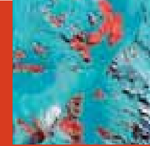
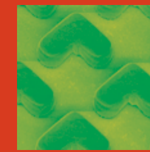
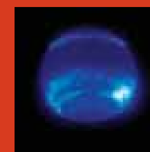
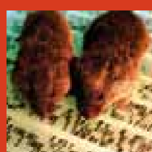
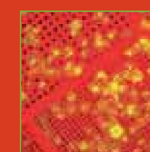
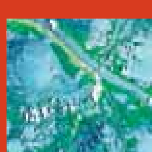
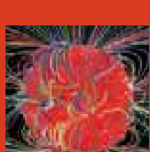
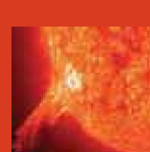
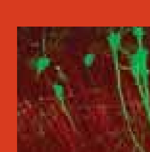
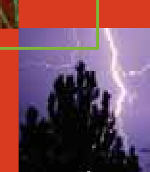





PROFILES IN TEAM SCIENCE



CENTERS

ABOUT PROFILES IN TEAM SCIENCE

This material is based upon work supported by the National Science Foundation under Grant No. 0609451, a Discovery Corps Senior Fellowship from the NSF Chemistry Division, to principal investigator (PI) Deborah L. Illman, University of Washington, Seattle, WA 98195.

Chapters in this booklet were developed by Deborah L. Illman unless otherwise indicated.

The PI would like to acknowledge NSF program director Kathy Covert for her support. Thanks also to the Science and Technology Center directors and participants for their assistance.

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"Universities Have Departments; Society Has Problems"

INTRODUCTION
TO PROFILES IN TEAM SCIENCE

BY DEBORAH ILLMAN

Science is an essential literacy — "a civil right, in many ways," said the president of the Science Museum of Minnesota, Eric Jolly, to me in an interview for this project.

At the heart of science literacy is the understanding that science is not a static body of facts; it's a process of inquiry. And something very interesting has been happening to that process lately that has not appeared on the radar screens of journalists or the public—something I think people should know about.

It's the increasing trend toward team science: tackling problems that could not be solved by any one discipline alone.

The conventional wisdom most people learn in school is that to study a system, scientists isolate the variables. They study the effect of one variable at a time.

But in recent years, scientists and engineers have taken on really hard, messy problems that involve many dimensions. They are banding together in large interdisciplinary teams to go after federal funding for "big" projects, conducted over a longer time frame than conventional research projects. Though not quite on the scale of the space program or the Manhattan Project, these centers nevertheless employ a mission-oriented, team approach that is reminiscent of those historic efforts.

Over the past three decades, for example, the National Science Foundation has invested in interdisciplinary science and engineering through center programs of various "flavors." Examples are the Industry/University Cooperative Research Centers (I/UCRCs), Engineering Research Centers (ERCs), and Science and Technology Centers (STCs), among others.

In a way, the proliferation of centers is a response to the experience encountered by many academic researchers of "throwing results over the wall and getting frustrated that the world doesn't change," in the words of S. Shankar Sastry, director of one of the NSF STCs, called the Team for Research in Ubiquitous Secure Technology, and a professor at the University of California, Berkeley.

History may look back on these last couple of decades as a time when science grew up and took on real-world problems instead of sticking to the safe and tidy world of the tractable, in which studies are undertaken because they are do-able, even if not directly useful.

Today, curiosity-driven basic research in the university is being augmented with mission-oriented research and development. In these pages, we hear from the people involved and how they are managing both ends of the spectrum.

Profiles in Team Science is the result of a year spent exploring the NSF Science and Technology Centers. It was made possible by a Senior Fellowship from the NSF Discovery Corps Program in the NSF Chemistry Division. The booklet is focused on

INTRODUCTION

Most Americans keep up to date about developments in science and technology through the news media. So media coverage relating to centers is critically important to the nation if policymakers, the scientific community, educators, and taxpayers are to understand the role that these modes of science play in solving critical problems facing society.

the group of currently funded STCs, and although these 17 centers are working on different topics, they all are organized following the same essential pattern: an integrated, 10-year program of research, education, diversity enhancement, knowledge transfer, and public outreach.

An STC typically involves several universities, dozens of faculty and postdoctoral researchers from many different departments, over a hundred graduate and undergraduate students, and dozens of industrial and community affiliates. A center has the staff, resources, and time to make a much larger and far-reaching impact than usually is possible with smaller grants.

Topics addressed by the STCs run the gamut from understanding what's happening to the Earth's ice sheets to learning what makes animals behave the way they do. One center is developing plastic electronics, while another develops water disinfection strategies that may help alleviate looming shortages of that resource around the nation and the world.

In the development of Profiles in Team Science, I set out to explore what taxpayers were getting for their investment in the STCs. What are these centers doing that otherwise couldn't be done—or done as quickly? What is team research like? How are the results being applied? How do directors manage these large operations? Why do they take on the task?

I knew going in that it would not be possible to cover everything happening in these centers. Accordingly, this booklet is intended to be a sampler. It is meant to be suggestive, not exhaustive. I chose to focus the scope primarily on research outcomes, results transferred to practice, and the personalities leading the charge.

I regret that I could not do justice to the complete array of activities going on in the STCs. For example, while selected examples of education and diversity enhancement are highlighted in these pages, it was not possible to include everything each center is doing in this regard. Diversity enhancement is one of the most significant legacies of the STC program, and an entire booklet could be written just on these efforts alone. After all, educating a diverse group of students provides the next generation of researchers to conduct team science, which is enhanced by peoples from all walks of life, and so this is a vitally important component of the STC mission. Furthermore, there were many more examples of K-12 and public outreach than could be included—and the same for startup companies and industrial partnerships, which are poised to move research results into practice for the benefit of society and our economy. What you'll see in these pages is just the tip of the iceberg. I hope readers will be enticed to visit the centers' Web sites and the NSF site for additional information.

I want to be clear about what this booklet is not. It is not an inventory of everything centers are doing. It does not officially represent the NSF STC program. It is not intended to be a critical evaluation of centers generally, or of the NSF STC program in particular.

I did not feel constrained to be "objective" in the journalistic sense—that is, I did not go out and find independent sources to quote, giving me the upside and the downside, the caveats and qualifiers.

Rather, what I sought to do was to lay some evidence on the table. To tell a few of the stories that seemed to be falling through the cracks because they didn't fit within the confines of the hard news format and traditional news beats in the media. To let readers hear, in the researcher's own words as much as possible, why they believe these outcomes are important, and how the experience has changed things for them and for their students, institutions, and disciplines.

I wanted to help shed light on a trend in science that has been increasing but largely invisible in the media, and therefore, to the public. Through the News Watch sections in this booklet, I have tried to point journalists toward emerging stories that are likely to break over the coming months.

Why should journalists and the public care about centers? Shouldn't journalists just report the results, never mind by what means obtained?

Most Americans keep up to date about developments in science and technology through the news media. So media coverage relating to centers is critically important to the nation if policymakers, the scientific community, educators, and taxpayers are to understand the role that these modes of science play in solving critical problems facing society.

If journalists fail to make the link between center-mode funding of research and the outcomes that centers achieve, government officials, scientists, and taxpayers will lack information they need to make informed decisions.

The appropriate level of federal funding for centers is an issue that continues to be debated nationally. It's a question of the balance between large, multi-investigator efforts versus smaller, single-investigator grants. For example, in 2005, responding to pressures, NSF modified the definition of a center, reducing the number of such entities from 300 to 200, according to

Photo: TRUST

Photo: ©2006 MBARI

reports in the Chronicle of Higher Education and Science. NSF's annual investment in centers was estimated in those reports at $350 million, or 7 percent of the agency's budget.

Furthermore, managing team science remains an issue of public concern. Federal agencies are focusing not only on funding mechanisms and portfolio balance but also on ways of overcoming barriers to interdisciplinary collaboration and of improving communication between disciplines. The risks of faculty participation in team science can be significant, and rewards within the traditional academic culture can sometimes be uncertain or even negative. Meanwhile, campuses struggle to manage entities that not only straddle departments and colleges and share FTEs, but that dot the country with a constellation of partners.

Team science "doesn't fit in the traditional silo," notes Dennis Matthews, director of the Center for Biophotonics Science and Technology, an STC headquartered at the University of California, Davis, observing that "everyone loves to anoint a single hero."

Centers are a countermeasure against academic rigidity. They create a matrix structure, first of all within a university, crossing department and college lines, but even beyond that, across institutions. Centers apply a forcing function on the evolution of our universities to accelerate change and to expand horizons for students.

On the other hand, faculty and directors have so many affiliations these days, it can seem like a spaghetti bowl of centers, institutes, and programs. It's a wonder how they keep the acronyms straight, let alone manage divided loyalties.

And it's just as hard for public information officers and journalists to grapple with these relationships. Most media relations personnel are assigned to beats following college lines: engineering, arts and science, social sciences, medicine, and so on. Covering centers seems, once again, to fall through the cracks.

Center participants acknowledge the overhead of time and energy needed to manage team work. Centers have utilized videoconferencing, but alas, it never seems robust enough. Centers likely will be eager early adopters of new conferencing technologies.

Working in a six- or seven-ring circus can be tough. There is a certain amount of attrition of the players: teamwork is not everyone's cup of tea. Centers have played to their strengths in working these things out, but it has taken time and a few false starts. The question now is how these efforts will be institutionalized to leverage the effort so that even after NSF funding ends, the value will continue. Many of the current centers are planning now for "life after NSF" and taking stock of the legacies they will leave.

Doubtless one of the most important legacies is the new kind of student educated at an STC. I do believe that centers produce a different kind of graduate, one more able to work in teams, speak the language of other disciplines, with a broader suite of professional skills and an appreciation for the broad spectrum of research through development and application.

These individuals have spent their formative years in a diverse culture of tackling big problems and developing disciplinary strengths in the context of multidisciplinary breadth. That seems like a powerful combination.

Center participants point to the legacy of the STC program in building diversity and enhancing programs at four-year institutions and Historically Black Colleges and Universities (HBCUs). Another lasting outcome will be models for effective partnerships between universities and museums, zoos, and other community organizations. Centers are spinning off startup companies, a handful of which are described here, out of literally dozens to stem directly or indirectly from center research. Throughout these pages, you'll see examples of tangible results of mission-oriented research transferred to industry, government, and communities across the country.

The unintended outcomes are fascinating. Time and time again, we see a center set out in one direction and end up with an entirely different application. One center, for example, set out to develop solvent-free green manufacturing technology and ended up with a new way to deliver cancer therapies.

Writing about the STCs was an adventure. Much of my career has been spent trying to make science more accessible, not only through my own writing but also by coaching young people to become more effective communicators. Toward that end, I am grateful that several writing students had the opportunity to share in this experience. The project has contributed to the portfolios of up-and-coming writers, some of whom will continue in scientific research while others pursue writing or communication careers.

I would like to thank all of the members and center directors of the NSF STCs who gave of their time and energy, with particular thanks to Dennis Matthews, Mark Shannon, Joe DeSimone, Chris Paola, Walt Wilczynski, and Claire Max. I'd like also to acknowledge Alvin Kwiram, emeritus vice provost for research and former chair of chemistry at the University of Washington, for his input on this project. Finally, I would like to thank Kathy Covert, NSF Discovery Corps Program Director, and the NSF Chemistry Division for their support.

Photo: CMOP

CENTER FOR ADAPTIVE OPTICS CfAO

ADAPTIVE OPTICS

ADVANCING THE SCIENCES OF SKY AND EYE

The Center for Adaptive Optics (CfAO) has brought together two very different worlds in science: one that treats the astronomically large, and another that treats the very small.

These realms—astronomy and vision science—have found common cause in the need for technologies to obtain very clear, sharp images. Together, they are advancing a remedy.

It's called adaptive optics (AO), a method for removing the blurring of images caused by changing distortions in optical systems. Turbulence in the Earth's atmosphere, for example, causes images of stars and planets to appear fuzzy. But by using adaptive optics, ground-based telescopes can see as clearly as if they were in space. Imperfections in the eye cause blurring of images, but adaptive optics for vision science provides a way to sharpen an image of the human retina.

Headquartered at the University of California, Santa Cruz (UCSC), the center has united a team of astronomers, physicists, engineers, and vision and life scientists in the quest for next-generation adaptive optics.

When the center started in 2000, AO wasn't something that the astronomy community had entirely accepted. NSF funding of the center helped make it a mainstay of astronomy—and transformed the field of vision science in the process.

"There has been a huge amount of cross-fertilization between those disparate communities," says center director Claire Max. "When we got started, there was one AO system for vision that was tentatively trying out what they could do. Now there are more than a dozen instruments in clinical settings and laboratories."

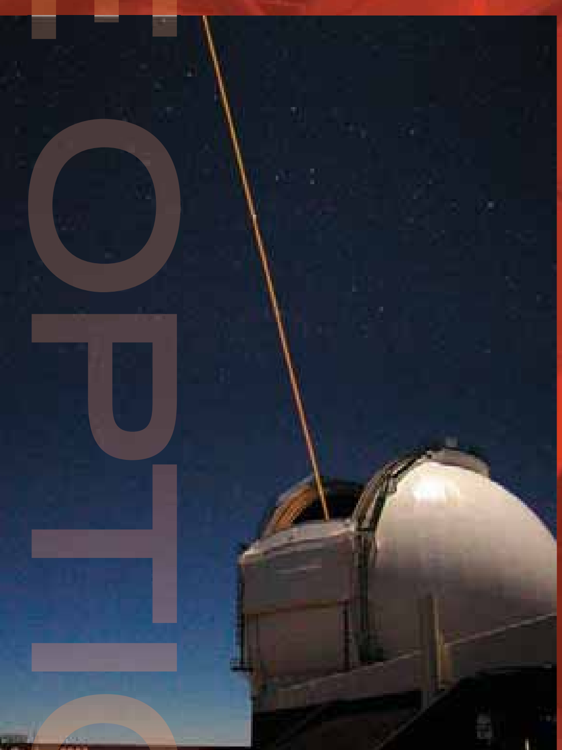
At the heart of an AO system is a wavefront analyzer along with a deformable mirror, which can change its shape rapidly to correct for distortions in the incoming light. In order to analyze the incoming wavefronts, a bright reference source of light is needed. In astronomy, the reference may be a bright star or an artificial star created by aiming a laser beam up into a sodium layer that surrounds the Earth at a height of about 100 km. It creates a spot of light called a laser guide star that can be used as a reference for measuring distortions caused by the Earth's atmosphere. In vision research, a laser reflected off a spot in the retina provides a reference.

Based on this information, commands are sent to actuators that exert force on the surface of the deformable mirror to change its shape—for the Earth's atmosphere, that means changing several hundred times a second.

Until recently, commercially available deformable mirrors have been relatively large and expensive, but for many applications, smaller and less-expensive mirrors are needed. The enabling technology is a micro-electromechanical system, or "MEMS," deformable mirror that consists of a reflective layer on top of a membrane under which are many tiny electrodes that impart forces on the mirror. Each device may have from hundreds to thousands of such deformation points.

The center has funded several companies including Boston Micromachines and Iris AO to spur improvements in MEMS deformable mirrors. "By setting benchmarks and performance characteristics to meet, we've helped to push the capabilities forward," notes Chris Le Maistre, managing director of CfAO.

One legacy of the center is the Laboratory for Adaptive Optics (LAO) at UCSC, a facility within the UCO/Lick Observatory established with more than $9 million from the Gordon & Betty Moore Foundation. The laboratory provides a place to develop and test new AO technologies and to train postdoctoral and graduate researchers. □

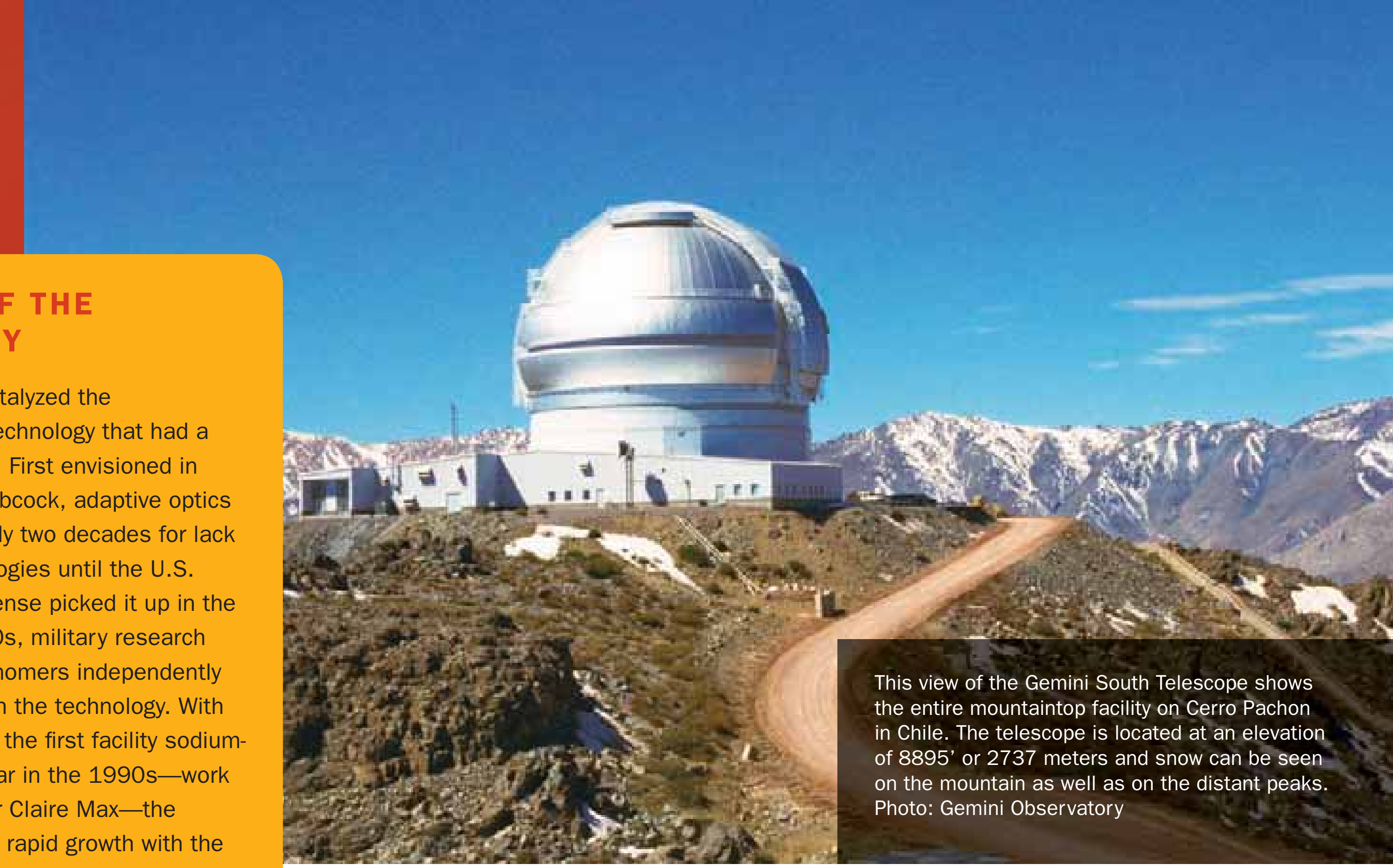


W.M. Keck Observatory

Pictured in background:
Gemini Observatory

TIMELINE OF THE TECHNOLOGY

CfAO has rapidly catalyzed the development of a technology that had a long induction time. First envisioned in 1953 by Horace Babcock, adaptive optics languished for nearly two decades for lack of practical technologies until the U.S. Department of Defense picked it up in the 1970s. In the 1980s, military research continued as astronomers independently started working with the technology. With the development of the first facility sodium-layer laser guide star in the 1990s—work led by CfAO director Claire Max—the field was poised for rapid growth with the establishment of the center in 2000.



This view of the Gemini South Telescope shows the entire mountaintop facility on Cerro Pachon in Chile. The telescope is located at an elevation of 8895' or 2737 meters and snow can be seen on the mountain as well as on the distant peaks. Photo: Gemini Observatory

A CONVERSATION WITH THE DIRECTOR

Claire Max

Claire Max, director of the Center for Adaptive Optics

Q: Why team science?

Max: When you're building a big instrument, the classical pyramid with the dictatorial PI on top and a bunch of minions working below just doesn't work anymore—you need a wider variety of expertise and skills. And when the project is big—aiming to look at thousands of galaxies for instance, doing the observations and understanding the results takes a lot of people. Big ambitious projects require a big team. The team needs to match the size of the dream.

Q: What qualities are needed to be a center director?

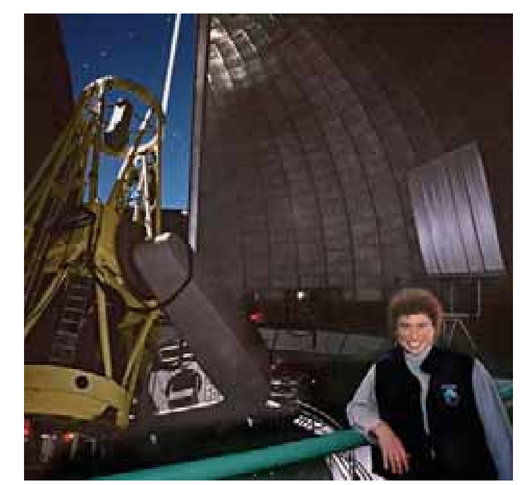
Max: You have to be the kind of scientist who takes pleasure in the work of others as well as in your own work. If you work very hard on your own research but it doesn't make you happy to see other people doing good stuff as well, then you're not going to be a good center director. Prior to the center, I was director of university relations at Lawrence Livermore National Laboratory. I ran a program encouraging people at national labs to do research with people from university campuses, so I had some practice before I came to the center.

Q: How do you promote effective interactions?

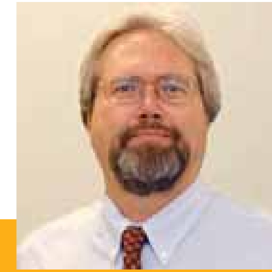
Max: We encouraged individuals with expertise in astronomy to spend time hanging out with vision scientists, watching how they worked, interacting with them. We realized that interpersonal interactions were going to be important, so we designed our center to have a lot of workshops and retreats and joint activities where people would get to know each other. Once people build up trust and working relationships at organized events, it becomes much more natural to say, 'Can I come to see your lab?'

Q: Are you starting to think about life after NSF funding?

Max: We are involved in exit planning now. Individual research projects will get their own grants, and we're pursuing three avenues for future education funding. But it's harder to get support to maintain the core of the center—we're trying to identify funding for core activities like retreats and workshops to keep the community going.



“We’ve been able to leverage off of a lot of the work that’s being done in adaptive optics in astronomy to do much better things for vision science than we otherwise would have.” — DAVID WILLIAMS



CfAO associate director David Williams of the University of Rochester

AO IN THE SERVICE OF VISION SCIENCE

“The Center for Adaptive Optics gives us contact with a branch of science that we would have no commerce with at all otherwise,” says center associate director David Williams of the University of Rochester. “Just listening and learning about astronomy has been a real eye-opening experience for us,” he laughs at the unintended pun. “That’s been exhilarating, but at a more practical level, we’ve been able to leverage off of a lot of the work that’s being done in adaptive optics in astronomy to do much better things for vision science than we otherwise would have.”

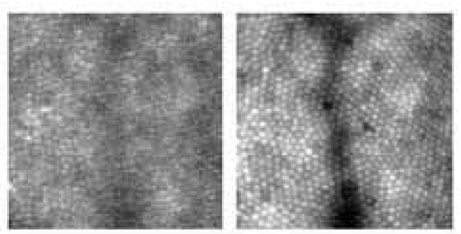
There are two main applications of AO in vision science. One has to do with correcting vision, namely, enhancements to the phoropter. If you’ve ever had an eye test, you know the phoropter—it’s “that binocular thing you look through and the doctor asks you which is better, A or B, one or two,” laughs Williams. Next-generation phoropters incorporating AO will determine your eye correction automatically in a fraction of a second. The technology is currently being developed for commercial instruments, he says.

The second application is to enhance retinal imaging for the diagnosis and treatment of eye diseases. For example, center researchers are using AO to image ganglion cells in the retina, important in treating glaucoma, one of the three major eye diseases. Using AO with fluorescence imaging, scientists are studying the layer of cells called the retinal pigment epithelial (RPE) cells, which are involved in macular degeneration. “Nobody had been able to see RPE cells in living eyes before,” says Williams.

Austin Roorda at UC Berkeley and colleagues are working to track cells one at a time in a living retina. “This ability will be especially important in the treatment of diabetic retinopathy where they ‘zap’ portions of the retina with a laser beam to try to stop proliferation of blood vessels,” explains Williams. “It may be possible to deliver this light much more precisely in a way that does much less damage to the eye.”

CfAO allowed vision science groups to build and maintain engineering expertise in AO, something that would not ordinarily be affordable for vision labs, says Williams. “The budgets would be prohibitively large—outside the scope of a typical NIH grant. Having the center helped us to jump-start this area of research,” and it subsequently led to funding for two major research initiatives.

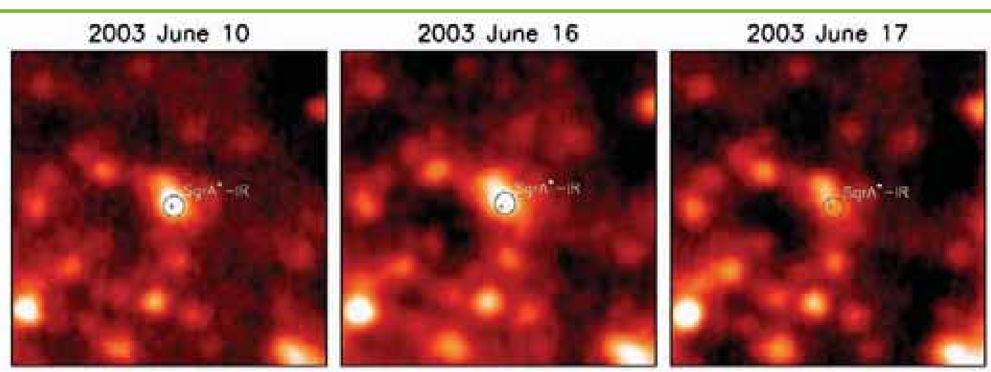
But the center mode of operation is not for every scientific project. What Williams worries about is over-hyping the team science. “What you need is a mix—and I don’t know what the right balance is. It’s very important to maintain both modes,” he stresses. “It has to be grass roots, not top down. When you start to mandate something, that’s when you lose the magic.”



Living human retina. The main factor limiting high resolution imaging of the living human retina is blurr caused by aberrations in the eye’s optics. Adaptive optical techniques work well to correct the aberrations. This pair of images shows the improvement offered by adaptive optics (right). Image: Austin Roorda

AO HELPS DETERMINE MASS OF THE BLACK HOLE AT THE CENTER OF THE MILKY WAY

Adaptive Optics and the Keck Observatory were used to take very high resolution images of stars near the center of our own galaxy and to track their movements, a feat that enabled UCLA astronomer Andrea Ghez to estimate the mass of the black hole around which they orbit (a whopping 3,700,000 times the mass of our Sun). These results have provided the best evidence yet for a supermassive black hole at the center of the galaxy, says Ghez.



This sequence represents the first detection of infrared light from plasma falling onto the supermassive black hole at the center of the Milky Way galaxy. The location of the black hole is marked with a cross and the newly detected infrared source is encircled and labeled as SgrA*-IR. The brightness variations reveal that the plasma is much more energetic than previously believed, showing that violent events occur almost continually. Image: A. Ghez et. al, UCLA/W.M.Keck Observatory

EDUCATION PROJECT YIELDS RESEARCH DIVIDENDS: EXPERIMENT IN INQUIRY-BASED TEACHING

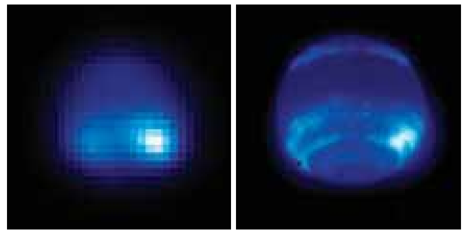
What started as a workshop opportunity for graduate students has led to unexpected dividends for researchers at the Center for Adaptive Optics and even for the university as a whole.

It was the brainstorm of education director Lisa Hunter to engage graduate students at the center in a workshop on how to teach inquiry-based learning of science for advanced high school students and undergraduates, in a process involving staff from the nearby San Francisco Exploratorium. Inquiry-based learning refers to learning science in the way that scientists actually think and work: by posing questions, designing and conducting experiments, and analyzing results.

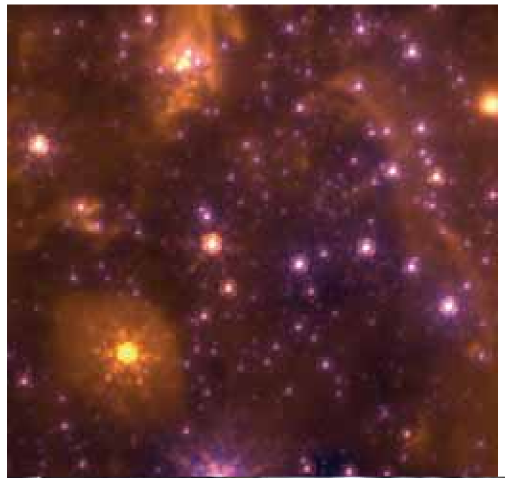
Teaching science in this way has captured the imagination of graduate students and cultivated ideas that they have applied in their own research. It has generated a sense of community and has become “a platform that unites the whole center,” notes CfAO director Claire Max. It also led to a bit of serendipity.

Through the workshop, a postdoc from astronomy met a graduate student in vision science and ended up helping to solve a problem with an optical system in the vision science lab.

The inquiry-based teaching experience has been made possible by long-term funding from the center grant. It led to the creation of a graduate course in the education department specifically for science and engineering graduate students.



Neptune observed in the near-infrared (1.65 microns) with and without adaptive optics. Neptune is the outermost of the giant planets in our solar system, but also has the most dynamic and rapidly-changing weather patterns. This near-infrared image is primarily sensitive to such high-altitude clouds, which appear bright against the darker disk. Adaptive optics allows ground-based telescopes to monitor Neptune’s evolving weather systems and to use spectroscopy to probe different altitudes in its poorly-understood atmosphere. Image: CfAO



Left: Narrow-field image of the Galactic Center. Exposures were obtained at 3.8 and 2.1 micron wavelengths, assigned a color, and combined to make a false-color image. Image is 10 arcseconds in size. Photo: W. M. Keck Observatory

Below: Star Trails Over Gemini North in Mauna Kea, Hawaii. Approximately 2 hours of stacked exposures of the summer sky over Gemini North. The setting moon provided light on right of dome and twilight provides a glow to the left side of dome, a small red light provides highlight on center of dome. A star field has been offset by about 30 minutes to show individual stars separated from trails revealing Scorpius and Sagittarius over the Gemini dome. Photo: Gemini Observatory

ADAPTIVE OPTICS IN THE SEARCH FOR PLANETS IN OTHER SOLAR SYSTEMS

Almost 200 planets have been discovered around nearby stars—not by seeing any light from the planets themselves, but rather, by watching the effect of the gravitational pull of the planet on the star.

Starlight is so bright that it swamps the light reflected from an orbiting planet. As a result, none of the planets in other solar systems has yet been seen directly, so scientists have been largely unable to analyze the composition, atmosphere, temperature, and other characteristics to see if these worlds might support life.

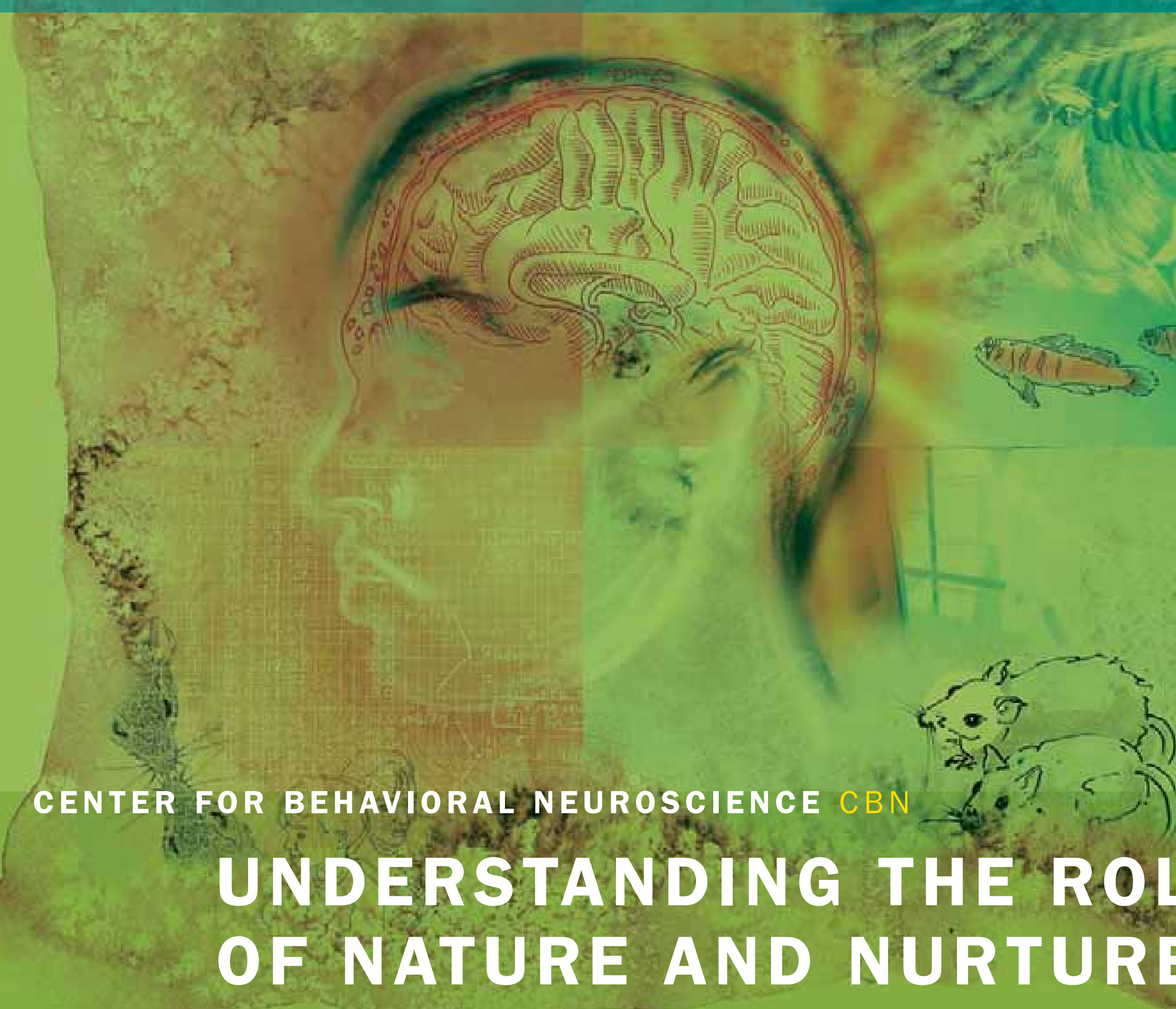
CfAO researchers are part of a team developing an AO system to cancel out that bright starlight and hunt for planets in other solar systems for an international telescope facility called the Gemini Observatory, which operates two 8-m telescopes, one in the Chilean Andes at Cerro Pachon, the other on Hawaii’s Mauna Kea.

When the Gemini Planet Imager is built, it will be “probably the most advanced adaptive optics system in the world,” says center investigator Bruce Macintosh, a physicist at LLNL, the lab leading this effort.

Parts of the system are under development at different partner institutions—the infrared spectrograph at UCLA and the precision interferometer at the Jet Propulsion Laboratory, for example. The LAO at UCSC will assemble and test the instrument before taking it to its final destination, likely the southern Gemini telescope, in about 2012.

“There is no one institution, even LLNL, that could build a system like this,” says Macintosh. “We really need this collaborative, multi-institution team. It was through the framework of the center that all of us started collaborating on the project.”

BEHAVIORAL NEUROSCIENCE



CENTER FOR BEHAVIORAL NEUROSCIENCE CBN

UNDERSTANDING THE ROLES OF NATURE AND NURTURE IN ANIMAL BEHAVIOR

Mating. Aggression. Fear. Researchers at the Center for Behavioral Neuroscience (CBN) are trying to understand the basic neurobiology in animals involved in emotional responses such as these.

Above: Voles. Much of the work on social bonding behavior, or "affiliation," comes from studies of these animals.

Work in the center is helping to shed light on the roles of both nature and nurture in animal behavior. One important outcome is the understanding that hormones like vasopressin and oxytocin play important roles in the forming of social bonds and more generally, in the processing of social information.

Although researchers are still a long way from applying very many of the results to human beings, the hope is that this work "will be the underpinning for new drugs for things like autism and depression," among other conditions, says center director Elliott Albers, Regents professor at Georgia State University (GSU), the headquarters for CBN. In addition to GSU, the partnership includes Clark Atlanta University and Emory University, Georgia Institute of Technology, Morehouse College, Morehouse School of Medicine, and Spelman College.

Much of the work on social bonding behavior, or "affiliation," comes from studies of hamster-sized rodents called voles. They provide a good model for affiliation studies, explains Larry Young of Emory University, because one species of vole is very highly social and takes a life-long mate, while another species is not monogamous. "So, we can do comparative studies," says Young. "They look the same, but the behavior is very different, and we can look in the brain and find things that are different between the two species that might explain that difference in social behavior. The voles give us an opportunity to understand what that neurochemistry might be."

The researchers have found that genes for vasopressin (AVP) and oxytocin (OT) regulate social recognition. These hormones act on the brain's reward circuitry to regulate the formation of social attachments between animals. Amazingly, transferring a receptor gene for AVP into the brain increases social or pair-bonding behavior in male monogamous species of vole, and it makes the "promiscuous" male meadow voles monogamous.

Young, who leads the research group at CBN focusing on affiliation, notes that "this research, which was started in the center and has been going on for the past eight years, has really important broader implications for the study of autism, antisocial behavior, and social communication and bonding. It has led to a much larger set of research efforts by others that show that these peptides also have some influence in human behavior. They've started to look at things like reading social information from the expressions of others."

In April 12, 2007, Zoo Atlanta officially opened the much anticipated Orangutan Learning Tree made possible with funding from a Center for Behavioral Neuroscience venture grant, the IBM Corporation, and an anonymous donor. Tara Stoinski, a CBN faculty member and scientist for Zoo Atlanta and the Dian Fossey Gorilla Fund, plans to use the tree to learn more about the orangutan's cognitive processes.

There are only 37,000 orangutans in the wild, and understanding their cognitive processes will help researchers understand what they need to survive in the wild. The Orangutan Learning Tree houses a large touch-screen computer. The orangutans will now be able to perform cognitive tasks on the computer screen out in the open where visitors to the zoo can watch. Photo courtesy of Zoo Atlanta

The affiliation group is one of several so-called "collaboratories" in the center that provide a research environment for about 15 to 20 researchers with similar interests.

In the fear collaboratory, led by Michael Davis of Emory, researchers are studying how we learn to be afraid of things. They're looking at how systems in the brain in the region called the amygdala are involved in conditioned emotional responses that lead to fear and anxiety, and the way in which individuals can overcome or unlearn this fear. The results hold promise for helping humans overcome post-traumatic stress disorder (PTSD), phobias, and anxiety disorders.

"The brain is plastic: it's made to change and reconfigure as function of experience. One of those changes is to acquire a response, another is to stop that response if it becomes inappropriate or detrimental," explains center co-director Walt Wilczynski. "If you are frightened by something, and it keeps happening but nothing bad happens to you, most people get used to that—they are no longer frightened, they become habituated to it." For example, when a door slams shut once, you may be startled, but if it shuts over and over again, most people ignore it.

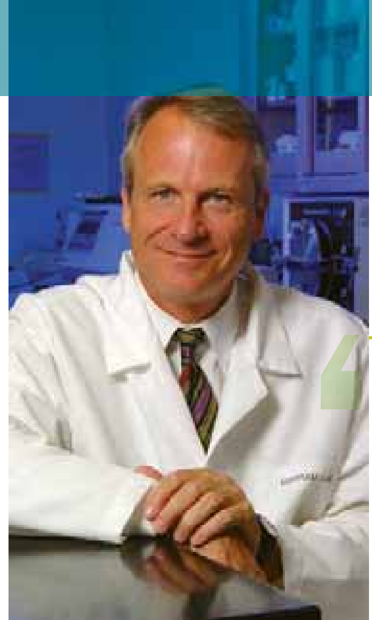
Davis and colleagues have studied a protein in the amygdala, called the NMDA receptor, that's involved in habituation of fear. They have found that a drug that makes this receptor work better, called D-cycloserine, can enhance habituation, enabling people to lose their fear faster. D-cycloserine has already been shown to improve psychotherapy for several clinical disorders, such as fear of heights, fear of public speaking, panic disorder and obsessive compulsive disorder, says Davis, and soon it will be tested in PTSD, in which people can't habituate to a fearful memory. "This is a classic example of basic research in animals on emotional conditioning with potential applications for humans," says Wilczynski.

The leadership of CBN currently is planning for life beyond NSF center funding. One of the main legacies of the center is a major increase in faculty lines devoted to behavioral neuroscience. Funding from the Georgia Research Alliance, a government-university-industry partnership, contributed toward building that infrastructure. Over 30 new faculty lines in behavioral neuroscience have been added across all of the partner institutions.

Young adds that the center has had a major effect on student recruitment to the field. "When I first came, most students didn't want to work in behavioral neuroscience because they didn't consider it to be a hard core science. But within just a few years, we completely turned the tides from behavioral neuroscience being unappealing to being a major draw of students," he notes.

What's going to emerge in the future, says Wilczynski, is more emphasis on translational and clinical research—trying to link basic research coming out of our labs with clinical problems. "And also more connections with industry—not only to see the research have an impact, but also for graduate and postdoctoral training. We have to start looking at a range of career choice for people coming out of our neuroscience graduate program." □

VIEWPOINT



Elliott Albers, director of the Center for Behavioral Neuroscience

FROM THE DIRECTOR

Elliott Albers

"In Atlanta, we have developed a community of investigators—we all know each other, we communicate frequently, and we work together on research and educational projects, so it's been a transformation of how we do science here," says CBN director Elliott Albers, Regents professor at Georgia State University and member of the Neuropsychology & Behavioral Neuroscience Program.

These relationships take a long time to establish, "and that's one reason why the NSF STC program really has it right: it gives you ten years," he affirms.

As a result, "we're increasing diversity in the field of neuroscience, developing courses that never would have happened, and we're doing research projects that wouldn't have happened otherwise," says Albers.

"Resources provided by the Science and Technology Center (STC) program allow us to really develop an inter-institutional interdisciplinary center," says Albers. "It's probably impossible to do that in a situation where you don't have some pool of money that's really dedicated to accomplishing that goal."

"Disciplines receive the budget lines at most institutions—biology or chemistry or whatever. And people don't easily give those resources up to an interdisciplinary group. So without some mechanism like this, it just doesn't happen to any significant extent," observes Albers.

We're still struggling in society to find the right balance between single investigator efforts and team science," says center co-director Walt Wilczynski. "Now and in the future, a lot of science will be generated by single investigator grants. The role of centers is to facilitate people doing that, rather than directing people to work together on a particular problem in a top-down approach." Vehicles developed by CBN to promote collaboration, like venture grants and postdoctoral fellows grants, have been key.

Venture grants provide seed money for two or more faculty members to start a collaboration and to obtain preliminary data, which they can then use to write grant proposals to NIH, NSF, or other funding agencies. In this way, no faculty member's research portfolio is funded entirely by the center—an important consideration in promotion and tenure decisions. In the postdoctoral fellows and graduate scholarships grants, the trainees are required to have two mentors, building a bridge between investigators.

"The philosophy of the CBN is that we provide guidance and we can help frame questions in general, but the interactions and particular collaborations are really a bottom-up approach. We facilitate people getting together and we provide resources that provide an incentive for people to collaborate. But exactly what the project is, who those people are, and what their contribution is going to be is really dictated by the individuals involved. There's no way from the top down that you can predict or dictate exactly what an individual should contribute," says Wilczynski.

"There's a big social element in science that's often overlooked, and it's those social bonds that stimulate the collaboration," says Wilczynski.

It's probably not unexpected that a behavioral neuroscientist would analyze team science in that way. Wilczynski laughs and adds, "Just like the studies we do on social bonding, there's a lot of individual variation in that. Some people work extremely well just by themselves and some work extremely well as part of collaborative teams. And we've had both as part of the center."

Photo: High School Institute On Neuroscience program, CBN

MARCH IS DECLARED BRAIN AWARENESS MONTH IN GEORGIA

On March 7, 2007, Governor Sonny Perdue signs a proclamation officially declaring March "Brain Awareness Month" in Georgia, making it the first state to officially dedicate a month to brain awareness, according to CBN. From left: Kerry Ressler and Rebecca Rosen of Emory University, CBN Director Elliott Albers of Georgia State University, Governor Perdue, and Kyle Frantz, Ann Murphy, Laura Carruth, and Michael Black of Georgia State University. The proclamation resulted from collaborative efforts between the CBN and the Atlanta Chapter of the Society for Neuroscience. Photo courtesy of Governor Sonny Perdue's Office

NEWS WATCH

CBN RESEARCHERS EXPLORE FACTORS IN EMOTIONAL RESILIENCE

Why do some individuals seem to overcome trauma or setbacks without difficulty, while others struggle to cope? A fundamental understanding of resilience and coping is going to be an emerging story in the next several years, both in the CBN and elsewhere, predicts CBN co-director Walt Wilczynski. "What are the mechanisms that protect one individual's brain from responding inappropriately or counterproductively? If we understood what the basic systems and parameters were that allowed some individuals to be resilient, we could develop strategies to keep people healthy, not just treat disease. That's a trend for the future."

BRAINS RULE AT ANNUAL NEUROSCIENCE EXPOSITION

In partnership with Zoo Atlanta, CBN reaches out to thousands of kids and adults during its annual spring Exposition, the largest public education event of its type in the country, according to the center.

Visitors learn about the brain and behavior through interactive booths on a range of topics from brain anatomy to learning and memory. Kids can don a pair of gloves and touch a real brain.

Photo: Brains Rule! Neuroscience Exposition, CBN

They can take an EEG to see their own brain waves. At another station, they see what happens to the brain during sleep.

"The Expo was fantastic this year," says CBN educator and exposition director Kyle Frantz. "Having it on site at the Zoo works very well because we can integrate some of our neuroscience activities with the animal exhibits. It attracts an extra crowd to the Zoo," she notes.

This year's public event included 35 different education stations, made possible through the efforts of more than 200 volunteers, including undergraduates, graduate students, postdoctoral fellows, and faculty members from Georgia State University and CBN partner institutions.

"This is not just outreach," notes CBN co-director Walt Wilczynski. "We try not to compartmentalize things at the center. This is a public outreach event but it's also tied to graduate and postdoctoral training and undergraduate education. The students and postdocs come up with these displays based on their research interests." Frantz affirms that the program contributes to CBN's science education research mission, which aims to identify the best approaches to teaching and learning neuroscience in diverse settings.

In addition to sponsorship by CBN and Zoo Atlanta, support for the Expo was provided by the Dana Alliance for Brain Initiatives and a 2007 Public Education Outreach Initiatives Grant from the American College of Neuropsychopharmacy.

Photo: Brains Rule! Neuroscience Exposition, CBN

EDUCATION & OUTREACH

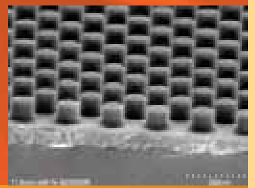
EDUCATION AND OUTREACH

CBN has developed an array of programs at many levels to prime the pipeline in neuroscience. Through programs such as Brain Camps for middle school students, the Institute on Neuroscience and a "Brain Bee" competition for high school students, and the BRAIN summer research program for undergraduates, the center is reaching out to all educational levels, in addition to targeting the general public, including K-12 teachers. Teacher workshops and Brain Camps are coordinated by science educator Laura Carruth. The Institute on Neuroscience is led by Kyle Frantz. Undergraduate and Graduate educational programs are led by Karen Falkenberg and Don Rainnie, respectively. For more information, visit www.cbn-atl.org

BEHAVIORAL NEUROSCIENCE

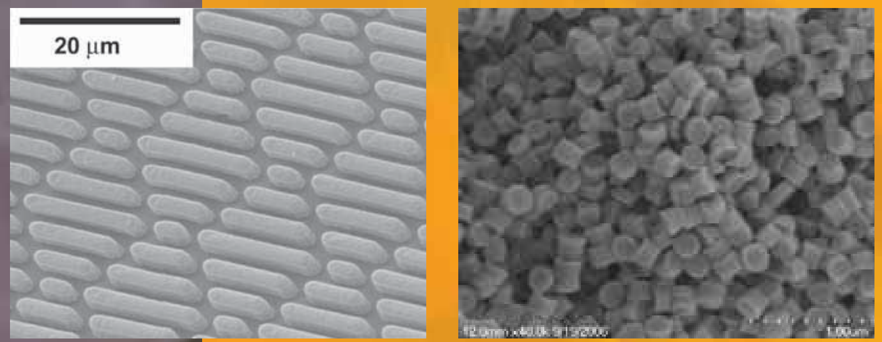
SOLVENTS AND PROCESSES

CENTER FOR ENVIRONMENTALLY RESPONSIBLE SOLVENTS AND PROCESSES CERSP



SOLVENT-FREE METHODS OF CHEMICAL SYNTHESIS LEAD TO CANCER THERAPIES, NCI CENTER

"Once you get scientists and engineers working in an interdisciplinary manner, you can't contain it," laughs Joseph DeSimone, director of the Center for Environmentally Responsible Solvents and Processes (CERSP) and the William R. Kenan, Jr. Distinguished Professor of Chemistry and Chemical Engineering at the University of North Carolina, at Chapel Hill (UNC-CH).



"Things have evolved certainly beyond the original scope of our center. Starting off with a focus on sustainability and green chemistry has led us into new cancer therapies and imaging agents," says DeSimone.

CERSP's initial goal was to establish the scientific fundamentals necessary to enable liquid and supercritical CO_2 and solvent-free processes to replace aqueous and organic solvents in a large number of key processes in our nation's manufacturing sector.

More than 30 billion pounds of organic and halogenated solvents are used worldwide each year as manufacturing process aids, cleaning agents, and dispersants. Considerably more water is used and contaminated in related processes.

In the future, manufacturing and service industries must work to avoid the production, use, and subsequent release into the environment of contaminated water, volatile organic solvents, chlorofluorocarbons, and other noxious pollutants.

CERSP is a multi-disciplinary effort with participants from five academic centers and two national laboratories: UNC-CH, North Carolina State University, North Carolina A&T University, University of Texas at Austin and the Georgia Institute of Technology.

CERSP codirector Ruben Carbonell points out that many companies are focusing today on finding alternatives to fluorinated surfactants that break down into a compound called perfluorooctanoic acid, or C8, which accumulates in the body and may pose a health threat. Center researcher Keith Johnston and colleagues are looking at alternative surfactants that have different chemical structures that won't bio-accumulate and have good surfactant properties.

The manufacture of Teflon™ is a case in point. The conventional process uses a C8 surfactant to make an emulsion. An alternate synthesis, developed in the center, doesn't require any surfactants, says Carbonell. It's done completely in CO_2.

The process has been commercialized. "There's a DuPont plant in Fayetteville, North Carolina that makes Teflon™ in carbon dioxide. The technology, developed in DeSimone's lab, was licensed by DuPont several years ago," says Carbonell. One of the advantages is a smaller environmental footprint. "There are no surfactants at all—it's just the monomer reacting in the presence of carbon dioxide. The particles grow, and when you reduce the pressure, the particles fall out of solution, completely dry and with no surfactant," says Carbonell. "And the process should be cheaper because there's no need to evaporate water at the end of the process. One of the major energy consumption points in making any polymer, but particularly Teflon-based materials, is that they're made in aqueous solvents or aqueous-organic emulsions. If you make it in CO_2 and depressurize, the polymer powder comes out completely dry. And the CO_2 is recycled for use."

New surfactants in development at the center are now of interest to companies wanting to do tertiary oil recovery using carbon dioxide, Carbonell adds. One of the ways of getting more oil out of the ground is to inject high pressure carbon dioxide into spent oil fields, using detergents to reduce the surface tension that's holding the oil globules inside the rock. For this purpose, surfactants that are soluble in carbon dioxide are needed. "One thing leads to another and then this problem of oil recovery that was not of any interest at all when the center began is now of great interest," notes Carbonell. Agility seems to be a recurring theme at CERSP. Carbonell notes: "We've been able to transform ourselves pretty readily."

Green Chemistry Pays Dividends for Research on Cancer Therapy

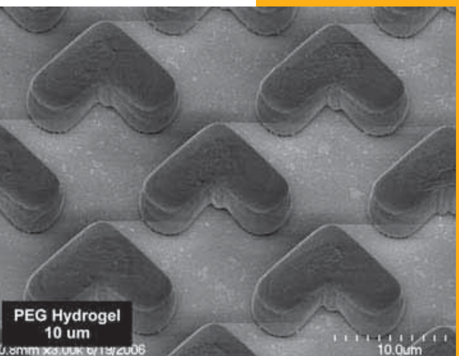
"What's curious—what has evolved—is that research on solvent-free methods has led to a new technology for making cancer therapeutics that we didn't anticipate," says DeSimone. It has led to us landing one of the eight centers of nanotechnology excellence funded by the National Cancer Institute, a $24-million center. It just shows the unbounded opportunities that happen when you get a bunch of good people together from different disciplines that are open-minded."

Initially, CERSP researchers were using carbon dioxide as a solvent-free method for making new fluoropolymers. They made some new materials that turned out to be excellent molding materials. The method called PRINT™—Particle Replication in Non-wetting Templates, was published in July 2005 issue of the Journal of the American Chemical Society.

The process begins with a liquid fluoropolymer that can wet surfaces very well. It is poured into a master and irradiated to make an array of tiny molds, not unlike a little ice cube tray, which can be used subsequently for mass production of particles of uniform size and shape, creating features of nanometer size.

The breakthrough came when they realized these particles could be used in medicine. "We use these particles as basically a 'delivery truck' for therapeutics and imaging contrast agents," says DeSimone. "Because it's such a gentle technique—we're just molding—we can easily paint the particles with targeting ligands, like monoclonal antibodies. And so now we have particles that can have on the surface an antibody and in the interior have a therapeutic. We're beginning to develop the tools and methods for scale-up and we've now molded particles and done our first pharmacokinetic studies in mice to see the biodistribution of these organic carriers," says DeSimone. □

STARTUP COMPANY



LIQUIDIA MAKES NANO-ENGINEERED PRODUCTS FOR LIFE SCIENCES, ENERGY, AND MATERIALS SECTORS

Joseph DeSimone and his colleagues from CERSP at the University of North Carolina at Chapel Hill have created a startup company called Liquidia Technologies based upon the PRINT™ nanoscale molding process, targeting applications in the life sciences, energy, and materials sectors.

Founded in 2004, Liquidia is working to precisely design and manufacture micro- and nano-structures in bulk, with particle sizes ranging from tens of nanometers to tens of microns. These structures may take multiple forms, including particles and patterned films.

Liquidia has partnerships with several major corporations to provide gram quantities of material for prototyping and feasibility studies. Examples include supplying particles that might become part of a medical device or an active layer in a display, and making fuel cell membranes or active layers in photovoltaic devices.

The company has grown to 24 people as of spring 2007 and has raised a total of $25 million, says co-founder and senior scientist Ginger Denison Rothrock, a former graduate student at CERSP. Located in Research Triangle Park and currently squeezed into 4,000 sq ft—"quite cramped but loving it"—the company is scheduled to move into a 17,000-sq-ft facility in August 2007.

In the life sciences, Liquidia is using the PRINT™ process to make particles containing therapeutic drugs that may be used to deliver medicine to a target site and gradually release it. The PRINT process gives precise control over particle size, shape, composition, modulus, and surface properties. According to the company, "Liquidia is the only company in the world that can independently tailor these variables simultaneously in the creation of engineered drug therapies." Rothrock notes that discussions are underway with three major pharmaceutical companies for prototyping projects.

Ginger Denison Rothrock, former graduate student at CERSP and co-founder of Liquidia

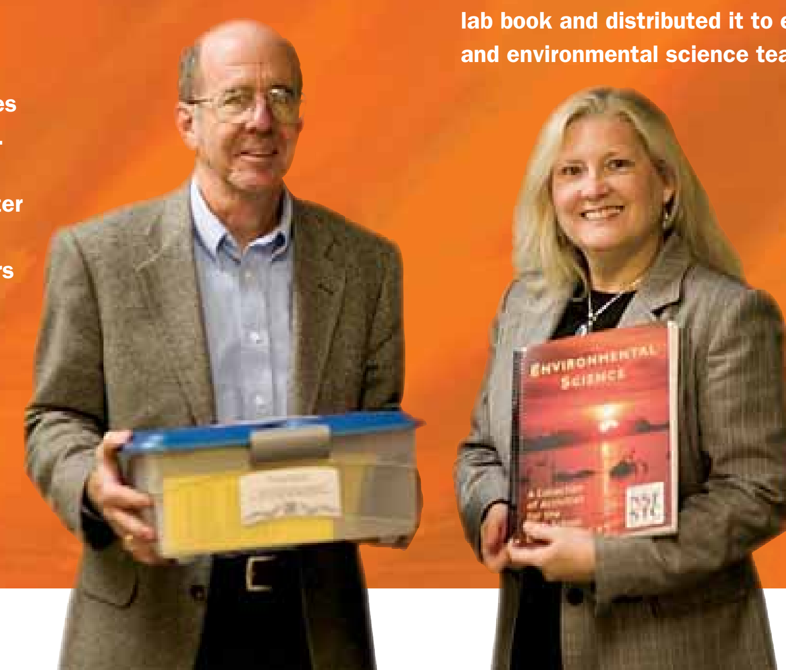
THE SCIENCE HOUSE

The convergence of three forces in North Carolina has resulted in a resounding success for K12 education that has reached thousands of teachers and their students. The ingredients: CERSP, The Science House, and a new required course for high school students in the state of North Carolina.

By coincidence, just about the time that CERSP was getting started, North Carolina adopted a new course on earth and environmental science that was required for graduation from high schools in the state. It was a brand new course: the curriculum had been written but the teachers were not trained to teach it and there were very few resources linked to the curriculum.

Enter The Science House, a K12 outreach program of the College of Physical and Mathematical Sciences at North Carolina State University. The Science House organizes curriculum projects, student camps, and science enrichment programs, and it develops teacher training programs reaching a few thousand teachers a year. It is led by physicist David Haase in conjunction with 12 full-time education staff involving five offices across the state of North Carolina.

With the adoption of the new course and the formation of a center on environmentally responsible solvents and processes, the players saw an opportunity that linked a real need in North Carolina schools and the general idea of green chemistry that featured prominently in the NSF Science and Technology Center (STC).



Experts from The Science House partnered with CERSP faculty to help determine which core topics in the STC should be developed for K12 outreach. They developed a lab book and distributed it to earth and environmental science teachers with a guide that showed how those materials linked to the North Carolina and Texas curricula.

Haase emphasizes the value of this kind of partnership and notes, "We'd like to do this for more centers."

The materials were distributed to some 4,000 teachers in North Carolina and Texas. They prepare teachers to teach the lab program and show them how to do the labs. "Some of the lab equipment vendors partnered with us," says Haase, "so that the teachers would walk away not only with the laboratory manual but also some materials they could use in their own classrooms."

The STC provides about $150,000 per year to The Science House, which in total is has an annual budget of about $1 million per year.

Center: Physics professor David G. Haase (left,) director, and Mary Louise Bellamy of The Science House at North Carolina State University

A CONVERSATION WITH THE DIRECTORS

Joe DeSimone & Ruben Carbonell

One of the characteristics that distinguish CERSP is its leadership in center management. "We were able to get our center up and launched very quickly," says center director Joe DeSimone. He identified the tools and brought in the infrastructure to facilitate the startup process, with a codirector and a deputy director to form a team of three leading the center.

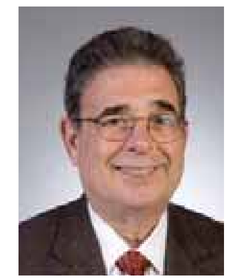
"Once you get through the launch phase—which is a heck of a lot of work," he laughs, "almost like a startup company—and you get everyone marching in one direction, then it's actually a little easier sailing. Then you just have great people doing fabulous science—and nothing speaks more clearly than their science."

An executive coach was brought in to help the team members analyze and characterize their different thinking styles. The idea came from DeSimone's entrepreneurial background, gained by launching startup companies. The coach educated the team on different communication and working styles and how to use those tools to engage with others.

DeSimone's style is to engage in blue sky brainstorming to identify options and then to focus in on the research targets with great intensity. "We've been expansive in our thinking to consider what could be done, and then we narrow in on it and come to closure."

The center recently has gone through another cycle of this process by means of workshops to identify new directions to see where the team could apply its expertise in a new arena. "We're morphing, we're looking at life sciences, alternative energy and power sectors, green chemistry, innovation, and entrepreneurship—looking at ways for the center to continue to be sustainable."

CERSP director Joseph DeSimone



CERSP co-director Ruben Carbonell

CERSP co-director Ruben Carbonell points to the complementary skills sets in the management team as a key factor for success. "Joe is a creative chemist, I'm a detail-oriented engineer," he laughs. "That's been a complementary set of skills."

Deputy director Everett Baucom has brought extensive industry experience to the team, which has allowed the directors to focus on research issues.

Carbonell reflects upon the benefits to faculty of participating in the center: "Those who have been with the center since 1999 have learned the advantages of doing collaborative work. One of the legacies of the STC is that faculty become better trained in a sense because they see the bigger picture, beyond the normal confines of their discipline. And as a result of that, they become leaders themselves.

"I can see among my younger colleagues that, after seven or eight years of being with us, they're now becoming the leads in new proposals that involve centers. That's been interesting to watch. They have a better appreciation of what it takes to run them, and of what they can do compared to single investigator work. They become, then, a source of new ideas for other faculty. That's not a legacy that maybe NSF counts, per se—obviously it's a difficult thing to quantify. We're struggling with how to report that. But it's an interesting observation."

SOLVENTS AND PROCESSES

NANOBIOTECHNOLOGY

NANOBIOTECHNOLOGY CENTER NBTC

SMALL WORLD, BIG SCIENCE

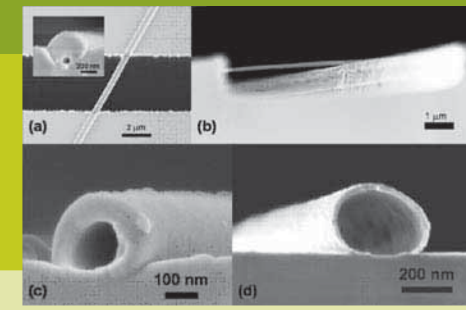
The dream of developing tools and processes to interact with biosystems on the scale of individual cells and biomolecules is being realized by researchers at the Nanobiotechnology Center (NBTC).

"We're studying the ways cells communicate with their environment at the molecular level," says center director Harold Craighead, professor of applied and engineering physics at Cornell University and the Charles W. Lake, Jr. Professor of Engineering. "We're developing new devices to allow us to investigate these properties at the finest level of detail, approaching single-molecule responses." Toward this end, the center fosters a close collaboration between life scientists, physical scientists, and engineers.

Center researchers have developed cell cultures "on a chip," that is, cultures in a laboratory system that can more accurately model the response of humans to pathogens or therapeutic drugs, for example. These systems integrate different types of human cell tissue in a biological test platform that may significantly reduce the amount of animal testing involved in early-stage screening of new drugs.

Another group is working on a laboratory model of the blood-brain barrier, which protects the brain from exposure to harmful substances in the blood stream. NBTC associate director Graham Kerslick explains that the researcher team can grow the required cell types on a sort of scaffold—a micropatterned polymer membrane—and can model how the barrier works when presented with various biomolecules, toxins, or drugs.

NBTC research by Kelvin Lee and colleagues on techniques to detect a suite of compounds associated with neurodegenerative diseases such as Alzheimer's may yield a rapid diagnostic test for the disease. Currently, there is no definitive way to diagnose the condition in humans while still alive. The researchers are developing methods to detect a set of proteins in spinal fluid as a signature of the disease.



Electrospun polymer nanofibers were used as templates for creating nanochannels in a variety of materials. (a) Top-down view of suspended sputtered glass nanochannel, with cross-section on bare silicon. (b) Side view of suspended glass nanochannel . (c) Cross section of chemical vapor deposited glass nanochannel. (d) Cross section of evaporated aluminum nanochannel. Image: NBTC, BDA2

Biological imaging technology has gained a boost from the development of a new kind of nanoparticle called Cornell dots, or CU dots for short. These silica nanoparticles may be used in displays, biological imaging, optical computing, and sensors. CU dots offer many advantages over the previous technologies for imaging: not only are they many times brighter than single fluorescent dye molecules, they don't fade as much as the alternative, called quantum dots. They provide a more constant light source and are less expensive and more inert than quantum dots.

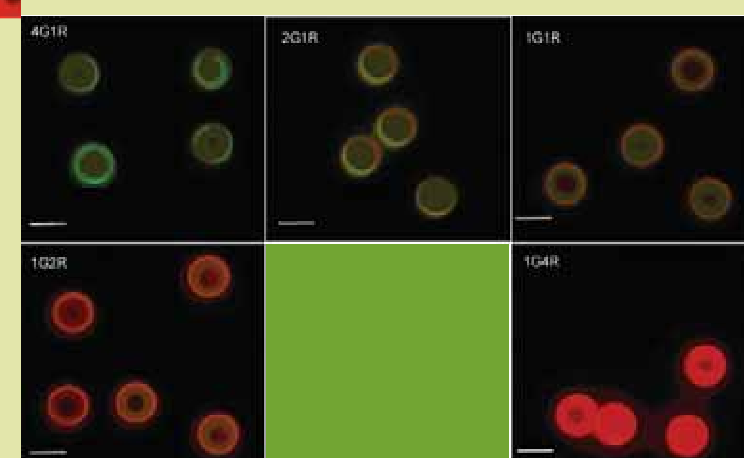
The brightly glowing particles contain fluorescent dye molecules surrounded by a protective silica shell, forming a package of about 25 nanometers in diameter. The surface may be coated with ligands to allow the particles to attach to species of interest. Center co-director Harvey Hoch, chair of plant pathology at Cornell, Geneva, N.Y., notes this development is a "significant contribution. It will provide a good marker for cell studies—it's a nice tool for microscopists and cell biologists." Hoch is a leader in using micro- and nanofabrication technologies to address questions in biology.

Kerslick notes the CU dot technology has been licensed by Cornell to a startup company called Hybrid Silicon Technologies, Ithaca, which is looking to commercialize the capabilities of fluorescent silica nanoparticles for biological imaging applications.

On another front, a group led by Dan Luo of Cornell has created "nanobarcodes" that can be used to rapidly identify genes, pathogens, drugs, and other chemicals. The technique uses multicolor fluorescent tags made out of synthetic DNA that attach to the target species. Under UV light, the tags produce a combination of colors unique to the species of interest, and can be read by a computer scanner or microscope. The method has been shown to distinguish several different pathogens simultaneously.

Luo, a professor of biological and environmental engineering, has utilized short strands of DNA molecules that can self-assemble into unusual shapes. By linking these DNA structures to polystyrene molecules, he created tiny geodesic spheres about 400 nm in diameter that could carry drugs into cells, among other potential applications. DNA buckyballs created by Luo were selected by R&D Magazine as one of the 25 "most innovative products of 2006" in the Inaugural MicroNano 25 competition. The winners were featured the August 2006 issue of R&D.

Luo's research on using DNA to construct new materials and nanodevices is being commercialized by an Ithaca startup company called DNANO Systems. The company recently won second place at the 7th Cornell BR Ventures Business Idea Competition. The company has also received funding from NYSTAR (New York Office of Science, Technology & Academic Research), which supports technology development and commercialization in New York State. □



Merged fluorescent colors (pseudocolors) of nanobarcodes from individual polystyrene microbeads under a fluorescent microscope. Note that only two colors were used in the barcodes. (from Nature Biotechnology, 23, p. 883, 2005) Photo: NBTC, BDA7

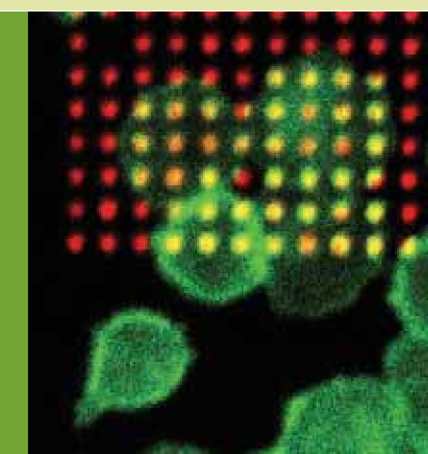
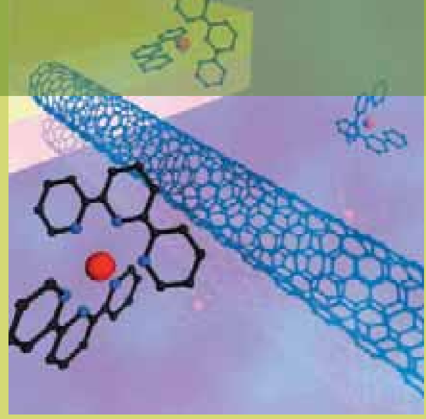
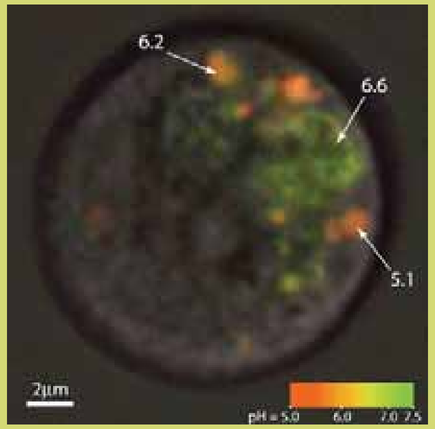


Image shows cell receptors that mount on a cell's surface and detect foreign bodies like allergens. Patterned "nano-keys" allow receptors to cluster in a way that activates the cell's inner machinery. Photo: Wu, Holowka, Craighead, and Baird

Nanobiotechnology Center co-director Harvey Hoch, chair of plant pathology at Cornell, Geneva, N.Y.





CU dots. Preliminary imaging data showing pH measurements made on RBL mast cells using 70 nm CU dot-based sensors. Image: NBTC, NCB1

VIEWPOINT

FROM THE DIRECTOR

Harold Craighead

Harold Craighead has a unique vantage point on the evolution of an NSF Science and Technology Center. He was the original director of the Nanobiotechnology Center when it was founded in 2000, then left to become interim dean of engineering, returned as center codirector, and now is director again.

He reflects on the changes since the founding of the center. "We were just 'wishful thinking' back then. Now, we're part of a brand new nanotechnology building, we have facilities and dozens of investigators and staff. We have people collaborating who didn't even know each other before. Now, students take for granted they will work in an interdisciplinary setting—they're going to combine cell biology, mechanical engineering or physics, immunology. A generation of students has gone through now, and it's just understood."

"Our students are highly sought after, getting jobs in government labs, industry, and academic settings," says Craighead. "We're producing a type of student that didn't really exist when we started. Students are in the vanguard leading a transformation of the academic environment. We publish papers, but the influence goes on much longer in the students that go out into the workforce," he emphasizes.

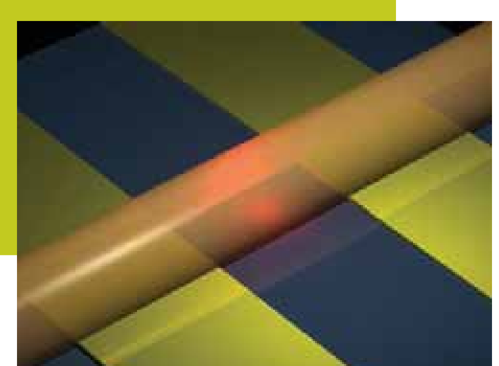
"My main mission is to keep the organization functioning so people can do their work. My motivation is to facilitate a broader range of work than I could do as an individual."

"The reality is, it takes a lot of diverse skills and efforts to make this happen," says Craighead. "Energy, negotiation, communication, motivation, intellectual curiosity, and commitment are the ingredients."

NANOLAMPS LIGHT THE WAY TO NEW FLEXIBLE ELECTRONICS DEVICES

Center researchers have produced microscopic "nanolamps"–light-emitting nanofibers about the size of a virus or bacterium. It's one of the smallest organic light-emitting devices to date, made of fibers just 200 nanometers wide. Potential applications include sensing, microscopy, and flat-panel displays. The work was published in the February 2007 issue of Nano Letters.

At right: An illustrated closeup of an electrospun fiber. During experimentation the organic devices gave off an orange glow. Photo: Jose M. Moran-Mirabal



NEWS WATCH

NANOBIOTECHNOLOGY

"IT'S A NANO WORLD" TRAVELING EXHIBITION

What if you could shrink to the size of a cell and zip through a blood vessel, or see what skin and hair are made of at the molecular level?

Thanks to an exhibit developed with the help of the Nanobiotechnology Center at Cornell University, you almost can. Working with the Sciencenter, Ithaca, N.Y., and its contractors, including Painted Universe Inc., also of Ithaca the team created a traveling 3,000 square-foot hands-on interactive museum exhibition that introduces children and their families around the country to the biological wonders of the very tiny.

"It's a Nano World" exhibition has traveled the U.S., even making a stop at Innoventions at Epcot in Lake Buena Vista, Fla., in 2004. The target audience for this traveling exhibition is 5 to 8 year-old children (K-3).

At one station in the exhibit, visitors can view highly magnified photographs of familiar objects like a penny or a bee and uncover photos with decreasing levels of magnification until an easily recognizable photo of the item is revealed. At another station, visitors can stick their hands into a glove box and use special tools to separate out different "cells" based on physical properties. The "Scope on a Rope" station has flexible projection microscopes to let visitors look at their own skin, hair, and clothing, magnified either 30 or 200 times.

The exhibition began touring in Winter 2003, and has been seen by more than 1 million visitors at museums throughout the U.S. The project is primarily funded by the Nanobiotechnology Center (NBTC) at Cornell University through a grant from the National Science Foundation.

"It's a Nano World" will be in Casper, Wyo., at The Science Zone during summer 2007. During fall 2007 it travels to the Austin Children's Museum, and during the first half of 2008, it is scheduled to be at Mobius Kids, Spokane, Wash.

The team created a traveling 3,000 square-foot hands-on interactive museum exhibition that introduces children and their families around the country to the biological wonders of the very tiny.

EDUCATION AT NBTC

Graduate education has received a boost at the center through a graduate-level nanobiotechnology course that is videoconferenced to NBTC partner institutions. The course covers biology basics as well as the principles and practice of microfabrication techniques, with a focus on applications in biomedical and biological research. Students participate in a team design project that stresses interdisciplinary communication and problem solving.

The Nanobiotechnology Center also plays a key role in transferring research to K12 audiences and museums, notes education director Jennifer Weil. "Just giving the raw research materials isn't enough—we need to help researchers to translate these materials and to design effective and appropriate ways to help teachers use them."

Weil has a staff of three dedicated to this mission. One of the programs they lead is a high school internship program over the summer. Ten juniors and seniors come to the center for four weeks in the summer to work on a research theme. Last year, they designed and built a micofluidics device to regulate mixing of chemicals. This summer, plans call for students to model the vascular system of a plant using microfluidics systems.

The center's Science Kit lending library is a source of science experiments and equipment that K12 teachers may borrow at low cost—only the price of shipping the materials back to the library. During the 2005-06 academic year, these materials reached 108 teachers and 3,036 students in 73 school districts across 16 states, says Weil. For more information, visit http://www.nbtc.cornell.edu/education.htm

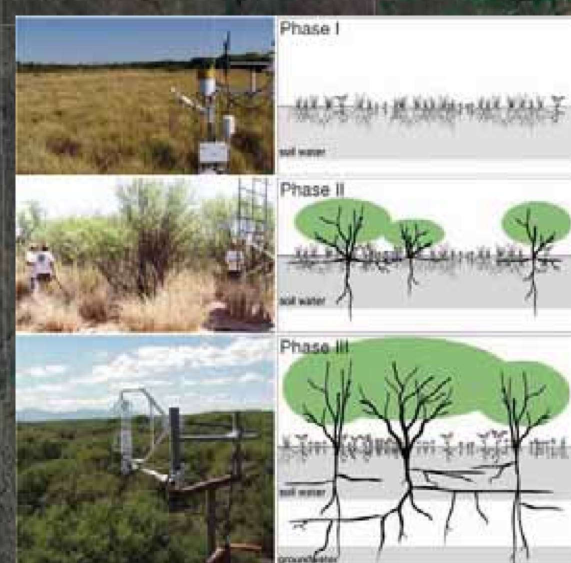
The Nanobiotechnology Center plays a key role in transferring research to K12 audiences and museums, notes education director Jennifer Weil (right).

HYDROLOGY AND RIPARIAN AREAS

SUSTAINABILITY OF SEMI-ARID HYDROLOGY AND RIPARIAN AREAS SAHRA

HOW'S YOUR HYDROLOGIC LITERACY?

Collecting water samples in the Upper Rio Grande of Colorado for geochemical studies on water and salt sources.



SAHRA researchers have found that encroachment of shrubs into grasslands has increased water loss from the sub-surface.

One-quarter of the contiguous U.S. is semi-arid or arid land;

The most rapidly growing U.S. states are in the semi-arid Southwest;

Many rapidly growing countries are concentrated in semi-arid regions of the world;

Climate change and variability are making a growing percentage of the Earth's population vulnerable to drought and flood.

These are just some of the challenges faced by planners and stakeholders in the U.S. and around the globe when it comes to water resources.

Improving the sustainability of these resources is a job that rests with elected officials, water managers, and policy experts at local, state, and national levels. The mission of the Center for Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA) is to furnish new knowledge to support their efforts in this regard.

"Part of the point of a center like ours is to provide understanding and decision support so that those responsible for taking decisions have the information and tools they need," says Jim Shuttleworth, SAHRA director and professor of hydrology and water resources and of atmospheric science at the University of Arizona. "We're trying to aid decision-makers."

The center has identified a slate of "tough questions that require center-mode science, and which are stakeholder-relevant," says Shuttleworth. Among them: What are the costs and benefits of riparian restoration and preservation? Under what conditions are water markets and water banking feasible? What are the impacts of vegetation change on the basin-scale water balance?

SAHRA researchers frame their studies in the context of the river basin—an approach they believe will facilitate the transition of results into practice. The center's primary geographical focus is on two river basins: the Rio Grande/Rio Bravo and the Upper San Pedro river basin in Arizona.

Concentrated along river systems are human population centers, agricultural activities, and regional biodiversity. The San Pedro river basin in Arizona is a case in point. It includes the growing town of Sierra Vista, a military base, and an expanding population. "It's one of the last remaining riparian ecosystems in the desert Southwest—used by migrating birds en route from North America to Mexico," says Shuttleworth. "If there is much more pumping of the groundwater to service the military base and growing township, the riparian ecosystem will disappear."

The San Pedro Partnership brings together over 20 stakeholder organizations to deal with these issues. In 2004, a law passed by Congress defined a timetable for bringing the basin into water balance by 2011, notes David Goodrich, a researcher with the USDA Agricultural Research Service and an adjunct faculty member at the University of Arizona who co-leads the River Systems Macro Theme of the center. SAHRA interacts with the San Pedro Partnership by providing scientific results and models it can use to evaluate possible future scenarios for developing and sustaining the ecosystem.

Center researchers are working to understand the effects of vegetation changes on water resources in the San Pedro basin. In the Southwest in recent decades, shrubs have invaded grasslands; pinyon-juniper and mesquite ranges have expanded; ponderosa pine forests have thickened; and fires and bark beetle infestations have caused large-scale changes. Center researchers have found that encroachment of shrubs into grasslands has increased water loss from the sub-surface. Along river corridors, shrub encroachment has doubled the evaporation, which is primarily derived from groundwater.

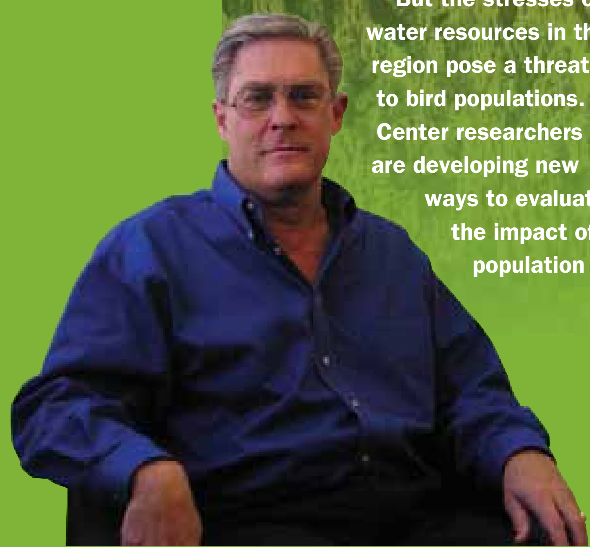
Furthermore, SAHRA researchers have discovered to their surprise that some 50 percent of the river water in the San Pedro comes from monsoon rainfall rather than groundwater, as was previously thought. "There is a great deal of persistence of water in soils along the banks and in shallow sediments that helps to sustain river flow in dry times," says Goodrich. This mechanism is different than in other regions of the country—rivers don't act the same everywhere, he notes. Understanding the mechanisms of groundwater recharge will be critically important to making management decisions in this region.

Increasingly, water markets and water banking are being considered in the Southwest as mechanisms for allocating water resources. The approach requires a detailed knowledge about factors that affect water supply and demand. Center researchers are developing new ways to improve estimates of precipitation and snow pack, and they are shedding light on the factors that affect residential and industrial demand for water. The results are being integrated into models that allow water resource managers to evaluate the potential of market-based mechanisms. "We're getting to the stage that we can run simulated markets on the computer and identify problems before people try to implement these approaches in practice," says Shuttleworth. He notes that state engineers in New Mexico have commissioned the center to do a trial in one of the catchments there and to explore the feasibility of a water market.

"Trading in water is provocative," Shuttleworth acknowledges. "We will hold a demonstration of the system with state officials and stakeholders and critics there who may be apprehensive about it so they can try it and play 'what if' scenarios—'If you do this, that stream will dry up, these people will be short of water, these ones will be fine.' The idea is to take the bite out of the tough decisions by creating something that stakeholders can use to understand what the consequences are."

Landsat image of New Mexico. Photo: Image courtesy of USGS National Center for EROS and NASA Landsat Project Science Office, http://eros.usgs.gov/Imagegallery/

SAN PEDRO: BIRDING HOTSPOT



"People from all over the country flock to San Pedro to view the birds. They bring a lot of economic value to the area in the form of tourism dollars," says SAHRA assistant director James Hogan.

But the stresses on water resources in the region pose a threat to bird populations. Center researchers are developing new ways to evaluate the impact of population and water use on the regional hydrology, how in turn those changes will affect vegetation and bird diversity and abundance, and ultimately, how tourists and residents respond to those changes.

Work by SAHRA researcher David Brookshire and colleagues is aimed at developing these so-called "nonmarket valuation" methods. Brookshire is an economics professor at the University of New Mexico in Albuquerque.

With support from a $385,000 grant from the U.S. Environmental Protection Agency, the researchers have been constructing scenarios based on anthropogenic or climatic changes in the ecosystem and estimating the societal and economic ramifications of those changes.

"What's unique about this project is that the valuation study is directly driven by the science models," says Brookshire. Having access to better underlying science developed through SAHRA has enabled the researchers to "move the state-of-the-art in nonmarket valuation methods significantly forward," he notes. "What SAHRA did was to bring this along at a more rapid pace—the center catalyzed and accelerated this work."

SAHRA assistant director James Hogan

SAHRA researcher David Brookshire and colleagues are developing "nonmarket valuation" methods. Brookshire is an economics professor at the University of New Mexico in Albuquerque.

CONVERSATION WITH THE DIRECTOR

Jim Shuttleworth

WHY A CENTER?

"It takes a big proportion of my time just to run the show," says SAHRA director Jim Shuttleworth. "I've had to give up a fair amount of my teaching and research.

"But on the other hand, what excites me is that we really do have benefit, we do address major problems that really are going to be beneficial. We're going to leave a legacy, and the world will be a better place for having done this job. And to see the young people that are growing in the job and getting more and more capable."

Having a center helps to provide the glue that makes things happen, he says. "You need a glue—and the glue is money. It motivates people to make the effort and spend the time learning the language of other disciplines. How else would you get an economist talking to a hydrologist? You wouldn't. But you can if you define a problem that needs the both of them, and you provide the resources. And when you provide resources for a more sustained period, you can hit harder problems.

"I would never have been able to write a proposal to study water markets, because the problem is too multidisciplinary. But once you have established the team, the credibility, and the capability, you can start to write proposals like that."

Echoing those sentiments is David Goodrich, a researcher with the USDA Agricultural Research Service and an adjunct faculty member at the University of Arizona who participates in SAHRA. "I've done a fair bit of interdisciplinary work, and I saw the center go through some of the same pain that we did when you get economists, social scientists, and hydrologists in a room together. They don't know how to talk to one another," he says.

"Getting this mix of disciplines to address complex physical, social, and economic issues wouldn't happen without a center. I could never go into the literature of economics, for example, and get up to speed. There are very few Renaissance people around. I can't get up to speed in plant physiology, riparian ecology, avian science, and economics—all of those things. But we can put those pieces together in an intelligent fashion in a center."

Moreover, the longer horizon of a center grant is essential for projects involving interactions with community and government officials, says Goodrich. "You can't build trust with decision-makers in the three-year time frame of a typical NSF grant."

SAHRA director Jim Shuttleworth

SAHRA ENGAGES CITIZENS IN SCIENCE PROJECT

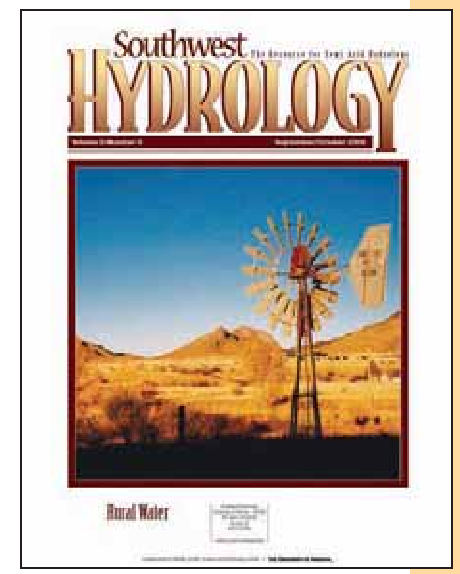
In many towns, rainfall totals are measured at the local airport or other official weather stations. But those data may not reflect how much fell in particular neighborhoods. "What rainfall actually hits the ground—and its variability—is really a big unknown," says James Washburne, SAHRA associate director for education. A project managed by the center is engaging volunteers in an effort to fill in the knowledge gap. Data collected by volunteers from over 600 rain gauges in Arizona are posted on the Web at www.rainlog.org. The site has an interactive map displaying rain totals for each of the gauges by day or year.

Data from more widespread observers, particularly in the mountains, are particularly important because rainfall amounts change dramatically as you go up in elevation, explains Washburne. "Typically, we've had a rain gauge at the bottom of the mountain and at the top, but never really in between to address what the real differences are in rainfall amounts across a range of elevations. These data have the potential to address that question."

SOUTHWEST HYDROLOGY MAGAZINE AND WEB SITE

Outreach and education are a particular emphasis of SAHRA, and a regional magazine published by the center features prominently in that mission.

"We recognize that we can produce good science and good tools, but ultimately, you have to involve the people who are actually going to use these tools," says Shuttleworth. "So we have an enormous outreach program. We're trying quite hard to share results from other sources in addition to center results," he emphasizes.



Southwest Hydrology is a trade magazine published by SAHRA to inform and connect the water communities of the semi-arid and arid Southwest. It is written by and for consultants, regulators, researchers, water managers, lawyers, policymakers, and industry representatives who work with water issues in semi-arid regions. The magazine is distributed free of charge six times per year to nearly 6,000 subscribers in the Southwest and throughout the U.S.

In 2006, it received awards from the Tucson chapter of the International Association of Business Communicators, from the Southwest Region of the Society for Technical Communication, and from Communications Concepts Awards for Publication Excellence.

WATER TEACHING KITS

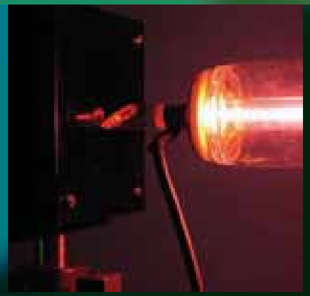
The WATER project is a standards-based water education program for use in 5th through 12th grade classrooms in Arizona. Materials from a variety of sources have been incorporated into the kits, each with inquiry-based activities that meet state standards in different subject areas. Participating teachers receive audio visual aids and water testing equipment, the opportunity to attend training workshops for professional development, and the chance to receive classroom support from water education specialists. For more information, contact Jim Washburne at jwash@sahra.arizona.edu

SAHRA MAKES A SPLASH

SAHRA's Student-centered Program for Learning About Semi-arid Hydrology (SPLASH) is a collaborative effort among high school science and social science teachers and science educators to create and implement a regionally focused water curriculum. Materials are currently being refined and are expected to be available on the SAHRA Web site by the beginning of 2008 or sooner. http://www.sahra.arizona.edu/education/

INTERDISCIPLINARY MASTER OF ENGINEERING DEGREE IN WATER RESOURCES.

An interdisciplinary master's degree program in water resources is offered by Arizona's three state universities: Arizona State University, Northern Arizona University, and the University of Arizona. The degree program is flexible and is designed to meet the needs of mid-career professionals. For more information, contact Gary Woodard at gwoodard@sahra.arizona.edu.



SHEDDING LIGHT ON LIFE

Extract a lot of information, but use a gentle touch. That's biophotonics: studying the interaction of light with biological materials and systems.

Because light can be used to analyze living tissues in a minimally invasive manner, advances in the field of biophotonics will be key to new clinical tools and biomedical instruments.

This is the challenge facing a band of scientists, engineers, biomedical researchers, clinicians, and instrument developers at the Center for Biophotonics Science and Technology (CBST), headquartered at the University of California, Davis (UCD) under the leadership of center director Dennis Matthews.

It's a job now made a little easier by a state-of-the-art facility for CBST within a new building adjacent to the UCD Medical Center in Sacramento, Calif. Dedicated in 2006, the $20-million, 40,000-sq-ft Oak Park Research Building also houses laboratories for the study of aging, infectious disease, and cancer research.

CBST is "pushing the envelope" of imaging science and filling gaps in existing technology. Tools such as X-rays, computerized tomography (CT scans), and light microscopy are able to image life down to the level of tissues and cells. On the other hand, recent advances in studying the human genome have revealed much about the structure of biological systems at the atomic and molecular scale. But in between these two scales, a critical gap exists in the ability to image at the level of groups of biomolecules and structures within the cell.

That's why CBST is supporting several research projects aimed at new bioimaging tools. These projects include work to develop X-ray lasers to enable diffraction imaging of single biomolecules, new gene-based optical labels for fluorescence imaging, and unprecedented levels of resolution with light microscopy.

"We have come up with the capability to use optical illumination to image something that's ten times smaller than the wavelength of the light we're using," explains Matthews. "We can basically look at objects 50 nanometers in size and resolve them using 500-nanometer light." Related research is expected to be commercialized with the help of an industrial partner and a research instrumentation grant from the NSF.

CBST is developing a host of new gadgets not only to study single cells in the lab but also to characterize tissues in living organisms. One research area focuses on interactions of DNA and proteins—an effort that may shed light on cancer, aging, and how genetic damage is recognized and repaired.

Another direction is understanding atherosclerosis, the artery-clogging disease. Despite the fact that atherosclerosis is the main cause of death in the U.S., the exact molecular mechanisms by which dietary fat and cholesterol lead to injury of arterial walls and ultimately to the formation of atherosclerotic plaques has been poorly understood. But how to reduce an inherently complex and dynamic system into manageable parts for study? Some of the key components include the membrane of the cells that line artery walls, conglomerates of fat and protein called lipoproteins, and components of the immune system.

One approach is the lipid microarray developed by Atul Parikh of the UCD Department of Applied Science and colleagues. These "membranes on a chip" allow researchers to observe and analyze in a well-controlled manner the molecular events that normally occur on a cell membrane.

"I am a bio-physical-chemist-materials-science type of a person," laughs Parikh, "and before the center, had no direct connection with clinical scientists. There was never a clear-cut reason why they would be interested in talking to us," he says. "The center enabled a lot of us to work together, so we ended up interacting with someone who was a practicing M.D. whose main research interest was to identify biomarkers for early events in atherosclerosis."

CBST education director Marco Molinaro, second from right, with students.

Center support gave Parikh and colleagues the time and "breathing space" they needed to do the high-risk fundamental work that contributed, in part, to getting a 4-year, $1.65-million NIH grant on how lipoproteins interact with endothelial cells that line the artery walls. Outcomes of these efforts are contributing to the notion currently gathering momentum that lipids are not mere passive players but rather play an active role in regulating protein function in biological processes.

Parikh is cofounder of a CBST spin-off company called Cherrimetrix, Alexandria, Va., an early-stage venture focused on the development of sensors, lipid microarrays, and other tools for biological research. This is just one of many startups and affiliated companies that have benefited from center expertise. □

A CONVERSATION WITH THE DIRECTOR

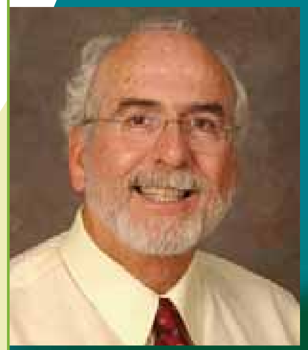
Dennis Matthews

"Team science is the only kind of science I've been involved with for a very long time," says center director Dennis Matthews. "In graduate school, I worked in a nuclear physics laboratory, and in order to get anything done, you soon found out you had to go charm a bunch of people to work with you.

"Then, working at Lawrence Livermore National Laboratory, every project there was a team science and engineering project—it's too complicated to pull off in the single investigator model. You've got to get a team of experts to work with you to accomplish the objectives.

"The academic way of life in the past has used the merit system as a way of providing reward. The merit system is based on individual performance—being PIs on a grant, being the first author on a paper, and so forth. That system is evolving to reward people for working in a team science approach. This is not new. The National Institutes of Health had a meeting on this subject a few years ago, and this was one of the primary conclusions: the academic environment should reward team effort.

"The academic department is the fundamental unit of governance for professors. Getting departments to change their procedures is hard, but I think it's going to come, as people see more and more reward for it. Universities are changing some of the ways they are organized—for example, an office of research having its own faculty lines to allocate for interdisciplinary work."



Dennis Matthews, director of the Center for Biophotonics Science and Technology

NSF INSTRUMENTATION GRANT FOR ADVANCED IMAGING PROJECT

In August 2006, CBST received a $600,000, two-year NSF Major Research Instrumentation award to develop an ultra-high resolution light microscope in collaboration with a company called Applied Precision (AP), Issaquah, Wash.

The project, led by Thomas Huser, chief scientist at CBST and a UCD professor of internal medicine, aims to develop and commercialize a high-resolution, structured-illumination fluorescence microscope system.

The effort builds upon a design developed with center funding at the University of California, San Francisco (UCSF) called OMX (Optical Microscope eXperimental). The prototype OMX system at UCSF has demonstrated a typical resolution of 100 nm, the highest resolution of any wide-field light microscope—nearly a factor of three better than existing instruments.

A commercial prototype of the new system is expected at CBST's facility at the Oak Park Research Building in late 2007. The final product would hit the market in the 2009 time frame, notes Joe Victor, senor vice president of life sciences at Applied Precision.

OMX fills an existing gap in microscopy. It covers the intermediate length scales between standard fluorescence microscopes and electron microscopy. Researchers expect to target important biological applications in this range, such as resolving subcellular structures, studying the organization of chromosomes, assembling large protein complexes, studying viral structure, and exploring processes affecting cellular organelles. In addition to its use in research, the OMX system will be used in the training of students as part of CBST courses in advanced microscopy.

"We hope to tackle samples that could not be analyzed with existing optical microscopes—for example, the entry and exit of viruses from cells. Current images of viruses are based on electron microscopy, "but it's static," says Huser. "Ideally, we want to study this dynamically and follow the replication of the viral particle. The new system allows us to make sequences of images over time to see a sort of movie." This kind of live cell imaging is done at multiple wavelengths and is a capability that distinguishes the new system.

In addition to Huser, the principal investigator of the grant; the inventors at UCSF; and researchers at UCD and Lawrence Livermore National Laboratory, the project involves the help of a graduate student and a postdoctoral research associate. The main engineering work will be done at AP.

"The center and AP have amazing synergy," says Victor. "Both organizations are very engineering oriented. That doesn't mean they aren't science oriented as well—but what you find often in a lot of academic organizations is a heavy weight on the science side and not too heavy on the engineering side. What you see at this center is really a core competency in both. We see a potential for multiple collaborations beyond this one," he adds.

AP has been in operation for about 20 years and has grown to 180 employees. With business areas in life sciences imaging instrumentation and in semiconductor metrology, a large part of AP's customer base is academic labs. "We value our relationships with universities," says Victor. "They help us to stay current with the latest technologies and to track where the boundaries are. And they provide a great opportunity to move technology into practice."

Helium Neon laser. Photo: Marco Molinaro

NEWS WATCH

LASER TRAP RAMAN SPECTROSCOPY TAKES THE MOLECULAR "FINGERPRINT" OF CELLS

Current methods used to study individual cells and to differentiate normal from abnormal ones are often time consuming, nonspecific, and destructive. CBST is developing a rapid technique that can accurately and non-destructively identify and sort cells for the diagnosis and potential treatment of cancer.

Center researchers have combined micro-Raman spectroscopy with optical trapping to sort and study cells while leaving them intact. This is all done without fluorescent tagging.

"We can study cells in their native state, getting a molecular fingerprint," says Matthews. "This capability is going to be important for treating cancer, and we're focusing initially on pediatric leukemia patients."

A BETTER WAY TO "SEE" THE STRUCTURE OF SINGLE BIOMOLECULES

Much of scientists' knowledge about the structure of biomolecules has come from X-ray crystallography, that is, X-ray studies of molecules in the crystalline state. But because it's so hard to produce high-quality crystals, only a small fraction of the biologically important molecules have yet been determined. And some biomolecules can't be crystallized at all.

CBST researchers are developing an X-ray diffraction method to determine the configuration of single biomolecules without needing to crystallize them. In this approach, a stream of individual biomolecules passes through an X-ray beam from a laser or synchrotron source. X-rays diffracted from each molecule are collected, and although a few molecules alone wouldn't be enough, a "running total" from many molecules yields a diffraction pattern with a high enough signal-to-noise ratio to allow the structure to be analyzed.

Matthews notes that tests are currently being conducted at facilities around the world, but in the future, they plan to use the coherent light source at Stanford University when it is completed. The work may lead to a new high-resolution method for obtaining structure information for proteins, protein complexes, and viruses.

Pictured in background: Cells in Raman trap

Center director Dennis Matthews with a group of high school students from Center High.

TEAM SCIENCE 101

The bell rings as the last few students filter into the seminar room and take their seats. One of the instructors begins to speak.

"As a research physician in a top-ranked medical research institution, you are aware of the need for improved technology to measure narrowing of carotid arteries. At a seminar, you discover that a brilliant faculty member in the physics department may have such a technology—a supersensitive wide-bandwidth microphone—but he hasn't filed a patent for his concept nor has he any known interest in applied research or medicine or anything but single-investigator, discovery-based research.

"You are given the challenge of putting together a multidisciplinary team to translate this technology into medical practice, and bring it to Phase II clinical trials in only two years. How should you proceed?"

The scenario is used in a course actually taught by CBST director Dennis Matthews, Marco Molinaro, and Frank Chuang at the University of California, Davis, in conjunction with the NIH-funded Mentored Clinical Research Training Program.

Not the typical chalkboard talk you might associate with graduate or medical school, the course tackles real-world problems that transcend traditional academic departments. It's one of the ways that the center is transforming the graduate educational experience.

"Students can be woefully underprepared for the team working environment, especially if they go into industry, where it is very team-oriented," says Matthews. "With our students, what our center tries to do is to instill in them (the) value of working together with other disciplines."

BIOPHOTONICS

NETWORKED SENSING

CENTER FOR EMBEDDED NETWORKED SENSING CENS

IMAGINE IF:

Endangered ecosystems could be equipped with chemical, physical, acoustic, and image sensors to continuously monitor global change.

Buildings could detect their own structural faults and respond to seismic events.

Buoys along the coast could alert surfers, swimmers, and anglers to dangerous bacterial levels in the water.

Engineers for CENS installing a robotic sensing system on the San Joaquin River in the California central valley.

Water quality and flow sensors positioned at the surface of the river.

These are the kinds of dreams that researchers at the Center for Embedded Networked Sensing are turning into reality through a collaboration between computer scientists, statisticians, seismologists, biologists, and engineers under the leadership of center director Deborah Estrin.

The approach uses sensors, computers, and wireless communication in systems that are distributed throughout the environment. These smart sensors and actuators allow researchers to monitor aspects of the world as a function of time and space to derive new knowledge that couldn't be obtained otherwise.

For example, CENS researchers have been able to demonstrate how different chemical and physical factors change when rivers come together. The work was done in the Central Valley of California at the confluence of the San Joaquin and Merced Rivers.

"In the Central Valley, there is a long-standing problem of high salt concentrations from agricultural runoff," explains Jeffrey Goldman, program development director at CENS. "The state right now makes measurements only very sparsely along the river at a single point, every so often. Based on those data, they developed models that suggest how they should release water for irrigation to try to minimize the impact of the salt.

"We're providing a much more detailed view of the mixing," says Goldman. "We'll be able to look at how salt is coming up from the groundwater and being deposited into the groundwater, and to feed those data into the models to help people manage the flow of water and irrigation in the Central Valley, which is a very important agricultural base for the whole nation."

CENS researchers have strung cables across the river and suspended a robotic shuttle from the cables. The shuttle can be controlled to move across the river and then up and down within the water in a grid pattern to make measurements on properties like nitrogen levels, dissolved oxygen, salt concentration, and flow.

"By deploying these technologies we've been able to see how mixing occurs, something that wasn't previously understood," notes Goldman.

CENS researchers have installed sensor platforms at the James Reserve in Riverside County, Calif., a research and teaching facility within the University of California Natural Reserve System. They

"Explaining from the perspective of the biologist or seismologist in the field how the instrumentation needs to work—what's important and what's not—is critical to making things work."

use these platforms for terrestrial and aquatic monitoring, acoustical sensing of animals, and microscopic sensing of roots, fungi, and chemical constituents of soils.

These networked instruments "constitute a complete ecology of observing systems suitable for reliable, long-term, automated measurements of organisms and ecological processes across 10 orders of magnitude in spatial and temporal scale—literally from microbes and molecules to whole watersheds," says reserve director Michael Hamilton. "Our unique test bed is internationally recognized as a foremost example of state-of-the-science terrestrial and aquatic ecological observing systems, and serves as a model for an emerging class of research infrastructure known as the ecological observatory."

Systems for aquatic monitoring are another thrust of the center. Lab-on-a-chip sensors for the identification of aquatic micro-organisms may help monitor, understand, and mitigate harmful blooms that cause fish kills, endanger human health, and result in economic effects. The ultimate goal is to put such sensors on a network of buoys offshore and observe these blooms as the events develop. Systems are currently being developed and tested at Lake Fulmor in the James Reserve.

Besides these and other practical applications, CENS researchers are exploring the fundamental research questions about the scientific and engineering design of embedded systems, and that work has helped this emerging field to evolve. "We've ended up in a different place than anticipated," Estrin admits. "Five to ten years ago we had an initial conception about what the problems were. But we've really learned from the experience what the real problems are and where the real challenges and opportunities are."

Their early strategy was focused on thousands of small devices, exploiting the power of many observations from fully autonomous systems. The issues were longevity and communication among the nodes of the system.

But the researchers have realized that even with many thousands of sensors, systems may still be undersampled. So the center is looking toward using multiple scales, mobility, adaptive sampling, and coupled human-observational systems as a new direction for research.

Throughout this process, communication has been key, says Goldman. "Engineers and computer scientists (each) have their own language. Left to their own devices, they would come up with something very neat, but not necessarily the most useful in the field," he laughs. "Explaining from the perspective of the biologist or seismologist in the field how the instrumentation needs to work—what's important and what's not—is critical to making things work."

VIEWPOINT

FROM THE DIRECTOR

Deborah Estrin

"I grew up with the Internet research community, which taught me about the value and the transformative effect of a community going after a vision together. No one person can create it—no one person could create the Internet, for example. That's my technical culture. That's how you have impact."

— CENS DIRECTOR DEBORAH ESTRIN

NEWS WATCH

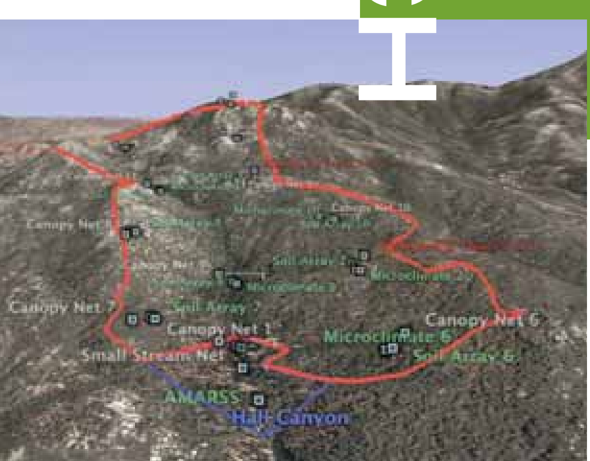
PUBLIC HEALTH APPLICATIONS OF EMBEDDED NETWORKED SENSING

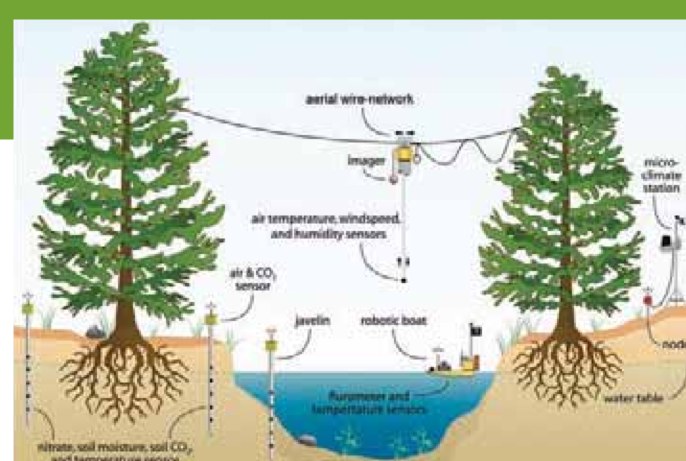
"We are starting to take advantage of the massively proliferated cell phone technology to apply mobilized and in-situ sensing observations to community health and public health issues," says CENS director Deborah Estrin.

People may be exposed to different levels of environmental and health risks depending on their particular lifestyles, which involve familiar variables such as diet and exercise but also where they go, what they breathe, how they travel, and other factors.

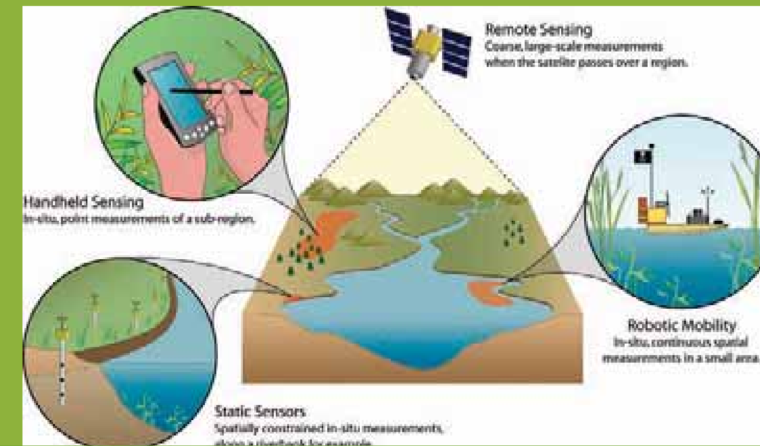
Principles of embedded network sensing may help researchers gain a better understanding of exposure levels encountered by individuals in their daily lives.

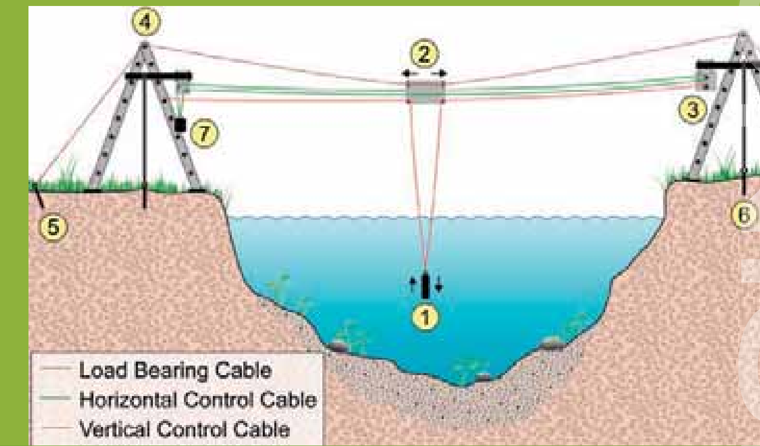
This work is in very early stages, says Estrin, but she anticipates asthma will be one of the issues they will work on. Data from weather information and smog and pollution sensing stations might be combined with detailed location information and activity level information on patients collected through a cell phone to gain a better understanding of the disease.





NETWORKED SENSING





WOMEN @ CENS:

IDENTIFYING BEST PRACTICES FOR INCREASING GENDER EQUITY IN COMPUTER SCIENCE AND ENGINEERING

Although progress has been made over the last few decades, women still lag behind their male counterparts in representation in the fields of engineering, computer science, and physical sciences, especially at the graduate level. The Center has undertaken a project both to understand and to counteract women's persistent underrepresentation in these fields.

Called Women@CENS, the effort has been aimed at developing a demonstration model of an undergraduate research program that is designed to promote women's long-term commitment to science and engineering.

The intent is to go beyond simply offering an undergraduate research experience and documenting the outcomes of such an experience. Rather, the goal is to use the demonstration model as a basis to identify the best practices and strategies for successful undergraduate research programs across the country.

"Our idea was to increase the number of women and underrepresented minorities who consider moving on into graduate school," says center director Deborah Estrin. "We do that by attracting their attention and engaging them in undergraduate research. For a number of women it's important to see the applicability of their work, and so we've focused on how to build effective undergraduate research experiences, having them work in groups with certain amounts of structure to it, and helping them to get a feeling of what it is to do multidisciplinary research with a lot of mentorship by graduate students," she says. The experiences help them see "that it's not something that you go off and work by yourself in a corner, but that it's a highly collaborative and creative process."

With support from a three-year, $899,000-grant from NSF, the Women@CENS working group has developed an online survey looking at undergraduate research internship programs with a focus on the practices and processes that foster women's long-term commitment to engineering and computer science, explains education director Karen Kim.

An online survey was sent to NSF-funded undergraduate internship programs in engineering, computer science, and related fields. It was followed by interviews with a subset of survey respondents.

The researchers found that the majority of undergraduate internship programs enrolled at least 30 percent or more female participants, according to project manager Amy Fann. Survey respondents reported that increasing the number of women in engineering and computer science Ph.D. programs was an essential or very important program goal.

Less than 12 percent of programs reported that they conducted any type of training or professional development that addressed gender bias issues. In follow-up interviews with a subset of 20 program administrators who had completed the survey, the researchers found that a handful of programs do specifically incorporate professional development addressing gender-equity issues, but do so indirectly.

Examples of promising practices identified by the study include: ensuring that women faculty and graduate students are well represented on workshop panels; inviting women scientists as guest speakers and highlighting the work and contributions of women scientists; ensuring that female faculty mentors, graduate students, and support staff are available to provide small group or individual counseling/support as needed; and providing opportunities for women participants to network with campus and professional organizations.

Women @ CENS team. Front: Kimberly Misa. Back, left to right: Karen Kim, Wesley Uehara, Linda Sax. Not pictured: Deborah Estrin (PI), Christine Borgman, June Chang, Amy Fann,Farnaz Farzad

SPACE WEATHER

CENTER FOR INTEGRATED SPACE WEATHER MODELING CISM

CISM MODELS ENHANCE SPACE WEATHER FORECASTING

Image of the Sun in the extreme ultraviolet range showing the solar corona at a temperature of ~1 million K. Recorded Sept. 11, 1997. Image: SOHO_EIT, http://sohowww.nascom.nasa.gov/gallery/EIT/eit029.html

Thanks to the magnetic cocoon surrounding the Earth, many people live out their lives oblivious to the harsh reality of our space environment.

At top right: The forecast and analysis branch of NOAA's Space Environment Center, Boulder, Colo., has the responsibility for providing the nation's real-time space weather services 24 hours per day. Photo: SEC

That is, unless you happen to run a power grid in New England, or you're on a polar flight from Chicago to Hong Kong and all the communications are blacked out.

Then you know firsthand that the sun is capable of lashing out with tentacles of radiation that travel through space at enormous speeds and buffet our planet's magnetic shield, wreaking havoc with electrical systems and satellites.

Whether you're combating corrosion in pipeline operations, conducting an offshore survey using high-precision GPS navigation, or just trying to get a clear satellite TV signal, you may be very interested in the latest space weather forecast.

Forging a better understanding of space weather is the mission of the Center for Integrated Space Weather Modeling. CISM researchers are developing new models of the entire system from the sun to the Earth, ones that are more comprehensive and powerful than ever before. And they are working to transition the models into practice in partnership with NOAA's Space Environment Center (SEC), Boulder, Colo.

Now in the testing stage, the technology is poised to dramatically improve the quality of space weather forecasting in the near future.

The Forecast Room

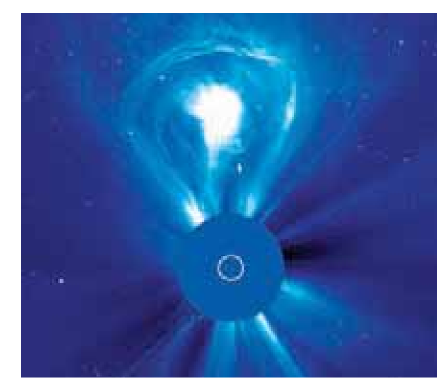
It's staffed 24/7, but most days, life is pretty calm in the forecast room at SEC, says Joe Kunches, chief of the SEC forecast and analysis branch. Around the room are monitors with real-time data feeds from NOAA and NASA satellites. Operators are eyeing plots of the solar wind speed near Earth, the magnetic field in the solar wind, the X-ray flux coming from the sun, and the energetic particle flux.

Conditions can be stable for a long time and then change fast. "When the sun has a flare, the X-ray flux, for example, can increase a millionfold in minutes," says CISM director Jeffrey Hughes.

It's a wild ride. Operators are watching graphs, they're hearing audio alarms. "You've got a whole lot of stuff coming at you very quickly," says Kunches. "You're on the phone, you're sending e-mails, and predicting when the next threshold may be reached or when it will taper off—and all the while the phone is ringing with customers asking, 'What is going to happen to my operation in six, twelve, twenty-four hours?'"

Next-Generation Models

In the past, models were developed to study pieces of the system, rather than to go from the sun to a forecast in a single step. While CISM has improved the models that describe regions of space, they have focused on coupling them together in a "Sun-to-the-Earth" chain.

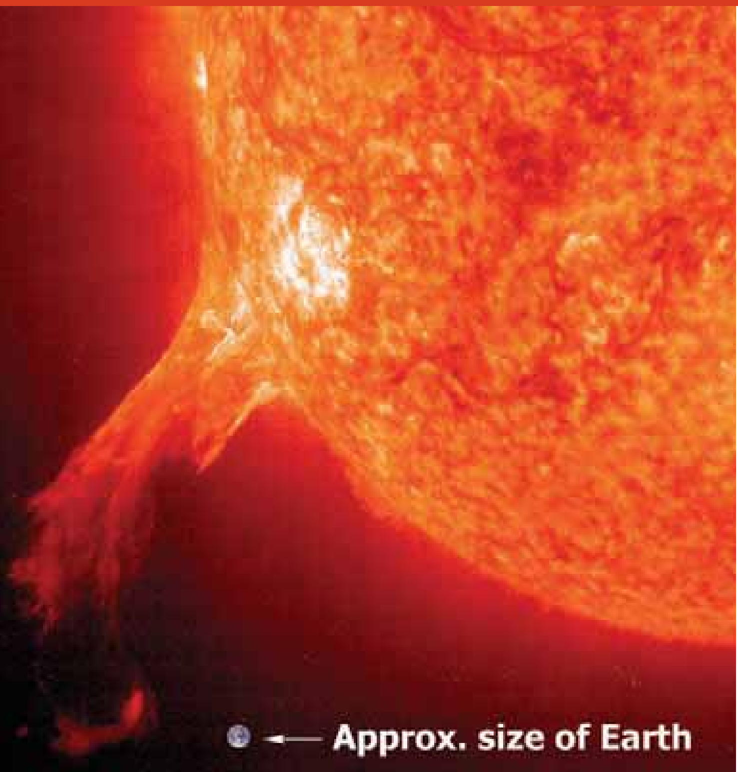


This "lightbulb" coronal mass ejection (CME) shows the three classical parts of a CME: leading edge, void, and core. Taken Feb. 27, 2000 by the LASCO C3 coronagraph. In coronagraph images, direct sunlight is blocked, revealing the surrounding faint corona. The approximate size of the Sun is represented by the white circle. Image: http://sohowww.nascom.nasa.gov/gallery/top10/top10_detail_c3bulb_cropt.html

Because of those innovations, two main advances in the forecasting ability of SEC are expected. First, it will be possible to predict, up to a week in advance, the varying structure of the solar wind, important to forecasting power disruptions. This component is in testing now at SEC with routine operation several months away.

Second, technologies are being transferred to model the magnetosphere and ionosphere. These are important for polar flights and communications. Forecasters will be able to model the Earth's environment from the upper atmosphere (~100 km above sea level to distances just beyond the moon. For comparison, 100 km is below the orbit of the space shuttle (200 km), below satellite orbits (above 400 km), and at the lower boundary of the ionosphere (important for radio transmissions). Operational use is expected in the 2008-09 time frame.

"The CISM-SEC partnership is going to accelerate the transition of models into operational practice," says Howard Singer, chief of the SEC science and technology infusion branch. "We've been able to give CISM researchers information about what the needs are, and they, in turn, provide us models that we can run in our test bed, determine what sort of improvements are needed, and feed that back to the developers. There's a nice synergy here, and a good interaction between scientists, developers, and users."□



A closeup of an erupting prominence with Earth inset at the approximate scale of the image. Taken July 1, 2002. Image: SOHO Top 10 Images, http://sohowww.nascom.nasa.gov/

EDUCATING THE NEXT GENERATION OF "SUN-TO-EARTH" SCIENTISTS

"Typically our field has thought of itself as several related but separate disciplines—solar physicists, interplanetary medium types, the magnetosphere types, the upper atmosphere specialists," says CISM director Jeffrey Hughes.

"Part of what CISM is trying to do is to make everybody think, 'You're a space-physicist sun-Earth-system person,'" says Hughes. "Maybe you concentrate on a certain piece of it, but you're studying part of a larger system, and you think of it that way."

Executive director Jack Quinn contrasts this approach to his own experience. "When we were graduate students, I learned primarily about the Earth's magnetosphere, and I was involved in team science—because space science has always been team science—but it was teams of other magnetospheric physicists," he reflects. "Now, the students in CISM are growing up interacting all the time with all of those different, previously separate disciplines—to them, it's the way it should be. It's normal."

Moreover, they're gaining other professional skills—things like action items, due dates, publishing, fund

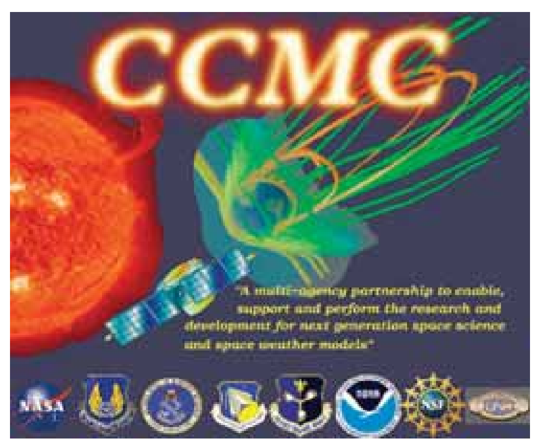
raising, and knowledge transfer. "They're getting a leg up on what we learned much later on," says Hughes.

To help prepare incoming graduate students, CISM organizes a space weather summer school. Lectures in the mornings are complemented by hands-on sessions in the afternoon in which students gain experience with CISM models and software.

Part of the transformation taking place is the development of pathways for diverse students to enter the discipline. In order to increase the participation of African American students in this field, CISM has helped establish a graduate program in space science at Alabama A&M University. The effort builds upon an existing undergraduate physics specialty in space science there, "so now a track exists for students to continue their graduate studies as members of the CISM team," say the CISM directors.

HOW'S THE WEATHER TODAY?

Our planet is bathed in a solar wind—the continuous flow of matter blown away from the sun, traveling through space at speeds of up to 1.5 million miles per hour. The composition of the solar wind resembles the sun itself: mostly protons—hydrogen atoms stripped of their electrons—and other elements. When the particles are trapped along the Earth's magnetic field lines at high latitude, we see the effects as auroras, the delicate, shifting curtains of light in the night sky. When an aurora is seen at lower latitudes, it's a sign of solar storms. The largest are caused by solar flares and coronal mass ejections (CMEs). Flares last for minutes or hours and originate in a thin layer close to the sun's visible surface. They give off energetic particles and high-energy photons, including ultraviolet light, X-rays, and gamma rays. Traveling at the speed of light, the light waves reach the Earth days ahead of particles released in the same event. Flare activity usually follows the 11-year sunspot cycle. CMEs consist of matter thrown out from the corona, the sun's outer atmosphere, visible as the "halo" during a total eclipse. These events occur when the magnetic field lines get tangled due to different rates of rotation of the sun's polar and equatorial regions. The tangled lines can snap in a violent explosion, spewing huge volumes of solar atmosphere at speeds of up to several million miles per hour.



CISM MODELS REACH SCIENTISTS AROUND THE WORLD

Want to run your own simulation of space weather? Researchers can, thanks to a multiagency partnership called the Community Coordinated Modeling Center (CCMC). Models developed at CISM and by other scientists are made available over the Web at no cost for use by researchers around the country and the world through the CCMC. http://ccmc.gsfc.nasa.gov

> "The apparent void between Sun and Earth is actually a maelstrom of wind and storm, with interludes of calm, always bathed in the harsh glow of ultraviolet and X-ray light. So strong is the outpouring solar wind that Earth's magnetic envelope is distorted, quivering even as it protects the fragile life on our planet."
>
> — SPACE ENVIRONMENT CENTER

NEWS WATCH

INTERNATIONAL HELIOPHYSICAL YEAR (IHY) 2007

This year marks the 50th anniversary of the International Geophysical Year (IGY), which in 1957 involved some 60,000 scientists from 66 nations, working at thousands of stations from pole to pole studying global phenomena. Now, the world's science community comes together again for the International Heliophysical Year (IHY) 2007 with a broader scope, extending the connections from the Earth to the sun and interplanetary space. The CISM summer school and the Space Weather Monitor Program are but two of many activities affiliated with the IHY 2007. Visit http://ihy2007.org

THE SPACE WEATHER MONITOR PROGRAM

High school students can detect for themselves when the sun is acting up, thanks to an outreach program headquartered at Stanford and sponsored in part by CISM. The program provides students with inexpensive monitors that can detect ionospheric disturbances such as those caused by solar flares. As an official IHY 2007 activity, monitors are scheduled to be placed in 191 countries. For more information, visit http://solar-center.stanford.edu/SID

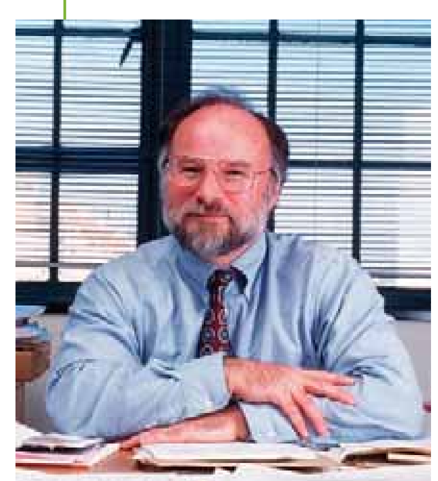
CISM HAS IMPACT ON HAYDEN PLANETARIUM SHOW

CISM researchers contributed to a show at the Hayden Planetarium of the American Museum of Natural History in New York. The show, Cosmic Collisions, is narrated by award-winning actor and director Robert Redford. One segment uses a CISM simulation showing the Earth bombarded by high energy particles from the sun. The show runs for several years. http://www.amnh.org/rose/spaceshow/cosmic/

A CONVERSATION WITH THE DIRECTORS

Jeffrey Hughes & Jack Quinn

"If a center is to be successful, it's got to have a clear idea of why it needs to be one, and what it is that makes the center important," says CISM director Jeffrey Hughes.



CISM director Jeffrey Hughes

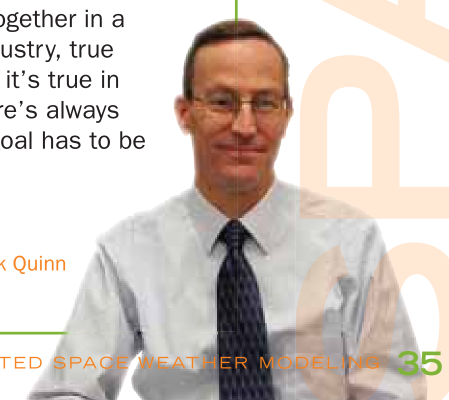
"If the reason is just 'We're going to enhance research in this field,' it probably shouldn't be a center. The approach should be employed in carefully selected cases in which the problem warrants this treatment—'Here's a problem that none of us can tackle alone. The goal is worth it, this kind of investment is needed.'"

The goal of modeling work at CISM is threefold: to support science, to supply forecasting tools, and to develop teaching tools. From the beginning, Hughes saw this as a natural fit with the integrated STC goals of scientific research, knowledge transfer, and education.

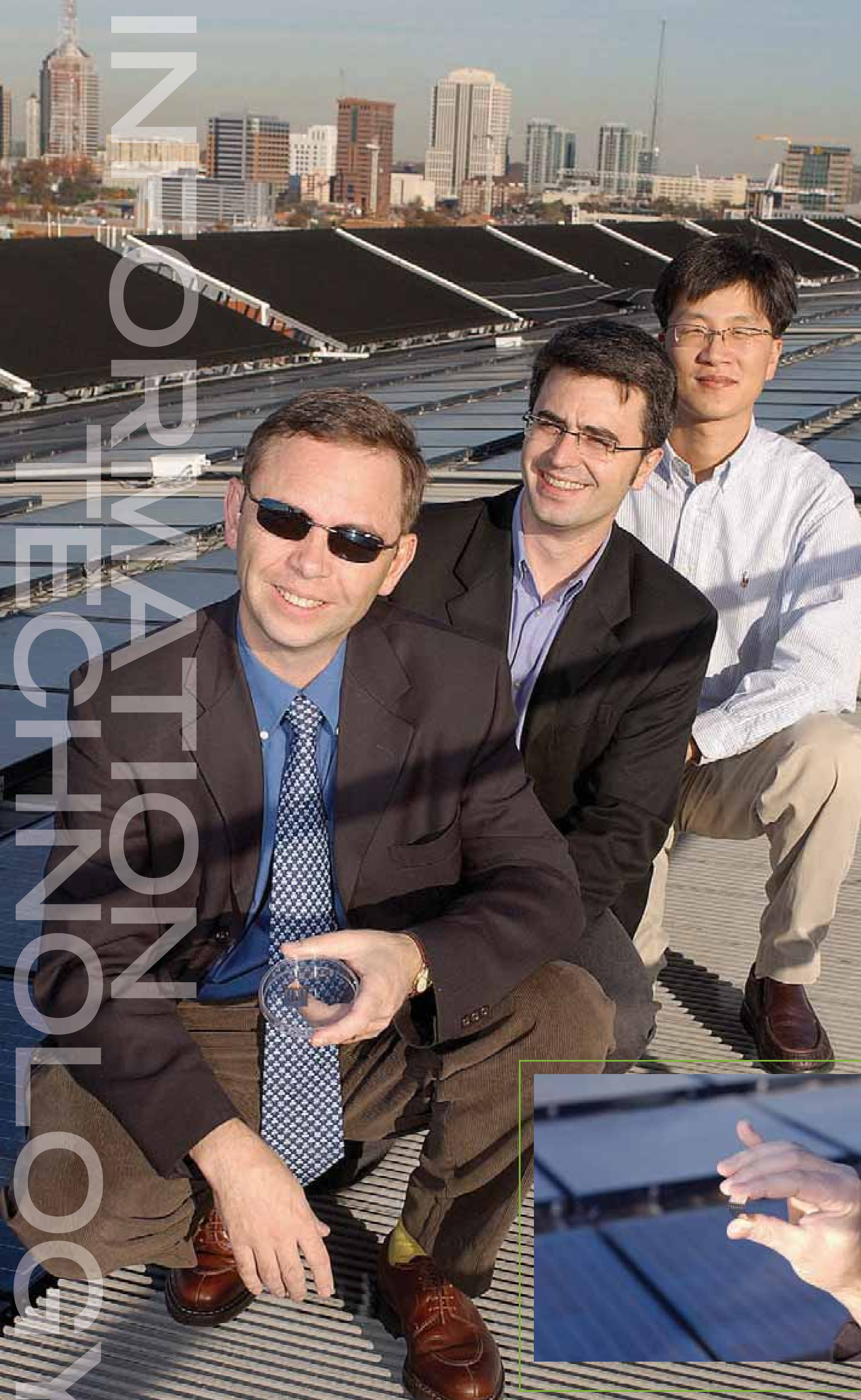
"We're an STC that's known even before we wrote the proposal what we wanted to do. That doesn't make the task any easier," he laughs, "but at least it was clear."

It's a balancing act to divide his time on science, education, and center management, says Hughes. "It's still a bigger management task than we thought, and we're coming to grips with that."

Executive director Jack Quinn points out, "there's a certain energy overhead in centers, but that's part of working together in a team. That's true in industry, true in engineering projects, it's true in building hardware—there's always that overhead. So the goal has to be worth that."



CISM executive director Jack Quinn



Bernard Kippelen of Georgia Tech, front, holds solar cell (inset). Photos: Nicole Cappello, Georgia Tech.

CENTER ON MATERIALS AND DEVICES FOR INFORMATION TECHNOLOGY RESEARCH CMDITR

CENTER HAS ITS "HIGH BEAMS" ON

Existing electronic and photonic devices based on inorganic materials such as silicon, gallium arsenide, and lithium niobate are about to "hit the wall"—that is, they are approaching their practical limits in terms of speed, flexibility, and cost.

Researchers at the Center on Materials and Devices for Information Technology Research (CMDITR) are working on organic-materials-based technologies that may provide attractive alternatives to those based on inorganic materials. Outcomes of center research are expected to provide the technological foundation for a thousandfold increase in throughput of telecommunications and information systems.

The center's research program has helped to attract interest from federal agencies, says center director Larry Dalton, professor of chemistry at the University of Washington (UW). "NSF-funded technology has produced complementary interest among mission-oriented agencies to focus on translation of basic research into defense applications."

Ultimately, center researchers hope to lay the groundwork for radically new approaches to the design of computers and sensors, with a move to ultrafast "all-optical" technologies and ubiquitous, embedded systems. CMDITR research will be key to the development of next-generation radar and navigation systems that will enhance U.S. defense capabilities, transform transportation, and facilitate space exploration.

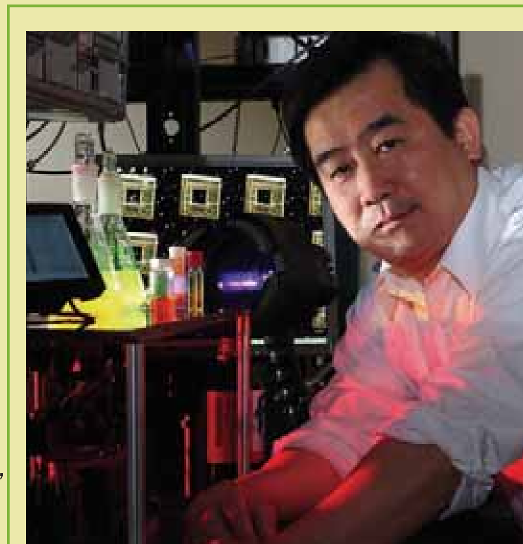
Benefits in the energy sector are also targeted, including the commercial deployment of practical, inexpensive, and lightweight solar cells.

The manufacturing operations needed to produce organic-based technologies not only will provide exquisite control of material structure on very small scales, but are also expected to employ manufacturing processes and materials that are safer, cheaper, and more environmentally benign than those employed in the silicon-based semiconductor industry.

One research area, led by Alex Jen, UW professor and Boeing/Johnson Chair of Materials Science and Engineering, concerns electro-optic (E-O) materials, used to convert information between the electronic and photonic (light) domains at ultrahigh speeds. These materials can be used in devices called electro-optic modulators that transform electrical signals into optical signals and back again as signals enter and leave the ends of a fiber-optic cable. If you've made a long-distance telephone call lately, you've likely used electro-optic modulators.

The process involves the fast and efficient manipulation of the refractive index (ability to modulate light) of a material with an applied electric field. Efforts at the center are therefore aimed at developing suitable materials with high E-O activity, a measure of a material's ability to undergo change in its refractive index with an applied field.

CMDITR researchers have developed and tested a class of novel organic materials that achieve an order of magnitude improvement in E-O activity compared to the best inorganic rivals. The new materials also are specially designed to self-assemble into a structure that facilitates fabrication for computing and communication applications, explains Jen, who is director of the new Washington Institute of Advanced Materials Science and Technology based at the UW.



Above: Alex Jen
At right: Susan Ermer

The new high E-O materials offer several advantages: They can be produced in thin films with much smaller size than their inorganic counterparts, offering the possibility of higher density of integration and higher speed and bandwidth for information technology applications. Devices made of these new materials also have the advantage of a lower drive voltage and therefore, lower power consumption.

This research thrust is of keen interest to Susan Ermer of Lockheed Martin, an industrial affiliate of the center since its inception. Ermer works on the research side of the organization—as she puts it, the side required to "have the high beams on."

"We have ongoing projects in the area of electro-optic materials and devices and we know that this center has creative expertise and depth of knowledge and extensive networks. We've got a long-standing interest in this very specific area, but beyond that, we also see that this interdisciplinary group of people who have been brought together in the center are the ones that have the headlights on into the future," she says.

Ermer is senior manager of materials and structures technologies at Lockheed Martin's Advanced Technology Center in Palo Alto, Calif. Her group comprises about 85 chemists, metallurgists, structural designers, materials scientists, physicists, and engineers.

"In industry, you often have many people who have no choice but to be putting out brushfires, and that's what keeps the enterprise going," says Ermer. "As a research site, though, we should be looking to the future, but very frequently we're tied up in day-to-day things. The relationship with the center allows us to have these pioneers scouting out there and we get the benefit of that."

Georgia Tech researchers Elisa Riedo and Robert Szoszkiewicz

HOOKED ON PHOTONICS

The center is trying to promote the interest of undergraduates in research with its program of summer research experiences, called "Hooked on Photonics." The program has a particular focus on lower-division undergraduates from community colleges and small four-year colleges—the so-called "gateway" undergraduates, or students with no exposure to research at their home institutions. Some 34 undergraduates took part in the 2005 summer program, 18 of which were female and 14 of which were from underrepresented minorities.

Left: Chemistry professor Phil Reid leads Hooked on Phonics.

MORPHING THE TECHNOLOGY

One government entity that has funded a major effort in the area of electro-optic materials is the Defense Advanced Research Projects Agency (DARPA), which is providing multimillion-dollar contracts for the development of materials and devices for applications in radar, phased array antennas, and remote control of antennas, among others.

It's part of a program called Supermolecular Photonics Engineering, or MORPH for short, led by DARPA program manager Devanand Shenoy. Having passed initial Phase I milestones, the MORPH program recently was awarded Phase II funding by DARPA.

"This is an area that is going to have a lot of impact for not only the military, but also the commercial sector," says Shenoy. "Center researchers have demonstrated a factor of ten improvement in electro-optic activity over lithium niobate. That's just one parameter—there are other parameters to keep in mind, such as the optical loss, stability, reliability of the materials, all of which will be tested in Phase II of this program. This is going to enable a large number of applications not only for the military for the next generation RF photonic components, for example, but also in enhancing bandwidth for voice, video, and data communication using devices that operate at a low drive voltage."

The participants in this effort, which is separate but related to the center, include researchers at the UW and Georgia Institute of Technology (GT) and a Seattle-area company called Lumera.

"The university researchers are doing a remarkable job in terms of pushing the state of the art," says Shenoy. "It's a good approach in that the paradigm of using theoretical guidance to develop new molecules and materials appears to be working."

Lumera's role is to demonstrate that the materials that have met the Phase I metrics can indeed be scaled up to large quantities with the same performance characteristics and to implement these materials into state-of-the-art electro-optic polymer modulators with low driving voltage, low insertion loss, and large bandwidths. "It is critical for success in the program that the Lumera team and the UW team work closely with each other to really push the performance," Shenoy says.

The key issue now is addressing the robustness, photostability, and chemical, thermal, and temporal stability of the new materials and electro-optic modulators. "Once we address all of those issues, we will enable the transformation of the next generation of photonics materials and devices," says Shenoy. "There's no doubt in my mind that this is going to be a huge step forward for our military capabilities." □

DIVERSITY ENHANCEMENT

Larry Dalton

For his long-term commitment to promoting diversity in science and engineering, and in particular for his recent work advising Norfolk State University (NSU) and Alabama A&M as they expand their graduate programs, center director Larry Dalton was awarded a "Giants in Science" award from the QEM Network.

The Quality Education for Minorities Network is a nonprofit organization based in Washington, D.C., dedicated to improving the education of African Americans, Alaska Natives, American Indians, Mexican Americans, and Puerto Ricans.

Dalton has spearheaded one of CMDITR's major collaborations to help develop a Ph.D. program in Materials Science and Engineering (MSE) at Norfolk State University. This will be NSU's second Ph.D. program and only the second MSE Ph.D. program in a Historically Black College or University (HBCU).

BUILDING A LEGACY: $3M SOLVAY GRANT TO GEORGIA TECH FOR RESEARCH ON ORGANIC LIGHT-EMITTING DIODES

The Center for Organic Photonics and Electronics (COPE) was established at Georgia Tech as a vehicle to help provide a legacy for the STC so that the center research at GT could continue once the STC funding was over, explains COPE director and CMDITR deputy director Seth Marder.

With a recent grant of over $4 million from an industrial sponsor for research on organic light-emitting diodes (OLEDs) and photovoltaic materials, that goal seems well on its way to being realized.

OLEDs are thin films of organic molecules that give off light when electricity is applied. The devices could be used in everything from television and computer monitors to household lighting and handheld computing devices.

Solvay, an international chemical and pharmaceutical group headquartered in Brussels, Belgium, with units in more than 50 countries and a strong presence in Georgia, has signed a three-year commitment with GT for the research.

Marder says the STC provided a "launching pad for us to get a lot of the research going that enabled us to attract Solvay as a sponsor. It is consistent with the STC's philosophy to get work going and to inspire industrial support that both enhances the work going on within the STC and potentially, a vehicle to transition that work into industry."

COPE has already developed a unique material platform for OLEDs that may be deposited over large areas using ink-jet printing and patterned using photolithography. GT researchers have found that exposing the material to ultraviolet light leads to hardened materials that are insoluble and maintain stability under high temperatures. This allows researchers to build a multilayered, solid-state device from liquid materials.

In addition to Marder, a professor of chemistry and biochemistry, other principal investigators at COPE include Jean-Luc Bredas, professor of chemistry and biochemistry and a Georgia Research Alliance Eminent Scholar; Bernard Kippelen, associate director of COPE and professor in GT's School of Electrical and Computer Engineering; and Marcus Weck, associate professor of chemistry and biochemistry.

Léopold Demiddeleer, director of Solvay Corporate R&D and New Business Development, noted that "the New Business Development division of the Solvay Group was looking worldwide to build a strong knowledge and innovation base in advanced materials for organic electronics. COPE was right on target, at the right time and at the right location for us. This winning partnership will take advantage of the world-class expertise of COPE and the industrial potential of Solvay in this highly challenging field. I consider this as the first critical step of a major long-term program for the company."

RESEARCH ETHICS

SHARPEN YOUR SKILLS

Alvin Kwiram CMDITR Executive Director

CMDITR has established a comprehensive program of ethics training and certification within the cross-disciplinary and multi-institutional context of the center for all faculty, postdocs, students, and staff who are classified as participants. This certification consists of three easy-to-use Web-based modules: (1) Rights and Obligations; (2) Collaboration, Communication, and Grants Management; and (3) Intellectual Property. The online tutorials are now available to the public for educational purposes. To register, visit www.responsibleresearch.org.

EARTH-SURFACE DYNAMICS

Background: Mississippi River Delta. Image taken 5/24/2001 by ASTER, the Terra Satellite's Advanced Spaceborne Thermal Emission and Reflection Radiometer. Image: USGS National Center for EROS and NASA

Inset photo left by Dan Marshall

Inset photo lower right by Jon Chapman

NATIONAL CENTER FOR EARTH-SURFACE DYNAMICS NCED

THE SURFACE IS THE ENVIRONMENT

Human beings erect disciplinary boundaries—and nature ignores them. "When you see how biological systems interact with physical systems like flowing water and the channels it shapes, you simply can't disentangle these things," says Chris Paola, director of the National Center for Earth-Surface Dynamics (NCED), headquartered at the University of Minnesota (UMN).

"If you want to come up with real, predictive tools for managing the environment, especially if you're interested in the long time scales that are implied by sustainability; if you want to understand a system and what makes it tick, and work with natural tendencies instead of against them, you can't get around the fact that these different aspects that we divide up into biology and chemistry and physical processes are all put together," says Paola. "Nature doesn't separate them."

The center is focused on understanding how the Earth's surface changes over time from a multidisciplinary point of view. The approach involves everything from hydrology—the flow of water over the surface and the transport of particles and the shaping and sculpting of the surface—to ecology and the social sciences that address how the fate of the Earth's surface is intimately interwoven with the life on it.

It's a job that's "way too big for anybody," laughs Paola. "But increasingly, the most ambitious problems are ones that cross disciplines, that require a sustained effort, and involve a wide range of people because they're simply large problems."

The mission of the center is something to which many people can easily relate but may have a hard time articulating. "If you ask the members of the public what the environment is, it's very hard to pin down," says Paola. "A lot of people use it interchangeably with ecology, because people are fascinated with life.

"But the landscape, the form of the land that we see around us, and in particular the dynamism of the land, is intimately connected with the life on it. They influence each other—for example, the way soil is created at the microbial level and the distribution of channels on a river delta like the Mississippi are all influenced by the interaction of the physical surface and life.

"We say: the surface is the environment. That's our mantra."

What does this approach enable researchers to do that they couldn't do otherwise? "You can predict how the environment will respond to changes, like climate change, or human activities such as mining, industry, logging, reforestation," says Paola.

When you log a piece of terrain, for example, or allow regrowth of forest on a logged area, you change not just the way it looks but also the amount of sunlight that reaches the streams, the amount of sediment that's delivered to the streams, and those things in turn affect the populations of all kinds of organisms, including fish.

"To some extent perhaps what the public sees is 'fish' or 'salmon,' but what they may not realize is that those salmon are the tip of an iceberg that includes not only other elements of the food chain but also the physical environment that the salmon inhabit. And that environment is dynamic."

TRANSFER OF TOOLS

Methods to calculate the movement of sediment might sound like mere mud pies to some people, but it's an important outcome of center research.

"As humble as it may be, sediment is what a lot of the world is built on," notes Paola. Knowing how fast it flows from one place to another is critical to understanding how the earth's surface evolves—and how long, for example, a reservoir will remain in service, what will happen to the lake behind a dam, or how fast you could fill in drowned marsh land in a place like the Mississippi Delta.

The Army Corps of Engineers is expected this year to adopt some of NCED's sediment transport tools, which means the technology would become part of the national standards for calculating the flow of particles in rivers.

FROM THE DIRECTOR

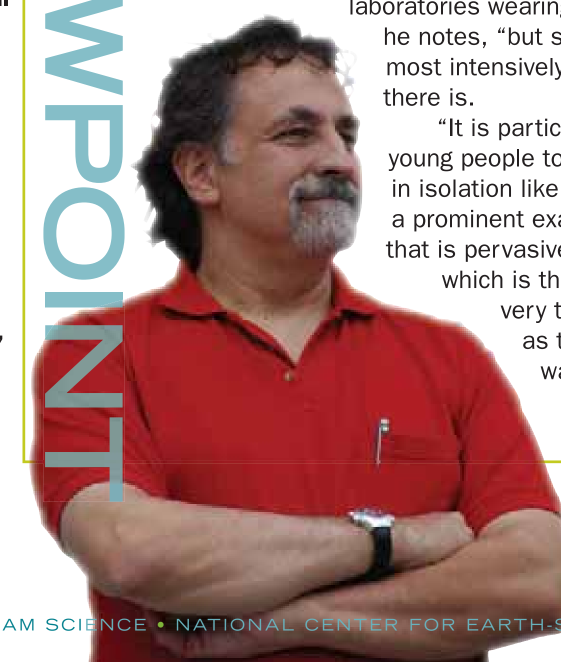
Chris Paola

VIEWPOINT

"When I interact with the public, particularly kids, they don't understand science is not done in isolation," says NCED director Chris Paola. "Most people think that scientists work by themselves in laboratories wearing white lab coats," he notes, "but science is one of the most intensively social disciplines there is.

"It is particularly important for young people to know we rarely work in isolation like that. The STCs are a prominent example of something that is pervasive across science, which is that it is very social, very team-oriented. It's as team-oriented as you want it to be."

Chris Paola, NCED Director



NEWS WATCH

RESEARCHERS UNLOCK THE MISSISSIPPI DELTA'S ANCIENT PAST TO CHART A COURSE TOWARD RESTORATION

Private Data Derived from Years of Oil Exploration Transferred to NCED for Research

The recent history of the Mississippi Delta region is more than meets the eye, says NCED director Chris Paola.

"It's not just about levees failing; it's not only a story about inadequate construction; and it's not just bad luck that a large hurricane happened to cross near New Orleans," he observes. "The story is intimately connected with the fact that we have allowed the loss of a great deal of delta surface area through sinking of the sediment column and drowning of the surface that hasn't been replaced by natural sedimentation."

Flying over the delta, you can see the effect of drowning of the surface in the form of enormous areas of dead and dying marsh and trees. "We need to understand the fundamental natural processes if we are to devise a long-term, sustainable plan," Paola believes. "Any place you are concerned about sustainability of the environment, you have to think about dynamism of the entire surface itself, whether it's a salmon stream in the Pacific Northwest, an urban stream in Baltimore, or the Mississippi Delta."

Paola is working with many colleagues inside and outside the center to develop tools to support sustainable restoration of the delta. Involved are researchers from Tulane University, the University of Louisiana–Lafayette, Louisiana State University, the U.S. Geological Survey, and the U.S. Army Corp of Engineers.

New insights may come from an unprecedented data set that is being made available to the center by oil companies, which have collected detailed information about the subsurface by bouncing sound off the layers under the delta.

"It's kind of a like an ultrasound of the Earth," explains Paola. "It gives you a record—and it's the only record we have—of how the Earth has worked over very long time scales. You can see its natural variability, how it responds to things that are quite topical right now, like climate change, like rises in sea level. We have a great deal of information in this subsurface 'archive' about how the earth has responded to those things in the past."

The data are the result of a very large investment on the part of the companies, which kept the results largely in-house until now. "The existence of a center that is committed to a sustained, large-scale effort allows the companies to justify transferring quantities of data that they probably wouldn't transfer otherwise," says Paola.

SCIENCE-ON-A-SPHERE AND WATER PLANET

Swirling clouds traverse the ocean, pushed by wind currents racing across the globe. You can view the moving projection from any angle and walk around the globe to see what's happening over Africa, Europe, or the U.S. Then change the program and follow a tsunami wave as it spreads across the oceans, watch an El Niño event move warm ocean waters eastward toward the Americas, or observe any one of a host of other geophysical processes at the touch of a button.

It's all thanks to an innovative visualization system that projects moving displays in time and space, not on a conventional flat screen, but rather, on a white sphere suspended above you in mid-air.

This is Science-on-a-Sphere, an exhibit developed by the National Oceanic and Atmospheric Administration and on display at the Science Museum of Minnesota (SMM).

The system will be a central element of a new 5,000-sq-ft traveling exhibition under development called Water Planet, which will help visitors better understand the role of water in critical global processes. Water Planet will allow visitors to observe global processes in a condensed time frame that otherwise happen on large temporal and geographic scales.

Two other NSF Science and Technology Centers join NCED in working with SMM on the development of Water Planet: The Center of Advanced Materials for Purification of Water with Systems (WaterCAMPWS) and the Center for Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA),

Water Planet is scheduled to open at SMM in fall 2008 and to be available for rental beginning in spring 2009. For more information, contact Patrick Hamilton, hamilton@smm.org

Science-on-a-Sphere

A PASSION FOR PUBLIC OUTREACH

Big things continue to come from a close working relationship between NCED and the Science Museum of Minnesota (SMM).

From 2002 to 2004, NCED researchers and SMM exhibit developers collaborated on the design, prototyping, and construction of a 1.75-acre outdoor science park at SMM, called The Big Back Yard.

The park encourages visitors to explore the Earth's surface, and the processes that shape it, through interactive exhibits and landscaping. It features a nine-hole, regulation miniature golf course that leads golfers from the uplands of North America to the Gulf of Mexico, and along the way reveals the processes of sediment erosion, transport, and deposition. Interspersed among the miniature golf holes are interactive exhibits based on NCED experiments.

"They know how to package and present our work for the public and we know the basic science," says NCED director Chris Paola.

NCED support to the museum through July 2007 totals some $2.9 million, says Pat Hamilton, director of environmental sciences and Earth-system science at SMM. A good chunk of that was spent on creating the centerpiece components of The Big Back Yard.

"From our perspective, we never would have been able to do what we have done without NCED," observes Hamilton. "Not just in terms of the money, but the fact that this outdoor exhibit really required a lot of prototyping, and although we have excellent prototypers here, we don't have flumes. And we don't have engineers. NCED made their experimental facilities and their engineering expertise available to us, and it was a tremendously fruitful collaboration."

Museum president Eric Jolly points to a dimension that reaches well beyond the exhibit grounds: "We built that magnificent braided stream exhibit that's in our Big Back Yard; and when it's running, young people play in it for hours and they study it and learn from it. But before we could build the finished exhibit, we had to do models.

"Now, we have in our storage, tabletop-sized braided streams. When our teacher resource center opens spring 2007, we're going to be able to make those tabletop versions available to schools, so that teachers will be able to provide that kind of hands-on experience to students all across a multi-state region."

SMM President Eric Jolly

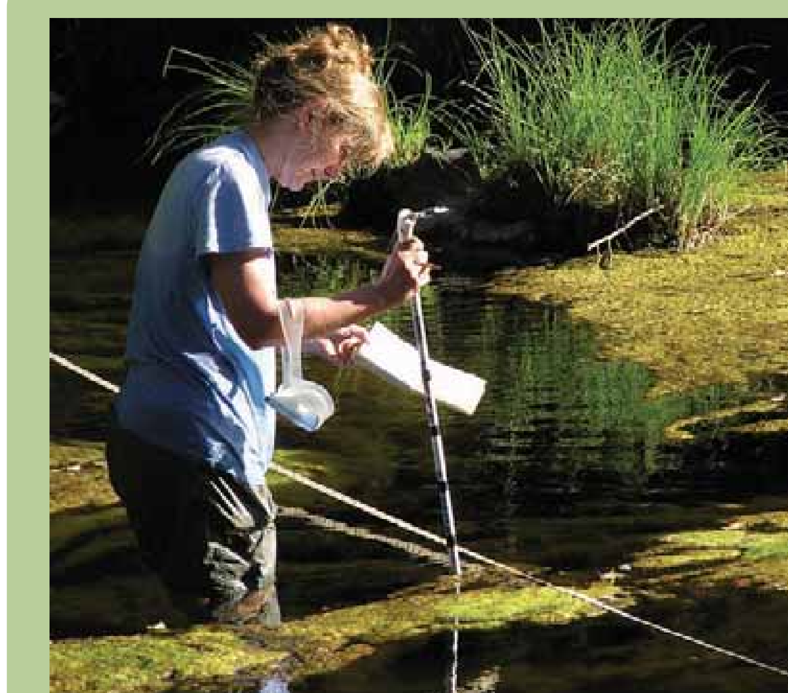
The partnership builds upon long-standing capabilities of SMM in exhibit development. "SMM develops and travels more exhibits than any other science museum in the nation," notes Jolly. "We're the largest exhibit construction company within any museum in the country—we have one hundred and sixteen people whose full-time job is building exhibits, renting them, and showing them."

Since joining SMM in 2004, Jolly has worked to cultivate a close working relationship with NCED, in part through the negotiation of a memorandum of understanding (MOU) that facilitates communication between SMM and UMN. Toward this end, Jolly has drawn upon his experience as a former psychology professor and university administrator. He is a nationally acclaimed leader in the field of science education and science literacy.

"The MOU allowed us to have a portal," Jolly explains. "It can be difficult to find a way in to a major research university—to an outside institution, a university can be overwhelming. You don't know exactly where to go—it's not intuitive. Having an MOU helped that," he says.

"There's a reciprocity in this that's pretty astounding," says Jolly. "I consider this one of the best examples of public-private partnerships in the country."

The energy that the players bring to the collaboration is infectious. "People have accused me of having too much fun," says Jolly. "I get to play scientist, educator, keeper of incredible treasures, and it's all aimed at my passion: science as an essential literacy for our youth—science education as a civil right in many ways."



GRADUATE CERTIFICATE PROGRAM IN STREAM RESTORATION FILLS AN EDUCATION GAP

BY KAREN GRAN

On a sunny day in central Minnesota, thirteen students armed with equipment and waders set up their cross-section lines and begin to measure channel topography. They are starting an investigation on the Maple River, where a local landowner has complained about bank erosion. The Department of Natural Resources wants to enhance fish habitat, and the Minnesota Pollution Control Agency hopes to reduce turbidity and improve water quality of the river.

These students are the first participants in the Stream Restoration Science and Engineering Graduate Program (SRSE), started by NCED at the University of Minnesota (UMN).

Stream restoration requires a complex understanding of engineering, physical, biological, and social sciences, yet few practitioners have such integrated training in these fields. NCED aims to fill that gap with a new year-long, interdisciplinary program, which completes its first year in June 2007. The certificate may be taken as a stand-alone qualification or incorporated into a master's or doctoral program. It is currently the only year-long graduate degree in the country specifically aimed at stream restoration, according to NCED.

WATER PURIFICATION

THE CENTER OF ADVANCED MATERIALS FOR THE PURIFICATION OF WATER WITH SYSTEMS WaterCAMPWS

FROM THE SEA TO SINK TO THE SEA AGAIN

When it comes to water, the statistics are staggering. Some 1.1 billion people worldwide lack access to safe drinking water, and 2.4 billion are without basic sanitation, according to estimates by the United Nations.

Here in the U.S., we are facing a critical shortage of potable water, says Mark A. Shannon, director of the WaterCAMPWS, headquartered at the University of Illinois at Urbana-Champaign (UIUC).

In addition to the problems of naturally occurring contaminants like arsenic, stresses such as human population growth and activities like agriculture, mining, and industrial operations are threatening our water supplies. Aquifers throughout the U.S. are suffering from declining water levels, saltwater intrusion, and inadequate recharging with fresh water. Major rivers and watersheds are being overdrawn.

Electric power plants are among the greatest users of water in the U.S., says Shannon, especially in certain parts of the Northeast, where 50 percent or more of the water withdrawals may go towards energy production.

To help ensure the continued supply of clean fresh water, researchers at the WaterCAMPWS are working to develop new materials and systems to safely and economically purify water for human use. At the same time, they are developing the diverse human resources needed to exploit the research advances and new knowledge base.

"It's a fundamental problem that resonates with people," says Shannon. "Water is connected to issues of the environment, energy, and human health."

The center serves as a hub for an 11-institution partnership. It is organized into interdisciplinary teams to address three major objectives for water purification: desalination/reuse, decontamination, and disinfection.

Co-leaders John Georgiadis and Menachem Elimelech are leading the effort to develop new materials, methods, and systems to improve the efficiency of desalination and reclamation processes. To remove contaminants from all types of water sources, co-leaders Yi Lu and Charlie Werth are leading the charge on methods for selective adsorption, catalytic reduction, and oxidation of pollutants that are conventionally difficult to treat. Items on their "hit list" include nitrate, perchlorate and arsenate, metal ions such as lead and mercury, and organic pollutants.

The center team on disinfection, led by Benito Marinas and Eric Mintz, is developing methods to economically destroy contaminants and pathogens without producing toxic substances. Projects in all of these areas were highlighted at the Spring 2007 national meeting of the American Chemical Society.

Work by several groups in the center on new photocatalysts is showing great promise as a means to treat wastewater without generating the toxic by products of chlorination. Work by Jian-Ku Shang and colleagues using nitrogen-doped titanium oxide, nicknamed TiON, as the photocatalyst has led both to a startup company and to an application project in conjunction with a metropolitan wastewater utility. Work on composites of TiON and alumina, a hydrated aluminum oxide, by Eric Mintz, a chemistry professor at Clark Atlanta University, is shedding light on the mechanism of the photoxidation process.

Another spinoff of center research has helped to spawn a major national effort on nanomanufacturing. Fundamental work by Paul Bohn, co-principal investigator of the WaterCAMPWS, and colleagues some years ago was focused on membranes that have many tiny cylindrical pores. This work in the area of "molecular gates" has led to new ways to move, manipulate, and chemically transform materials to effect exquisite 3-D control at the nanoscale. It has applications for chemical sensing as well as for the processing of materials, including water treatment.

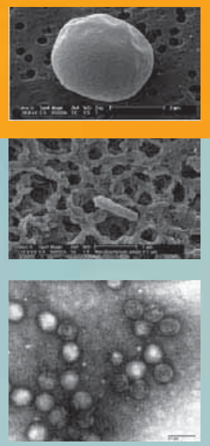
The work also led to the creation of a new $7.5-million NSF center for Nano-Chemical-Electrical-Mechanical Manufacturing Systems (Nano-CEMMS) headquartered at UIUC.

Bohn clarifies the relationship: "Part of the Nano-CEMMS was an outgrowth of part of the STC." A UIUC professor for some 23 years, Bohn recently moved to the University of Notre Dame as professor in the Departments of Chemical and Biomolecular Engineering and of Chemistry and Biochemistry. □

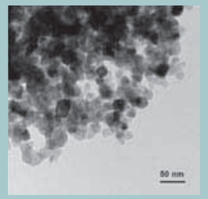
THREATS TO AMERICA'S WATER SUPPLY

More details can be found at http://www.watercampws.uiuc.edu and click on Water Crisis

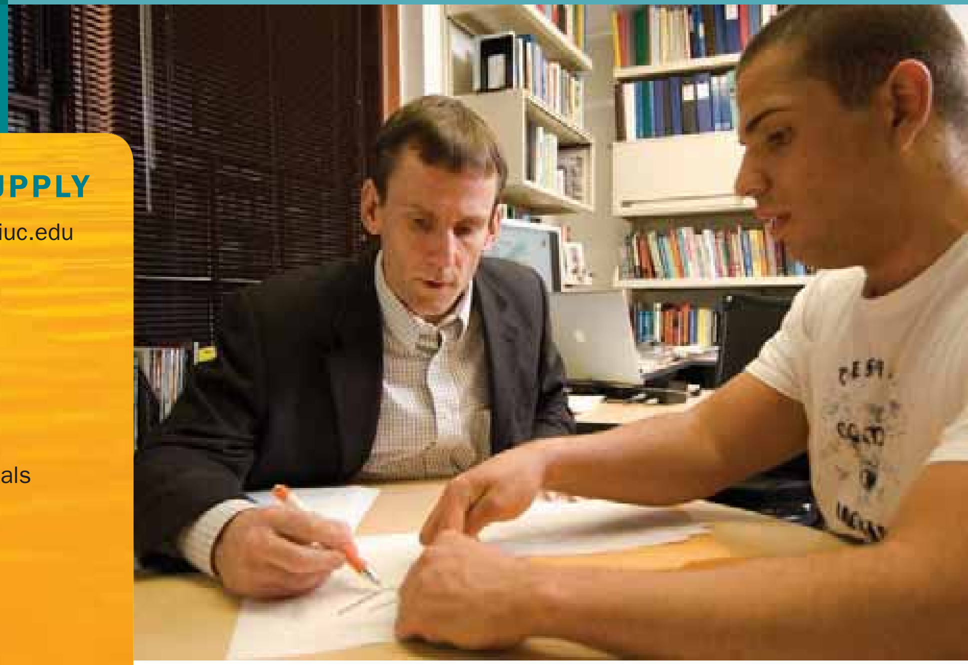
- Increased demand by energy production
- Agricultural run-offs, such as:
  - Nitrates
  - Herbicides
  - Phosphates
  - Hormones
  - Pesticides
- Leaching of radioactive materials and heavy metals
- Depletion of aquifers
- Contamination of aquifers by:
  - Salt water
  - Pollution
  - Toxins



Disinfection Targets: Waterborne pathogens (top to bottom: protozoa, bacterial spores, viruses) are a major cause of disease/death in developing countries, and an emerging threat to public health in the U.S.



TiON nanoparticles. Nitrogen-doped titanium dioxide shows promise for photocatalytic water disinfection. Image courtesy of Jian-Ku Shang, materials science and engineering, UIUC.



WaterCAMPWS director Mark Shannon, left, works with a student.

A CONVERSATION WITH THE DIRECTOR

Mark Shannon

WaterCAMPWS director Mark Shannon explains that the center is trying to address problems that are ten or more years down the line through what he calls a "mission approach."

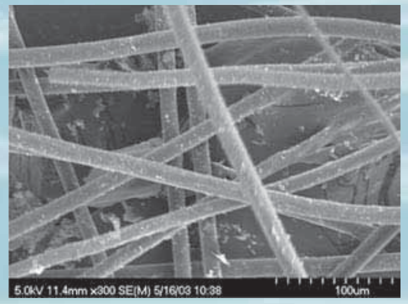
The idea is to proactively bring researchers together to tackle mission-critical projects. In many cases, it is work that would not have happened otherwise, since these researchers likely would not have had any interaction with each other if it had not been for the center. Shannon recognizes it's not for everyone, noting some "attrition of those investigators that can't get into the mission approach." But he says, "We're finding that people are doing things they couldn't do before."

Case in point: the center was looking for investigators with strengths in polymer synthesis and in membrane technology to overcome the problem of membrane fouling in wastewater treatment processes for water reuse. Because wastewater has a high content of organic materials, microbes are used to break down these constituents. Membrane bioreactors—systems that combine conventional biological wastewater treatment with a membrane separation process—offer the promise of high water quality and small size. Although membrane bioreactors work well for digesting and converting organics, their use has been limited due to membrane fouling.

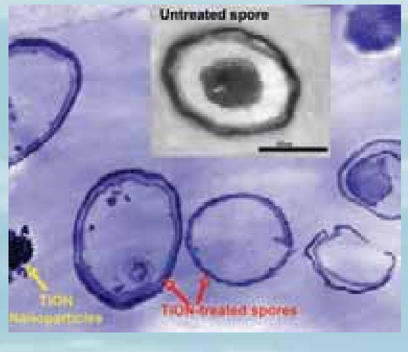
Shannon recruited to the project MIT professor Anne Mayes and Yale professor Menachem Elimelech with strengths in polymer synthesis and surface fouling, respectively. They started working with UIUC professor Eberhard Morgenroth, an expert in membrane bioreactors. "In an amazingly short time," says Shannon, "they started making membranes, testing them and characterizing them, doing postmortem analysis, and iterating on it until they hit on something that showed remarkable reduction in fouling potential." The work is published in the Journal of Membrane Science [285, 81-89, 2006].

THE STORY OF TiON:
PHOTOCATALYTIC POWERHOUSE

Top Photo: Metropolitan Water Reclamation District of Greater Chicago



Left: TiON fibers. Image courtesy of Jian-Ku Shang, materials science and engineering, UIUC.



Bacillus Subtilis spores killed by TiON. Image courtesy of Jian-Ku Shang, materials science and engineering, UIUC.

Municipal wastewater is a soup of bacteria, viruses, and spores, inorganic compounds and metal ions, as well as organic compounds including pharmaceutical and personal care products.

After a biological treatment step, wastewater from the three largest plants at the Metropolitan Water Reclamation District of Greater Chicago (MWRD) is currently discharged into the river without disinfection because the waterway is currently designated for secondary contact. However, to be proactive, MWRD needs to understand the implications of disinfection if regulations were to change.

The price tag for a conventional method would be high—about $0.5 billion. The three large wastewater facilities typically process 0.75 million gallons of water per minute, so they need a disinfection method that is both inexpensive and rapid.

"We're looking for ways to improve current operations, to save energy, to improve process efficiency," says Catherine O'Connor, coordinator of technical services at the MWRD. "Costs have gone up 30 percent over the past year in energy costs alone. We're considering energy every step of the way—and that's why we're so enthused about the technology that Jian-Ku Shang and his group at the WaterCAMPWS have developed."

She's talking about the development of a photocatalyst called TiON—a nickname for titanium oxide to which nitrogen has been added. Historically, titanium dioxide has been extensively studied as a photocatalyst, capable of carrying out photoxidation of organic substances in water. Center researchers have enhanced its performance in two fundamental ways.

First, by adding nitrogen and co-dopants, they shifted the energy of the process from the ultraviolet range into the more practical range of visible light. Secondly, by altering the physical form of the material to have an ultrahigh surface area by means of processing it into powders, films, or fibers, they have increased the disinfection rate by more than six orders of magnitude compared to conventional titanium dioxide, that is, by a factor of more than 1,000,000.

Furthermore, early attempts to improve on titanium dioxide using TiON powders couldn't kill spores such as those from anthrax. Second generation materials using a co-dopant were able to readily kill sizable concentrations of bacteria such as E. coli and Staphylococcus aureus ("staph") within about 30 minutes, and killed spores in a matter of hours. Generation four of the material can remove 100,000 E. coli per milliliter in less than 20 seconds—"the fastest anybody has every achieved," says Jian-Ku Shang, professor of materials science and engineering at UIUC.

Various versions of the material are the subject of U.S. patent applications, notes Shang, and the technology is the focus of a spin-off company called E&S Fibers, Inc., Champaign, Ill. The early-stage venture, now in the process of fund-raising, is developing systems using TiON and activated carbon to remove contaminants in water.

Generation four TiON is being tested at the Chicago MWRD using real wastewater in the laboratory setting. "The preliminary results showing E. coli inactivation with very rapid, flow-through treatment using TiON and visible light were quite encouraging," says O'Connor. "I think it's very much a breakthrough."

The researchers envision a modular photocatalytic system that could be installed at the end of the treatment process. "When you think of the construction of a wastewater utility, every one of them has, at the end of the process, a water clarifier in the open air," explains Richard Sustich, Industrial and Govermental Development Manager for the WaterCAMPWS and former assistant director of research and development at the MWRD.

"During daylight hours, you have a pretty good source of light" says Sustich, and because the center technology uses light in the visible range, it may be possible to use conventional lighting sources, like street lights. "Every plant has essentially the same physical spot at the end of the treatment process where you could apply the catalytic disinfection. So the process would be scalable for any size wastewater plant. We're thinking of this as a generic application for any wastewater plant anywhere."

The partnership provides a way for center researchers to test their technologies in the real world. "Prior to dealing with us, they've shown very encouraging results but it's all been with lab grade water," says O'Connor. "While our plant effluent is very clean, and we outperform what our national pollution discharge elimination permits require, the big issue is that there are still 1 to 2 mg/liter of suspended solids." These make treatment much more difficult compared to spiking lab grade water with microbes and disinfecting that water.

O'Connor estimates that the technology is more than three years a way from the marketplace, and that the potential is "huge."

"There's a one billion dollar industry in U.S. for reuse of photofinishing wastewater alone," says O'Connor, "and that's just one of many markets—disinfection in wastewater and water treatment, pump-and-treat contaminated groundwater. The opportunities are enormous."

DNA SENSOR TECHNOLOGY FROM WaterCAMPWS IS FOCUS OF ILLINOIS STARTUP COMPANY

Sensor researcher Yi Lu of the WaterCAMPWS works with students.

A catalytic DNA sensor developed by Yi Lu of the WaterCAMPWS and colleagues may lend itself to development as a simple, inexpensive field test kit.

The sensor uses DNAzymes—segments of DNA with enzymatic activities—that can bind analytes of interest. By coupling the DNAzymes with dyes or gold nanoparticles, the researchers can make sensitive and selective colorimetric sensors for a variety of contaminants in water.

For example, a fluorescent sensor made in this way can detect lead ion down to a level of 0.2 parts per billion (ppb)—significantly below the 15-ppb level for drinking water set by the U.S. Environmental Protection Agency (U.S. EPA), say the researchers. The work was selected as one of the top five presentations at the Materials Research Society Spring Meeting in San Francisco in April 2006.

This technology has become the focus of a start-up company, Dzyme Tech, funded by the U.S. EPA, the National Institutes of Health, and an Illinois venture-capital firm.

CENTER COSPONSORS SYMPOSIA ON "CHEMISTRY FOR A SUSTAINABLE WATER SUPPLY" AT THE SPRING 2007 NATIONAL MEETING OF THE AMERICAN CHEMICAL SOCIETY

Eric Mintz, a professor of chemistry at Clark Atlanta University and researcher in the WaterCAMPWS.

Sustainability was highlighted at a recent national meeting of the American Chemical Society, and thanks to the efforts of the WaterCAMPWS, new technologies for sustainable water supply featured prominently.

The looming shortage of potable water in the U.S. is a serious problem that many people underestimate, notes Eric Mintz, a center investigator and professor of chemistry at Clark Atlanta University. "We're running out of cheap water," he stresses. "We shouldn't take water for granted."

The center helped to sponsor eight symposia, bringing more than 100 presentations to conference-goers in Chicago around the central theme of water:

- Advanced Membrane Technology for Water Reuse
- Advances in Adsorption Processes for Drinking Water Treatment
- Advances in Desalination of Sea and Brackish Water
- Advances in Drinking Water Disinfection Processes
- Advances in Oxidation Processes for Water Treatment
- Catalytic Control of Emerging Micropollutants
- How Pure Is Our Drinking Water: Advances in Detection and Quantification of Water Contaminants
- Occurrence, Formation, Health Effects and Control of Disinfection By-Products in Drinking Water

CENTER FOR REMOTE SENSING OF ICE SHEETS CReSIS

CENTER PUTS ICE SHEETS ON THE CLIMATE CHANGE RADAR SCREEN

BY BEN RAKER

Above: CReSIS remote sensing equipment used in Greenland. Image courtesy of CReSIS.

Above in background: Along Greenland's western coast, a small field of glaciers surrounds Baffin Bay. Image courtesy of USGS National Center for EROS and NASA Landsat Project Science Office

Left to right: David Braaten and Center director, Prasad Gogineni, in Antarctica

"Polar ice sheets are changing significantly," says Prasad Gogineni, director of the Center for Remote Sensing of Ice Sheets (CReSIS). "Some of these changes have never been observed in human history. We really don't know why they're changing, what is causing these changes—that is really what we're trying to understand."

CReSIS, which is headquartered at the University of Kansas (KU) in Lawrence, Kan., takes as its focus one of these largest gaps of knowledge in the field of climate change research: how collapsing polar ice sheets contribute to sea level rise.

Toward this mission, the center is developing radar systems, remote-control vehicles, and other new technologies to map the polar ice sheets to a depth and scale never accomplished before. The researchers have already begun collecting data to drive models for better prediction of this poorly understood consequence of global climate change.

"How fast and how much sea level is going to rise—that's in a nutshell what we want to know," says David Braaten, deputy director of CReSIS.

Indeed, the 2007 report of the assembly of scientists and officials known as the Intergovernmental Panel on Climate Change (IPCC) finds ice sheet changes to be an area of concern for further research. The report acknowledges that current models would not have predicted the extent of increase in ice sheet melting that has been observed within the last decade.

As the world's only center dedicated exclusively to large-scale study of the polar ice sheets, CReSIS is playing a central role in filling this information gap. And assessing the potential effects of melting-induced sea level rise on human populations makes the center's research particularly important. "Even one meter of sea level rise would affect about 100 million people worldwide," says Gogineni. "There's no way to make a good estimate about sea level rise because we don't know enough yet about the behavior of the ice sheets," adds Braaten.

Mapping Uncharted Territories

In order to understand how an ice sheet moves, scientists essentially need to map its top, bottom, edges, and interior. They need to understand what is going on at the surface of the ice where new ice is accumulating, what the layers inside the ice reveal about its past movement, what is happening at the sides that might constrain the ice, and what the ice is flowing over—if it is ground, what the surface is like; if it is fluid, how much this helps the flow of the ice.

Since launching in 2005, one of the center's greatest achievements has been demonstrating success with synthetic aperture radar (SAR)—a system that can penetrate deep ice to provide a high-resolution record of the bed underneath. Recent work by CReSIS in Greenland was the first to use this technology successfully through roughly three kilometers of ice.

"Understanding what's happening under the bed of ice is extremely important," says Gogineni. "Right now there are not many tools available to do that over large areas."

As the radar passes over the ice—either on the surface or in the air—the radar casts its signal at an angle downward and records the reflected returns in a top-view swath of what is just to either side of the radar's path. By sweeping lawnmower-fashion back and forth, the researchers can put the swaths together and map a large area.

Much of the CReSIS fieldwork to this point has involved proof-of-concept exercises with this technology and initial ground-based surveys. But the goal is to soon put the radar on uncrewed aerial vehicles (UAVs), which can cover more area more quickly. Researchers aim to test newly developed aerial "drones" in Greenland in 2008, and then also on Antarctic ice sheets in 2008–2010.

Additionally, researchers affiliated with the center are already creating data sets using depth sounder radar and seismic surveys to map the ice and ice beds in cross-sections downward. They are working with satellite data to analyze the velocity of ice movement. A paper in the journal Science resulted from this work in 2006. And they are further developing existing sensor systems and ground-based robotic vehicles to survey large areas remotely.

Team Science for Timely, Coordinated Research

Much of the work on developing new technologies takes place back at the universities within the CReSIS partner system. Work on such projects as the design of aerial drones, robots, and miniaturized systems to be carried on aircraft require the coordination of engineers and scientists from various fields. This coordination also provides opportunities for a wide range of students at undergraduate and graduate levels.

David Braaten, left, and Prasad Gogineni, right, in Antarctica.

CReSIS researchers and students come together from the fields of aerospace, electrical engineering, computer science and engineering, geology, geography, and even education. Universities partnering in CReSIS include KU; Elizabeth City State University, a historically African-American university in North Carolina; Haskell Indian Nations University in Kansas; the Ohio State University; the Pennsylvania State University; and the University of Maine. CReSIS also collaborates with various industry and international partners.

"The greatest advantage of the center is that it brings together the engineers, the people who go into the field, and people like myself who take the data and analyze it," says Kees van der Veen, a professor in the department of geography at KU.

Braaten notes that the center brings people together more often than would happen if they only met at periodic conferences and meetings. This efficiency also serves a greater purpose because of the time-sensitive nature of research on sea level rise. "It's not something we can wait twenty years to solve," he says. □

HANDS-ON RADAR DESIGN

Under the sponsorship of CReSIS, students at the University of Kansas are designing a prototype radar system with the goal of eventually miniaturizing and deploying their equipment in the polar regions.

Undergraduates in KU's electrical engineering program are working on a year-long senior design project called Multi-waveform Radar for Classroom Demonstration and Ice Sheet Altimetry (MRAD). This type of radar will be used in the field to take high-resolution measurements of ice-surface features and thicknesses.

The students planned their design using computer software and then built it up component by component into a demonstration model. "It's cool to be able to learn about something in the classroom and then design it," says Heather Owen, an electrical engineering undergraduate working on the project. She says that the prototype is already being used in classrooms for demonstration.

The prototype will need to be miniaturized for use in aerial surveys, which is the work of Cameron Lewis, a KU graduate student. Lewis says that the box measuring 2 ft by 1.5 ft by 3 ft now holding the prototype will eventually need to hold it and all of the other sensors onboard an aerial drone. Eventually, the multi-waveform radar must be shrunk down to a board about 4 in by 4 in. Still, Lewis welcomes the challenge CReSIS is presenting him: "Not very many people build radars for civilian purposes—but CReSIS has a practical reason to do this," he says. "I'm using my education, and that's a great feeling."

Background: Left to right: Cameron Lewis, Heather Owen, John Hecker, James Sulzen, Deebu Abi

Below: Left to right: Deebu Abi, Heather Owen, Cameron Lewis, James Sulzen, John Hecker

Photo: Thomas Overly © 2006

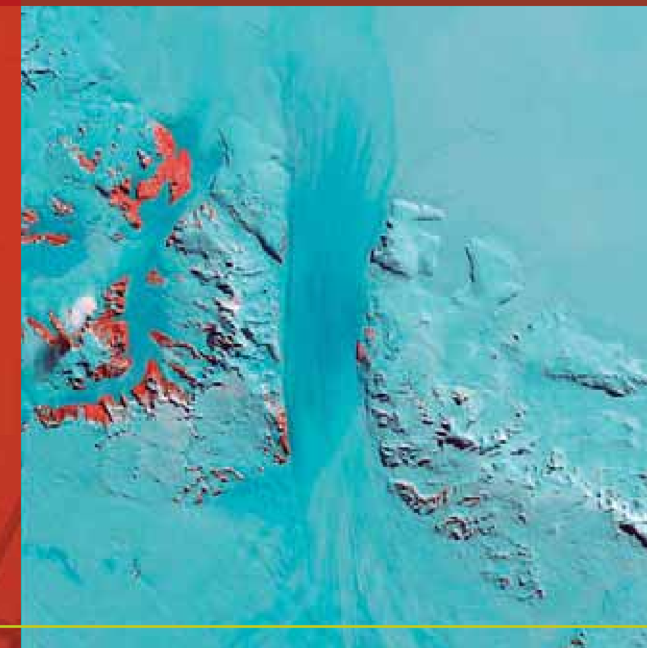
MEET THE DIRECTOR

Prasad Gogineni

Prasad Gogineni began work on remote sensing of ice sheets in 1992. This work gradually led to the predecessor program for CReSIS, called the Polar Radar for Ice Sheet Measurements (PRISM) project.

Gogineni credits time at NASA with insights into writing large-scale proposals and managing large projects. In his current program, he continues to enjoy working with students, and sees great promise for CReSIS in the years ahead.

"I am very excited about what the center can do—I really feel that we are on the cusp of a breakthrough to make major advances in glaciology and modeling of the ice sheets."



Students at Haskell Geographic Information Systems Laboratory

MAPPING SEA LEVEL CHANGE AT HASKELL INDIAN NATIONS UNIVERSITY

One of the CReSIS projects to attract broad press attention in early 2007 was a project completed by students at Haskell Indian Nations University (Haskell), a four-year university in the U.S. exclusively for Native Americans, and a CReSIS partner. Since 2001, Haskell has been working with its Lawrence, Kan., neighbor KU, and over this time has developed a lab and expertise in geographical information systems (GIS)—computer mapping systems that can essentially overlay different types of data on the same maps.

For its recent CReSIS project, Haskell students used GIS to make a digital elevation map of the world, and then input population data and projected scenarios for different possible levels of sea level change. This GIS dataset, which is now downloadable as a Google Earth overlay, shows the impact of sea level change on populations in eight different regions worldwide. It uses such high resolution that people in coastal Florida might zoom in on their street and see what sea level change would be required to inundate their neighborhood.

The maps may be viewed through the CReSIS Web site at: http://cresis.ku.edu/research/data/sea_level_rise/

In addition to having Haskell as a partner, CReSIS also draws on the strengths of Elizabeth City State University (ECSU) in Elizabeth City, N.C. It is an historically African-American institution with a record of research and education in remote sensing for undergraduates. Through the associations with these two institutions, CReSIS seeks to provide opportunities to populations traditionally underrepresented in science and engineering.

CReSIS GEARS UP TO TAKE TO THE AIR

Having tested radar technologies on ground-based vehicles in Greenland, and aerial drones at KU and partner institutions, CReSIS looks to gradually shift into aerial surveys in 2008–2010. "For basin-scale work, you really need aerial surveys," says CReSIS deputy director David Braaten. Before these aerial surveys can happen, technology must be miniaturized to work on a low-altitude, uncrewed airplane. Aerial surveys are planned for both Greenland and Antarctica, some in coordination with International Polar Year activities.

NEWS WATCH

Photo: Thomas Overly © 2006

SECURE TECHNOLOGY

TEAM FOR RESEARCH IN UBIQUITOUS SECURE TECHNOLOGY TRUST

CENTER TACKLES GRAND CHALLENGES IN CYBERSECURITY

Computing technologies are part of our nation's critical infrastructure. They form a part of everything from financial systems and the energy grid to telecommunication and transportation systems. Enhancing cybersecurity and computer trustworthiness is therefore of increasing importance as a scientific, economic, and social problem.

In response to this need, the Team for Research in Ubiquitous Secure Technology (TRUST) aims to transform the ability of organizations like software vendors, utilities, and government agencies to design, build, and operate trustworthy information systems.

Headquartered at the University of California, Berkeley, and led by center director S. Shankar Sastry, the center is working to catalyze collaboration between computing experts, social scientists, and the legal and policy communities in support of strengthening the security and trustworthiness of our nation's computing and critical infrastructures. Academic partners in TRUST with UC Berkeley include Carnegie Mellon University, Cornell University, Stanford University, Vanderbilt University, Mills College, San Jose State University, and Smith College.

Sastry, whose research is in the area of secure sensor networks and network defense, is a professor in the Departments of Electrical Engineering and Computer Sciences and Bioengineering at the University of California, Berkeley. He is the NEC Distinguished Professor of Engineering.

Kenneth Birman, computer science professor at Cornell University and TRUST coordinator for knowledge transfer

Fred B. Schneider, computer science professor at Cornell University and chief scientist of TRUST

TRUST education director Kristen Gates

Researchers at TRUST are working on three major research thrusts: security of physical infrastructure; combating identity theft and Web security; and access and privacy issues pertaining to electronic medical records. "The theme of the center is restoring trust to all infrastructures: physical, electronic, and information," says Sastry.

Over the last decade, the world has seen a rapid increase in computer security attacks at all levels, from the so-called "phishing" scams that lure people into revealing sensitive information to Internet attacks that paralyze Web sites. The center has developed many kinds of improved technologies to combat phishing, spyware, botnets, and related threats. But new technologies are only part of the answer.

"The solutions to today's cybersecurity ills or trustworthiness problems are not going to come only from the technical side or from the policy side of the house—but rather, from both sides working together," says Fred B. Schneider, computer science professor at Cornell University and chief scientist of TRUST.

These advances may come from research in computer science and engineering—but "sometimes the answer involves changing the law instead of changing the technology," says Kenneth Birman, computer science professor at Cornell and TRUST coordinator for knowledge transfer. Birman's research has focused on fault tolerance and distributed computing. He developed software used at the New York Stock Exchange and by the French air traffic control system, among other applications. But better technology sometimes won't be adopted unless the potential users face strong incentives to do so.

For example, TRUST researcher and clinical law professor Deidre Mulligan of UC Berkeley worked closely on California legislation that requires companies to track down and inform anybody whose private information was disclosed as a result of company negligence. The law passed, and now many other states are trying to enact similar legislation. "This has had an enormous nationwide impact," says Birman.

When the center started, the kind of connections happening at Berkeley, with legal scholars partnering with technology researchers, was relatively rare, says Sastry. "Now, each one of the partner campuses has an activity in terms of public policy, public health, or social sciences rolled into their agenda which adds to the richness of the issues being discussed," says Sastry. "It's gratifying to see all the wonderful links and connections that wouldn't have happened without the center." □

TRUST researcher and clinical law professor Deidre Mulligan of the University of California, Berkeley

SCADA FACILITY

Critical infrastructure, including power plants, water systems, and electric power networks, are controlled by devices that measure parameters of the system and activate controllers. Those devices are referred to as SCADA networks—Supervisory Control and Data Acquisition. "We feel these SCADA networks need to be replaced by more secure sensor networks, which is why it is one of the marquis grand challenge problems in the center," says Sastry.

The center's work on secure sensor networks responds to the need to build a new generation of technology to control our nation's physical infrastructure. TRUST researchers have developed new wireless network embedded systems with secure protocols built into them. They have developed models of attack and corresponding solutions, based on the mathematics of game theory, says Sastry. These solutions are built into the network embedded systems as security safeguards. Prototypes and software are now being transferred into practice, starting with oil and gas networks and power networks. "Those are the lead adopters," says Sastry. "Initial deployments were made on a 500-node network at Berkeley." The technology is now being transitioned to an oil company, he notes.

ELECTRONIC MEDICAL RECORDS: SECURITY, PRIVACY, AND ACCESS

TRUST researchers Janos Sztipanovits and colleagues at Vanderbilt University are involved in efforts to automate health care records. But there is an inherent tension between the goals of providing access to information to those who ought to have it, and protecting information from those who ought not to have it.

"Because Vanderbilt is at the forefront of this research nationally, we have a unique window into a laboratory where cutting edge work is going on," notes Schneider.

A health portal at the Vanderbilt medical school with some 10,000 patient records has been made available to TRUST as a test bed for research on access and privacy issues. Called "MyHealthAtVanderbilt," the system is one of the largest operational healthcare portals in the world, according to the center. "MyHealthAtVanderbilt" gives patients secure messaging with their providers. They can make appointments online and see the contents of their medical records.

TRUST researchers are working to develop a theory of privacy that is amenable to automation. "The challenge is to help organizations understand how to treat sensitive data, what they can and can't use it for, and how to track its use," says Mitchell. "We want to help organizations build information systems a with a privacy policy that helps them manage sensitive information correctly."

EDUCATING THE NEXT GENERATION OF CYBERSECURITY EXPERTS

Educational efforts at TRUST, led by Kristen Gates, focus on the enhancing the experience of graduate students by bringing them into contact with leaders in cybersecurity. "Not only are we helping to educate and inspire students but we're also helping to energize and invigorate younger faculty that are bringing these cybersecurity and technology issues into their classrooms at our partner institutions," she notes.

"We're seeing that these perspectives appeal to a diverse range of students," says Kenneth Birman of Cornell University. "They're drawn by the opportunity to have a very positive impact on society," he says. "We wonder if by engaging in this broader way, we may actually appeal to a larger community of students."

A new program staring summer 2007 combines a seminar experience combined with an internship in Silicon Valley companies. It's called SECuR-IT, short for Summer Experience Colloquium and Research in Information Technology, and it's a learning community of 20 graduate students who have applied from all over the country.

These students will be matched with companies that specialize in information technology, such as Cisco, Yahoo, eBay, and Intel, among others. Participants will live at San Jose State University in the dormitory as a learning community, and they will work at organizations in Silicon Valley four days per week. On Fridays, they attend Stanford seminars on cybersecurity given by faculty from partner institutions.

The program is an outgrowth of an industry group of chief security officers organized by John Mitchell, TRUST principal at Stanford, and Robert Rodriguez, a consultant, formerly of the Secret Service. The informal working group has met periodically to talk about issues in cybersecurity education and curriculum. "In addition to college curriculum recommendations from industry, two things came out of that process," says Mitchell, "the industry contacts for the summer internship program, and a speaker series, which we plan to record and archive on the Web."

A CONVERSATION WITH THE DIRECTOR

Shankar Sastry

When it comes to cybersecurity and computer trustworthiness, "the problems are so big, there is not the talent in any one university to put this together. So I thought we needed a coalition," says center director S. Shankar Sastry.

"I'm operating on a sense of conviction that the science and technology is important, but getting it out before it's too late is as important. So to do that means a combination of someone with research credentials and committed to getting the results out to stakeholders.

"Some researchers feel they come up with the best technologies and they just throw it over the wall, and then they get frustrated the world doesn't change.

"But the reason it doesn't is that there are important social, legal, economic, privacy considerations that do need to be addressed. And I think an STC needs to be a place to do that."

> "The problems are so big, there is not the talent in any one university to put this together. So I thought we needed a coalition."
>
> — SHANKAR SASTRY

GONE: PHISHIN'

A user inadvertently visits a Web site thinking that it's a trusted service provider, like a bank, when in fact it's a "fake" site set up by criminals to capture sensitive information for illegal purposes. This is the scam called "phishing."

TRUST researchers have developed several freely distributed software prototypes that are run with a Web browser to help protect passwords designed for ordinary Web users. "Our goal is to get these ideas picked up in industry and the main browser distributors," says John C. Mitchell, who is the Mary and Gordon Crary Family Professor of Computer Science at Stanford University.

In the abstract, the problem is one of "authentication" —establishing the identity of the entity you're talking to. Whenever you log into a computer and give your password, that's part of a protocol by which you authenticate your identity to the computer.

"We're used to having people prove their identity to machines. We're also actually pretty good at protocols for machines to prove their identity to other machines. But nobody appreciated that there's this other technical problem of having machines prove their identity to people—because really what you want is the web site to somehow prove to you it is who you think it is," says Schneider.

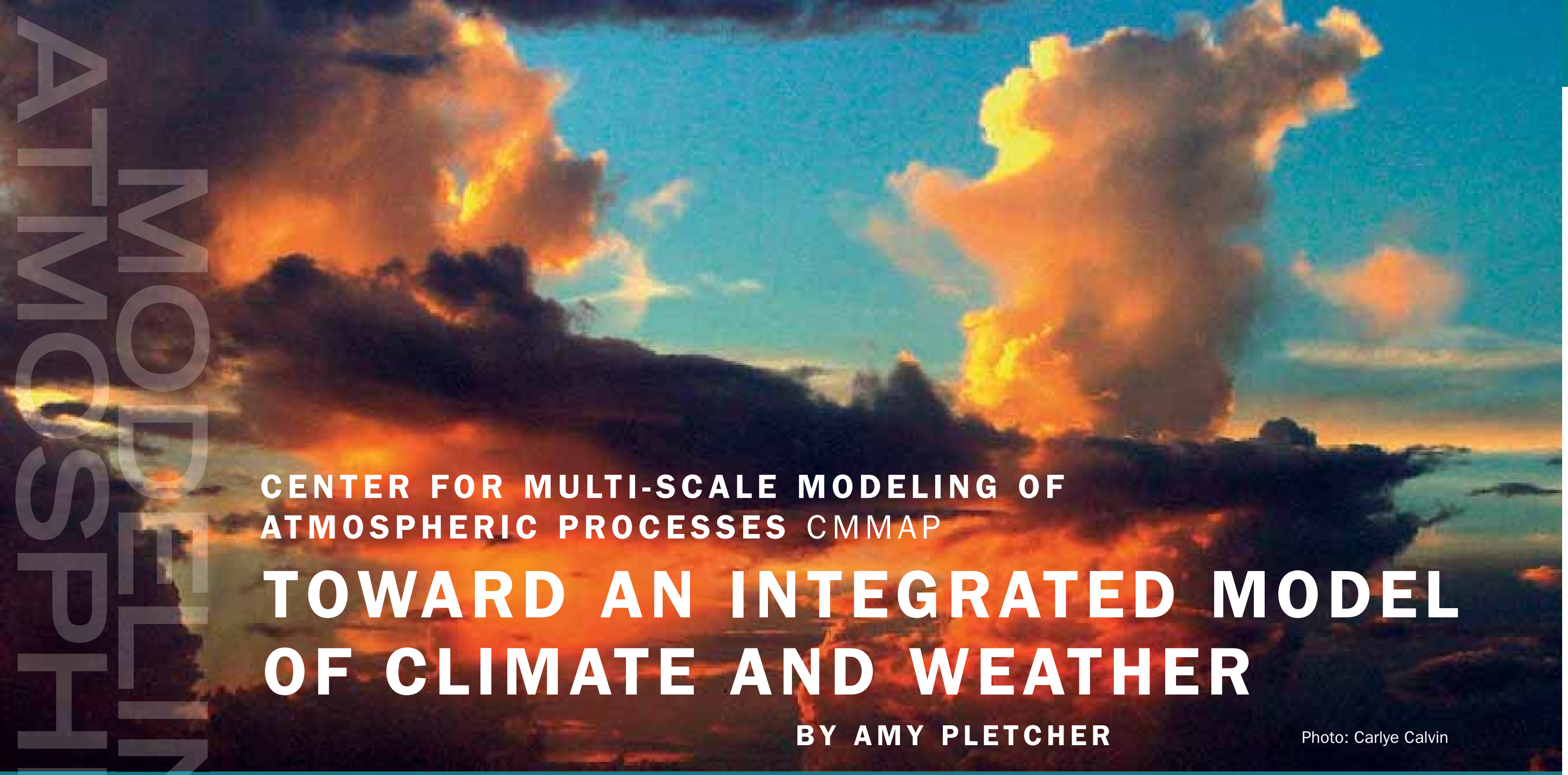
In one scheme, called Dynamic skins, developed by Doug Tygar of UC Berkeley and colleagues, the Web site displays for you a picture that is a secret you share with the site: a sailboat, a cat. Whenever you log in it shows you this picture. A phishing site won't know what your favorite picture is, and therefore it won't be able to reproduce the look of this site of your service provider.

Another scheme is based on the realization that a stolen password only has value if the phishers can reuse the password someplace else. "Most people, having bad memories, have a very small number of passwords that they use at the sites they visit," notes Schneider.

But TRUST researchers realized they could automatically take the password you typed and transform it—by applying a mathematical function called a cryptographic hash to a combination of the password and the name of the site you're visiting—and use that as the password they send to the site. Now, in effect you have a different password at each site but have to remember only one. Phishers get a password, but they cannot decompose it into your password and the word inserted into it. Why not? By analogy, "five plus two is seven, but if I tell you seven, you have no way to know if it was three plus four, one plus six, and so on," explains Schneider.

This development of this method inside a protective browser extension, called PwdHash, was done by Mitchell, Dan Boneh of Stanford, and colleagues. It was honored with an award from Computerworld in 2006.

Anti-phishing methods are but one example of many other research projects at the center addressing the general theme of identity theft and security of information systems. Companies are picking up these anti-phishing approaches, among other areas of center research. "We've seen enormous interest from industry," says Birman. "If you're a company out there and having a tough time overcoming a reliability or security problem and start to browse around, the appeal of an NSF STC is that it offers a kind of one stop shopping," he says. "Here's a group of tremendously talented researchers who have come together to do a coherent job of focusing on these questions."



CENTER FOR MULTI-SCALE MODELING OF ATMOSPHERIC PROCESSES CMMAP

TOWARD AN INTEGRATED MODEL OF CLIMATE AND WEATHER

BY AMY PLETCHER

Photo: Carlye Calvin

Critical mass can be defined as an amount necessary to have a significant effect or to achieve a result. For scientists in the field of atmospheric science and climate change, the creation of the Center for Multi-Scale Modeling of Atmospheric Processes (CMMAP) provides the critical mass needed to tackle fundamental problems that have remained mysteries for far too long.

Established in July 2006, and based at Colorado State University in Fort Collins, CMMAP is a partnership of nine degree-granting institutions and 20 additional collaborators whose mission is to improve climate and weather forecasting for scientists around the globe by building atmospheric models that will more accurately describe cloud processes than anything developed thus far. The center is undertaking work on many of the same atmospheric science topics that scientists have been targeting for years. What sets the center apart, however, is the scale at which they are able to tackle these issues.

"We're using new mathematical methods to simulate in the computer the way the clouds interact with the global circulation of the atmosphere, relying on extremely powerful computers in a way that wasn't possible until five years ago," says center director David Randall.

Eventually, with enough computing power, center researchers hope to gain the ability to actually simulate individual clouds and atmospheric circulation. This critical mass in computing power and resources is allowing the center to tackle several phenomena that scientists have long sought to understand, including the Madden-Julian Oscillation (MJO) and the boundary layer of thunderstorms.

"The embarrassing thing for atmospheric scientists is that no one knows how [the MJO] works even though we've known about it, [and] we even have a model that simulates it pretty well," says Randall. The combination of computing power and the number of institutions involved are allowing the scientists to finally confront these modeling problems head on.

Scientists will go through multiple phases in their research, first developing a new model that will more accurately represent the atmospheric effects of interest and evaluating the model based on comparisons with actual observations, and then eventually applying the model to understand how clouds interact with global systems like oceans and land surfaces. Projects range from the macro to the micro scales: everything from observations of entire weather systems to the properties of individual ice crystals. Until now, groups of research studying these phenomena have had trouble communicating because there weren't global models that took into account data sets from these different scales.

Because the center was recently founded, much of the science is still getting started, but there are several projects already underway that focus on cloud models. Historically, modeling has been done in roughly three levels of granularity, or resolution: global climate models, which operate on the scale of thousands of kilometers; cloud system resolving models, which represent processes between 1 and 500 km in scale; and large-eddy simulation models representing individual clouds on a scale between 10 m to 1 km. These distinctions in resolution are done for practical purposes and have little do to with the existence of actual differences in nature, explains project scientist Akio Arakawa of the Department of Atmospheric and Oceanic Sciences at UCLA. Center researchers are trying to incorporate information from these different scales into one unifying model. □

AN INTERVIEW WITH CENTER DIRECTOR

David Randall

Q: What should the public know about interdisciplinary centers?
Randall: NSF has struck a good balance between single principal investigator projects and the centers. Most NSF money goes to single-PI projects, but we need larger centers to attack the bigger problems.

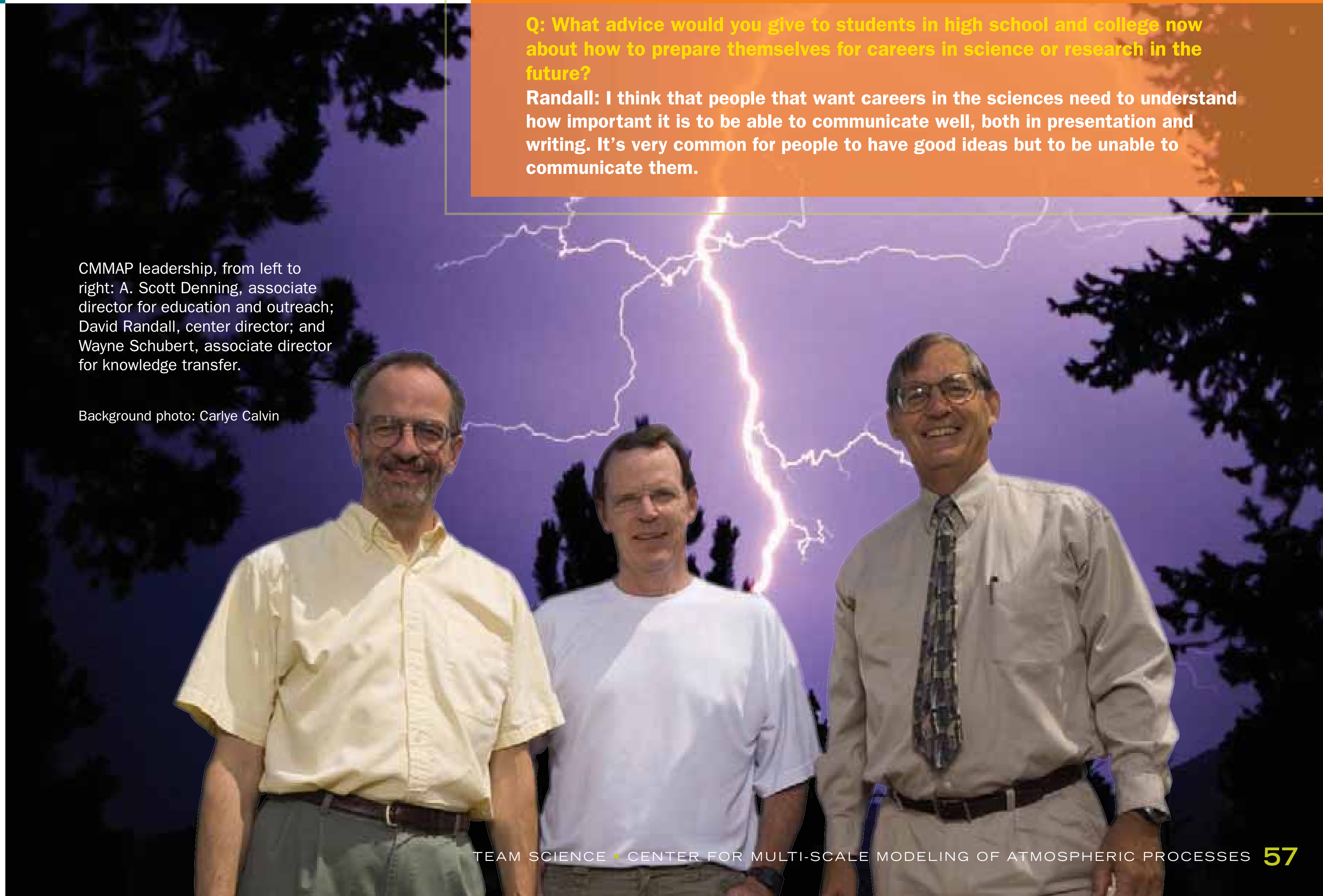
Q: What has surprised you most about your center as a whole, or about being a center director?
Randall: You spend a lot more time fighting for things that you need that you couldn't even have asked for previously. I've also been really happy with the willingness of scientists and educators to come together and work on a problem defined at the center level—to bend their research goals to match and work with the center.

Q: If you could have one or more wishes granted today for your center, what would they be?
Randall: Right now we're still in the process of getting going, so we're in the middle of the hiring process. I'd want that to go faster.

Q: What is your greatest challenge right now?
Randall: I'm awfully busy. What it feels like is skeet shooting: a problem comes up and you have to shoot it immediately.

Q: How did you get to this point in your career?
Randall: It's not what I expected. When I took my faculty position in 1988, I came from a job in NASA. I thought that I'd get my feet under me and I'd have three or four grad students and a postdoc and that would be my lifestyle. It turns out that's not my natural mode of operation, and I found that out as it happened. I apparently tend to naturally build these collaborations, these structures like the STC—it was a bit of self-discovery.

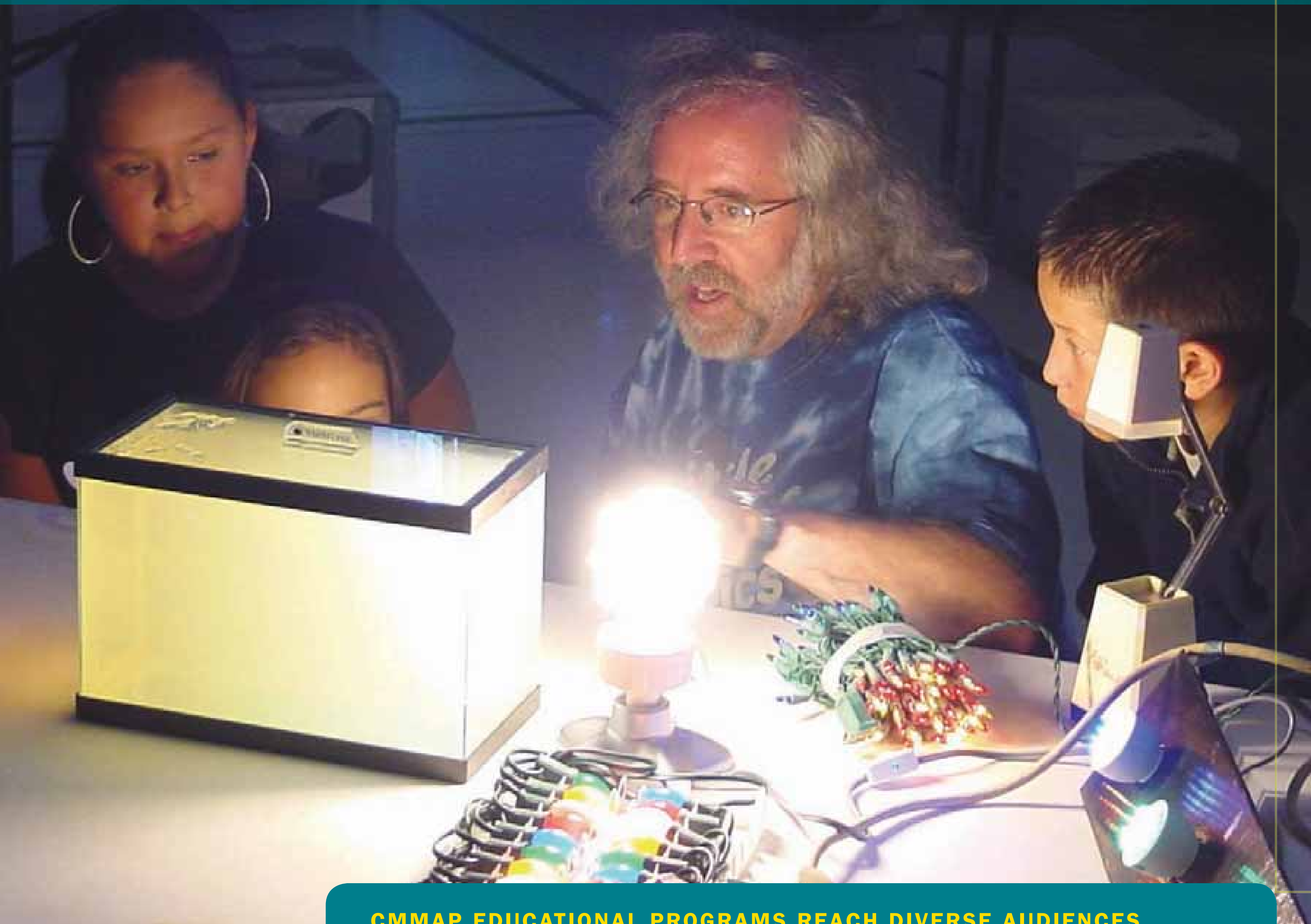
Q: What advice would you give to students in high school and college now about how to prepare themselves for careers in science or research in the future?
Randall: I think that people that want careers in the sciences need to understand how important it is to be able to communicate well, both in presentation and writing. It's very common for people to have good ideas but to be unable to communicate them.

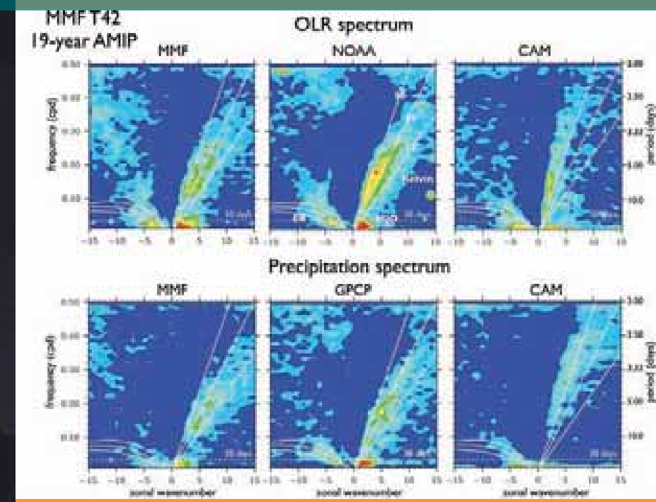


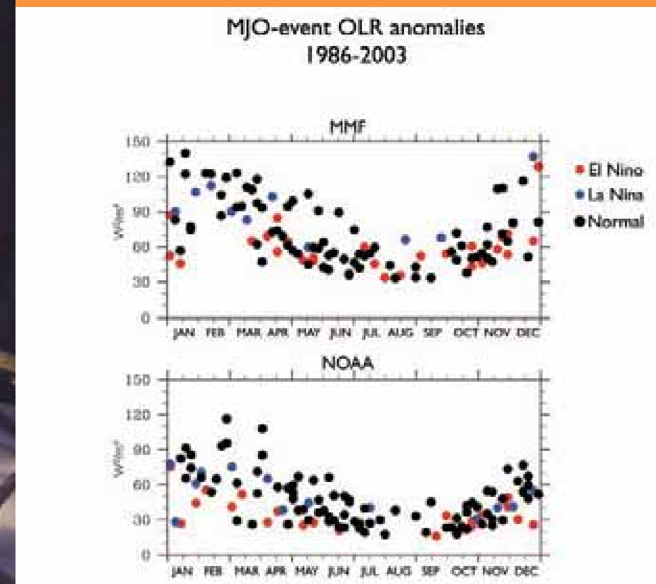
CMMAP leadership, from left to right: A. Scott Denning, associate director for education and outreach; David Randall, center director; and Wayne Schubert, associate director for knowledge transfer.

Background photo: Carlye Calvin

MODELING OF ATMOSPHERIC PROCESSES







Above: Little Shop of Physics director Brian Jones, a CMMAP education partner, and a group of students use a fish tank full of gelatin to demonstrate light scattering in the atmosphere and why the sky is blue.

CMMAP EDUCATIONAL PROGRAMS REACH DIVERSE AUDIENCES

While the research and modeling projects at CMMAP are just getting started, the educational activities of the center are well underway. Education ranges from employing and supporting graduate and undergraduate students across the nine degree-granting institutions to outreach to state policy makers, farmers, teachers, and K-12 students.

CMMAP supports graduate research assistants not only in atmospheric and ocean sciences but also in fields as divergent as sociology, psychology, and education. Each student is involved in or studying the research at the center. In addition to their own research, graduate students are involved in teaching and public policy.

Broader education is part of CMMAP's strategy as well, with outreach to local stakeholders at the forefront. CMMAP is creating a series of pamphlets on climate change that are developed in conjunction with workshops for regional stakeholders, including farmers and water managers.

CMMAP has the advantage of being situated at Colorado State University, where there is already an active educational outreach program called the Little Shop of Physics, which reaches over 15,000 K-12 students with hands-on experiments every year. The "Little Shop" also produces a television series called Everyday Science that airs on Rocky Mountain Public Television. A DVD of the series is expected to be available soon.

CMMAP works with both of these initiatives, providing materials, information, and hands-on experiments. And because Little Shop of Physics is primarily run by undergraduate students at CSU, the effort delivers a double impact.

"The undergraduates have lots of face time with the kids, learning about teaching and learning about working with schools," says CMMAP education director Scott Denning. "We're delivering the material, but we're also developing science educators."

CMMAP also is one of the collaborators on a set of Web-based outreach tools called "Windows to the Universe," providing science materials to the public.

Photo: University Corporation for Atmospheric Research

ABOUT THE MADDEN-JULIAN OSCILLATION

The El Niño and La Niña meteorological phenomena have been much in the news in recent years. An El Niño event occurs when unusually warm surface waters in the western Pacific Ocean, near Asia, flow eastward toward the west coast of South America. This flow of warm water toward the Americas prevents upwelling of nutrient-rich, cold, deep water and disrupts regional and global weather patterns. It tends to occur at intervals of two to seven years and usually lasts from several months to a year or more.

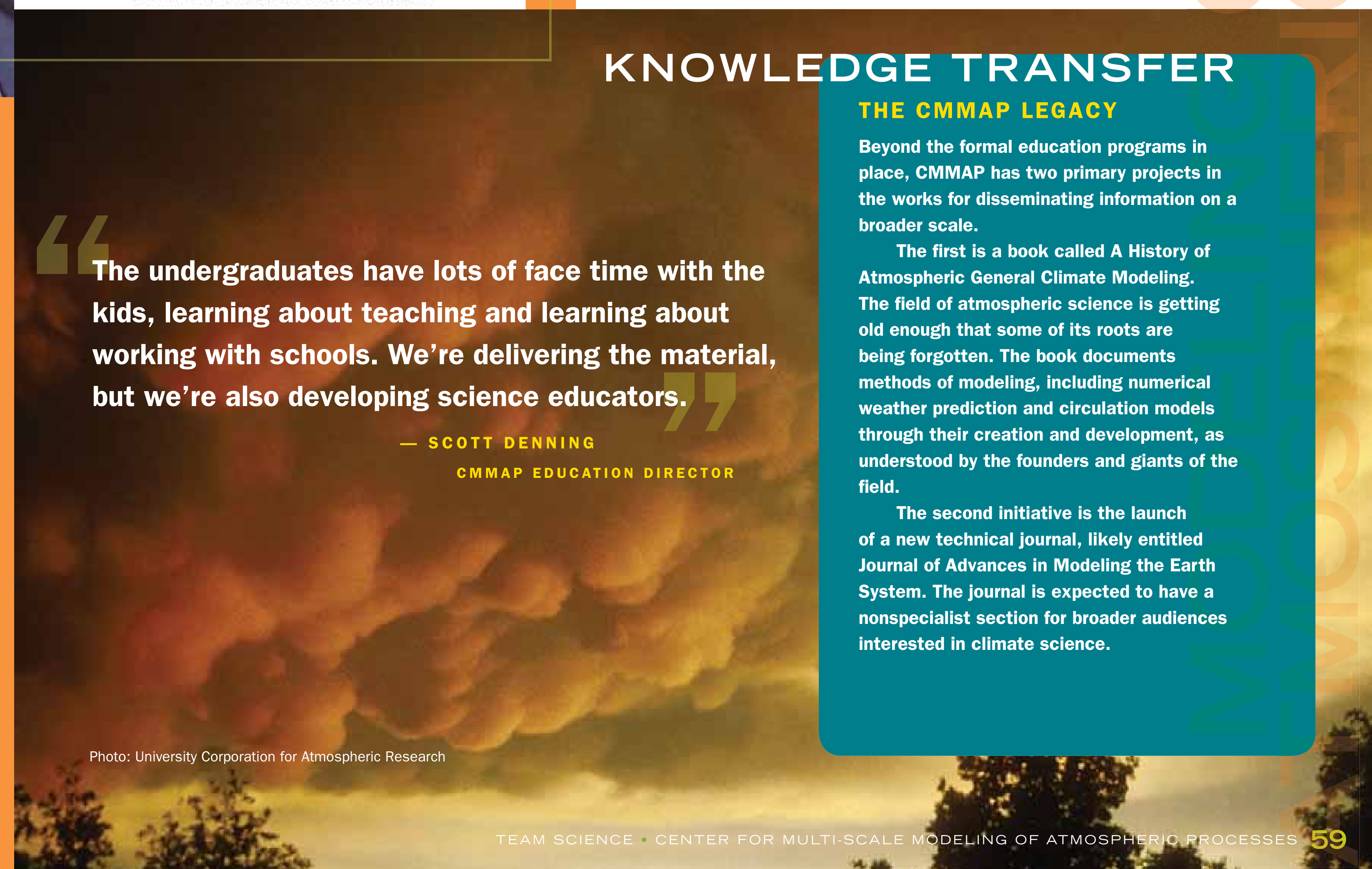
However, there are also phenomena lasting less than a season that still have large effects on weather on a global scale. One of the most infamous of these is the Madden-Julian Oscillation, or the MJO.

Residents in the Pacific Northwest know the MJO by another name, the Pineapple Express, with its propensity to drown the West Coast of the United States with as much as 20 inches of rain in a month during the winter.

The MJO is about a 40- to 50-day oscillation that affects weather variations in the tropics, most notably in the Indian and western Pacific Oceans. The MJO involves variations in wind, sea surface temperature, cloudiness, and rainfall. These events begin over the Indian Ocean and move slowly eastward over the Pacific.

Tracking and predicting the movements of the MJO may help researchers assess whether conditions are conducive to tropical storm development during the Atlantic hurricane season and may help West Coast residents deal with future drenchings.

KNOWLEDGE TRANSFER



"The undergraduates have lots of face time with the kids, learning about teaching and learning about working with schools. We're delivering the material, but we're also developing science educators."

— SCOTT DENNING
CMMAP EDUCATION DIRECTOR

Photo: University Corporation for Atmospheric Research

THE CMMAP LEGACY

Beyond the formal education programs in place, CMMAP has two primary projects in the works for disseminating information on a broader scale.

The first is a book called A History of Atmospheric General Climate Modeling. The field of atmospheric science is getting old enough that some of its roots are being forgotten. The book documents methods of modeling, including numerical weather prediction and circulation models through their creation and development, as understood by the founders and giants of the field.

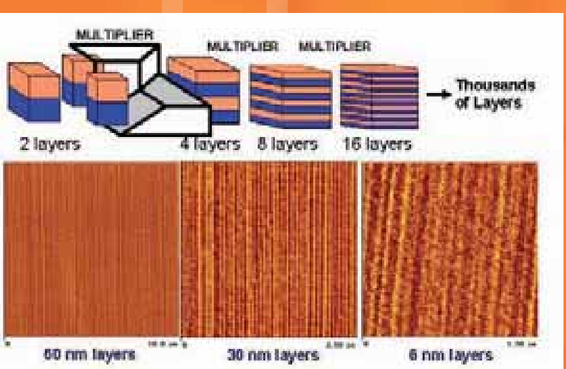
The second initiative is the launch of a new technical journal, likely entitled Journal of Advances in Modeling the Earth System. The journal is expected to have a nonspecialist section for broader audiences interested in climate science.

LAYERED POLYMERIC SYSTEMS

CENTER FOR LAYERED POLYMERIC SYSTEMS CLiPS

SPLIT IT, SPREAD IT, AND RECOMBINE IT:

STRATEGY FOR MAKING MULTILAYERED MATERIALS WITH NOVEL PROPERTIES



Anyone who has made croissant dough or puff pastry knows the process: roll the dough very thin, spread it with butter, fold it over, roll it again and repeat many times to produce a flaky pastry.

That's the central idea of the enabling technology behind the Center for Layered Polymeric Systems (CLiPS), headquartered at Case Western Reserve University. The center is using a co-extrusion process that takes two polymer melts and combines them as two layers, multiplies the layers to four, and doubles that again as many times as desired.

"Pretty soon you have thousands of layers of alternating polymers—as many as perhaps 4,000, and these layers can be as thin as 50 angstroms," says center director Anne Hiltner, the Herbert Henry Dow Professor of Science and Engineering in the department of macromolecular science and engineering at Case. Serving as research chair of the center at Case is Eric Baer, who holds the Leonard Case Professor of Engineering.

When polymers are combined in this so-called "forced assembly," magical things can happen. The multilayered material can behave quite differently than the starting ingredients. What was once brittle becomes ductile in a multilayer. Colorless ingredients now give off a color without the presence of dyes.

As layers become thinner and thinner, the effect of the interface between these materials begins to dominate, says center investigator Donald Paul, professor of chemical engineering at the University of Texas at Austin and director of the Texas Materials Institute. "What happens is not so well understood," he admits. "Therein lies the frontier."

CLiPS researchers are working at the intersection of polymer science, engineering, chemistry, physics, and biology to catalyze research and application of this nanoscale technology and facilitate its translation to the commercial sector through partnerships with industry and other organizations.

In addition to fundamental research on the polymer science and engineering, one research thrust at CLiPS focuses on optical and electronic materials. Multilayered polymers are being developed for use as impermeable films on flexible screens and electronic devices, which must be protected from water and oxygen.

Preliminary results on a melt processable glass that can be incorporated into layered materials to provide such a barrier were described by center researcher David Schiraldi at a meeting of the American Chemical Society in March 2007. Schiraldi is associate professor of macromolecular science and engineering at Case. His goal is to develop a glass with excellent barrier properties and that melts at a low enough temperature to be fluid at the processing temperature of the polymer.

Another thrust deals with barriers and membrane systems that have applications, for example, in the food industry. Keeping vegetables fresh requires that the packaging material allow the right exchange of gases in and out of the package. Because each vegetable has unique needs in terms of gas transport, researchers are exploring the possibility of tailoring the performance of multilayered materials to extend shelf life of produce and perhaps even control the timing of ripening of packaged fruit.

The co-extrusion process offers the advantages of simplicity, compatibility with existing polymer materials, and scale of production. "We can take a polymer off the shelf and do it—and we can make miles of the stuff," says Hiltner. "None of this 'little milligram quantities' and laborious synthesis and worrying about scale-up," she notes. "We have two co-extrusion lines and it's not a particularly difficult process once you have it set up and know how to work it—so it's really good for students. The students run it and we have undergraduates who can help and even have had high school students help. So it's a process that can be very hands on for the students."

"We can take a polymer off the shelf and do it—and we can make miles of the stuff. None of this 'little milligram quantities' and laborious synthesis and worrying about scale-up."

— CLIPS DIRECTOR ANNE HILTNER

KNOWLEDGE TRANSFER

LAYERED LENS TECHNOLOGY FOR ADVANCED CAMERAS

Researchers at the center have taken inspiration from nature in the development of nanolayered lenses that are not unlike the lenses in the eyes of fish.

In fish lenses, the material's ability to bend light, or refractive index, gradually changes with depth inside the lens: in other words, they have a refractive index gradient. "We are able to copy that using the nanolayer approach," says center research chair Eric Baer.

Lenses of this type exhibit a wider field of view with less aberration than conventional lenses having no index gradients. The "gradient refractive index" or GRIN lens shown in the figure below mimics a segment of the octopus lens. It contains more than 500,000 nanolayers.

Baer notes that the technology is being considered by public and private sector organizations for use in advanced cameras.

Gradient Refractive Index (GRIN) Lens

NEWS WATCH

SURFACE EMITTING LASERS

Center researchers have recently demonstrated use of multilayer films in all-plastic lasers. The approach provides a new way to make lasers in which the light is emitted from the surface of the material. These "surface-emitting" lasers are important because they can be used in display technology, notes center investigator Kenneth Singer, professor of physics at Case Western Reserve University and leader of the research platform on optical and electronic materials. Inexpensive and easy to make, these multilayer lasers are flexible and can be made to produce light of different colors.

REFLECTIONS ON STARTING A CENTER

Established in August 2006, CLiPS is new enough that the experience of planning a center and competing for funding is fresh in the minds of participants.

Center director Anne Hiltner reflects upon the center's origins: "Eric Baer and I have been involved with layer-multiplying coextrusion since the1970s when The Dow Chemical Company invented the process. Recognizing the novelty and potential of the process, we installed our own, highly flexible coextrusion line in the 1990s to explore some of our ideas.

"It became obvious to us that there were more opportunities than two people could handle, and that some of these (in optics and electronics, for example) required expertise that we did not have. In concept and even operation, the process was accessible to students at all levels. It was clear that it would be the ideal enabling technology for an interdisciplinary, multi-investigator program."

"I think none of us anticipated that the STC competition would be the one that we would win," says Hiltner. "Each time we passed a gate, I, for one, felt thrilled and challenged. However, essentially all the parts of the proposed center were there from the beginning: the research platforms, the education programs, the Case-Fisk Alliance, the Envoys Program. I do know that our confidence in our vision grew as we continued to flesh it out for each phase of the competition, and responded to reviews from the previous phase."

David Schiraldi, associate professor of macromolecular science and engineering at Case Western Reserve University, reflects upon the planning effort to coordinate with partner institutions. "Once we had the idea, we had to organize it. Line up all the players, get the commitments," says Schiraldi. He remembers "getting in the car and driving through the snow drifts of Ohio in the middle of winter to meet with institutions and share the vision, get their input."

The process involved a preproposal competition, notes Schiraldi. "When you make it through the first cut, you're both relieved and horrified simultaneously. Relieved, because you were successful; and horrified, when you realize you have to do ten times as much work in the next level," he laughs. There were about 160 preproposals, he recalls, of which some 37 were selected to go forward with full proposals. Twelve were selected to receive site visits, and of those, six were selected for funding, two during 2005 and four in 2006.

VIEWPOINT

FACULTY VIEWPOINT

Kenneth Singer & Donald Paul

Q: How do you like participating in the center?

Singer: You have all these people working together, doing things I can't even imagine doing alone . . . . So it really is a team. We have very frequent meetings, pretty much every week, between the faculty and students. We're trying to get the students to collaborate with each other.

Whenever you have a large group working on something, there's a lot of overhead in communication. You meet more, but the payoff is you have many hands helping with the work.–you just have to coordinate all the hands.

The laser is a great example of why the team mode is needed. I brought the idea of doing this to the group. Eric and Anne had been working on the process for many years without knowing what the possibilities for lasers were. Then Chris Weder made the dye that goes into the laser to make it work, and he had a key idea on how to get a result quickly. It's not just individual expertise—there's a real synergy there.

It's a creative force; a forcing function that helps people to be better or more creative than they were. What team science does is to take you beyond the cutting edge—when you get together with somebody has an idea that you haven't thought about before, it increases the creativity.

By yourself, you can only be so creative; you can't imagine things you haven't thought about. Everybody improves upon each others' ideas, and there's a certain element of competitiveness—a good kind.

Everybody brings their little corner of science and you end up with a big room.

Q: Why a center?

Paul: Case Western Reserve University has the capability of making laminated thin layer systems. We don't have that at the University of Texas at Austin (UTA) but we have measurement and theoretical expertise that complements expertise at Case.

This is research that would not have happened individually just because of the different skill sets and capabilities that are involved.

I think the students are really excited about the center because it offers a rather different kind of project than just a normal Ph.D. student would pursue. They really do have to interact with these other people, and we envision that UTA students will probably have to go to Cleveland and interact with people at Case, and that's an enriching experience that normally doesn't happen.

To make progress in science and technology, we really need both modes of operation—team and individual. We need an appropriate balance. There are some ideas that happen by only one mode or the other...

You can't be interdisciplinary until you're disciplinary. You have to learn your area first before you have anything to offer to interdisciplinary efforts.

Donald Paul

EDUCATION AND DIVERSITY

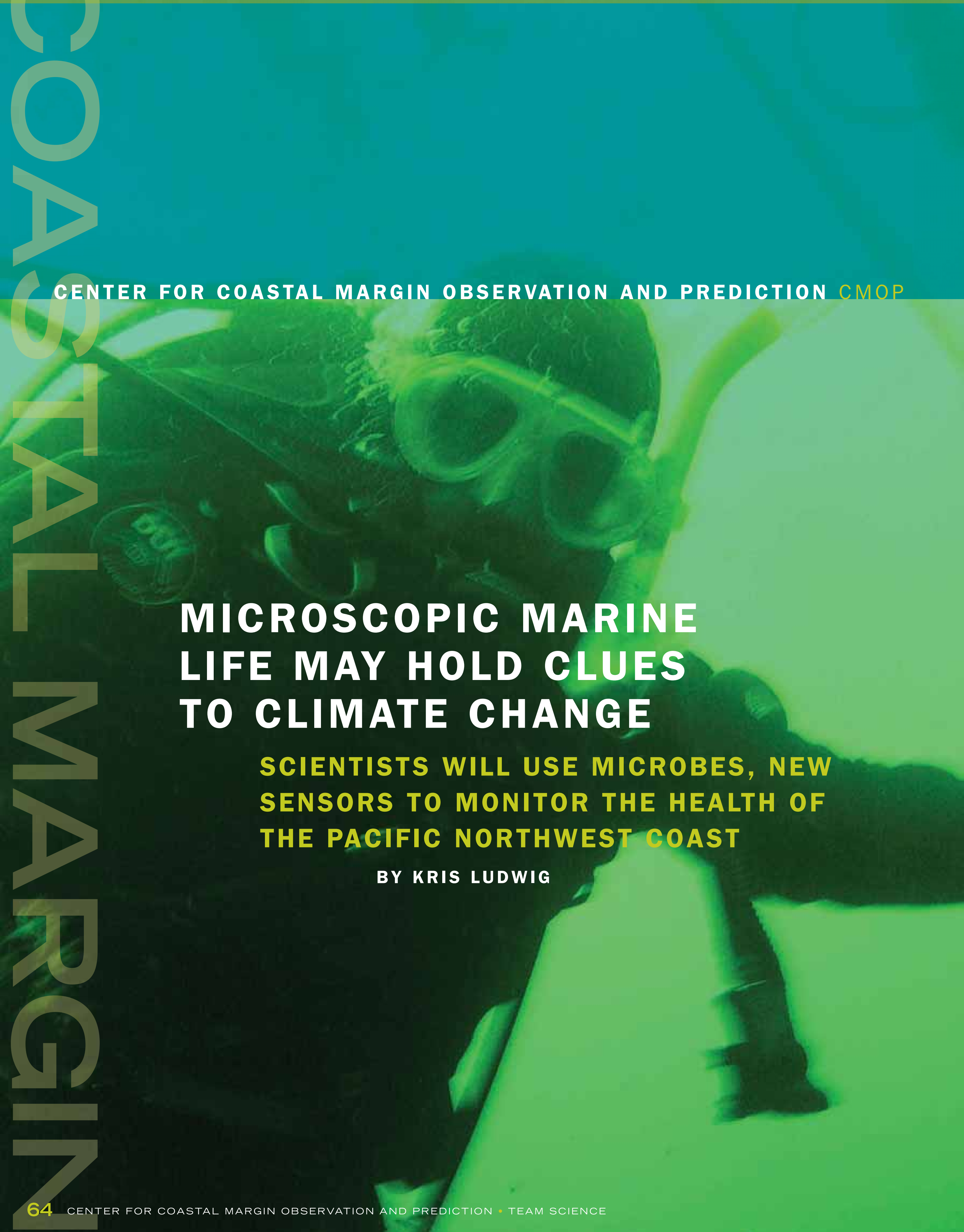
CLiPS works to broaden participation in engineering and science through pre-college outreach programs and partnerships with historically Black and non-Ph.D. granting institutions.

Overseeing all of the education and diversity programs in the center is LaRuth McAfee, who has bachelors and doctoral degrees in chemical engineering and postdoctoral research experience on engineering education funded by the Center for Advancement of Scholarship on Engineering Education.

Through its affiliates program, the center works with several non-Ph.D. granting institutions and regional schools. Each receives funding for educational as well as research activities that are aligned with the CLiPS research agenda. Faculty and students take part in exchanges and extended visits to Case. Schools currently participating in the program include Rose Hulman, Indiana; Ohio Northern in Ada; Penn State, Erie; SUNY Fredonia, and Rochester Institute of Technology, NY.

McAfee also notes that the "Polymer Envoys" program brings high school juniors and seniors from Cleveland Municipal School District to CLiPS for research experiences during the school year and summer.

COASTAL MARGIN



CENTER FOR COASTAL MARGIN OBSERVATION AND PREDICTION CMOP

MICROSCOPIC MARINE LIFE MAY HOLD CLUES TO CLIMATE CHANGE

SCIENTISTS WILL USE MICROBES, NEW SENSORS TO MONITOR THE HEALTH OF THE PACIFIC NORTHWEST COAST

BY KRIS LUDWIG

Like a canary in a coal mine, marine bacteria living on Oregon's coast are sensitive to changes in their environment such as water temperature fluctuations or an influx of pollution. Scientists and engineers at the Center for Coastal Margin Observation and Prediction (CMOP) are exploring the ability to monitor changes in microbial communities to assess climate change and human influence on the Washington-Oregon coast.

At top: The Pacific Ocean and Oregon Coast from Cape Lookout State Park. Photo: © AJ Steffani Photography

At left: Ninety feet below the surface of the Pacific, OHSU diver Michael Wilkin grasps a mooring cable that anchors an ocean observing buoy to the seafloor. Photo: Jon Graves, OHSU

Headquartered at Oregon Health & Science University (OHSU) in Beaverton, Oregon, CMOP is one of two National Science Foundation-supported Science and Technology Centers (STCs) that focus on the ocean. It is the first STC dedicated to researching the health of the ocean and the impact of human activity in the Oregon-Washington coastal margin, where the Columbia River meets the Pacific Ocean.

With more than 40 collaborators, CMOP is embarking on a mission to fuse innovative interdisciplinary research, technology, and education to answer complicated questions about the interactions between the ocean, Earth's climate, and humans. Participants include researchers at Oregon State University (OSU) and the University of Washington (UW), computer scientists from several partner universities as well as industry partners Intel and IBM, leaders from the Institute for Tribal Government, educators from local outreach programs and high schools, and engineers from the UW Applied Physics Lab (UW-APL) and WET (Western Environmental Technology) Labs, Philomath, Ore.

Coastal margins mark the interface of rivers and oceans. Natural features such as estuaries, freshwater and sediment plumes, continental shelves, watersheds, and rivers are all part of coastal margins. These zones are found all over the world and mark unique and ever-changing environments where constant fluxes in temperature and salinity–and human activity–affect populations at every level of the food chain.

Increasingly the focus of scientific study, the coastal margin of Oregon and Washington is a natural laboratory. The Columbia River flows more than 1,200 miles from its headwaters in British Columbia. Famous for providing Lewis and Clark with a gateway to the Pacific, the "mighty Columbia" ranks first in freshwater input to the Pacific Ocean in the Western Hemisphere. It is the lifeblood for a dense population founded on a rich economy of trade, fishing, logging, recreation, and hydroelectric power industries in the Northwest.

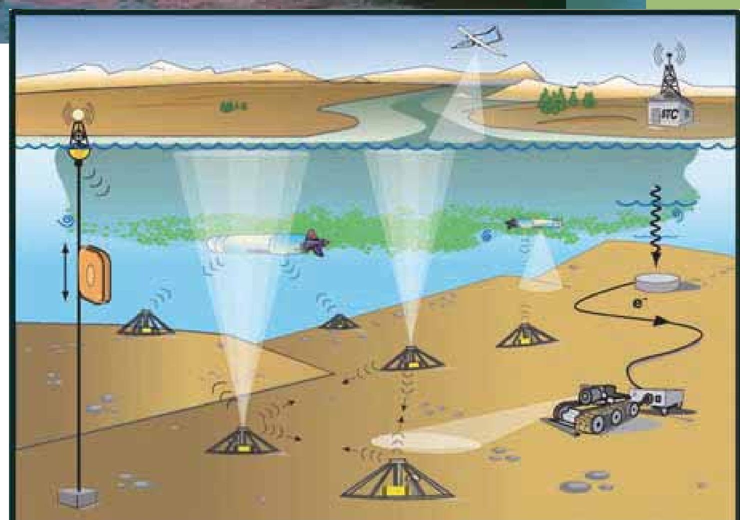
Because of the economic and societal importance of coastal margins, oceanographers have long studied the physical and chemical conditions within these dynamic environments. They have quantified the seasonal fluxes of sediment discharged by the river to the sea, the changes in salinity as a result of melting snow, the trends in ocean temperature as a result of El Niño events, and the impacts of these changes on seasonal salmon runs. However, the role of microorganisms living within the coastal zone remains poorly understood, and these microorganisms may hold clues to understanding and even predicting the physical and chemical changes that long have been observed in the ocean and atmosphere.

CMOP director António Baptista describes the microbial world of coastal margins as the "black box" in trying to understand the coastal margin ecosystem. With CMOP, he explains, "we really are trying to use new techniques that come from environmental genomics and open that box, and look carefully at what these microbial populations are doing."

CMOP researchers ultimately will try to correlate microbial populations in the coastal zone with changes in climate. "Microbes are probably the first organisms to respond to environmental changes," says postdoctoral researcher Isaac K'Owino of OHSU. "So if a human being can rely on the information that can be provided by these tiny organisms, then they'll be more prepared for environmental changes."

CMOP science revolves around three themes: applications of coastal margin observatories, improved understanding of coastal margin ecosystems, and creation of coastal margin observation and prediction technologies.

This integrated research program would not be possible without an STC, says CMOP co-director David Martin of UW-APL. In the coastal zone, "everything is interconnected--the hydrosphere, the lithosphere, the chemosphere, the biosphere, the atmosphere," he observes. Trying to understand the entire ecosystem would be impossible through the myopic view of one discipline.□



Above: OHSU field staff members Michael Wilkin and Jon Graves rewire an ocean observing buoy on a calm day in the Pacific Ocean west of Seaside, Oregon. Photo: Courtesy of CMOP

At right: An artist's rendering of the CMOP sensor network. CMOP research will involve advanced observation and modeling technologies, including a range of underwater platforms. Photo: Bruce Howe, UW/APL

AN UNDERWATER SATURN

At the heart of CMOP's environmental prediction abilities is a new observatory named "SATURN" that will be installed on the seafloor of Oregon's coastal zone. Completely unoccupied by humans, SATURN will be equipped with sensors to monitor changes in everything from salinity and temperature to microbial gene expression and bacterial diversity on a 24/7 basis. Instruments will transmit data to scientists working on shore. Via the Internet, scientists working on the East Coast will be able to see the same stream of data as colleagues in Oregon or elsewhere.

At first, the SATURN observatory sounds like something lifted from science fiction. But in many ways, SATURN is representative of the future of ocean sciences, in which integrated data sets are collected remotely over sustained periods of time. CMOP engineers are already designing the prototypes of SATURN's instruments and expect to deploy the first sensors within the next two to three years. Tom Sanford at UW-APL is devising an instrument that will exploit changes in electrical currents to estimate vertical profiles of salinity. Engineers at UW-APL and OSU are designing torpedo-shaped, unmanned underwater vehicles that will continuously monitor the continental shelf and examine freshwater plumes. Biosensors are the focus of research in Holly Simon's lab at OHSU. These gadgets will detect changes in the composition and activities of microbial communities. Researchers expect that these biosensors will ultimately help them understand the coastal margin ecosystem, and how it responds to natural variability and anthropogenic inputs.

NEWS WATCH

THE NEXT WAVE IN OCEAN SENSING

On a research cruise to the Columbia River estuary and coastal zone in August 2007, CMOP scientists will identify and profile underwater microscopic residents by sampling different environments within the estuary and across the continental shelf. The effort, led by assistant professor Byron Crump of the University of Maryland Center for Environmental Science and postdoctoral researcher Lydie Herfort of OHSU, is expected to produce results not unlike a census survey: the goal is to see "who's there." Data from this expedition ultimately will be used to help design underwater sensors that will be part of a permanent seafloor observatory.

In the next two to three years, CMOP scientists will have a first crack at putting their new instruments to the test. Sensors that use chemical changes as a proxy for biological activity will help researchers understand how the coastal margin ecosystem responds to changes in the environment. CMOP plans to deploy Tom Sanford's salinity sensor and biosensors developed by Holly Simon and Isaac K'Owino in the ever-changing waters of the Columbia River coastal zone. Sensors will transmit real-time data to shore via the Internet.

PORTLAND'S DOWNTOWN WATERFRONT: SITE OF FUTURE CMOP FACILITY

Portland's waterfront will become the new headquarters of CMOP team science. In five to seven years, CMOP is expected to move to a new space on the Willamette River in downtown Portland. The space will host office, lab, and classroom areas and will feature interactive displays highlighting CMOP's unique blend of science, technology, and education focused on coastal margins.

At top: OSHU diver Michael Wilkin prepares sensors for deployment at the Marsh Island station of the CORIE observation network in the Columbia River estuary. Photo: Courtesy of CMOP

CMOP IN THE CLASSROOM

CONNECTING STUDENTS WITH THE SEA

To establish an "enduring pipeline" of scientists, engineers, and citizens capable of using a systems approach to addressing complex problems, CMOP is creating education and outreach programs for students and instructors at the K-12 and university levels.

Higher education and diversity director Vanessa Green is developing multidisciplinary graduate degree "tracks" at OHSU that will be accessible to CMOP graduate students attending any of the partner institutions. Students in the Environmental Information Technology track will enroll in a variety of courses ranging from aquatic chemistry and bioremediation to software design and digital signal processing. Students in the Environmental and Biomolecular Systems track will receive training to understand and solve complex environmental problems through integrative studies across multiple scales, from molecular to global. "There is a growing awareness in the U.S. of the need to focus on environmental issues in general," says Green. She sees CMOP as an educational crossroads, providing students with "many ways to intersect with a very specific mission" focused on coastal margins.

CMOP also is developing a science enrichment curriculum for middle and high school students through a partnership with The SMILE (Science and Math Investigative Learning Experiences) Program, OSU's successful academic enrichment and college readiness program. Director of K-12 education Karen Wegner is developing CMOP's CoaCh (Coastal Challenge) series, extending SMILE's courses for high school students to address timely coastal margin themes.

CMOP will deliver CoaCh in several ways: as an after-school program, as a nine-week in-class integrated science curriculum, and as an interactive module on the CMOP education Web site. The after-school enrichment program begins during the fall of 2007, with the in-class curriculum to follow. With the Internet, Wegner envisions expanding CoaCh to include individuals and schools across the country. "We think it's one of the best ways that we can reach a national audience."

Portland-area high school students will soon have the opportunity to hone their public speaking skills while learning about marine science and policy. Wegner is developing a speech and debate program based on ocean science policy and issues. CMOP will also host regular workshops for researchers to help them understand the importance of their roles as educators beyond the university environment, and to help them learn to be more effective communicators outside of their scientific communities.

At top: OHSU divers Michael Wilkin and Jon Graves. Photo: Courtesy of CMOP

COASTAL MARGIN

MEET THE DIRECTOR

António Baptista

CMOP director António Baptista sees Oregon's coast as the ideal laboratory for studying the impact of climate change variability in coastal margins. He is no stranger to establishing collaborative programs.

Ten years ago, he began work on CORIE, the precursor to CMOP's SATURN seafloor observatory. In 2000, he was the founding member of OHSU's Department of Environmental and Biomolecular Systems, which merged environmental science and engineering with biochemistry and molecular biology. For Baptista, creating CMOP seemed to be a logical step forward in the evolution of team science.

With CMOP, "we are going to have to understand difficult systems across scales, and we are going to have to understand the biology of these systems in an ecosystem context," says Baptista. "Because of its size and duration, the center provides a mechanism to achieve that and in the process make fundamental contributions to education, knowledge transfer, and workforce diversity."

With the responsibility of coordinating more than 40 partners in research, industry, and education, Baptista is a busy man. He is convinced "the days have shrunk" and admits, "this does not compare with anything that I have done before." Despite the seemingly shorter days, Baptista's belief in team science shines: CMOP "has to be a transformative agent for the field of ocean sciences and that's what we are trying to do."

CMOP director António Baptista. Photo: OHSU News and Publications

MICROBIAL OCEANOGRAPHY

CENTER FOR MICROBIAL OCEANOGRAPHY: RESEARCH AND EDUCATION C-MORE

CENTER LINKS MARINE MICROBES TO ECOLOGICAL PROCESSES

BY JEN SCHRIPSEMA

Established in August 2006, C-MORE is focused on a comprehensive understanding of the diverse communities of microbes in the sea: what their genes code for, how they work together to control the flux of energy and matter in the ocean, and how all of this may change in the future.

Above left: The Kilo Moana

Top: On deck of the Kilo Moana

Bottom: Micrograph of oceanic microbes. Photo: Courtesy of Ed DeLong

Located at the University of Hawaii, the center is focused on "linking genomes to biomes." So how do you connect the narrow focus of molecular genetics to the broad focus of ecology? With a lot organization and communication, it turns out.

Research at C-MORE is organized into four interconnected themes. The first thrust focuses on the diversity of microbial life in the ocean. "One of the discoveries we are going to make at our center is to finally, once and for all, have an accurate, ecumenical, comprehensive inventory of the structure and function of the microbial populations in the sea," says center director David Karl. "This might take us a decade, but it's a target that is well within our reach, at least for the open ocean where we are focusing our fieldwork."

Researchers use conventional cultivation techniques to isolate, identify, and characterize the major microbial species present in the ocean to develop theoretical models of ocean ecology. New genome sequencing techniques are allowing researchers to look directly at the genetic code of these organisms.

"Looking at these genomes is a lot like looking at a parts list, but we never had the parts list for the microbes in the ocean before," says research coordinator Ed DeLong. Having that "allows us to get much more fine-grained information about what makes up these microbes."

Information gathered from this research contributes to the second theme, which focuses on biogeochemistry—how the cycling of carbon, nitrogen, phosphorus, and other elements is driven by microbial activities. The rise in levels of atmospheric carbon dioxide is an area of particular concern. "It's hard to even imagine, but because microbes move large amounts of greenhouse gases through their combined physiological activities, microbes can actually have an effect on weather, for example," says DeLong.

Research in the third theme has an applied engineering focus: development of remote and continuous sensing technology. Currently, oceanographers must go out on the ocean for a certain length of time to gather samples and then return to the lab for testing. Being able to monitor various ocean processes continuously greatly speeds up hypothesis-testing and allows researchers to ask different questions—for example, how the expression of genes relate to circadian rhythms or the lunar cycle or a particular meteorological event, notes theme leader Chris Scholin.

The final, broadest research thrust at the center integrates all the relevant research into computerized models that can predict how the ocean will change in the future. One major concern is that the increased level of carbon dioxide in the atmosphere is dissolving in the ocean, increasing its acidity. "More-acidic conditions could select for or against certain microorganisms; it could cause massive death of calcium-carbonate-bearing organisms like corals," says Karl.

These four themes keep everyone organized, but DeLong emphasizes that these "bins" are artificial constructs. "The goal is really that they are all conducted in synergy to understand the complexity of the system of the living ocean." The key to making that happen is communication, which can be a challenge at a center as dispersed as C-MORE.

Although the center is headquartered in Hawaii, investigators are located at the Massachusetts Institute of Technology, Woods Hole Oceanographic Institute, Monterey Bay Aquarium Research Institute, the University of California, Santa Cruz, and Oregon State University. "So we are spread out both geographically and with respect to our expertise, and that again requires a sort of glue to hold things together," says DeLong. "Part of the research coordination is making sure the right people are talking to one another and research efforts are coordinated."

C-MORE may be new, but many of its researchers have been working together for at least 10 years. DeLong says, "In the end, the thing that will really make everything work together in a sustained way is a deep level of trust. And I think because we are all friends, colleagues, and scientific collaborators—and have been so over a good amount of time—we have already established that."□

Divers working on the second-generation environmental sample processor in the Monterey Bay Aquarium Research Institute (MBARI) test tank. Photo: Todd Walsh (c) 2006 MBARI

SCIENCE AT A DISTANCE

CENTER DEVELOPS REMOTE SENSING INSTRUMENT

At the most basic level, the goal of C-MORE research is to understand how small-scale microbial genomic information connects to large-scale ecological and biogeochemical processes. "Conducting experiments to answer questions like that in the ocean currently requires a physical presence. You have to be there to acquire the samples, which are then brought back to a laboratory, which are then subjected to all kinds of tests," says theme leader Chris Scholin.

"We go out to sea for a relatively short period of time. You just go gangbusters on sample collection, and then you bring them back and retrospectively try to reconstruct what was happening at this molecular level." While at sea, researchers cannot alter their experiment based on the metabolic processes taking place because they are still awaiting the laboratory results. "You really have little opportunity to respond dynamically," says Scholin.

To remove this limitation, Scholin is working on a remote sensing instrument called the Environmental Sample Processor (ESP). "So I'm dialed into my machine, which is sitting in the water in Hawaii, while I'm sitting here in California directing an experiment. I'm testing a hypothesis without physically being at that site, without acquiring the samples and filtering the bugs and bringing it back and so on."

Work on the ESP is still preliminary. But Scholin predicts that within a couple of years he will be able to analyze the microbial community in a sample of water for the presence and expression of a broad range of genes, all from the comfort of his office.

Remote sensing technology like this could have a variety of applications outside C-MORE as well, both in and out of the research community. For example, public health agencies could monitor beaches for fecal bacteria, red tide, or cholera remotely, instead of relying on the current tests accepted by the EPA, which are relatively slow.

A CONVERSATION WITH THE DIRECTOR

David Karl

Microbial oceanography is a field full of surprises. It seems every time scientists think they have it all figured out, they find out there's more to learn.

When C-MORE director David Karl graduated with a Ph.D. in 1978, he was ready to leave the field because he thought that we knew all there was to know about the ocean. "We'd been studying this for a hundred years. There were clever and intelligent people [in the field] and we had books and we had paradigms and we had models. And I thought all that there was left was to dot the i's and cross the t's—and I didn't like to do that kind of stuff. So I was thinking about going into some other field that might be more pioneering and more cutting-edge.

"Well, the year that I graduated, a group of scientists who are now part of our center discovered the second-most abundant group of organisms in the sea—before that, we didn't even know about these organisms. A decade later in 1988, the most abundant group of plants in the ocean was discovered.

"As recently as five years ago, a whole new group of organisms was discovered in the ocean that is able to absorb sunlight just like green plants do. But these are not green plants; they don't fix carbon dioxide. What they do is absorb sunlight and use that energy directly for their metabolism. So, in effect, we have to rewrite all the basic biology textbooks because green plant photosynthesis is now not the only solar energy capturing process on the planet.

"So we are still in this very formative and very embryonic discovery stage in oceanography and in microbial oceanography. New discoveries are likely as we move forward with the center."

On March 16, 2006, the second-generation version of an underwater, robotic DNA lab called the Environmental Sample Processor (ESP) was deployed in Monterey Bay, Calif. Photo: (c) 2006 MBARI

MICROBIAL OCEANOGRAPHY

MICROBIAL OCEANOGRAPHY BRINGS K-12 EDUCATION ALIVE

The ocean is an integral part of island life in Hawaii; teachers capitalize on this fact by using the interdisciplinary field of oceanography to teach students about biology, chemistry, and physics. "So we have a very strong interest on the part of many teachers to learn everything they can about the ocean," says C-MORE education coordinator Barbara Bruno. "But when they do this, often microbial oceanography is left out."

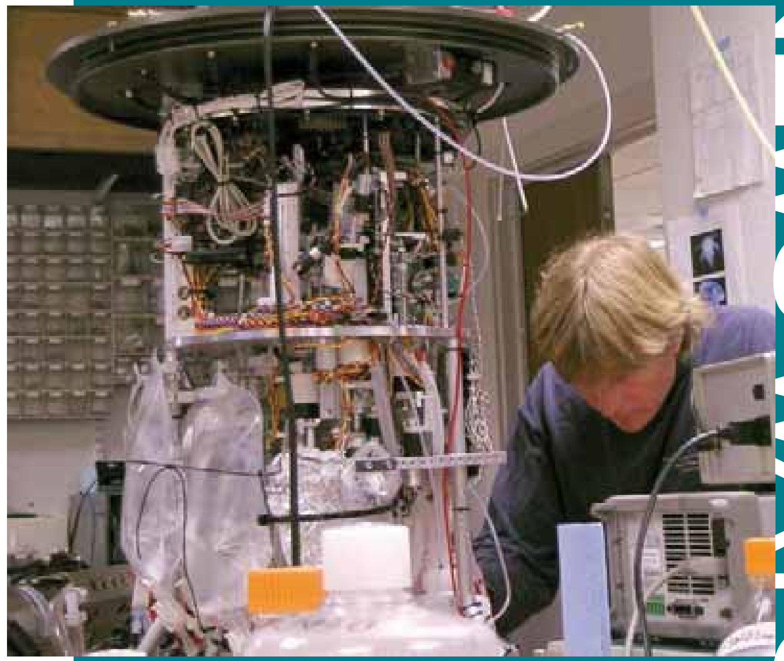
Bruno is working directly with secondary school educators and curriculum developers to support the development of education programs and to update teacher training and science curricula to include the role of microbes. One program just getting off the ground that has garnered considerable interest is the teacher-at-sea program.

Secondary school teachers or peer educators will accompany scientists on monthly research cruises, working as scientists themselves for four days. "In the summertime, we will have [a] more consolidated effort where we take groups of teachers out there," says center director David Karl. They will conduct specially designed experiments and then work with C-MORE researchers to convert what they have learned into lesson plans for class.

"We are setting up a real-time Internet link [with video] from the ship into the classroom, so that the kids in the classroom can see what's going on in the ocean as we collect samples and analyze the samples for various parameters of interest," says Karl.

> "It's hard to even imagine, but because microbes move large amounts of greenhouse gases through their combined physiological activities, microbes can actually have an effect on weather."
>
> — ED DELONG
> C-MORE RESEARCH COORDINATOR

NEWS WATCH



Chris Scholin working on the second-generation environmental sample processor in the laboratory. Photo: Kim Fulton-Bennett (c) 2006 MBARI

EARLIER DETECTION OF RED TIDES

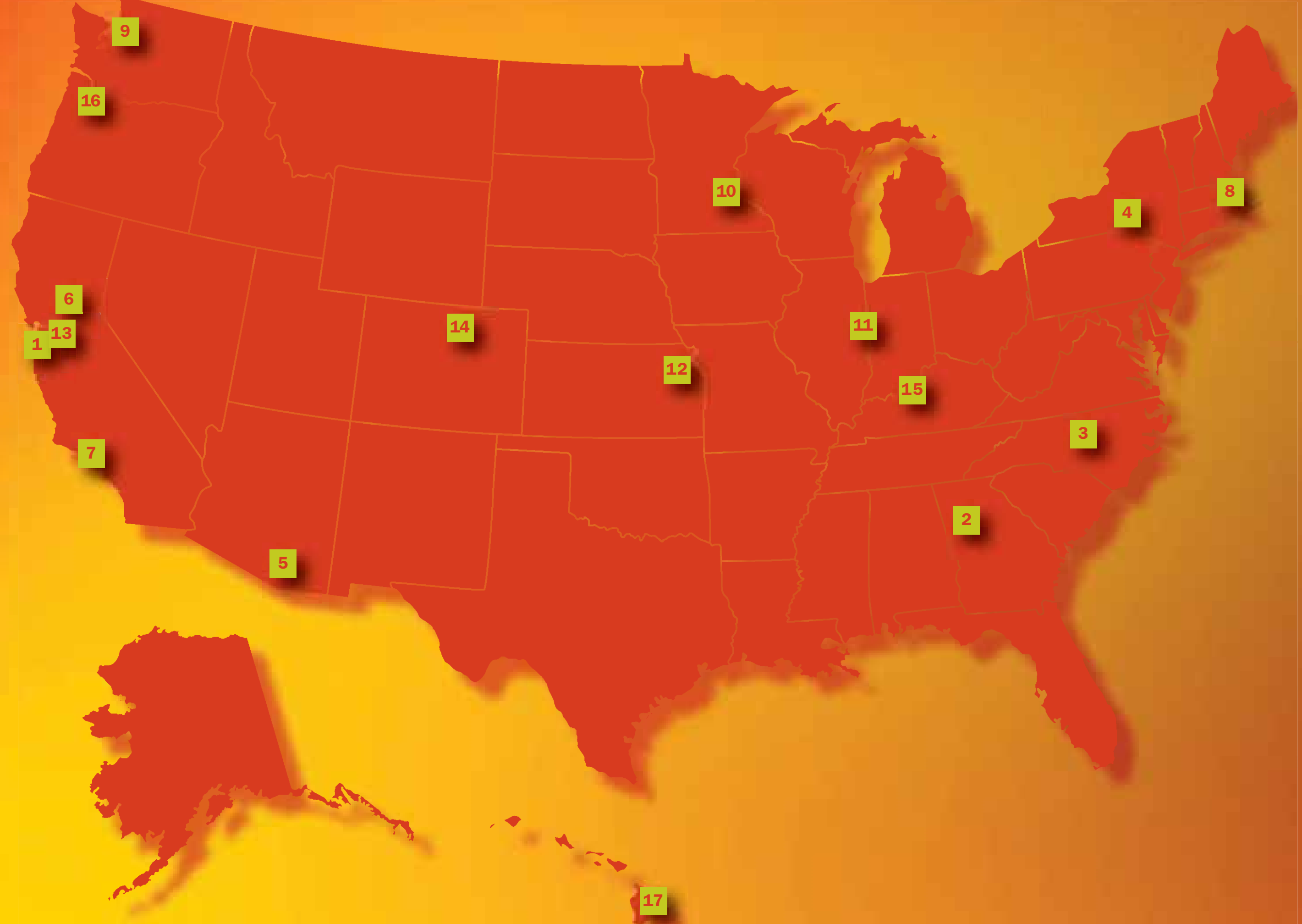
A small percentage of microbial algae in the ocean produce toxins such as those found in "red tides." Harmful algal blooms can lead to massive deaths among fish and shellfish, disruption of marine ecological structure, and human illness and even death.

The current EPA standards for detecting the presence of these algae or their toxins are relatively slow because they rely on ship-based testing and "wet chemistry" tests. Detecting harmful algal blooms and closing beaches more quickly could prevent many human illnesses. C-MORE researcher Chris Scholin is currently researching ways to use remote sensing technology to do just that. He has several articles currently in press on the subject.

A project like this requires more than just bringing together scientists from different fields; it requires bringing together engineers to build the equipment and technicians to install and repair it. "This is a real exercise in interdisciplinary work and bringing very disparate types of people and talents together," says Scholin.

The effort will require further studies and acceptance by regulatory agencies before it can be used in practice, but Scholin is working hard to make implementation a reality.

CENTERS AND PARTNERS



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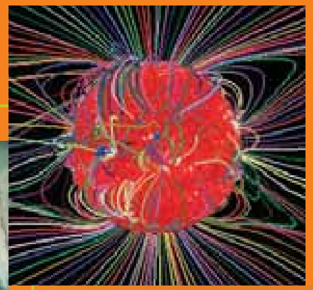

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