The newsletter of the Massachusetts Institute of Technology
System Design and Management Program

sdmpulse

in this issue

MITsdm system design and management

SDM helps student take on global development challenges

By Alex Shih, SDM '09

When I joined SDM in January 2009, I expected to get a top-tier education in engineering strategies and management principles that would further my career working on large-scale, complex solutions at Raytheon. I also expected systems thinking to provide a powerful approach to combating problems related to domestic poverty—a personal passion of mine.

I was right on both counts—but I have also gained much more.

Alex Shih, SDM '09, far left, and Jennifer Woodfin, MBA '10, far right, gather with patients and family members in Uganda with whom they worked on a project to combat AIDS.

Thanks to SDM and the connections I've made through the program's unique position in both the MIT Sloan School of Management and the MIT School of Engineering, I have not only learned about management, leadership, and the importance of systems thinking. I've also expanded my personal interests, developing a passion for tackling larger, global challenges containing multiple dimensions such as technology, business, and policy.

SDM has provided me with opportunities to take on projects in India, Uganda, and Israel, and led to my decision to pursue a dual master's with MIT's Technology and Policy Program—all of which, I hope, will further my efforts to address sustainable, international development and social justice in the future.

Tackling illiteracy in India

India has an illiterate population of approximately 300 million, a majority of which live in rural areas. At the same time, the country boasts a mobile phone penetration of about one third of the overall population, a figure that is expected to grow to about two-thirds within the next couple years. It seemed

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MITsdm system design and management

Welcome

This edition of the *SDM Pulse* covers a wide range of systems and domains, including: energy, poverty and global development, health care, systems engineering education, applications in defense and aerospace, system dynamics applied to social sciences, and other topics across the spectrum of SDM stakeholders. "Systems thinking" is interwoven through all of SDM's activities, and is well illustrated in the articles.

Leading off is Alex Shih, SDM '09 (also taking MIT's Technology and Policy Program master's as a second degree), discussing how his SDM education has helped him tackle global projects as diverse as literacy in rural India and AIDS treatment sustainability in Uganda. His experiences in synthesizing the contents of the curriculum and experiences from SDM in unconventional environments and challenges highlight the experiential learning that is an integral part of SDM and MIT.

Gene Achter and Jessica Levesque of the Instrumentation Laboratory explain how they are leveraging both the SDM certificate and degree programs to develop and diffuse systems thinking through the product development program, describing their selection process for candidates.

One of the challenges in developing and teaching a core course like systems engineering is the immense breadth of the methods, tools, and underlying theory in so broad a field—particularly when faced with an SDM classroom full of experienced professionals from so many different industries. New faculty member Qi Van Eikema Hommes describes how she approached taking long-term ownership of this critical course and used an integrating framework of opportunity sets around the many facets of the Toyota "unintended acceleration" case.

Qi's use of this very systems-rich case to pull together different disciplines and analyses was very effective, based on course feedback. When combined with a set of separate systems projects accomplished in small teams, all of the students had ample opportunity to practice what they were learning in developing solutions to real problems. The resulting course was a rich learning experience, and the *Pulse* also features an article that explores two projects from the course, both dealing with energy challenges in Hawaii, where the relative isolation places a premium on efficient use of energy.

These descriptions are but a few examples of the domains and projects you will find chronicled in this issue, highlighting the rich diversity of the SDM students, curriculum, supporting industries, and the MIT environment.

I turn finally to the task of expressing how much we miss our retired industry codirector, John M. Grace. It was my great pleasure to work with "Jack" as he built the strong framework of industry engagement we enjoy today. Jack put a lot of his time and experience into the *SDM Pulse*, and all of us will miss him as he moves on to new challenges and, hopefully, some actual retirement time! Not surprisingly, he is proving difficult to replace, and during the period of our search, I am certain some of you may feel neglected, but please know that our highest priority is finding another leader for partner engagement and relationships—SDM is a program that is committed to serving the needs of our industry stakeholders, and to helping you develop your future leadership. If you know of someone who would be a great candidate, please let me know. For now, join me in expressing heartfelt gratitude to Jack for a wonderful example of building relationships around our program.

Pat Hale
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SDM aids Instrumentation Lab's health-care mission

By Gene Achter and Jessica Levesque

Gene Achter

Jessica Levesque

Editor's note: *In this article, two executives from Instrumentation Laboratory—Gene Achter, vice president of advanced development and technology and chief technology officer, and Jessica Levesque, human resources manager—team up to describe how the company works with, and benefits from, its association with SDM.*

Instrumentation Laboratory (IL) develops, manufactures, and markets in vitro diagnostic (IVD) systems. To put it in personal terms, when you visit a physician and a blood sample is drawn, IVD systems test the blood to provide analytical results that the physician uses to make clinical decisions—in effect, in vitro diagnostics provide the link between the patient's vein and the physician's brain.

At every stage of development and manufacture, our products integrate a wide range of disciplines, technologies, and subsystems. Systems thinking and effective system management techniques are essential for dealing with these complex interactions, hence our interest in MIT's System Design and Management Program (SDM).

IL focuses on two main areas within diagnostics—hemostasis and immediate care. Hemostasis deals with clotting—the delicate balance between excessive bleeding and thrombotic events such as pulmonary embolism, heart attack, and stroke. Immediate care deals with blood gases, electrolytes, and similar parameters where time is of the essence.

The underlying physiology, biochemistry, and medical science define the parameters to be measured and the clinical relevance. The measurements are performed using electro-optical or electrochemical sensor systems, aided by biochemical and chemical reagents that selectively interact with components of the blood sample or calibrate the measurements. For example, some of the electrochemical sensors incorporate enzymes within polymer membranes deposited over metal electrodes. The engineering implementation includes mechanisms, electronics, thermal control, and multiple layers of software for user interface, direct control of the measurement processes, data analysis, and data connectivity to report the result to the physician.

IVD products are regulated to assure safety and efficacy. Our products are marketed worldwide, and must meet regulatory requirements and customer expectations in each country as well as differences in health-care delivery systems.

As you can see, our products and our operations are multidisciplinary and deal with multifaceted systems. However, most of our people focus on their primary disciplines—electronics, mechanics, biochemistry, and so forth. A few of us tend to be generalists, speaking everybody's language to some extent and working to forge bonds between the disciplines. However, this intuitive approach is only part of the answer. IL looks to the SDM program to help us develop people who are well trained in systems thinking and the enlightened use of modern tools for system design and management.

Instrumentation Laboratory has been involved in the program for three years, and to date we have had six students earn SDM certificates. Of the six, two have gone on to enroll in the master's program. We are planning to enroll at least three more students in the next session of the certificate program.

We encourage engineers from all IL disciplines to consider participating in the program. We run an internal application process, starting with an onsite Graduate Record Exam (GRE) prep course for potential students. Because some of our applicants have been out of school for several years, we thought this would help potential students remember how to study and would refresh the basic information that they will need to be successful at MIT.

Our selection process includes looking at the applicant's work performance, years of experience and length of service, undergraduate major, GRE scores, and an essay that asks the applicant why they want to participate in the SDM program. In the past, SDM Industry Codirector John Grace (now retired) has helped us select students from the pool of applicants based on the aforementioned information. We found John's assistance invaluable as he had insight as to which candidates were most likely to succeed based on his knowledge of the SDM program and the academic rigors it would present. We matched that information with what we knew about each candidate as an employee, and made our selections from there. We can easily say that not only did each student succeed in the program but every one maintained a high level of performance at work while participating in the program.

The affects of the SDM program on the scientists and engineers of Instrumentation Laboratory are still taking shape. In some areas, we see such evidence as diagrams left on a white board or a group gathering

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Systems engineering class tackles complex real-world design issues

SDM students learn from top MIT researchers

By Qi Van Eikema Hommes, research associate, MIT Engineering Systems Division

Qi Van Eikema Hommes

Editor's note: *In this article, Qi Van Eikema Hommes describes Systems Engineering, a course she taught this summer in MIT's System Design and Management Program (SDM).*

Systems Engineering is one of the required core courses for MIT's System Design and Management Program (SDM). The course's objective is to help students develop a systems thinking capability by introducing classical and advanced systems engineering theory, methods, and tools. In this class, students learn to:

- Develop a systems engineering plan for a realistic project.
- Judge the applicability of any proposed systems engineering process, strategy, or methodology, using fundamental concepts from such disciplines as probability, economics, and cognitive science.
- Understand the roles and responsibilities of systems engineers, as well as of systems engineering organizations.
- Apply systems engineering tools (e.g., requirements development and management, robust design, design structure matrix, or DSM), to realistic problems.
- Recognize the value and limitations of modeling and simulation.
- Formulate an effective plan for gathering and using data.
- Proactively design for, and manage, a system's life-cycle targets.

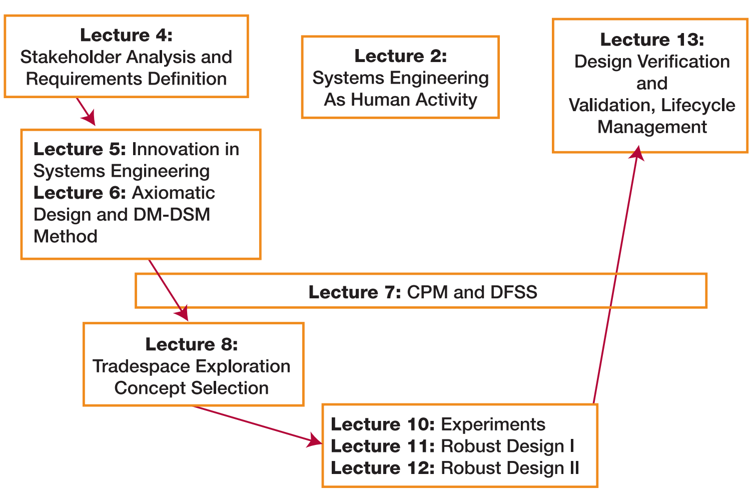

Figure 1. This vee diagram illustrates the structure of SDM's course in systems engineering. (Missing lecture numbers are classes devoted to student presentations and industry guest speakers.)

The subject of systems engineering sits at the intersection of engineering design, social science, and business economics. Topics including requirements management, system modeling and simulation, risk management, decision analysis, robust design, reliability, safety, and security all fall within this discipline. The first challenge in developing this course is how to help students get a good grasp of the fundamentals of systems engineering in a nine-week summer term.

In addition, systems engineering is deeply rooted within the engineering discipline. Many systems engineering tools and methods evolved to solve the engineering design problems found in increasingly large and complex engineering systems. However, these methods and tools, and the philosophy of systems thinking, extend to other systems that are not traditionally viewed as engineered systems—such as the enterprise system, the health-care system, and the energy system. So, the second challenge that I faced in teaching this course was helping students make the connection between the traditional systems engineering methods and tools, and the problems that are relevant today.

With the aforementioned challenges in mind, I designed several features into this course. First, this class introduced students to a range of advanced, cutting-edge research topics—including the roles of leadership and innovation in systems engineering, requirements-driven predictive design structure matrices, one-factor-at-a-time vs. orthogonal arrays in design of experiments, and trade-space exploration techniques. Many of these topics emerged from the latest MIT Engineering Systems Division faculty research—and we were fortunate to have several faculty members themselves give the relevant lectures. Students had the privilege to learn material directly from Professor Dan Frey, Dr. Madhav Phadke, Dr. Donna Rhodes, and Dr. Adam Ross. This is one of the ways SDM's course in systems engineering stands out from what might be offered at another school.

To help students to organize these diverse topics in their minds, the class was structured in the form of the Systems Engineering Vee (see Figure 1).

The second feature of this course is a series of five context-based opportunity sets, designed to reinforce materials learned in class. When I was preparing for this class in the early spring of 2010, Professor Steven Eppinger, SDM's MIT Sloan faculty codirector, encouraged me to put the class exercises in a context to help students better ground what they learn from the lectures. Toyota's safety recall was a heated topic in the news this summer, so I decided to focus on that.

Choosing that Toyota case study had two advantages: first, the publicly accessible information about cars and; second, a car is a complex system that every student can actually get his or her hands on. Therefore, the first four assignments were designed to engage students in applying a variety of methods and tools to the Toyota safety recall investigation, including stakeholder analysis and requirements definition, axiomatic design and DSM methods, TRIZ (Russian acronym for Theory of Inventive Problem Solving), robust design, and design of experiments. Students learned to look at system design problems through the lens of systems engineering methods and tools.

No collaboration was required for the first four assignments, so I designed the fifth assignment as an opportunity for students to share what they had learned about the Toyota case. Students formed teams of five and prepared presentations as if Toyota or the National Highway Traffic Safety Administration had called upon them to help with their investigation.

In this exercise, students shared with and learned from one another what they found in the news media, and how they analyzed the case. In the classroom, they presented their analyses to several systems engineering experts, including Dr. Richard John, director emeritus of the Volpe National Transportation Systems Center; Frank Serna, director of systems engineering at Draper Laboratory; Tony Lockwood, Ford hybrid systems engineering manager; and MIT's own expert on automotive system design, Dr. Daniel Whitney, senior research scientist at the MIT Center for Technology, Policy and Industrial Development. These experts provided additional comments and suggestions that enhanced the students' learning experiences.

So that students could calibrate their thinking against what the experts in the field were saying, I invited MIT Institute Professor Sheila Widnall, who serves on the Toyota Quality Advisory Panel, to share her experiences on the case with the class. In addition, Tom Baloga, BMW's vice president of product development and safety in the United States, gave a lecture outlining the automotive industry's strategy on safety (ISO 26262—Functional Safety Standard for Road Vehicles) and product recall. Overall, the context-based opportunity sets enabled students to practice what was taught in class on a real, up-to-date problem, which enhanced their learning experiences.

The third feature of this course was the term project, designed to give students an opportunity to apply the systems thinking and systems engineering framework to a project near and dear to their own careers or passions. The SDM students really took this assignment to heart and selected a wide variety of topics, including:

- Alternative Energy Solution for the State of Hawaii, and Hawaii 2030 Energy Independence Goals Feasibility Analysis [see story, page 6]
- Future Mobility Solution for Los Angeles Commuters
- Systematic Development of Engine Control Software
- Education System for Rural Secondary School Students
- A System Failure Analysis of the BP Oil Spill
- MIT Medical Flu Project
- Emergency Room Operation System Improvements

All teams worked hard to collect data and analyze the systems they were designing. Many started with very broad topics, but with the guidance of the three faculty members in this class, students learned how to properly scope down a systems design problem and focus their resource on the most important questions. The term project exercise served as a sandbox to prepare SDM students to take real-world problems in stride.

Reflecting on this summer's teaching experience, I want to thank all of the SDM students for their effort and dedication. The active class discussions, the late night email questions, and project discussions inspired me to continue improving this course. I also want to thank my co-instructors SDM Director Pat Hale and the director of SDM's Certificate in Systems and Product Development, David Erickson, and my teaching assistants Ellen Czaika, SDM '08, and Ipshita Deepak, SDM '09. Their support, experiences, and knowledge helped me tremendously.

I look forward to teaching this class again next summer!

SDM teams address Hawaii's clean energy challenges

By Karl Critz, SDM '10, and Donny Holaschutz, SDM '10

Karl Critz
SDM '10

Donny Holaschutz
SDM '10

***Editor's note:** In this article, Karl Critz and Donny Holaschutz summarize the work of two teams of students in SDM's class in systems engineering. The teams investigated the impact of renewable resources on Hawaii's transportation and electricity systems.*

The state of Hawaii has great incentive to pursue renewable energy projects. The Hawaii Clean Energy Initiative (HCEI) has provided top-down pressure for change by setting targets of 40 percent renewable energy and a 30 percent increase in energy efficiency by 2030. Electricity costs triple the national average, and gas at the pump is 50 percent more expensive than on the mainland. This combination of political and economic drivers encourages Hawaii to test new systems for energy efficiency and sustainability significantly before such systems are explored on a national scale. For this summer's course in systems engineering, SDM students undertook to find ways to help Hawaii reach its targets in these two areas: increased transportation efficiency and stable renewable electricity production.

Team Rental Car Efficiency: Electrifying the Rental Fleet

Team members: Swope Fleming, SDM '10, Khalid Al-Ahmed, SDM '10, Chang Bae Park, SDM '10, and Donny Holaschutz, SDM '10.

Team Rental Car Efficiency looked at ways to help the Hawaii Clean Energy Initiative increase energy efficiency within the islands. Creating the infrastructure, incentives, and policies that would encourage alternative forms of transportation could substantially help HCEI meet its goals. According to Hawaii's Department of Business, Economic Development, and Tourism, 18.8 percent of Hawaii's oil usage comes from transportation.

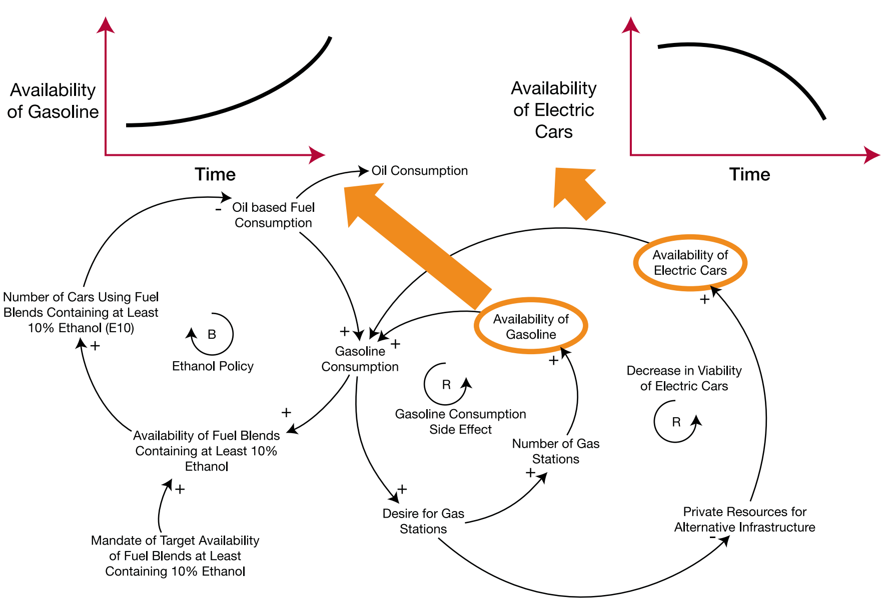

Figure 1. This system dynamics model illustrates how the current ethanol policy promotes the development of more gasoline-consuming infrastructure.

The SDM team discovered that current policy emphasizes reducing short-term petroleum consumption, rather than the long-term solution—making the island's transportation systems less petroleum-intensive. Some current policies even have side effects that undermine the potential success of other transformational policies. For example, through the creation of a system dynamics model, the SDM team discovered that the current ethanol policy is promoting the development of more gasoline-consuming infrastructure by subsidizing and mandating the introduction of 10 percent ethanol to the gasoline mix (see Figure 1). The policy sends mixed signals to the private sector and could potentially compromise the investment in the electric infrastructure needed to support electric vehicles and plug-in hybrids.

Team Rental Car Efficiency was committed to finding ways for HCEI to incentivize small, effective changes that would help it meet its targets and would lead to positive, long-term changes in the energy consumption ecosystem. After exploring a large number of focus areas, the team zeroed in on the car rental fleet. The team found that if managed properly, the car rental industry could be used as a platform to introduce more efficient vehicles into the islands.

As the team discovered, the car rental company is quite different from the private car owner. Car rental companies will replace their car rental fleets with newer cars every 2-3 years. If car rental companies began purchasing plug-in hybrids or hybrid cars and were incentivized to sell their used cars to the islanders, an alternate car market of more efficient vehicles could be created, serving the more cost-sensitive islanders who prefer to purchase used vehicles.

The team deployed a complete set of systems engineering tools to test its policy recommendations. By using system dynamics, the team was able to develop a model that could test the effects of various policies related to different mile per gallon (MPG) mandates and subsidy levels for alternative vehicles such as hybrids and electric vehicles. The current MPG mandate is set at 27.5 MPG, and the federal government

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SDM student helps DOE evaluate investment trade-offs

"The United States is, in fact, at a historical point where the nation's energy innovation system is being examined, significantly expanded, and reshaped. As the country does this, it not only has a rare opportunity, but indeed a responsibility, to ensure that it improves the efficiency and effectiveness of this system to make sure that the country is getting the maximum payoff from its investments."

—"Institutions for Energy Innovation: A Transformational Challenge," a report from the Harvard Kennedy School, by Venkatesh Narayanamurti, Laura D. Anadon, and Ambuj D. Sagar

Kacy Gerst, SDM '09, has been working to help the US Department of Energy use systems thinking to make better decisions about the nation's energy portfolio.

The Department of Energy (DOE) is in the process of making critical decisions under extreme uncertainty regarding the optimal size and shape of the nation's public energy investment portfolio. Working with the DOE chief financial officer's team through an independent study arrangement, SDM student Kacy Gerst had the opportunity to advise on the development of a large decision tool that will assist DOE leadership in evaluating complex investment trade-offs.

These trade-offs address high-level questions within the DOE's portfolio of programs and initiatives. Examples of trades investigated include: which would yield greater public benefit—a heavier investment in loan guarantees for nuclear energy generation or a larger investment in thin-film solar research and development (R&D); or which would have the greatest impact on US greenhouse gas emissions—greater funding for wind energy development or greater funding for carbon capture and sequestration R&D. Gerst's research was guided by two knowledgeable research scientists working on tradespace exploration methodologies, Dr. Donna Rhodes and Dr. Adam Ross of MIT's Systems Engineering Advancement Research Initiative (SEAri). Gerst's work illuminated critical issues within the decision tool's structure, as well as proposed methods for evolving the architecture to evaluate portfolio performance across changing futures.

A recent paper by Gerst, Rhodes, and Ross highlighted that as an organization broadens its investments—placing bets across market segments and technologies—it increases its vulnerability to market, technological, and political shifts, a risk that faces the Department of Energy. Given the DOE's broad technology portfolio, which spans basic R&D to demonstration and deployment, investments are extremely susceptible to external policy, market, and technological disturbances. In fact, the only certainty is that such disturbances and context shifts will occur.

Several historic examples exist of market and policy shifts that dramatically affected the DOE's ability to supply value to the public. One such example was the DOE's investment in the Synthetic Fuels Corporation, a public-private entity that was charged with producing 500,000 barrels of oil per day by 1987. Initial cost-benefit estimates determined the investment to be economical in the static context of the day. However, when gasoline prices unexpectedly dropped, the external environment changed and the project became uneconomical. The investment decision was subsequently viewed by the public as a government boondoggle. A more robust initial analysis of possible changing futures as related to market dynamics, such as the impact of petroleum price variations, could potentially have prevented such an outcome.

Despite its place in a complex, changing environment, the results produced by the DOE's current investment modeling approach will represent an evaluation conducted in terms of a static context. Yet it is critical for the DOE to have the ability to evaluate and select a portfolio of investments that performs robustly in the face of many possible futures. Gerst's investigation focused on evolving the DOE's current investment decision tool to allow for this type of scenario-based evaluation.

Using Epoch-Era Analysis methodology, developed by Ross and Rhodes, Gerst was able to make recommendations for the structural augmentation of the DOE's decision tool. When fully applied, these enhancements will enable DOE leadership to visualize and evaluate portfolios of investments across changing needs and contexts.

According to MIT SEAri's lead research scientist, Ross, "Epoch-Era Analysis incorporates a view of systems in the context of discrete time segments, similar to a movie composed of a series of static frames running in quick

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SDM thesis to focus on the dynamics of seasonal labor migration

By Rafael Maranon, SDM '10

Editor's note: *Rafael Maranon is a telecommunication engineer who has worked on information technology projects for the public and private sector in Spain, and has also served at the United Nations headquarters in New York and at the Spanish consulate in Moscow. In this article, he discusses his SDM master's thesis research, which is designed to improve the management of migration flows in his native Andalusia. (The work is sponsored by the Andalusian Ministry of Economy, Innovation, and Science.) The* Pulse *will follow up on Maranon's work once his thesis has been published.*

In the last 20 years, Spain has been transformed from a region that emigrants left in search of employment to one in which immigrants make up 12 percent of the population. The driving forces behind this change have been low birth rates and fast economic growth in the agriculture and tourism industries, prompted by Spain's 1986 entry into the European Union.

Rafael Maranon, SDM '10, meets with Cartaya Mayor Juan A. Millan, leader of the European Union project in circular migration, after signing a collaboration agreement to model labor migration flows between Africa and Andalusia.

In Andalusia, a region in southern Spain, growth in the agricultural sector prompted concerns about a labor shortfall. In accordance with a 1997 state law, local administrators implemented a successful guest worker program to supply farms with foreign workers by managing migratory flow.

Circular migration

Agriculture labor migration in Andalusia is mainly seasonal; guest workers travel to the region to work on farms, return to their home countries after the harvest, then come back the following year—the migration flow is circular. To address the labor shortfall, Andalusia fostered a guest worker program that allowed farmers to hire guest employees in their home countries, creating a legal route for migration, and stemming the illegal flow of workers from Africa to Europe.

However, this program now needs to be improved and consolidated. Since the start of the recent global financial crisis, Andalusia's unemployment rate has reached 26.3 percent—and native-born workers are willing to return to agricultural work. This shift in the labor market has led the Spanish government to limit the number of temporary visas it issues, and the local government is experimenting with severe adjustments in the size of the contingent of foreign workers.

Complicating the issue, native-born workers tend to consider farm work difficult and undesirable. They only take these jobs while looking for better paying work in the service sector. While farmers have been pressured to hire locals, many prefer the foreign workforce and do not wish to jeopardize it. Because of all these factors, circular migration continues to be an essential tool, allowing migration flows to be adjusted yearly according to labor market needs.

For my SDM thesis research, supervised by Dr. Ricardo Valerdi, a research associate in the Lean Advancement Initiative and a lecturer in the Engineering Systems Division at MIT, I plan to examine the history of circular migration in the city of Cartaya in Andalusia with the goal of developing a useful case study.

Cartaya, with more than 13 years of experience implementing labor supply management techniques, has become an exemplar in circular migration strategies under the European Union's $3 million Aeneas project. This innovative program helps to develop and regulate legal migration, which annually benefits more than 300 farmers in Huelva (the province in which Cartaya is located), 33,000 foreign workers, and governments from different countries in Africa.

To date, I have been able to collect a considerable amount of data by working with governmental institutions in Andalusia, including local administrations, labor unions, farmer associations, the Foundation for Foreign Workers, and the University of Huelva. In order to analyze the implications of abrupt changes in the flow of this legal migration during periods of high unemployment, I am creating a model to help characterize the dynamics of managing the labor supply in Andulasia's agricultural sector. Substituting stakeholders' existing mental model for one based on systems dynamics, this research will provide specific recommendations on how to efficiently regulate migration flows under varying labor market conditions.

System dynamics modeling

In order to develop new conceptual instruments that will be incorporated into the current review of the circular migration program in a time of high unemployment, the

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SDM demystifies multidisciplinary system design optimization

By Genevieve Flanagan, SDM ’10

Genevieve Flanagan
SDM ’10

The concept of “model-based design” has generated a lot of buzz in recent years, primarily because virtual simulations and analysis can be used in conjunction with our existing product development processes to release a better, less expensive product in less time. (Figure 1 shows an idealized view of how this might be applied in a product development cycle.)

In practice, however, the application of model-based simulation and design has typically been narrowly scoped and focused on a single objective. While this works well during the early design phase of a component or subsystem, it is less helpful during early system-level specification development or system integration phases.

SDM’s class in multidisciplinary system design optimization provides a fresh design approach to developing complex engineering systems, one that combines both technical and qualitative objectives. Taught by Associate Professors Olivier de Weck and Karen Willcox, the course begins by defining the architecture of a model of a multi-disciplinary system. Design variables and objective functions are identified and categorized into subsystem disciplines. Dependencies are described in a N^2 matrix format, and then optimized to reduce the coupling.

With the model defined, the next part of the course is to examine single-objective optimization. Numerical techniques (i.e. Newton’s Method and Steepest Descent) and heuristic methods (i.e. Genetic Algorithms and Particle Swarm Optimization) are introduced. These are used to find the optimal design vector to satisfy a single system objective.

Once the basics of these optimization techniques are understood, the course moves onto multi-objective optimization. Using many of the same algorithms learned earlier, the trade-offs among the multiple objectives of a system are realized by displaying the relationship between objectives as their common design variables change within a design space. Simulation analysis methods are presented to help students understand the success of the simulation and design variable sensitivity.

Students complete five assignments during the semester to reinforce their understanding of course concepts. However, the class primarily revolves around a semester-long group project, which is generally taken from thesis research or from industry.

My group for the project included Justin Kraft (SDM ’09), a senior engineer for John Deere. We chose to work on optimizing the design of a battery powered autonomous vehicle for John Deere. A model of this product existed, but it was narrowly scoped. We supplemented the model with additional disciplines to add to its system-level functionality. Our new subsystems then used information from the initial model to input new cost, reliability, and other functions, resulting in no loss in technical fidelity while providing new quantitative and qualitative features to the model.

When we ran the single-objective optimization routines, the flaws in that type of analysis were clear. Optimizing on two separate objectives independently—cost to manufacture and total cost of ownership—led to two very different design vectors for the vehicle (see Figure 2). Reduced manufacturing costs resulted in a low-powered small vehicle while total cost of ownership focused on increasing efficiencies and battery life.

In the end we chose a multi-objective optimization using a

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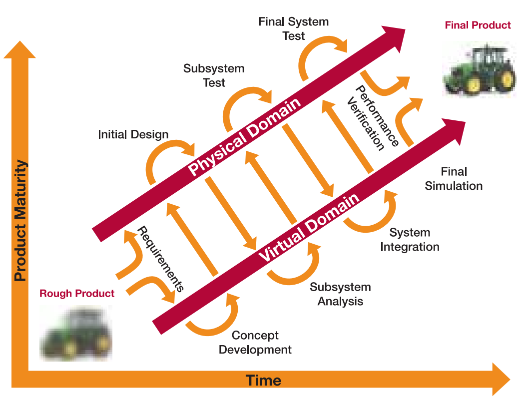

Figure 1. In this idealized view of model-based design, development in the virtual domain parallels physical development, speeding the product to market.

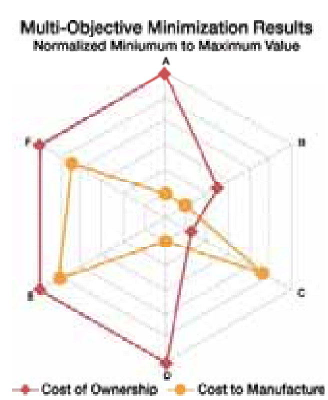

Figure 2. This graphic shows that very different results come from optimizing on two separate objectives independently—cost to manufacture and total cost of ownership.

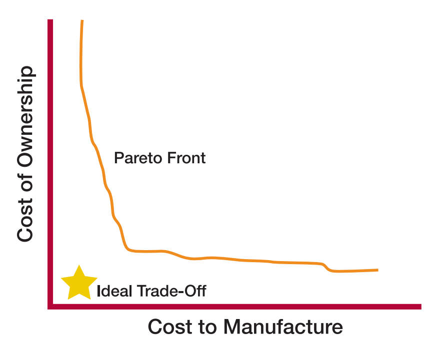

Figure 3. Multi-objective optimization reveals the Pareto front (or balance point between goals), making it easier to visualize the trade-offs between cost goals.

Capstone project for SDM centers on improving defense systems

By Troy Peterson, SDM Certificate '09

Troy Peterson,
SDM Certificate '09

Editor's note: *Troy Peterson is a senior associate with Booz Allen Hamilton, a strategy and technology consulting firm, which sponsored his enrollment in MIT's System Design and Management (SDM) Graduate Certificate Program in Systems and Product Development. In this article, Peterson outlines how the methodologies he's learned at SDM can help better integrate the science and technology and system acquisition life cycles to improve technology transition.*

The transition and integration of new technologies to strengthen the armed forces' operating capability within the US Department of Defense (DoD) is critically important to meeting the disparate and dynamic needs of combat, humanitarian assistance, and domestic emergencies. Yet, the DoD recently reported to Congress that transitioning technology into established programs has been a longstanding challenge.

The DoD has also acknowledged the need to accelerate the system and technology development life cycles to improve responsiveness. However, such acceleration requires a heightened level of collaboration, analytical rigor, and the use of robust methods to mature and integrate technologies as well as identify and mitigate associated risks.

In my consulting role at Booz Allen, I have had the privilege of supporting the US Army on both science and technology (S&T) and systems acquisition programs. This experience—coupled with the systems thinking approach, methods, and tools prescribed in MIT's System Design and Management Program (SDM)—led me to develop an approach to improve integration of the S&T and systems acquisition life cycles.

My experience in the SDM Graduate Certificate Program in Systems and Product Development has greatly influenced my thoughts on addressing this challenge. In particular, I learned key approaches from Associate Professor Olivier de Weck's work on technology infusion, Professor Edward F. Crawley's system architecture course, Professor Steven Eppinger's overview of the design structure matrix (DSM), and Research Associate Qi Van Eikema Hommes' class in systems engineering.

Project focus and scope

The acquisition of new systems and the modernization of legacy systems within DoD is highly complex and requires many disparate organizations to collaborate over a sustained timeframe. The S&T community complements acquisition through research and development of technologies to fill identified gaps in current and future systems. To focus my capstone project I began by using object process methodology (Figure 1A) to depict some of the fundamental elements involved in system acquisition and technology infusion as well as their high-level interdependencies as seen in Figure 1B.

Integrating products and personnel

Integrating the products and personnel that enable technology transition requires an in-depth understanding of the parent system, the technology, and the key stakeholders involved. To gain a better understanding of how these elements interact, I leveraged the use of DSM, domain mapping matrix (DMM), and multi-domain matrix (MDM) as shown in Figure 2. The DSM is a powerful system integration and analysis tool which shows relationships between elements of a system where the n^{th} row has the same description as the n^{th} column—the resultant matrix shows relationships between row and column elements.

The approach I arrived at in my SDM capstone project was to create a component-based DSM for the parent system (Figure 2A) and any technology to be incorporated (Figure 2B). These DSMs provide a compact way for teams to represent and analyze the interrelationships within each domain (domains 3 and 4 of Figure 1B). They also give the parent system and technology teams the ability to use DSM modeling and analysis methods, which can provide useful information on system modularization, change propagation, integration

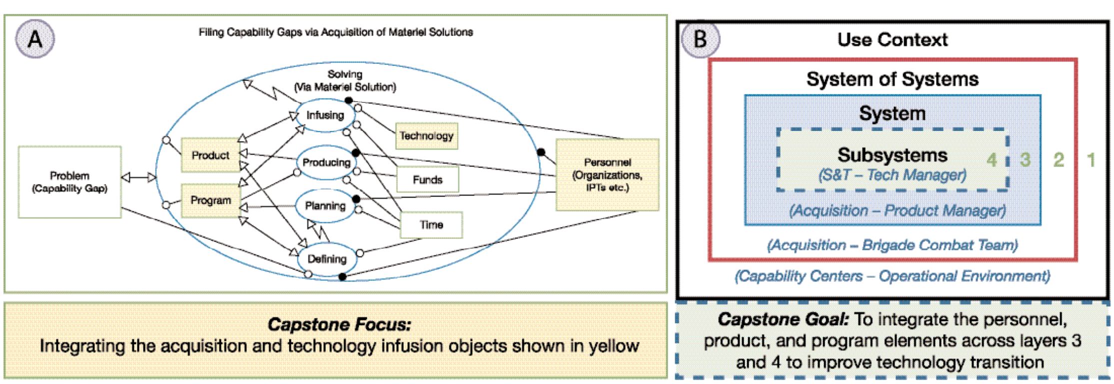

Figure 1. This high-level object process diagram and system boundary diagram depict acquisition and science and technology relationships.

maturity, constraints to technology transition, and interface types.

I then combined these independent yet compatible DSMs along the diagonal to form a Technology Transition MDM (T2 MDM). This new matrix provides a holistic view and a complete system model depicting interactions within and between the technology and the parent system components. This view (Figure 2C) enables the analysis and system integration assessment that is essential in bridging the technology transition chasm in programs.

The MDM quickly reveals which elements are highly integral and pose complexity and risk in the technology transition process. In building the MDM, one can couple simple binary DSMs as shown or select weighted analysis DSMs, or clustered DSMs for specific analysis of the technology transition effort. Additionally, multiple technologies could be used to investigate and compare technology invasiveness as proposed by de Weck in his work on technology infusion.

The technology transition mapping matrix (T2M2) is populated by the key stakeholders from the technology and parent systems programs. This undertaking inherently integrates the two communities and focuses their attention on the products and their interrelationships—the primary value instruments providing the required capability. The rich dialog around system and technology integration that ensues while populating the MDM assists the teams in identifying technology transition risks and opportunities. The DSMs produced can also help to integrate the teams within and

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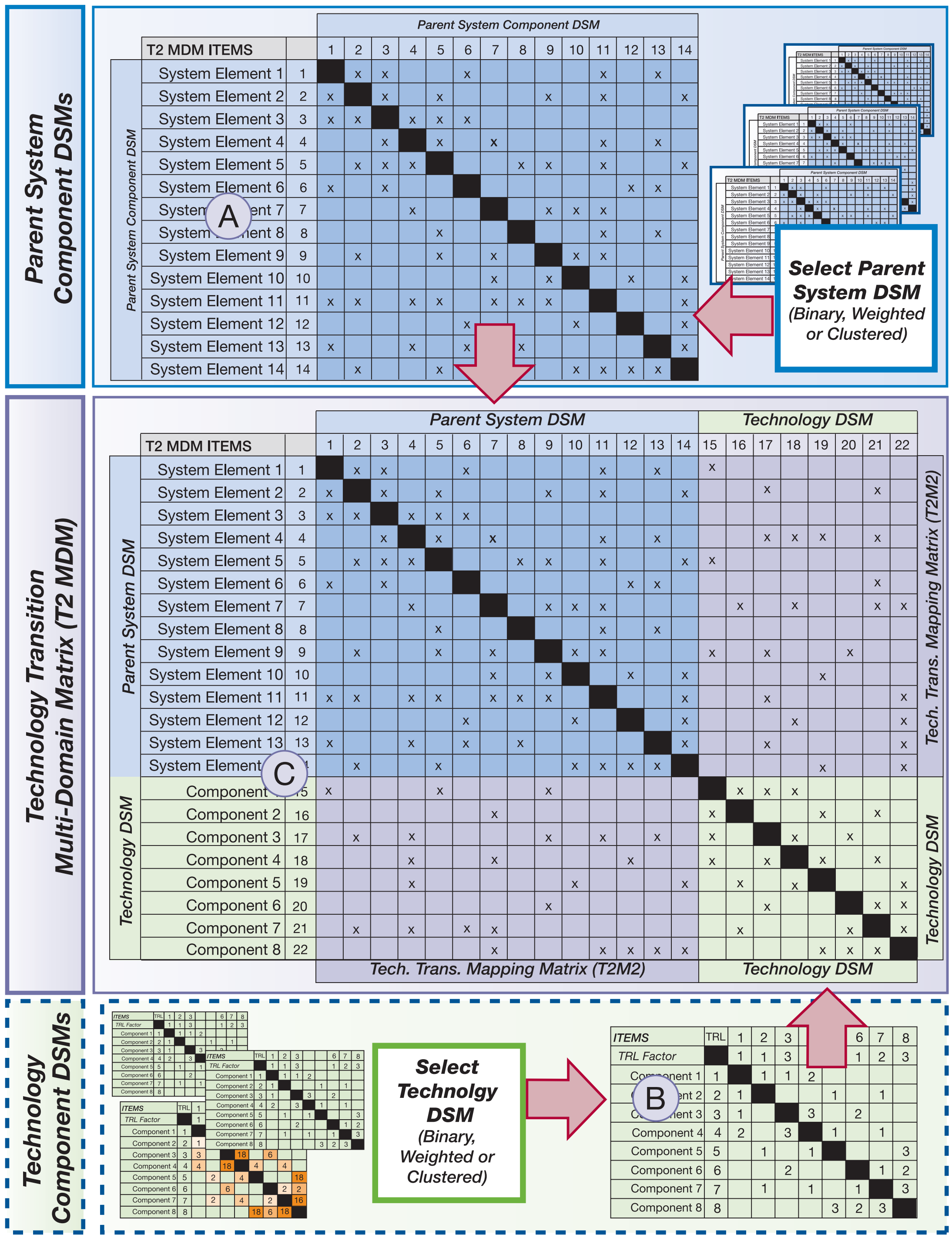

Figure 2. This technology transition multi-domain matrix combines information from the parent system with the technology design structure matrixes.

SDM capstone project centers on improving defense systems

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across their domains to establish more effective and efficient team structures through improved communications and information exchange, as illustrated by Eppinger in his article, “Innovations at the Speed of Information.”

Linking programs and personnel

Figure 3 provides both acquisition and S&T high-level frameworks derived from the DoD System Acquisition, Technology, and Logistics Life Cycle Management System and S&T Technology Readiness Levels.

The key point of Figure 3 is to formalize the technology and system acquisition team interaction across the various reviews by the use of linked requirements. Integrating requirements across reviews will inform both the acquisition and S&T communities of their status regarding technical and programmatic requirements across the life cycle. Increasing the frequency of status updates as shown in Figure 3 will accelerate iterations, reduce rework, and inform and direct the technology transition effort. Furthermore, ensuring key stakeholder’s from each domain participate in each other’s reviews will provide important contextual information that may not be fully described by formal requirements. Mutual participation will integrate teams and help bridge the chasm shown in Figure 3 where collaboration is essential given the technology integration focus of these life-cycle phases. Lastly, the matrix analysis of the previous section provides the rigor necessary to objectively define a technology’s readiness for transition at these reviews rather than subjective inputs.

Concluding thoughts

Focusing on key elements within the technology transition process as outlined above can provide insight to what risks or opportunities might emerge when integrating the related products, programs, and personnel across life cycles and traditional domain boundaries. While it is clear that early and frequent communication is needed—it is not always clear how to structure that collaboration to improve value delivery. By using a systems approach, one can begin to decompose and solve very challenging problems—including those faced at the DoD.

Looking ahead, I plan to present my work to senior systems engineering and integration (SE&I) leadership within Booz Allen, and I am investigating opportunities where this approach may aid programs we currently support. In addition, I was selected to present this approach at the National Defense Industrial Association 13th Annual Systems Engineering Conference in San Diego, CA, in October to share how it might complement currently published DoD S&T best practices. Meanwhile, I continue to research and run use cases through the process to identify areas for improvement as well as dialog with Booz Allen senior SE&I leaders and MIT faculty to receive their counsel.

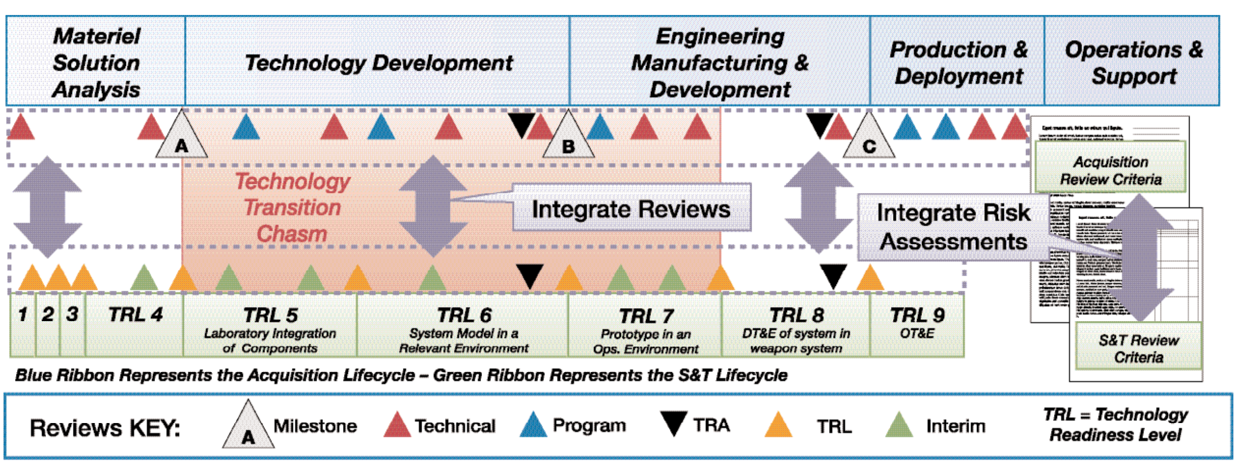

Figure 3. This graphic shows the links among review criteria across the S&T and acquisition life cycles.

SDM student juggles coursework, company, speaker series

By Kathryn O'Neill, managing editor, *SDM Pulse*

Charles Iheagwara
SDM '10

MIT's System Design and Management Program (SDM) attracts many students with master's degrees, but perhaps no one has entered with more academic credentials than Charles Iheagwara, who joined the 2010 cohort with four advanced degrees—including a PhD in computer science.

The founder and chief technology officer of Unatek Inc., a US government information technology contractor, Iheagwara has also taught at the university level and has 40 published works to his name. Nevertheless, he said that studying at SDM has been "fantastic."

"Going to MIT is the dream of every engineer," he said. "The coursework and the curriculum [at SDM] are the best that anyone could imagine."

Iheagwara said he is particularly benefiting from the management portions of the curriculum. "I haven't had any formal management education. So this is the opportunity for me to learn about the theoretical and practical aspects of management and leadership," he said. "In today's corporate world, technology is an indispensable tool .... [SDM] demonstrates how effective management can lead to better utilization of technology to enhance the bottom line."

He said he is already putting his new SDM skills to use on the job—particularly the lessons he learned about forging alliances in SDM's course in technology strategy. "I don't think in the past I was able to do that so well at Unatek. But immediately after [taking the course] I was able to strengthen areas where I was weak," he said.

Never one to do things by halves, Iheagwara is not just working and going to school full time. He is also organizing SDM's speaker series as a member of the program's Industrial Relations Committee, a student-led group that works to forge links between SDM and the business community.

As both an executive and an academic, Iheagwara said he felt a responsibility to put his resources to use for the benefit of the SDM program. "I thought I could tap contacts I had to help promote the program," he said, noting that he had organized several big conferences at Unatek. "I believe that if you are part of an organization, you should work to advance the interests of that organization."

The first series of talks organized by Iheagwara took place this past summer. Highlights were a keynote address on entrepreneurship and leadership by Mamoon Yunus (MIT '93, '95), president and CEO of Crosscheck Networks, and a panel discussion among Ajay Mishra, global head of innovations management at Nokia Siemens Networks; Rob Kramer, chief of applications development and operations at the Washington Metropolitan Area Transit Authority; and Darren Hammell, co-founder and executive vice president for business development at Princeton Power Systems.

"I like the panel sessions because, if nothing else, they make it possible to have more speakers from a diverse spectrum of the work force," Iheagwara said, noting that the series has three main goals:

1) To give the SDM cohort the opportunity to learn directly from high-caliber professionals on the front lines of industry.

2) To disseminate information about the program to the speakers themselves, who come to MIT from different companies and organizations.

3) To promote the program more generally. "Each time we invite speakers and have speaker events, it generates some sound bites that can help promote the program," Iheagwara said.

Typically, the SDM speaker series is open only to members of the SDM community, allowing SDM students to meet with speakers in small groups and to ask questions during presentations and afterward. Iheagwara and others on the Industrial Relations Committee have been working to line up other speakers for the fall and have a commitment from Luwanda Jenkins, Maryland's special secretary of minority affairs. They're also reaching out to many chief technology officers and entrepreneurs and expect to have an exciting program lined up, Iheagwara said

"We think the fall and spring will be very busy with events," he said.

For current SDM event information, go to sdm.mit.edu and esd.mit.edu.

SDM teams address Hawaii's clean energy challenges

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provides a $7,500 tax credit for the purchase of a plug-in hybrid. The team used trade space exploration to determine how the various stakeholders—including the rental car industry, government, and tourists—perceive important attributes of these policies, such as the subsidy level, the time taken to change the MPG mandate, and the increase in MPGs in every policy change.

The team found that a policy sensitive to the tourism economy would take into consideration the extra costs imposed on car rental companies by the MPG mandate. Currently electric hybrids have a premium of ~$5K over a comparable gasoline powered vehicle and a PHEV has a premium of ~$20K over a comparable gasoline powered vehicle. If an aggressive MPG mandate were passed without the appropriate subsidy level, then the price premiums paid on the alternative cars would have to either be absorbed by the car companies or passed on to renters. The team found that changing the MPG target at a rate sensible to the car companies is important to achieving a significant reduction of oil consumption in this sector.

Team Grid: Intermittent Resources, System Adequacy

Team members: Kacy Gerst, SDM '09, Karl Critz, SDM '10, Matt Harper, SDM '10.

Much economic and policy research has already focused

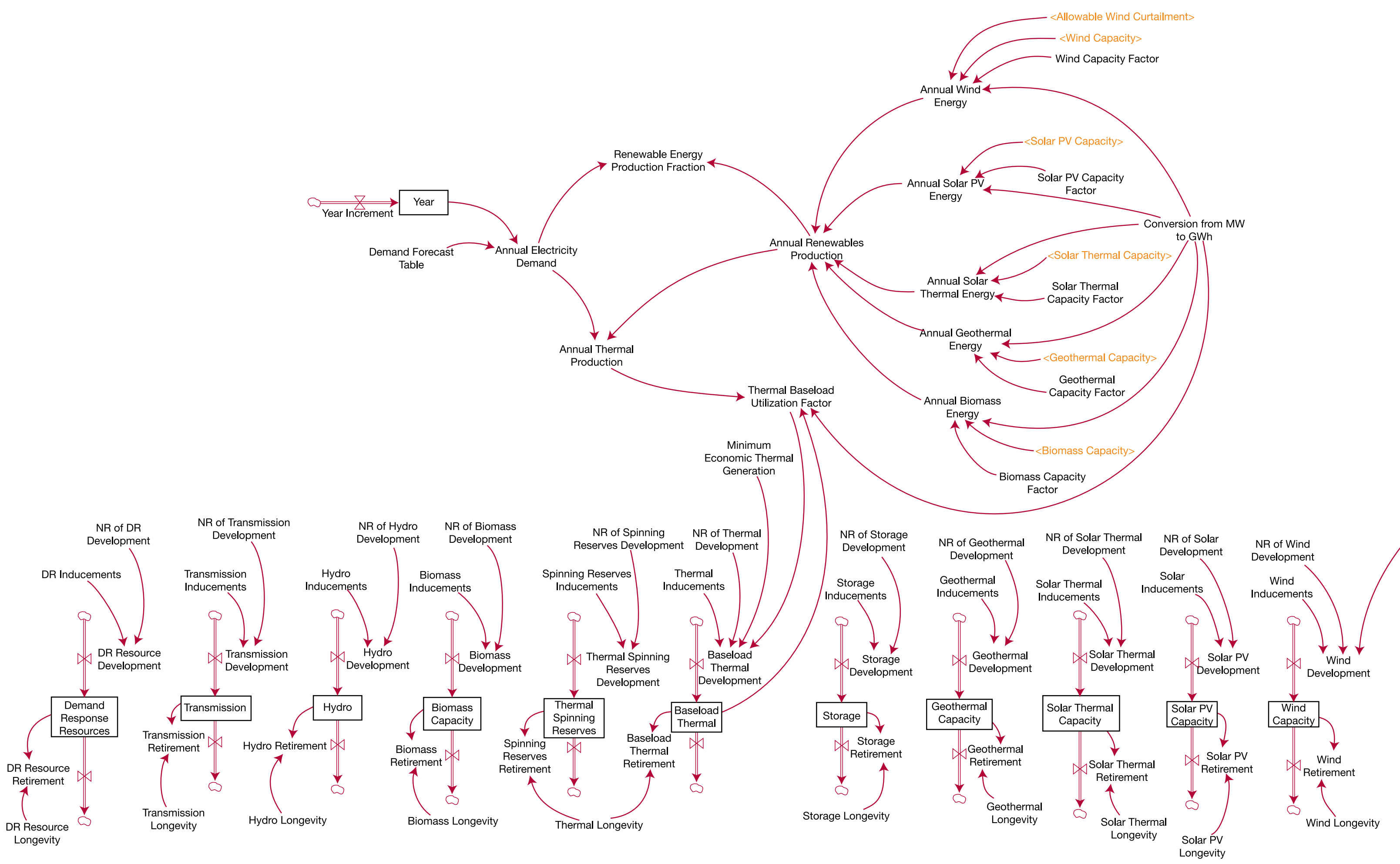
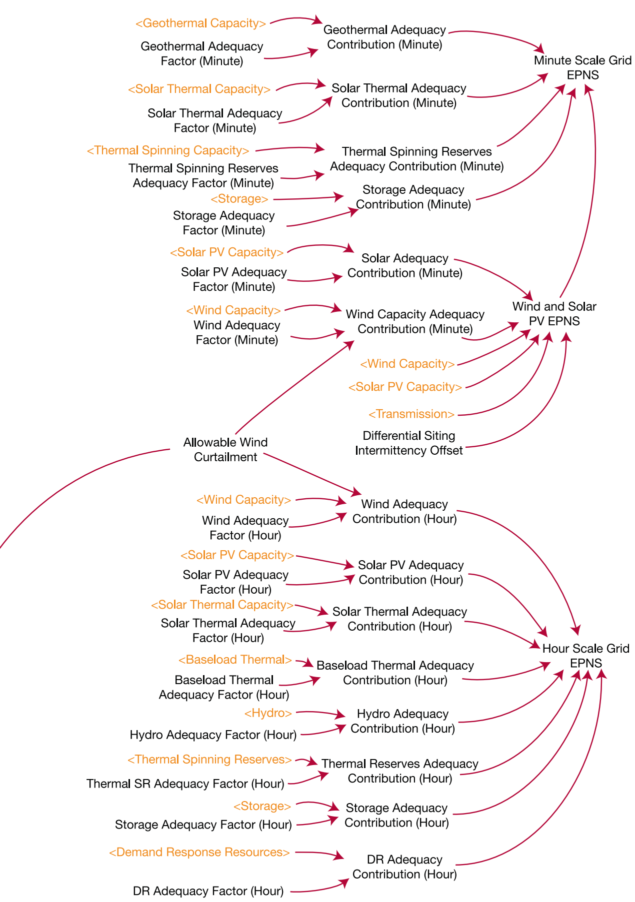


Figure 2. This system dynamics model is designed to capture annual energy balance, capital stocks, and power not served.

on how to structure incentives in order to meet a 40 percent renewable portfolio standard. Team Grid therefore chose to focus on the less-studied systems issues and incentives involved in integrating intermittent sources of energy, such as wind and solar power, into the electrical grid. While some renewable energy sources, such as biomass or biofuel, act like the status quo fossil fuels and can be ramped up or down as needed, others do not. Geothermal energy installations usually have a fixed maximum capacity and have limited ability to respond to demand variation. Worse, wind and solar sources are entirely at the mercy of nature. A grid supplied by these intermittent sources must work harder to meet demand when the wind stops blowing.

The SDM team deployed a rich set of systems engineering tools to address the problem (an example is a complex system dynamics model shown in figure 2). Characterizing the proposed electricity grid for 2030 exposed the scope of the problem on the minute and hour timescale. A model of the grid from today until 2030 revealed the connections between generation, demand, investment, equipment retirement, transmission, and stabilization. The team also developed a model of stakeholders to put hard economic values on the cost of blackouts, not-in-my-backyard attitudes, habitat destruction, and behavior change. By using experimental design, the team evaluated a set of portfolios for its economic and social costs. This analysis revealed an optimal set of stabilizers for assuring an adequate energy supply with intermittent resources.



The best portfolios focused on simple solutions that use existing infrastructure. It is not, strictly speaking, economical to maintain oil-fired power plants when they will only be used infrequently. However, compared to other storage technologies it is much less expensive (economically and socially) to keep these plants maintained and ready to step in when the sun and wind cannot provide. The team therefore recommended that the Public Utilities Commission guarantee that low-utilization oil plants be compensated by ratepayers.

Unfortunately, such plants are unable to take extra energy when the wind is blowing strong and demand is low ("down-regulate"). To react quickly to unexpected changes and stabilize the grid, the team also recommended the use of chemical energy storage devices such as batteries or fuel cells. Since the storage would supply broad grid benefits, it makes sense that it be controlled by the electric company and not by individual wind/solar developers. The general benefits of storage should also qualify investments for public subsidies similar to the producer tax credit offered for wind and solar developers.

In addition to these two themes, the team also found benefit in (1) dynamic billing policies to shave demand during emergencies and (2) streamlined siting for transmission lines and geographically distributed intermittent sources. Each of these policies will create the strong grid Hawaii needs to reduce its fossil fuel imports and assure the continued services upon which its economy depends.

These projects were developed in close collaboration with Michael Duffy at the National Renewable Energy Lab, who provided continuous feedback and guidance to SDM students throughout the course. Both teams thank Duffy (who received a master's from MIT and a PhD from Ohio State University) for his mentorship.

Alumnus applies SDM lessons to aerospace industry

By Kathryn O'Neill, managing editor, *SDM Pulse*

Bob Smith
SDM '97

Bob Smith, SDM '97, doesn't take systems thinking lightly. As chief technology officer of Honeywell Aerospace, he's using everything he learned in MIT's System Design and Management Program (SDM)—and more—to consider how to change the way aircraft fly. The goal is to minimize delays, ease congestion, and improve fuel efficiency.

"Air traffic control is a system of systems challenge," Smith said. "It includes airline operators who want a high utility of assets, airports, the regulatory environment, and other systems that must be integrated very well to achieve more efficient route structures and free up capacity at major airports."

Honeywell Aerospace serves three major industry markets—defense, air transport, and business and general aviation. A division within Honeywell International, it provides a broad range of products, both mechanical and electrical, from propulsion jet engines to radar to avionics.

"We make many of the underlying technologies [used in airplanes], so we have to work that system of systems problem," he said. " Fortunately, we've been able to work with both Eurocontrol (the European Organization for the Safety of Air Navigation) and the FAA (the US Federal Aviation Administration) .... We're conducting research on how to develop certain navigation systems and how to get that systems-level analysis and research done so that we can be in on the deployment level of the national airspace transformation as we evolve from a ground-based system of air traffic control to a satellite-based system of air traffic management."

While Honeywell Aerospace is working on the big-picture issues, it must also take on the day-to-day systems challenges. "There are probably three different fundamental ways in which systems thinking is really affecting our business," Smith said. The problem of air traffic control is one, he said, and the second is the increasing demand for tighter integration of aircraft systems components. For example, the US Defense Department's F-35 Joint Strike Fighter is a very small aircraft that needs to perform many different tasks—according to the DOD, it's designed to be "affordable, lethal, supportable, and survivable"—so tight integration is a necessity, Smith said.

Thirdly, Honeywell is increasingly assuming more program management functions—ensuring that Honeywell components work well with each other and with third party components too, a classic systems challenge. "A couple of generations ago," Smith said, "they would ask Honeywell to build an auxiliary power unit, and we would say here's our gas turbine engine. That would be it. Now we also have the responsibility for integrating the generator and the muffler. There's an evolution there where they want you to help design the whole tail cone."

Smith brings years of experience to tackling the complex challenges at Honeywell Aerospace. A technical expert in guidance navigation and control, he rose to hold leadership roles as system director at The Aerospace Corporation and executive director at United Space Alliance before joining Honeywell in 2004 as vice president of advanced technology. He was promoted to chief technology officer in September 2009.

He also brings with him the lessons he learned at SDM in the late 1990s. "I liked SDM for a couple reasons," he said. "The program did a really nice job providing a good balance of the critical aspects needed to be successful as a business or functional leader in the aerospace industry: technical acumen, managerial capabilities, and an understanding of how to manage system complexity."

Smith said he has particularly valued the organizational design and development tools he learned at SDM. Since change management is an ongoing occurrence, "you can always tune up your business using these tools," he said. "I was able to apply [them] on day one at Honeywell."

SDM also connected Smith to a network of systems professionals that continues to serve him well today. "That network has been preserved, and it's one that I really value," Smith said.

"My fellow SDM students were outstanding. For me, being in a program that is for people who have had some experience in business—not students fresh out of school—led to a much richer experience," he said. "[Class discussions] weren't theoretical, but based on real-world experience."

Smith has agreed to give a presentation to current SDM students in spring 2011. Although he has not zeroed in on a topic yet, he said he will likely focus on some of the larger socioeconomic trends he sees and ways to

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Conference sponsors share views on the value of systems thinking

By Kathryn O'Neill, managing editor, *SDM Pulse*

Editor's note: *There are six platinum sponsors for the 2010 MIT Conference on Systems Thinking for Contemporary Challenges. In this article, spokesmen for the six—Global Project Design, John Deere, Merck/MSD, MITRE, United Technologies Research Center, and Werfen/Instrumentation Lab—share why they value systems thinking, the strategic imperative for technical professionals who understand management, how they work with SDM, and why they are supporting the systems thinking conference. For more information on the SDM conference, see Page 28 or visit sdm.mit.edu.*

Global Project Design

Global Project Design (GPD) is a company that assists executives and teams with real-time design of complex initiatives. Founded in 1999 by Bryan Moser, a 1989 graduate of MIT's Technology and Policy Program, GPD integrates architectural modeling of products, processes, and organizations to create feasible, lean plans for complex projects. The company has created and delivers the innovative TeamPort software suite that aids in the integration of these activities.

"The impact of our work is the capability of a team of teams to plan early and rapidly, with accuracy in cost, schedule, and quality risk," Moser said. "An effective project design exercise leads to situational awareness of a system and its risk due to the overlap of product, process, and organization architectures."

GDP is sponsoring this year's SDM conference because the company is dedicated to spreading systems thinking throughout industry, Moser said. "If a company wants to be competitive, they need to ensure their workforce has this skill set."

Moser said that GDP and SDM are still on the leading edge of this transformation—too many companies remain attached to traditional planning processes. "For a century, the way that most professions characterized work and how we organized for work had one fundamental assumption—stability in product, process, or organization," Moser said. "What's different today is that really it's a system of systems—products, processes, and organizations are shifting constantly."

Moser said his company uses visual representations—such as the design structure matrix (DSM) taught in SDM—to trim weeks or even months of centralized planning down to a days of collaborative visual planning and simulation. "The DSM taught now is one good example of stepping back to visualize and analyze the essential architectural quality of modern complex work," he said. "There are patterns and insights [gained from using this tool] that would otherwise be lost."

Although GDP is still an emerging company, Moser said he sees the SDM connection as an investment in the future. "The first people I want to hire to build up my company will be SDM grads," he said.

John Deere

John Deere is a world leader in providing advanced products and services for agriculture, forestry, construction, lawn and turf care, landscaping, and irrigation. John Deere also provides financial services worldwide and manufactures and markets engines used in heavy equipment.

Systems thinking is central to John Deere's business, according to Brian J. Gilmore, manager of worksite productivity. "We have applied [systems thinking principles] to all of our major machine subsystems, mainly in the advanced technology systems—engines, power systems, intelligent vehicles, and electronic vehicles."

The company also faces complex challenges that require a systems approach, he said. "We continue to work toward reducing engine emissions per federal guidelines and to help our customers become more productive through the delivery of more intelligent equipment," he said.

John Deere has sponsored the MIT SDM systems thinking conference at the platinum level for the past two years because the company supports the program's mission, Gilmore said. "We believe strongly in systems engineering, and this is a forum to bring people together with similar viewpoints," he said. "Our people can attend and bring some ideas back into the company."

Among the likely attendees this year are the four SDM master's students and 18 SDM certificate students that John Deere currently sponsors in the program. The company, which has been involved in SDM for five years, has sent more and more students each year. "We do recommend the program to other companies, and we encourage the right people within our company to consider it," said Gilmore, noting that John Deere has been very pleased with the results it has seen.

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Conference sponsors share views on the value of systems thinking

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"Whether they pursue the SDM master's or certificate, [SDM graduates] say that they really understand the product delivery process much better," he said. "They are then more effective in doing what they're doing and in providing guidance to the rest of the organization."

Merck/MSD

Merck/MSD is one of the world's largest health-care solutions companies. With operations in more than 140 countries, Merck delivers health-care solutions through prescription medicines, vaccines, biologic therapies, consumer care, and animal health products.

The company sponsors the SDM conference because systems thinking can help Merck provide better and more innovative health-care solutions, according to Michael P. Thien, ScD, senior vice president for global science, technology, and commercialization in Merck's Manufacturing Division.

"The world of pharmaceuticals is getting very complicated," Thien said. "With the emphasis on emerging markets, the advent of biosimilars, the recognition of opportunities in consumer care and the global need for vaccines, it is no longer possible to make strategic advances by focusing on single functional elements of our business. Using a systems approach, like the frameworks offered up at MIT's SDM program, allows us to navigate many business challenges."

Merck values the SDM conference for two reasons, Thien said. "The first is in enhancing the mindset of the attendees to think more broadly and holistically about complex system problems," he said. "The second element has been in the formation of cross-academic, cross-industry connections." Over the years, such connections have led to beneficial collaborations between the company and MIT, ranging from simple email interchanges to longer-term projects, he said.

While Merck has only been formally involved with SDM since 2009, the company has a long association with MIT, including participating in the Industrial Liaison Program. Partnering with SDM is helping the company evaluate its technology strategy as well as address more tactical problems, such as design choices, Thien said.

"Merck has been and plans to be very active in SDM," Thien said. "Through our sponsorship of students in SDM, we are increasingly able to easily learn from and access the work of MIT experts for solving real business problems."

MITRE

MITRE is a not-for-profit organization chartered to work in the public interest. The company manages Federally Funded Research and Development Centers, partnering with government customers to support their most crucial operational missions.

Since the federal government faces ever increasing complexity in its systems and enterprises, systems thinking is critical to MITRE's mission, according to Louis Metzger, a senior vice president at MITRE and the company's corporate chief engineer.

"Networked systems must interoperate with, respond to, and co-evolve with an environment that constantly changes," he said. "Systems thinking has always been important, but it is even more crucial now."

MITRE has been involved with SDM for 10 years and has been a sponsor of the systems thinking conference for the past three. "Much of what is presented at these conferences is relevant to the research MITRE is fostering in systems engineering," Metzger said, noting that the conference helps MITRE stay abreast of the best practices in this evolving field and enhances the company's recruitment efforts by building name recognition within the systems engineering community.

"Systems engineering skills, discipline, and thinking are foundational capabilities that enhance MITRE's ability to support our government sponsors," Metzger said. "We try to understand the full problem space and all the factors that influence success. We account for all necessary technical and non-technical aspects. We then combine engineering knowledge and rigor with an intimate understanding of end-user needs, so that our advice and recommendations are based on solid data and convincing, defensible analysis set in the context of the applicable mission environment."

MITRE employs several SDM alumni and continues to send staff through the program and to recruit on campus. "Expanding the number of staff who can apply systems thinking will help us and our customers to be more successful," Metzger said.

United Technologies Research Center

United Technologies Research Center (UTRC) delivers advanced technologies and research to the businesses of United Technologies, industry leaders in aerospace propulsion, building infrastructure and services, heating and air conditioning, fire and security systems, and power generation.

"UTRC is proud to sponsor the SDM conference because energy, sustainability and systems design align with our priorities," said Isaac Cohen, director of UTRC's Systems Department. "The conference is an opportunity to dialogue with leaders of industry and academia and engage on current technical challenges as well as see what's being done in terms of technology development."

"The opportunity for developing technology options and solutions using a systems-based approach is great, and in many areas represents value that can be realized in the very near term," Cohen said. For example, a building has a security architecture, an HVAC system, safety controls, and a multitude of operational functions that historically have not been designed to operate as an integrated system, he explained. "Consider the possibilities of sustained, efficient performance in buildings once you enable capabilities to drive awareness, reaction, and adaptability across the life cycle of operation."

Cohen added, "From a systems engineering perspective, a key challenge is how do you control and activate these components—which are designed and developed from a variety of independent sources—and what are the best pathways to pursue as priorities?"

Cohen said that consequently UTRC is not only interested in supporting the systems thinking conference, but also in connecting with SDM students who will be in attendance.

"UTRC is experiencing very strong growth, and we're looking for exceptional talent with systems engineering thinking and healthy creativity," Cohen said. "More and more we need different skill sets—people who can comprehend systems' complexity."

Werfen Group/Instrumentation Laboratory

A worldwide developer, manufacturer, and distributor of in vitro diagnostic instruments, Instrumentation Laboratory (IL) has been involved with SDM for three years. Not only does IL support the SDM conference, the company also sponsors students in the certificate program (some employees have gone on to pursue master's), and has benefited from "lunch and learn" sessions with MIT professors, who have visited the company to share insights on current systems problems.

Gene Achter, vice president of advanced development and technology and chief technology officer, said SDM has helped IL to spread systems thinking throughout the company. "Systems thinking helps you address the interactive part of challenges, which are the hardest to deal with," he said. "In the end the instruments don't care and the molecules don't care. You can't talk the systems into working."

IL has sponsored six SDM students to date, but is already seeing a difference in the organization, according to Jessica Levesque, IL's human resources manager. "One of the things I've noticed with SDM grads is that they're very interested in imparting their knowledge," she said. "Getting people in different parts of the organization participating [in SDM] helps get people thinking—I'm not just a mechanical engineer working on this rotary valve, I'm part of a system. And that's huge."

Both Achter and Levesque plan to attend this year's conference, as they have in years past. "The thing that I liked the most about the last of these sessions was the chief engineer of NASA talking about role of systems engineers," Achter said. "He said some are working on subsystems and think that as long as they focus on meeting the requirements for that subsystem, everything will be fine. But requirements are written by people and may not be accurate. Every engineer has to be looking out for interactions."

Levesque said that she finds all the conference presentations interesting, but that's not the main reason the company sponsors the event. Sponsoring the conference helps IL to raise awareness about its business, she said. "When you work with MIT there's so much visibility."

SDM helps teams take on global development challenges

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reasonable to consider whether this prevalent technology might be used to address a common social ill.

During the summer of 2009, I took an MIT class called NextLab, which focuses on using mobile technologies to address global challenges. A class assignment soon brought me to Jhansi, India, a rural area south of Delhi, where I co-led a project called Celedu (Cellular + Education) that aimed to spread literacy in the developing world using cell phone applications.

Our team of SDMs, MBAs, and computer science students developed and deployed a pilot study to assess the effectiveness of an interactive game application to address illiteracy. While technology was crucial to our application, we built our business model around the culturally relevant theme of community-based learning. It was designed to be interactive in order to leverage India's existing social system and to encourage community involvement and accountability.

Considering cultural context as the broader system for our application allowed us to build a more successful model. We used technology that required very few behavioral changes from users, and that decision contributed to the results showing quick adaptation. Ultimately, we were able to demonstrate receptiveness from our target users to an unfamiliar technology, and we found that our application dramatically quickened short-term learning relative to the current book- and even computer-based method.

In SDM's system architecture class the following fall, we retroactively identified areas for improvement. We mapped out the system architecture of Celedu's model and identified gaps between the function of different subcomponents and the form they should have taken. For example, while we were sponsored by Development Alternatives (a nongovernmental organization) and partnered with Nokia for our pilot, we needed to better understand the stakeholder network and the value flow among them in order to align the incentives of each contributor. I am currently in the process of further developing the software and establishing a long-term partnership through courses at MIT and government agencies.

Fighting AIDS in Uganda

The project management, business analytics, and systems thinking skills I've learned at SDM also proved useful for the project I undertook last fall for the Global Entrepreneurship Lab (G-Lab), a premiere international internship course at Sloan. In G-Lab, my team worked with a project partner in Africa to address business and operational issues related to health-care delivery.

The Sustainable Household Income Project (SHIP) I worked on was developed to help HIV/AIDS patients in Uganda to increase their individual income generation. Prior research and collaborations with patients had demonstrated that an increase in household income improved treatment adherence, a critical factor in health-care outcomes. While many patients of the clinic we worked with were able to obtain free antiretroviral (ARV) treatment, they often had difficulty funding the

While researching sustainable household income in Uganda, Alex Shih, SDM '09, found that raising chickens was often a good business prospect for AIDS patients. Chickens (left) were fed feed containing vitamins and other nutrients (center) and their eggs were packaged and transported to market (right).

associated costs, such as transportation to the clinic, opportunity costs for the time and labor spent getting care, and additional food required. Many patients in rural Uganda were actually spending 30 percent to 50 percent of their income on transportation alone to pick up monthly refills.

SHIP set out to fund income-generating activities (IGAs) with a central income generator, a lemongrass distillery. My team was tasked with assessing and analyzing the profitability of the distillery, determining the feasibility of independent household IGAs, recommending an optimal governance structure, and identifying major project risks.

We discovered that the estimated profits generated by the central lemongrass distillery would only sustain SHIP operations for about three years due to the high capital expenditures and operating losses of the distillery. Ways to augment distillery profits included building a visitor center and marketing products using an organic/fair-trade brand. SHIP could also cut operating costs by running a leaner organization, scaling up more gradually, or creating strategic partnerships with other nonprofits that may fill in gaps in competencies/expertise.

More significantly, when we examined the distillery plan within the larger system of individual households, we found that lemongrass growing at that level required substantially more land than other IGAs and carried more risk as a cash crop. In contrast, other IGAs—such as chicken coops and fruit growing—were more suitable for many patients. Best practices advised that each participant should draft a custom business plan considering resource availability and costs specific to his or her household.

Our home visits, subject expert and faculty interviews, and secondary research further demonstrated that each household's characteristics and resources uniquely affected the feasibility and profitability of any given IGA. What could be an outstanding success for one household is likely to be a disastrous failure for another. Furthermore, many households took on a variety of IGAs simultaneously, ranging from crops to animal rearing to clothing products, adding further layers of complexity to the already unique system of each household.

Overall, we determined that the distillery project would only be feasible with better governance and project management, compelling SHIP to proceed with caution. This experience helped to cement for me the importance of risk transparency so that all project stakeholders and participants can better mitigate internal risks and plan for external risks. Plainly, any effort to relieve a social ill must examine and consider the whole social system involved.

In his paper "Doctors Without Orders," Josh Ruxin writes that the failure to construct viable public health systems in the developing world has helped create the conditions for the pandemics of today. He emphasizes that these health institutions and infrastructure in developing landscapes cannot be treated as independent silos and disconnected projects. There are too many projects only focused on water, education, or specific diseases. Instead, integrated approaches—those that take into account water, sanitation, economic opportunity, education, and infrastructure along with health—have a better chance to address public health needs both sustainably and adequately.

Both Ruxin and the World Health Organization contend that the "complex matrix of development" requires systems thinking, financial knowledge, and management. We must bring together perspectives from economists, sociologists, management consultants, and politicians, and create solutions that focus on every aspect of life that contributes to health, from the management of care programs to agricultural productivity to telecommunications improvement and the provision of clean water. This means that we must not only recognize that Uganda's economy can affect the country's national health-care system and vice-versa, but embrace its interconnected-ness and integrate all the current initiatives out there that are still largely in siloed operations.

I am now in my third and final year at MIT. I returned from a summer in Jerusalem working for a nonprofit educational organization called Middle East Education through Technology (MEET), whose vision is to bring Israeli and Palestinian youth together through the language of education. There, I taught business and entrepreneurship to high-school students, while gaining a glimpse of the complex challenges engendered by prolonged conflict.

It is the beginning of a new academic year, and I hope to continue internalizing classroom teaching and perspectives gained from global experiences into my courses and eventual thesis. I am convinced that society's problems must be dealt with holistically and owned by the beneficiaries in order for solutions to be sustainable.

Thesis targets seasonal labor migration

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question that this research will answer is:

How do we improve and consolidate the circular migration program to dynamically adapt to the flow of immigrants under varying economic conditions while maximizing value to all stakeholders?

To address the aforementioned question, further issues will be analyzed, including: why this tool that regulates labor migration flows was created; how it was successfully implemented in Cartaya; finally, how it is currently functioning during a period of high unemployment. Covering one city (Cartaya) and a time period of the past 24 years, this research will formulate a single case study about circular migration.

Among all the tools and methodologies we have been using in our SDM courses, I will approach my research using system dynamics to create the model of this multi-dimensional migration management system. Perspectives from economics, sociology, and public policy will all come into play, making this an ideal case for applying system dynamics. In order to formulate my dynamic hypothesis, I will consider in this model the social integration of guest workers as a key element to explain the benefits of implementing responsible labor supply management practices while having a just-in-time workforce.

In addition, some aspects and logistics of the international relations between Spain and African countries such as visa processing—aspects originally left out of the Cartaya process because of implementation difficulties—will be incorporated in the system dynamics model because the power of this modeling technique. Modeling the factors that made this circular migration program a success over the time, and using feedback loops and "stocks and flows" diagrams, will allow the stakeholders to better understand system constraints and design a robust and sustainable system of circular migration.

This research has been supported by the Ministry of Economy, Innovation and Science, Junta de Andalusia—TALENTIA Graduate Fellowship Program.

SDM thesis roundup

This sampling of SDM thesis research illustrates the range of systems questions SDM students tackle. To read these theses in full, contact Lois Slavin, SDM communications director, at lslavin@mit.edu.

Andrei Akaikine, SDM '09

Title: The Impact of Software Design Structure on Product Maintenance Costs and Measurement of Economic Benefits of Product Redesign

Fixing software bugs can be extremely costly, both in terms of time and money. It has been estimated that for most software products, the cost of maintenance activities exceeds the initial cost of development and can reach up to 90 percent of total life cycle cost. Yet, most research on software products economics focuses on cost management during the development phase of the software life cycle. This study focuses on software complexity as one of the main drivers of maintenance costs. To measure the complexity of software systems under investigation, Akaikine designed a complexity measure, based on the design structure matrix, suitable for use in the maintenance phase of software lifecycle. He presents an empirical analysis of the effects of software complexity on costs associated with maintenance tasks within a large-scale commercial software product organization. The study found that with reduction of propagation cost from 38 percent to 11 percent, the productivity of engineers working on similar maintenance tasks improved by more than 10 percent.

Akshat Mathur, SDM '08

Title: The Evolution of Business Ecosystems: Interspecies Competition in the Steel Industry

This thesis builds on the work of Theodore F. Piepenbrock, whose 2009 MIT doctoral thesis, "Towards a Theory of Evolution of Business Ecosystems," proposed that firms in the same industry vary systematically in performance over time as a result of differences in architecture. Piepenbrock defines architecture in terms of the strength, closeness, and the specific morphology of relationships that exist between the core firm and the four markets that are its key stakeholders—product markets, capital markets, supplier markets, and labor markets. Mathur extends Piepenbrock's model to examine its validity in commodity industries, specifically the steel industry from the 1860s to the present. He finds the theory is consistentlysupported by the steel industry data, and he concludes that the evolution of business ecosystems is a reasonably robust theoretical framework.

Mario Montoya Jr., SDM ’09

Title: On Developing Business Architectures: A Multi-Framework Evaluation of an Early-Stage Enterprise

Montoya examines the efficiency and effectiveness of using multiple frameworks to analyze an early-stage enterprise within the medical technology industry, Lentesco Luminarium. The company faces a critical choice between two growth strategies: vertical penetration within existing modalities or horizontal growth into new modalities, and Montoya explores what tools might inform and guide the executive team to make the right decision for Lentesco’s particular industry, maturity, and size. In addition to the standard Lean Advancement Initiative suite of tools, he uses Nightingale and Rhodes’ eight Enterprise Architecture views, Kaplan’s Balanced Scorecard, McKinsey’s 7S framework, and Grave’s Spiral Dynamics. He concludes that Lentesco needs to improve transparency and communication, and he suggests the use of the McKinsey 7S framework to put concepts into perspective as simply as possible. For a multiple perspective evaluation, he suggests the EA 8 Views framework.

Shailendra Yadav, SDM ’08

Title: Analysis of Value Creation and Value Capture in Microfluidics Market

In the last two decades, microfluidics has been changing the shape of genomics, drug discovery, proteomics, and point-of-care diagnostics. Advances in the technology have resulted in faster analysis time, increased throughput, and reduced cost, among other important benefits. Yet, in this thesis Yadav reports that the life sciences end-users and the microfluidics players themselves are far from fully capturing the value of these advances. As an immature technology, microfluidics is to date still only in the hands of innovators and early adopters, who are academic laboratories and research institutes. Yadav analyzes the current state of the market and finds genomics and point-of-care diagnostics have captured the most value from the technology, while drug discovery has seen the least. He then proceeds to recommend short- and long-term strategies for increasing value capture and accelerating the adoption of microfluidics.

To learn more about SDM thesis research, contact Pat Hale, director of SDM fellows program, at Pat_Hale@mit.edu.

SDM aids IL’s health mission

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around a graduate who is explaining a systems concept. One of our graduates, Guy Criscenzo, explained the impact of the SDM on his thinking as follows: “The SDM program has provided me a system to increase the effectiveness and value of my system engineering capabilities by focusing all of my past product development knowledge and experiences using clear and concise principles, methods, and tools.” He went on to say, “The SDM program has changed everything, and product development will never be the same.”

Another one of our certificate graduates, Sassan Zelkha had this to say: “SDM’s certificate program has had a great impact on both my professional and personal life. Through the program, I have learned how to think globally while acting locally. I have become a systems thinker for life. I have also gained many valuable tools such as DSM, OPM (object process methodology), SysML (systems modeling language), and many others that are aiding me to be more effective system engineer.

“Another great benefit of this program is the interaction and connection made with many great minds such Professor (Edward F.) Crawley and other system engineers from different industries. The benefit of the program was so great that I decided to continue the program part time to get my master’s in SDM.”

Instrumentation Laboratory designs and manufactures complex medical instrumentation that is sold around the globe. Although so far only a small fraction of our staff have been trained in the SDM concepts, their efforts to impart that knowledge to others within the organization has already had a positive impact on how we do business.

IL is one of six platinum sponsors of SDM's systems thinking conference. Read more about all six on pages 17-19.

INCOSE at 20—new domains, new promises, new people

By Pat Hale, director, SDM Fellows Program


Pat Hale

Editor's note: *Pat Hale is a former president of the International Council on Systems Engineering (INCOSE).*

The International Council on Systems Engineering (www.incose.org) held its 20th annual symposium in Chicago this July, celebrating an organization and a profession that are growing at a steady rate as new areas of product and practice are exposed to the power of systems engineering.

Since 1991, when the first symposium was held in Chattanooga, TN, attended by just over 100 representatives from the defense/aerospace industry, government agencies, and academia, INCOSE (then NCOSE) has grown into a vibrantly international and impressively diverse group. Members represent a range of industries from defense to finance and medicine.

That diversity was highlighted at this year's symposium, when INCOSE's most prestigious award, INCOSE Pioneer, was presented to Julian Goldman, MD. The citation read:

> *"For demonstrated extraordinary leadership in the advancement of the state-of-the-art and practice of systems engineering in the biomedical and healthcare fields. Through his pioneering work, Dr. Goldman has shown that breakthrough improvements in patient safety can be achieved by bringing together individuals and groups from the commercial, non-profit, education, and government sectors to focus on 'the system of interest.' The most impressive legacy of his work is in hearts and smiles of living, breathing patients, who, without his trailblazing efforts, might not be here today."*

The award of this honor—based on uniquely applying the engineering of systems to outcomes enhancing society—not to an engineer, but to a physician, is a milestone for INCOSE. Goldman is the founding director of the Program on Medical Device Interoperability at the Center for Integration of Medicine and Innovative Technology, and his award underscores the impact of systems engineering in new domains of practice.

The growth of INCOSE in every dimension, mirrored in the number of new faces and the energy within the technical working groups, provides evidence that the field of systems engineering is expanding to meet the challenges of an ever more complex set of societal needs.

MIT's System Design and Management Program (SDM) has drawn much of its material for the systems engineering core course from the technical community in INCOSE, including the course text, which is the *INCOSE Systems Engineering Handbook*. This year, the partnership between SDM and INCOSE will expand further with the planned establishment of an MIT student chapter under the sponsorship of INCOSE's New England chapter. And, next fall, SDM will welcome Goldman as keynote speaker at its annual systems thinking conference.

SDM demystifies multidisciplinary system design optimization

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heuristic genetic algorithm to visualize the trade-off between the two cost goals resulting in a Pareto front (essentially the balance point at which you cannot make progress toward one goal without detracting from the other). This chart (see Figure 3) showed the optimal necessary system design options and allowed us to evaluate the most appropriate design choices. Further analysis revealed design vector sensitivity so that we could see what design variables and model parameters would most affect our result—and where additional concessions could be made with minimal impact to the objectives.

An analysis like this one, which reveals design parameters and how the trade-offs necessary to reach multidisciplinary objectives are achieved, is at the heart of our idealized view of model-based design. This is precisely the sort of information that so often is not available early in the process when its impact would be most useful.

Although this course required a significant investment in time and thought, I have gained the tools necessary to take complex problems out of the purely heuristic realm in order to address very real situations. Overall, I think multidisciplinary system design optimization is valuable for those interested in embracing model-based design to improve product quality, delivery, and production time.

2 from MIT receive Outstanding Paper Award from *Systems Engineering*

The journal *Systems Engineering* has given its 2009 Outstanding Journal Paper Award to Senior Lecturer Dr. Donna Rhodes and Research Associate Dr. Ricardo Valerdi, along with co-author Garry Roedler, engineering outreach program manager at Lockheed Martin Corp. The paper, "Systems Engineering Leading Indicators for Assessing Program and Technical Effectiveness," appeared in the spring 2009 issue of the journal.

Donna Rhodes

Ricardo Valerdi

Garry Roedler

Systems Engineering, the scientific journal of the International Council on Systems Engineering (INCOSE), is considered the primary vehicle for disseminating scholarship in the field of systems engineering to practitioners and academics. Both Rhodes and Valerdi hold appointments in MIT's Engineering Systems Division, within which the System Design and Management Program (SDM) resides.

The award was announced at the closing plenary session of the 20th Annual International Symposium of INCOSE, held July 15 in Chicago (see page 24).

The award-winning paper discusses a six-year initiative, led by Roedler and Rhodes, to transform classical systems engineering measures into leading indicators, and describes the guidance information and research directions that have emerged from the work. Systems engineering leading indicators are measures for evaluating the effectiveness of a program's systems engineering activities in a manner that provides information about impacts that are likely to affect the system or program performance objectives. Leading indicators are intended to provide insight into the probable future state, allowing practitioners to improve the management and performance of complex programs.

One outcome of the initiative is a guidebook developed through a collaborative partnership of industry, government, and academic organizations that is now widely used within the systems engineering community.

The work described in the journal paper has continued to evolve, and has spawned thesis research at several universities, Rhodes said. At MIT, research extending from this paper is ongoing within the MIT Lean Advancement Initiative and the MIT Systems Engineering Advancement Research Initiative. Several SDM students have performed or are presently performing related research.

SDM grads are in high demand

By Helen Trimble, SDM director of career development

Helen M. Trimble

As companies across all industries become increasingly aware of the criticality of systems thinking to compete effectively in global markets, graduates of MIT's System Design and Management Program (SDM) continue to be in high demand. Their interdisciplinary studies in engineering *and* management, coupled with SDM's emphasis on leadership, innovation, and systems thinking, give them the unique ability to work and lead effectively across increasingly evolving organizational and geographic boundaries. Moreover, because SDMs have an average of seven years experience (and many more than two to three times that), they are able to hit the ground running.

Industries that hired recent SDM grads include retail and e-commerce (Sears Holdings Corporation), construction (Thoughtforms Corporation), telecom (Verizon), consulting (Booz Allen Hamilton), software (Redhat and Tibco), IT (EMC), patent commercialization (IP ValueManagment), and others. Their titles include chief operating officer; vice president of engineering; IT strategist; senior manager; intellectual property licensing; strategic business development manager; senior systems engineering; product marketing manager; and director of technology.

Moreover at least one SDM student has already been hired—months before he is scheduled to graduate! SDM '10 student Irfan Mohammed secured a position as vice president of engineering at India's largest producer of cell phone apps, Sourcebits, last summer.

Recruitment activities are now under way for prospective employers of upcoming SDM graduates. Please contact me at htrimble@mit.edu if you would like to learn more.

SDM student helps DOE evaluate investment trade-offs

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succession." This snapshot depiction allows for the extension of a typical, static tradespace analysis to a dynamic analysis. A pictorial of viewing tradespace plots in a "movie real" format in shown in Figure 1.

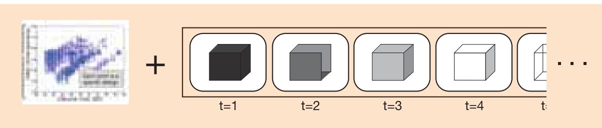

Figure 1. Epoch-Era Analysis (Ross and Rhodes, 2008[1])

The investment decision tool being developed at the DOE is designed to create a portfolio optimized for the public good, as measured by utility, rather than maximum private profit. The proposed tool couples multi-attribute decision analysis methods with a global climate model, ultimately producing cost and utility trades between various investment portfolio configurations. To put it simply: the desirability of a portfolio of investments is calculated as a function of weighted benefits. Benefits, as determined by the DOE, include such things as greenhouse gas emissions reduced, jobs created, and barrels of oil saved. The value of those benefits, for each level of investment, is an output of a linked economy-energy-climate model. Portfolios with varying levels of technology investments can then be compared in a cost versus utility tradespace and the cost-utility efficient solutions identified and analyzed.

The DOE's predicament is typical of government agencies that characteristically face highly dynamic funding and operating environments, but must frequently rely on decision making methods that do not perform well under extreme uncertainty. Gerst asserts that the proposed augmentation of the DOE's decision tool with anticipatory analysis via applications of Epoch-Era Analysis will enable the DOE to better prepare possible responses and strategies in the face of a dynamic future.

SEAri has been evolving Epoch-Era Analysis in case applications from space, aerospace, and transportation systems. The research team looks forward to the opportunity to apply the method in other areas of the public sector. Meanwhile, Gerst is continuing to work with the Department of Energy's Planning Analysis and Evaluation team on multifaceted strategic issues.

This article was contributed to the SDM Pulse *by Donna H. Rhodes, PhD and principal research scientist; Adam Ross, PhD, SEAri lead research scientist, and Kacy Gerst, SDM '09.*

[1] Ross, A.M., and Rhodes, D.H., "Using Natural Value-centric Time Scales for Conceptualizing System Timelines through Epoch-Era Analysis," INCOSE International Symposium 2008, Utrecht, the Netherlands, June 2008

Alumnus applies SDM lessons to aerospace industry

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respond to them. For example, he said Honeywell is working on sustainability issues, including green fuel development. "The drive for fuel efficiency is built into everything we do," he said. "If you can make a plane lighter and use less fuel, people will pay for that and the environment will benefit."

Smith said systems thinking is fundamental to all these efforts—which is why his SDM experience continues to be relevant more than 10 years later. "Being able to understand the complexity of the business interactions and the necessity of technical iterations is increasingly important," he said. "The trajectory of technology and systems and organizations have evolved where interoperability is a requirement now in almost every field." This trend is likely to continue, he said, with more and more businesses taking on system of systems challenges.

SDM faculty unveil *The Journal of Enterprise Transformation*

By Ricardo Valerdi, research associate, and Deborah Nightingale, codirector, Lean Advancement Initiative at MIT

Ricardo Valerdi

Deborah Nightingale

Enterprises increasingly need to consider and pursue fundamental change—transformation—to maintain or gain competitive advantage. This need raises important research issues concerning how transformation is best understood and pursued.

The Journal of Enterprise Transformation (JET)—a joint publication of the Institute of Industrial Engineers and the International Council on Systems Engineering—is the first journal devoted exclusively to examining the phenomenon of transformation. JET's focus is interdisciplinary research addressing enterprise transformation challenges within and across different domains such as aerospace, health care, financial services, government and public-private partnerships, etc. JET promotes a holistic approach to advancing our understanding of enterprise transformation by addressing the challenges from technical, behavioral, managerial, and social perspectives.

"JET has the opportunity to make important contributions to the field of enterprise transformation," said Pat Hale, director of MIT's System Design and Management program and past president of INCOSE. "We are indebted to Professor Nightingale and Dr. Valerdi for helping to spearhead this endeavor."

Published quarterly beginning in winter 2011, JET will provide a forum for original articles on trends, new findings, and ongoing research related to enterprise transformation. Bringing together interdisciplinary research in management, industrial and systems engineering, information systems, organizational behavior, political science, and economics, JET will cover the latest developments and directions for future research (both theory and application). JET is designed to serve professionals and researchers who conduct enterprise-level planning, manage organizational transformation, or work in related research areas. Topics to look for in future issues include:

- Enterprise definition and boundaries
- Context-specific case studies of transformation
- Enterprise change management
- Theory of the process of transformation
- Behavioral aspects of transformation
- Role of information technology in transformation
- Enterprise architecting, modeling, and simulation
- Enterprise performance measurement
- Policy considerations

Specific emphasis will be placed on the enterprise as the unit of analysis, interdisciplinary research with socio-technical perspectives, a balance of both rigor and relevance, and studies across the spectrum of research methods (qualitative and quantitative). JET papers are not meant to focus exclusively on isolated processes (i.e., manufacturing floor) or be theoretically dense.

For more information visit, www.tandf.co.uk/journals/ujet.

Companies will meet at MIT to discuss engaging with SDM

By Lois Slavin, MIT SDM communications director

The annual meeting of companies that engage with MIT's System Design and Management Program will take place Wednesday, October 20, 2010, from 8:30 am to 5 pm at the MIT Faculty Club. These companies engage with SDM through sponsoring internships, thesis research, class projects, and/or students in SDM's master's degree or graduate certificate program.

This year the meeting will feature research presentations by MIT faculty and SDM students as well as discussions on how SDM can help your company meet its needs. Meeting attendees are also invited to attend the annual MIT SDM Conference on Systems Thinking for Contemporary Challenges, to be held on the two days following the meeting, October 21-22. See page 28 for locations and times.

Engaging with SDM keeps companies informed about the latest systems research—and helps ensure the program remains relevant to the needs of industry.

For further information, please contact Pat Hale, director of the SDM fellows program, pat_hale@mit.edu.

Massachusetts Institute of Technology

SDM calendar fall 2010

If you or your colleagues are interested in attending any of the events listed, please contact Lois Slavin, SDM communications director, at 617.253.0812 or lslavin@mit.edu.

October 19, 2010
SEAri Research Summit 2010
Location: MIT Faculty Club

Time: 8 am–5 pm

October 19, 2010
SDM Information Evening
Location: MIT Faculty Club

Time: 6–9 pm

October 20, 2010
SDM Partners Meeting
SDM industry partners are invited to review curriculum activities, hear from MIT faculty on relevant cutting-edge research, and develop opportunities for internships and theses.

Location: MIT Faculty Club

Time: 8:30 am–5 pm

October 20, 2010
SDM Alumni and Student Mixer
Location: R&D Pub, Stata Center

Time: 6–9 pm

October 21, 2010
2010 MIT Conference on Systems Thinking for Contemporary Challenges (Day 1)
Location: MIT Media Lab

Time: 8:30 am–5 pm

October 21, 2010
SDM Conference Reception and SDM Best Thesis Award Presentation
Location: MIT Media Lab

Time: 6–9 pm

October 22, 2010
2010 MIT Conference on Systems Thinking for Contemporary Challenges (Day 2)
Location: MIT Media Lab

Time: 8:30 am–5 pm

November 8, 2010
MIT SDM Webinar Series: Systems Thinking for Contemporary Challenges
Topic: The Evolution of Business Ecosystems: Interspecies Competition in the Steel Industry

Speaker: Akshat Mathur, SDM '08

Time: Noon - 1:00 p.m.

Log-in instructions to be posted at http://sdm.mit/edu after November 1, 2010

Event information includes all details available at press time. For more current event information, go to sdm.mit.edu and esd.mit.edu.