

Engineering Systems Division

Academic year 2005 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.

Professor Daniel Hastings became ESD's director, effective July 1, 2004. Professor Hastings holds a dual appointment in the Department of Aeronautics and Astronautics and ESD. He has taught courses and seminars in plasma physics, rocket propulsion, advanced space power and propulsion systems, aerospace policy, technology and policy, and space systems engineering. Professor Hastings's recent research has concentrated on issues of space systems and space policy and has also focused on issues related to spacecraft-environmental interactions, space propulsion, space systems engineering, and space policy. He served as chief scientist of the US Air Force from 1997 to 1999. He is serving as a member of the National Science Board, the Applied Physics Lab Science and Technology Advisory Panel, as the chair of the Air Force Scientific Advisory Board, and as chair of the academic council of the International Consortium of Systems Engineers (INCOSE). He is a member of the MIT Lincoln Laboratory Advisory Committee and is on the Board of Trustees of the Aerospace Corporation. He has served on several national committees on issues in national security space. He was named a "2005 Giant in Science" by the Quality Education for Minorities/Mathematics, Science, and Engineering Network, for his "outstanding contributions to research and education."

The ESD faculty continued to expand. We are delighted to announce that the following individuals have joined our faculty and teaching staff:

—Sanjoy K. Mitter, PhD, holds a dual appointment as professor of electrical engineering and computer science and engineering systems. Professor Mitter's research has spanned the broad areas of systems, communication, and control. Although his primary contributions have been on the theoretical foundations of the field, he has also contributed to significant engineering applications, notably in the control of interconnected power systems, character recognition, and automatic recognition and classification of electrocardiograms. His current research interests are theory of stochastic dynamical systems, nonlinear filtering, stochastic and adaptive control; mathematical physics and its relationship to system theory; image analysis and computer vision; and the structure, function, and organization of complex systems. Professor Mitter received his PhD from the Imperial College of Science and Technology, University of London, in 1965. He had previously worked as a research engineer at Brown Boveri & Co. Ltd., Switzerland (now ASEA Brown Boveri) and Battelle Institute in Geneva, Switzerland. He taught at Case Western Reserve University from 1965 to 1969 and joined MIT in 1969, first as a visiting professor and then in 1970 as associate professor in the Department of Electrical Engineering and Computer Science and in 1973 as a professor of electrical engineering. He was the director of the MIT Laboratory for Information and Decision Systems from 1981 to 1999 and director of the Center for Intelligent Control Systems, an interuniversity (Brown-Harvard-MIT) center for research on the foundations of intelligent systems from 1986 to 2000. He has held visiting positions at the Tata Institute of Fundamental Research, Bombay, India; Scuola Normale

Superiore, Pisa, Italy; Imperial College of Science and Technology; Institut National de Recherche en Informatique et en Automatique, France; University of Groningen, the Netherlands; ETH, Zürich, Switzerland; and several universities in the United States, including the University of California–Berkeley where he was the McKay professor in March 2000 and held the Russell-Severance-Springer chair in fall 2003.

—Devavrat Shah, PhD, holds a dual appointment as assistant professor of electrical engineering and computer science and engineering systems. His primary research interest is in the theory and practice of networks. He is interested in the algorithms for large complex networks such as the internet, wireless sensor networks, and the “natural” networks. He is also interested in areas of network information theory, stochastic networks, and random graphs. Professor Shah’s PhD thesis, entitled “Randomization and Heavy Traffic Theory: New Approaches for Switch Algorithms,” presented novel design and analysis techniques for scheduling algorithm for high-speed internet routers (e.g., Cisco’s flagship product GSR 12,000 series router). Professor Shah received his BTech degree in computer science and engineering from IIT–Bombay in 1999. He received his PhD from the computer science department at Stanford University in 2004. He was a postdoc in the Statistics Department at Stanford in 2004–2005. He was awarded the Best Paper Award at the INFOCOM 2004 and he received the President of India gold medal from IIT–Bombay in 1999.

In academic year 2004, Ms. Rania Hassan continued as ESD’s postdoctoral associate. During her second year of postdoctoral work at ESD and MIT’s Department of Aeronautics and Astronautics, Dr. Hassan has been concentrating on two projects: a NASA–sponsored Concept Exploration and Refinement (CE&R) project and a project sponsored by British Petroleum (BP). The NASA CE&R project investigated the design of optimal Moon and Mars transportation architectures, the planning of exploration campaigns, and the design of the crew exploration vehicle, which is a shuttle replacement for human space exploration. The BP project has focused on the establishment of methods and approaches to design flexible, staged pipeline network architectures for offshore oil production. In addition, Dr. Hassan has focused on her private research in bio-inspired optimization approaches and design methodologies. Dr. Hassan cotaught the class 16.888/ESD77 Multi-Disciplinary System Design Optimization in the spring 2005 term.

Currently there are 47 ESD faculty members: 34 in engineering, 10 in management, 1 in science, and 2 in humanities, arts, and social sciences. Twenty-six hold dual appointments and 21 hold joint appointments. There are 5 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 over 300 graduate students. Now in their second year, the Engineering Systems PhD and Engineering Systems SM programs admitted the second full classes of 25 ESD PhD and 2 ESD SM students, respectively. An additional 15 ESD SMs entered LFM in June 2005 (Class of 2007). As importantly, 12 ESD PhDs and 2 ESD SMs, plus 3 LFM ESD SMs, graduated in this academic year.

In addition to the ESD SM, master's-level programs include Leaders for Manufacturing (LFM), the Master of Engineering in Logistics (MLOG), System Design and Management (SDM), and Technology and Policy (TPP). A PhD is offered in Engineering Systems.

ESD has three affiliated research centers: the Center for Technology, Policy, and Industrial Development; the Center for Transportation Studies and Logistics; and the Center for Innovation in Product Development. These are described later in this report.

Ongoing Initiatives

Engineering Systems Learning Center

In 2005 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 a conference at MIT on electronic learning materials 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 is associate program director on the MIT side, has a number of initiatives with strong links to ESD. The Technology and Policy Program (TPP) has continued to work with Cambridge University (CU) 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 CU is also being used in new courses offered at MIT. Enrollment in the CU 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 three students from CU, and two TPP students are currently working with faculty in the UK.

Program on Emerging Technologies

In January 2004, the National Science Foundation (NSF) awarded MIT \$2.9 million for a multidisciplinary program on assessing effects of emerging technologies. The five-year award is under the NSF Integrative Graduate Education and Research Training (IGERT) program. The resultant Program on Emerging Technologies (PoET) was formed and is led by four principal investigators: Daniel Hastings, director of the Engineering Systems

Division, and Dava Newman, director of the Technology and Policy Program within ESD; Kenneth Oye of the Department of Political Science, the Engineering Systems Division, and the Center for International Studies; and Merritt Roe Smith of the Program in Science, Technology and Society (STS). This academic year, PoET was awarded a two-year grant by the Cambridge–MIT Institute to conduct workshops in the UK exploring implications of emerging technologies.

During academic year 2005, eight doctoral students from ESD, Political Science, and STS participated in PoET. The IGERT trainees' program gave students full tuition and generous stipends. They participate in PoET activities and research, in addition to their regular doctoral training.

As part of the IGERT training program, PoET faculty members have created new courses that the IGERT trainees take in addition to their other disciplinary coursework. This year, courses were taught by Kenneth Oye and Roe Smith. Curriculum development is currently underway, led by Daniel Hastings, for an integrative doctoral seminar to be offered next fall.

PoET research is organized around multidisciplinary panels that focus on specific areas of rapidly developing technology. Panels are composed of scientists and engineers with insights into directions of technological change, engineers with insights into potential applications of technologies, and social scientists and humanists with expertise on potential effects on economy, security, environment, and society. During AY2005, PoET efforts addressed ubiquitous computing. An initial daylong workshop focusing on applications of radio-frequency identification technology was held in the fall at the American Academy of Arts and Sciences for PoET faculty and students, along with other invited researchers and faculty. In the spring, two workshops were held: one at MIT that addressed technology assessment and one on ubiquitous computing held in the UK and sponsored by the CMI grant.

PoET has engaged in other activities over the course of the past year, including open seminars with invited speakers and smaller seminars for the participating faculty and students. These included, for instance, a seminar on the history of assessment and predictions about the automobile, a seminar comparing different disciplinary research methods, and an invited speaker from the Swiss Federal Laboratories for Materials Testing and Research, whose presentation was entitled "The Precautionary Principle and Its Application to Pervasive Computing." During the spring, PoET faculty and staff also admitted four new students, who were offered IGERT traineeships and will join the program this summer or in September.

Faculty Notes

Professor George Apostolakis was honored with the Ruth and Joel Spira Award for Distinguished Teaching.

AgeLab director Dr. Joseph Coughlin was appointed by President George W. Bush as a member of the advisory committee to the 2005 White House Conference on Aging. The conference, which occurs only once every 10 years, provides recommendations to the

president and Congress to help shape aging policy for the next 10 years. Dr. Coughlin also cochaired a summit leadership forum with Newt Gingrich and Willis Goldbeck at the Emerging Technologies and Healthcare Innovations Congress. The forum addressed the promise and impact of technologies in health care and aimed to influence public policy and industrial innovations that may help shape the future of aging. CEO-level professionals from industry and government were amongst the audience members of this invitation-only forum.

Dr. Joel Cutcher-Gershenfeld coauthored a book with J. Kevin Ford entitled *Valuable Disconnects in Organizational Learning Systems: Integrating Bold Visions and Harsh Realities*, published by Oxford Press in January 2005. Cutcher-Gershenfeld is editor of Douglas McGregor's *The Human Side of the Enterprise*, Annotated Edition, scheduled for publication by McGraw-Hill in 2005. A paper entitled "What System Safety Engineering Can Learn from the Columbia Accident," coauthored by Dr. Cutcher-Gershenfeld and Professor Nancy Leveson, received a Best Paper Award at the International Conference of the [System Safety Society](#) in August 2004. He also coauthored—with Professor Levenson, Professor John Carroll, Betty Barrett, Alexander Brown, Nicolas Dulac, Lydia Fraile, and Karen Marais—a working paper entitled "Effectively Addressing NASA's Organizational and Safety Culture: Insights from Systems Safety and Engineering Systems" (working paper, 2004) and "Systems Approaches to Safety: Socio-Technical Systems, High Reliability Organizations, and Engineering Systems," which will be included in *Management Lessons from the Columbia Disaster*, Bill Starbuck and Moshe Farjoun, eds. (New York: Blackwell, 2005). As a Fulbright senior specialist, he spent several weeks at the University of Sydney. Project funding received includes CPMR fellow and CPMR study of "System Safety" (Nancy Leveson, PI), NASA/USRA Center for Program/Project Management Research (2004); a study of "Lateral Alignment in Complex Systems" (Joel Cutcher-Gershenfeld, PI), FAA/NASA (2005); and a study of "Collective Bargaining and Workplace Transformation" (Joel Cutcher-Gershenfeld and Thomas Kochan, co-PIs), Federal Mediation and Conciliation Service (2005).

Professor Richard de Neufville received the Joseph A. Martore Excellence in Teaching Award in October 2004. The award was established to recognize and honor a full-time ESD faculty member who has made outstanding contributions to one of ESD's academic programs in the area of education and program development.

Professor Olivier de Weck, with Professor David Simchi-Levi, received NASA funding for interplanetary supply chain research. Professor de Weck served as the technical chair of the 1st [AIAA Multidisciplinary Design Optimization Specialist Conference](#), held April 18–21, 2005, in Austin, Texas. He was the invited lecturer at the [MITRE Corporation's](#) monthly technology speakers series on March 23, 2005, at their McLean, VA, campus and spoke about the topic of "Supersize Me? . . . or Architecting the Evolution of Engineering Systems." He also published several articles in MIT's faculty newsletter.

Professor Thomas W. Eagar, the Thomas Lord professor of materials engineering and engineering systems, was selected as the College of Engineering and Technology lecturer at Brigham Young University.

Professor Steven Eppinger and Karl T. Ulrich coauthored an updated version of *Product Design and Development*, McGraw-Hill/Irwin, 2004.

Daniel D. Frey, assistant professor of mechanical engineering and engineering systems, has received a National Science Foundation CAREER Award to develop new engineering design methods. The primary focus of the research will be “robust design” — a set of techniques for systematically exposing designs to adverse conditions and seeking designs with improved reliability. Professor Frey was also named a Robert N. Noyce career development professor, a three-year appointment, effective July 1, 2005. In fall 2004, he and ESD assistant director Ann Tremelling participated in the Disability Mentoring Day, sponsored by the [Massachusetts Rehabilitation Commission](#) and [MIT’s Office of Human Resources](#) and [Staff Diversity Initiatives/Affirmative Action](#). The event was designed to provide engineers who have disabilities with information about a variety of career options.

Patrick Hale, senior lecturer, was appointed director of the System Design and Management Fellows Program.

Professor John Hansman was selected by Aviation Week & Space Technology Magazine as a recipient of a 2004 48th Annual Aerospace Commercial Air Transport Laurel. Hansman was cited for pioneering research on vertical navigation displays.

Professor Paul A. Lagace gave the banquet speech at the International Conference of the [System Safety Society](#) in August 2004 and discussed general issues of perception and models.

Professor Richard C. Larson, professor of civil and environmental engineering and engineering systems, was appointed a Mitsui professor on November 1, 2004.

[Professor 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.

Professor David Mindell, Frances and David Dibner professor of the history of engineering and manufacturing and engineering systems and Margaret MacVicar Faculty Fellow, was promoted to full professor.

Professor Earll Murman was elected as a foreign member of the Royal Swedish Academy of Engineering Sciences. This honor recognizes Professor Murman’s many years of work in systems engineering, product development, aerodynamics, computational fluid dynamics, and engineering education.

Professor Dava Newman received the NASA Group Achievement Award. She was also named to the faculty of the Harvard–MIT Health, Sciences, and Technology Program.

Professor Kenneth Oye published the following: “On Beliefs and Regimes: Justification, Causal Knowledge, and Indicators of Performance” (Kenneth Oye, David Reiner, and Thomas Bernauer); papers for Conference in Honor of Robert O. Keohane, Woodrow Wilson School of Public and International Affairs, Princeton University, February 18, 2005; “Position Papers on Universal Location Infrastructure” (Shirley Hung, Spencer Lewis, Jon Lindsey, Christine Ng, and Kenneth Oye); informal working papers prepared for Oxford Internet Institute and MIT PoET Workshop on “New Approaches to Research on Implications of Emerging Technologies,” Oxford University, April 15–16, 2005; “Contingent Spirals: CDM, AIJ and Rentseeking” (David Reiner and Kenneth Oye); CMS4 Stream 27: “Technology and Power,” Judge Institute of Management, Cambridge University, June 2005.

Professor Oye also participated in the following: “Trade and Environmental, Health, and Safety Regulations: Causes of Diversity, Implications for Conflict Management,” International Workshop on Comparative US–EU Environmental Policy, July 16, 2004; “Environmental Innovation: Competitive Advantage and Environmental Regulation,” August 27, 2004, Helsinki, Finland; “Assessing Implications of Emerging Technologies,” presented to PoET Emerging Technologies Symposium at American Academy of Arts and Sciences on October 1, 2004; to ESD Visiting Committee on November 10, 2004; to MIT Alumni Club of Washington on January 11, 2005; “Monetary Politics and Future of Dollar” presentation to Renaissance Weekend, December 28–30, 2004; “Market Failure and Institutional Failure: Non-Market Strategies and Environmental Regulation,” Judge Institute of Management, Cambridge University, January 21, 2005; “On Beliefs and Regimes: Justification, Causal Knowledge, and Indicators of Performance,” Conference in Honor of Robert O. Keohane, Woodrow Wilson School of Public and International Affairs, Princeton University, February 18, 2005; “Economic and Political Factors and the Uptake of New Technologies,” Alliance for Global Sustainability, Conference on New Technologies for Sustainability, March 22, 2005; “Bush Administration Foreign Policy,” lecture to American Friends Service Committee Conference, April 8–9, 2005; “Keynote on Economic Security” and “Energy Security Issues,” Seminar 21, Airlie House, April 29–May 1 Weekend on National Economies in a Globalizing World.

Dr. Donna Rhodes was the keynote speaker at the INCOSE–ICSE. The title of her presentation was “[Partnerships for Realizing 21st Century Systems.](#)”

Professor David Simchi-Levi, with Professor Olivier de Weck, received NASA funding for research on interplanetary supply chain management. The second edition of Professor Simchi-Levi’s book, *The Logic of Logistics*, coauthored with Xin Chen and J. Bramel, was published by the Springer Series in Operations Research, 2004.

Professor Joseph Sussman’s new book, entitled *Perspectives on Intelligent Transportation Systems (ITS)*, was published by Springer in April 2005. This book represents his work on ITS over the past decade.

Professor James Utterback was appointed a member of the University of Chicago’s Board of Governors for Argonne National Laboratory for a three-year term through 2007.

Annalisa Weigel '94, assistant professor of aeronautics and astronautics and engineering systems, was honored with the Harold E. Lobdell '17 Distinguished Service Award, given in recognition of alumni relations service to the Alumni Association and MIT that is of special depth over a sustained period.

Student Honors

ESD PhD candidate Heidi Davidz was awarded Best Doctoral Student Presentation as judged by her peer researchers in an award sponsored by the Center for Systems Management at its conference in March 2005. Also at the conference, ESD doctoral student Jason Bartolomei presented his paper, "Dynamic Utility in Systems Architecting."

ESD PhD candidate Erica R. H. Fuchs was named an Industrial Performance Center fellow.

ESD PhD candidate Guang-lih (Kenneth) Huang received the Merck–MIT Fellowship.

SDM students Sandro Catanzaro, Fernando Cela-Diaz, and Evan Mamas received 1st place in the General Motors Case Competition, and LFM students Brooke Kahl, Andy Louis (Sloan), Sean Holly, Matt Hasik, and Jeff Baer received 2nd place.

TPP student [Elizabeth Masiello](#) was named a Rhodes scholar.

Two TPP students were winners in the 2005 MIT IDEAS Competition, sponsored by MIT–Lemelson. Stephanie Dalquist was a member of the Bicilavadora team, which won the top award of \$5K. Matt Orosz is from the Parabolic Power team, which won a \$2K prize.

TPP grad Ayanna Samuels won the Sigma Xi Scientific Research Society Award.

TPP grad Jessica Cohen received the TPP Leadership Award for Student Social Initiatives and the TPP Leadership Award for Student Leaders.

TPP grads Erisa Hines and Nuri Demirdoven received the TPP Leadership Award for Student Leaders.

TPP students Michael Berlinski, Ned Calder, and Salem Esber received the TPP Leadership Award for Communication with Incoming Students.

Shaunak Roy, an MLOG and TPP student, was part of a multidisciplinary team that won the Social Enterprise Track of the Harvard Business School's 9th annual Business Plan Contest.

MLOG '05 students Sumit Kumar and Matthew Harding each received a Center for Transportation and Logistics Fellowship.

LFM '05 student Christopher McFadden was on the team that won the MIT Enterprise Forum Cummins Award.

LFM '05 student Heath Holtz won the Martin Trust Community Fellowship.

LFM '05 students Vik Sahney and Aaron Raphael were named Siebel scholars for outstanding academic performance, leadership, and contribution to the overall mission and values of the school. Raphael coauthored an article that was published in the June edition of *INFORMS' ORMS*.

LFM '05 student Ronak Shah received the NetWorld Master Thesis Prize.

LFM '06 students Jeff Baer and Ian MacDonald were part of the Nanocell Power team that was awarded home runner-up in the 2005 MIT \$50K competition.

LFM '06 students Aimee L. Vessell and Christy Prilutski received the Charles "Harrison" Smith III Award.

Program Honors

For the fourth 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

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.

Events

ESD Five-Year Celebration and Brunel Lecture on Complex Systems

On October 7, 2005, ESD hosted two events in commemoration of its 5th anniversary. During the afternoon, Institute Professor and MIT School of Engineering dean [Thomas L. Magnanti](#) delivered the 4th annual Brunel Lecture on Complex Systems. The title of his presentation was "Engineering Engineering Systems." That evening, a by-invitation-only gala hosted by Daniel Hastings was held at the Royal Sonesta Hotel in Cambridge. Speakers included Charles Vest, Robert Brown, Thomas Magnanti, Arthur Gelb, Joel Moses, and Daniel Hastings. Professor Richard de Neufville was presented with the

second annual Joseph A. Martore Award for Excellence in Teaching. A special tribute was held to honor Professor Daniel Roos, ESD's founder.

Charles L. Miller Lecture

Mr. James Champy, chairman of consulting at Perot Systems, delivered the annual Charles L. Miller Lecture on April 21, 2005. The title of his lecture was "In Charlie's Vision: The Future of Engineering at MIT." Both Dean Magnanti's and Mr. Champy's lectures can be viewed on *MIT World*, at <http://mitworld.mit.edu/>.

Major Meetings

ESD Offsites

ESD held two offsites in AY2005.

The main purpose of ESD's winter offsite, held January 5–6, 2005, at the Hotel@MIT, was to focus on ESD's strategic plan as well as on its mission statement, core competencies, internal/external scans, and the upcoming five-year review. Breakout groups were held on ESD's major foundational and application thrusts, the needs of the educational programs, and next steps.

The main purpose of ESD's spring offsite, held May 23–24, 2005, at the Endicott House, was to arrive at an ESD-wide understanding of what the intellectual foundations of engineering systems are and what they might become. The content focused on research goals for engineering systems foundations, the accomplishments to date, and appropriate methods and methodologies. The format centered on a set of plenary panel sessions. The panel topics included Uncertainty, Risk, and Statistics; Critical Infrastructures and Sustainability; Architecture and System Evolution; Enterprise Architectures; System Theories; and Organization and Safety. Each panel addressed the same set of basic questions within the context of its own subfield. A panel of advanced graduate students also addressed these questions from the perspective of the field as a whole. The key questions were the following:

1. What does success in developing a robust intellectual foundation for engineering systems look like?
2. In order to help us define what the goals and expectations should be for ESD's intellectual foundation, what are the foundations in the *other* field where you hold your dual or joint appointment? Where do these overlap with and differ from engineering systems?
3. What foundational concepts already exist in engineering systems, and what foundational issues should be tackled next?
4. What analysis methods and design methodologies are needed for engineering systems?

The offsite was successful in identifying the areas that the ESD faculty thinks are the fundamental areas of engineering systems.

MIT/MITRE Workshops

The MIT/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. Three were held in AY2005. Participants in the workshops were leading professionals from MITRE; MIT faculty, researchers, and ESD PhD students; and several invited participants.

The objectives of the first workshop, held on November 19, 2005, in Cambridge, were to (1) become acquainted with our respective research directions and researchers; (2) identify research topics of mutual interest; and (3) explore strategies for collaborative research. This session involved several stage-setting presentations and working sessions to explore areas of research.

The MIT/MITRE Mini-Workshop on Complex Systems Engineering was held March 4, 2005, at MITRE in Bedford, MA. ESD director, Professor Daniel Hastings, introduced the MIT ESD academic programs and strategic directions. ESD senior lecturer and Lean Aerospace Initiative (LAI) researcher Dr. Donna Rhodes highlighted systems engineering research initiatives at MIT, including the efforts of the LAI research group. Three MIT ESD doctoral students—Heidi Davidz, Adam Ross, and Jason Bartolomei—presented their research. Several presentations by MITRE personnel highlighted research and advanced concepts in systems engineering.

On March 9, 2005, MIT hosted the MIT/MITRE Mini-Workshop on Enterprise and Organizational Transformation. A panel session of leading experts from MITRE presented highlights of MITRE's research and initiatives. ESD professor John Carroll and LAI researcher George Roth highlighted the MIT research and interest areas. The workshop was a lively exchange on research topics of mutual interest and discussed strategies for collaborative research on several key research ideas.

ESD Alumni Advisory Council

- The ESD Alumni Advisory Council convened its first meeting on October 7, 2004 [[Check date here and below.]]. Members include Paul B. Adamsen II, Vernon Altman, Jason Amaral, Thomas Clark Davis, Moises Goldman, Robert Graham Hall, Joseph Harrington, Benjamin R. Jurewicz, James Kim, 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.

A second meeting was held on April 21, 2005. Lively discussions were held on the directions that ESD is taking. In particular, they effectively critiqued the ESD strategic plan.

ESD Seminar Series

This ESD Seminar Series, created by ESD professor Randolph Kirchain, included the following:

- “The Topology and Dynamics of Complex Man-Made Networks,” by Professor Dan Braha, New England Complex Systems Institute, Cambridge, MA, University of Massachusetts, Dartmouth, MA (February 1, 2005)
- “Engineering Enterprises with Processes,” by Michael Hammer, PhD, president, Hammer and Company, Inc. (March 7, 2005)
- “Relational Contracts in Supply Chain Management,” by Erica Plambck, Stanford University (April 28, 2005)

Diversity Outreach

As part of ESD’s plan to increase enrollments of women and underrepresented minorities in its programs, ESD staged exhibits at the national conferences of the Society of Women Engineers (SWE), the Society of Hispanic Professional Engineers (SHPE), and the National Society of Black Engineers (NSBE). At the latter, ESD partnered with 10 academic and administrative units throughout MIT to present a strong, unified image. Also at NSBE, Professor Dan Hastings made a presentation on ESD’s interdisciplinary academic programs and ESD cosponsored a reception with the School of Engineering, MIT Sloan School of Management, and the MIT Graduate Student Office. Over 20 ESD students, alumni, and staff participated in the NSBE preparation and exhibition. Professor Hastings held a lunch to thank the ESD participants and to discuss preliminary plans for the next academic year. ESD’s diversity recruitment conference efforts are led by communications director Lois Slavin.

ESD Reports

In March 2005, ESD published the first edition of its online newsletter, *ESD Reports*. The theme was “leadership” and it included articles from each of its academic programs. The second issue of *ESD Reports* will be published in July 2005. The theme will be ESD research, and the theme of the fall issue will be diversity. *ESD Reports* will be published three times annually—in the fall, spring, and summer terms. They can be viewed at http://esd.mit.edu/esd_reports/esd_reports.html.

Daniel Hastings

Director

Professor of Aeronautics and Astronautics and Engineering Systems

More information on the Engineering Systems Division can be found online at <http://esd.mit.edu/>.

Leaders for Manufacturing

The Leaders for Manufacturing (LFM) program is a partnership between MIT and over 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 17th 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 a common staff, enabling conservation of resources.

Academic Program

Forty-eight students in the Class of 2005 completed the LFM Fellows Program. Each of these graduates completed an internship at a partner company during the summer and fall of 2004. 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 48 students (Class of 2006) completed their first year of on-campus studies and started their six-month internships. Applications decreased about 15 percent for the Class of 2007; 46 new students were admitted and began an intensive summer session. The Class of 2007 has an average of 4.8 years of work experience.

Don Rosenfield continues to serve as the director of the LFM Fellows Program. Codirectors for the LFM and SDM programs were David Simchi-Levi and Tom Allen. Ron Slahetka was appointed industry codirector in 2005, replacing Bill Hanson.

In terms of new endeavors, ESD created two new courses for LFM: ESD.60 Lean/Six Sigma Processes is taught by Joel Cutcher-Gershenfeld and ESD.730 Materials Selection, Design, and Economics is taught by Joel Clark.

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. Alison McCaffree, research associate for 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.

In September of 2004, LFM held a forum for faculty and partner companies, and the result was the creation of three active research groups: Supply Chain Visibility, Lean and Product Development, and Flexible 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 George Conrades of Akamai; Tomi Lahcanski of Kodak; Stephen Cook of Dell; Len Baxter of GM; Tim Copes of Boeing; John Boyd of UTC–Hamilton Sundstrand; Mary Puma of Axcelis; Dick Hunter of Dell; Rick Cohen and Reuben Harris of C&S Wholesale Grocers; Brett Smith of S&S Cycle; Richard Dauch of American Axle; Chip Goodman of American Medical Concepts; Paul Winter of Harley-Davidson's Tomahawk Factory; Jai Hakhu of Intel; Jeff Wilke of Amazon.com; Bill Anderson of Biogen Idec; and Michael A. Fury of DuPont EKC Technology.

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 Genzyme, Cambridge, MA; Raytheon, Andover, MA; Broad Institute, Cambridge, MA; Intel, Hudson, MA; Kodak, Rochester, NY; GM, Detroit and Lansing, MI; Ford, Dearborn, MI; American Axle, Detroit, MI; Boeing, Seattle and Everett, WA; Dell, Austin, TX; Honeywell, Juarez, Mexico; Intel, Colorado Springs, CO; Agilent Technologies, Colorado Springs, CO; Pratt & Whitney, Middletown, CT.

The International Plant Tour to China included Lenovo, Beijing; Motorola, Tianjin; Tsinghua University, Beijing; Shanghai Jiao Tong University; ABB, Shanghai; Bao Steel, Shanghai; Foxconn, Shenzhen; Li and Fung, Hong Kong.

Career Development

LFM students, sponsored and nonsponsored, continue to be highly sought 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-one percent of the Class of 2005 accepted positions within manufacturing and operations companies, and 42 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 Dick Hunter of Dell. 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.

Major endeavors for the standing committee for academic year 2006 year include marketing, new partners, partner education, internships, partner recruitment, and research. New internship participants included Pepsi-Cola Bottling, iRobot, and Toyota. Motorola rejoined as a managing partner.

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 online at <http://lfm.mit.edu/lfm>.

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-granting program at MIT that can be earned primarily from a remote location.

The SDM program 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 was appointed director of the SDM Fellows Program following the departure of Denney Mahoney at the end of academic year 2004. Codirectors for the program are David Simchi-Levi and Tom Allen. John Grace was appointed as the industry codirector in March 2005.

Student Statistics

In January 2005, SDM admitted its 9th class, enrolling 62 students. As was done in FY2004, SDM put on informational evenings in July, September, October, April, May, and June, including one in Dearborn, MI, for local MIT alumni and others interested in SDM as a way to recruit prospective students for SDM '05. These successful events brought more than 90 prospective students to campus, where they heard presentations from several faculty, students, and alumni about the program. In academic year 2005, these events have been expanded to include out-of-town information evenings in areas with strong MIT alumni presence and high minority populations.

System Design and Management Admissions Statistics

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

MIT-Industry Partners System Engineering Program

This past year, SDM and its partner program, Leaders for Manufacturing (LFM), along with United Technologies Corporation (UTC), continued with a third year of the MIT-Industry Partners Systems Engineering Program. This year the program was expanded to include other SDM partner companies—Boeing and Nortel.

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 84 students completing the Certificate Program and more than 100 organizational leaders completing the six days of content in the Manager/Supervisor Workshop. With its active participation in all levels of the program, UTC now has over 200 employees touched by SDM. The next cohort of certificate

students for FY2005 is expected to reach 30, with students from UTC, Boeing, and Visteon.

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. The codirectors recognize the need to bring in more distance education students in the January 2005 cohort to justify the costs of distance education for this program. In January 2005, the video bridge services were outsourced to a supplier to handle the greater number of video sites and avoid a significant capital expenditure MIT bridge capacity expansion. Quality and service from the supplier have been excellent.

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 online 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 wish 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 the area of policy development and analysis and requires a significant research thesis as fundamental components of engineering systems studies. The program provides a high-impact, high-quality education to its students. 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 both 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 of MIT, but it also has several internal admits each year, with many students pursuing a masters or doctoral degree in another program concurrent with their TPP SM degree. Each entering class is around 40 students, with approximately 35 percent of the students pursuing dual degrees, which may require an additional semester or two to complete. This year, 37 students

graduated with master's degrees in technology and policy, and three master's students were accepted to continue their studies at the doctoral level. This year's Best Thesis in Technology and Policy was awarded to Juan-Pablo Torres, supervised by Dr. Joseph Saleh and Professor Dava Newman. The TMP track within the ESD PhD program has a current enrollment of 23 students, reflecting a steady-state admission rate of about five students per year. Six students received their technology, management, and policy PhD in this past academic year.

TPP has been ramping up several initiatives to promote diversity within its student body. Following a year in which recruiting targets were not met in terms of either women or underrepresented minorities, TPP made several changes in its practices, including funding trips by current students to promote TPP at their alma maters and actively working with the dean of the Graduate School to develop support for incoming students. These and other activities have resulted in an incoming class that will be 40% women and will represent 11 countries (55% US citizens), with more than 10% underrepresented minority students. While there is still much to do in this regard, this entering class is a significant improvement over last year's.

Fellowship funding was provided to several incoming students in order to attract the top TPP candidates to MIT, including funds provided by the Office of the Dean of the Graduate School. In addition, the Keill Fellowship provides tuition-only funding. Fellowship funding, which includes the Rabinowitz and de Neufville funds, has been provided by TPP alumni and donors who 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 840-plus alumni and works to foster a strong alumni community through the biannual publication of the *Alumni Directory* and regional gatherings in Washington and Boston. For example, this January's gathering in Washington, DC, was held at ICF Consulting's DC offices and was attended by over 50 local alumni. Professor Newman also hosted a get-together in the Seattle area this spring. TPP alumni also receive e-newsletters several times a year, including newsletters written by current TPP students as well as faculty and staff.

The Technology and Policy Program greatly values practical experience and actively encourages students to take summer internships between their first and second years of study. In January 2004, 18 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 of our 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 Phillip Ng, Francis Chin, and Donald Cooke—in order 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 the Technology and Policy Program to recognize TPP students for leadership. In addition to recognizing the

student board of TPSS, this year's leadership prizes also went to (1) the administration of TPSS for their community support and development; (2) the set of students who prepared a *Student Guide* for incoming TPP students in support of TPP's recruiting and outreach efforts; and (3) Jessica Cohen for her contributions to the TPP community. Highly dedicated students in the program make these and many other TPP initiatives possible.

This past year, the course ESD.10 Introduction to Technology and Policy was team-taught for its first year under the direction of professors David Mindell and Annalisa Weigel. Additional fine-tuning will be possible for next year through the availability of curriculum development funds from the Lord Foundation, which also supports other course changes at TPP. This teaching team will be joined by Professor Dan Roos in the coming year. Dr. Joseph Saleh, Professor David Marks, and Dr. John Reilly were awarded Faculty Appreciation Awards by the TPP students.

With support from the Cambridge–MIT Institute, the Technology and Policy Program has maintained its close collaboration with the Technology Policy Master of Philosophy (MPhil) program at Cambridge University (CU), which has just completed its third year. Collaborative curriculum development efforts continue, with some of the new educational material developed for CU being incorporated into TPP teaching at MIT. Over a 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 three summers, TPP has sent seven students to Cambridge University for summer internships to support the new curriculum there. For the third year, TPP has welcomed several Cambridge students to MIT to pursue summer internships in research. This year, TPP imported a course in telecommunications that had been developed for the CMI–developed MPhil in technology policy. The telecommunications policy course was taught this spring, led by David Clark, Sharon Gillett, Frank Field, and Bill Lehr. The Department of Electrical Engineering and Computer Science (EECS) has expressed interest in working with TPP to continue to support this course over the coming years.

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. TPP repeated last year's melding of TPP's annual symposium with PoET activities during its spring workshop, focusing this year on different perspectives and practices in technology assessment. Proceedings will be published this summer, and planning for a fall event has begun. This year, PoET hired a postdoctoral associate to help with the development of the program education and research: Dr. Jason Black, a recent graduate of the ESD TMP program. There are now 14 PhD students from ESD, CIS, and STS funded by PoET IGERT traineeships. The ubiquitous computing focus area will continue for a second year, and we will also

initiate our second focus area of biotechnology this coming year. Visit <http://poet.mit.edu/> for more information.

With the completion of our second year in the academic space on the 3rd 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.

Following several difficult semesters, TPP filled its available staff position with the hiring in January of Ms. Yoko Urano, who acts in support of the TPP director and the education director. Her activities include support of student admissions, recruiting, and program operations.

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://tppsver.mit.edu/>.

Center for Innovation in Product Development

The Center for Innovation in Product Development (CIPD) unites industry practitioners with leading academic researchers to investigate the end-to-end product development process. A joint effort between MIT’s School of Engineering and Sloan School of Management, CIPD researches all aspects in the process of product development (PD) from engineering concept to management practice and from product design to market delivery and beyond.

CIPD was founded in 1996 as an NSF Engineering Research Center. Since its inception, the center has executed over 200 research projects and produced nearly 150 refereed journal articles and 100 conference papers. Our faculty has received over 20 awards for outstanding research, and our work has led to the creation of a dozen spin-off companies. In AY2005, CIPD’s 13 faculty and 21 graduate students pursued product development research with a budget of \$1.2 million. Under the guidance of center director Chris Magee and assistant director Nils Nordal, CIPD continues to advance the theory and practice of product development with research programs focusing on complex systems.

Research Programs

CIPD investigates specific problems with immediate relevance to industry. As a research center focused on clearly defined issues, CIPD develops projects of particular interest to individual sponsoring companies—projects that provide direct benefits in terms of solutions to current challenges.

Many of our projects are related to the emerging field of engineering systems—the study of systems characterized by their especially large scale, complexity, and high or varying rates of change. Our core initiatives explore complex system design, development, and management, concerns of increasing importance to contemporary engineering.

CIPD is directed by our vision that product development will be dispersed, global, and driven by new information and communication technologies. As we probe the end-to-end PD process, we recognize the value of cross-disciplinary integration among and within research goals. Our portfolio is a versatile suite of seven research initiatives that inform each other. The initiatives are detailed below.

1. Virtual Customer

The Virtual Customer (VC) initiative seeks to increase the speed, accuracy, and usability of customer input. With our integrated suite of projects, we pursue a radically reduced lag time between customer input and PD response at a fraction of current cost. PD teams and customers become joint participants in a dynamic exchange that benefits customers, companies, and the market (see demos, working papers, and downloads at <http://mitsloan.mit.edu/vc>). The paragraphs below highlight current research.

A Bayesian truth serum for subjective data. Subjective judgments—an essential information source for science and policy—are problematic because there are no public criteria for assessing judgmental truthfulness. This work proposes a scoring method for eliciting truthful subjective data in situations where objective truth is unknowable.

Generalized polyhedral methods for adaptive choice-based conjoint analysis: Theory and application. Polyhedral methods for choice-based conjoint analysis provide a means to adapt choice-based questions at the individual-respondent level. However, these methods are deterministic and are susceptible to the propagation of response errors. This work proposes improvements, and simulations thus far suggest that the new methods we propose have good predictive ability relative to existing methods.

Greedoid-based noncompensatory consideration-then-choice inference. This work explores methods to test whether respondents use noncompensatory processes, and if so, to infer the details of those processes. “Greedoid languages” provide a structure that decreases estimation time by a factor of approximately 109 for practical 16-aspect problems—which translates into cost savings—and also appear to predict better (in most cases) than purely compensatory estimates.

Ideation, creativity, and incentives. Idea generation (ideation) is critical to effective advertising, marketing strategy, and the design and marketing of new products. But little formal research has considered the underlying incentives that encourage novel ideas. This work examines whether carefully tailored ideation incentives can improve creative output. Results thus far provide insight into the mechanisms of ideation and demonstrate that incentives do have the capability to improve it.

“Listening in” to explore unmet customer needs. By “listening in” to ongoing dialogues between customers and web-based virtual advisors (e.g., Kelley Blue Book’s Auto

Choice Advisor), we identify new product opportunities based on new combinations of customer needs. These data are available at little incremental cost, and they provide the scale necessary for complex products. Results thus far have identified opportunities for the production of new truck platforms worth from \$1 to \$3 billion.

Managerial efficiency. In many managerial situations, some decisions are more critical than others. For example, in a conjoint analysis to support product design, some features may be critical and irreversible while others might be easy to change or vary after product launch. This project proposes alternative “managerial efficiency” criteria, considers their properties, and explores examples where managerial efficiency can be improved with a slight reduction in standard measures.

Polyhedral methods for adaptive choice-based conjoint analysis (CBC). CBC is widely used in marketing for product design, segmentation, and marketing strategy. We propose a new “polyhedral” question-design method that adapts each respondent’s choice sets based on previous answers by that respondent. Our findings so far suggest that polyhedral question design does well in many domains, particularly those in which heterogeneity and partworth magnitudes are relatively large.

Innovation research: A review and agenda for marketing science. Innovation is a critical issue in business research today, and it has been studied in the context of many independent research traditions. To advance this study, we have integrated the innovation literature with a review of these traditions, identifying 16 topics relevant to marketing science classified into five research fields. We summarize key concepts, highlight research challenges, and review current thinking, applications, and findings.

The impact of utility balance and endogeneity in conjoint analysis. Adaptive metric utility balance is at the heart of one of the most widely used and studied methods for conjoint analysis. This work uses formal models, simulations, and empirical data to suggest that adaptive metric utility balance leads to estimates that are relatively biased, which in turn could lead to erroneous managerial decisions. We examine viable alternatives to metric utility balance that avoid biases and inefficiencies.

Other VC highlights. This past year, VC published six research papers in journals that include *Science*, *Marketing Science*, the *Journal of Marketing*, and the *Journal of Marketing Research*. An equal number of working papers are slated for similar publications. We also received two major academic awards (John Little Best Paper Award for best paper in the marketing sciences and American Marketing Association’s Explorer Award for Leadership in On-Line Marketing Research). VC is a finalist for a third award (Paul Green Award for Contributions to Marketing Research) and has been nominated for a fourth (Frank Bass Dissertation Award given by the INFORMS Society of Marketing Science).

2. Distributed Object-Based Modeling Environment

A fundamentally new approach to integrated modeling and simulation, Distributed Object-based Modeling Environment (DOME) can incorporate the efforts of hundreds of developers working on radically different platforms in widely dispersed locations. All

designers participate simultaneously in the modeling process, using their preferred tools and methods in a user-friendly web-based environment. While maintaining information integrity, DOME models the integrated characteristics of large, complex, rapidly evolving products and systems. Its seamless infrastructure provides the management controls of a centralized system while preserving the responsiveness of a locally autonomous system. The paragraphs below detail our current projects.

Peer-to-peer search mechanisms to identify model behaviors. DOME is helping to foster a worldwide simulation web that can provide global access to models and simulation services. Like the World Wide Web, this simulation web will require a robust search mechanism, but it will also need to locate desired model behaviors and will need peer-to-peer mechanisms for discovering models. Nearly complete, this project has developed a user-friendly algorithm for finding and identifying models within the DOME environment and more generally on the internet. This past year the algorithm was tested on a contrived suite of 16 “deceptive” models and on a suite of 60 real models—all related to energy systems. In the coming year, we will refine the algorithm, conduct further tests on a suite of over 500 models, and incorporate into the algorithm a peer-to-peer discovery mechanism.

Architectural templates for an integrated PD simulation. This project is developing generic templates for engineering processes into which reusable models can be inserted to rapidly create custom tools for specific products. This past year we proposed an architectural template representation based on the idea of model catalogs and developed an extensive DOME library of high-quality, carefully tested domain models. In the coming year we will implement a prototype for testing the system architecture template representation and will devise an interface for PIM/PIM systems.

Distributed probabilistic simulation. Probabilistic simulation is an important capability for robust design. The new DOME architecture has been developed so that information type can change seamlessly while models are executing. Our goal is to develop appropriate solving methods so that distributed simulations may run deterministically or probabilistically. A key challenge is scalability. In a large system of real models, traditional probabilistic simulation is infeasible. Therefore, we propose a hybrid deterministic/probabilistic approach. This past year we prototyped various Monte Carlo algorithms and began tests to evaluate potential directions and issues. In the coming year we will define our specific solving algorithm and work on a prototype test bed within the DOME framework.

3. Information Flow Modeling

This initiative uses Design Structure Matrix (DSM) and other advanced tools to model and simulate the flows of information throughout an organization. MIT is at the heart of DSM research. We use DSM to capture system-level knowledge and to accurately represent complex product architectures and large development organizations. Our visual representations provide integrated maps of all development activities—a gateway to PD process improvement. Focusing on knowledge exchange in early development phases, we aim to better convert top-level specifications into component specification,

ensuring the harmonious function of systems, subsystems, and components. Current projects include the following:

Physical limits to modularity. Modularity is a central concern in engineering systems theory. The freedom for designers to choose modules is often taken for granted as a design essential. But physical phenomena often interfere, with the result that (1) designers do not have the freedom to choose modules, or (2) they prefer not to divide their systems into the smallest possible units. Very Large Scale Integration (VLSI) electronics exemplify the former, while mechanical items like jet engines exemplify the latter. This work argues that fundamental reasons based on natural phenomena keep mechanical systems from approaching the ideal modularity of VLSI.

Standards and the research of standardization in the field of engineering systems. Standards are key to the development of modern industries. This work summarizes different typologies of standards and proposes a framework of standards based on their purposes. Investigating standards and standardization at the macro-, meso-, and microlevel, we review approaches to the study of standards and standardization and identify knowledge gaps in the literatures. Our preliminary findings about the growth and interdependence of standards suggest that research of standards and standardization can be valuable to the field of engineering systems.

4. Platform Architectures

This program develops comprehensive, dependable system architecture principles for vehicle family design. Our current focus is the automobile industry, where heterogeneous customer demands have fragmented the market, resulting in smaller per-vehicle sales volumes. In response, we are helping the industry to optimize the number and type of platforms for given product families, reducing production time and cost while maintaining product variety. This initiative seeks to (1) match customer needs with function, (2) match function with technology, (3) transform complex technologies into a set of integrated design modules, and (4) optimize these modules against rigorous portfolio architecture principles.

Effective product platform development. Manufacturers often modularize products to enable multiple product variants, increasing flexibility and cost savings. But modularity also brings greater complexity and the likelihood of additional redesign effort. Our work introduces a new metric that provides decision support during the modularization process and minimizes redesign during future product changes. In this past year, we developed an algorithm using ratio scales to identify common modules for product families that is more precise and less subjective than prevailing methods. This resulted in several conference papers.

Flexible product platforms. Companies are designing product platforms more flexibly so that developers can more readily respond to future uncertainties. Our work introduces a design process for building flexible product platforms with regard to those uncertainties. This year we introduced a process to identify critical elements of flexibility that allow the product platform to respond to future conditions. We also quantitatively demonstrated how flexibility gains value as the degree of uncertainty increases.

5. System Dynamics and Complex Systems

The history of management practice is filled with innovations that failed to live up to their early promise, even when compelling evidence suggests that appropriate adoption would have provided substantial benefits. We use the system dynamics method to understand the sources of success and failure in large-scale design and development projects. Our research broadens the method's typical application, applying it to cases where multiple projects compete for a common resource pool. Our ultimate goal is to develop management "flight simulators" and other decision-support tools to help managers accurately model scenarios before making resource allocation decisions.

Dynamics of multiple release product development. This work investigates firefighting in software development. We have built simulation models to capture development process dynamics and have evaluated hypotheses on why problems with quality and delay occur and persist. Results this past year suggest several causes, including the accumulation of defects in the code base across multiple releases, the effect of work pressure on error rate, and the consumption of resources by current engineering activities. These can form a set of core reinforcing loops that trap a product development team in firefighting mode. Also, the sharing of resources between releases makes these dynamics contagious from one release to another, therefore institutionalizing some of the problems in the work processes of teams involved.

Quantitative approaches to assessing complexity and its sources. This work quantitatively assesses levels of complexity with an eye toward combining structural and functional aspects. We aim to understand the sources of complexity using a framework that identifies different areas where complexity can be assessed: the complex system itself, its environment, and the interface between them. Analysis this past year applied to two test-bed systems: an air traffic control radar and a maritime surveillance radar. Results to date reveal that the complexity of a system depends largely on the complexity of the environment in which it is embedded.

Executing major projects through contractors. Many managers responsible for delivering major projects or systems have bemoaned the adversarial relationships that can develop between project sponsors and their contractors. This research investigates the project performance as a function of those relationships. We use a system dynamics model to examine the influence of the contractor/sponsor relationship on the execution of a project. Our latest analysis reveals the significance of product or system complexity on communication, as well as the elements of effective team integration.

6. Product Development Enabling Factors

This CIPD initiative seeks to understand how large organizations approach crucial decision making and to optimize the approach. We are developing a method for making more robust decisions that is insensitive to variation in uncontrollable factors. The method synthesizes decision-making approaches currently used by industry with techniques drawn from Design of Experiments. We want to provide a superior alternative to current decision processes for making important decisions (by "important," we mean decisions that will have a substantial financial impact and that require knowledge from an interdisciplinary set of stakeholders).

This past year we completed preliminary analysis of our new decision method. We applied it to a simulated company and, based on results to date, we believe our method has the potential to yield good decisions—better, in fact, than those resulting from other methods. Several organizations have expressed interest in our work, and in the coming year we will apply our method at corporate settings to analyze implementation issues and to collect feedback from experimental users.

7. Robust Design and Product Life Cycle

Robust design is a set of techniques for making machines function more consistently despite variations in system inputs, interfaces, and operating conditions. Application of robust design tends to be resource intensive because it requires exploration of the design space, as well as the space of uncertain parameters in the machine's environment. This initiative investigates the development and validation of effective robust design methods and their effect on product life cycle.

Systems issues in design of experiments. This project is creating a hierarchical probability model of engineering systems and quantifying the effect sparsity, hierarchy, and inheritance typical of real engineering systems. In the past year, with funding from Xerox, we extended our effort with two major new outcomes. First, we demonstrated the viability of a remarkable new hybrid robust design method that performs with six to seven times greater effectiveness over an existing method. Second, we discovered a significant new regularity in the experimental database that is based on the definition of synergistic interactions. In the coming year, we will explore the implications of these interactions and document our results.

Reuse of design of experiments (DOE). This project seeks to understand the reuse of DOE data in design of products and systems. In recent months our focus has shifted to computational simulations in robust design. This shift is because, in practice, the majority of physical knowledge about engineering systems is currently codified within these simulations rather than in databases of experimental results. To support this new emphasis, we have defined a framework for considering how computational simulations can be trusted as a basis for design. This work is funded by Raytheon, and a proposal is pending with the NSF Human and Social Dynamics program.

Life cycle view of a system: The effect of noise correlation and noise intensity. To improve the robustness of any system, we must understand the noise factors (variation) coming into that system. We must also understand the correlation among those noise factors, as well as their respective intensities. How do systems with 2nd-order and 3rd-order interactions behave if we remove correlation among noise factors? This work considers that question and focuses on the difference between systems with 2nd- and 3rd-order interaction with respect to correlation among noise factors.

Engineering value over the life cycle of products. This project seeks to improve the life cycle cost and utility for decision support software products. We employ research in cognitive engineering to develop high-level software requirements for useful tools. We then translate those requirements into software patterns that improve development and maintenance costs. In recent months we completed our work in high-level design

requirements and are now finishing our work on patterns with the dissemination of general guidelines for their creation. Over the next few months, we will extend this new framework to additional products and systems.

Education Programs

CIPD is an interdisciplinary program between the MIT's School of Engineering and the Sloan School of Management. We believe that students' course experiences should address the interplay between the technical, social, and system elements of product development and should prepare them for work in a globally distributed services marketplace. Our PD education programs target three communities: working professionals, graduate students, and undergrads.

For Working Professionals

SDM product development track. Created in collaboration with MIT's System Design and Management (SDM) program, the product development track is a 24-month distance learning degree program (or 13-month on-campus program) that targets midcareer engineering professionals who are potential leaders in product development settings. At graduation, students receive an MIT degree in engineering and management.

Since the program's inception in 1997, 23 CIPD faculty have participated in SDM's product development track. Nearly 300 students from 55 organizations have enrolled, with over 200 students graduating. In 2005, participating organizations included ArvinMeritor, Ford, NASA, Raytheon, UTC, and others. Approximately 40 students began the program in January 2005, and a similar number graduated between September 2004 and June 2005.

Systems engineering course. CIPD faculty have taught ESD.33 Systems Engineering, which examines sources of complexity that can adversely affect new product design and development. The course formulates a systems engineering process that can mitigate the effects of complexity. Class size averages about 40 students, many enrolled in the SDM PD track.

Executive education courses. CIPD faculty have created and taught a full suite of short courses as nondegree programs. These industrial minicourses have been offered during the year through MIT's office of summer professional programs and through Sloan's office of special executive programs. Since the center's inception, well over 2000 students have attended. In AY2005, students attended courses that included Strategic Marketing for the Technical Executive, Business Dynamics, and Understanding and Solving Complex Business Problems.

For Graduate and Undergraduate Students

This past year, CIPD faculty taught numerous courses on product development, complex systems, and engineering systems, including the following:

- *Doctoral seminar in engineering systems.* Core theory and contextual applications of the emerging field of engineering systems.

- *The product engineering process.* Product development phases, with experience working in teams to design and construct high-quality product prototypes.
- *Product design.* Addressing the theory and practice of transforming design ideas into successful products that are properly matched to the user and the market.
- *Advanced system architecture (new).* Deep understanding of engineering systems at a level intended for research on complex engineering systems.
- *Product design and development.* Modern tools and methods as teams of students conceive, design, and prototype a physical product.
- *Mechanical assemblies: Design, manufacture, and role in product development.* Assemblies and assembly automation on micro and macro levels.
- *System project management.* Management principles, methods, and tools to effectively plan and implement system and product development projects.
- *Multidisciplinary system design optimization.* Principles, methods, and tools, with applications from aerospace, mechanical, civil engineering, and so on.

In the past academic year, CIPD funded 13 PhD and two masters candidates. Of those, one PhD and one master's student graduated in June 2005.

Noon seminars. In AY2005, CIPD hosted two dozen lunchtime seminars—informal talks from researchers at CIPD and throughout the Institute. Guest speakers included researchers, industrial product developers, and executive officers from organizations such as CoCreate Software, the Hydrogen Center of Competence, Integrated Development Enterprise, QuesTek Innovations, and Science Serving Society.

Visiting scholars. This past year, CIPD continued its tradition of hosting visiting scholars from technical universities and organizations around the world. These included Katja Holttä-Otto from the Helsinki University of Technology; Todd Alwart from Dupont; Sangman Han, visiting professor from SungKyunKwan University in Korea; Dr. Heebyung Koh, postdoctoral associate from the CAD/CAM Research Center at the Korea Institute of Science and Technology; Flemming Larsson from the Technical University of Denmark; Jean Francois Ouellet from the University of Montreal; Laurent Zenou from the National Institute for Advanced Technologies in Paris; and Jan Kraemer from the Technical University of Karlsruhe in Germany.

Personnel

CIPD underwent no personnel changes in AY2005, reflecting its assurance and stability as a focused research center. Director Chris Magee continues to guide the center's product development investigations with a concentration on complex systems. Professor Magee's extensive background in product development is the result of many years in R&D for the Ford Motor Company. Nils Nordal continues to serve as the center's assistant director, with Michael Mack as communications coordinator, Kathleen Sullivan as office and finance manager, and Susan MacPhee as media design and production specialist.

Nils Nordal **Assistant Director**

More information about the Center for Innovation in Product Development can be found online at <http://cipd.mit.edu/>.

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 members, researchers, and staff from the fields of 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, motor vehicles, telecommunications, information management, and environmental law.

The Engineering Systems Division 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 of the Institute, while ESD provides academic opportunities for CTPID faculty, students, and staff.

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

The director of CTPID is Professor Fred Moavenzadeh, the James Mason Crafts professor of systems engineering and civil and environmental engineering, who also directs the Technology and Development Program. Su Chung serves as CTPID's administrative officer, and Emily Kearney is the administrative assistant. CTPID's administrative offices are located in MIT's Room E40-227.

Highlights of the Year

*As the Lean Aerospace Initiative (LAI) approached the end of its three-year Enterprise Value Phase, LAI stakeholders approved a \$24.4-million extension of the LAI consortium, funding a fifth, five-year phase which will begin on September 1, 2005. LAI celebrates the accomplishments of its Enterprise Value Phase, in which government and industry stakeholders united with LAI researchers to map the enterprise value streams of Textron's Sensor Fused Weapons Programs and of several US Air Force air logistic centers, and in which stakeholders implemented many LAI products such as the Lean Enterprise Value Simulation and the *Product Development Value Stream Manual*.*

The Communications Futures Program (CFP) was launched on July 1, 2004, merging the Internet and Telecom's Convergence into an Institute-wide coalition of research

programs led by Professor David Clark of the Computer Science and Artificial Intelligence Lab (CSAIL) and CTPID, Professor Charles Fine of the Sloan School of Management, senior research scientist Andrew Lippman of the Media Lab, and CFP executive director and CTPID principal research associate Sharon Gillett. CTPID research associate William Lehr, the Media Lab's David Reed, and Cambridge University's Jon Crowcroft also lead CFP working groups. CFP collaborates with Cambridge University through a seed grant from the Cambridge–MIT Institute. In September 2004, the US Department of Commerce awarded funds to support Sharon Gillett's research on measuring the economic impact of broadband deployment.

The Ford–MIT Alliance initiated new projects in nanotechnology while continuing research on the environment, product development, active safety, and powertrains. With the negotiation of legal agreements on the licensing of the Distributed Object-based Modeling Environment (DOME) software, the alliance began to see its research applied on the Ford product development pipeline.

The International Motor Vehicle Program (IMVP) launched the Lean Locational Logic project, partnering with automotive suppliers to study the factors involved in the choice of where to locate new plants and design operations. IMVP launched a Global Automotive Program, a one-week program for emerging automotive industry managers. IMVP increased its funding base, renewing three-year sponsorship agreements with General Motors Corporation, Honda Motor Company, and Toyota Motor Company. IMVP also initiated three-year sponsorship agreements with Magna International, Tenneco Automotive, and the Department of Trade and Industry of the United Kingdom.

The Lean Aerospace Research Agenda (LARA) team assembled a new institutional initiative, the *Aerospace Industry Council*, a forum for industry-level dialogue on labor and employment issues under the auspices of the Labor and Employment Relations Association's major new initiative to establish industry councils. LARA also signed a new corporate agreement with the Federal Aviation Administration to study lateral alignment in complex systems and a new agreement with the Federal Mediation and Conciliation Service to study collective bargaining and workplace transformation.

The MIT Information Quality Program (MIT IQ) hosted the 9th International Conference on Information Quality in November 2004. MIT IQ and Acxiom Corporation initiated a Customer-Centered Information Quality Management (CCIQM) research program. MIT IQ also renewed their contract with Acxiom for a second year of research on CCIQM.

Awards and Recognition

Assistant professor Martin L. Culpepper, a researcher affiliated with the Ford–MIT Alliance, received a 2004 Presidential Early Career Award for Scientists and Engineers, presented by President George Bush at the White House in June 2005.

LAI codirector Professor Deborah Nightingale and doctoral candidate Alexis Stanke were both awarded Commander's Coins by Major General Sullivan of the US Air Force

in September 2004, for their efforts in effecting enterprise transformation at Hill Air Force Base.

IMVP codirector Michael Cusumano's *The Business of Software* was named one of the top IT business books of 2004 by Booz Allen Hamilton's quarterly magazine, *Strategy+Business*. IMVP's Professor Sandra Rothenberg of the University of Rochester was awarded the Sloan Industry Center Junior Faculty Fellowship.

Dr. Joseph Saleh, executive director of the Ford–MIT Alliance, received the Faculty Appreciation Award from the Technology and Policy Program, the 2005 Award for Best Thesis on Technology and Policy for serving as thesis supervisor to Juan Pablo Torres Padilla, and the Vickie Kerrebrock Award from the MIT Department of Aeronautics and Astronautics "for countless hours spent teaching, advising, mentoring, and befriending undergraduate and graduate students in the Department of A/A."

Dr. Richard Wang, director of MIT IQ, received the Data Administration Management Association International's 2005 Academic Achievement Award and received a certificate of appreciation in recognition of outstanding contribution to the US intelligence community, under the director of national intelligence.

Selected Publications

Books

Joel Cutcher-Gershenfeld et al., *Valuable Disconnects in Organizational Learning Systems: Integrating Bold Visions and Harsh Realities*, Oxford University Press, 2005.

Janice A. Klein, *True Change: How Outsiders on the Inside Get Things Done in Organizations*, Josey-Bass/Wiley, 2004.

Daniel Whitney, *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*, Oxford University Press, 2005.

Articles and Book Chapters

Nicholas Ashford, "Government and Environmental Innovation in Europe and North America," in *Towards Environmental Innovation Systems*, Matthias Weber and Jens Hemmelskamp, eds., Heidelberg: Springer, 2005.

Nicholas 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.

Nicholas Ashford, "Implementing the Precautionary Principle: Incorporating Science, Technology, Fairness, and Accountability in Environmental, Health, and Safety Decisions," *International Journal of Risk Assessment and Management*, 2005.

Nicholas Ashford, “Scientific, Ethical and Legal Challenges in Work-Related Genetic Testing in the United States,” *Proceedings of the Collegium Ramazzini*, October 2004.

Nicholas Ashford, “Major Challenges to Engineering Education for Sustainable Development: What Has to Change to Make It Creative, Effective, and Acceptable to The Established Disciplines,” *International Journal of Sustainability in Higher Education* 3(4): 2004, pp. 239–250.

Nicholas A. Ashford and Charles C. Caldart, “Negotiated Regulation, Implementation and Compliance in the United States,” in *The Handbook of Environmental Voluntary Agreements*, Eduardo Croci, ed., Kluwer, 2005, pp. 135–159.

Betty Barrett, “Boeing St. Louis Case,” presented at the Conference on the British Aerospace Industry, Oxford University, Oxford, UK, September 2004.

Joel Cutcher-Gershenfeld, “Industry Councils: A National Impact Anticipated,” *Perspectives on Work* (Winter), 2005.

Sharon E. Gillett, William H. Lehr, and Carlos Osorio, “Municipal Electric Utilities’ Role in Telecommunications Services,” forthcoming in *Telecommunications Policy*, 2005.

Harn Wei Kua and Nicholas A. Ashford, “Co-optimization through Increased Willingness, Opportunity and Capacity: A Generalisable Concept of Appropriate Technology Transfer,” *International Journal of Technology Transfer and Commercialization* 3(3): 2004, pp. 324–334.

William H. Lehr, Marvin A. Sirbu, and Sharon E. Gillett, “Wireless Is Changing the Policy Calculus for Municipal Broadband,” forthcoming in *Government Information Quarterly*, 2005.

Isabel Neto, Michael L. Best, and Sharon E. Gillett, “License-Exempt Wireless Policy: Results of an African Survey,” *Information Technologies and International Development* 2(3): 2005, pp. 73–90.

Marvin A. Sirbu, William H. Lehr, and Sharon E. Gillett, “Evolving Wireless Access Technologies for Municipal Broadband,” forthcoming in *Government Information Quarterly*, 2005.

Personnel Changes

- *Ford–MIT Alliance.* Simon Pitts, bringing 28 years of experience at the Ford Motor Company, came to MIT in August 2004 to serve as Ford’s executive director of the Ford–MIT Alliance. Previous codirectors Kristen and Steven Schondorf returned to positions at Ford’s main headquarters. Pitts joined Joseph Saleh, MIT’s executive director of the alliance.
- *Lean Aerospace Initiative.* After three years as LAI’s Raytheon-sponsored Stakeholder codirector, Frederick Terrence Bryan returned to work on the Raytheon campus. Jacqueline Candido joined LAI as a research affiliate to lead LAI’s educational initiatives. LAI’s Enterprise Change group added two new research staff, postdoctoral associate Jennifer Hartwell and research associate Chester Labeledz. LAI’s Alexis Stanke stepped down from her position as research engineer in order to pursue her doctorate in the Engineering Systems Division. Alexis Stanke will continue to work with LAI as a research assistant. Juliet Perdichizzi, after serving two years as administrative assistant, was promoted to the administrative position of services manager at LAI. Tara Eisner joined LAI as administrative assistant.
- *CTPID Administration.* Communications director Nancy DuVergne Smith left CTPID for a new role at MIT’s Alumni Association. Emily Kearney was promoted to administrative assistant II.

Communications Futures Program

Effective August 1, 2004, CTPID’s Internet and Telecoms Convergence (ITC) research program officially merged into the Communications Futures Program, a joint venture across several parts of MIT. Its objective is to promote growth and innovation across the communications value chain by conducting research and facilitating cross-industry interactions through 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).

Key CFP Accomplishments

In the past year, CFP launched working groups focused on the following:

- Broadband access, led by Sharon Gillett of CTPID
- Value chain dynamics, led by Charlie Fine of Sloan and CTPID
- Interprovider Quality of Service, led by David Clark of CSAIL and CTPID
- Viral communications, led by Andy Lippman and David Reed of the Media Lab
- Next-generation spectrum policy, led by Jon Crowcroft of Cambridge University in partnership with William Lehr of CTPID

CFP held three-day plenary meetings in January (at MIT) and June (in Cambridge), as well as daylong workshops for specific working groups held in September, October, January, March, and May. CFP’s roster of sponsors has expanded from two companies (BT and France Telecom) last year to nine this year, adding Cisco, Comcast, Deutsche Telekom /T-Mobile, Intel (through the CeB), Motorola, Nokia, and Nortel.

In addition to their work with CFP, CTPID researchers Sharon Gillett (PI) and William Lehr received a one-year grant, effective September 1, 2004, from the US Department of Commerce to carry out a statistical study of broadband's economic impact. This study extends data analysis on municipal broadband performed in the previous year with NSF funding. Also based on this work, Gillett and Lehr, in collaboration with Professor Marvin Sirbu of CMU, published several academic papers (listed above) and continued their outreach work on the subject of municipal broadband, speaking to numerous industry, policy, and academic audiences.

With funding from the Sloan Foundation, MIT's Political Science Department conducts an annual seminar for congressional staffers on a selected focus area in technology policy. This year's seminar, held at the end of March, focused on telecommunications and the internet. Sharon Gillett and David Clark collaborated with professors Stephen Ansolabehere and Eugene Skolnikoff to develop the program and speaker list. Feedback from the staffers was quite positive, and the event led to numerous follow-up contacts between attendees and presenters.

CFP Student-Related Activities

In the spring term, Sharon Gillett, Frank Field, William Lehr, and David Clark cotaught a new graduate course, ESD.937 Communications and Information Policy. This half-semester course used lectures, readings, and discussion to engage students in critical thinking around selected technology policy issues arising from advancing telecommunications and internet technologies. Students from ESD/TPP, EECS, and ESD enrolled in the course. Student feedback indicated strong interest in a longer version of the course; the teaching team is currently seeking funding to support that idea and/or a yearly offering of the course.

Gillett, Lehr, and Field also continued their CMI-funded collaboration with Tim Wilkinson of Cambridge University to teach 5-CMI2 Telecommunications: Technologies and Policies in the Networked Digital World, again in the 2004 Michaelmas term. This course is offered in the MPhil in Technology Policy Program.

ESD (TMP) doctoral student Carlos Osorio is funded by and working on the Department of Commerce-funded study of broadband's economic impact.

In June, Technology and Policy student Gabriel Weinberg completed his MS thesis, "A Systems Analysis of the Spam Problem," under the supervision of David Clark and Sharon Gillett.

Sharon Gillett served on the Admissions Committee for the Technology and Policy Program, with particular focus on applicants in fields related to information and communications technologies.

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 that the alliance identifies, develops, and funds in close partnership with Ford, it also brings the vice presidents involved to the 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 powertrains. 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 to assess 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 Corporate Average Fuel Economy standards for controlling carbon emissions. We have also funded a project utilizing nanotechnology to increase the storage capacity of ultra capacitors 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.

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

The alliance continues to aggressively explore emerging opportunities. A third project in natural language interface has been initiated to further develop this capability,

as the earlier work moves toward production at Jaguar. New research areas include Optimal Pricing, which utilizes mathematical modeling to discover and recommend more rational vehicle incentive pricing. With the increased focus on fuel efficiency, an increased use of lightweight materials is likely, and electromagnetic welding is being explored as an inexpensive, high throughput joining method for aluminum. As the use of embedded systems and software continues to proliferate in the vehicle, a six-month MIT study has been commissioned to survey academic and industry experts to identify future risks and opportunities and make recommendations on how Ford should best allocate resources.

A number of past alliance projects are now moving toward application or production within the Ford system. After a long negotiation, a legal agreement has been reached with MIT on licensing the DOME software for commercial development. This will allow Ford to coordinate many separate models and run them concurrently. A patent and license agreement is also in process, with MIT covering a new pollution control valve (PCV) design developed in an alliance project. This new design holds promise to substantially improve robustness, eliminate freezing, and significantly reduce cost. Prototypes are currently undergoing testing at Ford and, if successful, a supplier will be contracted to take the concept to volume production. The first generation natural language program is slated for production on the 2007 Jaguar X150 with Volvo expected to follow shortly thereafter. And finally, the steering nibble project is beginning to show positive results and in-vehicle prototypes are being tested at Ford. Though current prototypes are not representative of production configuration, valuable insight into the phenomenon is being gained.

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 project level. Examples follow:

- Three annual Executive Committee meetings bring Ford vice presidents and senior directors to the 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 from 30 to 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, Michigan.

International Motor Vehicle Program

The International Motor Vehicle Program (IMVP) is the oldest and largest international research consortium aimed at understanding the challenges facing the global automotive industry. Founded (1979) and headquartered at MIT, IMVP has evolved to become a network of top-notch 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, the University of Michigan, Carnegie Mellon University, Oxford University, the University of Cambridge, INSEAD, École Polytechnique, the University of Mannheim, Seoul National University, the University of Tokyo, and the Indian Institute of Management.

Leadership

IMVP maintained the same leadership structure as in the previous fiscal year. Professor Michael Cusumano of the Sloan School of Management 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

IMVP increased its funding base by renewing several important sponsorship agreements and attracting new sponsors to the program. Three-year sponsorship agreements were signed by General Motors Corporation and Honda Motor Company, both longtime IMVP sponsors. Toyota Motor Corporation also renewed IMVP sponsorship under a three-year term—but at a funding level of \$150,000 per year, twice the amount of the previous three-year agreement. This brings all IMVP sponsors into a consistent and transparent funding structure based on the size of the sponsor (annual revenue) and the type of sponsor (vehicle manufacturer, supplier, or other).

IMVP also negotiated three new sponsorship agreements: Magna International, Tenneco Automotive, and the Department of Trade and Industry of the United Kingdom. Magna International, with \$19.9 billion in sales to automotive customers worldwide in 2004, is the third-largest automotive supplier in the world. The Canadian company is a leading global supplier of technologically advanced automotive systems, components, and complete modules. Tenneco Automotive designs, manufactures, and distributes automotive ride control and emission control products and systems for more than 25 original equipment manufacturers (OEMs) and 500 wholesale and retail customers. The \$3.5-billion manufacturing company operates 100 facilities in 22 countries. The UK Department of Trade and Industry (DTI) works with businesses, employees, and consumers to drive up productivity and competitiveness. A central DTI objective is to make the most of the UK's science, engineering, and technology skills and resources.

IMVP and Wharton Launch Global Automotive Program

In April 2005, IMVP and [Wharton Executive Education](#) launched the Wharton-IMVP Global Automotive Program (GAP), a one-week executive education program emphasizing strategy, competitive dynamics, and leadership development topics for current and future leaders of global automakers and suppliers.

The 2005 inaugural GAP was tailored for a group of executives from Mercedes-Benz USA (MBUSA) after they expressed strong interest in the program concept. GAP offered a unique mix of Wharton faculty leading sessions on management and leadership topics

combined with IMVP faculty drawing on their research to provide sessions focused on the automotive industry. The program provided an opportunity for the MBUSA executives to step out of the operational demands of their positions and consider the long-term strategic issues facing their company and the global industry as a whole.

In developing the content for the program, GAP academic director John Paul MacDuffie drew upon his experience with the [Toyota Executive Development Program](#). In addition to his roles as associate professor of management at Wharton and codirector of IMVP, MacDuffie has been academic director of the Toyota program since he developed and launched the program in 1999. The program brings together Toyota mid- to upper-level managers, nominated by senior executives and based all over the world, each year for one week in Philadelphia and one week in Mikkabi, Japan. Other IMVP faculty in the April 2005 GAP included Michael Cusumano, MIT Sloan School of Management and IMVP codirector; Charlie Fine, MIT Sloan School and former IMVP director; and Frits Pil, University of Pittsburgh. Professor Cusumano explored how companies in the software industry have positioned themselves as providers of products versus providers of services and contrasted this dynamic with the automotive industry. Professor Fine discussed business and supply chain strategy, contrasting fast-clockspeed industries (e.g., information technology) with slower clockspeed industries (e.g., automobiles). Professor Pil drew upon his research from *The Second Century* to suggest that automotive companies need to reconnect the industry value chain with end customers.

The next offering of GAP is scheduled for February 13–17, 2006. This program targets mixed participation among automotive OEMs and suppliers from different regions of the world. For more information, please see <http://www.whartonglobalauto.com/>.

IMVP and World Economic Forum Automotive Program

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 July 22, 2004, 20 executives from vehicle manufacturers and suppliers from six countries participated in the forum's Automotive Industry Agenda Meeting in Dearborn, Michigan. The program focused on an array of high-level strategic issues confronting the global automotive industry. IMVP codirector John Paul MacDuffie presented an overview of outsourcing/offshoring and managing the global footprint, including research findings from IMVP's Lean Locational Logic project. IMVP researcher Frits Pil, University of Pittsburgh, led a discussion with industry executives on new distribution models in the auto industry, including specific findings from IMVP's recently published book, *The Second Century: Reconnecting Customer and Value Chain through Build-to-Order*.

IMVP research was also introduced into the program of the forum's Automotive Governors Meeting, a private meeting for the CEOs of the global automotive industry

that takes place within the forum's Annual Meeting in Davos, Switzerland. John Paul MacDuffie introduced findings from IMVP's Lean Locational Logic project.

IMVP Advisory Committee

MIT professor Daniel Roos continues his role as chairman of the IMVP Advisory Committee. The objective of the advisory 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 8–10 members for the Advisory Committee balanced among North America, Europe, and Asia. To date, the following individuals have agreed to serve on the 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

IMVP Research Impact

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

- Implications of Build-to-Order for Supply Chain, Vehicle Distribution, and Product Development
- Product Architecture and Supply Chain Structure: Global Survey of Front-End Modules
- Developing Supplier Capabilities: From Components to Modules, Systems, and Domains
- Global Automotive Supply Chain in China
- Business Strategies of the Japanese OEMs in China
- Offshoring, Interfaces, and Collaboration Across the Supply Chain: A Case Study in Automotive Product Development
- Challenges of Increasing Modularization
- The Structure of Knowledge and Tasks: Implications for Performance
- Product Variety and Recalls
- Collaboration with and without Trust
- Complementary Investment Strategy: States and MNCs in the Industrialization Process
- Dynamic Model for Business Architecture and Performance
- Supplier Clusters in India: Emerging Forms of Governance
- Innovation in Automotive Emissions Control Technology: Government Action, Inventive Activity, and Learning
- Interpartner Learning and Organizational Capabilities in Horizontal High-Commitment Strategic Alliances (Ford-Mazda, Renault-Nissan, DaimlerChrysler-Mitsubishi)
- Launching Innovative Services: Lessons from Automotive Telematics
- Lean Locational Logic: Developing a Better Framework for Location Decisions

IMVP hosted its Annual Sponsors Meeting on October 10–12, 2004, at the University of Cambridge, United Kingdom. More than 35 sponsors and researchers explored innovation, supplier relations, outsourcing, the impact of temporary workers, and other industry topics. Scholars from Europe, Asia, and the United States broached topics ranging from new business models to a comparative analysis of products and services in the software industry. Key events included a lunch talk by Daniel T. Jones, coauthor of *The Machine That Changed the World* and leader of the UK's Lean Enterprise Academy, on "The Solution Economy."

IMVP hosted a workshop for members of Volkswagen AG's Project Moonraker team on March 8, 2005, at the MIT Faculty Club. IMVP researchers Charlie Fine, Frits Pil, John Paul MacDuffie, and IMVP executive director John Moavenzadeh participated in the workshop. Project Moonraker is a special cross-functional team reporting directly to top management assigned with the task of reinvigorating Volkswagen's North American market.

IMVP researchers were quoted in a variety of publications, including *Business Week* and *The Economist*. IMVP researchers Matthias Holweg, University of Cambridge, and John Paul MacDuffie, Wharton School, along with IMVP executive director John Moavenzadeh, were quoted in two articles in *Knowledge@Wharton*, a biweekly online resource that offers the latest business insights, information, and research from a variety of sources.

The Wharton School at the University of Pennsylvania hosted the IMVP Annual Researchers Meeting June 1–3, 2005, in Philadelphia. Over 30 professors and graduate students shared their research findings on an array of topics related to the global automotive industry. The participants were based at universities in China, France, Germany, Japan, South Korea, the United Kingdom, and the United States.

A number of IMVP researchers contributed notable academic achievements during the fiscal year, including the following:

- Professor Koichi Shimokawa, Tokai Gakuen University and professor emeritus at Hosei University, published his latest book, *A Business History of the Japanese Automotive Industry*
- Professor Susan Helper, Case Western Reserve University, served on the Sloan Foundation Industry Studies Advisory Committee
- Professor Mari Sako, Oxford University, completed the second year of an EPSRC fellowship from the UK government
- Dr. Matthias Holweg, lecturer at the Judge Institute, University of Cambridge, participated in an EU-funded research program on automotive distribution
- Professor Ki-Chan Kim, Catholic University of Korea, served on the Advisory Committee of Hyundai Motor Company
- Professor Takahiro Fujimoto received funding from the Japanese government to support his Manufacturing Management Research Center, an IMVP partner
- Professor Sandra Rothenberg, University of Rochester, received the Sloan Industry Center Junior Faculty Fellowship

More information about the International Motor Vehicle Program can be found online at <http://imvp.mit.edu/>.

The Lean Aerospace Initiative

In the final year of its fourth phase of operations—the Enterprise Value Phase (September 1, 2002–August 31, 2005)—the Lean Aerospace Initiative (LAI) calibrated its research focus toward a highly detailed understanding of the ongoing interactions between and across various core enterprise functions. The main organizing principles of this Enterprise Value Phase are LAI’s responses to several key findings outlined in the award-winning book, *Lean Enterprise Value: Insights from MIT’s Lean Aerospace Initiative*. Chief among the book’s tenets is that lean is not just a matter of elimination of waste; becoming lean is a process of eliminating waste with the goal of creating value for enterprise stakeholders.

With the knowledge, experience, and tools researched and developed in this phase, the national aerospace enterprise is enabled to more quickly improve its capability and agility in delivering best life-cycle value. Additionally, enterprise-level research increasingly provides the foundation for emerging systems approaches to enterprise architecting and enterprise transformation.

LAI Goals

During the past year, LAI continued its pursuit of its stated mission: to research, develop, and promulgate lean knowledge, principles, practices, and tools that enable and accelerate the envisioned transformation of the greater US aerospace enterprise through people and processes. The following six goals have provided the framework for the consortium’s efforts during the Enterprise Value Phase:

1. Support the ongoing lean transformation of the national aerospace industry;
2. Enable a lean value-creating supplier base;
3. Support lean transformation of the government;
4. Educate and train stakeholders in value-creating lean principles and practices;
5. Enhance the effectiveness of the national workforce;
6. Support member lean implementation efforts by sustaining the tools and knowledge base and by sponsoring outreach events.

Transforming the US Aerospace Enterprise

As the current phase approaches its conclusion, there is compelling evidence that industry members have, with the active collaboration and support of LAI, already gone far beyond achieving lean implementation in production operations and have in fact made significant progress in implementing lean principles and practices at the enterprise-wide level, with quantifiably positive results. For the consortium as a whole, there are now several “islands of success” (some more obvious than others). There is every expectation that these successes will continue apace and increase in number and scope as lean becomes diffused throughout an enterprise. As for specific successes within the past 12 months, consider the following activities, all of which reflect LAI’s commitment to enterprise-level change.

- A historic collaborative effort to map the enterprise value stream of Textron's Sensor Fused Weapons program—with participation from the US Air Force and several LAI members—flawlessly showcased how a collaborative engagement can benefit all stakeholders in an enterprise relationship.
- Similar collaborative enterprise value stream mapping engagements (EVSMA) have been replicated elsewhere recently at US Air Force air logistic centers (including Ogden, Robins, and Tinker) and with consortium member L-3com, which involved both government and industry participation. These collaborative assessments are a hallmark and key benefit of membership in LAI.
- Another very large consortium member, Boeing, is now using LAI's *Product Development Value Stream Manual* (PDVSM) with marked success across the enterprise—the first time it has been implemented on such a large scale.
- Aircraft Management Technologies and LAI announced a collaborative effort to engage industry, airline, and academic partners to establish the Lean Flight Initiative (LFI). The purpose of LFI is to develop and promote lean principles, practices, and tools among aircraft operators and companies involved in facilitating airline operations.
- Several LAI products, designed to convey lean practices and principles in real-world settings and led by the Lean Enterprise Value Simulation, PDVSM, and Supplier Networks Transformation Toolset tools, are experiencing record usage across the consortium and have accrued intense demand from nonmembers as well. Ongoing research and follow-up indicates that these tools have had significant positive impact at the enterprise level and are rapidly being assimilated into member organizations' in-house lean training.
- LAI's Product Support EVSMA initiative has received executive-level support from the USAF's Materiel Command and carries with it the ambitious goal of becoming the benchmark for product support from start to finish across the entire enterprise.

LAI Accomplishments, Research Results, and Knowledge Deployment

In the past year, LAI further increased efforts to help transform the US aerospace enterprise by developing and deploying education programs, as well as leadership and transformational tools steeped in ongoing research. An important operative norm for all LAI products and educational programs is that they be the direct result of LAI's research. There is an indissoluble link between the research—which must precede any offerings—and the products and knowledge deployment that follow from this research effort.

LAI Research

LAI's research initiatives focus on the following three key knowledge areas, which are of vital importance to the consortium. This research is undertaken with the goal of meeting both current and future challenges faced by members in these specific areas. As such, it addresses matters of real-time and future importance and seeks to enable members to view their enterprise's transformation as an ongoing process.

- Enterprise architecting. Creating a future lean vision and designing an enterprise to support it by incorporating information, organization, process, technology, and strategic dimensions
- Enterprise change. Strategic, enterprise-level approach to accelerating effective and sustainable improvement and change
- Product life cycle. “Pushing the envelope” in the area of designing and developing aerospace products in a complex system-of-systems environment to shorten cycle time, reduce cost, and increase delivery of best life-cycle value; this knowledge area has two components: product development and systems engineering

Relevant research questions that fall within these categories and to which LAI directs its attention and resources include the following:

- How to architect/design future lean enterprises
 - o Lifecycle value creation perspective
 - o Organizing principles
 - o Integration strategies
- How to accelerate lean enterprise transformation
 - o Workforce and cultural change
 - o Metrics for motivating desired behavior
 - o Information technologies
- How to create more efficient and effective product development and management capabilities, as well as generate knowledge about approaches and methods for systems engineering that address the full life cycle of complex systems and systems of systems
 - o Kinds of enterprise architectures or architecture attributes that enable more effective product and system management
 - o Changing stakeholder values, impacting product/system and enterprise architecture
 - o Methods to be used in designing systems when future changes and requirements are unknown

LAI Publications

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 of these works are available on the LAI web site at <http://lean.mit.edu/>. Following is a sampling of these publications:

- Christoph Bauch, “Lean Product Development: Making Waste Transparent,” thesis at the Technical University of Munich, August 16, 2004.
- P. Henrik M. Bresman, “Learning Strategies and Performance in Organizational Teams,” thesis, November 19, 2004.
- Troy Downen, “A Multi-Attribute Value Assessment Method for the Early Product Development Phase with Application to the Business Airplane Industry,” thesis, January 7, 2005.
- Martin Graebisch, “Information and Communication in Lean Product Development,” thesis at the Technical University of Munich, January 2005.

- Justin Hemann, “Improving Complex Enterprises with System Models,” conference paper presented at the Lean Aerospace Initiative Plenary Conference, March 25, 2005.
- Jin Kato, “Development of a Process for Continuous Creation of Lean Value in Product Development Organizations,” thesis, May 6, 2005.
- Hugh McManus, “Lean Engineering: Doing the Right Thing Right,” conference paper presented at the First International Conference on Innovation and Integration in Aerospace Sciences, August 4–5, 2005.
- Eric Rebentisch, “Using Stakeholder Value Analysis to Build Exploration Sustainability,” conference paper presented at the American Institute of Aeronautics and Astronautics Conference, 2004.

LAI Products

The LAI tool suite now numbers 22 distinct offerings, with several new entries within the past 12 months. A comprehensive list of these tools is available online at the LAI website. A brief description of some of the most requested tools follows.

- *Enterprise Value Stream Mapping and Analysis*. 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 to prioritize opportunities.
- *Government Lean Enterprise Self-Assessment Tool*. Version 1 of this product is now complete and ready for testing in a government setting. This tool was built from a foundation provided by the Lean Enterprise Self Assessment Tool and reconstructed relative to System Program Office operations.
- *Lean Enterprise Value Simulation (or “Game”)*. This is a unique tool for demonstrating the value and challenges of implementing lean principles and practices at the enterprise level. It currently comprises four modular simulations developed on a foundation of insights gained through more than 11 years of LAI intensive research and consortium real-world experience. It is a complete, flexible simulation of a complex enterprise, which allows interactive, hands-on lessons in lean improvement.
- *The Product Development Transition to Lean (PDTTL)*. This roadmap and accompanying manual, now in beta version, is a set of strategic tools for applying lean to product development processes. It is intended for use in engendering PD improvements within an overall lean enterprise and works well with the Enterprise TTL. Leaning of both PD functional organizations and development tasks of a program are considered.
- *Product Development Value Stream Analysis and Mapping Manual*. Also now in beta version, 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 of and reference to more than four years of product development group experience facilitated through LAI.

- Supplier Networks Management Toolset. This integrated set of products includes the Supplier Management Assessment Tool for self-assessment of internal progress in creating lean supply chain management capabilities, the *Roadmap*, a “how-to” guide for building lean supplier networks, and a *Reference Guide* with lean principles for supply chain management.

LAI Knowledge Deployment

Critical to effective knowledge deployment are LAI’s Educational Network (EdNet) and in particular the LAI Lean Academy™. Both support continuous learning throughout the US aerospace enterprise by sharing knowledge and curriculum developed by members. These programs have experienced phenomenal growth, with a record number of academies already deployed and scheduled for this year.

In addition, the annual LAI Plenary Conference—which set a record for attendance this year—is regarded by many in the aerospace community as the single most important lean event of the year, a venue that offers a wealth of lean knowledge and is replete with unparalleled opportunities for networking and collaborative engagement.

LAI continues to hone its specialized knowledge deployment activities with short courses, workshops, training sessions, onsite visits, conference collaborations, and other venues. A listing of current and upcoming events of this nature may be found on the LAI website.

Finally, LAI this year established a consortium-wide Communications Group to explore ways to ensure that the immense wealth of LAI’s knowledge base is successfully disseminated and the articulation of its mission and vision appropriately conveyed. In tandem with this effort was the release of a brand-new website with considerably heightened functionality, including interactive forums and other mechanisms to foster online consortium collaboration.

The EdNet is about active communication and collaboration among member schools supporting the transformation of the greater US aerospace enterprise. Its 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, the University of Southern California, the University of Michigan, the University of Texas at Arlington, and Worcester Polytechnic Institute.

The LAI Lean Academy™ is a one-week course that provides a hands-on introduction to lean fundamentals. It is targeted toward undergraduate students and is taught at the point of use during an internship, co-op, or new hire assignment. The LAI Lean Academy™ also serves as a platform 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.

This year's LAI Plenary Conference attendees learned firsthand the elements necessary for a successful transformation at the enterprise level from interacting with people who had gone through the process and done exactly that. These individuals shared practical experiences and research findings from the perspectives of government programs, industry, and academia, as well as a few organizations from outside traditional aerospace circles. Consensus held that the keys are shared language and definitions; trustful relationships and connecting people to the process; focusing on valued results and equitable incentives; leadership support and participation; in-house expertise; and cultures that support openness and teamwork.

The overall takeaways from the 2005 Plenary Conference can be expressed by the following four thematic challenges:

- Take action with partial planning: The spiral development of lean thinking
- Standardize tasks and processes in ways that encourage innovation: Lean is a verb—a way of thinking—not just a collection of tools
- The definition of the enterprise is crucial, but difficult: It is more about value and stakeholder relationships than about control
- Patience is essential: The business case is ultimately based on faith (the measures and numbers come later)

LAI Moving Forward

Now nearing the conclusion of its Enterprise Value Phase, there can be no doubt that LAI has grown and flourished as an innovative and perhaps unique model of an industry, government, and academic partnership. The consortium also represents a true learning community with the ability to leverage multiple perspectives for longer-term solutions within a neutral, nonpartisan forum. This enables LAI to maintain an unusually high and robust degree of knowledge sharing, create a common vocabulary, infuse new ideas into the aerospace industry and policy that governs it, and enhance communication among all stakeholders. This accelerates lean transformation efforts by bridging sectors and cultures as well as organizational functions, layers, and competing interests. It also creates a system to rapidly diffuse best practices throughout the enterprise.

Today, LAI's learning community includes stakeholders from nearly 40 organizations, including aerospace companies, US government offices and programs, and academia. LAI also collaborates internationally with the Lean Aerospace Research Program at Linköping University in Sweden, as well as the UK LAI. A consortium-guided research program at its core, LAI is led by the MIT Department of Aeronautics and Astronautics in close collaboration with the MIT Sloan School of Management and is managed under the auspices of the Center for Technology, Policy, and Industrial Development.

The following four overarching imperatives will provide the framework for the consortium's efforts during the next phase:

- Sustain the LAI consortium as a partnership among industry, government, the workforce, and academia to address process excellence and take collective action for continuous improvement

- Facilitate enterprise transformations within and between industry and government
- Expand enterprise transformation knowledge and diffuse knowledge applications
- Foster a learning community within the consortium

LAI Leadership

For much of the past year, LAI was managed by a trio of codirectors representing the various stakeholder interests: Professor Deborah Nightingale, Department of Aeronautics and Astronautics and ESD; Professor John Carroll, MIT Sloan School of Management and ESD; and an industry codirector, Frederick “Terry” Bryan of Raytheon. This management model will shift slightly as of the beginning of the next phase, with the industry codirector position being jointly held by two industry nominees.

More information about the Lean Aerospace Initiative can be found online at <http://lean.mit.edu/>.

Labor Aerospace Research Agenda

The Labor Aerospace Research Agenda (LARA) is committed to advancing theory, practice, and policy relating to the 21st-century aerospace workforce. The program focuses on the impact of instability on employment and new work systems. We also consider factors such as intellectual capital investments, effective institutional infrastructure, and global employment dynamics in the industry. Within the last year the LARA team began three new projects, so despite the completion of our funding cycle for LARA, the team remains engaged in research with aerospace stakeholders as well as new groups, including the following:

- The MIT Project on Collective Bargaining and Workplace Transformation
- Lateral Alignment in Complex Systems
- The Aerospace Industry Council

LARA Accomplishments

Research scientist Betty Barrett presented the paper, “Boeing St. Louis Case” at the Conference on the British Aerospace Industry, Oxford University, Oxford, England, September 2004.

Codirector Joel Cutcher-Gershenfeld authored the article, “Industry Councils: A National Impact Anticipated,” *Perspectives on Work*, Winter 2005.

Joel Cutcher-Gershenfeld and Betty Barrett hosted an event on February 11, 2005, in Washington, DC, entitled, “Building the 21st Century Aerospace Workforce: Challenges and Approaches for Business, Labor, and Government.”

Research scientist Betty Barrett and postdoctoral fellow Lydia Fraile completed a case study at the Warner Robins Air Logistics Center in Georgia. The case study, “Lean at the C-5 Galaxy Depot: Essential Elements of Success” (May 2005) will soon be available on the LARA website.

The Research Team is completing preliminary analysis of the third round of the National Aerospace Survey. The survey was administered to a random national sample of the US aerospace industry, and analysis will be done on the newest data collected as well as a time-series study of panel of respondents from all three survey rounds.

The LARA team was instrumental in putting together a new institutional initiative, the Aerospace Industry Council, whose draft charter was approved January 2005. 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 major new initiative to establish industry councils in many sectors of society, each of which will address labor and employment issues in that sector.

About LARA

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 is an MIT-based team conducting research with funding provided via the Manufacturing Technology initiative of the US Air Force and other sources. The project's funding expired April 15, 2005. The final report of the project is available on the LARA website. Coprincipal investigators/codirectors are senior research scientist Joel Cutcher-Gershenfeld and Professor Thomas A. Kochan.

More information about the Labor Aerospace Research Agenda can be found online 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.

MSL's research sponsors include major automakers and materials suppliers. A five-year agreement with General Motors established the Collaborative Research Laboratory in Materials and Manufacturing Systems Analysis. 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 strategic position of new automotive technologies both from economic and environmental standpoints.

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. The new Markets and Electronics Recycling project applies ideas from auto recycling to the electronics industry. MSL researchers Randy Kirchain, materials science and engineering and ESD

assistant professor, and Frank Field, CTPID senior research associate, have visited half a dozen electronic recyclers in the past year to gather data on current practices and to develop an economic model for improving product design and recycling technology. This research responds to pressures from new European regulations and laws passed or pending in Massachusetts and 22 other states on electronics firms to create environmentally friendly products.

MSL has also expanded into the area of microphotonics. Professor Randy Kirchain has 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. 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 upon 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. Further, MSL researchers 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 defensible product strategies that take life-cycle information into account.

Richard Roth is the director of MSL. Joel Clark is principal investigator.

More information about the Materials Systems Laboratory can be found online at <http://web.mit.edu/ctpid/www/msl.html>.

MIT Information Quality Program

The MIT Information Quality (IQ) Program develops new knowledge in the information quality field and information quality benchmarking standards. MIT IQ, launched in 2002, equips professionals with the understanding and skills to significantly improve their organization's information and to use that information as a strategic tool. MIT IQ is an outgrowth of MIT's Total Data Quality Management Program founded in 1989 by CTPID principal research associate Rich Wang and the Sloan School of Management's J. N. Maguire information technology professor Stuart Madnick.

MIT IQ Accomplishments

MIT IQ hosted the 9th International Conference on Information Quality, a forum for researchers and practitioners to exchange IQ knowledge and ideas in November 2004 at MIT. More than 100 participants from both academic and industry worldwide attended this conference, which is now considered the premier conference in the information quality field.

In a new initiative, MIT IQ and Acxiom Corporation initiated a Customer-Centered Information Quality Management (CCIQM) research program. One outcome from this research was a Talburt-Wang index that measures the distance of different transactions related to an entity (say a customer). 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.

MIT IQ offered a three-day executive IQ course at MIT titled “Information Quality: Principles and Implementation” through the MIT Professional Education Program. MIT IQ also offered initial short courses leading to an IQ certification program for information quality professionals. In addition, MIT IQ has begun to develop a two-day course with case studies materials developed under the MIT IQ Program to be offered (July 14–15, 2005) through the MIT Professional Education Program.

Dr. Wang received the Data Administration Management Association International’s Academic Achievement Award for 2005. Previous recipients of this award include Dr. Peter Chen (father of the Entity Relationship Model), Dr. E. F. “Ted” Codd (father of the Relational Model), and William (Bill) H. Inmon.

In May 2005, Dr. Wang received a certificate of appreciation in recognition of outstanding contribution to the US Intelligence Community, under the director of national intelligence.

MIT IQ Funding

Acxiom Corporation and MIT IQ continued to fund the research project focusing on CCIQM, with an extension to explore Enterprise Architecture deployment. Acxiom Corporation, which integrates data, services, and technology to deliver customer and information management solutions, is the founding corporation in the consortium.

Additionally, Firstlogic continued to sponsor a joint research program (Total Data Quality Management) codirected by Dr. Wang.

With the foundation established, MIT IQ is now seeking additional funding and a permanent research associate to further accelerate the program.

More information about the MIT Information Quality Program can be found online 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 colisted with Urban Studies: Law, Technology, and Public Policy, a core subject in the Technology and Policy Program; and Sustainability, Trade, and Environment. Both are listed jointly with Engineering and Sloan. The latter course continues to be offered at Cambridge, England, as part of the Cambridge–MIT Institute. Two course books related to these offerings are in preparation: *Environmental Law, Policy, and Economics* by Nicholas Ashford and Charles Caldart and *Globalization, Technology, and Sustainability* by Nicholas Ashford.

Technology and Law Publications

N. 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; "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; "Implementing the Precautionary Principle: Incorporating Science, Technology, Fairness, and Accountability in Environmental, Health, and Safety Decisions," *International Journal of Risk Assessment and Management*, 2005; "Scientific, Ethical and Legal Challenges in Work-Related Genetic Testing in the United States," Proceedings of the Collegium Ramazzini, October 2004; "Major Challenges to Engineering Education for Sustainable Development: What Has to Change to Make It Creative, Effective, and Acceptable to the Established Disciplines," *International Journal of Sustainability in Higher Education* 3(4): 2004, pp. 239–250.

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

Harn Wei Kua and Nicholas A. Ashford, "Co-optimization through Increased Willingness, Opportunity and Capacity: A Generalisable Concept of Appropriate Technology Transfer," *International Journal of Technology Transfer and Commercialization* 3(3): 2004, 324–334.

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

More information about the Technology and Law program can be found online at <http://web.mit.edu/ctpid/www/tl/>.

Fred Moavenzadeh

Director, CTPID

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

MIT Center for Transportation and Logistics

Established in 1973 to develop and coordinate the wide range of transportation-related activity at MIT, the Center for Transportation Logistics (CTL) provides a focal point for transportation education, facilitates transportation research, conducts an outreach program to the transportation industry, and encourages a sense of common purpose among the many departments, centers, and laboratories involved in transportation and logistics at MIT.

On our website there is a wealth of information about the center and its programs, including descriptions of current research projects and a listing of MIT theses in transportation since 1980. Transportation faculty and research staff are also listed with their areas of interest, along with connections to other interesting resources on the web.

Education

Thirty-three new students arrived on campus in the fall of 2004 to enter the center's Master of Engineering in Logistics (MLOG) program as the Class of 2005. 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 2005 was our most experienced yet (average age of 31.6 with just under seven years of business experience). The class was geographically dispersed, with 60% being US citizens and the remainder coming from 12 different countries. The visibility of the program is increasing, with US-based applications up by 40% this year and total applicants increasing by 16% to a record 185 total. At time of graduation, 94% of the class had at least one job offer (with an average of 2.6 per student), and within two weeks, 100% had job offers. The median outgoing salary for students was 60% higher than the incoming salary for the students.

MIT ranked first in logistics and supply chain management. For the fourth year in a row, MIT was ranked first among graduate business programs in the area of logistics and supply chain management, according to a survey by [U.S. News & World Report](#). As part of a comprehensive evaluation of US colleges and universities, the magazine regularly asks deans and senior faculty of business schools to nominate up to 10 of the best programs in several specialties. This year's other top programs for logistics and supply chain management were Michigan State, Ohio State, Arizona State, Wharton, and Stanford University. The survey also ranked MIT first among graduate engineering schools, as it did for the past two years. The other top graduate engineering schools were, again this year, Stanford, Berkeley, and Georgia Tech.

Expanded orientation period. In order to better prepare the incoming MLOG students, an intensive two-week orientation period was added to the beginning of the academic year. The period featured solving various supply chain projects focused on honing quantitative analyses and team skills. Also, there were several cohort building exercises and activities to further familiarize the students with each other and MIT.

Exchange with Zaragoza Logistics Center students. In January 2005, during the Independent Activities Period (IAP), the MLOG class and the Zaragoza Logistics (ZLOG) students

conducted a monthlong exchange. First, the ZLOG students came to MIT for two weeks, where they participated in a number of trips, classes, and workshops. Following this, the MLOG class traveled to Zaragoza to visit a number of logistics facilities and partake in a team-based supply chain design simulation.

MLOG alumni interaction. Building on last year's first-ever MLOG reunion, the program continued to strengthen the connections between the program and its alumni. A bimonthly newsletter was established specifically for the alumni. Featuring stories, events, and profiles of current students and alumni, the newsletter served to increase the awareness of the program. Additionally, alumni are invited back for a number of events at MIT. This year, alumni have begun to bring their companies in for recruiting of current MLOG students.

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

- Improving the use of real time data in forecasting with the Gillette Company
- Developing an optimal store delivery plan for Albertsons/Shaws supermarkets
- Analyzing the costs and benefits of using vendor-managed inventory practices at hospitals with Cardinal Healthcare
- Designing a distribution center bypass network for Reebok

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 scores of continuing projects carried over from previous years—a total of more than 100 efforts listed in various categories and cross-indexed with their principal researchers. Many of those entries were research programs that included within them still more individual projects.

Corporate Outreach

At the beginning of the fiscal year, CTL embarked upon an ambitious campaign to expand and enhance our Corporate Outreach program. With a new director in place, the center introduced a three-tier outreach model and began aggressively recruiting corporate partners. The model builds upon the center's successful Affiliates Program in Logistics, which was relaunched in the fall of 2004 as the MIT Supply Chain Exchange Program to reflect an increased focus on supply chain management and to exploit the center's reputation for convening industry-leading symposia and other interchange events. Following the launch of the exchange, we recruited 15 new companies to join, bringing the number of CTL's corporate partners to 35. New partners include BT Group, C&S Wholesale Grocers, Inc., Cardinal Health, Inc., Caterpillar Logistics Services, Inc., C. H. Robinson Worldwide, Inc., Corporate Express, Inc., Fairchild Semiconductor, Pepsi Bottling Group, Inc., Raytheon Company, Schwan Food Company, Sealed Air Corporation, Solutia Inc., Staples, Tyco Healthcare, and Unilever.

In a significant milestone for the center, Procter and Gamble agreed to become the charter member of the highest level in our new outreach model, called Strategic Partner. The Strategic Partner category is designed to promote a close partnership with a small number of industry leaders. Strategic Partners participate in all of the center's events and research activities and comprise an Executive Board for the center to help us direct our efforts in supply chain research and education.

We conclude the year with a very strong outreach program in place, including marketing messages, materials, and database systems. We have a large number of prospective sponsors in the sales "pipeline" and we are working actively with Procter and Gamble to recruit additional Strategic Partners.

Major New Projects

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 new building for the 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, the ZLC offers graduate and executive education in logistics to students from around the world. This year saw the graduation of the initial class in the masters degree program, which is modeled on MIT's Master of Engineering in Logistics program. Students from both masters programs participated in an international exchange during IAP, in which they took seminars on the MIT campus and at the ZLC in Spain. The doctoral program is being launched this coming year. The ZLC hired several permanent professors from leading international universities to conduct research and deliver courses in the MIT–Zaragoza Program. In addition, the MIT–Zaragoza Program hosted several visiting professors. Research partnerships were established with Lucent Technologies, Bell Labs, Sun Microsystems, and EDS. In May, the MIT–Zaragoza Program hosted a major conference on globalization featuring keynotes by CEOs, prominent academics, and a panel of journalists from leading international business publications.

Supply Chain 2020. The Supply Chain 2020 (SC2020) Project is a multiyear research effort to identify and analyze the factors that are 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 that they can be better prepared for the future. This work can create value in society through improvements in transportation, logistics, and supply chain management (SCM) 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 comprised of 44 supply chain executives from over 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 written.

SC2020 research is broad and far reaching and is 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, Phase II of the research (to commence in FY2006) will project the future 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 [[Unknown acronym; spell out?]] 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 the Zaragoza Logistics Center. In total, 12 masters theses, 5 working papers, and 1 PhD thesis have been written under the aegis of Phase I.

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 Harvard Business School Publishing to produce *Supply Chain Strategy*, a monthly newsletter available in electronic and hard copy formats. The newsletter's mission is to 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

Crossroads gets high marks. Supply chain management “is an increasingly strategic topic,” said MIT president Dr. Susan Hockfield at the opening of “At the Crossroads of Supply Chain and Strategy,” a landmark symposium inaugurated by the MIT Center for Transportation and Logistics on March 1, 2005. President Hockfield and center director Yossi Sheffi were among the speakers at the symposium. The Crossroads symposium brought together senior executives from C&S Wholesale Grocers, Hammer & Co., IBM, P&G, Reebok, experts from MIT, and journalists from the *Boston Globe*, *Fast Company*, and the *Harvard Business Review* to discuss the strategic importance of supply chain management. More than 170 attendees gained insights into how companies can realize the potential of the supply chain as a strategic asset.

International logistics summit. An international symposium held in Zaragoza, Spain, in May brought together thought leaders from around the world to share their strategic insights on globalization and the future of offshore manufacturing. The meeting was sponsored by the center in cooperation with the Zaragoza Logistics Center and the government of Aragón. Keynote speakers included David Abney, president, UPS International; John Allan, CEO, Exel plc, and Edouard Michelin, CEO, Michelin. In addition to the keynoters, there were presentations from a number of notable speakers, including Nicky Hartery, vice president–manufacturing, EMEA, Dell; B. G. Srinivas, head of Infosys, EMEA; and Dr. Yossi Sheffi, director, MIT Center for Transportation and Logistics.

Smaller Function

New roads to e-commerce. Amazon.com is driving growth in the international business-to-consumer channel with groundbreaking work to standardize carrier and postal practices across countries. The company has cut last-mile shipment delays through the use of multiple postal authorities and is pursuing efficiencies in other parts of its international business. Girish Lakshman, Amazon’s director of worldwide transportation engineering, explained the company’s strategy at a special conference organized by the MIT Center for Transportation and Logistics on April 27–28, 2004. The invitation-only event, entitled “Innovations in Transportation: Focus on Procurement and Management,” brought together industry experts to talk about leading-edge developments in transportation procurement.

Professional Education

Supply Chain Management for Competitive Advantage, our annual weeklong summer program, was offered June 13–16. Fundamentals of Supply Chain Management, a CTL executive education course, was offered January 5–7.

Personnel Changes

Research and support staff changes. The center’s research staff was enhanced this year with several new hires: Mahender Singh, Edgar Blanco, and Timothy Griffin (transferred from Information Services & Technology). Departures from the center included Kai Jiang and Scott Campbell, a long-term, part-time employee of the center, who left for a full-time position with the School of Architecture.

Recognition

Bush chooses MIT’s Coughlin to join Advisory Committee on Aging. President George W. Bush has selected Joseph F. Coughlin, director of MIT’s AgeLab, to serve in his administration as a member of the Advisory Committee to the 2005 White House Conference on Aging. The conference, which occurs only once every 10 years, provides recommendations to the president and Congress to help shape aging policy for the next 10 years. Past conferences have led to the passage of Medicare and Medicaid, the Supplemental Security Income (SSI) program, and the Older Americans Act. The Advisory Committee is composed of 22 members and will advise the president and Congress on a variety of policy areas including technology, economic security,

transportation, housing, health care, and other key areas confronting the nation's aging population.

MIT alumni win research awards. During its 2004 annual conference in Philadelphia, the Council of Logistics Management recognized MIT alumni Pinaki Kar and Paulo Gonçalves for their innovative research in logistics and supply chain management. Kar, 2002 graduate of MIT's MLOG program, was presented with the 2004 A. Grovesnor Plowman award for the best research submitted for conference presentation. He shared the award with three fellow researchers for their paper entitled, "An Introduction to Semantic Modeling for Logistical Systems." The researchers are building an intelligent modeling network that improves the productivity of modeling and accelerates the reuse of model elements for models in financial, health care, and logistics applications. Kar is an independent consultant working in the pharmaceutical industry. Gonçalves is a 1998 masters graduate of MIT's Technology and Policy Program and a 2003 doctoral graduate of MIT's Operations Research Program. He received the 2004 Doctoral Dissertation Award for his paper, "Demand Bubbles and Phantom Orders in Supply Chains," which explores two aspects of supply chain instability: inflated orders and last sales. Gonçalves conducted much of his research with sponsor companies from the [Integrated Supply Chain Management Program](#), run by the MIT Center for Transportation and Logistics. He is an assistant professor in management science at the University of Miami's School of Business Administration.

Quarter Century Club. Three members of the center—Scott Campbell, Paula Magliozzi, and center director Yossi Sheffi—were inducted into the Quarter Century Club on April 11, 2005.

MLOG student awards. Derek DeScioli won the Outstanding MLOG Thesis award for his research on implementing vendor-managed inventory policies at a hospital. Derek worked with Cardinal Healthcare and two partner hospitals for this project.

The New England Roundtable of the Council of Supply Chain Management Professionals (CSCMP) made the following four awards to MIT MLOG students:

CSCMP–NERT Academic Achievement Award (\$1000). Fidel Santos was nominated for the Academic Achievement Award. Fidel has excelled in activities in and outside of the classroom. In the classroom, Fidel has taken one of the heaviest course loads and still has achieved top marks. He leads the MLOG Class Career Committee and is actively involved with MLOG's external outreach programs. Upon graduation, Fidel will join Bristol-Meyers Squibb in their Supply Chain Management rotational program.

NERT–CSCMP Annual Conference Award (paid trip to conference). Bindiya Vakil was nominated for the Annual Conference Award. Bindiya is a force unto herself. She has put in tremendous hours of effort and energy helping to develop, promote, and strengthen the MLOG program. She has personally brought in outside speakers for workshops and organized side activities for the entire class. At the same time, she maintained a sterling academic record in her classes. Upon graduation, Bindiya will join Cisco Systems as a product materials manager.

CSCMP–NERT Academic Achievement Award (\$1000). Colby [[Full name?]] achieved a perfect 5.0 grade point average while in the MLOG program. His thesis examining the retail supply chains of Amazon and Wal*Mart was part of the Supply Chain 2020 project. After graduation, Colby took a job with Accenture in their supply chain practice based out of Atlanta.

NERT–CSCMP Annual Conference Award (paid trip to conference). Chris Kerslake came to the MLOG program from General Mills. He applied his background in operations management to develop an optimal delivery frequency for Shaw’s Supermarkets as part of his thesis. Chris will join Amazon in their supply chain group based in Seattle upon graduation.

Yossi Sheffi

Director

Professor of Civil and Environmental Engineering and Engineering Systems

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