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TechTalk

SERVING THE MIT COMMUNITY

PHOTO / **ANTONIO TORRALBA**

QUESTION:

What do you see in these pictures?

ANSWER: They're all the same. Professor Antonio Torralba created these low-resolution images, in which the circled shapes were inserted and are all identical, to demonstrate how context affects our recognition of objects.

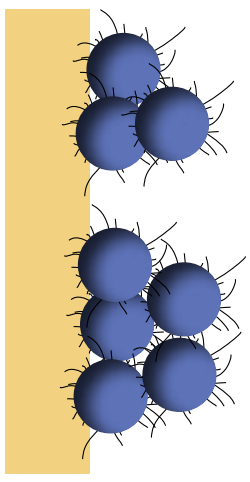
MIT helps develops new image-recognition software

David Chandler
News Office

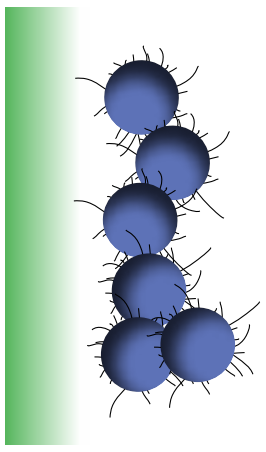
It takes surprisingly few pixels of information to be able to identify the subject of an image, a team led by an MIT researcher has found. The discovery could lead to great advances in the automated identification of online images and, ultimately, provide a basis for computers to see like humans do.

Antonio Torralba, assistant professor in MIT's Computer Science and Artificial Intelligence Laboratory, and colleagues have been trying to find out what is the smallest amount of information—that is, the shortest numerical representation—that can be derived from an image that will provide a useful indication of its content.

▶Please see PICTURES, **PAGE 3**



Above, bacteria stick to the stiffer surface. Below, Researchers at MIT have manipulated the mechanical stiffness of polymer films, like the surface below, so bacteria are less prone to stick to them.



MIT: Microbe adhesion depends on surface stiffness

Researchers craft bacteria-resistant films

Anne Trafton
News Office

Having found that whether bacteria stick to surfaces depends partly on how stiff those surfaces are, MIT engineers have created ultrathin films made of polymers that could be applied to medical devices and other surfaces to control microbe accumulation.

The inexpensive, easy-to-produce films could provide a valuable layer of protection for the health care industry by helping to reduce the spread of hospital-acquired infections, which take the lives of 100,000 people and cost the United States an estimated $4.5 billion annually.

The researchers, who described their work in a paper in an upcoming issue of Biomacromolecules, found they could control the extent of bacterial adhesion to surfaces by manipulating the mechanical stiffness of polymer films called polyelectrolyte multilayers. Thus, the films could be designed to prevent accumulation of hazardous bacteria or promote growth of desirable bacteria.

"All other factors being equal, mechanical stiffness of material surfaces increases bacterial adhesion," said Krystyn Van Vliet, the Thomas Lord Assistant Professor of Materials Science and Engineering and the paper's anchor author.

Van Vliet and her colleagues found the same trend in experiments with three strains of bacteria: Staphylococcus epidermidis, commonly found on skin, and two types of Escherichia coli.

▶Please see SURFACE, **PAGE 5**

Anne Trafton
News Office

As Charles Darwin showed nearly 150 years ago, bird beaks are exquisitely adapted to the birds' feeding strategy. A team of MIT mathematicians and engineers has now explained exactly how some shorebirds use their long, thin beaks to defy gravity and transport food into their mouths.

The phalarope, commonly found in western North America, takes advantage of surface interactions between its beak and water droplets to propel bits of food from the tip of its long beak to its mouth, the research team reports in the May 16 issue of Science.

These surface interactions depend on the chemical properties of the liquid involved, so phalaropes and about 20 other bird species that use this mechanism are extremely sensitive to anything that contaminates the

▶Please see BIRD BEAKS, **PAGE 8**

PHOTO / **RAINEY SCHULER**

MIT researchers have figured out how the phalarope, a shorebird with a long, narrow beak, transports food from the tip of its beak to its mouth.

PEOPLE

Microbe bash

A sea-dwelling microbe discovered only 20 years ago by researchers including Professor Penny Chisholm is the focus of a two-day "party" of sorts later this month.

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NEWS

Hope on the Horizon

MIT experts sound off on various technologies that could drive the economy in coming years.

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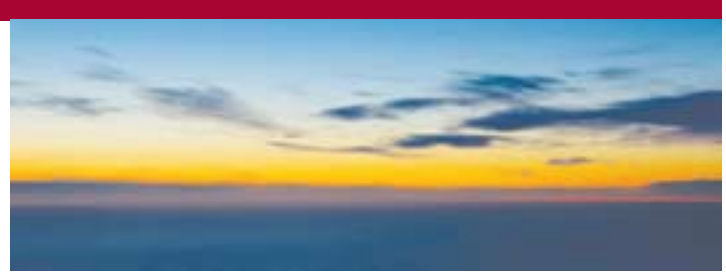

Entrepreneurship contests reward energy, diagnosis plans

'Diagnostics for All' team takes top prize in annual 100K Competition

David Chandler
News Office

Business plans focused on harnessing clean energy and making fast, inexpensive medical diagnostic devices were big winners last week in a series of high-profile entrepreneurship competitions at MIT.

Diagnostics for All, a nonprofit company that has developed a unique process for making simple medical test kits out of paper, was the top winner of MIT's 100K Entrepreneurship Competition. The company's inexpensive tests require only a single drop of blood to provide a color-coded response indicating the presence of any of several different diseases.

The week's biggest winner, however, was a company called FloDesign Wind Turbine, which has an innovative way of building wind turbines with much shorter blades, housed inside a ring, based on jet-engine designs. The system can generate power in much slower winds than a conventional windmill and is said to be three to four times more efficient. Because of its smaller overall size, it is also expected to cost less.

FloDesign won the inaugural $200,000 MIT Clean Energy Entrepreneurship Prize and also won the separate Ignite Clean Energy competition, sponsored by the MIT Enterprise Forum of Cambridge, for an additional $100,000. And the publicity generated by the contests has already led to discussions with potential venture capital investors (including Al Gore's company, according to press reports), who may provide the $8 million the company says it needs to build a full-scale operational prototype.

Nearly two decades after its creation, the 100K competition has become the world's leading business-plan contest. Organizers say the competition has facilitated the birth of more than 85 companies with a market capitalization of more than $10 billion to date. This year's 100K contest started out last fall with 230-plus entries. In February, those were narrowed down to 35—a total of five finalists in each of seven categories ranging from aerospace to biotech. Winners were selected in each of the seven areas—with prizes of at least $10,000 for each.

PHOTOS / **JEREMY GILBERT**

Members of the grand-prize-winning team in the MIT 100K Competition, including Roozbeh Ghaffari, second from left and below, who is currently a postdoctoral research associate in the Micromechanics Group at the MIT Research Laboratory of Electronics.

This year, for the first time, the audience that packed Kresge Auditorium for the final 100K contest awards also got to pick their own winner. The Audience Choice award, an additional $10,000, went to Covalent Solar, a team made up of three MIT alums who came up with an inexpensive way of concentrating sunlight onto photovoltaic cells using sheets of treated plastic, without requiring a mechanism to track the sun.

AWARDS & HONORS

Erez Lieberman, a graduate student in the Harvard-MIT Division of Health Sciences and Technology; and **Ankur Moitra**, a graduate student in Electrical Engineering and Computer Sciences, have both been awarded Hertz Fellowships from the Fannie and John Hertz Foundation, a nonprofit organization focused on empowering young scientists and engineers. Valued at more than $250,000, Hertz Fellowships are unique no-strings-attached fellowships allowing exceptional applied scientists and engineers the freedom to pursue their own ideas with financial independence under the guidance of the finest professors at the country's top universities.

The Camille and Henry Dreyfus Foundation recently selected **Dr. Mohammad Movassaghi**, a professor in the MIT Chemistry Department, as a 2008 Camille Dreyfus Teacher-Scholar. The $75,000 unrestricted award will support Movassaghi's research program.

MIT professors **Daniel Roos, Dava Newman, David Marks** and **Richard de Neufville** have all been appointed as professors at Portugal's Instituto Superior Técnico. The four are currently involved with the MIT Portugal Program, and their new assignments will strengthen the relationships between MIT and Portugal and facilitate the development of courses and the conduct of research programs.

Cecilia Scott, a sophomore in mechanical engineering, is the first MIT student to be named a Udall Scholar, which is awarded to students who are committed to environmental careers or Native American and Alaska Native tribal public policy or health care. Winners receive a $5,000 stipend for tuition.

The Merage Foundation, established by immigrants to the United States, announced that Brain and Cognitive Sciences senior **Rany Woo** has been named a Merage Foundation fellow. The foundation awards $10,000 stipend annually for two years toward the efforts of fostering education, traveling and learning, securing mentors and supporting internship opportunities.

Fabiola Lopez-Duran, a doctoral candidate in architecture, has been named one of 29 Charlotte W. Newcombe Doctoral Dissertation Fellows for 2008. The 2008 Newcombe Fellowship, a highly competitive national award, provides $23,000 for 12 months of work on a dissertation in the humanities or social sciences that addresses questions of religious or ethical value.

Noubar Afeyan, a senior lecturer in the MIT Sloan School of Management, was honored recently in New York City as one of the 2008 Ellis Island Medal of Honor recipients. The award recognizes Noubar's contributions to the local community, as well as his extensive role in supporting long range visions for the country of Armenia, its business environment and culture, and world-wide understanding and awareness of Armenian issues.

Chemistry Professor **Richard R. Schrock** is among the eight new foreign members elected to Britain's Royal Society. Schrock is distinguished for his seminal contributions to synthetic and mechanistic inorganic and organometallic chemistry.

Gardeners' group holding plant sale

The MIT Gardeners' Group May event will be a plant sale in conjunction with our colleagues at Endicott House. The sale will be on Wednesday, May 21, and Thursday, May 22, from 9 a.m. to 2 p.m. on the "dot" lawn outside of Building 54.

Staff from Endicott House (with help from the Gardeners' Group) will be selling a selection of vegetables, herbs, flowers, and other garden-related items. The sale is a great way to get healthy and reasonably priced plants while also supporting the greenhouses at MIT's Endicott House. Community members who expect to buy a lot of plants should try to bring boxes.

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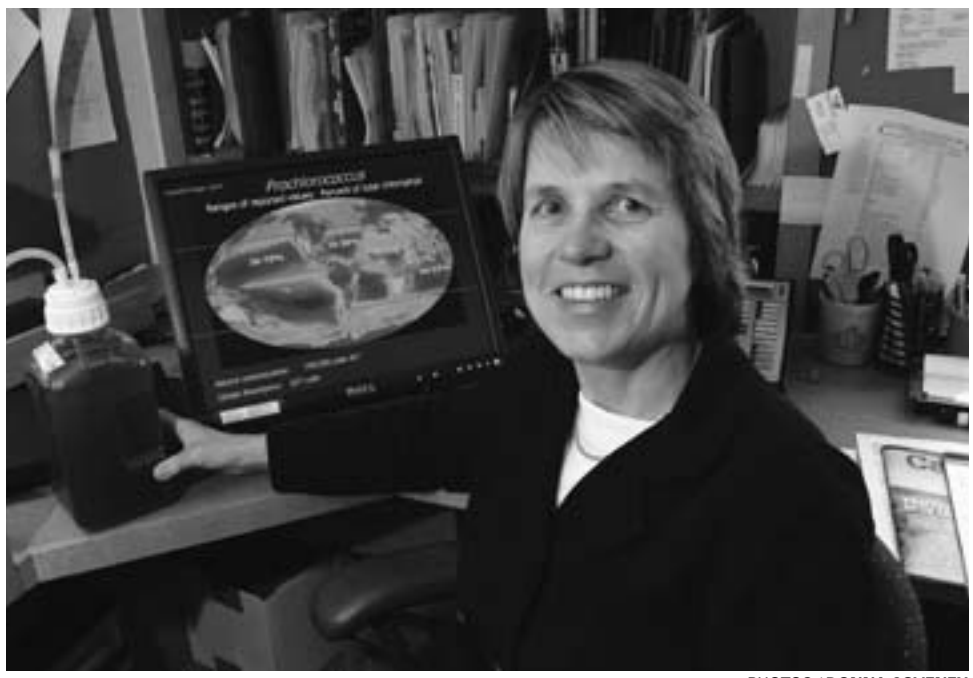


PHOTOS / **DONNA COVENEY**

Happy anniversary
PROCHLOROCOCCUS

Researchers holding bash 20 years after microbe's discovery

LEFT: Professor Penny Chisholm in 1988. RIGHT: Now, 20 years later, Chisholm holds a container filled with Prochlorococcus microbes. Its proliferation in the world is tracked on the screen behind her.

Elizabeth Thomson
News Office

A sea-dwelling microbe of global importance discovered only 20 years ago by researchers, including one at MIT, is the focus of a two-day "party" of sorts later this month.

The ProchlorococcusFest, to be held May 30-31 at MIT, will feature a range of talks highlighting past, current and future research on the smallest—and most abundant—photosynthetic organism in the oceans.

"It's been a really exciting ride," said MIT Professor Penny Chisholm, commenting on what's been learned about Prochlorococcus since it was first identified. The tiny cells—there are 100 million in a quart of seawater—are now known to play a key role in the ocean carbon cycle, which is important in climate regulation.

Chisholm, the Lee and Geraldine Martin Professor of Environmental Studies and Biology, was on the team that discovered the microbe and first described it in the journal Nature. Her co-discoverers are Robert J. Olson, Erik R. Zettler, and John Waterbury of Woods Hole and Ralf Goericke and Nicholas A. Welschmeyer, then at Harvard.

Chisholm, Olson and Waterbury will be attending the ProchlorococcusFest, which was co-organized by Chisholm and Professor Zackary Johnson '94 of the University of Hawaii, who began working on Prochlorococcus while a postdoc in Chisholm's lab.

Among other important Prochlorococcus research advances, scientists have sequenced the genomes of 12 different strains of the microbe. "If we can understand how this one cell evolved and assembles into these rich communities, we'll better understand microbial diversity in general," said Chisholm, who participated in some of the sequencing (see http://web.mit.edu/newsoffice/2003/plankton.html).

That wealth of genomic data, all available on the public genome database, is facilitating new discoveries—and questions. For example, Chisholm said, "just a few weeks ago a fellow e-mailed me that he'd found a gene in Prochlorococcus that encodes an antibiotic. We didn't know that! What role is there for an antibiotic floating around in the ocean?"

Future research directions include understanding the role of viruses and predators in shaping the structure of the Prochlorococcus community. "Viruses are important not only as a source of mortality for Prochlorococcus, but also because they help move genes around, which is important to the evolution and stability of the system," Chisholm said. Another unknown? "We're just now starting to understand what eats Prochlorococcus."

For more information on the ProchlorococcusFest, go to: http://www.soest.hawaii.edu/pro2008/.

Planning under way for Diversity Leadership Congress

Planning is under way for MIT's Diversity Leadership Congress, an event that will be held next year as a keystone of the Institute's ongoing efforts to further enhance its long-standing commitment to diversity on campus.

The congress, which President Susan Hockfield announced during MIT's Martin Luther King Jr. celebration breakfast in February, will include leaders from across MIT's academic, administrative, and student communities.

As Hockfield noted in her address at the breakfast, "The Diversity Leadership Congress will give us a forum to learn from each other and to reflect on one another's experiences of MIT. It will give us a chance to learn together from people who have successfully built a culture of inclusion in other organizations, and then to think together, creatively, about the next steps for MIT. From this shared understanding, we will develop goals for changing the way we operate, and we will come away with a vivid sense that each of us bears direct responsibility for creating this kind of change."

Chancellor Phillip Clay, Vice President for Institute Affairs and Secretary of the Corporation Kirk Kolenbrander, and Vice President for Human Resources Alison Alden are co-chairing the planning effort.

The co-chairs are working with a variety of faculty and staff stakeholders across campus to develop ideas for the conference. Among those consulted include the Committee on Race and Diversity, The Initiative for Faculty Race and Diversity, the Council on Staff Diversity, and representatives from the Undergraduate Association and Graduate Student Council, and they will also be reaching out to many other groups for feedback.

The organizers welcome input from the community to help shape this conference. Suggestions and questions may be e-mailed to DiversityCongress@mit.edu.

PICTURES: MIT helps create image-recognition software

Continued from **Page 1**

Deriving such a short representation would be an important step toward making it possible to catalog the billions of images on the Internet automatically. At present, the only ways to search for images are based on text captions that people have entered by hand for each picture, and many images lack such information. Automatic identification would also provide a way to index pictures people download from digital cameras onto their computers, without having to go through and caption each one by hand. And ultimately it could lead to true machine vision, which could someday allow robots to make sense of the data coming from their cameras and figure out where they are.

"We're trying to find very short codes for images," says Torralba, "so that if two images have a similar sequence [of numbers], they are probably similar—composed of roughly the same object, in roughly the same configuration." If one image has been identified with a caption or title, then other images that match its numerical code would likely show the same object (such as a car, tree, or person) and so the name associated with one picture can be transferred to the others.

"With very large amounts of images, even relatively simple algorithms are able to perform fairly well" in identifying images this way, says Torralba. He will be presenting his latest findings this June in Alaska at a conference on Computer Vision and Pattern Recognition. The work was done in collaboration with Rob Fergus at the Courant Institute in New York University and Yair Weiss of Hebrew University in Jerusalem.

To find out how little image information is needed for people to recognize the subject of a picture, Torralba and his co-authors tried reducing images to lower and lower resolution, and seeing how many images at each level people could identify.

"We are able to recognize what is in images, even if the resolution is very low, because we know so much about images," he says. "The amount of information you need to identify most images is about 32 by 32." By contrast, even the small "thumbnail" images shown in a Google search are typically 100 by 100.

Even an inexpensive current digital camera produces images consisting of several megapixels of data—and each pixel typically consists of 24 bits (zero or one) of data. But Torralba and his collaborators devised a mathematical system that can reduce the data from each picture even further, and it turns out that many images are recognizable even when coded into a numerical representation containing as little as 256 to 1024 bits of data.

Using such small amounts of data per image makes it possible to search for similar pictures through millions of images in a database, using an ordinary PC, in less than a second, Torralba says. And unlike other methods that require first breaking down an image into sections containing different objects, this method uses the entire image, making it simple to apply to large datasets without human intervention.

For example, using the coding system they developed, Torralba and his colleagues were able to represent a set of 12.9 million images from the Internet with just 600 megabytes of data—small enough to fit in the RAM memory of most current PCs, and to be stored on a memory stick. The image database and software to enable searches of the database, are being made publicly available on the web.

Of course, a system using drastically reduced amounts of information can't come close to perfect identification. At present, the matching works for the most common kinds of images. "Not all images are created equal," he says. The more complex or unusual an image is, the less likely it is to be correctly matched. But for the most common objects in pictures—people, cars, flowers, buildings—the results are quite impressive.

The work is part of research being carried out by hundreds of teams around the world, aimed at analyzing the content of visual information. Torralba has also collaborated on related work with other MIT researchers including William Freeman, a professor in the Department of Electrical Engineering and Computer Science; Aude Oliva, professor in the Department of Brain and Cognitive Sciences; and graduate students Bryan Russell and Ce Liu, in CSAIL. Torralba's work is supported in part by a grant from the National Science Foundation.

Torralba stresses that the research is still preliminary and that there will always be problems with identifying the more-unusual subjects. It's similar to the way we recognize language, Torralba says. "There are many words you hear very often, but no matter how long you have been living, there will always be one that you haven't heard before. You always need to be able to understand [something new] from one example."

FEMA trailer gets new lease on life

Sarah H. Wright
News Office

A little bit of hurricane history has come to MIT. A FEMA trailer, one of thousands of mobile homes the Federal Emergency Management Agency purchased to shelter victims of hurricanes Katrina and Rita, is now parked in an MIT rental space at 620 Putnam Ave. in Cambridge.

Jae Rhim Lee, lecturer in the visual arts program, began organizing the FEMA trailer's trip to MIT in 2007. That year, thousands of the mobile units were sent to surplus yards after formaldehyde, an embalming fluid used in manufacturing the trailers, was found to cause illness in trailer residents.

Jae Rhim Lee

Lee worked through FEMA and the Pennsylvania Surplus Property Division to have the trailer donated and delivered to Cambridge on April 30. The previously unused trailer now has a new lease on life: It will serve as centerpiece for a new course on research as artistic practice and for the MIT FEMA Trailer Challenge, organized with the Public Service Center, providing students with a laboratory in which to explore building techniques and environmental health and justice issues, Lee says.

"The trailers are a symbol of response to disaster, and they are the response. Having one here provides a hands-on way to study the history of emergency management after Katrina," says Lee SM '06, a specialist in built forms, such as coffins, and biological types, such as mushrooms, that straddle life and death.

Lee has seen emergency management after Katrina up close. She volunteered in New Orleans on the architecture department's LIFT House project in 2005 and still works at the city's Office of Recovery Development and Management. The trailers, she says, provide both shelter and a constant reminder of how many Gulf Coast residents remain isolated and traumatized.

"There are historical, psychosocial, technical and scientific issues to explore, with the trailer as a lab and an anchor," Lee says.

By spring, co-teaching with Ute Meta Bauer, associate professor and director of the visual arts program, she had assembled a FEMA trailer team of five undergraduate and graduate students. She devised the interdisciplinary FEMA Trailer Project course, the point of departure for a visual arts program lecture series on zones of emergency.

The FEMA Trailer Project will focus on historical, design and environmental issues in the fall. There's an economic component, too—currently, FEMA has about 41,000 unused trailers for sale.

"The trailer is a heavy symbol. Now that we've got one here, I want students to engage hands-on with the materials and the questions. For example, how can this be used? If the materials are safe, could it be a mobile health-care unit? A food pantry? A trauma center? It's a great laboratory," Lee says.

Student projects in the FEMA trailer course include developing a life-cycle analysis to investigate the trailer's environmental impact, from manufacturing to disposal or recycling; full environmental testing of materials and air quality in the trailer and interviews with current and former trailer residents. It's unclear whether MIT's trailer is tainted by formaldehyde; people visiting or working in the trailer aren't required to take any special precautions.

The MIT FEMA Trailer Project, comprised of the Trailer Challenge and the course, received funding from the MIT Council for the Arts and the Visual Arts Program.

At the conclusion of the course, the Visual Arts Program and the School of Architecture and Planning will donate the trailer to a community organization, according to Lee.

MIT student ingenuity plus high-tech batteries yields advanced all-electric Porsche

Nancy Stauffer
MIT Energy Initiative

With a click and a hum, the sleek Porsche 914 pulled away from the curb while onlookers watched anxiously and the passenger gazed down at a laptop plugged into the dashboard.

Why the drama? Once powered by a conventional gasoline engine, the 1976 Porsche now operates on 18 high-tech batteries—the result of work by dedicated MIT students and their mentors.

Converting the car to an advanced electric vehicle is an achievement in itself and serves to demonstrate the viability of the technology. But for the students, the real fun starts now. Said mechanical engineering graduate student Craig Wildman, "Now we get to take data while we're driving. We can record everything that happens on a laptop, come back and change parameters, and test drive it again." With the Porsche as a test platform, the students can monitor conditions in the car while looking for ways to increase efficiency, performance and range, and to bring down costs.

The Porsche was donated two years ago by Professor Yang Shao-Horn of mechanical engineering and the Electrochemical Energy Laboratory, who with her husband, Quinn Horn, bought it on eBay and made it available to students interested in converting it to electric power. In addition to providing an unusual opportunity for hands-on learning, the project will ultimately yield information valuable to Shao-Horn's research on advanced batteries.

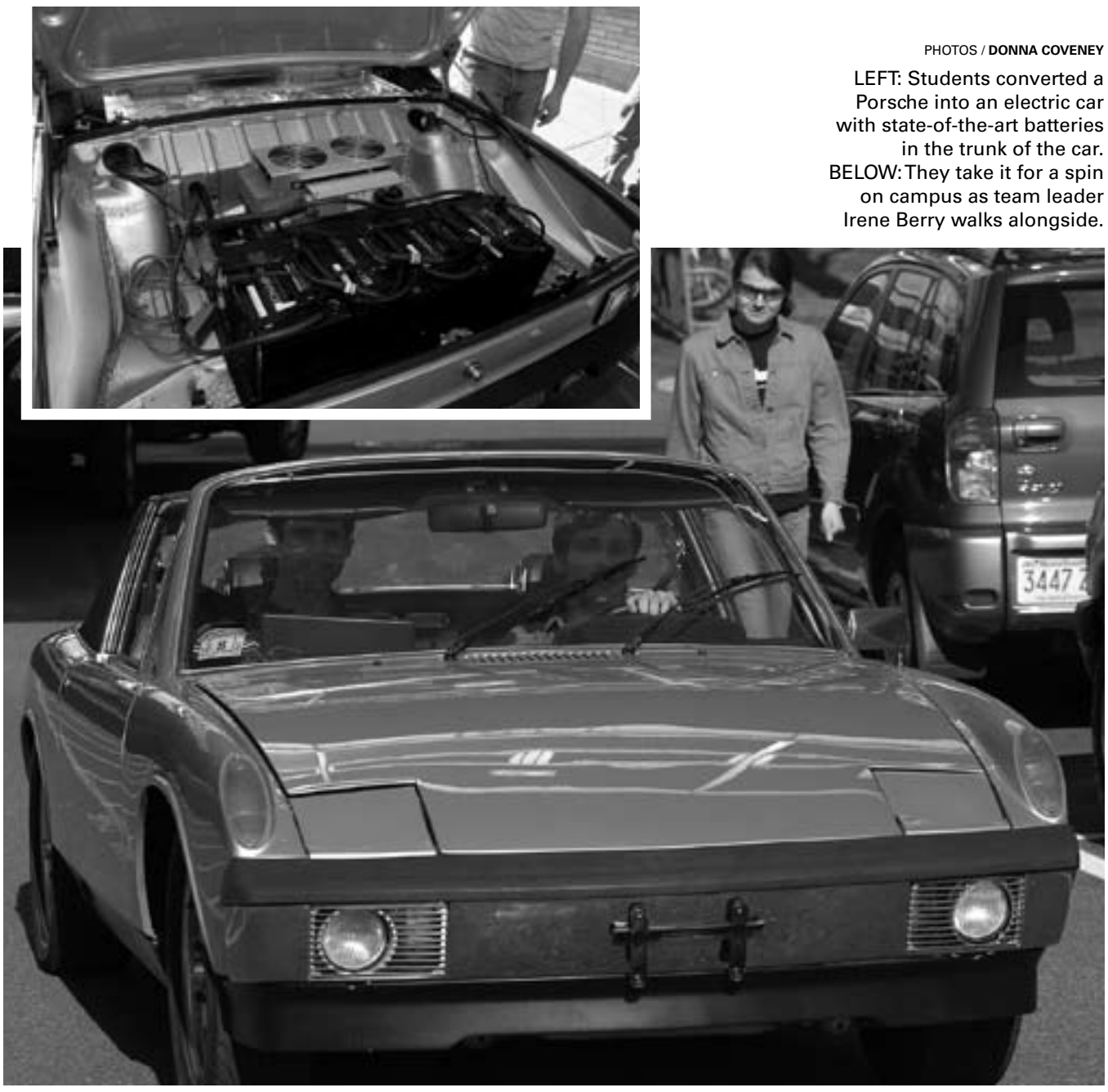
"In the laboratory we work on materials to make batteries safer, last longer and have higher energy," she said. "But we are also interested in gaining a good perspective on the system. What's involved in building an electric vehicle, and what's required of the batteries?"

The student project took off last year when Valence Technology Inc. donated 18 lithium phosphate rechargeable batteries valued at $2,030 each, plus a battery-management system. The team began by removing the original engine, exhaust lines and fuel tank and installing an electric motor and motor controller, the batteries and battery-management system, a battery charger and various smaller components. Each of the batteries is equipped with a built-in computer that monitors its conditions—ideal for the data-gathering task.

However, getting all the computers to communicate with one another and with the battery-management system—a separate computer—proved a challenge. While the students had made great strides with a commercial converter kit, they ultimately had to scrap it because it was designed to handle 12 conventional lead-acid batteries rather than 18 lithium ion batteries. They subsequently redesigned the wiring and reprogrammed both the motor controller and the battery controller.

The two test drives thus far have been confined to MIT parking lots, so serious data-gathering is yet to come. In the meantime, Irene Berry, team leader and a graduate student in mechanical engineering and the Technology and Policy Program, has done some performance estimates with a vehicle-modeling computer program. She found that the Porsche should have a top speed of up to 100 miles per hour with an estimated range of 130 miles before the batteries need recharging—a task achieved by plugging it into a wall socket for about five hours. The car should consume about 185 watt-hours per mile of electricity, the equivalent of about 65 miles per gallon of gasoline.

What's next for the electric Porsche? One idea is to modify how the batteries are wired together. "We should be able to change our range and performance characteristics very easily," said Josh Siegel, a freshman who has been restoring cars in imaginative ways since he was 14. The students are also thinking about developing conversion guidelines that will enable others to do what they've done—without the fuss.



PHOTOS / **DONNA COVENEY**

LEFT: Students converted a Porsche into an electric car with state-of-the-art batteries in the trunk of the car. BELOW: They take it for a spin on campus as team leader Irene Berry walks alongside.

MIT creates new material for fuel cells

Increases power output by more than 50 percent

PHOTO / **AVNI ARGUN AND NATHAN ASHCRAFT**

The new thin material was developed by MIT engineers for use in methanol fuel cells.

Elizabeth Thomson
News Office

MIT engineers have improved the power output of one type of fuel cell by more than 50 percent through technology that could help these environmentally friendly energy storage devices find a much broader market, particularly in portable electronics.

The new material key to the work is also considerably less expensive than its conventional industrial counterpart, among other advantages.

"Our goal is to replace traditional fuel-cell membranes with these cost-effective, highly tunable and better-performing materials," said Paula T. Hammond, Bayer Professor of Chemical Engineering and leader of the research team. She noted that the new material also has potential for use in other electrochemical systems such as batteries.

The work was reported in a recent issue of Advanced Materials by Hammond, Avni A. Argun and J. Nathan Ashcraft. Argun is a postdoctoral associate in chemical engineering; Ashcraft is a graduate student in the same department.

Like a battery, a fuel cell has three principal parts: two electrodes (a cathode and anode) separated by an electrolyte. Chemical reactions at the electrodes produce an electronic current that can be made to flow through an appliance connected to the battery or fuel cell. The principal difference between the two? Fuel cells get their energy from an external source of hydrogen fuel, while conventional batteries draw from a finite source in a contained system.

The MIT team focused on direct methanol fuel cells (DMFCs), in which the methanol is directly used as the fuel and reforming of alcohol down to hydrogen is not required. Such a fuel cell is attractive because the only waste products are water and carbon dioxide (the latter produced in small quantities). Also, because methanol is a liquid, it is easier to store and transport than hydrogen gas, and is safer (it won't explode). Methanol also has a high energy density—a little goes a long way, making it especially interesting for portable devices.

The DMFCs currently on the market, however, have limitations. For example, the material currently used for the electrolyte sandwiched between the electrodes is expensive. Even more important: that material, known as Nafion, is permeable to methanol, allowing some of the fuel to seep across the center of the fuel cell. Among other disadvantages, this wastes fuel—and lowers the efficiency of the cell—because the fuel isn't available for the reactions that generate electricity.

Using a relatively new technique known as layer-by-layer assembly, the MIT researchers created an alternative to Nafion. "We were able to tune the structure of [our] film a few nanometers at a time," Hammond said, getting around some of the problems associated with other approaches. The result is a thin film that is two orders of magnitude less permeable to methanol but compares favorably to Nafion in proton conductivity.

To test their creation, the engineers coated a Nafion membrane with the new film and incorporated the whole into a direct methanol fuel cell. The result was an increase in power output of more than 50 percent.

The team is now exploring whether the new film could be used by itself, completely replacing Nafion. To that end, they have been generating thin films that stand alone, with a consistency much like plastic wrap.

SURFACE: Researchers create new films

Continued from **Page 1**

Stiffness has usually been overlooked in studies of how bacteria adhere to surfaces in favor of other traits such as surface charge, roughness and attraction to or repulsion from water. The new work shows that stiffness should also be taken into account, said Van Vliet.

The new films could be combined with current methods of repelling bacteria to boost their effectiveness, said Michael Rubner, an author of the paper and director of MIT's Center for Materials Science and Engineering.

Those methods include coating surfaces with antimicrobial chemicals or embedding metal nanoparticles into the surface, which disrupt the bacterial cell walls.

"For those bacteria that readily form biofilms, we have no delusions that we can prevent bacterial films from starting to form. However, if we can limit how much growth occurs, these existing methods can become much more effective," Rubner said.

Jenny Lichter, graduate student in materials science and engineering, and Todd Thompson, a graduate student in the Division of Health Sciences and Technology, are joint lead authors of the paper. They note that the films could also be used on medical devices that go inside the body, such as stents and other cardiac implants.

"Once a foreign object enters into the body, if you can limit the number of bacteria going in with it, this may increase the chances that the immune system can defend against that infection," said Thompson.

Another possible application for the films is to promote growth of so-called "good bugs" by tuning the mechanical stiffness of the material on which these bacteria are cultured. These films could stimulate growth of bacteria needed for scientific study, medical testing, or industrial uses such as making ethanol.

The researchers built their films, which are about 50 nanometers (billionths of a meter) thick, with layers of polyelectrolytes (a class of charged polymer). Alternating layers are added at different pH (acidity) levels, which determines how stiff the material is when hydrated by near-neutral pH liquids, such as water. Polymer films assembled at higher pH (up to 6) are stiffer because the polymer chains cross-link readily and the polymers do not swell too much; those added at lower, more acidic pH (down to 2.5) are more compliant.

Van Vliet says the team's results could be explained by the relationship between surfaces and tiny projections from the bacterial cell walls, known as pili. Stiffer surfaces may reinforce stronger, more stable bonds with the bacterial pili. The researchers are now working on figuring out this mechanism.

The research was funded by the National Science Foundation, National Institutes of Health and the Arnold and Mabel Beckman Foundation Young Investigator Program.

Maricela Delgadillo, a senior in materials science and engineering, and Takehiro Nishikawa, a former postdoctoral researcher at MIT, now at the Advanced Medical Engineering Center in Osaka, Japan, are also authors of the paper.

PHOTO / **DONNA COVENEY**

Assistant professor of material science and engineering Krystyn Van Vliet, left, Director of the Center for Materials Science and Engineering Michael Rubner, graduate student Jenny Lichter and senior Maricela Delgadillo, both in materials science and engineering, examine new surface coatings that limit the growth of bacteria

EMBEDDED ELECTRONICS

Michael S. Strano
Charles and Hilda Roddey Associate Professor of Chemical Engineering

One transformation on the near term horizon is the embedding of low-cost electronics into almost every object that we encounter on a day-to-day basis. A pair of sunglasses may have the ability to project a visual display accessing the Internet, have an embedded cell phone and actuate other devices as one glances at them. The technology for this already exists. Flexible electronic paper and electronic clothing will change the way information is projected and harnessed at a personal level. Everyday objects may sense, detect and constantly adjust to our environment, controlling temperature, lighting, noise level, etc.

BIOENGINEERING

Phillip Sharp
Institute Professor

New technology is a source of wealth that can elevate the standard of living of all humankind. For the first time we are challenged not only to enhance our way of life but also to also protect all life forms. Part of the response to this challenge will be increasing production of materials and foods by biologically based processes. Thus, design of biological organisms and engineering of production processes will be more important tomorrow than today. We need to make investments now. In the short term, the merging of engineering and biology will generate new technologies that will impact the economy through generation of better medicines, agriculture and materials.

LIFE EXTENSION

Mehmet Fatih Yanik
Asst. Professor of Electrical Engineering

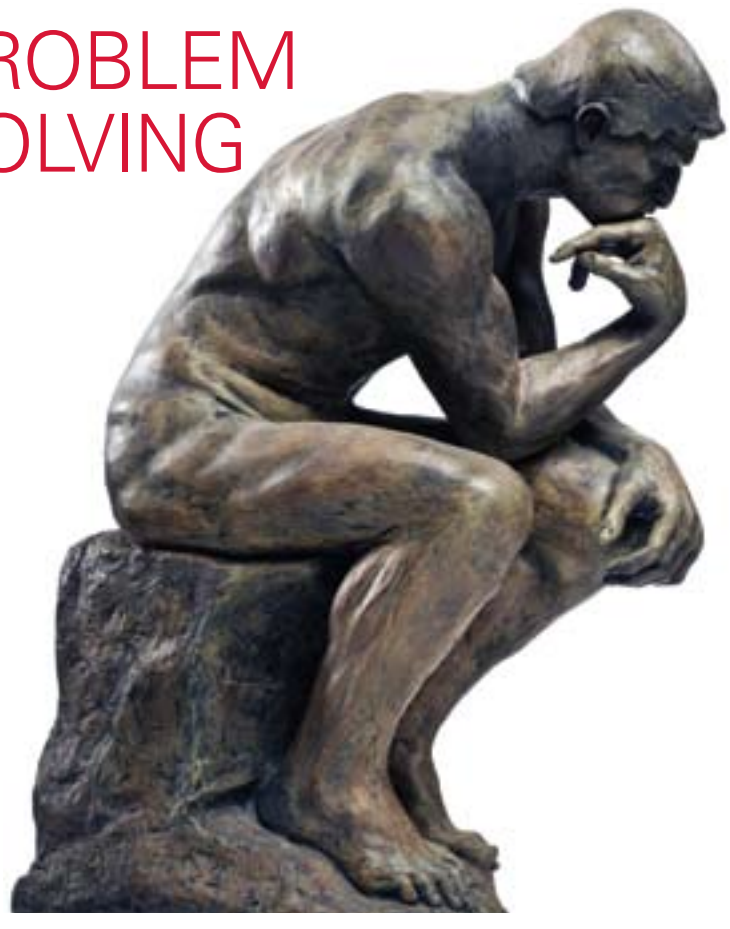
Significant extension of the human lifespan by disease-preventive and tissue-regenerative technologies within the next one to two decades will dramatically impact the world economy. These technologies will probably span everything from small molecule therapies and nano- and microscale devices to whole organ replacement technologies using stem cells. Beyond the scientific and technological hurdles, temporary challenges will include the cost versus benefit of these technologies, legal and ethical concerns, and regulations and strategic investment choices among various options. The current economic slowdown may delay this revolution, but I strongly believe it is unstoppable, and hopefully it will take place within most of our lifetimes.

EDUCATION

Eric Klopfer
Scheller Career Development Professor of Science Education and Educational Technology

The economy of tomorrow will be determined by the students today. As we begin to realize that strict standards-based education has squeezed out much of what makes the U.S. education system unique, new solutions will be required. Solutions that emphasize creativity and innovation, qualities that have become the envy of the rest of the world, will be required. Look for schools to embrace systems that emphasize and enhance these characteristics, including games, media, collaboration and social networking. These products will bridge the widening gap between what students do in and out of school. Solutions such as these, which incorporate both services and software, could be the next frontier for schools, providing business opportunities and preparing for future innovation.

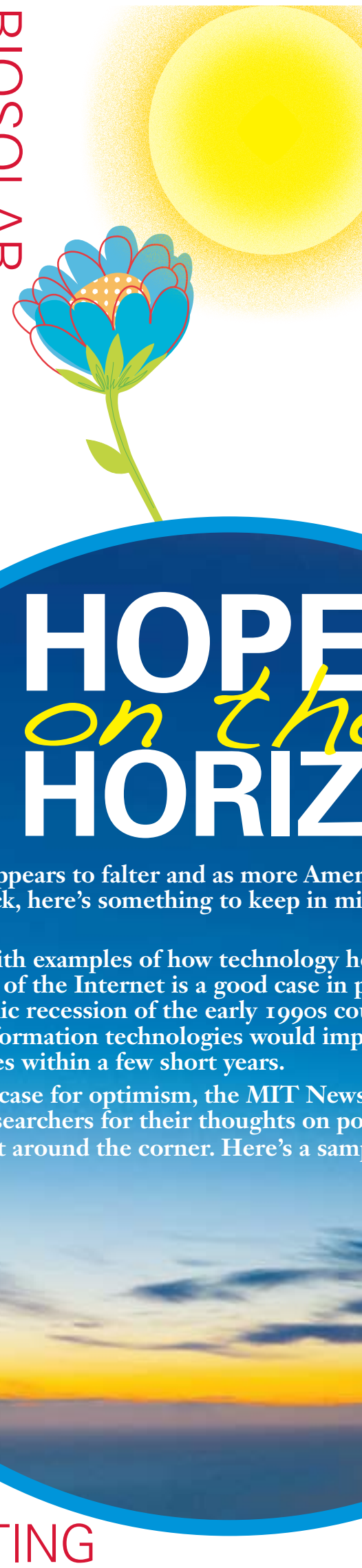
PROBLEM SOLVING



Ed Boyden
Benesse Career Development Professor; Asst. Professor, MIT Media Lab & Dept. of Biological Engineering

We humans are terrible at taking future problems seriously and solving them, especially those that present consequences more than a few days off. A great need is the ability to effectively solve problems when they are small, or at least before they become enormous threats. This problem is present at the personal, the community and the global level—whether it's dealing with personal diet and exercise and diabetes, or global climate change. Why are we so bad at anticipating, deciding and acting upon the prevention of problems in the future? One possibility is that we need to use our knowledge of the mind to engineer better information-handling tools and software, for visualizing, understanding and figuring out how to fix problems. We need to understand data and deal with problems at a higher level: Information, by itself, is not enough.

BIOSOLAR CELLS



As the economy appears to falter and as more Amer is on the wrong track, here's something to keep in mi horizon.

History is filled with examples of how technology h prosperity. The rise of the Internet is a good case in p rienced the economic recession of the early 1990s co Web and related information technologies would imp whole new industries within a few short years.

To help build the case for optimism, the MIT News MIT faculty and researchers for their thoughts on po nologies that lie just around the corner. Here's a sam

MITIGATING AUTISM

Rosalind W. Picard
Professor of Media Arts and Sciences

An estimated $35 billion in direct medical, direct non-medical, and "lost productivity" costs are spent each year to care for children diagnosed with autism and related disorders in America. Beyond these financial costs, however, is the enormous opportunity cost incurred by not enabling these individuals to become full participants in society.

My students and I are building new technologies to enable people diagnosed with autism—now 1 in 150 American children—to be able to communicate better and have better independent and interdependent living skills. These technologies are also likely to have some application for people with Parkinson's, sleep disorders, non-verbal learning disabilities epilepsy and other problems.

PHOTOS / ISTOCKPHOTO

Shuguang Zhang

Associate Director, Center for Biomedical Engineering

Among the most pressing challenges to civilization, nothing is greater than securing our energy future.

A low-cost and flexible biosolar energy nanodevice is one of the long-term solutions. Currently, solar cells are expensive and not affordable—even for the most-developed nations. Radical solutions must be found. Nature has already made efficient photosynthesis molecular nanomachines in thermophilic photosynthetic bacteria, algae and plants. We can isolate or emulate them to stabilize them in extended time onto inexpensive semiconducting nanostructured surface in extremely high density to directly harvest photons. This process must be simple, easy to follow and affordable even for developing nations. Our laboratory is developing the process for a decentralized or individualized system for low-cost photovoltaic devices: biosolar cells.

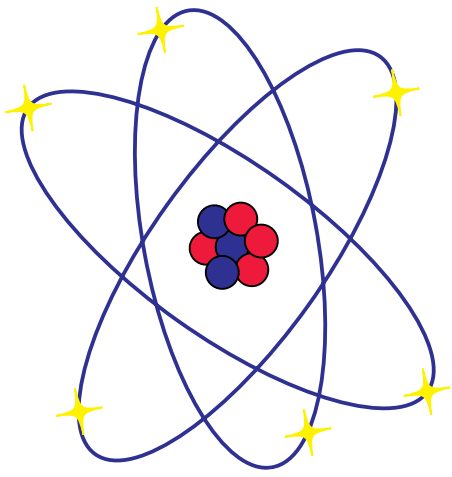
DIGITIZATION

Neil Gershenfeld

Director, Center for Bits and Atoms

The most significant coming technology is the digitization of fabrication, the impact of which will be analogous to the digitization of communication and computation. Like those earlier revolutions, the consequence will be personalization, in this case, allowing anyone to make almost anything, anywhere. Coupled with digital video and digital libraries, this means that the formerly scarce resources (facilities, books, people) of advanced technical institutions (such as MIT) can become much more widely accessible.

FUSION



Leslie Bromberg

Principal Research Engineer
Plasma Science and Fusion Center

At the Plasma Science and Fusion Center, our largest projects involve fusion energy research, which has great potential benefit for the long term, but not for the immediate future. However, other developing plasma technologies and spin-off technologies could have a more immediate benefit.

Imagine using garden, forest and household wastes to make energy. Using plasma to convert waste to fuel could make a substantial difference in our lives. The hydrocarbons from waste could be turned into hydrogen-rich gas, which could be passed through catalysts to create liquid fuel. Although the process could increase the cost of fuel, it is CO_2-neutral and would provide energy security (i.e., independence from fuel provided by unstable governments). The question is: Can we make it small enough so that fuel can be generated in a distributed manner? And will the fuel be stable and have the characteristics necessary for use in internal combustion engines?

ELECTROCHEMICAL ENERGY

Paula Hammond

Bayer Professor of Chemical Engineering

Long-standing efforts to manipulate materials on the nanometer scale are coming to fruition in some areas. One of those areas is electrochemical energy—devices such as solar cells, capacitors and supercapacitors, fuel cells and batteries. Electrochemical energy involves the reduction and oxidation of materials to either generate energy or to store it.

A number of the challenges in achieving high storage capacity and being able to generate power in a highly efficient manner involves manipulating the interfaces between organic and inorganic material systems and facilitating the pathways of charge in devices. In recent years, there has really been an explosion in the number of methods and the level of control over which we can do that. This could mean we're on the cusp of very real achievement in this area—leading to new, more-efficient photovoltaic devices, batteries and fuel cells.

TRANSCENDING TECHNOLOGY

Rebecca Henderson

Eastman Kodak LFM Professor, MIT Sloan School of Management

When the MIT News Office asked Rebecca Henderson for her thoughts, she replied that she did not necessarily agree with the premise. Henderson foresees significant social, political and environmental stresses around the world in the coming years—challenges that technology will not be able to fix by itself.

I think what we have here is a social and political problem, not a technological problem. I don't mean to call into question the technological enterprise or suggest that we at MIT don't have an extremely important role to play. But without the political and social will to value externalities—most obviously carbon but more generally environmental destruction—we're not going to use these technologies until it's too little, too late.

I am struck by how the political discourse across the world continues to talk about growth—how there will be no tradeoffs and how technology will mean we won't have to choose. It's not at all clear that that's correct.

The pressure for growth in India and China will not slow, so the price for primary commodities will continue to escalate. Correspondingly, the rate at which we emit carbon dioxide, use up fresh water supplies and put arable land and the oceans under stress will continue to increase. We have already started to see significant political problems in countries suffering from severe environmental stresses—Sudan is the most obvious example—and it is possible we'll begin to see breakdowns or partial failures in the global supply chains that provide developed regions such as Europe and the United States with very significant fractions of their needs.

We tend to assume that everything is nicely linear and everything either goes up very gently or comes down very gently. Historically that's not accurate. We've had very nonlinear times—the most obvious would be the Great Depression. But once you get accelerating economic and political pressure then it becomes increasingly difficult to do anything about the environmental root causes.

Think about it: Here we are, one of richest societies the world has ever known, and we are not comfortable making at least minimal sacrifices to postpone or take out insurance against climatic stress. Now, suppose we all get a lot poorer and there's massive political unrest: Who is going to put a carbon tax in place? You can quite straightforwardly write a scenario in which we do nothing to curb carbon output and the kind of nonlinear effects that scientists are worried about start to kick in—things such as a collapse in the world's fisheries by 2050, or an increase in the release of methane from permafrost that causes an acceleration in global warming and a corresponding rise in sea levels.

I must stress that I think most of these problems are eminently containable. But left unchecked, we could see cumulative shocks that make an incredibly complex and interlinked system begin to need to become much less complex and much less interlinked.

SUSTAINABLE CITIES

William J. Mitchell

Professor of Architecture and Media Arts and Sciences

The building and rebuilding of our cities in "smart" sustainable form will produce the next big improvement in our lives. This is an essential task, and a massive one that has the potential to generate a long-term economic boom.

As with the Internet, the revolution will not result from a single technology, but from the timely convergence of multiple streams of technological development.

One part of it will be the replacement of the clunky, inefficient, dangerous gasoline-powered automobile with personal mobility systems based upon fleets of lightweight, "smart," wirelessly networked electric vehicles. A second part will be the emergence of clean, efficient, geographically distributed systems for electricity generation, storage and distribution. A third part will be the embedding of networking capability and intelligence in buildings and products of all kinds. And finally, ubiquitous networking will—like a nervous system—tie all this together so that cities respond, like intelligent organisms, to dynamic changes in their environments and the needs of their inhabitants.

ROBOTS

Rodney Brooks

Panasonic Professor of Robotics

As the baby boomers age, the demographics of Europe, North America, East Asia and Australia will demand that the productivity of all aspects of manual work increase dramatically. Fortunately, robots are just now maturing to the point where they can help with real productivity at practical prices. From virtually no mobile robots deployed anywhere in the world six years ago we now have thousands on active duty in the U.S. military and millions cleaning the floors of American homes. This is the lead-up to a classic hockey-stick growth curve. Just as computers we interact with personally (e.g., desktops, laptops, PDAs, cellphones) transformed our lives over the last 25 years, so, too, will robots transform our lives over the coming 25. And it just so happens that Massachusetts is the epicenter of this nascent industry.

The MIT News Office wants to hear from you

What technologies do you think will help usher in a new era of prosperity? Feel free to send us your submissions and we will publish a sampling online. Submissions should be no more than 125 words and should be e-mailed to frost@mit.edu.

MIT In the World

On a roll

Students help bring mobility to developing countries

David Chandler
News Office

Throughout the developing world, 20 million people need wheelchairs but are unable to get them. And even the lucky ones who do get them—usually through charitable donations—often get chairs designed for the smooth floors and sidewalks of the industrialized world, which can be difficult or even impossible to use on the unpaved roads and narrow hallways that people often face.

Amos Winter, an MIT graduate student in mechanical engineering, has spent much of the last three years trying to address these problems by working with wheelchair workshops in various countries in Africa and Asia to help develop new designs. His focus has been on chairs that work better under the rough conditions they face in each location, that can be made locally with readily available materials and by local workers, and that are rugged enough to stand up to the rough roads, gear-clogging dust and wet and muddy conditions they often face.

This semester, for the second time, Winter also taught a class on wheelchair design for the developing world. The 22 students in this year's class split into five teams and each came up with new variations on how to help bring mobility to people whose lives could be dramatically changed by it.

One team came up with a clever adapter to turn a conventional four-wheeled chair into a tricycle powered by hand-operated pedals. Many people who can't walk use such pedal-powered tricycles to travel long distances along dirt roads, because the three-wheeled structure is much more stable than a four-wheeler on uneven surfaces, and turning pedals by hand is a much more efficient way of covering long distances than turning the rims of the large rear wheels of conventional wheelchairs.

But such chairs are larger and heavier than conventional ones and are often not suitable for indoor use. While some people use two different chairs, one for indoors and the other for covering long distances, that's an option that's unaffordable by many people—and takes up a lot of extra space even for those who can afford it.

So this team developed an attachment made out of ordinary bicycle parts—easy to obtain in most developing nations—that simply clamps onto the front of a regular wheelchair, raising its two small front wheels off the ground and substituting a bicycle wheel further out in front. The attachment also uses the bicycle's gearing system to allow more efficient power for climbing steep slopes. The whole attachment could be built for well under $100, the team concluded—a fraction of the cost of a separate chair.

Two other teams concentrated on developing attachments to help people who use wheelchairs to be able to work and earn a living. One of these is a small cart that can be towed behind the chair, to enable people to carry heavy loads without the strain and awkwardness of having to balance it on their laps as the move around. For example, in many countries where women are expected to fetch water for the household, often over long distances, this cart would allow them to easily carry a large bucket behind them, without affecting the stability or mobility of the chair.

The other attachment is a table that snaps onto the front of the chair, above the armrests, with a set of tough nylon bags attached. This would allow people in wheelchairs to carry products with them, and then display them conveniently for sale on the table. Street vending is a very common source of income in many developing nations, and this attachment could help disabled people become self-supporting.

All of the designs were developed in close consultation with people who work on wheelchair construction in Tanzania, Kenya, Vietnam, the Philippines and other locations in the developing world, so the designs, materials and construction methods were carefully chosen to be appropriate and accessible. These consultations were made possible by partnerships Winter has formed with 13 wheelchair workshops—the local companies that develop chairs adapted to the specific needs of local conditions—in nine different countries.

This summer, several of the students will travel to some of those countries, some with the help of grants from MIT's Public Service Center, to further develop these concepts into production-ready prototypes. "We really try to foster the collaborative aspect of this class," Winter says. "We're not trying to solve problems for the people in these countries, we're trying to solve problems with them."

Because of this close collaboration, Winter says that "these all have a pretty good likelihood of being applied" to real production. Of the four other designs developed during last year's class, he says, three are actively being produced, and elements of the fourth are also being applied.

Without access to a wheelchair, Winter says, "most people were using crawling as their primary means of getting around." So providing affordable, appropriate chairs is "a huge need, with a huge potential for impact. It means these people can go out and get a job, instead of staying around the house."

BIRD BEAKS: Work finds that phalaropes defy gravity to get food up their long, thin beaks

Continued from **Page 1**

water surface, especially detergents or oil.

"Some species rely exclusively on this feeding mechanism, and so are extremely vulnerable to oil spills," said John Bush, MIT associate professor of applied mathematics and senior author of the paper.

Wildlife biologists have long noted the unusual feeding behavior of phalaropes, which spin in circles on the water, creating a vortex that sweeps small crustaceans up to the surface, just like tea leaves swirling in a tea cup.

The birds peck at the surface, picking up millimetric droplets of water with their prey trapped inside. Since the birds point their beaks downward during the feeding process, gravity must be overcome to get those droplets from the tip of the bird's long beak to its mouth. Until now, scientists have been puzzled as to how that happens.

Scientists speculated that the feeding strategy depended on the drop's surface tension. Surface tension normally dominates fluid systems that are small relative to raindrops (for example, the world of insects), but it was not clear how it could benefit shorebirds. A key observation was that in order to propel the drop, the birds open and close their beaks in a tweezering motion.

To unravel the mystery, Bush teamed up with Manu Prakash, a graduate student in MIT's Center for Bits and Atoms, and David Quere, of the École Polytechnique in Paris, a visiting professor in MIT's math department at the time of the study. They built a mechanical model of the phalarope beak that allowed them to study the process in slow motion.

The process depends on a surface interaction known as contact angle hysteresis, typically an impediment to drop motion on solids. For example, raindrops stick to window panes due to contact angle hysteresis. In the case of the bird beak, the time-dependent beak geometry couples with contact angle hysteresis to propel the drop upward.

"This may be the first known example where droplet motion is enabled rather than resisted by contact angle hysteresis," Bush said.

As the beak scissors open and shut, each movement propels the water droplet one step closer to the bird's mouth. Specifically, when the beak closes, the drop's leading edge proceeds toward the mouth, while the trailing edge stays put. When the beak opens, the leading edge stays in place while the trailing edge recedes toward the mouth.

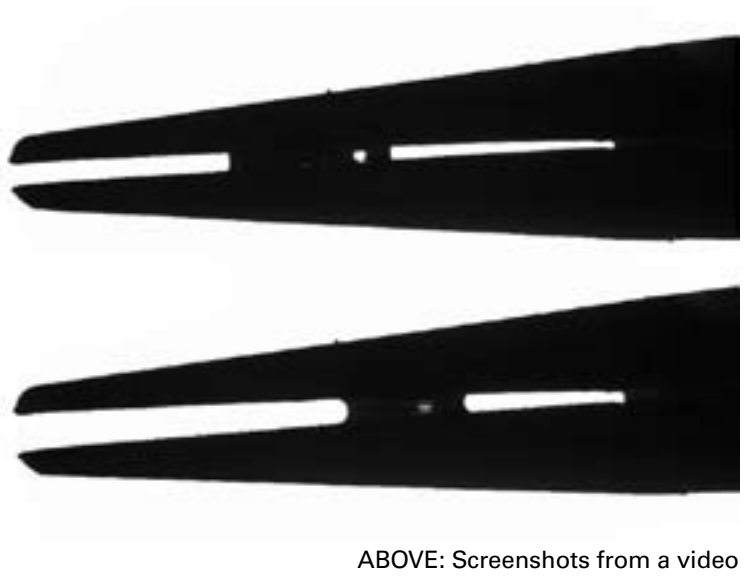
In this stepwise ratcheting fashion, the drop travels along the beak at a speed of about 1 meter per second.

The efficiency of the process, which the authors dub the "capillary ratchet," depends on the beak shape: Long, narrow beaks are best suited to this mode of feeding. The study highlights the sensitivity of this mechanism to the opening and closing angles of the beak: "Varying these angles by a few degrees can change the drop speed by a factor of 10," Quere said.

The capillary ratchet also depends critically on the beak's wettability—a measure of a liquid's tendency to bead up into droplets or spread out to wet its surface. Oil is much more "wetting" than water, so if the beak is soaked in oil from a spill, this process won't work.

The researchers note a potential application of nature's design: "We are currently exploring microfluidic devices in which this mechanism could be exploited for directed droplet transport, allowing for controlled stepwise motion of microliter droplets," Prakash said.

The research was funded by the National Science Foundation, the Centre National de la Recherche Scientifique (France) and MIT's Center for Bits and Atoms.



PHOTOS / **RAINEY SCHULER**

MIT researchers have figured out how the phalarope, a shorebird with a long, narrow beak, transports food from the tip of its beak to its mouth.

ABOVE: Screenshots from a video show water going up the beak. The full video is available on the News Office web site at http://web.mit.edu/newsoffice/2008/bird-beak-0515.html

HR@Your Service

One of the best things about working at MIT is the opportunity for career advancement. Some people have several jobs in their tenure here, while others have several careers. Just consider Diana Hughes, who started at MIT eight years ago with "no intention of staying more than a year," she says.

Hughes is a prime example of someone who worked hard, took advantage of MIT's resources and benefited from excellent managing and mentoring along the way. Her first job was a one-year position in the Reference Publications Office. She was referred by an MIT colleague, who, as so many of us do, recommended MIT as a great place to work. Her job as communications assistant got extended another six months and during this time, Hughes "went to every session HR had" on career planning. She attended workshops on interviewing skills, on writing resumes, on learning about her Myers-Briggs type. She worked closely with what was formerly the Workforce and Career Planning Office, now called Career and Talent Management, and found a new position as communications coordinator for the HR Payroll Project.

"I had a small nervous breakdown when I first started," jokes Hughes, referring to the vastness of this project and the experience of reporting to new people with different work styles. But she continues: "Being uncomfortable is sometimes a good thing." Her manager at the time, Alyce Johnson, recognized her discomfort and asked her how she likes to learn. This mentoring made a huge difference and she ended up staying on the project for four years. During this project she became communications and project manager for Jerry Grochow, vice president of IS&T. "Working directly for a VP was a great experience as I continued to build my skills," remembers Hughes. "Jerry was incredibly supportive," providing opportunities for her to grow and use her learning on the job. She ended up getting promoted to special assistant.

The experience was clearly win-win, as Grochow remarks, "Diana is just the type of person we are looking for on MIT administrative staff: energetic, organized, gets along with people, interested in career advancement by both taking academic subjects and gaining practical experience. I was pleased to be able to work with her on strategies for personal development while keeping her here at MIT."

Indeed, Hughes' ability to apply what she learned from her professional development courses is every trainer's success story. For example, Hughes took a facilitation course and then used her new knowledge in work meetings. By working with colleagues such as Johnson, who is the manager in organization and employee development (OED), Hughes learned about a whole new field and realized that she had a natural affinity for it. This exposure led Hughes to pursue a master's degree in OED, and, after three years, Hughes graduated on May 17. Even better, she landed a job at Lincoln Lab as IT transformation lead. "This is a huge job, and I'm grateful for the network I've built up back on campus as I start to build a bridge between IS&T and HR colleagues here."

Hughes' career trajectory took her to unexpected places and she took advantage of those places. Her career advice is to take the time to figure out what you really want to do. In addition, find a mentor to help you navigate the scene and who believes in you. As she says, "Alyce believed in me before I believed in myself." Finally, recognize that you are really in control of your own career—but realize that there are plenty of people and resources to help you along the way.

COMMENCEMENT 2008

ABOVE: Facilities carpenter Rick Hadge checks and replaces old wood in the Commencement platform in preparation for graduation on June 6.
BELOW, LEFT: Facilities carpenter Judd Carlisle replaces wood from the platform.
BELOW, RIGHT: Facilities carpenter Bob Stewart works on putting the stage together for Commencement.

PHOTOS / **DONNA COVENEY**

CLASSIFIED ADS

Members of the MIT community may submit one ad each issue. Ads should be 30 words maximum; they will be edited. Submit by e-mail to ttads@mit.edu or mail to Classifieds, Rm 11-400. Deadline is noon Wednesday the week before publication.

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Who ya gonna call? Riskbuster!

Professor Nancy Leveson has developed unique approach to managing risky businesses

MIT Professor of Aeronautics and Astronautics and Engineering Systems Nancy Leveson

David Chandler
News Office

Whenever something really bad happens in this high-tech world—or whenever someone wants to make sure it doesn't—there's a good chance that before long, someone will be calling Nancy Leveson. Or wishing they had. And whether the issue involves anything from advanced spacecraft to pharmaceuticals or critical computer systems, chances are the MIT professor of aeronautics and astronautics and engineering systems will have a good answer to the problem.

Risk analysis for complex systems like nuclear power plants or space shuttles typically involves analyzing sequences of failures, figuring out every part of the system that might fail and what effects that might have, and putting all those pieces together—essentially, a bottom-up way of looking at things. Leveson, after nearly three decades of working on such problems, has revolutionized the field by developing a new top-down way of analyzing the risks of complex systems, which leads to a more integrated approach to managing the risks.

Her advice and analysis have been applied in recent years to helping a presidential commission understand how to prevent the communications failures that led to the space shuttle Columbia accident, helping pharmaceutical companies manage the risks of new drugs being introduced, and helping the Federal Aviation Administration assess new technology for air traffic control. She's also investigated how to make sure that a new missile defense system being developed by the U.S. would not be vulnerable to an accidental launch, and how to reduce the risks of corporate fraud that could damage the economy.

What tends to happen in complex, high-tech systems, Leveson has found, is not so much a random failure of one or two parts of a system, but rather a gradual drift over time from a safe operation to one where the safety margins have eroded and one small problem can throw everything out of kilter.

Sometimes, there is no failure in the traditional sense: Each part of the system did what it was supposed to do, but there was an underlying error in the overall design. That's what happened, for example, in the loss of NASA's Mars Polar Lander a few years ago, after the lander's engineers failed to inform colleagues working on its onboard software of a potentially dangerous source of "noise."

For Leveson, the turning point came in 2000, when she realized, "after about 20 years, nobody was making any progress" in figuring out how to manage the risks of complex systems, she says. "Usually, that's means there's something wrong with the underlying assumptions everybody is using."

She realized that the basic component-based approach to assessing risk was something that had prevailed at least since World War II, and "it just didn't apply" to many of the highly computerized technological systems in operation today. "Accidents just occur differently. Risk has changed as the technology has changed." So she started developing her new approach, based on systems theory.

At first, she was afraid that nobody would take her radical new approach seriously. "I thought people would just think I was nuts," she says with a laugh. But when she started applying her new approach to specific cases, such as identifying the potential for inadvertent launch in the new missile defense system, it clearly worked: It identified significant hazardous scenarios that nobody had noticed otherwise.

"We tried it on extremely large, complex systems, and it worked much better than what people do now," she says. "I realized we could solve problems that weren't solvable before."

The new approach to analysis led to a whole new way of dealing with the risk management of complex, socio-technical systems. Instead of looking at the individual components and trying to minimize the chances that each would fail, "what you really want is to enforce safety constraints" on the behavior of the entire system, Leveson says.

"We used to build systems that were simple enough so that you could test everything, and test the interactions," she says. "Now, we're building systems so complex that we can't understand all the possible interactions." While traditional analysis assumes a linear, causal chain of events, accidents in complex systems often unfold through very nonlinear effects, feedback loops and so on.

Leveson calls her new approach STAMP, for System-Theoretic Accident Model and Processes. She has set up a company to implement the system in analyzing a wide variety of systems in different fields, and is finishing a book on the system that will be issued by MIT Press this fall. In the meantime, chapters of the book are available online on Leveson's web site (http://sunnyday.mit.edu/book2.pdf).

"Nancy Leveson has developed a control-based modeling approach to systems safety which can be applied to complex networks of hardware and humans," says professor Jeffrey Hoffman, a colleague of Leveson's in MIT's Aeronautics and Astronautics Department. "Her work has elicited considerable interest inside NASA, where safety analysis has traditionally concentrated on the reliability of individual pieces of complex systems."

While NASA is using her new approach to analyze risks in the development of the Orion spacecraft that will replace the shuttle, and in developing a future robotic planetary probe, the Japanese space agency has gone even further: They sent two engineers to work in Leveson's lab for a couple of years and observe how she does her analysis, and have been applying the lessons learned to their space systems while creating improved tools.

Though her work focuses on disasters, Leveson is upbeat about what she does. Using the old ways, she says, "it was discouraging to have something that only works in a small subset of cases." But with her new approach, she says, "it's very exciting to have something that actually works, and to be able to apply this in the social and organizational realm."

The cost of repealing blue laws

Sarah H. Wright
News Office

Repealing America's blue laws not only decreased church attendance, donations and spending, but it also led to a rise in alcohol and drug use among people who had been religious, according to a new study by economists Jonathan Gruber of MIT and Daniel Hungerman of the University of Notre Dame.

Blue laws, or Sunday closing laws, refer to statutes that restrict certain activities on the Christian Sabbath. By the end of the 19th century, nearly every state had at least some law prohibiting certain activities on Sunday. The 1960s saw the beginning of push to repeal these laws in favor of commerce, although a few still remain on the books.

In their study, which appears in the May 2008 edition of The Quarterly Journal of Economics, Gruber and Hungerman show what happens when religious services must compete with shopping, hobbies and other activities.

To measure that competition, they studied the large number of states that repealed their blue laws over the past 50 years. (Massachusetts, for example, repealed its blue laws in 1994.)

"That policy-driven change in state laws allowed us to identify secular competition, as opposed to interreligious competition, which had been studied before," Gruber says. "We wanted to find out how people spent their time and money."

The economists used data from the General Social Survey on religious attendance and from the Consumer Expenditure Survey to show a very strong reduction in religious attendance and a decline in religious contributions once the blue laws were repealed. They found no change in other charitable activity, Gruber notes.

To confirm their findings and to complete the economic portrait, the authors also analyzed budget data for four major Christian denominations over the past 40 years. Church expenditures declined significantly since the repeal of the blue laws, they found.

Gruber and Hungerman did more than track how individuals chose to allocate their resources on Sunday once the malls were opened, a change widely celebrated from the early 1960s onward as freedom from old-fashioned ways.

They considered the negative consequences for individuals or society from loosening secular constraints and they found those consequences in behaviors associated more with Saturday night than Sunday morning.

Using data from the National Longitudinal Survey of Youth (NLSY) on consumption of alcohol and illegal drugs, the economists found that repealing the blue laws did lead to an increase in drinking and drug use.

What's more, they found that individuals who had attended church and stopped after the blue laws were repealed showed the greatest increase in substance abuse, Gruber notes.

Those effects have significant economic and social implications, the authors say.

The study, "The Church vs. the Mall: What Happens When Religion Faces Increased Secular Competition?" can be viewed online at http://www.mitpressjournals.org/doi/pdf/10.1162/qjec.2008.123.2.831.

MIT class asks: Fly me to the moon?

David Chandler
News Office

Even for MIT, where so many classes and activities involve competitions and the creation of proposals that might lead to new businesses and to solving large technological challenges, this one was unusual. This semester's aero-astro graduate space systems engineering class, 16.89, was aimed at figuring out whether MIT could, or should, mount an entry into the $20-million Google Lunar X-Prize competition, announced last fall.

After three and a half months of research on what it would take to meet the prize's requirements—getting a privately-funded robotic craft to the moon, having it travel at least 500 meters once it gets there, and sending back streams of high-definition still and video imagery—the bottom line the students arrived at was: Yes, we can (technically)!

Whether it's possible to raise the necessary funding and pull together the necessary partnerships with industry, and whether the investment of time, money and hard work is worth pursuing, are matters still under discussion. A decision is expected within about six weeks, says Aeronautics and Astronautics Professor of the Practice Jeffrey Hoffman, who taught the class together with Professor Edward Crawley.

A prize entry would cost between $20 and $30 million, the class concluded, most of it for purchasing launch services to get the craft into low-Earth orbit.

The class looked at several different options for each phase of the mission. For example, one choice is whether to launch the craft to the moon directly from Earth, or send it into Earth orbit first and then to the moon. Another is how to achieve the 500-meter trip once it arrives on the moon: Either having a wheeled rover or a spherical "roller" separate from the craft after lunar touchdown, or using a "hopper" approach, by having the whole craft land, then take off again, move to the side, and land again. And there were dozens of smaller choices to be made, including the materials to use for the structure, the kind of batteries to use and the best ways of communicating data back to Earth.

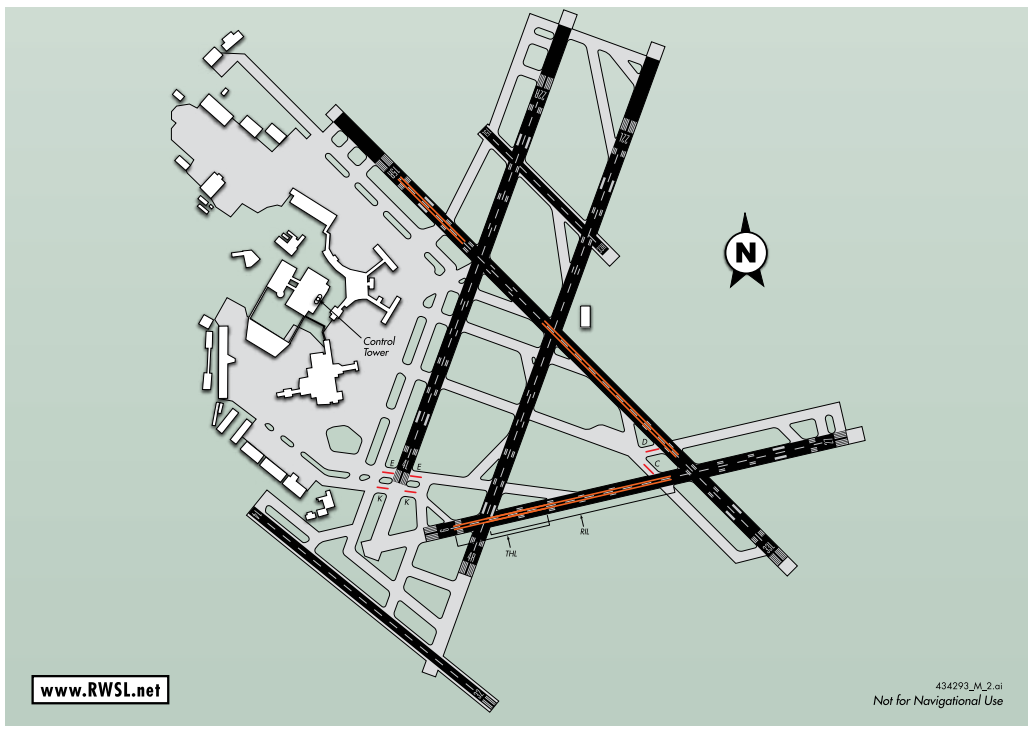
Hoffman, a former astronaut who flew five shuttle missions and carried out the first repair mission to the Hubble Space Telescope, says this class served a dual purpose. First, as students in the class do every year, they got to solve a very specific challenge to design an entire space mission, learning about all the different aspects involved in that process, from evaluating the technical tradeoffs involved in every choice of hardware or strategy, to the challenges of working together as an effective team.

Going through that process "illustrates some of the basic principles of the design process," Hoffman says, and thus fulfills the pedagogical purpose of the course. But in addition, "in this case, the idea of designing a lunar robotic mission is interesting in its own right," and because of the possibility that an MIT-led team might actually enter the contest, gives this project an extra dose of reality and excitement.

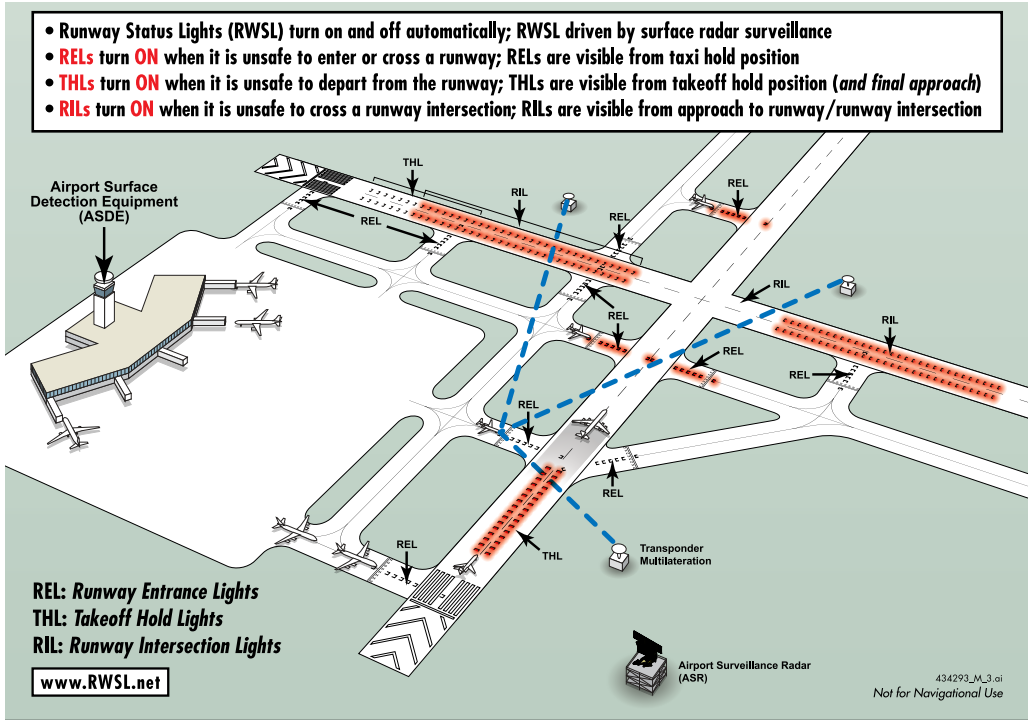
"It's not just a paper study, in the sense that something is riding on it," Hoffman says. And if the decision is made to go ahead with a contest entry, "it's a major undertaking, a multiyear project. It will mean putting together a team—students will come and go, and faculty will provide continuity," he says.

There were 15 students in the class, but if MIT decides to enter the competition, the team might include some of them as well as others who are not yet involved. "We would hope to attract others, including participants from other departments," such as EECS, CSAIL, EAPS and the MIT Sloan School of Management.

"It's a big challenge," Hoffman says. Ten teams have already officially registered to participate in the lunar challenge, which was created by X-Prize Foundation founder Peter Diamandis '83, SM '88. Among the teams is a student group from Carnegie-Mellon University, which has a partnership with Raytheon and has vowed to reach the moon by July 20, 2009—the 40th anniversary of the first lunar landing by astronauts.



ABOVE: An airport diagram of Boston's Logan International Airport shows the runway intersection lights, takeoff hold lights and runway entrance lights (in red).
BELOW: A Runway Status Lights operational concept depicts a notional deployment of runway intersection lights, takeoff hold lights and runway entrance lights.



Logan to get Lincoln Lab-developed runway safety system

Dorothy Ryan
MIT Lincoln Laboratory

Next year, Boston's Logan International Airport will become one of the first U.S. airports to deploy Runway Status Lights (RWSL), a new technology originally developed at MIT Lincoln Laboratory as part of the Federal Aviation Administration's continuing program to improve runway safety.

RWSL—an automated, all-weather safety backup to pilots, airport vehicle operators, and air-traffic controllers—is designed to aid in the prevention of runway accidents while not interfering with the efficient tempo of operations required at high-capacity airports. The system was developed at Lincoln Laboratory under the FAA's Runway Incursion Reduction Program.

The RWSL system improves safety by enhancing the situational awareness of flight crews and vehicle operators through automatic and timely status lights that indicate when runways are occupied. The automatic control of the lights is performed by software-based control logic driven by a fusion of primary and secondary radar data that provides an accurate picture of runway usage by aircraft and ground vehicles. The RWSL concept comprises takeoff hold lights (THLs), runway entrance lights (RELs), final approach runway occupancy signals (FAROS) and runway intersection lights (RILs).

Operationally suitable versions of RWSL are being tested at the Dallas-Fort Worth International Airport and the San Diego International Airport. Lincoln Laboratory is supporting successful extended operational evaluations of RELs and THLs at Dallas-Fort Worth and RELs at San Diego. The Laboratory is also scheduled to support an operational evaluation at Logan once RELs, THLs and RILs, which will have their first-in-the-nation deployment at Logan, have been installed in late 2009.

In the early 1990s, Lincoln Laboratory developed a preliminary operational concept of runway-status lights followed by a concept demonstration at Logan. In the mid-1990s, NASA Langley Research Center reported the results of a cockpit simulation study of pilot acceptance of runway-status lights while the Volpe National Transportation Systems Center studied the design and physical installation of runway-status lights at Logan International Airport.

All of these studies concluded that runway-status lights could be an effective means to prevent runway incursions and runway-conflict accidents and would be supported by pilots and controllers, provided that the performance of the surveillance and light control logic could be optimized to be compatible with high-density airport operations. However, it was concluded at the time that the existing surface surveillance quality was inadequate to support an RWSL system with a low enough false-activation rate to be compatible with operations at a complex, busy airport. In the past decade, FAA-sponsored programs have advanced surface surveillance technology to the level needed to make RWSL practical. In 2002, Lincoln Laboratory reinstated its RWSL development effort under FAA sponsorship.

Disarmament expert sees U.S.-Iran solution

Sarah H. Wright
News Office

An MIT expert on Iran's nuclear ambitions is gaining recognition for his work in developing a possible face-saving solution to the tense nuclear standoff between the United States and Iran.

Jim Walsh, research associate in MIT's Security Studies Program at the Center for International Studies, says the United States and Iran could develop significant common purpose if Iran's uranium enrichment program were managed and operated on Iranian soil by a multilateral consortium—and if the United States were to give up its demands that Iran abandon its nuclear activities completely.

Walsh developed his proposal with colleagues William Luers, former U.S. ambassador to Czechoslovakia and Venezuela, and Thomas Pickering, former U.S. ambassador to six countries, including Russia and Israel, and the United Nations.

"This is a historic moment for U.S. leadership. Sanctions aren't working and Iran has accelerated its uranium enrichment. Multilateral management of Iranian nuclear facilities will provide transparency about their fuel program and reduce the chances of Iran acquiring nuclear weapons," says Walsh.

Walsh and his colleagues' proposal was recently featured in The New York Review of Books and in MIT's Audits of the Conventional Wisdom. The title is, "A Solution for the U.S.-Iran Nuclear Standoff."

Walsh also presented his research on Iran's nuclear ambitions to the Senate Committee on Homeland Security and Governmental Affairs on April 24, 2008. It was his third appearance before Congress to testify on U.S.-Iran relations.

Tensions about Iran's nuclear program, mounting for decades, have nearly boiled over this year. Multilateral management of Iran's nuclear program has been proposed before; Walsh's plan is drawing widespread interest now as many officials are looking for a way out of the potentially dangerous U.S.-Iran standoff, he notes.

> *Multilateral management of Iranian nuclear facilities will provide transparency about their fuel program and reduce the chances of Iran acquiring nuclear weapons.*
>
> **Jim Walsh**
> **research associate,**
> **MIT's Security Studies Program**

Taking the lead on resolving the nuclear standoff would give the United States a chance to work with Iran on defeating the Taliban and al-Qaeda and on developing common goals in Afghanistan and Iraq, Walsh says.

Washington's historic moment—the opportunity to negotiate with Iran on managing its nuclear program—arises from two recent propitious developments, Walsh says. First, the National Intelligence Estimates concluded in December 2007 that Iran halted its weapons program in 2003. Second, the United States and Iran have held successful direct talks on Iraq, reducing the flow of improvised explosive devices and foreign fighters through Iran.

"These events have created the political space for new thinking about the U.S.-Iran relationship, and they demonstrate that negotiations with the Iranian Republic can produce tangible results," the authors write.

Walsh and his colleagues have met regularly with Iranian academics and policy advisers over the past five years, and Walsh met twice with Iranian President Mahmoud Ahmadinejad during a U.S. visit. Walsh has visited Iran three times and will return there in June.

Tehran has changed since Walsh's first visit in 2006, illustrating the marginal effects of U.S. sanctions, in effect since the 1979 hostage crisis, he says.

"Wealthier neighborhoods don't look like they are suffering from sanctions. There's a construction boom, with new buildings and shops going up. One result of the new sanctions is that wealthy Iranians who had kept their money in foreign banks have brought it back to Iran; they're investing in real estate at home," Walsh says. "Nobody has stopped buying oil."

Sanctions have also been ineffective, according to Walsh, because they reflect a mismatch between U.S. policy and U.S. goals.

"Economic sanctions are a long-term strategy; they're not designed to achieve near-term goals like containing or dismantling a nuclear program. The United States needs to take the initiative in the near term," Walsh says.

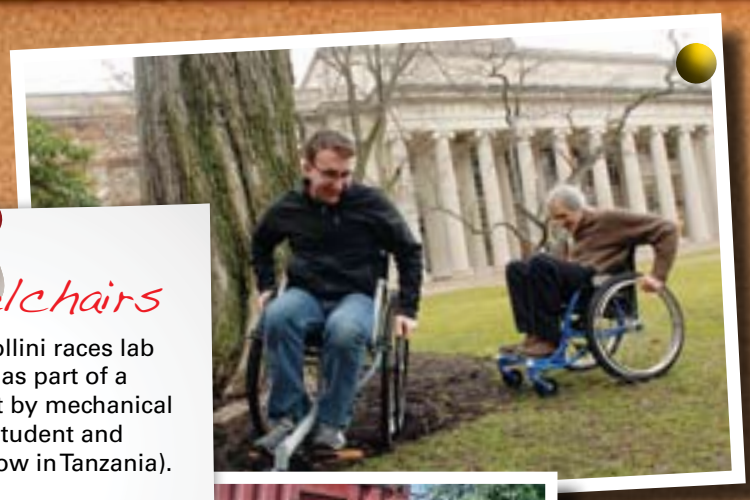
Taking that initiative would quickly profit both the United States and Iran, he says. Through upgraded international safeguards and inspections, multilateral ownership and management will provide the United States transparency about Iran's production of nuclear fuel. In exchange for accepting the multilateral plan, Iran would be able to jointly own and operate an enrichment facility on its own soil and also enjoy increased trade with Europe, among other benefits.

"The process is likely to be painful and difficult, but the reward may be a more stable and peaceful Middle East," the authors write.

No Tech Talk next week

In honor of Memorial Day, there will be no Tech Talk on Wednesday, May 28. The next Tech Talk will be published on June 4 and include the Awards and Honors special section. For ongoing MIT news updates, please go to the News Office web site at web.mit.edu/newsoffice/.

How I spent my semester

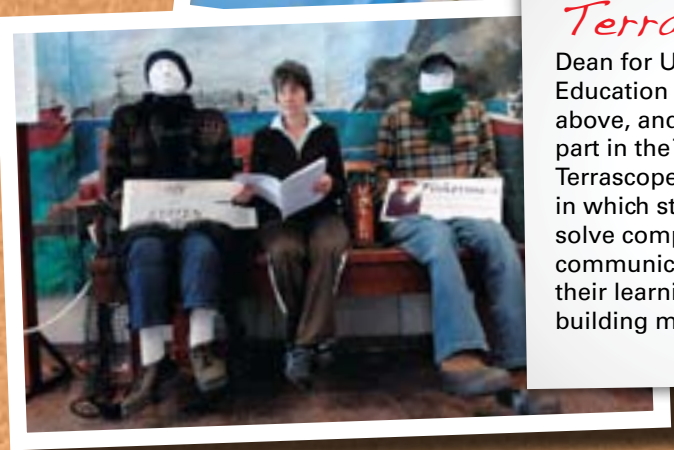


Making wheelchairs

RIGHT: Junior Mario Bollini races lab instructor Gwyn Jones as part of a wheelchair class taught by mechanical engineering graduate student and Amos Winter (seen below in Tanzania).

Winter's course challenged students to come up with new variations on how to help bring mobility to the 20 million people in the developing world who need wheelchairs.

Read more about the class in this week's 'In the World' column. **Page 8**



Terrascope

Dean for Undergraduate Education Daniel Hastings, above, and Pat Bras, left, take part in the Terrascope exhibit. Terrascope is a yearlong program in which students are asked to solve complex problems and to communicate some aspect of their learning by designing and building museum-style exhibits.

Curling

Sean Rogers, Elizabeth Finn and Jamie Smadbeck, all juniors in chemical engineering, have been experimenting with ice and a curling stone in an effort to quantify the best ice condition for curling.

Toy design

Civil engineering sophomore Brooke Jarrett, left, and freshman Christian Segura-Rivera, below, demonstrate their creations for MIT's Toy Product Design course.