

Research, Education, Outreach

Third Annual Report

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July 3, 2008

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Center for Engineering Systems Fundamentals (CESF): Research, Education, Outreach

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OVERVIEW: This was a year of producing results for the still new Center for Engineering Systems Fundamentals. There are now six graduate students working directly on CESF-related research projects, and some of these are now leading to journal publications. And more MIT faculty members are becoming involved in the research, especially as a result of the path-breaking “Energy Box” work being supported by the MIT-Portugal Program and the pandemic flu research supported by the Sloan Foundation. Much of this is linked to IBM-affiliated initiatives to establish a new applied discipline, “Service Science.” Also, 2007-2008 was an academic year providing the second offering of the new required ESD doctoral subject, ESD.86, *Models, Data, & Inference for Socio-Technical Systems* (with Prof. Dan Frey).

MIT LINC, Learning International Networks Consortium, gave one of the largest international conferences ever offered by MIT on foreign soil – in Jordan and Dubai. We are in current discussions with foundations about follow-on research and implementation work to leverage the results of the LINC conference. Including LINC, MIT-Portugal and the Sloan Foundation, the total of new funds committed to CESF this year is approximately \$1,000,000.

1. **ESD.86: Continuing Developments on a new MIT Subject on Fundamentals**

In the middle of a three-year subject development plan, ESD.86 was taught for the 2nd time during the spring semester (2008):

ESD.86 Models, Data, Inference for Socio-Technical Systems (New)
Prereq: ESD.83, 6.041 G (Spring) 3-0-9

Use data and systems knowledge to build models of complex socio-technical systems for improved system design and decision-making. Enhance model-building skills, including: review and extension of functions of random variables, Poisson processes, and Markov processes. Move from applied probability to statistics via Chi-squared t and f tests, derived as functions of random variables. Review classical statistics, hypothesis tests, regression, correlation and causation, simple data mining techniques, and Bayesian vs. classical statistics. Class project. Enrollment limited to 25 students. Preference given to ESD Ph.D. Students.

Richard C. Larson, Daniel D. Frey

This year 19 students took the subject for credit and about another five were listeners. Professors Frey and Larson view the past year's offering as the second or 'beta version,' and next year as the final steady state version.

Continuing development of "Engineering Systems Fundamentals" leading to ever-newer materials for this subject, is being supported in part by the new MIT-Portugal Program. We are pleased to announce that the educational materials of this subject are ported to MIT's OpenCourseWare (OCW) system and are now available on OCW web pages.

2. CESF Research Initiatives

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

We benefited this year from the following support:

Cordell Hull grant, \$100,000. Strategies To Overcome Network Congestion In Infrastructure Systems.

Research in Engineering Fundamentals. MIT ESD Portugal Project. \$100,000.
Electricity Management. MIT ESD Portugal Project. \$100,000.

The Sloan Foundation of New York. PANDEMIC INFLUENZA: *Social Distancing & Hygienic Policies* to Reduce its Prevalence. \$350,000.

In addition, we received substantial financial support from many different organizations in support of the international conference, MIT LINC 2007.

As of this writing we have four submitted proposals under review:

Linking Assessment and Measurement to Performance for PHEP (Public Health Emergency Preparedness) through Engineering Systems Analysis. Stan Finkelstein, PI; Richard Larson, Co-PI, submitted with the Harvard School of Public Health to the CDC. 5 years, \$1,000,000 for the MIT CESF portion.

Decision-Oriented Analysis of Hurricane Response, Richard Larson, PI, John Carroll, Co-PI, submitted to the National Science Foundation, 2 years, \$400,000.

BLOSSOMS, Blended Learning Open Source Science Or Math Studies, Richard Larson, PI; Dan Frey, Co-PI, submitted to the Hewlett Foundation, 2 years, \$300,000.

BLOSSOMS, Blended Learning Open Source Science Or Math Studies, Richard Larson, PI; Dan Frey, Co-PI, submitted to the Sloan Foundation, 2 years, \$45,000.

Much of our research is focused on the services sector of the economy. This focus is combined with our emphasis on the Venn diagram intersection: engineering, management and the social sciences. This year Professor Larson has led a group of over 20 ESD-affiliated faculty members, exploring new research and educational initiatives in SSME, Service Science, Management and Engineering. Some of his ideas about this topic are presented in the new invited paper,

Service Science: At the Intersection of Management, Social, and Engineering Sciences, R. C. Larson, *IBM Systems Journal*, Vol. 47, No. 1, 2008, pp. 41-52.

2a) Presidential Elections

With ESD research affiliate and long-time friend of MIT, Dr. Alex Belenky, Dick Larson has been studying queuing at election precincts during U.S. Presidential elections. This past year that effort has expanded to consider the mathematics, logic and tradition of presidential elections worldwide, culminating in a major book on presidential elections, edited by Dr. Belenky, and to be published before the U.S. presidential elections in November, 2008. The book, to be published by Elsevier, is entitled, “Systems Studies of Voting Systems and Elections.”

Dr. Belenky has published numerous Op-Ed pieces on presidential elections during this past year, and they are summarized on the news page of CESF web site: <http://cesf.mit.edu/news.html>.

2b) Social Distancing in an Influenza Pandemic

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

New publications this year are as follows:

Pandemic Influenza: Preparations and Plans. DRAFT Report of the MIT Team, distributed to participants of the Workshop on Pandemic Influenza, MIT, April 22, 23, 2008. Distributed for Comments and Suggestions. Richard C. Larson, Stan Finkelstein, Karima Nigmatulina.

PLANNING FOR A FLU PANDEMIC: POLICIES TO EMPOWER INDIVIDUALS AND FAMILIES, Shiva Prakash, Stan Finkelstein, Richard

Larson, DRAFT Report, distributed to participants of the Workshop on Pandemic Influenza, MIT, April 22, 23, 2008. Distributed for Comments and Suggestions.

Living with influenza: Impacts of government imposed and voluntarily selected interventions, Karima R. Nigmatulina, Richard C. Larson, to appear, *EJOR, European Journal of Operational Research*.

Our research into pandemic influenza has been supported by a grant by The Sloan Foundation (Dr. Stan Finkelstein, co-PI) and by an IBM Faculty Research Award. In part as a result of this research on pandemic influenza, Dr. Larson has been invited to join the Health Sciences Policy Board of the Institute of Medicine (IOM).

The project benefited from the active participation of internationally known flu historian, John M. Barry, who visited MIT in a public forum, *A Conversation with John M. Barry*, Oct. 15, 2007. Available on *MIT World*. <http://mitworld.mit.edu/video/499/>.

Ms. Karima Nigmatulina, principal Ph.D. research student working on the pandemic flu project, received first place honors at a poster session sponsored by the National Academies of Science. The poster session was part of a two-day public event entitled “Student Forum on Science, Technology and Policy.” Intended for students, postdoctoral fellows, and recent graduates interested in studying and pursuing careers in these areas, it was held in Washington, DC, on January 4-5, 2008. The event featured both invited presentations and interactive discussions that convened a cross-section of government, academia, and industry to address practice and opportunities in the science and technology professions. The poster session was designed to enable students to share their work with a wide range of policy professionals. Karima, a third year PhD student, was awarded first place for her poster, which focused on government and community interventions for stopping pandemic flu. Although many researchers, primarily epidemiologists, have examined this complex challenge, Karima’s work goes beyond medical interventions and other traditional methods because it employs an interdisciplinary engineering systems approach.

2c) Hurricane Decision-Making: Example of Disaster Preparedness & Response

Fourth year Ph.D. student Michael Metzger has been working with Dick Larson, creating a quantitative planning model to frame and formulate rational policies for preparedness and response to hurricanes. This is a specific example of a broader interest and expertise at MIT, preparedness and response models for disasters of all types. Metzger has identified aspects of all three parts of the Venn diagram – engineering in the form of operations research, management (in the form *not* demonstrated in the response to Hurricane Katrina) and social science, all as important in this work. This work has already been reported at four national research conferences. The CESF “hurricane team” expanded this year to include Maurice Davis Murphy, a Master’s student in ESD’s TPP program and at the Operations Research Center.

Michael Metzger won second place at the aforementioned National Academies forum for his poster entitled “Avoiding the Eye of the Storm,” which outlines the use of decision

modeling to mitigate risks and damage in hurricane emergencies. Using an engineering systems approach, Metzger's presentation outlined the complex fixed and variable factors in planning for hurricane emergencies. Fixed include pre-positioning supplies and pre-planning for mobilization and deployment of personnel to assist residents in stricken areas. Variables include the storm's location, time and intensity. To address these issues, Metzger used a stochastic dynamic program incorporating economic, social, and logistical impacts of alternative sequential decisions. While some costs are easy to calculate, such as fuel for busses to evacuate residents, others like the specifics of evacuating the elderly are more difficult. Nevertheless, because economists believe the latter could run as much as \$1million/mile, finding ways to model the costs is essential.

Michael Metzger also received second place honors for his research on strategies for hurricane preparedness and response at the second annual Department of Homeland Security (DHS) University Network Summit. The event, held March 19-20, 2008 in Washington, DC, showcased key research and education priorities of DHS Centers of Excellence, the Science and Technology Directorate and the Department of Homeland Security at-large. Undersecretary of Homeland Security Jay M. Cohen presented Metzger with his award at a gala luncheon. In addition, Metzger was invited to serve on the DHS scholars "best and brightest" panel. He was the only student to both win an award and speak on the panel.

2d) The Energy Box.

Supported by the MIT-Portugal program, the Energy Box is being designed and created as an Open Source software system to manage silently in the background – from an available desktop computer -- the electricity usages of a home or small business. The ideas build from concepts first proposed by MIT's Professor Fred Schweppe in the late 1980's and brought algorithmically to early prototype stage by MIT doctoral student Panos Constantapolis in his doctoral thesis (co-supervised by Professors Schweppe and Richard Larson).

Attributes. The Energy Box is being created in a much richer environment than that envisaged by Constantapolis et al. This environment includes the following attributes:

- 1) Electricity pricing can be in many different forms, including fixed flat pricing, fixed time-of-day pricing, or dynamic demand-sensitive 'spot' pricing;
- 2) Each electrical appliance is assumed addressable and controllable from the computer hosting the Energy Box;
- 3) The user may or may not have local capability to create electrical energy (e.g., from sunlight) and/or to store it (e.g., flywheel, capacitor, battery) and to sell it back to the grid at prevailing prices;
- 4) The heart of the Energy Box is an Algorithm Bank which is being designed to host any number of device-controlling algorithms, eventually to be designed and created 'by the World' as part of an Open Source community;

- 5) The utility selling electricity into the grid may or may not have weather-dependent sources of renewable energy (e.g., from sunlight, wind and/or waves). The Energy Box will have access to weather reports and predictions, and make decisions related to usage, purchase and sale of electricity based on such weather forecasts;
- 6) The Energy Box will offer a partial load shedding service to the major utility supplying electrical power to the grid, the load shedding being voluntary in response to a utility's load shedding requests. In exchange for participating in this load shedding program, the user will receive discounted electrical power.

The Energy Box research currently includes collaborations with researchers from both FEUP (Faculdade de Engenharia da Universidade do Porto, Portugal) and IST (Instituto Superior Técnico). Key ESD doctoral students researchers in this effort include Daniel Livengood, Kathy Donnelly and Woei Ling Leow.

Key Papers related to the Energy Box:

To Intelligent Energy Infrastructure: Achieving Energy Efficiency through Behavioral Economics and Energy Box Technology Implementation, White Paper. Daniel Livengood, Kathy Donnelly, January 2008. (working draft)

The Energy Box, Architecture, Design and Interface. Woei Ling Leow, May, 2008. (draft for review)

Strategies to Overcome Network Congestion in Infrastructure Systems. J. Black and R. C. Larson, *Journal of Industrial and Systems Engineering*, Vol. 1, No. 2, pp. 2 - 19, 2007.

2e) MIT LINC International Conference, Dead Sea, Jordan, and Dubai

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

With the belief that Education may be the ultimate #1 high-impact beneficiary of the Internet, the Massachusetts Institute of Technology (MIT) on November 1 completed its first LINC international conference away from its campus in Cambridge, Massachusetts.

<http://linc.mit.edu/conference/> Technology-enabled learning and e-learning were featured. E-Learning uses the Internet and satellites to deliver education to distant locations. Technology-enabled education includes e-learning and much more, as new computer-based technologies can dramatically transform the learning environments available to our students. If used creatively, technology can improve learning for students in ways previously unimagined.

The LINC 2007 Conference was bi-located in Jordan (on the Dead Sea) and in the U.A.E. (Dubai). Her Majesty Queen Rania of Jordan, esteemed Patron of LINC-Jordan, participated in the Opening Ceremonies in Jordan on October 28. Over 500 participants from over 40 different countries attended these Opening Ceremonies. On October 31 the LINC 2007 conference moved to Dubai for an Executive Session, attended by the Patron of Dubai LINC, His Highness Sheikh Maktoum bin Mohammad bin Rashid Al Maktoum, Chairman of the Dubai Technology and Media Free Zone Authority. H.H. Sheikh Nahyan Bin Mubarak Al Nahyan, Minister of Higher Education and Scientific Research gave the Opening Address in Dubai. The presence and participation of these esteemed leaders of Jordan and the U.A.E. demonstrate the strong commitment of the region to educational innovation – supported by technology.

In his welcoming remarks, H.H. Sheikh Nahyan said,

“The MIT LINC project represents a simple idea: using distance and e-learning to help countries increase access to a quality university education. To make this simple idea a reality takes technology for delivery, good content for courses, and effective pedagogy for instruction. But more than that, it takes imagination, cooperation, and hard work.”

In attendance in Jordan were over 150 Jordanian professors and approximately 100 Jordanian high school teachers of math and science, the teachers’ participation sponsored by MIT. Internationally-known speakers presented state-of-the-art use of technology to deliver compelling learning environments to school children, university students and life-long learners, with major case studies from Jordan, Mexico, Pakistan, Kenya, Egypt, Botswana, Algeria, the U.A.E. and the USA. Best practices were shared and new collaborations were established. The 18 keynote speakers represented a world-class assemblage of experts in e-learning.

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

3. Outreach

There were many public CESF presentations this past academic year (July 1, 2007 – June 30, 2008). Among them are:

Invited Lectures on Queues. Lincoln Labs, Lexington, MA, July 2007. (R. C. Larson)

The De-Widgetization of OR: The Importance of Human Behavior in What We Do. 2nd Annual Behavioral Operations Conference, Carlson School of Management, **University of Minnesota, Minneapolis. Invited Plenary Lecture.** July 23, 2007. (R. C. Larson)

Police OR: From Golden Oldies to Emerging Newbies. *Ann. Symposium of the National Institute of Justice*, Washington, D.C. **U.S. Department of Justice.** July 25, 2007.

Potential technology-enabled outreach at the SSE, lessons from LINC. Presentation before LUMS Advisory Board. **Stanford University, CA.** September 22, 2007. (R. C. Larson)

Designing and Managing Critical Infrastructures at the Intersection of Engineering/OR, Management & Social Sciences. *Harvey Mudd College Mathematics Conference on Public Sector Operations Research*, **Harvey Mudd College, Claremont, CA. Invited Keynote Lecture.** Department of Mathematics. Sept. 29, 2007. (R. C. Larson)

Services Sciences and Engineering: Importance to Humanitarian Supply Chains. Invited Lecture NSF Workshop on Humanitarian Supply Chains and Engineering. October 8, 2007, **University of Washington**, Seattle, Washington. (R. C. Larson)

Distance Learning as a Tool for Poverty Reduction: A Focus on Two Countries, China and Mexico, lecture presented to participants in MIT LINC 2007. **Dead Sea, Jordan**, Oct. 29, 2007. (R. C. Larson, M. E. Murray),

Where From Here? Some Thoughts from MIT. Lecture presented at Dubai LINC Executive Session Program, MIT LINC 2007, Nov. 1, **Knowledge Village, Dubai.** (R. C. Larson)

MIT Sloan School of Management. *Service Science: At the Intersection of Management, Social and Engineering Sciences.* MIT, Nov. 19, 2007. (R. C. Larson)

OR for the OR and Much More! Engineering a Learning Healthcare System. A Look at the Future IOM Engineering Workshop, **IOM/NAS, Washington, D.C.** April, 2008. (R. C. Larson)

Distance Learning as a Tool for Poverty Reduction: A Focus on Chain and Mexico, and BLOSSOMS, Blended Learning Open Source Science or Math Studies, MIT Global Poverty Initiative Millennium Campus Conference, April 19, 2008. (M. E. Murray and R. C. Larson)

Living with Pandemic Influenza, via Non-Pharmaceutical Interventions (NPI's), Invited Lecture, **Dartmouth College**, Hanover, NH, May 15, 2008. (R. C. Larson)

4. Other International Outreach.

CESF undertook additional activities leading to international outreach related to complex systems.

These include publication of the papers,

Distance Learning as a Tool for Poverty Reduction and Economic Development: A Focus on Two Countries, China and Mexico. R. C. Larson, M. E. Murray, *Journal of Science Education and Technology, Journal of Science Education and Technology*, Vol. 17, No. 2, April 2008, pp. 175-196. DOI: 10.1007/s10956-007-9059-1

Open Educational Resources for Blended Learning in High Schools: Overcoming Impediments in Developing Countries, Larson, R. C. and M. E. Murray, *Journal of Asynchronous Learning Networks*, V. 12, No. 1, Feb. 2008.

Disasters: lessons from the past 105 years, Kourosh Eshghi, R. C. Larson, *Disaster Prevention and Management*, Vol. 17 No. 1, 2008, pp. 62-82.

Professor Larson was invited to participate in the Fifth Meeting of the Council of Presidents of the Federation of Middle Eastern and US National Academies of Sciences, Dead Sea, Jordan, 13-15 January, 2007. As a result of this meeting, he will lead an effort to create a web portal of on-going research of interest and relevant to countries and territories in the Middle East region near the Dead Sea.

Finally, Dick Larson with two other senior MIT faculty members have been serving on the senior advisory team of LUMS, Lahore University of Management Science, a major private university in Pakistan that is now opening a new School of Science and Engineering – patterned after MIT and the India “IIT’s.” The new school at LUMS is scheduled to open on September 1, 2008.