

## Engineering Systems Division

MIT's Engineering Systems Division (ESD) represents a bold educational initiative aimed at establishing engineering systems as a field of study and advancing theory, policy, and practice in this domain. Within MIT, ESD is an interdisciplinary academic unit spanning most departments within the School of Engineering, as well as MIT's School of Humanities, Arts, and Social Sciences, MIT Sloan School of Management, and MIT's School of Science.

ESD brings [faculty](#) and [students](#) together with engineering and management professionals interested in researching large-scale, complex engineering systems. The division focuses on complex, technology-based products (automobiles, airplanes, etc.) and systems (transportation, telecommunications, energy, etc.) While technology is a fundamental part of these systems, so too are issues of managerial and, more generally, societal interactions.

Nearly 50 faculty members, all holding dual or joint appointments within ESD and one of the aforementioned units, are devoted to teaching and research in the emerging field of engineering systems. Approximately 300 students are enrolled in ESD's five master's programs, plus about 60 students in our PhD program. All are working together to understand, model, and predict the behavior of technologically enabled complex systems in order to help the engineering profession address contemporary critical issues and better serve humankind.

Academic year 2007 was one of significant accomplishment for ESD as we continued to move forward toward our goals.

Institute Professor Joel Moses continued as ESD's acting director after Professor Daniel Hastings was named dean of undergraduate education in December 1995. Professor Moses was also named acting director of the Center for Technology, Policy, and Industrial Development, effective July 1, 2006. Professor Moses holds appointments in the Department of Computer Science and Engineering and in ESD. He has served as MIT's provost, dean of engineering, head of the Department of Electrical Engineering and Computer Science (EECS), associate head of EECS, and associate director of the Laboratory for Computer Science.

The ESD faculty continued to expand during the past year. We are delighted to announce that the following individuals have joined our faculty:

Hamsa Balakrishman joined ESD in January 2007, as assistant professor in air transportation/critical networked infrastructure systems, with a dual appointment in ESD and the Aeronautics and Astronautics Department.

Dr. Balakrishman received a PhD in aeronautics and astronautics from Stanford University, with a minor in electrical engineering, in May 2006, as well as a MS in aeronautics and astronautics from Stanford and a BTech in aerospace engineering from Indian Institute of Technology (Madras).

Dr. Balakrishman's research interests include systems and control theory (estimation, model identification, and stability analysis of hybrid systems), target-tracking and identity management (applications to sensor networks and air traffic surveillance), and market-based mechanisms (applications to airport and airspace resource allocation). Currently she is interested in developing tools aimed at improving the efficiency of the National Airspace System.

Michael A. Cusumano, Sloan Management Review Distinguished Professor of management, joined ESD as professor of engineering systems. Professor Cusumano specializes in strategy, product development, and entrepreneurship in the computer software industry, as well as in the automotive and consumer electronics sectors. He teaches courses on strategic management, technological innovation and entrepreneurship, and the software business.

Professor Cusumano received a BA from Princeton in 1976 and a PhD from Harvard in 1984. He completed a postdoctoral fellowship in production and operations management at the Harvard Business School from 1984–1986. He received two Fulbright Fellowships and a Japan Foundation Fellowship for studying at Tokyo University. He has been a visiting professor in management at Hitotsubashi University, Tokyo University in Japan, and the University of St. Gallen in Switzerland, and a visiting professor in computer science at the University of Maryland.

Professor Cusumano has published several books. They include *The Business of Software: What Every Manager, Programmer, and Entrepreneur Must Know to Thrive and Survive in Good Times and Bad* (2004); *Microsoft Secrets* (1995, with Richard Selby); *Platform Leadership: How Intel, Microsoft, and Cisco Drive Industry Innovation* (2002, with Annabelle Gawer); *Competing on Internet Time: Lessons from Netscape and its Battle with Microsoft* (1998, with David Yoffie); *Thinking Beyond Lean: How Multi-Project Management is Transforming Product Development at Toyota and Other Companies* (1998, with Kentaro Nobeoka); *Japan's Software Factories: A Challenge to US Management* (1991); and *The Japanese Automobile Industry: Technology and Management at Nissan and Toyota* (1985). He is also coeditor of *Strategic Thinking for the Next Economy* (2001, with Costas Markides).

Maria C. Yang came from Stanford to join MIT as assistant professor of mechanical engineering and engineering systems. Professor Yang's research interest is in the product design process, particularly in the early phases of the design cycle.

Dr. Yang earned her SB in mechanical engineering from MIT and her MS and PhD from Stanford University's Mechanical Engineering Department's Design Division and the Center for Design Research, under an NSF Graduate Fellowship. She is the 2006 recipient of a NSF Faculty Early Career Development (CAREER) award.

Currently there are 49 ESD faculty members—35 in engineering, 11 in management, one in science, and two in humanities, arts, and social sciences. Twenty-seven hold dual appointments, 21 hold joint appointments, and one holds a full-time appointment. There are five additional 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. 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.

Now in their fourth year, the Engineering Systems PhD and Engineering Systems SM programs admitted the fourth full classes of 13 ESD PhD and three ESD SM students. An additional 21 ESD SMs entered LFM in June 2007 (class of 2009). Graduating this academic year were 13 ESD PhDs, four ESD SMs, and 15 LFM ESD SMs.

ESD has three affiliated research centers: the Center for Engineering Systems Fundamentals (CESF); the Center for Technology, Policy, and Industrial Development (CTPID); and the Center for Transportation and Logistics (CTL). These are described later in this report.

## **Ongoing Initiatives**

### **Undergraduate Education**

In spring 2006, ESD launched a new undergraduate subject, FAMES—Frameworks and Models in Engineering Systems (ESD.04), taught in conjunction with 1.041 Engineering System Design in Civil and Environmental Engineering. This mirrors Professor Joseph Sussman's appointment as a dual faculty member in ESD and CEE.

The subject was offered again in spring 2007 and upgraded in various ways. This class is a complex system design project-oriented subject. In 2006 it focused on the transportation of spent nuclear fuel to Yucca Mountain, Nevada, a complex technical problem within a challenging societal context. In 2007, the scope was expanded; while still dealing with spent nuclear fuel and the viability of the nuclear industry, it further considered global climate change and asked the students to contrast the nuclear option with alternative ways of lowering the carbon footprint on our energy production system. The class considered this issue as a complex, large-scale, interconnected, open, sociotechnical (CLIOS) system and used the CLIOS process to study it.

### **MIT-Portugal Program**

The [MIT-Portugal Program](#) is a strategic investment in people, knowledge, and ideas designed to encourage enhanced collaborative programs in research and education among Portuguese universities and institutions, to perform basic research and education, and to strengthen the country's knowledge base.

The MIT-Portugal Program is coordinated at the Institute by ESD and includes collaborations with various other MIT departments, divisions, and schools. ESD founding director Professor Daniel Roos is the Institute's director of the MIT-Portugal Program. The engineering systems collaboration gives emphasis to large-scale systems that not only have critical technological components, but also have significant enterprise and sociotechnical-level interactions that call for engineers in leadership positions to

have the kind of training in engineering systems that goes beyond traditionally defined engineering disciplines.

The Institute's role will be to pursue its basic research and teaching in the focus areas of the Program and to collaborate on activities implemented in Portugal.

The four focus areas are engineering design and advanced manufacturing (EDAM), transportation systems, energy systems, and bioengineering systems. ESD faculty serving in leadership roles include Professors Joel P. Clark and Christopher L. Magee, co-leads, EDAM focus area; Professor David Hunter Marks, lead, Sustainable Energy Systems focus area; and Professor Dava Newman, lead, Bioengineering Systems focus area. In addition, an integrative anchor program in engineering systems is being developed.

### **MIT ESD-MITRE Workshop**

The MIT ESD-MITRE workshops are designed to foster research collaboration. The long-term objective is to perform joint research related to many aspects of the engineering of complex systems. The third annual workshop was held at MITRE on November 30, 2006. Participants included leading professionals from MITRE; MIT faculty, researchers, and ESD PhD students; and several invited attendees.

The event provided the past year's progress highlights for the four joint MIT/MITRE research projects funded by MITRE Corporation. The four projects are Enterprise Dynamics and Modeling, Social Contexts of Enterprise Systems Engineering, Real Options in Investment, and Real Options and "Ilities." The event will also feature presentations on initiatives within MIT ESD and MITRE Corporation.

### **Interplanetary Supply Chain Management and Logistics Architectures**

This interdisciplinary project is sponsored by NASA with a \$4 million budget over two years. The objective is to develop new methods and tools for optimizing the flow of vehicles, crew, and cargo for future space exploration. The main research product is a methodology and software, based on the theory of time-expanded networks, which allows simulation and optimization of future manned space exploration missions in the vicinity of the Earth, in cislunar space and eventually Mars. The resulting space logistics software tool, SpaceNet 1.4, has been ranked first out of over 400 software tools at NASA in terms of relevance for the Constellation Program and is currently undergoing formal verification, validation, and acceptance.

Principal investigators are Professor Olivier de Weck and Professor David Simchi-Levi. The project website can be viewed at <http://spacelogistics.mit.edu/>.

### **Engineering Systems Learning Center**

With the departure of Dr. Joel Cutcher-Gershenfeld to be dean of the Institute for Labor and Industrial Relations at University of Illinois/Urbana-Champaign, the Engineering Systems Learning Center ceased operation in 2006.

## Faculty Notes

Thomas J. Allen coauthored *The Organization and Architecture of Innovation: Managing the Flow of Technology* with award-winning German architect Gunter Henn. Dr. Allen is a Margaret MacVicar faculty fellow, Howard W. Johnson professor of management, professor of engineering systems, and codirector of LFM and SDM.

George E. Apostolakis, professor of nuclear science and engineering and engineering systems, was named a fellow of the National Academy of Engineering for “innovations in the theory and practice of probabilistic risk assessment and risk management.”

Richard de Neufville, professor of civil and environmental engineering and engineering systems and Dr. Tao Wang, an ESD alumnus, won the Best Paper Award at the 16th annual INCOSE international symposium in July 2006. The full title of the paper is “Real Options ‘in’ Projects and Systems Design—Identification of Options and Solutions for Path Dependency.” Dr. Wang is now with Morgan Stanley in Hong Kong.

Olivier L. de Weck, associate professor of aeronautics and astronautics and engineering systems, was elected associate fellow of the American Association of Aeronautics and Astronautics (AIAA). Professor de Weck was also named associate editor of the *Journal of Spacecraft and Rockets*, effective December 4, 2006, and was awarded an outstanding service award by the AIAA Multidisciplinary Design Optimization Technical Committee for 2002–2006.

Steven D. Eppinger, General Motors LFM professor of management science and professor of engineering systems, became interim dean of the MIT Sloan School of Management in June 2007.

Daniel D. Frey, Robert N. Noyce career development professor and associate professor of mechanical engineering and engineering systems, received ESD’s 2006 Joseph A. Martore Award for Excellence in Teaching. 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 Frey and David Wallace, Esther and Harold E. Edgerton associate professor of mechanical engineering and engineering systems, jointly served as content directors of a new educational television program broadcast nationally on public television. The show (titled *Design Squad*) features children designing and building a variety of devices, such as vehicles, sports equipment, and household appliances. The show was launched during National Engineer’s Week in February 2007.

Paul Lagace, Margaret MacVicar faculty fellow and professor of aeronautics and astronautics and engineering systems, was granted an award of merit with the honorary title of fellow by the American Society for Testing and Materials. Professor Lagace was cited for “meritorious and dedicated service to ASTM International Committee D30 on Composite Materials, with commitment to increased efficiency and safety of composite structures via research, education, and standards development, and for respected technical expertise, outstanding leadership, and exemplary professionalism.”



Nancy Leveson, professor of aeronautics and astronautics and engineering systems, served on the James Baker British Petroleum (BP) task force, helping to research and author BP Refineries' independent safety review panel report. It was published on January 16, 2007 and can be found at <http://www.bp.com/bakerpanelreport/>.

The establishment of the Stuart Elliot Madnick IQ Best Paper Award was announced at the annual International Conference on Information Quality (ICIQ). This award will further the emerging field of information quality (IQ) and encourage high-quality papers to be published in this premier IQ conference. Dr. Madnick is John Norris Maguire Professor of Information Technology and Engineering Systems.

Christopher Magee, professor of the practice of mechanical engineering and engineering Systems, and Dr. Heebyung Koh, a postdoctoral researcher, won the 2006 Elsevier prize for Best Paper in Technological Forecasting and Social Change. The title is "A Functional Approach for Studying Technological Progress: Application to Information Technology."

Sanjoy Mitter, professor of electrical engineering and engineering systems, won the American Automatic Control Council's 2007 Richard E. Bellman Control Heritage Award. Professor Mitter was specifically cited for contributions to the unification of communication and control, nonlinear filtering and its relationship to stochastic control, optimization, and optimal control and infinite-dimensional systems theory.

Ernest Moniz, Cecil and Ida Green professor of physics and engineering systems, was named director of the MIT Energy Initiative. He also became director of the Laboratory for Energy and the Environment.

Deborah Nightingale, professor of the practice in aeronautics and astronautics and engineering systems and director of the Lean Aerospace Initiative, was the lead speaker at a two-day Lean symposium, sponsored by the [Irish Centre for Business Excellence](#) in March 2005. The event was titled "[A Strategy for Sustainable Growth and Prosperity in a Fiercely Competitive Global Market.](#)"

Warren Seering, Weber-Shaugness professor of [mechanical engineering](#) and engineering systems was named codirector of the Leaders for Manufacturing and System Design and Management Programs, effective July 1, 2007. He also received the Institute's Frank E. Perkins Award for service as an excellent advisor and mentor for graduate students.

Yossi Sheffi, professor of civil and environmental engineering and engineering systems, received the Plaza 2006 Award from the government of Aragon for the greatest contributions to that region's economic growth and development.

David Simchi-Levi, professor of civil and environmental engineering and engineering systems and LFM-SDM codirector, was elected an INFORMS fellow. The Fellow Award recognizes members of INFORMS who have made significant contributions to the advancement of operations research and the management sciences.

In addition, the paper “Supply Chain Coordination and Influenza Vaccination,” coauthored by Professor Simchi-Levi, Stephen E. Chick, and Hamed Mamani, was awarded the 2006 Pierskalla Best Paper Award, given by INFORMS. The Pierskalla Award recognizes research excellence in the field of health care management science.

John Sterman, Jay W. Forrester professor of management and engineering systems, received the Technology and Policy Program’s Faculty Appreciation Award.

Joseph M. Sussman, JR East professor and professor of engineering systems and civil and environmental engineering, delivered the keynote address at the 60th anniversary of Portugal’s national civil engineering lab, [Laboratório Nacional de Engenharia Civil](#) (LNEC) in June 2007. The title of Professor Sussman’s keynote was “A Regionally-Scaled Intermodal Transportation System for Portugal: Critical Design Considerations for Sustainability in a Changing World.”

James M. Utterback authored *Design-Inspired Innovation* (<http://www.worldscibooks.com/business/6052.html>). He is the David J. McGrath, Jr. (1959) professor of management and innovation and professor of engineering systems.

Annalisa Weigel, assistant professor of aeronautics and astronautics and engineering systems, was appointed the inaugural Jerome C. Hunsacker career development professor.

## **Student and Alumni Honors**

### **ESD PhD Program**

ESD PhD alumnus Dr. Ralph Hall received the University Transportation Center’s Outstanding Student Award.

### **ESD SM Program**

Damien Bador, who received a MS in aeronautics and astronautics and a MS in engineering systems in 2007, was awarded the Lean Enterprise Value Foundation Best Student Paper Prize.

### **Leaders for Manufacturing Program**

Toni Albers, LFM 2000, was recognized as one of 11 winners of Honeywell’s 2006 Premier Achievement Award, the highest honor Honeywell bestows to individuals for superior performance.

LFM 2007 graduates Sabrina Chang and John Heiney shared the honors for this year’s LFM Best Thesis Award. Chang’s thesis is titled “Allocation of Engineering Resources to Global Sites Based on Coordination Cost and Project Structure” and based on research conducted at Honeywell. Heiney’s thesis, “Optimization of Preclinical Profiling Operations in Drug Discovery,” was based on research he conducted during his LFM internship at Novartis Institutes for Biomedical Research.

Scott Hiroshige, LFM 2006, was the coauthor of a paper titled “TaintTrace: Efficient Flow Tracing with Dynamic Binary Rewriting,” which was presented at the IEEE Symposium on Computers and Communications. The conference was held from June 26–29 in Pula-Cagliari, Sardinia, Italy.

C. Y. Lee, LFM 2008, received the Charles “Harrison” Smith III Award.

Nicholas Padgaskas, LFM 2007, was named a Siebel Scholar by the Siebel Scholars Foundation.

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

Babis Antoniou, Benjamin Harper, Purdy Ho, and Joseph Mauro, all members of the LFM class of 2008, won the Campus Championship for the inaugural McKinsey Business in Technology Challenge.

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

Sorin Grama, SDM 2007, was a member of Promethean Power, one of two finalists in the development track of the MIT \$100K Entrepreneurship Competition.

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

TPP 2008 Sarah Bird’s team, SaafWater, received one of two finalist awards in the MIT \$100K Entrepreneurship Competition development track.

## **Program Honors**

### **Master of Engineering in Logistics Program**

Josh Merrill, 2007, received the Academic Achievement Scholarship from the Council of Supply Chain Management Professionals.

### **System Design and Management Program**

Monica Giffin, SDM 2006, won the SDM Best Thesis Award. The title of her thesis is “Change Propagation in Large Technical Systems.” It is based on research she conducted on a large government contract that spanned 10 years and involved multiple vendors.



## **Technology and Policy Program**

Two 2007 TPP graduates received the TPP Best Thesis Award. They are Nicolas Osouf, whose thesis is titled “The Potential for a Nuclear Renaissance: The Development of Nuclear Power under Climate Change” and Wen Feng, for “Driving Segments Analysis for Energy and Environmental Impacts of Worsening Traffic.”

Sharon E. Gillett, an alumna of the Technology and Policy Program and the Communications Futures Program, was named Commissioner of the Department of Telecommunications and Cable by Massachusetts governor Deval Patrick.

## **ESD Alumni Advisory Board**

James D. Shields, ESD Alumni Advisory Board member, was selected as president of Charles Stark Draper Laboratory Inc. Previously, Shields was Draper’s vice president for programs.

## **INCOSE**

At the 2006 international symposium of the International Council on Systems Engineering (INCOSE) Pat Hale, director of the SDM Fellows Program, became president-elect. At the 2007 INCOSE symposium, held in San Diego, CA from June 24–28, Pat Hale entered his second year as president-elect of INCOSE. He will assume the presidency in January 2008. ESD’s Dr. Donna Rhodes co-led a workshop, along with CTPID/LAI researcher Dr. Ricardo Valerdi, aimed at doctoral students working on systems engineering research topics.

## **Engineering Systems/ILP Conference**

On September 26, 2006, ESD cosponsored a conference with MIT’s Industrial Liaison Program (ILP) titled “Complex Systems, Complex Times: Reflections on the 21st Century Enterprise.” The event addressed the daily challenges that increasingly complex environments present to corporate decision makers and how they can be addressed by the leaders of today and the future. ESD faculty, visiting professors, and teaching staff made presentations. They included Yossi Sheffi, professor of civil and environmental engineering and engineering systems; Nancy Leveson, professor of aeronautics and astronautics and engineering systems; Deborah Nightingale, professor of the practice of aeronautics and astronautics and engineering systems; Dr. Joel Cutcher-Gershenfeld, former director of the Engineering Systems Learning Center; Irving Wladawsky-Berger, vice president of technical strategy at IBM and an ESD visiting faculty member; Donald Rosenfield, director of the LFM Fellows Program and a senior lecturer at MIT Sloan School of Management; and Michael Hammer, ESD visiting professor.

## **2006 MIT Manufacturing Conference**

On December 6–7, 2006, ESD’s Leaders for Manufacturing Program and System Design and Management Program cosponsored a conference with ILP and the Forum for Supply Chain Innovation. The theme was “The Impact of Globalization on New Product Development: Imperatives for Success.” Speakers from MIT included Richard Schmalensee, dean of MIT’s Sloan School of Management; David Simchi-Levi, LFM-

SDM codirector and professor of civil and environmental engineering and engineering systems; Donald Rosenfield, director of the LFM Fellows Program and senior lecturer at MIT Sloan School of Management; and Thomas Malone, Patrick J. McGovern professor of information systems.

Speakers from industry included keynote speakers Michael McNamara, CEO of Flextronics and James Owens, chairman and CEO of Caterpillar, Inc; Patrick Byrne, managing partner of Accenture; James Miller, senior vice president, Manufacturing Technology Group, Cisco; William Crandall, senior director, Global Engineering Services, HP; and Irving Wladawsky-Berger, vice president of Technical Strategy, IBM and an ESD visiting faculty member. Professor Karl Ulrich of the Wharton School at University of Pennsylvania also spoke.

The event was moderated by Professor Thomas Allen and Donald Rosenfield, director of the LFM Fellows Program and senior lecturer at MIT Sloan School of Management.

### **Brunel Lecture on Complex Systems**

On October 12, 2006, Dr. Charles M. Vest, president emeritus of MIT, delivered the 6th annual Brunel Lecture on Complex Systems. The title of his presentation was “Education Engineers for 2020 and Beyond.” Dr. Vest is now president of the National Academy of Engineering. Dr. Vest’s lecture can be viewed on MIT World, at <http://mitworld.mit.edu/video/409/>.

### **Charles L. Miller Lecture**

Dr. Yossi Sheffi delivered the annual Charles L. Miller Lecture on April 4, 2006. The title of his lecture was “Geeks and The World Turned Upside Down: The Impact of the Return of India and China to Their Historical Global Weight.” Dr. Sheffi is professor of engineering systems, professor of civil and environmental engineering, director of the MIT Center for Transportation and Logistics, and director and founder of the Master of Engineering in Logistics Program. His lecture can be viewed on MIT World, at <http://mitworld.mit.edu/video/449/>.

### **Major Meetings**

#### **ESD Meetings**

ESD held three offsite meetings in AY2007.

On September 9, 2006, the ESD faculty attended an offsite meeting that included an overview of the past summer’s events and a look ahead to the fall’s, a presentation by Professor Daniel Roos on the MIT-Portugal Program, and a discussion of ESD’s draft response for the upcoming MIT faculty meeting where the ESD Review Committee’s recommendations would be presented by its chairman, Professor Ahmed Ghoneim. That evening a dinner and speaking program were held to honor Professor Daniel Hastings, ESD’s former director.

ESD's winter offsite was held on January 8, 2007 at the Endicott House Brooks Conference Center. The agenda included an ESD overview by ESD and CTPID acting director Professor Joel Moses, a presentation and panel discussion by ESD doctoral students, a presentation by Professor Richard Larson on various approaches to the structure of the ESD doctoral program, and a report on the Task Force on Educational Commons by Professor Joseph Sussman. As always, a lively discussion followed each presentation.

ESD's spring offsite was held on May 30, 2006, at the Hotel@MIT. The following presentations were made: a report on the ESD Graduate Committee and review of ESD's doctoral students by Professor Richard de Neufville; an ESD update by Professor Joel Moses; an update on the ESD Student Society by ESD PhD candidate Michael Hanowsky; and an overview of the doctoral program structure by Professor Joseph Sussman. A reception for attendees and significant others followed.

The Visiting Committee meeting was held November 14–15, 2006. Chairman Art Gelb welcomed attendees. Thomas Magnanti, dean of MIT's School of Engineering presented the Dean's Overview, followed by Professor Moses's overview of ESD, a review of the ESD Review Committee's recommendation, and the 2005 ESD strategic plan. The Visiting Committee met in separate closed meetings with the senior and junior faculty, and then saw research presentations by professor Richard Larson and associate professor Olivier de Weck. Professor Daniel Roos, director of the MIT-Portugal Program, gave an overview covering that program and other international activities. Professor Yossi Sheffi made a presentation at a dinner that evening. On the next day, members of the ESD Visiting Committee had breakfast in a closed meeting with ESD graduate students. This was followed by a presentation on the ESD Doctoral Program by Professor Richard de Neufville and overviews of the ESD Master's programs by Professor Tom Allen (codirector of LFM and SDM), Professor Dava Newman (Director of TPP), and Professor Sheffi (director and founder of MLOG). Professor Moses spoke on "Looking Ahead." A review of the report to the senior administration concluded the day.

### **ESD Alumni Advisory Council**

The ESD Alumni Advisory Council convened on April 5, 2007 at MIT. The agenda included a presentation on system safety by Nancy Leveson, professor of aeronautics and astronautics and engineering systems; an ESD overview by ESD and CTPID acting director Professor Joel Moses; and a group discussion of Alumni Council Issues. The group also attended Professor Yossi Sheffi's Miller Lecture, then convened at the Cambridge Marriott Hotel for a Miller Lecture reception and dinner.

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

### **ESD Seminar Series (sponsored by CESF)**

How America Chooses Its Presidents

*The Electoral College in US Presidential Elections: Logical Foundations, Mathematics, and Politics* by Dr. Alexander S. Belenky (April 25, 2007)

### **ESD Seminar Series (cosponsored by IBM and ESD)**

IBM and ESD cosponsored the IBM-MIT Innovation Lecture Series: *Engineering Systems Solutions to Real World Challenges*. This included:

- *Engineering Systems Solutions to Real World Challenges*, by Linda Sanford, senior vice president, Enterprise On Demand Transformation & Information Technology, IBM (October 23, 2006)
- *Engineering Systems Solutions to Real World Challenges in Healthcare* by Daniel Z. Aronzon, M.D., F.A.A.P., president and CEO, Vassar Brothers Medical Center; Nicholas Christiano, Jr., vice president and CIO of Health Quest; and Steven A. Katz, M.D., chief medical officer and senior vice president of medical affairs at Vassar Brothers Medical Center. (December 14, 2006)
- *Engineering Systems Solutions to Real World Challenges in Media and Entertainment: Threshold Animation Studios* by Larry Kasanoff, CEO, Threshold Animation Studios and producer/director/cocreator/writer of Foodfight! (March 22, 2007)
- *Systems Solutions to Real World Challenges at NYPD, The Real-Time Crime Center* by Jim Onalfo, NYPD deputy commissioner and CIO (May 3, 2007)

ESD visiting professor of engineering systems Irving Wladawsky-Berger, vice president of technical strategy and innovation at IBM, served as moderator for the series.

Randolph E. Kirchain, assistant professor of materials science and engineering systems, was the academic lead for the series, assisted by ESD communications director Lois Slavin.

### **ESD Seminar at IAP**

ESD offered a seminar on January 29, 2007 during MIT's IAP. The title was *Children's Hospital Boston and Its Physicians: More than the Sum of the Parts?* by Gregory Young, MD, president and CEO, Pediatric Physicians Organization at Children's Hospital; vice president for community pediatrics, Children's Hospital Boston; and assistant clinical professor of pediatrics, Harvard Medical School.

### **Employee Recognition**

At the Infinite Mile awards ceremony in May 2007, the School of Engineering honored CTL event coordinator Nancy Martin with the Infinite Mile Award for Sustained Excellence. Nancy was recognized for her gift for problem solving under pressure, as well as for her remarkable event-planning skills, terrific team-building skills and wonderful interpersonal skills.

## Space Changes

ESD relocated some faculty, staff, and students to NE20 (3 Cambridge Center). This included a section of the Lean Aerospace Initiative, former members of the CIPD and some staff and students associated with the MIT-Portugal Program, which involves several ESD faculty.

## Personnel Changes

There were no personnel changes in ESD HQ.

**Joel Moses**

**Acting Director, Engineering Systems Division**

**Acting Director, Center for Technology, Policy, and Industrial Development**

**Institute Professor and Professor of Computer Science and Engineering Systems**

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

## Leaders for Manufacturing

An active partnership among MIT School of Engineering, the MIT Sloan School of Management, and more than 25 corporations, the MIT Leaders for Manufacturing (LFM) program produces world-class leaders for manufacturing and operations. This innovative two-year graduate program, created in 1988, includes an integrated engineering and management curriculum along with a six-and-a-half month internship at a partner company. Students earn an MBA or master of science in management as well as a master of science in one of eight participating engineering programs. LFM focuses on theory and global practice from concept development through product delivery, including challenges faced on factory floors and in global supply chains. Corporate partners provide generous fellowships for all students.

LFM was launched with significant industry funding and is in its 19th year of operation. The program is a 24-month dual master's degree experience, involving a single integrative research project carried out on site in partner firms. Within the School of Engineering, LFM students can earn degrees in eight master's programs.

On the administrative level, LFM and System Design and Management (SDM) are managed by a common staff, enabling conservation of resources. Both LFM and SDM are cosponsored by MIT's School of Engineering and School of Management and reside within ESD.

## Academic Program

Forty-six students in the class of 2007 completed the LFM Fellows Program. Each of these graduates completed an internship at a partner company during the summer and fall of 2006. 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 and implementation.

Another 47 students (class of 2008) completed their first year of on-campus studies and started their six-month internships. Applications were down from 200 to 191, but were up significantly from 2005; 48 new students (class of 2009) were admitted and began an intensive summer session in June of 2007. The class of 2009 has an average of five years' work experience.

Don Rosenfield continues to serve as the director of the LFM Fellows Program. Codirectors for the LFM and SDM programs are David Simchi-Levi from the School of Engineering and Tom Allen from the MIT Sloan School of Management. On July 1, 2007, Warren Seering replaced David Simchi-Levi, who will be on sabbatical. Ron Slahetka continues as industry codirector.

LFM's academic program consists of a mix of management and engineering courses. Regular ESD courses include ESD.60 Lean/Six Sigma Processes, taught by Steven Spear, and ESD.73 Materials Selection, Design, and Economics, taught by Joel Clark. Both of these courses were developed by ESD. Other courses listed in ESD required or taken by a significant number of students include ESD.267J Supply Chain Planning (taught by Steve Graves and David Simchi-Levi), ESD.268J Manufacturing System and Supply Chain Design (taught again by Graves and Simchi-Levi), ESD.32J Product Design and Development (cotaught by Warren Seering), ESD.750 Engineering Probability and Statistics (taught by Arnie Barnett and Roy Welsch), and ESD.750 Systems Optimization and Analysis for Manufacturing (taught by Steve Graves and Jeremie Gallien).

LFM students are enrolled in eight engineering disciplines. These include:

- Aeronautics and Astronautics
- Biological Engineering
- Chemical Engineering
- Civil and Environmental Engineering
- Electrical Engineering and Computer Science
- Engineering Systems
- Materials Science and Engineering
- Mechanical Engineering

The LFM 2009 class, by engineering discipline, is as follows:

- Aeronautics and Astronautics: 0
- Bioengineering: 2
- Chemical Engineering: 3
- Civil and Environmental Engineering: 3
- Electrical Engineering and Computer Science: 7

- Engineering Systems: 25
- Materials Science and Engineering: 1
- Mechanical Engineering: 7

### **Marketing Efforts**

In 2005, LFM applications had been decreasing for a number of years. LFM increased its marketing efforts, and secured and implemented a significant marketing budget. New marketing efforts for the classes of 2008 and 2009 included the scheduling of information nights, rewriting the LFM website, improvements made to both the Sloan and Engineering websites, improved admit packets, new self-mailing postcards, an Interview Fest in which all finalists come to MIT for interviews, Virtual Visits, and year-round purchase of GMASS names. LFM had 191 applications this year, higher than our low in 2005, although still short of our goal.

### **China LFM**

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

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

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

MIT and SJTU signed a memorandum of understanding on August 29, 2006, in Shanghai. We now have 12 companies signed up for CLFM, with a goal of 14 or 15 by May 2008. CLFM industry partners include Caterpillar, China Longgong, Dell, Flextronics, GITI Tire, Honeywell, Intel, Novartis, Schlumberger, The Timken Company, and United Technologies Corporation.

## **LFM Alumni**

The LFM Alumni Council, which is in its fifth year, meets (virtually) each month, with the aim of improving the LFM network and the LFM program and enriching the lives of the alumni. All alumni are welcome. Jay Burkholder, LFM 1998, remains as the official voice of the alumni at the LFM Operating Committee. The LFM 2006 Conference took place in Morristown, New Jersey, where alumni gathered to see presentations by Honeywell, Cisco, and Booz Allen Hamilton executives, and participated in breakout sessions focusing on various topics associated with the conference theme, "Competing in a Shrinking World."

As part of LFM's and SDM's commitment to lifelong learning, an initiative begun in FY2002 was continued to encourage LFM and SDM alumni to stay connected with MIT by sharing relevant information. LFM and SDM continued to schedule monthly webcasts presented by MIT faculty and various LFM and SDM alumni. The content of each webcast, also called a webinar, provides valuable information on the latest trends, cutting-edge developments, and innovative strategies, all of which pertain to manufacturing and/or systems design. The presentations are given in real time via the Internet and telephone; this 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.

The alumni have also been instrumental in setting up an infrastructure to support LFM. Through an organized fundraising effort, the alumni have established three different funds to support the program:

- William C. Hanson and Don W. Davis Leadership Fund
- Alumni Annual Fund
- Endowed Discretionary Fund

This year the funds distributed \$5,000 to support the students on the International Plant Trek and \$25,000 for first-year scholarships.

## **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 2006 and spring 2007 included Steve Cook, director, TN Manufacturing, Dell; Jean Francois Baril, senior vice president, Nokia; Tim Lee, vice president of manufacturing and labor relations, GM North American Operations; Scott Gilfoil, Duco Pasmooij, and Aaron Raphel of Apple; Tim Cawley, senior vice president, Motorola; Roland Sargeant, manager, Future Plane Production, Boeing; Mary Puma, CEO, Axcelis; Mario van Vliet, senior vice president, CapGemini; Professor John Deutch of MIT; Camilla Denison, CEO, Champion Labs; Don Allen, vice president, ABB; Rick Dauch, executive vice president,

American Axle and Manufacturing; Matthew Bromberg, vice president and general manager, Pratt & Whitney; and Edmond Hardin, senior manager, Bearing Point.

### **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, local plant tours were held at the following locations: Intel, Hudson, MA; Genzyme, Cambridge, MA; Axcelis, Peabody, MA; Novartis, Cambridge, MA; and Raytheon, Andover, MA. Students also participated in the annual two-week plant trek that included visits to American Axle & Manufacturing, Ford, and GM in Detroit; The Boeing Company and Amazon in Seattle, WA; Honeywell in Phoenix, AZ; Dell, Solectron, and Cisco in Austin, TX; and UTC in Ponce, Puerto Rico.

The International Plant Tour went to Singapore, Malaysia, and Thailand. While in Singapore, the group attended a panel discussion with the Economic Development Board, toured the Port of Singapore Authority—the world's largest container transshipment hub, and visited BD Medical, a leading manufacturer of medical devices. The group toured these facilities along with students in the Singapore-MIT Alliance (SMA). In Malaysia, LFM students spent a morning at Flextronics International in Johor Bahru. Later in the trek, in Kuala Lumpur, Malaysia, the group visited the operations center at General Electric Engine Services Malaysia—a major provider of engine overhaul services to various commercial airline customers, and Freescale Semiconductor Malaysia—a modern semiconductor facility for assembly and testing of integrated circuits. The final portion of the trip in Thailand included a tour of the General Motors Thailand Assembly Center.

### **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. Of the class of 2007, 52 percent accepted positions within manufacturing and operations companies, and 37 percent accepted positions within partner companies.

### **Internships and Research**

The matching of students to partner internships and faculty advisers is a complex process that the program has managed from inception. This year LFM made two major changes. First, a two-way matching process that explicitly captures company preferences was implemented. The method requires significantly less lead time and led to higher satisfaction from the different constituents. We also linked 12 internships for the LFM 2008 class to company-faculty-student research groups. These groups allow for cross-internship learning and the development of common themes. The groups are:

- Call Center Operations
- Rationalizing the Supply Base
- Lean in Product Development
- Lean Enterprise

### **Student Awards**

Sabrina Chang and John Heiney each received a best thesis award, given for the second year by the program. Award winners were given laptop computers generously donated by Dell. C.Y. Lee received the Harrison Smith Award, a leadership award given annually to honor a first-year LFM who exemplifies Harrison Smith's most remembered qualities while at LFM: living life to the fullest, bringing the class together, and making happy and lasting memories of the LFM experience for the entire cohort. Smith died tragically in a car accident shortly after his graduation in 1999 while en route to a position at Dell.

### **LFM at IAP**

Dr. Donald Rosenfield, director, LFM Fellows Program and senior lecturer, MIT Sloan School of Management, presented *The Role of Operations in Corporate and National Competitiveness* on January 23, 2007.

### **Governance**

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

### **Faculty Publications**

Several LFM-affiliated faculty published books this past year, including Donald Rosenfield, whose book, *Operations Strategy: Competing in the 21st Century*, was coauthored with Sara Beckman.

Another LFM-affiliated faculty member who published a book this year is Thomas J. Allen, who coauthored *The Organization and Architecture of Innovation: Managing the Flow of Technology* with award-winning German architect Gunter Henn. Dr. Allen is a Margaret MacVicar faculty fellow, Howard W. Johnson professor of management, professor of engineering systems, and codirector of LFM and SDM.

James M. Utterback authored *Design-Inspired Innovation*. He is the David J. McGrath Jr. (1959) professor of management and innovation and professor of engineering systems.



## **New Partners**

An active student, staff, and company committee has been very successful at bringing new partners to LFM. New partner companies that have joined in the past 18 months include Pepsi Cola Bottling, General Dynamics, PerkinElmer, and Amgen. Companies that joined last year and are continuing include American Axle and Manufacturing, Cisco Systems, and Flextronics International. New internship sponsors include iRobot and Schlumberger.

**Tom Allen, Codirector, Howard W. Johnson Professor of Management, and Professor of Engineering Systems**

**David Simchi-Levi, Codirector and Professor of Civil and Environmental Engineering and Engineering Systems**

**Ron Slahetka, Industry Codirector**

**Don Rosenfield, Director, LFM Fellows Program**

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

## **System Design and Management**

SDM was created in 1996 in response to industry's need to develop the next generation of leaders in product design and systems engineering. SDM combines cutting-edge courses from the MIT Sloan School of Management and MIT's School of Engineering, enriching the experience with innovative distance learning, flexible matriculation options, and an interdisciplinary perspective. SDM prepares graduates to think outside the box, lead across organizational boundaries, and inspire others to collaborate and innovate in both technical and nontechnical arenas.

The centerpiece of SDM's portfolio is its rigorous 13- to 24-month graduate program. Built on a foundation of core courses in system architecture, systems engineering, and system and project management—and integrated with classes in engineering and specially designed courses in management—this program leads to a master of science degree granted jointly by the School of Engineering and MIT Sloan School of Management.

Targeted to professional engineers with three or more years of experience, SDM has a 15-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 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.

## Distance Education Delivery

SDM continues to evaluate its distance education delivery with the goal of increasing the quality of the remote-learning experience while reducing costs, both for MIT and for sponsoring companies. An innovation in the past year includes streaming all classes on the web so that students who cannot attend a session can view the video of it almost immediately, without having to wait for a videotape to be mailed to them. This has increased student satisfaction, since many SDM students continue to work at their companies and occasionally travel and must miss a class.

Pat Hale continues as director for his third year. This past year, Pat was elected and served as president-elect of the International Council on Systems Engineering (INCOSE); he will assume the role of president next year. This role has provided the program a high level of visibility in an organization of industry and educational institutions highly aligned with the SDM academic mission. Codirectors for the program are David Simchi-Levi from the School of Engineering and Tom Allen from MIT Sloan School of Management. Warren Seering will take over as the Engineering codirector beginning July 1, 2007, while David Simchi-Levi is on sabbatical. John Grace is the industry codirector.

## Student Statistics

In January 2007, SDM admitted its 11th class, enrolling 61 students. As was done in FY2006, SDM put on information evenings in July, September, October, April, May, and June for local MIT alumni and others interested in SDM as a way to recruit prospective students for SDM 2007. These successful events brought more than 100 prospective students to campus or suburban locations, where they heard presentations about the program from several faculty, students, and alumni.

### System Design and Management Admissions Statistics

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Admitted	35	58	47	50	37	27	36	37	62	58	61
On campus	8	16	6	14	8	7	18	27	44	44	47
Self-supported	3	1	2	5	2	1	6	25	42	34	40
Research assistant	3	12	2	4	3	1	10	0	0	0	1
Distance education	27	42	41	36	29	18	17	10	18	14	14
Company-sponsored	29	45	43	41	32	25	20	12	20	24	21

This past year John Grace, SDM industry codirector, developed a new partnership structure for companies interested in engaging in a lifelong, systems-based approach to leadership and innovation. With this partnership structure, SDM also goes beyond traditional master's programs by addressing not just the needs of individuals, but the entire system of which they are a part. There are many ways that companies can participate in SDM to develop a systems-thinking capability for the entire organization. For example, SDM's one-year, primarily-at-a-distance certificate program in systems engineering is designed for individuals who are interested in acquiring or deepening

systems thinking skills and for companies that want to extend this capability among their staff. And a weeklong organizational leaders program, intended for those to whom students in SDM's degree and certificate programs report, helps managers to understand how to apply these new concepts, develop their SDM employees, and deploy systems thinking throughout their organizations.

### **Sponsoring Theses of Self-Funded SDM Fellows**

In the past few years, companies have also engaged the program using self-funded fellows for research internships that then develop into SDM theses. Support typically involves identifying a thesis topic and naming a company mentor to work with a student and MIT faculty member on a topic of pressing concern. Thesis sponsorship allows a company to expand its presence within SDM at a modest cost, work with an SDM fellow and MIT expert on a relevant project, and favorably position the company for a broader relationship with SDM and MIT.

### **MIT-Industry Partners System Engineering Program**

This past year was the sixth for the MIT-Industry Partners Systems Engineering Program. This year, program involvement included United Technologies Corporation, Boeing, and John Deere. 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 116 students completing the Certificate Program and more than 100 organizational leaders completing the six days of content in the Organizational Leaders Workshop. With its active participation in all levels of the program, UTC now has more than 220 employees who have benefited from the SDM program. The next cohort of certificate students for FY2007 is expected to reach 24, with students from UTC, Boeing, John Deere, Wachovia, and Tata Interactive.

### **Career Development for SDM Self-Sponsored Students**

Led by career development director Helen Trimble, SDM has provided career services to its self-funded students for the past three years. These services include individual career consultation and coaching in presentation skills; resume writing; networking and negotiating; company, career, and opportunity research; and government regulations for foreign nationals. SDM graduates have achieved 100 percent employment during this same period in industries and organizations as diverse as nonprofits, aerospace, financial services, and in technology consulting and leadership roles in product development, business strategy, and operations.

**Tom Allen, Codirector, Howard W. Johnson Professor of Management, and Professor of Engineering Systems**

**David Simchi-Levi, Codirector, Professor of Civil and Environmental Engineering and Engineering Systems**

**Jack Grace, Industry Codirector**

**Pat Hale, Director, SDM Fellows Program**

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

## Technology and Policy Program

The Technology and Policy Program (TPP) is an interdisciplinary graduate-level program that focuses on issues at the interface of technology, policy, and the sociotechnical aspects of complex systems. TPP is dedicated to educating engineers and scientists who wish to lead in the development and implementation of responsible technology strategies and policies for the benefit of humankind.

TPP's mission is "To educate engineers and scientists in responsible leadership of technology development by implementing policies for the benefit of humanity." Embedded in this mission statement are several guiding principles:

- Dual professional excellence with technical rigor in engineering or science and understanding of policy analysis culminating in a research master's thesis
- Knowledge and flexibility to manage conflicting interests and values at all stages of the policy process
- Effective leadership and communication skills in the technology policy process.

TPP is founded on the premise that the solutions to most challenging technical problems confronting society are not purely technical ones. Engineering and science approaches alone are insufficient because these problems reside within both social *and* technical contexts—both of which must be considered in formulating successful solutions. Solving these sorts of problems requires leaders who have technical skills, along with a sophisticated understanding of the political, economic, and legal concerns that govern the ways in which solutions are devised, chosen, financed, and administered. TPP strives to give students a thorough understanding of the interface between technology and policy and to create leaders who are engineers and scientists rather than engineering and scientific leaders.

Within the intellectual and educational ambit of the School of Engineering's Engineering Systems Division (ESD), the TPP graduate educational program focuses on the development of skills in policy development and analysis, and the program requires a significant research thesis as a fundamental component 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 two-year master's 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 master's or doctoral degree in another program concurrent with their TPP SM degree. Each entering class numbers around 40 students (39 this coming fall), comprising approximately 40 percent women and 35 percent international students, with 35 percent of the students pursuing dual degrees, which may require an additional semester or two to complete. This year, 33 students graduated with master's degrees in technology and policy, and four master's students were accepted to continue their studies at the doctoral level. This year's Best Thesis in Technology and Policy was awarded jointly to Wen Feng

and Nicolas Osouf, supervised respectively by Professor David Marks and Dr. John Reilly. Feng's thesis title is "Driving Segments Analysis for Energy and Environmental Impacts of Worsening Traffic." Osouf's is "The Potential for a Nuclear Renaissance: The Development of Nuclear Power Under Climate Change Mitigation Policies."

The TMP track within the ESD PhD program currently has 30 students, reflecting a steady-state admission rate of about five students per year. Eleven students received their TMP PhD this past academic year.

Fellowship funding was provided to several incoming students in order to attract the top TPP candidates to MIT. This year these funds came from the Rabinowitz and de Neufville funds, as well as a tuition-only Keil Fellowship. The Office of the Dean of the Graduate School also provided matching fellowship funding to TPP students this year, specifically for underrepresented minority (URM) students. These fellowships continue to allow us to recruit and attract excellent students. In particular, in the past two years we have been fortunate to have 100 percent of our admitted URM students enter MIT and TPP for their graduate studies. Fellowship funds have been generously provided by TPP alumni and donors who also make possible several other student benefits, including funding for recruitment and outreach, support of TPP women student events, support for portions of the TPP visiting speaker series, and alumni relations. This past year, TPP students benefited from discussions with Professor Noam Chomsky and Doug Engelbart, a debate between professors Nicholas Ashford and Harvey Sapolsky, and alumni panels on leadership and careers.

TPP maintains ties to its more than 900 alumni and works to foster a strong alumni community through the biannual publication of the *Alumni Directory* and regional gatherings in Washington, D.C. and Boston. For example, this January's gathering in Washington was attended by more than 50 people, including 30 local alumni. TPP alumni also receive e-newsletters several times a year, including articles written by current and former TPP students, as well as faculty and staff. Following TPP's 30th anniversary in 2006, TPP has worked to document its history, which we expect will soon be posted on the TPP website, <http://web.mit.edu/tpp/>.

TPP initiated a much closer working relationship with our MIT Washington office this year. Dr. William Bonvillian has been a pleasure to work with, and he and Professor Dava Newman meet at every opportunity to assure a science, technology, and policy agenda and opportunities for MIT students both at the undergraduate and graduate level. The events TPP endorsed and helped facilitate this past year included our summer internship program in Washington D.C., faculty panel discussions at MIT, and an IAP and spring offering of Science, Technology, and Policy boot camp, which Dr. Bonvillian offers.

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 2007, 20 students (half the first-year class) traveled to Washington to learn more about career options from TPP alumni and attend meetings with prospective internship employers, including the World Bank, US government agencies such as NASA and the White House Office of Management and Budget, and private consulting



companies and think tanks such as ICF and the Center for Strategic and International Studies. Several of our students found internships in Washington this summer, while others are working elsewhere in the United States or abroad, including at the Far East Organization in Singapore and Malaysia, and for nonprofit groups in Peru and Pakistan. Students whose internships were unfunded were able to earn valuable experience by taking advantage of living-cost funding provided by TPP alumni and donors—including Larry Linden, Phillip Ng, Francis Chin, and Donald Cooke—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. Starting this year, the Student Leadership funding will be provided by the new TPP Leadership Challenge for extra student events that emphasize leadership and team building. In many respects, this additional funding is recognition of all the very dedicated students in the program who make so many TPP initiatives possible.

Each year, TPP students also nominate faculty members and research for their TPP Appreciation Award. This year's nominees were Nicholas Ashford, Ernst Berndt, Richard de Neufville, David Marks, Dava Newman, Kenneth Oye, Jonathan Raab, and John Sterman. At the annual TPP Student Banquet, Professor Sterman was recognized as the recipient of this award. Past winners are Nicholas Ashford, Joseph Sussman, Richard de Neufville, Kenneth Oye, David Marks, Joseph Saleh, John Reilly, and Ernst Berndt.

This past year, ESD.10 Introduction to Technology and Policy was team-taught by professors Annalisa Weigel and Daniel Roos. Professor Weigel has been leading this core introductory course for the Program for several years. Professor Weigel leads the continuous refinement of this course through the availability of curriculum development funds from the Lord Foundation, which also supports other course changes at TPP. Dr. Frank Field will be the lead instructor for 2007–2008. Another notable TPP curriculum development is the addition of a course from the Department of Economics (14.003 Microeconomic Theory and Public Policy), which is the result of numerous discussions between the TPP director and director of education, along with faculty from the Economics Department, who were very receptive to working together. We now offer two courses to students to fulfill their economics requirement—namely, 14.003 and 15.011 Economic Analysis for Business Decisions from the Department of Management (a part of the TPP core since the inception of the Program). This year, TPP also supported a new energy course in the Department of Urban Studies and Planning, taught by Jonathan Raab.

TPP is a founding member of the Technology, Management, and Policy Graduate Consortium, which includes programs in North American, European, and Asian universities, and allows TPP master's students and TMP-track ESD doctoral students to share their research and network with students in similar programs. At the Consortium's sixth annual conference, hosted by Carnegie Mellon University in Pittsburgh, PA from June 24–26, 2007, six MIT students presented their research. Previous meetings were held in Portugal, the Netherlands, Washington D.C., Cambridge, UK, and here at MIT.

Although financial support from the Cambridge–MIT Institute has ended, the Technology and Policy Program maintains a special relationship with the Technology Policy master of philosophy (MPhil) program at Cambridge University, a Consortium member. MIT TPP was instrumental in developing and initiating the program in the early 2000s, and for many years participated in an intern exchange with them. We are still supporting one TPP student to spend the summer of 2007 at Cambridge University to work with the Tech Policy faculty on research.

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 five-year, \$2.97 million grant from the National Science Foundation's IGERT program and a grant from the Cambridge–MIT Institute, PoET aims to improve responses to emerging technologies by increasing understanding of the economic, security, environmental, and cultural implications of technological advances and the uncertainties surrounding them. This year's work saw the continuation of the research in emerging computing technologies, including a workshop conducted at the Oxford Internet Institute. In addition, the program has been working with Professor Drew Endy in the Department of Biological Engineering on topics emerging in the area of synthetic biology, with several research collaborations developing. PhD students from ESD, CIS, and STS are funded by PoET IGERT traineeships. Visit <http://poet.mit.edu/> for more information.

Both TPP and PoET offered seminars during IAP. PoET sponsored *Protocols and Standards for Emerging Technologies: Issues in Synthetic Biology and the Future Internet*, by Kenneth Oye, associate professor of political science and engineering systems; Merritt Roe Smith, Cutten professor of the history of technology; Dave Clark, senior research scientist, CSAIL; and Tom Knight, senior research scientist, EECS (February 1, 2007). TPP sponsored a series that included *Pathways to Sustainable Development: Co-optimizing Competitiveness, Employment, and Environment* by Nicholas Ashford, professor of technology and policy (January 30, 2007), and *Issues in Lean Enterprise Architecting and Transformation* by Deborah Nightingale, professor of the practice of aeronautics, astronautics, and engineering systems (January 23, 2007).

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

**Dava Newman**

**Director**

**Professor of Aeronautics and Astronautics and Engineering Systems**

More information about the Technology and Policy Program can be found at <http://tppsver.mit.edu/>.

## **Center for Engineering Systems Fundamentals**

This was the second academic year for the Center for Engineering Systems Fundamentals (CESF), which was formed as a new center within ESD in 2005. The major research focus of CESF is on the fundamentals and cross-cutting issues in engineering systems.

CESF researchers seek to identify and extract fundamental concepts, methodologies, and formalisms that will eventually define the new field called engineering systems. The process requires research on real problems, working at the intersection of engineering, management, and social science. In the end, we are engineers, wanting to design and build systems, but with an awareness of the complexities and multifaceted nature of such systems. CESF currently engages in five research areas:

**Preparedness and Response to Pandemic Influenza.** This effort focuses on understanding the dynamics of influenza progression under alternative controls in the form of social distancing and hygienic steps.

**Preparedness and Response to Hurricanes.** This research examines the sequence of decisions available to governmental decision makers in the days and hours before a hurricane hits the mainland. The process is replete with uncertainty, yet decisions must be made in a timely manner, including mobilization, repositioning of supplies and equipment, and evacuation.

**US Presidential Elections: Fairness of the Voting Precinct Queueing Process.** This work seeks to understand the relationship between queueing delays for voters and the resources (people and technology) deployed to voting precincts. The goal is to devise a scientifically based method for deployment of these resources to provide equitable access to all voters in a region (county or state).

**Congestion Pricing for Critical Infrastructure Systems.** This research examines alternative ways of pricing electricity, automobile access to urban centers, and similar infrastructural services to match supply/demand patterns, in an effort to shave peaks of demand and fill in the valleys of demand.

**Distance Learning Systems and Processes for Developing Countries.** This work is closely affiliated with LINC (the Learning International Networks Consortium), the CESF volunteer effort aimed at assisting developing countries to use e-learning in creative ways to bring quality higher education to underserved communities.

### **A New MIT Subject on Fundamentals**

At the ESD off-site retreat in January 2007 it was decided that a new required subject was needed for ESD doctoral students, one that would cover engineering systems fundamentals focusing on quantitative modeling and research methods. As a result, professor Daniel Frey and CESF director Richard C. Larson agreed to codevelop such a subject and offer it in the 2007 spring semester. The course, ESD.86 Models, Data, and Inference for Socio-Technical Systems, was offered this spring. It emphasized (1) the use

of data and systems knowledge to build models of complex sociotechnical systems for improved system design and decision-making; (2) enhancing model-building skills; and (3) review of classical and Bayesian statistics, hypothesis tests, regression, correlation and causation, and simple data-mining techniques.

About 15 students took the subject for credit and about another five were listeners. The enrollment in the next academic year will not be restricted to ESD students, as master's students in various professional degree programs have also expressed interest in the subject.

### **Research Initiatives**

We have had an active year pursuing CESF research initiatives, and our work has involved numerous MIT faculty members, both inside and outside ESD. In selecting promising targets of research opportunity, we were guided by the ESD mission that our work should focus on the intersection of traditional engineering, management (broadly defined), and social sciences. We have written an invited paper on this topic, "Holistic Trinity of Services Sciences: Management, Social, and Engineering Sciences," currently under review by the *IBM Systems Journal*.

### **Voting in US Presidential Elections**

Along with ESD research affiliate and long-time friend of MIT Dr. Alex Belenky, CESF director Richard Larson has been studying queueing at election precincts during US presidential elections. There are those who argue that potential voters were discouraged from voting in both the 2000 and 2004 presidential elections due to too few voting machines and support personnel in certain voting places. Belenky and Larson have written a paper about this topic, "To Queue or Not to Queue? In a US Presidential Election, That Should NOT Be a Question!," published in the June 2006 issue of *OR/MS Today* (available online at <http://www.lionhrtpub.com/orms/orms-6-06/frqueues.html>). Larson and Belenky have also written op-ed columns and letters to the editor (these are available on request).

Belenky and Larson recently submitted a proposal in this area to the Pew Charitable Trusts, in response to an RFP, leading to a new "services science" method of deploying voting machines and support personnel that would guarantee voter parity for voters of all political parties. As of this writing, the proposal is under review.

### **Social Distancing in an Influenza Pandemic**

CESF has arranged a team of students, faculty members, and senior research staff to examine preparedness and response to a potential influenza pandemic, along the lines of the 1918–1919 Spanish Flu, for which Boston was the urban epicenter. Participating students have ranged from a freshman UROP to ORC doctoral students. We have established ties to the Harvard School of Public Health and, with MIT's Bill Van Schalkwyk, are coordinating our work with MIT's plans for response to pandemic influenza.

Our first research paper on this topic, “Simple Models of Influenza Progression within a Heterogeneous Population,” was published this year in the journal *Operations Research*. An accompanying blog has sparked interest in this research: <http://orforum.blog.informs.org/>.

Our research into pandemic influenza has been accelerated by the generous support of a grant by the Sloan Foundation (Dr. Stan Finkelstein, coprincipal investigator) and by an IBM Faculty Research Award.

### ***Hurricane Decision-Making: Example of Disaster Preparedness and Response***

PhD student Michael Metzger has been working with Richard Larson to create a quantitative planning model to frame and formulate rational policies for preparedness and response to hurricanes. This is a specific example of a broader interest and expertise at MIT in preparedness and response models for disasters of all types. Metzger has identified aspects of all three parts of the ESD engineering/management/social science model mentioned earlier as important in this work. Findings have already been reported at two national research conferences.

### **MIT LINC Fourth Annual Conference**

MIT LINC—the Learning International Networks Consortium (<http://linc.mit.edu/>), a volunteer effort housed in CESF—is a consortium of educators from around the world who are interested in using distance and e-learning technologies to help their respective countries increase access to quality university education for a larger percentage of the population.

Arrangements are underway to hold the next LINC international symposium in October 28–30, 2007, at the Dead Sea near Amman, Jordan with a follow-on executive session in Dubai on October 31–November 1. Private sources in Dubai have pledged \$100,000 to underwrite the symposium. Other support is leading us to our goal of \$200,000. One key theme will be on the high school blended learning project. Updated accounts of the symposium are available at <http://linc.mit.edu/conference/>. We are most thankful for the energy and support of a large network of LINC volunteers, including students, alumni, and staff of MIT, and academics from the Middle East.

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

### **Awards and Proposals**

We benefited this year from the following awards:

- Cordell Hull grant (\$100,000): Strategies to Overcome Network Congestion in Infrastructure Systems
- IBM Faculty Research Award (\$40,000): Modeling Pandemic Influenza
- Research in Engineering Fundamentals (\$100,000): MIT ESD Portugal Project



- Electricity Management (\$100,000): MIT ESD Portugal Project
- The Sloan Foundation of New York (\$350,000): Pandemic Influenza: Social Distancing and Hygienic Policies to Reduce its Prevalence

We have several proposals under review:

- Pew Charitable Trusts: Educating Election Day Planners (a pilot project, with Alex Belenky)
- NSF ERC: Engineering Research Center for Network Sciences for Large Critical Infrastructure Systems: Center for Dynamic Monitoring and Decision Systems (C-DYMONDS), Carnegie Mellon University Core Partner Institution: MIT, Marija Ilic, principal investigator
- NSF ERC: Center for Rapid Automated Fabrication Technologies (CRAFT), USC, MIT, and others, Behrokh Khoshnevis, director
- DHS University Center of Excellence: National Center of Excellence for the Study of Natural Disasters, Coastal Infrastructure and Emergency Management (with the University of Washington, NPS, and others), Mark Haselkorn, principal investigator
- NSF: Humanitarian Service Science and Engineering

## Outreach

There were many public CESF presentations this past academic year (July 1, 2006–June 30, 2007). Among them are the following:

- “Operations Research, Public Safety and Homeland Security,” in invited session, Applications of Operations Research to the Criminal Justice System, The Annual Conference of the National Institute of Justice, Washington, D.C., July 17-19, 2006.
- “Police OR: From Routine Operations to Catastrophe Response,” Symposium on Operations Research and the Criminal Justice System, September 28–29, 2006.
- “Holistic Trinity of Services Sciences: Management, Social, and Engineering Sciences,” IBM Workshop, Services Sciences Management and Engineering, New York, October 6, 2006.
- Invited to organize an Invited Cluster of Sessions for the Pittsburgh National INFORMS Meeting.
- “Simple Models of Influenza Progression and Control,” invited lecture, University of Massachusetts, Amherst, MA, March 9, 2007.
- “A Bayesian Data Trawler for Urban Public Safety,” Workshop of the National Institute of Justice, US Department of Justice, Boston Police Headquarters. One Schroeder Plaza, Boston, Massachusetts, June 6, 2007.
- “Holistic Trinity of Services Sciences.” Invited annual presentation, Analytics Corporation, Dover, Massachusetts, June 14, 2007.

- “Designing and Managing Critical Infrastructures at the Intersection of Engineering, Management and the Social Sciences.” OECD Workshop on Critical Infrastructures. Lisbon, Portugal, June 26, 2007.
- Other international outreach

In addition, CESF is publishing a working paper by Richard Larson and M. Elizabeth Murray in the *Journal of Science Education and Technology*, “Distance Learning as a Tool for Poverty Reduction and Economic Development: A Focus on Two Countries, China and Mexico.”

Finally, Richard Larson and two other senior MIT faculty members have been serving on the senior advisory team of the Lahore University of Management Science (LUMS), a major private university in Pakistan that is opening a new School of Science and Engineering. (LUMS is patterned after MIT and the India “IITs”). The second trip to Lahore occurred in February 2007; it is expected that there will be annual trips in the years ahead.

**Richard Larson**

**Director**

**Professor of Civil and Environmental Engineering and Engineering Systems**

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

### **Center for Technology, Policy, and Industrial Development**

The Center for Technology, Policy, and Industrial Development (CTPID) focuses on contemporary industrial problems at the nexus of social, natural, and technological systems, and the dilemmas that emerge from interactions among these systems. CTPID examines the opportunities and challenges these dilemmas offer our industrial enterprises, as well as constraints they impose on the scope and extent of their activities.

Founded in 1985, CTPID brings together more than 80 faculty, researchers, students, and staff from the fields of engineering, management, and social sciences to approach the complex issues that shape modern economies. Participants in the research programs that CTPID develops come from industry and government as well as from academia. Among the sectors of current focus at the Center are aerospace, automotive, information quality, materials systems and environmental law.

CTPID is a major research center associated with the School of Engineering’s Engineering Systems Division (ESD), which aims to unite interdisciplinary faculty and students to study large-scale, complex engineering systems. CTPID contributes to 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. AY2007 projects included the Communications Futures Program (CFP), the Ford–MIT Alliance (administered by CTPID), the International Motor Vehicle Program (IMVP), the Labor Aerospace Research Agenda (LARA), the Lean Aerospace Initiative (LAI), the Materials Systems Laboratory (MSL), the MIT Information Quality program (MIT IQ), and the Technology and Law program (T&L).

CTPID's administrative officer Su Chung became director of MIT's Administrative Services Organization at the end of the 2007 fiscal year. Su spent 19 years at CTPID and had great experience with all its programs. We are pleased to announce that Su was replaced by Lissa Natkin, who has had long experience as an administrative officer at MIT.

The acting director of CTPID is Professor Joel Moses, Institute Professor, professor of computer science and engineering systems, and acting director of the Engineering Systems Division. CTPID's administrative offices are located in E40-227.

### **Highlights of the Year**

In December 2006 Professor Fred Moavenzadeh, CTPID's director for eight years (until July 1, 2006), published "The Center for Technology, Policy, and Industrial Development." This 82-page report, which was written to mark CTPID's 20th anniversary, documents CTPID's accomplishments, intellectual contributions, and impact on MIT and the larger academic, governmental, and industrial communities. The report is available in PDF format on the CTPID website at <http://web.mit.edu/ctpid/www/>. It is not intended as a comprehensive history of the Center; rather, the report focuses on tracing the development of the emerging field of engineering systems to which CTPID has contributed. Professor Moavenzadeh, James Mason crafts professor and professor of civil and environmental engineering and engineering systems, received assistance on this publication from Susan Cass and Timea Pal.

In December 2006, the Ford-MIT Alliance, the Institute's longest-running research partnership with industry, was pleased to announce renewed funding: \$3 million per year for a third five-year term. The new funding period will take effect on January 1, 2008 and will run through 2012. Continued funding is an acknowledgement by Ford of the Alliance's significant contributions to the strategic work of the company's Scientific Research Laboratory. The renewal also acknowledges CTPID's contributions to a diverse group of research initiatives involving product development, active safety, and powertrain technologies.

During in the past year, the Ford-MIT Alliance has continued its work on cutting-edge environmental and energy technologies and policy issues. These include carbon mitigation and a nanotechnology project designed to increase the storage capacity of ultra capacitors, replace batteries, and compete with fuel cells. The Alliance is a founding partner in the MIT Energy Initiative, and is contributing to the MIT Energy Initiative's (MITEI) effort to define future energy systems.

At the end of 2006, Elaine Savage replaced Joseph H. Saleh as the MIT executive director of the Ford-MIT Alliance.

Another of CTPID's research entities, the Lean Aerospace Initiative (LAI), continues to make significant contributions to the implementation of lean transformation principles in the aerospace industry. The program has expanded its assistance to the United States Air Force, with support to its Material Command and the Space and Missile Systems Center (SMC). In addition, several new members joined the LAI consortium in the last year, including the United Launch Alliance (a joint venture between Boeing and Lockheed Martin), the United Space Alliance, and the US Army. Boeing Commercial Airplanes also became a member, and William Schnettgoecke Jr., vice president of Lean for The Boeing Company, joined LAI's Executive Board. In another development, consortium members recently agreed to new affiliate-level and collaborative associations, which will further broaden the scope of LAI's reach. LAI has also agreed to expand its membership outside the aerospace community and has an active membership campaign ongoing.

Since January 2007, LAI also began a series of knowledge exchange events (tutorials, workshops, executive seminars, and roundtables) designed for researchers and practitioners to share cutting-edge research directly with consortium and public participants. They have garnered attention not only from LAI consortium members, but also from interested parties outside of MIT.

In November 2006, the MIT Information Quality Program (MITIQ) hosted the 11th International Conference on Information Quality (ICIQ-2006), the premier conference in the information quality (IQ) field. More than 160 participants from academic and industry communities worldwide took part in this forum. At the conference, MITIQ announced the establishment of the Stuart Elliot Madnick IQ Best Paper Award. The award will encourage the publication of high-quality papers in the emerging field of IQ, in which MITIQ plays a leadership role.

During the past year, MITIQ also received approval from the Publications Board of the Association of Computing Machinery (ACM) to launch the new *ACM Journal of Data and Information Quality*. Professor Stuart Madnick and Professor Yang Lee (Northeastern University) at MITIQ are the editors-in-chief. And in a new initiative, MITIQ helped the University of Arkansas at Little Rock to establish the first-of-its-kind master of science degree in information quality (MSIQ). MITIQ will also help the University of Arkansas to establish a PhD program in IQ.

In its final year as a formal CTPID program, the Communications Futures Program (CFP) continued to lead industry-academic working groups on such topics as spectrum policy and interconnection, value chain dynamics, viral communications, and privacy and security. In April 2007, CFP also helped to organize the IEEE Dynamic Spectrum Access Networks conference in Dublin. This is the leading international research conference for new work on cognitive/software radios and other dynamic spectrum access technologies as well as for policies critical to enabling new spectrum management paradigms and the wireless futures investigated in two of CFP's working groups.

In April 2007, Sharon Gillett, former principal research associate in CTPID's Communications Futures Program and former chair of the CFP's Broadband Working Group, was named by Massachusetts Governor Deval Patrick as commissioner of the state's newly formed Department of Telecommunications and Cable, an agency that will oversee connectivity issues.

### **Awards and Recognition**

Joel Cutcher-Gershenfeld, senior research Associate and codirector of the lateral alignment program, was appointed dean of the Institute of Labor and Industrial Relations at the University of Illinois, Urbana-Champaign.

Professor Ki-Chan Kim of CTPID's International Motor Vehicle Program (IMVP) was named dean of the Catholic University of Korea Business School. Also at IMVP, visiting professor Sebastian Fixson received one of two honorable mentions in the Sloan Foundation Industry Studies Program best paper competition.

Several other awards were made this year to IMVP scholars. Carnegie Mellon University postdoctoral fellow Jaegul Lee was awarded first prize in the Sloan Foundation's Industry Studies Program's 2006 Dissertation Award, for his dissertation titled "Innovation in Automotive Emission Control Technologies: Government Actions, Sources of Innovation, and Innovation Strategies." Professor Frits Pil of the University of Pittsburgh, an IMVP affiliate, received one of three Sloan Foundation Industry Studies Program Best Paper prizes for 2006. In addition, Professor Pil received the Sloan Industry Studies Best Book prize for *The Second Century* (MIT Press, 2006), together with coauthor Matthias Holweg from the University of Cambridge.

In the fall of 2006, the Lean Aerospace Initiative learned that one of its PhD students, Jason Bartolomei, was awarded the Joint Service Medal from the Office of the US Secretary of Defense, for the application of his research at LAI to the global fight against terrorism.

This year, the Lean Aerospace Initiative (LAI) sponsored its second annual Lean Enterprise Value Student Prize, a monetary gift to the eligible student whose undergraduate or graduate coursework has or has the potential to contribute to transformation of enterprises based on the concepts in LAI's book *Lean Enterprise Value*. The awardee was LAI-MIT student Damien Bador.

Former LAI Student Henrik Bresman, now an assistant professor at INSEAD (the global business school), was the recipient of two awards from the Academy of Management, including one for the best paper of 2006.

### **Communications Futures Program**

The Communications Futures Program is a joint venture across several entities at MIT, led by David Clark of MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) and CTPID, Charles Fine of MIT Sloan, and Andrew Lippman of the Media Lab. CFP's objective has been to promote growth and innovation across the communications



value chain. In addition to its research, the Program has facilitated cross-industry interactions through industry-academic working groups, groups that have been focused on issues requiring cross-industry coordination. CFP has also partnered with Cambridge University through a seed grant from the Cambridge-MIT Institute (CMI).

Within CTPID, Sharon Gillett and William Lehr have led several of CFP's working groups. At the end of the summer in 2006, Sharon Gillett departed MIT to seek her doctorate at Boston University (and has since been named commissioner of the newly-formed Massachusetts Department of Telecommunications and Cable), and William Lehr joined David Clark in the CSAIL laboratory. Although no CTPID personnel remain who are formally associated with CFP, CFP continues to work with CTPID students and other faculty with ongoing research interests in the communications industry value chain.

### **Key CFP Accomplishments**

During the past year, CFP continued to lead industry-academic working groups on the following topics:

- Spectrum policy and interconnection, led by William Lehr, formerly of CTPID and currently with CSAIL
- Value chain dynamics, led by Charles Fine of the Sloan School of Management
- Viral communications, led by Andy Lippman and David Reed of the MIT Media Lab
- Privacy and security, led by Karen Sollins of CSAIL

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

- Participation in the organization of the IEEE Dynamic Spectrum Access Networks conference in Dublin, Ireland, in April 2007. This is the leading international research conference for new work on cognitive/software radios and other dynamic spectrum access technologies; also, for policies critical to enabling new spectrum management paradigms and the wireless futures investigated in the viral communications and spectrum policy working groups.
- Preparation of research papers for peer-reviewed journals and workshops on such topics as the design of innovative radio systems and network neutrality.
- Ongoing research on the economic impact of broadband technologies and its growth. This included participation in the organization of a national conference on broadband metrics, with sponsorship from the National Science Foundation and the Pew Foundation.

CFP's roster of sponsoring companies includes BT, Cisco, Comcast, Deutsche Telekom/T-Mobile, France Telecom, Telecom Italia, Intel, Motorola, Nokia, Nortel, Samsung, Swatch and Telmex.

Also during the past year, CFP's William Lehr helped Dr. Frank Field of CTPID teach the Cambridge University course "Telecommunications: Technologies and Policies in the

Networked Digital World,” which was codeveloped with Tim Wilkenson as part of the Cambridge University MPhil in Technology Policy Program. This course was developed with CMI funds.

### Research Publications

John Chapin and William Lehr, “The Path to Market Success for Dynamic Spectrum Access Technologies,” *IEEE Communications Magazine*, Special Issue on Cognitive Radios for Dynamic Spectrum Access, May 2007.

John Chapin and William Lehr, “Time-limited Leases for Innovative Radios,” with John Chapin. Accepted paper for proceedings of *IEEE DySPAN2007*, Dublin, April 18–20, 2007, forthcoming in *IEEE Communications Magazine*, 2007.

William Lehr, Marvin Sirbu, Jon Peha, and Sharon Gillett, “Scenarios for the Network Neutrality Arms Race,” forthcoming in *International Journal of Communications*.

David Clark, William Lehr, Steve Bauer, Peyman Faratin, Rahul Sami, and John Wroclawski, “Overlay Networks and the Future of the Internet,” *Communications and Strategies*, no. 63 (3rd quarter 2006), pp. 1–21.

Peyman Faratin, “Economics of Overlay Networks: An Industrial Organization Perspective on Network Economics.” In *Proceedings of the Joint Workshop on The Economics of Networked Systems and Incentive-Based Computing (NetEcon+IBC)*, in conjunction with ACM Conference on Electronic Commerce (EC2007) San Diego, California, June 11, 2007 (forthcoming).

Peyman Faratin and Timothy Wilkening, “Interconnection Discrimination: A Two-Sided Markets Perspective,” in *Proceedings of Fifth Workshop on Hot Topics in Networks (HotNets-V 2006)*, Irvine, CA, November 29–30, 2006.

### Ford-MIT Alliance

The Ford-MIT Alliance, an Institute-wide initiative established in 1997, was renewed in December 2006 for its third five-year term, at \$3 million annually, beginning January 1, 2008 and running through 2012. Obtaining renewed funding was a significant accomplishment, given the current challenges to the Ford Motor Company. The renewal reinforced the role the Institute has in shaping the strategy of a corporate research agenda, and underscored the value of this kind of cross-cultural partnership.

The Alliance is the Institute’s longest-running research partnership with industry, and represents an acknowledgment by Ford of MIT’s relevance as an academia-based research engine. Since 1997, the Alliance has funded more than 100 projects, with budgets ranging from \$150,000 to \$1.3 million, throughout the School of Engineering, the MIT Sloan School of Management, and at various interdisciplinary labs and centers, including the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL).

The Alliance structure includes an operating committee that identifies areas of mutual interest to Ford and MIT and develops a research portfolio managed by the codirector,

Professor John Heywood, and the Alliance executive directors, Simon Pitts for Ford and Elaine I. Savage for MIT. Dr. Savage accepted the position as MIT executive director on December 1, 2006, during third-term Alliance renewal discussions with Ford.

The Alliance's Operating Committee reports to the Executive Committee, including MIT's leadership champion, Chancellor Phillip L. Clay. It also works in close partnership with Ford's key executives. The Alliance hosts the Executive Committee on campus three times annually for interactions with MIT faculty. The aim of these visits is to promote synergies as well as provide custom briefings on areas of interest and introductions to researchers across the Institute.

### ***Ford-MIT Alliance Research Activities***

Ford-MIT Alliance research focuses on four key areas: (1) energy and the environment, (2) product development, (3) active safety, and (4) powertrain. The Alliance's goal is to be aligned with the strategic agenda of Ford's Scientific Research Laboratory and its overall innovation initiative. Emerging opportunities are evaluated for new technologies, and areas, such as controls, are evolving as new and timely research topics. Projects have been funded in several areas, including model-based diagnosis and recovery of automotive software systems, as well as controls for self-calibration of power. These projects are related to research in the powertrain domain, as well as novel applications of global positioning system (GPS) algorithms for controlling hybrid electric vehicles.

Nine projects have been funded since January 2007, including lookahead control and sensing, for active navigation and hazard avoidance; expressive interaction, for information and driving assistance (both funded in CSAIL); and two fuel cell projects. The Alliance manages approximately 20 active projects at any given time.

Environmental projects include Ford's long-term, founding support of the Alliance for Global Sustainability. Ongoing research on policy includes carbon mitigation and scenarios for the future, such as the Before a Transition to Hydrogen project. Emerging opportunities in the energy area include a nanotechnology project designed to increase the storage capacity of ultra capacitors, replace batteries, and compete with fuel cells. Commercialization is the ultimate goal for this technology.

The Active Safety area supports pedestrian detection, enhanced vehicle stability, and complex alerting systems development. A significant study of driver wellness and impairment detection is underway with the MIT Age Lab, which is conducting driver studies in a Ford-donated Volvo SUV that was delivered in September 2006. Through custom instrumentation, the vehicle, known as the Driver Aware Car, is being evaluated in collaboration with a team of visiting engineers from Ford and Volvo. The goal is to incorporate the study's results as safety enhancements in future products. The Age Lab is part of the Center for Transportation and Logistics, which is closely associated with the Engineering Systems Division.

Current powertrain research includes homogenous-charge compression ignition (HCCI), oil aeration, and control software for engine management.

Within the Product Development area, the Closure Systems project made a final report to the Executive Committee; implementation at Ford is expected.

Finally, Ford has supported MIT's CSAIL-based autonomous vehicle team for the DARPA Urban Grand Challenge Race with the donation of a Land Rover and technical assistance.

### ***Ford-MIT Alliance Future Directions***

As a founding partner, the Alliance expects to pursue a significant role in the MIT Energy Initiative, drawing on existing projects and joining the rich industrial research community that will participate in defining future energy systems.

### ***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 at MIT in 1979 and headquartered at MIT, IMVP has evolved to become a network of professors and researchers engaging with managers and executives in the global automotive industry. IMVP researchers are based at universities around the world, including MIT, the University of Pennsylvania, the University of Michigan, the University of Pittsburgh, Carnegie Mellon University, Oxford University, the University of Cambridge, the École Polytechnique, the Catholic University of Korea, and the University of Tokyo.

The IMVP Research Framework includes six broad areas of study:

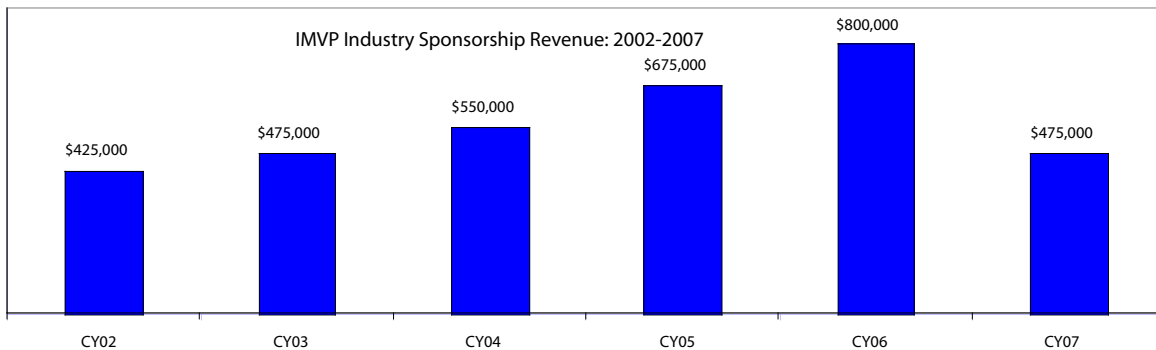
- Innovation in the automobile industry
- Next-generation product development
- Lean value chains: the evolving supply base
- Lean production revisited
- Next-generation distribution
- Sustainability: environmental and social impacts of the automobile

### ***IMVP Leadership***

In FY2007, IMVP maintained the same leadership structure as in the previous year. Professor Michael Cusumano of MIT Sloan continued to serve in his role as IMVP codirector, sharing that responsibility with Professor John Paul MacDuffie of the Wharton School at the University of Pennsylvania. Professor Daniel Roos continued to serve as chairman of the IMVP Advisory Board. Dr. John Moavenzadeh departed his role as executive director of IMVP as of January 2007, and a modified version of the position is close to being filled for FY2008.

### **IMVP Funding**

IMVP is almost fully funded from industry sponsors. The recent funding history for the program is shown below.



After several years of growing sponsorship revenues, 2007 saw a decline, due in part to the November 2006 expiration of Hyundai Motor Corporation's sponsorship and the cancellation of the third year of the program's agreement with Magna. IMVP is currently seeking renewal of the Hyundai contract, and will prepare for renewals with General Motors, Toyota, Honda, and Tenneco, all of whose current sponsorship contracts will expire by the end of CY2007. Nissan is the only current sponsor whose contract extends into 2008.

Despite a difficult business environment for securing research funding from the global automotive industry, IMVP is in discussion with a number of new potential sponsors, including Fiat, PSA (Peugeot and Citroen), Renault, Tata Motors, and (recently, given the pending sale to Cerberus) Chrysler. We also anticipate returning to the following companies to follow up on past sponsorship discussions (from one or more years ago) and leads: Daimler-Benz, BMW, Volkswagen, Bosch, Johnson Controls, Valeo, Hewlett Packard, SAP, and Microsoft.

### **IMVP Continues Relationship with World Economic Forum**

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

On January 25, 2007, IMVP codirector John Paul MacDuffie participated in the full program for the Governors Meeting of the Automotive Industry, a CEO-level meeting held during the Forum's annual meeting in Davos, Switzerland. He facilitated a discussion of three alternate scenarios for the auto industry's future: (1) Innovate or Die, (2) Asian Giants Take the Lead, and (3) A Sustainability Crisis.



### ***IMVP Advisory Committee Meets***

The first meeting of the IMVP Advisory Committee took place on October 19, 2006, at MIT. The objective of the committee is to help shape the IMVP research agenda to ensure that topics are valuable for senior executives within the industry. Professor Daniel Roos continues his role as chairman. The following members were among those who participated:

- Paul Anderson, former head of Booz Allen Hamilton's automotive practice
- Dana Mead, chairman of the MIT Corporation, former CEO of Tenneco
- Jack Smith, former CEO of General Motors
- Katsuhiko Nakagawa, vice chairman, Toyota Motor Corporation (representing Shoichiro Toyoda, honorary chairman)

Another member of the advisory committee, Louis Schweitzer (chairman of Renault, former CEO of Renault), was unable to attend but participated in several telephone conferences prior to the event. Also sitting in at the meeting were two additional guests from Toyota Motor Corporation (Mr. Handa, vice president, and Toshio Ohashi, project general manager), as well as MIT professor Charles Fine and two doctoral student researchers (Hidetada Higashi of the University of Tokyo and Jianxi Luo of MIT). MIT professor Ernest Moniz presented a lunchtime report on the MIT Energy Initiative, "Meeting the Global Energy Challenge."

### ***IMVP Research Impact***

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

- Complementary investment strategies and capability building (in Brazil)
- Change in product architecture and OEM-supplier relationships
- How learning on an assembly line is impacted by variety
- Product architecture: Combining perspectives from engineering and organization economics
- Pragmatic collaboration and the interorganizational automotive design chain
- Integration of continuous improvement and advanced engineering through knowledge management on assembly lines
- GHG emissions reduction policy and automotive design
- Role of alliances in product architecture and product development
- Outsourcing of tasks and outsourcing of assets
- Collaborative concept development and advanced engineering studies
- Globalization and Japanese strategy in the Asia Pacific region
- Automotive OEM-supplier relationships
- International benchmarking of the automobile industry

- In-house R&D, R&D outsourcing, and R&D alliance in the Chinese auto industry
- Lean locational logic: Developing a better framework for location decisions
- Creating a responsive supply chain: Challenges and opportunities
- Flexible manufacturing systems under uncertainty

The Wharton School hosted the annual IMVP Researchers Meeting on June 11–12, 2007, in Philadelphia. Nearly 40 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 France, Spain, Italy, Switzerland, the United Kingdom, Japan, South Korea, and the United States. Also convened in conjunction with this year's meeting was the second annual IMVP Automotive Mini-Conference (AMC). Held on June 13, 2007, this one-day event provided an opportunity for more in-depth discussion around a selected set of papers. Several academics from outside of the IMVP network participated.

On April 25–27, 2007, a number of IMVP researchers participated in the Sloan Industry Studies Annual Conference in Cambridge, Massachusetts, including John Paul MacDuffie (Wharton School), Loren Brandt (University of Toronto), Michael Cusumano (MIT), Charles Fine (MIT), Sebastian Fixson (MIT), Daniel Roos (MIT), Susan Helper (Case Western Reserve University), Arnaldo Camuffo (University of Padova, Italy), Matthias Holweg (University of Cambridge), Frits Pil (University of Pittsburgh), Jamie Winebrake (Rochester Institute of Technology), Mari Sako (Oxford University), Eric Thun (Oxford University), Francisco Veloso (Carnegie Mellon University), Josh Whitford (Columbia University), and Jaegul Lee (Carnegie Mellon University). John Paul MacDuffie convened two brief meetings of these researchers to discuss recent IMVP developments.

IMVP researchers were quoted in a variety of publications. IMVP researchers John Paul MacDuffie (Wharton School), Michael Cusumano (MIT), and Takahiro Fujimoto (University of Tokyo) were interviewed for a *New York Times Magazine* feature article about Toyota Motor Company. John Paul MacDuffie (Wharton School), Matthias Holweg (University of Cambridge), and Ulrich Juergens (WZB, Berlin Germany) were quoted in an article on the German auto industry in *Knowledge@Wharton*, a biweekly online resource that offers the latest business insights, information, and research from a variety of sources and has more than 900,000 subscribers. John Paul MacDuffie also recorded numerous *Knowledge@Wharton* podcast interviews about the current troubles of the auto industry.

Notable academic achievements by IMVP researchers during the last fiscal year included the following:

- Professor Ki-Chan Kim was named dean of the Catholic University of Korea Business School.
- Carnegie Mellon University postdoctoral fellow Jaegul Lee was awarded first prize in the Sloan Foundation's Industry Studies Program's 2006 Dissertation Award, for his dissertation titled "Innovation in Automotive Emission Control Technologies: Government Actions, Sources of Innovation, and Innovation Strategies."

- Professor Frits Pil of the University of Pittsburgh received one of three Sloan Foundation Industry Studies Program Best Paper prizes for 2006, and along with coauthor Matthias Holweg from University of Cambridge, the Sloan Industry Studies Best Book prize for *The Second Century* (MIT Press, 2006).
- Professor Sebastian Fixson (visiting professor, MIT) received one of two honorable mentions in the Sloan Foundation Industry Studies Program best paper competition.

More information about IMVP can be found at <http://imvp.mit.edu/>.

### **The Lean Aerospace Initiative**

Now in its fifth phase of operations (September 1, 2005–August 31, 2010), the Lean Aerospace Initiative (LAI), with its focus on lean transformation, has enhanced its operating model to provide resources and attention to three areas: knowledge creation, relationship building and knowledge deployment.

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

In its fifth phase, LAI continues to focus on delivering more value to all stakeholders, with a new model providing novel hands-on engagement with its members and the public. Through research, collaboration, and knowledge deployment among the consortium members, LAI underscores the maturation of the lean transformation process within enterprises and its requisite need for appropriate tools and leadership.

### ***LAI Strategic Imperatives***

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

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

To accomplish these imperatives, LAI engages in a large number of activities: (1) knowledge creation, to include product/tool/process development; (2) deployment, to include fostering transformation and the exchange of knowledge; and (3) relationships,

to include enabling a neutral forum for the sharing of knowledge and exploration of common issues in the consortium. It is important that LAI consortium members receive value from these activities, and that this value is evenly distributed among the different stakeholder groups within the consortium. This desire guides how the consortium is organized what processes it uses.

### ***Transforming the US Aerospace Enterprise and Beyond***

LAI continues to affect lean enterprise transformation of the aerospace industry. The Air Force's Air Force Smart Operations 21st Century—nicknamed AFSO21—is in full operation. LAI can lay claim to having initiated lean thinking through several USAF lean initiatives, including support of the Air Force's Material Command and, most recently, the Space and Missile Systems Center (SMC).

Air Force personnel continue to be engaged with LAI, and seek guidance in this major transformation effort. LAI directors have met in recent months with Air Force Brigadier General Taco Gilbert, who was charged with leading AFSO21. Other affiliates of LAI have been directly involved in AFSO21 process changes, providing the organization with a direct link to lean enterprise best practices from LAI. In addition, LAI leaders have provided direct assistance to leaders at SMC, through training and mentoring. In fact, SMC became a new member of the consortium as a result of the assistance LAI provided.

Once again, Air Force leaders spoke at LAI's annual conference (April 2007) about their transformation efforts and the lessons learned from them. Beyond the Air Force, US Navy Vice Admiral (Ret.) Walter Massenburg spoke at the event about the Naval Air Systems Command's transformation journey and the leadership required to support it. In addition, Boeing's executive vice president and president of integrated defense systems, James Albaugh, discussed what Boeing has done to transform its organization and the important supportive role that LAI has played.

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

There are many other successes in the past 12 months that should be noted as well. Taken together, they show that lean enterprise thinking has, and will continue to be, diffused throughout the enterprises involved in LAI. The following summary reflects LAI's commitment to enterprise-level transformation:

- LAI welcomed a new member, Boeing Commercial Airplanes, to the consortium in summer 2006. In addition, William Schnettgoecke Jr., vice president of Lean for The Boeing Company, joined the LAI Executive Board.
- LAI Researcher Dr. Ricardo Valerdi helped to create the commercial release of the Constructive Systems Engineering Cost Model (COSYSMO), which he developed and has refined since coming to LAI more than a year ago. The cost model product is a result of his PhD research and is now available in products by PRICE Systems, Galorath, and SoftStar Systems.

- Former LAI Student Henrik Bresman, now an assistant professor at INSEAD (the global business school) in France, was the recipient of two awards from the Academy of Management, including one for best paper of 2006.
- LAI held its Lean Facilitators Course at Northrop Grumman Mission Systems in the summer of 2006. The course, based on the experience of the “Lean Now” effort, was developed to train project facilitators. Twenty-seven students attended the event from various organizations.
- In October 2006, the Lean Enterprise Product Development Simulation made its debut at a training event held at BAE Systems headquarters in Maryland. The simulation is a new companion to LAI’s successful Lean Enterprise Value (LEV) simulation. It is designed to demonstrate the applications of lean tools and principles to managing and improving the performance and throughput of a product-development enterprise.
- LAI’s Lean Academy held its first open enrollment course at the University of Alabama, Huntsville, which was attended by seven different organizations, including representatives from three Air Force bases. A second open enrollment is scheduled.
- LAI researchers continued their collaboration with MITRE Corporation on Enterprise Dynamics and Modeling, meeting in October 2006 to discuss and coordinate related research projects. The collaboration, which began in October 2005, brought together integrated capabilities in enterprise architectures, system acquisition, and modeling and simulation. This is one of four collaborative research projects between ESD and the MITRE Corporation that are funded as MITRE-sponsored projects.
- In the fall of 2006, LAI learned that one of its current PhD students, Jason Bartolomei, was awarded the Joint Service Medal from the Office of the US Secretary of Defense for the application of his research at LAI to the global fight against terrorism.
- In October 2007, the USAF Space and Missile Systems Center hosted a workshop of the Enterprise Value Stream Mapping and Analysis (EVSMA) tool and helped the organization conclude its Enterprise Value Stream Mapping and Analysis project.
- In December 2006, LAI’s book, *Lean Enterprise Value*, was made available in a Chinese translation.
- In January 2007, LAI launched a new series of training events to more directly deploy its cutting-edge knowledge and research to LAI consortium members and others. The first event highlighted research on leading indicators for programmatic performance. Subsequent events have provided information on world-class enterprises, LAI’s Lean Enterprise Self-Assessment Tool, and Enterprise Value Stream Mapping and Analysis.



## ***LAI Research and Knowledge Deployment***

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

### ***LAI Research***

The LAI Phase V research program continues to be driven by the key goals defined in Phase IV. These are: (1) the need to accelerate lean enterprise transformation; (2) the need to design future lean enterprises; and (3) the need to evolve adaptive lean enterprises. The LAI Phase V research program seeks to provide further knowledge, insight, and tools to enable true enterprise transformation. As such, the Phase V program is formulated around four core research questions and further structured around seven unique research threads that extend from the consideration of these questions:

1. How can I understand how my organization/enterprise currently operates within its larger context?
2. How can I define and evaluate the future possibilities for a more efficient and effective enterprise?
3. What are the most effective strategies and tactics to achieve these future possibilities for my enterprise?
4. How can I best manage the enterprise change process?

### ***LAI Research Clusters***

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

#### ***Concepts and Models for Designing Future Enterprises Research Lead: Kirkor Bozdogan***

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

#### ***Enterprise Lean Product Development Research Lead: Eric Rebentisch***

Enterprises are faced with increasingly complex products and portfolios of products that are beginning to defy traditional notions of the product lifecycle. As the complexity of these products and portfolios increases, there is even less room for poor product development performance with cost and schedule overruns. The research in this area

seeks to characterize the elements and architectures of lean and effective enterprise product development systems that are capable of efficiently, consistently, and responsively producing streams of products that are valued by enterprise stakeholders.

*Value-Based Methods of Architecting Systems Research Lead: Donna Rhodes*

Enterprises are faced with the need to make decisions on very complex architectures under conditions of high uncertainty. These include decisions required to architect the product system, as well as decisions regarding the architecture of the enterprise itself. This area of research is developing methodologies that will provide mechanisms for performing the complex trade space exploration and decision-making strategies to support system and enterprise architectural decisions.

*Enterprise and Cost Metrics Research Lead: Ricardo Valerdi*

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

*Strategies for High-Performance Enterprises Research Lead: Debbie Nightingale*

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

*Enterprise Change Capability Research Lead: George Roth*

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

*Enterprise Integration Enabled by IT Research Lead: Jayakanth "JK" Srinivasan*

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

In the area of communicating regular research updates and findings to the consortium, LAI has created a new research committee, with membership by consortium representatives, to focus specifically on transferring this information to the members.

### ***LAI Knowledge Deployment***

LAI deploys knowledge in several targeted ways, with the newest focus on knowledge exchange events where LAI researchers and practitioners can share their cutting-edge research directly with consortium and public participants. These events, which were launched in January 2007, cover a wide variety of new research and related tools and are presented in the form of tutorials, workshops, executive seminars, and roundtables. They are designed to deploy knowledge and gain new insights from the participants that can be applied to the research.

These events have taken place on or near the MIT campus and have garnered attention not only from LAI consortium members, but also from interested parties outside of MIT. Below is a list of events that have taken place or are planned:

- January 2007: Leading Indicators for Technical and Programmatic Performance
- January 2007: IT-Enabled Integration in Aerospace Enterprises
- February 2007: World-Class Lean Enterprises: The Executive's Perspective
- March 2007: Cost Estimation for Systems Engineering
- May 2007: Using the Lean Enterprise Self-Assessment Tool (LESAT) for Transformation
- June 2007: Architecting Future Enterprises
- June 2007: Applying Enterprise Value Stream Mapping and Analysis (EVSMA) to Your Enterprise
- July 2007: Using Product Development Value Stream Mapping (PDVSM) for Improving Product Development
- July 2007: Sharing Success Stories of Lean Enterprise Change Through the Lens of Enterprise Change Capabilities
- September 2007: Supply Chain Toolset
- October 2007: World-Class Lean Enterprises: The Executive's Perspective
- November 2007: Leading Indicators for Technical and Programmatic Performance
- January 2008: Lean Enterprise Value (LEV) Simulation

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

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

EdNet's strategic plan includes the following goals:

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

In support of these goals, EdNet has initiated new alliances, such as with Microsoft and the Lean Enterprise Institute, to further awareness and deployment of the EdNet curriculum. One result of these alliances was free software provided to LAI EdNet members. In addition, LEI cohosted the EdNet annual conference in October 2007, providing speakers and insight into how the two organizations might work collaboratively.

The LAI Lean Academy® is LAI's one-week course, providing a hands-on introduction to lean fundamentals. It was initially targeted toward undergraduate students, but during the last year its reach has expanded beyond this original target audience. New this past year was the development of a short version of the LAI Lean Academy® focusing on lean enterprise engineering concepts and principles. Another short version course was developed related to supply chain issues.

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

Another important setting for LAI's knowledge deployment is its annual conference, which is considered one of the most important events of the year. In 2007, the LAI Annual Conference featured lean enterprise leaders from aerospace, academia, and government as keynote speakers who discussed leadership through the lean journey. They included Vice Admiral (Ret.) Walter Massenburg, US Navy, Naval Air Systems Command; MIT professor Yossi Sheffi; and James Albaugh, executive vice president and president of integrated defense systems, The Boeing Company. These speakers offered different perspectives on how to manage and create a successful lean enterprise.

The conference also served as the setting for the LAI Lean Product Lifecycle Knowledge Area Meeting and the LAI EdNet, Executive Board, and Champions meetings. At this year's conference, general session attendees heard from several lean enterprise experts on methods for implementing lean principles and transforming enterprises. In breakout sessions led by LAI researchers, attendees learned about such topics as enterprise

integration enabled by IT, fundamentals of lean enterprise transformation, and lean enterprise transformation across the life cycle. Attendees learned about the latest LAI research and absorbed practical examples from those within the LAI consortium who have completed different levels of lean transformation.

### **LAI Publications**

LAI consistently produces new research, papers, and presentations. Several recently published LAI research documents, in the form of reports, conference papers, and student theses, include detailed findings and recommendations in several key areas. All of these works are available on the LAI website at <http://lean.mit.edu/>. The list includes the following:

Bador, Damien, “[Improving Commonality Implementation in The Cockpits Of Commercial Aircraft](#),” master’s thesis, MIT, June 2007.

Bador, Damien, Warren J. Seering, and Eric S. Rebentisch, “[Measuring The Efficiency of Commonality Implementation: Application to Commercial Aircraft Cockpits](#),” LAI Working Paper, February 2007.

Glazner, Christopher G., “Enterprise Integration Strategies Across Virtual Extended Enterprise Networks: A Case Study F-35,” master’s thesis, MIT, November 2006.

Hartwell, Jennifer and George Roth, “Ariens Company: A Lean Enterprise Change Case Study,” LAI Case Study, October 2006.

Horng, Tzu-Ching, “A Comparative Analysis Of Supply Chain Management Practices by Boeing and Airbus,” master’s thesis, MIT, December 2006.

Makumbe, Pedzisayi, “Systems Development Technical Interactions And Innovation: A Networks-Based Investigation,” master’s thesis, MIT, June 2006.

Myers, Kevin Michael, “Building Flexibility in The Volatile Aftermarket Parts Supply Chains of Defense Aerospace Industry,” master’s thesis, MIT, April 2007.

Roth, George, “Lean Enterprise Change Case Study: Rockwell Collins,” LAI Case Study, September 2006.

Shoepe, Ted V., “In Pursuit Of Understanding Lean Transformation: Capturing Local Change Journeys in DoD Environment,” LAI Report, December 2006.

Stanke, Alexis Kristen, “Creating High Performance Enterprises,” PhD thesis, MIT, September 2006.

Tang, Victor, “Corporate Decision Analysis: An Engineering Approach,” PhD thesis, MIT, September 2006.



Utter, Darlene Ann, "Performing Collaborative, Distributed Systems Engineering (Cdse): Lessons Learned," master's thesis, MIT, January 2007.

### **LAI Products**

The LAI tool suite is regularly updated and revised to reflect the latest research and best practices. A comprehensive list of these tools is available online at the LAI website. A brief description of some of the most recently updated tools includes the following:

**Lean Enterprise Product Development Simulation.** Lean Enterprise Product Development (LEPD) simulation is a powerful tool for demonstrating the value, and challenges, of implementing lean principles and practices in product development systems at an enterprise level. It builds on a foundation of insights gained through more than eight years of intensive LAI product development research and Lean Aerospace Initiative consortium real-world experience.

**Lean Enterprise Value (LEV) Simulation (or "Game") Version 2.0 and Short Course.** This is a unique tool for demonstrating the value and challenges of implementing lean principles and practices at the enterprise level. It was updated in June 2006 to include new enterprise functionality and improve ease of adoption by LAI consortium members.

**COSYSMO (Constructive Systems Engineering Cost Model).** The COSYSMO model was designed to help organizations eliminate cost-guessing games associated with systems engineering. It helps large corporations pinpoint systems engineering costs that are factored into planning and executing large system projects, and helps government agencies to evaluate proposals from contractors using a more objective approach. The author of the model, Dr. Ricardo Valerdi, has refined the tool since his arrival at LAI.

**Leading Indicators for Programmatic and Technical Performance Project, June 2007.** The set of leading indicators was developed based on a research project originating from the June 2004 Air Force/LAI Workshop on Systems Engineering for Robustness. That workshop established the groundwork for several initiatives in support of systems engineering revitalization—including one to develop a set of leading indicators for evaluating the goodness and predicting the effectiveness of systems engineering on a program. The project was undertaken as a collaborative effort of LAI and the International Council on Systems Engineering (INCOSE), with participation from leading industry measurement experts and in cooperation with PSM (Practical Software and Systems Measurement) and SSCI (Systems and Software Consortium).

**Enterprise Value Stream Mapping and Analysis 1.0 (EVSMA) with Facilitator's Guide, August 2005.** This product presents a coherent method for analyzing and improving enterprise performance and integrating strategic objectives, stakeholder interests, and process performance. It is a decision aid for enterprise executives to help them identify barriers to the creation/delivery of value to each stakeholder, specify a vision of their future lean enterprise, determine significant gaps between current and future states, and prioritize opportunities.

Product Development Value Stream Mapping 1.0 (PDVSM) and Manual, September 2005. This is a practical guide tackling the application of lean to product development. It is focused at the tactical level—engineering process improvement—and is a summary and reference for more than four years of product development group experience facilitated through LAI. The manual is intended for product development personnel working on improving their own processes, and the lean change agents working with them. Its aim is to provide practical guidance for applying lean concepts to product development process improvement, specifically, Product Development Value Stream Mapping (PDVSM).

### **LAI Membership**

LAI consortium members are enhancing and broadening the membership base. A new membership campaign has been initiated, and several new members have joined in the last year, including United Launch Alliance (a joint venture between Boeing and Lockheed Martin), United Space Alliance, and the US Army. Consortium members also recently agreed to new affiliate-level memberships, which will further broaden LAI's reach. To support these efforts, new membership kits, brochures, and flyers were created internally.

### **LAI Moving Forward**

As LAI moves further into Phase V, a major effort is underway to continue to strengthen the Initiative's innovative industry, government, and academic partnership, and to assist its partners with enterprise transformation in light of major government and corporate lean initiatives (for example, the US Army's transformation efforts and the US Naval Air Systems Command's lean transformation initiatives). LAI plans to provide assistance where needed to ensure that its consortium members use the latest tools and practices backed by research.

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

LAI also plans to raise its profile among consortium membership and in the general public, and has already done so in several ways. During the past year, LAI received attention in business and international press for its involvement in the commercial release of COSYSMO and for the upcoming release of a new version of Leading Indicators for Programmatic and Technical Performance, developed through a joint project involving LAI, Lockheed Martin, and other major consortium members.

LAI sponsored a second national Lean Enterprise Value Student Prize this year; it awarded a monetary gift to the eligible student whose undergraduate or graduate coursework has contributed or has the potential to contribute to the transformation of enterprises based on the concepts in LAI's book *Lean Enterprise Value*. This year's prize, funded by the Lean Enterprise Value Foundation Inc. (which controls royalties from the book), was awarded to LAI-MIT student Damien Bador. LAI also hopes to

raise awareness of its work and research through interconsortium communication collaborations organized by its communications group and through its website—which engages public visitors and consortium members via a variety of content and multimedia, including audio podcasts, web videos, and newsletters.

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

### ***LAI Leadership***

The cochairs of LAI, each representing LAI stakeholder groups, are General Bruce Carlson (representing the US Air Force Material Command), Blaise Durant (representing the Office of the Assistant Secretary of the Air Force), Robert Stow of BAE Systems (representing industry), and Institute Professor Sheila Widnall (representing MIT). LAI's codirectors, Professor Deborah Nightingale of the MIT Department of Aeronautics and Astronautics and Professor John Carroll of the Sloan School of Management, represent a multidisciplinary research approach.

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

### ***Labor Aerospace Research Agenda***

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

LARA's funding cycle via the US Air Force's Manufacturing Technology Initiative ended on April 15, 2005. Nevertheless, some members of the LARA team have remained engaged in research with aerospace stakeholders in the Aerospace Industry Council and have stayed involved with other projects. Included among those projects has been (until April 2007) Lateral Alignment in Complex Systems and a Network and Social Capital Study.

### ***Aerospace Industry Council***

The LARA team was instrumental in putting together a new institutional initiative, the Aerospace Industry Council. This council is an emerging forum for industry-level dialogue on labor and employment issues. It falls 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.

### ***Lateral Alignment***

Under the auspices of PARTNER—the Partnership for Air Transportation Noise and Emissions Reduction, a leading aviation cooperative research organization and a FAA/NASA/Transport Canada-sponsored Center of Excellence—the LARA team focuses on lateral alignment in aviation environmental issues. More specifically, the focus is on alignment across stakeholders associated with the architecture and implementation of the Next Generation Air Transportation System (NGATS). Sponsorship comes through the FAA's Office of Environment and Energy (AEE) and NASA.

The project features a working group of leading scholars that is still active and growing, and is engaged in inductive and deductive theory development around the concept. The Working Group on Lateral Alignment in Complex Systems is a sounding board for this research. It is cochaired by CTPID acting director Joel Moses and Dr. Joel Cutcher-Gershenfeld, formerly of MIT and now dean of the Institute of Labor and Industrial Relations at the University of Illinois, Urbana-Champaign. Twenty-two people from six different MIT and University of Illinois departments are members of the working group. Participation has periodically included representatives from the FAA, Ford, MITRE, and NASA, and the group provides opportunities for others to join in.

### ***Network and Social Capital Study: Program on Regional Innovation***

This short-term project, which ended in September 2006, evaluated whether the Cambridge-MIT Institute's funding created greater capacity to leverage resources, innovate ideas, and assist the flow of information across a wider stream of people and groups.

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

### ***Materials Systems Laboratory***

The MIT Materials Systems Laboratory (MSL) is internationally recognized for its innovative work analyzing the competitive position of materials and the strategic implications of materials 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. The lab's recent emphasis has been on automotive applications.

MSL has five researchers (two professors and three full-time research staff), and 12 graduate students. MSL graduate students come from a number of departments and programs at MIT, including the Engineering Systems Division, the Technology and Policy Program, the Department of Materials Science and Engineering, and the Department of Mechanical Engineering. Five students are currently working on their PhDs; all have passed their general/qualifying examinations. Several of MSL's master's degree candidates are planning to continue toward their PhD or have plans to pursue multiple master's degrees. MSL will likely expand in the coming year, adding several new students as a result of increased funding that has been obtained from a variety of sources.

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 also has 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.

### ***MSL's Role in the MIT-Portugal Program***

MSL has played a key role in developing the engineering design and advanced manufacturing (EDAM) degree programs to be offered by the MIT-Portugal Program. This involvement has drawn on MSL's considerable experience in conducting joint research activities with universities in Portugal, and our role in the development of an advanced automotive design and engineering center in the north of Portugal. Joel Clark (professor in the Department of Materials Science and Engineering and the Engineering Systems Division) is codirector of the EDAM education and research activities. Jeremy Gregory (research scientist in the Laboratory for Energy and the Environment) has coordinated the curriculum development and other activities related to both the advanced master's and PhD degree programs. With the aggressive plans for the deployment of both a master's and a PhD program, many members of the MSL staff are actively working on curriculum development with Portuguese partners and are making excellent use of the badly needed space allocated for the program by MIT.

Numerous research activities have been conducted as part of the MIT-Portugal Program. Richard Roth (research associate at CTPID) has directed a multiuniversity program (in conjunction with Instituto Superior Technico of Lisbon, Faculdade de Engenharia da Universidade do Porto, and the University of Minho) to develop innovative design solutions using advanced materials for automotive body applications. This work has included interaction with Volkswagen/AutoEuropa in Portugal as well as the recently opened automotive design center, CEIIA. Other joint research projects have recently been initiated as part of the MIT-Portugal Program, including projects involving the investigation of improved methods for injection molding, tool design and use strategies, and improved recycling systems.



### ***Collaborative Research Laboratory with General Motors***

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, focusing in particular on the strategic position of new automotive technologies both from economic and environmental standpoints. As part of this collaborative research arrangement with General Motors, MSL currently has research projects in flexible automobile manufacturing, lightweight materials and automotive design, and the economics of the vehicle launch process.

MSL has recently begun a new initiative with General Motors and a group of materials suppliers to add more depth to the research in the areas of lightweight materials and design. This new industrial consortium includes representatives of the steel, aluminum, and polymer composites industries. The focus of this work has been to investigate the opportunities for advanced materials solutions for automotive applications and to understand the institutional barriers to the use of these novel solutions.

### ***Sustainable Materials Systems***

Several MSL research efforts explore the notion of sustainability in the context of materials systems. These projects include an examination of the economics of recycling, the role of sustainability metrics in engineering design, the implications of resource scarcity for firms, and the exploitation of compositional statistics in scrap re-melting to increase the use of scrap materials.

### ***Recycling Economics***

MSL is also conducting more in-depth research in the area of recycling. Historically, MSL has examined automotive industry recycling practices as well as material selection and substitution in the electronics industry, particularly in packaging. MSL has an ongoing project in markets and electronics recycling. Researchers Randy Kirchain, (assistant professor in the Department of Materials Science and Engineering and the Engineering Systems Division), Frank Field (senior research associate at CTPID), and Jeremy Gregory have been working to understand current recycling practices and to develop an economic model for improving product design and recycling technology. They have been working closely with a number of industrial partners, including Hewlett Packard, Microsoft, and Philips Electronics.

### ***Sustainability Metrics in Design***

MSL is conducting a research program in conjunction with two Sloan Foundation Industrial Centers: the International Motor Vehicle Program and the Center for a Sustainable Aluminum Industry. This year's efforts have focused on an exploration of the kinds of design signals that can be extracted from the current crop of life-cycle analysis tools, to help product developers make material choices—or, more precisely, characterize the degree to which different tools yield different signals. This work is complemented by a series of industry interviews with automobile and materials decision makers to explore

the forms of sustainability metrics employed today in product development, and the weight given to these signals in comparison with more conventional product evaluation metrics.

### ***Resource Scarcity and the Firm***

As an outgrowth of past work for the Supply Chain 2020 program, MSL has been working to explore the specific implications of resource scarcity on the operation and planning functions of the firm. Traditional examinations of resource scarcity have tended to consider the notions of market efficiency and intertemporal equity within the context of the entire economy, and the conclusions of this work have tended to suggest that markets can take care of these issues in the long term. However, from the perspective of the firm, there are open questions as to the best strategies to employ in the face of potential resource scarcity and the kinds of information that are most effective in the development of these strategies. MSL is most fortunate that MIT's Robert Solow is an active member of the doctoral committee of this activity's lead graduate student.

### ***Uncertainty and Scrap Utilization***

A final topic in this area of sustainable materials systems is a continuation of an effort to explore the application of modifications to the conventional methods for devising furnace charges in metal foundries. These modifications focus on the incorporation of statistical information about feedstock composition into the mathematical programming employed. Early results suggest that there are real opportunities to improve the rate of consumption of scrap streams, offering a win-win opportunity for conventional foundry practice: improved environmental *and* economic performance. While the work to date has been entirely theoretical, MSL is currently working with Alcoa to develop a testbed application of these tools in one of their foundry facilities, with an eye toward a more substantial development program starting next year.

### ***Microphotonics/Optoelectronics***

MSL has also been continuing its work in the area of microphotonics. Professor Randy Kirchain and Richard Roth have been working on a number of research activities aimed at gaining a better understanding of the materials and processes used to manufacture a variety of critical components for the microphotonics industry. Through close interaction with the Center for Integrated Photonics Systems and sponsoring companies such as British Telecom and a number of microphotonics components suppliers, they have developed models to address questions of network architecture and the influence of new component technology on network deployment strategies. In particular, this has led to a better understanding of future optical network deployment strategies, both from an investment and operating cost perspective. MSL has also worked closely with the Communications Futures Program and the Communication Technology Roadmap within the Microphotonics Center to understand the economics and market drivers behind a variety of microphotonics applications.

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

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

## **MIT Information Quality Program**

The MIT Information Quality Program (MITIQ) develops new knowledge in the information quality field. Launched in 2002, MITIQ conducts research on all aspects of information quality, such as how to manage information as a product, how to develop an information product map, and how organizations adopt information quality over time. MITIQ is an outgrowth of MIT's Total Data Quality Management Program, which was founded in 1990 by then-Sloan School of Management associate professor Richard Wang and J. N. Maguire information technology professor Stuart Madnick.

### **MITIQ Accomplishments**

The Publications Board of the Association of Computing Machinery (ACM) has officially approved the proposal – which grew out of efforts initiated by MITIQ and the International Conference on Information Quality – to launch the new ACM *Journal of Data and Information Quality*. Professor Stuart Madnick and Professor Yang Lee (Northeastern University) are the editors-in-chief of the ACM-JDIQ and are working out the details with ACM. The journal's website is <http://www.acm.org/pubs/periodicals/jdiq/>.

This year, Richard Wang, MITIQ's director, submitted research proposals for more than \$700,000 in funding to assist law enforcement agencies in their efforts to improve information quality in areas such as criminal history records and information sharing. The proposals were developed based on Dr. Wang's previous participation in a working group sponsored by the Bureau of Justice Assistance (BJA) (Office of Justice Programs, US Department of Justice) – the Global Justice Information Sharing Initiative, Privacy, and Information Quality Working Group. One of Dr. Wang's proposals was selected for full-proposal submission.

In a new initiative, MITIQ helped the University of Arkansas at Little Rock (UALR) to successfully establish the first-of-its-kind master of science degree in information quality (MSIQ). Twenty-five students enrolled in the first MSIQ offering, beginning in fall 2006. UALR is rapidly becoming the focal point for information quality education, both in the US and internationally. In a May 2007 meeting at UALR, Dean Mary Good announced the reappointment of Dr. Wang as visiting university professor of information quality. His goals will be to assist UALR in establishing a first-of-its-kind PhD degree program in information quality, launch professional training programs that will be offered at the Clinton Presidential Library, and position the UALR IQ program to become part of the rollout of the Arkansas Research Alliance (sponsored by the Arkansas Governor's Office) by applying information quality theories developed at MITIQ and UALR.

At MIT in November 2006, MITIQ hosted the 11th International Conference on Information Quality (ICIQ-2006). ICIQ-2006, the premier conference in the information quality field, presented a forum for researchers and practitioners to exchange IQ knowledge and ideas. More than 160 participants from both academia and industry worldwide took part.

In December 2006, MITIQ initiated the MIT IQ Industry Symposium, designed to bring together practitioners, vendors, and academicians to address IQ issues. In addition to

presentations and workshops, the July 18–19, 2007 symposium included topics such as vendor presentations, product announcements, and consultancy methods; all will complement the annual International Conference on Information Quality at MIT. The idea for a symposium was well received by vendors and professionals in the information quality field, and some 150 delegates committed to participate.

### **MITIQ Funding**

The MITIQ consortium continues to receive sponsorship from Lockheed Martin and Axiom Corporation totaling \$150,000 per year. It is expected that other leading organizations and participants in the ICIQ Conference will join the consortium.

### **MITIQ Publications**

Yang W. Lee, Leo L. Pipino, James D. Funk, and Richard Y. Wang (2006), *Journey to Data Quality*, Cambridge, MA: MIT Press.

Yang W. Lee, Elizabeth Pierce, John Talburt, Richard Wang, and Hongwei Zhu, “A Curriculum for a Master of Science in Information Quality,” Summer Issue, Vol. 18, No. 2, *Journal of Information Systems Education*, 2007.

Additional information about MITIQ can be found at <http://mitiq.mit.edu/>.

### **Technology and Law Program**

The Technology and Law Program (T&L) 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 the prevention of chemical pollution through regulation, liability, and economic incentives; promoting environmental justice by involving communities in governmental decisions that affect their health, safety, and environment; and addressing the effects of globalization on sustainability.

T&L offers a two-semester sequence in environmental law and policy that is colisted in Engineering and Urban Studies. ESD.132J Law, Technology, and Public Policy, a core subject in the Technology and Policy Program, and ESD.137J Sustainability, Trade, and Environment are listed jointly with the School of Engineering and MIT Sloan. Originally part of the Cambridge–MIT Institute, the latter course continues to be offered at Cambridge University; it is also taught at the Harvard-Cyprus Institute of the Environment in Nicosia. A course in European and international environmental law is also taught at the Harvard-Cyprus Institute. As a result of the program, the MIT perspective on environmental law and sustainability has achieved international recognition.

A textbook titled *Environmental Law, Policy, and Economics: Reclaiming the Environmental Agenda*, by T&L director Nicholas Ashford and Charles Caldart, a lecturer in civil engineering, will be published by MIT Press next fall. A second textbook, *Globalization, Technology, and Sustainability*, is in preparation by Professor Ashford.

### **Technology and Law Publications**

Nicholas A. Ashford. "The Legacy Of The Precautionary Principle in US Law: The Rise of Cost-Benefit Analysis and Risk Assessment as Undermining Factors in Health, Safety and Environmental Protection" in Sadeleer, Nicolas (ed.), *Implementation Of The Precautionary Principle in The Nordic Countries: Lessons from the EU and the United States* Earthscan, 2007; "Workers' Compensation," in *Environmental and Occupational Medicine*, 4th Edition, W.N. Rom (ed.), Lippincott-Raven, Philadelphia, 2006.

Lars Koch and Nicholas A. Ashford, "Rethinking the Role of Information in Chemicals Policy: Implications for TSCA and REACH," *Journal of Cleaner Production* 14(1): 31-46 2007.

### **Technology and Law Personnel**

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

**Joel Moses**

**Acting Director**

**Institute Professor, Professor of Computer Science and Engineering Systems**

**Acting Director, Engineering Systems Division**

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

### **MIT Center for Transportation and Logistics**

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

Our website, at <http://ctl.mit.edu/>, offers a wealth of information about the Center and its programs, including descriptions of current research projects, event listings, explanations of our corporate outreach program, a listing of MIT theses in transportation since 1980 and in logistics and supply chain management since 1999, and details on our educational offerings, including master's, PhD, and executive education programs.

### **Education**

Thirty-three new students arrived on campus in the fall of 2006 to enter the Center's master of engineering in logistics (MLOG) program as the class of 2007. MLOG is an



intensive nine-month degree track that prepares graduates for logistics management careers in manufacturing, distribution, retail, transportation, and logistics organizations.

The MLOG class of 2007 was geographically dispersed, with 50 percent coming from outside the United States, representing 10 different countries. By graduation, 85 percent of the class had at least one job offer (with an average of two offers per student).

### **MLOG Alumni Interaction**

CTL held its second MLOG ReConnect Day in May 2007. This two-day event, which is open to MLOG alumni, current MLOG students, and incoming MLOG students, features research presentations and professional development talks from selected faculty members. Its objectives are threefold. First, the event encourages networking. Second, it provides executive training to alumni. Finally, it allows incoming students an advance look at thesis research projects. Approximately one third of the alumni base attended this year, along with half of the incoming class.

### **MLOG at IAP**

During IAP 2007, MLOG sponsored the Supply Chain Innovation and Leadership Series, which consisted of the following:

“Technology in the Pharma Industry,” by Robin Koh, chief strategy officer, SupplyScape (January 22, 2007).

“Strategic Supply Chain Initiatives,” by Mark Jamison, vice president, Customer Supply Chain, Kimberly Clark (January 23, 2007).

“Implementing a Retail Demand Chain Driven by Service,” by Simon Osborn, vice president, Logistics, 7-Eleven (January 25, 2007).

“Supply Chain Challenges at Boston Scientific,” by Bob Cantow and Larry Strauss, Boston Scientific (January 29, 2007).

“Managing Uncertainty in the Agriculture Industries,” by Eli Partyka, Global Food Chain Partnerships manager, Syngenta (January 30, 2007).

“The Importance of Leadership in Supply Chain Projects,” by Ted Schaefer, director, Global Logistics Design, Rohm and Haas Company (February 1, 2007).

“Global Supply Chain Challenges,” by Roger Bloemen, vice president, Supply Chain, Solutia (February 2, 2007).

### **Supply Chain Education Partners Program**

This year, 13 companies participated in the Partners Program, which promotes supply-chain knowledge-sharing among leading executives and students in the MLOG program. A team of students is assigned a jointly scoped-out project that has both

practical and research aspects. This is double the number of companies sponsoring projects in years past. This year's projects included:

- Statistical Process Control Approach to Reduce the Bullwhip Effect—Cordis
- Sales And Operations Planning In a Global Business—Cordis
- Quantifying The Value of Customer Service—Boston Scientific
- Leveraging Downstream Data in the Footwear/Apparel Industry—Reebok/Adidas
- Biofuel Supply Chain Characterization—Shell Oil
- Demand and Supply Synchronization for Promotional Events—P&G and CVS Stores
- Managing Risk Versus Managing Crisis: Mitigating Supply Chain Disruptions—W. R. Grace
- Who Stocks The Shelf?: An Analysis of Retail Replenishment Strategies—Schwans Foods
- Strategic Outsourcing Framework for Logistics in the Pharmaceutical Industry—Pfizer
- What Is the Value Of Logistics for a Large Pharmaceutical Company?—Pfizer
- Reducing Risk In the Medication Administering Process—Cardinal Healthcare
- Quantifying the Value of Reduced Lead Time and Increased Delivery Frequency—P&G
- Inventory Segmentation and Operational Policies for a Chemical Producer—Solutia
- Optimizing Dedicated and Core Transportation Assets—Chiquita
- Rolling Out Rapid Replenishment: A Consumer Product Goods Case Study—General Mills
- Replenishment Prioritization of Highly Perishable Goods: A Case Study in Nuclear Medicine—Tyco Healthcare

## **Research**

During the past academic year, many new research projects were posted on our website, along with numerous projects carried over from previous years—a total of 99 efforts listed in various categories.

## **Major Projects/Initiatives**

### ***The MIT-Zaragoza International Logistics Program***

The MIT-Zaragoza International Logistics Program is part of a multiyear agreement with the government of Aragón, Spain, to help create an international education and research program in logistics and supply chain management. The government of Aragón

established the Zaragoza Logistics Center (ZLC) as a special research institute associated with the University of Zaragoza. A new building for the ZLC has been designed, and construction is beginning 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.

### *Organization*

The ZLC began the year with six full-time faculty members and added one adjunct faculty member: Fabrizio Salvador, professor of operations management at Instituto de Empresa (IE) Business School. In addition, the following research staff members were hired to work on funded projects: Asvin Goel, (PhD, University of Leipzig); Rosa Birjandi (PhD, University of Maryland Business School); Desiree Knoppen (PhD, ESADE Business School); and Alessio Trentin (PhD, University of Padova, Italy). Jarrod Goentzel, executive director of the MIT-Zaragoza program, continued his temporary assignment in Zaragoza to help establish the international education, research, and outreach programs. In addition, the MIT-Zaragoza program hosted visiting professors from Dartmouth, Instituto de Empresa (Madrid), and INCAE (Costa Rica).

### *Education*

This year saw the graduation of the third class in the Zaragoza master's degree program (ZLOG), an intensive nine-month program modeled on MIT's master of engineering in logistics program (MLOG). Fifteen students (including seven women) from eight countries comprised the class of 2007.

The MLOG-ZLOG international exchange, occurring during January (IAP), brought MLOG and ZLOG students together for three weeks at CTL and one week at the Zaragoza Logistics Center in Spain. The course included more emphasis on team leadership skills this year than in the past. There were a series of seminars from supply-chain executives, and a four-week simulation exercise in which teams of students from both programs competed against each other in managing a virtual supply chain.

The MIT-Zaragoza doctoral program continued to grow slowly this year; one new student will visit MIT in the fall of 2007 for courses in his second year of study. Three new PhD students will join the program in the fall of 2007.

MIT-Zaragoza extended its relationship this year with Instituto de Empresa (IE) Business School to include a formal exchange option for PhD students. One ZLOG student completed the new dual master's degree program with IE, earning both the ZLOG and the IE International MBA.

On March 3, 2007, the board of directors of the MIT Alumni Association approved the MIT-Zaragoza program for associate member status. MIT-Zaragoza graduates, who have secured good positions with international companies, should be valuable, professional members of the MIT alumni network.

### *Research*

On a national level, the ZLC continued its leadership of the Spanish National Center of Excellence on Integrated Logistics (CNCLI), and obtained additional funding from the national government for the Singular Strategic Project for research in logistics. The CNCLI coordinated the newly formed National Technology Platform for Integrated Logistics (LogisTop), which engages industry and research institutes to define research and development priorities and action plans on strategically important issues for Spain's future growth and competitiveness. One key deliverable for LogisTop this past year was the "Visión Estratégica 2020 de la Logística Integral en España" report.

MIT-Zaragoza established a strategic research partnership with Deutsche Post/DHL, the largest logistics company in the world, to discover and develop innovative solutions for international supply chains; the partnership is linked with the new DHL Innovation Center near Bonn, Germany. In addition, DHL reassigned members of its innovation team to the ZLC, to work alongside MIT-Zaragoza researchers. The collaborative venture launched research projects in three key areas: (1) in-transit visibility, (2) reverse logistics, and (3) postponement strategies, with financial support from the EU and from InnovAragón, an initiative of the government of Aragón in northern Spain.

This year, research projects were also conducted with the following companies and organizations: PLAZA Logistics Park, Aragón Exterior, Lucent/Alcatel, AENA (the airport authority of Spain), Acciona, the International Federation of Red Cross and Red Crescent Societies, Save the Children, the Center for Global Development, and the Gates Foundation. In addition, two major research proposals for EU Framework Program funding were submitted in partnership with SAP.

### *Outreach*

The major outreach event for the MIT-Zaragoza program this year occurred in March 2007—the Crossroads 2007: Supply Chain Innovation Summit. It combined two flagship events: the 3rd MIT Supply Chain Crossroads Symposium, and the 3rd Zaragoza Supply Chain Summit. It also featured a keynote address by MIT President Susan Hockfield, who was joined by top executives from such industry leaders as Best Buy, Johnson & Johnson, IBM, Zara, DHL, SAP, and Intel. These executives shared details of their companies' varied approaches to driving innovation in complex supply chains. In addition, the program launched a monthly seminar series featuring international researchers and supply-chain executives who present their innovative work to ZLC faculty, research staff, and graduate students, as well as to the wider industry and academic community in Aragón.

### ***Supply Chain 2020***

The SC2020 project is a multiyear pioneering research effort to identify and analyze the factors that are critical to the success of future supply chains, one that 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 do, the project hopes to deliver practical breakthroughs on the design and management of future supply chains. The project also aims to help companies understand the forces that are changing supply

chains so they can be better prepared for the future. This work can create value in society through improvements in transportation, logistics, and supply-chain management (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 more than 40 leading companies—the Industry Advisory Council and the European Advisory Council—routinely meet to play a crucial role in helping to shape the work and generate new ideas. To date, seven advisory council meetings have been conducted. (The proceedings are available online.)

SC2020 research is 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, the objective of Phase II was to 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 (master of science in transportation), and was supervised by five MIT faculty advisors from Sloan, CTL, Materials Science and Engineering, and the Lean Aerospace Initiative. 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 master's theses, five working papers, and one PhD thesis have been written under the aegis of Phase I.

Phase II of SC2020 was completed in June 2006. The objectives were to develop a set of 2020 macro factor scenarios, including natural resource-related issues such as energy and material availabilities, as well as environmental pressures. Three working scenarios were developed. In addition, six MLOG students researched different supply chain functions—including order fulfillment, customer collaboration, supplier collaboration, demand supply matching, after-market service, and new product introduction—by comparing prominent companies in nine different industries. The underlying idea of this research was to identify practices in various functions that cut across industries and practices that are unique.

In November 2006, CTL organized a symposium titled “Building the Future Supply Chain Now.” This event brought together MIT faculty and staff, industry Advisory Council members, and CTL sponsors to discuss visions of the future and how supply chains might be reshaped by them. Another event was run in Zaragoza, Spain in early April 2007, to solicit European input on similar issues.

Phase II research was conducted by one postdoctoral fellow and 11 MIT graduate students from MLOG, TPP, and CEE; they were supervised by MIT faculty advisors from CTL, Materials Science and Engineering, and LAI. The SC2020 project funded five of these students with full or partial research assistantships, as sponsored one postdoctoral



fellow. So far, six master's theses and two working papers have been written based on the work carried out during this phase.

Phase III of the project was designed to carry out the research in close collaboration with the participating companies, to test and explore more ideas for our supply chain strategy development process. During AY 2006–2007, we had the opportunity to engage with companies such as Pfizer, P&G, Intel, and Solutia, and apply our research findings to date. The results of the workshops and engagement with the companies were better than we had expected. Feedback has been positive, and we have received useful suggestions that will further enhance our understanding of the domain and the process. At the same time, we continue to use the updated teaching material that was developed based on our research to deliver three- and four-hour sessions in the two executive education meetings offered by CTL each January and June. We currently are working closely with a Fortune 50 company to implement our process in its entirety, and to develop the strategy for them. This will be our first full engagement, one that will help us validate the methodology. We expect this work to go on for the next few months.

### ***Demand Management***

In 2006, demand management (DM) research began with a variety of initiatives. The major question being addressed is: “What strategies, principles, and methods can be leveraged to optimally match supply and demand over time?” To address this question, a comprehensive database of DM practices and survey results across a multitude of industries is being established. The focus is on the exchange of information, practice profiling, interviews with experts, and industry surveys.

A symposium on “Demand Management: Optimizing Supply and Demand over Time” was held from September 12–13, 2006, at MIT. The symposium, whose participants included CTL Supply Chain Exchange sponsors, involved information-sharing on sales and operations planning, customer service policies, and the building of demand-supply bridging processes. This was a launch event for the creation of a special interest group comprised of sponsor companies interested in DM. DM workshops have been conducted onsite at Chiquita and TI, to share knowledge and profile DM practices.

### ***Hydrogen Supply Chain***

In May 2007, the Zaragoza Logistics Center received a €290,000 research grant for systems modeling and analysis of the hydrogen supply chain, with the objective of developing options and helping guide large-scale infrastructure development. The three-year project will be developed in direct collaboration with Acciona Energy, the third-largest operator of wind energy, and other key partners Gas Natural and Repsol YPF. The expected result is a comprehensive decision support model—utilizing principles from commercial supply chain, systems engineering, and operations research—that can be used to assess various scenarios for a hydrogen supply chain and weigh complex alternatives. The model would enable a strategic evaluation of various technologies for production, storage, and distribution of hydrogen, and would assess infrastructure development as a phased rollout. The MIT-Zaragoza program could help link this project with ongoing work in the MIT Energy Initiative.

### **MIT-Volpe Transportation Human Factors Research Program**

CTL will play an important role in the newly established MIT-Volpe Transportation Human Factors Research Program. Since its founding in 1970, the DOT/RITA Volpe Center has provided analytical, scientific, and engineering support to the US Department of Transportation. Collaborative relationships naturally arose between MIT faculty and Volpe researchers, managed either via direct contracts between Volpe and MIT administrative units or via a blanket task order with the MIT Center for Transportation (now the Center for Transportation and Logistics). Many of these relationships focused on issues in the transportation human factors area. In the late 1990s, the CTL Task Order provided \$3–5 million in annual support, much of which went directly to MIT graduate student stipends and tuition. Projects involving graduate students physically working at Volpe (adjacent to MIT) qualified for MIT's off-campus overhead rate, lowering the costs of research for Volpe's DOT sponsors, and providing physical space for student offices and labs that were increasingly scarce on the MIT main campus. The arrangement also provided access to unique Volpe facilities in the areas of air traffic control, acoustics and air quality, flight simulators, and railroad simulators. Volpe created a Volpe/MIT Transportation Human Factors Laboratory in 1993 in its Building 6, and signed a cooperative research and development agreement with MIT. The atmosphere was collegial, with students, faculty, and Volpe staff working side by side and holding frequent joint seminars. Between 1998 and 2003, 13 MIT faculty members participated, collaborating with an equal number of Volpe senior researchers.

In the spring of 2004, MIT and Volpe sought to renew the task order agreement. However, during the negotiations it was learned that DOT's post-9/11 security policies required that—like all other Volpe employees—all MIT employees (including graduate student research assistants) working on the task order now had to be US citizens or permanent residents, and needed to undergo background investigations and training appropriate for handling sensitive information. MIT has had a longstanding policy that foreign faculty, students, staff, and scholars should not be singled out for restrictions in their access to MIT's on-campus educational and research activities. Volpe appealed the DOT policy to the Secretary of Transportation, but was denied. Reluctantly, MIT and Volpe decided not to pursue task order renewal, and most tasks were terminated in September 2004. Faculty and students—even those who were US citizens—turned in their Volpe badges and closed their offices. In cases where the research could be completed entirely on the MIT campus and did not require access to Volpe simulators or other unique facilities, separate contracts were put in place—at the on-campus MIT indirect cost rate. Lacking Volpe security credentials, MIT faculty and students could now visit Volpe colleagues only when escorted. The collegiality that results from daily professional contact ceased.

MIT's longstanding policy against foreign national restrictions for work performed on the MIT campus has been motivated by the desire not to create a "two class" atmosphere. However, MIT has long recognized that there are several federally-sponsored programs specifically designed for education of US citizens, such as NIH and NSF training grants and the NASA Graduate Student Researchers Program, and routinely administers government and private fellowships (for example, minority fellowships) that carry citizenship restrictions (though they do not necessarily provide

access to restricted facilities). MIT's June 2004 official policy on Foreign National Restrictions on Research Projects specifically acknowledged that in circumstances where the research enhances US capability and manpower in a particular area of science and engineering, exceptions to foreign national restrictions for training programs could be made.

MIT currently has contracts for graduate student support with the Draper Laboratory and the Lincoln Laboratory in which only US citizens or permanent residents are eligible. Students are physically located at Draper and Lincoln Labs and obtain their security credentials there; their work is cosupervised by MIT faculty and Draper/Lincoln Labs staff. However, these students attend regular MIT classes. Because of their proximate location to the MIT campus, their thesis research is not considered in absentia. MIT has recognized that background checks and information technology security procedures are necessary and appropriate in specific cases where MIT employees work offsite. MIT considers the Draper and Lincoln Labs fellowship programs compatible with MIT policy on foreign nationals because the students are able to fully participate in both their research group and department activities and can openly present their work to their peers in the same way that students working on campus can. The MIT-Volpe Transportation Human Factors Research Program will operate on a similar model.

In late 2005, the operations plan for the new program (described below) was reviewed and approved by the director of CTL, the MIT Provost, the MIT Research Policy Committee, the director of MIT's Engineering Systems Division, and the heads of the Departments of Civil and Environmental Engineering and Aeronautics and Astronautics. This plan has now been formally put in place.

The goal of the new MIT-Volpe Transportation Human Factors research program is to initiate active research collaborations in the areas identified below. Collaborations will be between Volpe technical staff members, MIT faculty and senior research staff members, and the graduate student(s) they cosupervise. The MIT supervisor's role will not be limited to that of pro forma thesis reader/signer. The MIT supervisor is expected to actively participate in the genesis and progress of the project, make a commitment to spend time at Volpe, remain in contact with his/her Volpe collaborator, actively cosupervise the MIT student's work, and provide academic and professional counsel to the student on their roles and responsibilities. The faculty member will ensure that the student presents their work both at Volpe and in their home department at MIT as well as at professional conferences, and publishes their results in scholarly journals in a timely fashion. Undergraduate students may also participate as assistants (5 to 10 hours per week) through MIT's Undergraduate Research Opportunities Program (UROP), although they will usually have to work on an escorted basis since obtaining information security credentials for them is likely to be impractical.

The objective of this contract is to conduct advanced transportation-related research into aspects of transportation technology, policy, and safety consistent with the graduate and undergraduate educational mission of the contractor. Tasks to be defined will cover all modes of transportation operations and safety-related programs, including, but not limited to, the following general areas:

- Applying computer science techniques to air traffic control, traffic management systems, intelligent transportation systems, transportation system scheduling and planning, and safety enhancement
- Using test facilities for verification of appropriate application of new technologies to transportation systems problems
- Using simulators and modeling tools to develop, analyze, and improve transportation safety, policy, and planning, including asset management and risk management
- Applying the expertise and resources of the Volpe/MIT Center for Human Factors Research to conduct research on advanced man-machine interfaces in transportation systems
- Determining benefit-costs of various human factors safety, security, and mobility issues and solutions within and across transportation systems.

This contract was officially signed in the late spring of 2007.

### **New England University Transportation Center**

In August 2006, the US Department of Transportation's (USDOT) Research and Innovative Technology Administration (RITA) named MIT as the lead university of the New England University Transportation Center. CTL is the Institute's host department for the New England Center, which is one of 10 university centers set up in each of the standard federal regions by USDOT to provide a national resource for research and education in both freight and passenger transportation.

This leadership appointment comes with a \$6.25 million grant for the New England Center, to be awarded over three years. The award was made for proposed research on "Strategic Management of Disruptive Change on Transportation Systems." This area of inquiry builds on research currently being done by the CTL AgeLab on aging and transportation, specifically, on the impact of disruptive demographics. Dr. Joseph F. Coughlin, founder of CTL's AgeLab, is also the director of the New England University Transportation Center.

The partner universities of the New England University Transportation Center led by MIT include Harvard University and the state universities of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

### **MIT Supply-Chain Newsletter (Frontiers)**

*Frontiers* is an electronic newsletter created by CTL to disseminate information to more than 3,000 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 CTL representatives and staff appointments.

### **Supply Chain Newsletter (Supply Chain Strategy)**

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

### **CTL's Outreach Program**

CTL's outreach program works primarily with corporations to: (1) generate revenue in support of our research and outreach activities, (2) establish relationships with a wide range of organizations that can serve as research collaborators and ready sources of real-world input, and (3) foster rapid adoption of supply chain management innovations developed by the Center.

The foundation of our corporate outreach is the Supply Chain Exchange, a nonresearch corporate membership program designed to foster interaction and networking—the “exchange” inherent in the name—among CTL researchers, our corporate members, and industry at large. We believe the Exchange to be the largest and most active membership program in the supply chain management field. Since mid-FY2004, new Exchange members have paid an annual fee of \$25,000. Membership in the Exchange is prerequisite to all other interactions with CTL, including directed research projects, sponsorship of MLOG thesis projects, and membership in higher tiers of the outreach model.

The current Exchange members are listed below:

1. APL
2. Boston Scientific Corporation
3. BT Group
4. C.H. Robinson Worldwide, Inc.
5. Cardinal Health, Inc.
6. Caterpillar Logistics Services, Inc.
7. Cephalon
8. Chiquita Fresh North America
9. Cordis, a Johnson & Johnson Company
10. Covidien
11. CSX Transportation
12. CVS Corporation
13. DHL
14. EMC Corporation
15. Fairchild Semiconductor



16. General Mills, Inc.
17. General Motors
18. Goodyear
19. i2 Technologies, Inc.
20. Intel Corporation
21. Limited Brands, Inc.
22. LXP
23. Masterfoods USA (M&M Mars, Inc.)
24. The Michelin Group
25. Monsanto Company
26. MTA New York City Transit
27. NYK Line (North America), Inc.
28. The Pepsi Bottling Group, Inc.
29. Pfizer Inc.
30. Philips Lighting
31. The Procter & Gamble Company (P&G)
32. Reebok International Ltd.
33. The Schwan Food Company
34. Sealed Air Corporation
35. Shaw's Supermarkets, Inc.
36. Shell
37. The Siam Cement Public Company Limited
38. Solutia Inc.
39. Staples
40. Tata Steel
41. Texas Instruments Incorporated
42. Tyco International
43. Unilever
44. UPS
45. USTRANSCOM
46. W. R. Grace & Co

## Corporate Relations

The ongoing strategy driving our outreach program is to increase the number of CTL's partner organizations via membership in the Exchange program, and to deepen our engagement with individual partners by growing their participation in our educational and research activities.

During 2006–2007 we invested increased effort in examining the quality of our partner relationships, focusing on such criteria as the timely and complete payment of membership fees and the effectiveness of our key contacts within partner companies. As a result, Exchange program memberships of five companies were declared lapsed: Raytheon; Manhattan Associated; Lucent Technologies, Inc.; C&S Wholesale Grocers, Inc.; and Corporate Express, Inc. On the plus side, five companies were added to our partner community: Shell, General Motors, Goodyear, CVS/Caremark Corporation, and Cephalon.

As a result, the number of Exchange partners remains stable at 46, although we clearly ended the year with a more engaged portfolio of partners—and, through the account review process, our partner relationships are stronger and more productive. For the coming year we would like to increase the absolute number of partners (50 is a goal) while deepening our partner engagement overall. Aware of the demands that a larger, more active partner base represents, we plan to augment our resources accordingly.

## Outreach Events

The 2006–2007 year was an exceptional one for CTL: we find ourselves with a rich body of knowledge created by our ongoing Supply Chain 2020 Project, as well as an exciting roster of new research directions. As a result, we organized symposia, roundtables, workshops, conference sessions, and a Research Fest to achieve our varied outreach objectives, as follows:

- In September, we held a two-day symposium on demand management to examine cutting-edge practices in that area. The event was unique for its stress on cross-functional coordination. In addition, we encouraged partners to send teams from various departments, including logistics, manufacturing, and sales and marketing. In March we held the third of our annual Crossroads events at Zaragoza, Spain, focused on the topic of supply chain innovation. This event targeted executives from supply chain management functions and beyond to emphasize the intersection of supply chain with corporate strategy.
- We organized three roundtables as a means of convening expert-level dialogue around specific topics. We included 20–25 people from a variety of relevant organizations, and the discussion was primed via a position paper and moderated by CTL personnel. The first of this year's roundtables, on the healthcare supply chain, was held in August 2006. This event proved extremely helpful in the development of a new research consortium that CTL launched on July 1, 2007. In March 2007 we held a second roundtable, discussing supply chains for emerging markets. The event resulted in a deep examination of this important area and helped to frame a potential research agenda. In May 2007, at

- the request of Proctor & Gamble, we held another roundtable to brainstorm the supply chain capabilities that will be important in the near future (three to five years). This event generated extremely positive feedback.
- During 2005–2006, CTL developed a set of executive workshops designed to deliver research results from our Supply Chain 2020 Program. In the year just ending, we continued to implement these workshops and refine our delivery modalities. We held open enrollment workshops in business continuity planning and scenario planning during the first half of the year. In addition, we achieved significant evolution of our content delivery by moving into customized implementations for partner companies. We conducted workshops for Pfizer, P&G, Intel, Solutia, and Siam Cement. Positive feedback led to repeat events with some companies.
  - During the last year, CTL also explored a new channel of industry outreach by partnering with the Council of Supply Chain Management Professionals (CSCMP), the leading professional association in supply chain management. At the CSCMP annual conference in October 2006, CTL drove two major sessions: a “hot topics” plenary session on the energy-efficient supply chain and a large breakout session on supply chain disruption. The first of these was designed to host a discussion around a future-focused issue—something seldom attempted in the conference setting. The second event was a delivery to a broad and general audience of mature content that we had previously delivered to partners via a symposium and a workshop. In April 2007, CTL also teamed with CSCMP on a conference on energy and the supply chain. We plan to build on these events to modify and enhance CTL’s participation in the 2007 annual conference. In particular, we plan to emphasize MIT as the authority on hot topics in order to capitalize on our reputation—and our strengths—in helping supply chain professionals look over the horizon.
  - This year, CTL’s MLOG Program Office extended its year-end thesis review—dubbed the MLOG Research Fest—to our Exchange Partners. The result was an opportunity, over the course of a day and a half, to hear about a wide range of freshly completed research and to network with a diverse group of partners, students, alumni, and faculty/staff.

## **Major Events**

### ***Demand Management: Optimizing Supply and Demand Over Time***

On September 12–13, 2006, CTL held a symposium in Cambridge that focused on bridging the gap between supply and demand. The two-day event attracted more than 50 professionals from more than 20 companies, and featured presentations by thought leaders and experts in demand management from a variety of industries. The symposium, which supported CTL’s recently-launched demand management research initiative, examined the connections between traditional SCM activities and the demand generation and management processes in four related areas: (1) setting customer expectations, (2) planning, (3) scorecards and dashboards, and (4) bridging the supply-demand gap.

### ***Crossroads 2007: Supply Chain Innovation Summit***

As mentioned earlier, CTL partnered with the Zaragoza Logistics Center (ZLC) for this premiere supply chain event, where top business leaders and supply chain experts from around the world gathered to share the innovative strategies, processes, and tools being used to successfully manage increasingly complex supply chains, and to examine the impact of these advances on businesses and consumers. The summit brought together two flagship events: the annual CTL Crossroads Symposium organized by the MIT Center for Transportation and Logistics, and the Zaragoza Supply Chain Summit, organized jointly by the Zaragoza Logistics Center and CTL. More than 400 executives attended the conference, which featured presentations by MIT president Susan Hockfield; Lorena Alba, managing director of logistics, Zara-Inditex Group; Tim Carroll, vice president of supply chain operations, IBM; LaVerne H. Council, CIO of Johnson & Johnson; Yossi Sheffi, professor, MIT Engineering Systems Division and director of MIT-CTL; and Robert A. Willett, CIO of Best Buy and CEO of Best Buy International.

### ***Achieving the Energy-Efficient Supply Chain***

Also mentioned earlier was CTL's cosponsorship with the CSCMP of this April 30, 2007 symposium in Cambridge. The event brought together leading industry experts to explain the business implications of higher energy costs, and to offer strategies to build energy efficiency into the supply chain. Topics discussed included developing an ROI for energy cost-cutting programs, measuring the carbon footprint, integrated approaches to supply chain energy efficiency manufacturing and distribution network design, and transportation and packaging.

### ***Smaller Functions***

#### ***Healthcare Supply Chain Roundtable***

The roundtable CTL held on August 29, 2006 was designed to frame key issues and help define a multiyear research agenda for a new CTL initiative focused on the healthcare supply chain. The initiative will build on a range of work we have done in the past, as well as our partnerships with key players in this domain, including Cardinal Health, Tyco Healthcare, Proctor & Gamble, Johnson & Johnson, and CVS; many of those companies sent representatives to the event.

#### ***Managing a Supply Chain in Crisis***

At the annual CSCMP Conference held in October 2007 in San Antonio, Texas, CTL staged a real-time simulation of an avian flu outbreak to show how global supply chains are severely disrupted by such emergencies. This session was featured in this year's Hot Topics track, a new session introduced by CSCMP to highlight topical supply chain issues. A panel of executives responded in real-time to the unfolding emergency, which was shaped by prompts and scripted news bulletins delivered by a facilitator.

#### ***SC2020: Building the Future Supply Chain Now***

CTL once again held symposia on both sides of the Atlantic this year, each one leveraging the insights from CTL's [Supply Chain 2020 Project](#). MIT faculty and staff, SC2020 Advisory Council members, and CTL sponsors came together—in Cambridge in

November 2006 and in Zaragoza, Spain in April 2007—to discuss visions of the future and how supply chains might be reshaped by them. They examined how several macro factors, such as an aging population, technology, and energy will affect future supply chains, and looked at ways to use scenario-planning techniques to prepare for the future.

### ***Emerging Market Supply Chains Roundtable***

Our March 7, 2007 roundtable in Cambridge on emerging market supply chains focused on defining challenges presented by these large and untapped markets, strategies for successfully organizing the supply chain, and developing capabilities to serve these markets. This event provided participants with access to the latest research, observations from companies with experience in emerging markets, and an opportunity to discuss new ideas and possible solutions with business and academic leaders.

### ***Future Capabilities Roundtable***

Our May 8, 2007 roundtable for CTL partners and invited guests focused on the capabilities companies will need to build into their supply chain to maintain competitive advantage in the next three to five years. It included informal briefs from CTL partners.

### ***MLOG 2007 Thesis Review***

On May 23–24, CTL invited members of the Center’s Supply Chain Exchange to get an insider’s look at the innovative research being done by students in CTL’s master of engineering in logistics (MLOG) program. During this day-and-a-half-long review, MLOG students presented their thesis projects, many of which were sponsored by CTL partners. This year, the Research Fest included 22 presentations on a variety of topics, including S&OP processes, promotion planning, fleet scheduling, and product segmentation and portfolio management.

## **Professional Education**

### ***Executive Courses***

Twice a year, CTL hosts an executive course titled “Supply Chains Driving Strategic Advantage: Managing Dynamics & Innovating the Future.” The course is a fast-paced mix of management exercises, case studies, and interactive sessions featuring an impressive lineup of MIT’s leading supply chain thinkers. This year, the course was offered from June 19–22, 2006 and January 3–5, 2007.

### ***Executive Workshops***

CTL added three new open-enrollment executive workshops this year in the areas of business continuity planning, scenario planning, and strategy alignment. These highly interactive, two-day events can be brought onsite to companies, using real business cases from within that organization. CTL also offers general workshops at MIT for business continuity planning and scenario planning. These are not company-specific and are open to the public.



### ***Business Continuity Planning Workshop***

As mentioned above, our November 28–29, 2006 workshop at MIT took participants through a real-time simulation of a large-scale business disruption—specifically, an avian flu outbreak. As the unfolding events disrupt a global supply chain and threaten to overwhelm the organization, participants took on the roles of responders across corporate disciplines who must work together to develop and execute response and continuity strategies.

### ***Scenario Planning Workshop***

Held March 27–28, 2007 at MIT, this workshop presents participants with a set of scenarios—each a specially constructed model of a distinct, plausible view of the future. The purpose is not to pinpoint future events, but to highlight large-scale, driving forces that push the future in different directions. By working within the bounds of these scenarios, participants are able to think productively about contingencies and alternatives and learn to work with uncertainty rather than try to eliminate it from forecasts.

### ***Strategy Alignment Workshop***

Held at Intel Corporation in Phoenix, AZ, in August 2006 and at Siam Cement in Thailand in spring 2007, this two-day onsite workshop walked executives through the process of developing strategically aligned supply chains through the use of real supply chain case studies from inside their own companies. This workshop fostered the sharing of knowledge among executives and managers from across disciplines and encouraged more forward-thinking and collaboratively based process innovation.

### ***CTL's Web Presence***

The Center's web presence and use of web services grew steadily during the 2007 fiscal year. The Center's main website, <http://ctl.mit.edu/>, continues to average more than 18,000 page views per month, with higher figures around event dates and focused marketing campaigns. The site's content continues to expand, and iterative work moves ahead at a steady pace. The Center developed and launched a number of smaller sites for specific projects, and new sites for the MIT Efficient Healthcare Delivery Research Group and the Supply Chain 2020 project have steady traffic.

CTL also maintains a number of other smaller websites. These include a supply chain security website; a companion site for the Center director's award-winning book, *The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage*; Center director Yossi Sheffi's personal website; and the MLOG graduate program site. The latter recently underwent a navigation and content overhaul.

Mblog, a blog for students of CTL's MLOG program, continues to be a successful vehicle for networking, conversation, and learning for the program's incoming and current students.

During FY2007 the Center completed research and implementation of an email marketing strategy, using an online subscription service; we also are making regular use of online webinar services.

Work continues on integrating the Center's web portal with the MIT Alumni Association's online directory. The goal for this project is to provide a valuable networking tool for graduates of the Center's MLOG and ZLOG programs.

FY2007 saw the further integration of CTL's web presence into all marketing and brand identity strategies and tactics. This will continue as the Center looks forward to providing more valuable online resources and events for our corporate partners, faculty, and students, both domestically and internationally.

### **Personnel Changes**

The Center's staff was enhanced this year with several new hires: Jonathan Long, Saskia Michl, Cristobal Carmona, Jennifer Simckowitz and international visiting students Anna Pohlmeier and Vincent Lammers. Departures from the Center included Lillian Lai, long-time employee Kimberly Mann, and Roz Puleo.

### **Recognition**

Professor Yossi Sheffi was awarded one of Spain's top honors in the field of logistics, the PLAZA 2006 Award. The president of Aragon, Marcelino Iglesias Ricou, presented the award to Dr. Sheffi at a special ceremony held in Zaragoza, Spain on October 5, 2006. Professor Sheffi was selected for this prestigious honor because of his leadership in establishing the MIT-Zaragoza International Logistics Program, and to acknowledge the contribution of the program to Aragon's economic development.

In July 2006, 3M selected CTL's Supply Chain 2020 project and project director Mahender Singh for a \$50,000 3M-MIT Innovation Award. The award will help to fund SC2020's ongoing research into the future of supply chain. 3M awards these funds annually to nontenured faculty in selected technical fields; the aim is to encourage the recipients to remain in academia, teach, conduct research of general interest to 3M, and to develop an awareness of science in an industrial setting.

The International Association for Travel Behaviour Research (IATBR) presented Professor Moshe Ben-Akiva with a Lifetime Achievement Award at the 11th IATBR conference in Kyoto, Japan, on August 19, 2006. The award recognizes individuals who have made fundamental and sustained contributions to travel behavior research over his or her professional career, and who have influenced the field through his or her writings, teaching, service, and nurturing of younger professionals.

In May 2007, the School of Engineering honored CTL event coordinator Nancy Martin with the Infinite Mile Award for Sustained Excellence. Infinite Mile Awards are given to individuals who stand out because of their high level of commitment and dedication, and the enormous energy and enthusiasm they bring to their work. At the ceremony, Nancy was recognized for her gift for problem solving under pressure, and her excellent event planning, team building, and interpersonal skills.

**MLOG Student Awards**

Shardul Phadnis won the MLOG 2007 Outstanding Thesis award for his research on developing inventory segmentation and operational policies for Solutia, Inc. Shardul will be joining the doctoral program at the MIT Engineering Systems Division.

The New England Roundtable of the Council of Supply Chain Management awarded Josh Merrill, MLOG 2007, its \$1,000 Academic Achievement Scholarship, based on his exemplary academic record and impressive recommendations. Josh served as president of the Institute's Supply Chain Management Club, which continues to host innovative supply chain speakers and events for the entire MIT community. After graduating from the MLOG program in June 2007, Josh will work for Chiquita Brands, Inc. in Cincinnati, Ohio, as a transportation planner, a role that will involve network optimization across the entire organization. Before coming to MIT, Josh worked as a senior business analyst at ABG, Inc., and earned a BS in quantitative agriculture economics at Purdue University.

**Yossi Sheffi**

**Director**

**Professor of Civil and Environmental Engineering and Engineering Systems**

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