CTL held two symposia on either side of the Atlantic, both leveraging the insights from CTL's Supply Chain 2020 Project. Leaders from industry and academia came together—once in Cambridge, MA, on November 29, 2005, and once in Zaragoza, Spain on April 6, 2006—to consider the future of supply chains by an interactive process. They examined how several macro factors, such as an aging population, technology, and energy, will affect future supply chains and discovered how to use scenario planning techniques to prepare for the future.

Innovations in Transportation 2006

An ongoing capacity crisis in the US freight transportation network is threatening economic growth, yet collaboration between carriers, shippers, and government agencies to find solutions is virtually nonexistent. CTL's third annual Innovations in Transportation Symposium, held May 16–17, 2006, in Cambridge, MA, brought together the three key stakeholders of the transportation network to focus on identifying short- and long-term solutions to the ongoing capacity crisis. Speakers discussed tactical approaches to finding additional capacity as well as longer-term strategic solutions. Attendees also participated in a hands-on, half-day group exercise exploring future scenarios for potential transportation strategies.

MLOG 2006 Thesis Review

On May 25, CTL invited members of the Center's Supply Chain Exchange for an insider's look at the innovative research being done by students in CTL's MLOG program. MLOG students are required to complete a thesis as part of their degree and often work with partner companies on their research projects. This year, CTL faculty and researchers selected the five best theses, which were then presented to the Supply Chain Exchange members.

CTL's Web Presence

The Center's web presence has grown significantly during the 2006 fiscal year. After ramping up through summer 2005, we launched the Center's web portal in early November. Since then, the site has averaged 8,300 visits a month with higher peaks around event dates and focused marketing campaigns. The site's content continues to grow and iterative work moves ahead at a steady pace.

The Center launched a companion website for the director's best selling book *The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage*, a publication that has furthered the Center's international exposure.

The Center launched a redesigned New England University Transportation Center website, has a new blog for students of the Center's MLOG program, and maintains a number of other smaller websites, including MLOG program's site.

Also during FY2006, work began on integrating the Center's web portal with the MIT Alumni Association's online directory, with the goal of providing a valuable networking tool for graduates of the Center's MLOG program.

FY2006 saw the formalization of a marketing team and the hiring of a web communications manager and a marketing communications officer. This new team has worked to raise organizational awareness of the emerging importance of marketing and brand identity for higher education generally and the Center specifically. These issues now permeate every conversation about Center programs and initiatives.

Professional Education

Supply Chains Driving Strategic Advantage, our annual weeklong summer program, was offered June 13–16, 2006. Leadership Supply Chain Management, a CTL executive education course, was offered January 4–6, 2006.

Personnel Changes

The Center's staff was enhanced this year with several new hires: Michelle Pratt, John Attanucci, Eric Greimann, and Jessica Rosekrans. Departures from the Center included Nicole Blizek, Lisa Emmerich, and Tiauw Go.

Recognition

CTL Director Yossi Sheffi's latest book, *The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage*, was named one of the best business books of 2005 by *The Financial Times*. The book provides a rich set of lessons on how today's business leaders can prepare for and manage the large-scale disruptions that have become increasingly common in our global markets. Other books on the list included Thomas Friedman's *The World Is Flat*, *Freakonomics* by Steven Levitt and Stephen Dubner, and *Travels of a T-shirt* by Pietra Rivoli.

John C. W. Parsons, a 2004 graduate of CTL's MLOG program, was selected as cowinner of the case competition at the INFORMS annual meeting in November 2005 in San Francisco. Parsons, currently an associate at McKinsey & Company, presented a case with MIT Professor Stephen Graves based on research they had done in 2004 in partnership with Reebok International Ltd. on the company's demand forecasting of NFL team replica jerseys. Parsons conducted the research under the direction of Dr. Graves as part of his MLOG degree at MIT.

Less than three years after partnering with CTL, ZLC in Zaragoza, Spain, has been designated the lead center in the country's new National Center of Excellence in Logistics. The designation affirms ZLC's status as a major center for supply-chain education and research. ZLC is one of the partners involved in the MIT–Zaragoza International Logistics Program—a research and education partnership established in

2003 by the MIT CTL, the University of Zaragoza, the government of Aragón, industry partners, and the PLAZA logistics park in Zaragoza, Spain.

Mike Mulqueen won the MLOG 2006 Outstanding Thesis award for his research on creating transportation policy in a network utilizing both contract carriers and an internally managed fleet.

The New England Roundtable (NERT) of the Council of Supply Chain Management Professionals awarded MLOG 2006 graduate Anne Davidson a $1,000 scholarship. Davidson maintained a perfect 5.0 GPA at MIT. Her thesis topic, "Performance Metrics within the Humanitarian Supply Chain," required her to work with government and nongovernmental officials from around the world. She has represented MIT at conferences in Europe and worked directly with the Fritz Institute. NERT said that Davidson's ability to work effectively with such a wide range of people is truly amazing, and she is a future supply-chain leader.

Yossi Sheffi
Director
Professor of Civil and Environmental Engineering and Engineering Systems

More information about the Center for Transportation and Logistics can be found at http://ctl.mit.edu/.