MIT Center for Future Civic Media:
Engineering the Fifth Estate

The MIT Media Lab and Comparative Media Studies Program propose a Center for Future Civic Media. Bridging two established programs at MIT – one known for inventing alternate technical futures, the other for identifying the cultural and social potential of media change – the C4FCM would be a crucible of new technical and social systems that allows geographic communities to share, prioritize, organize, and act on information. Simply put: the Center would take techniques and technologies that have proven themselves powerful for distributed and *virtual* communities, and re-envision and re-engineer them for *actual* communities. Mixing engineering, analysis, and debate, the C4FCM would create a platform for testing and investigating civic media in local communities.

The Center will:
- Develop new technologies that support and foster civic journalism and political action
- Serve as an international resource for the study and analysis of civic journalism
- Coordinate community-based test beds in the United States and internationally

These three activities are vitally interconnected: We study the existing uses of civic media to identify best practices and urgent needs; we connect those insights to the development of new tools; we partner with local groups to put these tools into the hands of community builders; and we monitor the results to inform the next phase of development.

MIT has a long tradition of developing systems for civic media, advanced communications technologies, and citizen-empowering political technologies. Key elements of the Internet, MPEG, and JPEG standards were developed here, and MIT is the home of the Free Software movement, perhaps the most important civic technical movement in history. From collaborative filtering to public-key cryptography, many of the technologies by which we access, sort, transmit, and safely communicate information were developed on the MIT campus. Decisions made here in the last Century – for instance, that the Internet should be agnostic both in *what* information it transmits, and to *whom* – have profound daily impacts for nearly everyone in the world.

The Media Lab and Comparative Media Studies are world leaders in understanding – and fomenting – the digital information revolution. Both institutions have explored the social, cultural, and political dimensions of technology in ways that traditional engineers cannot. Both have been researching citizen-powered journalism, participatory culture, and grassroots creativity since their inception. The proposed Center would demonstrate to technologists from around the world the importance of journalism in fostering and maintaining open societies, would help professional journalists develop a better understanding of the potential opportunities for collaboration with their readers, and would provide local communities a chance to learn about and deploy new forms of civic media. In doing so, the C4FCM would help to develop an emerging "Fifth Estate" of participatory news, media, and civic change.

This proposal starts by offering an overview of the motivations and history, research themes, and structure of C4FCM. Next, we present the deliverables we imagine the Center would produce in the first two years of operation. Finally, we describe the people and departments that would make up the Center.

Foundations

The 2006 election season demonstrated the power of networked communications to change the face of the US political landscape at the national level. Letting loose a barrel of macacas, bloggers, 'tubers, and one-click campaign donors demonstrated a new form of grass-roots activism as citizens took media in their own hands and asserted themselves into the political process through sometimes unfamiliar or previously unanticipated roles as citizen journalists, pundits, organizers, and monitors. Their contributions were most profound at the congressional level. This was, in part, due to the ease by which contemporary web and Internet technologies straddle geographic boundaries. The Internet was designed to allow for

disembodied communication; its creators were often part of an international group of academics, and they saw the power of a transformative worldwide network modeled on their own distributed intellectual community.

New media has demonstrated its power in opening up global yet grassroots channels of communications and collaborations, and in the emergence of new kinds of virtual communities. Yet, we have often neglected the transforming impact these same technologies can have on geographically grounded communities and their interests. Research suggests that those online communities that survive and thrive are those that are renewed through regular face-to-face contacts among their members. Just as the net can bridge across national borders, it also has the potential to enable communications across various forms of social stratifications within local communities.

Part of what we want to do through this center is revitalize citizen's connections to their governments, but we also seek to re-engage citizens with other individuals in their communities, using new media to create an incentive for neighbors to interact and learn from each other. The issue is partially one of technologies – new tools enable new forms of communication. It is also about social institutions and cultural practices – new institutions and practices support new kinds of community life. Since citizens are already creating new techniques for using media, it's important to collect the best practices, principles, curricula, and techniques for disseminating them so that they may more effectively advocate for their own perceived interests with both their local governments and others in their own community.

The MIT Center for Future Civic Media would develop new techniques and technologies for civic engagement. The Center is interested in reshaping the tools we have for sharing news and information, reprogramming them to operate on the level of the neighborhood, school district, or town. We want to explore the intersections between technological innovation and cultural transformation, code and mortar, hardware and conversation. We want to empower citizen journalists by giving them the tools and training they need to do their work and, at the same time, offer professional journalists new models for how they might better serve their local constituencies.

The result may be to develop a communications system that reflects the diversity of contemporary American towns and cities, one that promotes democracy and encourages shared experiences amongst all residents of a local area. As we do so, we have an opportunity to transform our understanding of the Fourth Estate from one focused on special, professional classes of people who have the skills and resources to investigate powerful institutions, to a Fifth Estate where everyone is able to pool their knowledge, share their experience and expertise, and speak truth to power.

Even as we can now access millions of web sites, news radio stations and cable news networks even in the most remote of rural communities, most of us have little or no access to solid local reporting. The Fourth Estate has been emaciated at the local level, due to a variety of commercial and technical issues of ownership and distribution. Most of us have trouble finding even basic information about candidates on the ballot for the local election, or issues on the agenda for the school board meeting. In some cases, we lack access to locally specific information for dealing with natural disasters and other emergencies.

Some of our institutions – say, the structure of schools – serve to isolate citizens from each other rather than help them to identify shared experiences and mutual interests. City newspapers often neglect rural communities in the surrounding region. And minority and ethnic populations within cities lack the core information they need to go about their day-to-day lives. A successful solution – one that allows citizens to create, find, and share information critical to where they live, work, and vote – will require new techniques for gathering and distributing information at the most local levels. It will also require "killer apps," rhetorically powerful examples of how these media can transform communities, and the relationships of these communities to global corporations, federal government, and international media organs. Finally, it will necessitate new models of reward, monetary or social, to make such applications self-sustaining and impervious to influence or interference.

Old News

The MIT Media Lab began looking for solutions long before user-created content made the cover of Time Magazine. In the mid-1990s, our lab launched a community-based news gathering and distribution system called "Silver Stringers." [http://stringers.media.mit.edu/] Working with the AARP, a Media Lab sponsor, researchers noticed that issues affecting the elderly were systematically under-reported in local and community newspapers. Moreover, those same people were important sources of information about the community, with specific local knowledge about its history and transformations.

The Silver Stringers concept and technology was first tested in Melrose, Massachusetts, under the banner of the *Melrose Mirror*, and the online site has since been maintained by a community of seniors – and occasionally their technically adept grandchildren – for more than ten years. Over time, dozens of other local communities have adopted the Silver Stringers approach and technologies. We now see new opportunities to use media production as a bridge across generations and as a vehicle to help young people develop a deeper appreciation of the history and culture of their own community. We envision, for example, the use of digital storytelling (mixed media works that are designed to convey personal and communal narratives) and living newspapers (community theater based on actual events). These shared activities would stir young people to ask questions and listen closely to the memories and insights of seniors, and then translate what they hear into the resources for their own creative expression.

Henry Jenkins, Co-Director of the MIT Comparative Media Studies Program (CMS), coined the term "participatory culture" almost twenty years ago to refer to the earliest signs of the emergence of a do-it-yourself media culture. From the start, the CMS program has been invested in understanding the ways everyday people make meaningful use of media technologies and content – both old and new – in the course of their everyday lives. CMS researchers have done groundbreaking projects on the shifting relations between media producers and consumers, including the production and consumption of news. The program's commitment to an applied humanities perspective has pushed them to translate these new conceptualizations back into pragmatic real world interventions.

Through the MIT Communications Forum, CMS fosters public conversations centered on topics that are central to our understanding of civic media and grassroots creativity. Through the Education Arcade project, CMS explores the pedagogical use of computer and video games, including the use of game platforms to enhance civic participation and closer observance of people's immediate physical surroundings. And through the New Media Literacies Project, funded by the MacArthur Foundation, CMS directs attention to the ways young people learn and process information in the new media landscape, identifying some of the core social skills and cultural competencies that are necessary to fully participate in their society. These findings allow the group to develop and test curricular materials designed to help teachers and students make ethical choices as media makers.

This work on youth and digital learning continually reminds us that kids don't know that new media is new. They grew up within the new media landscape and they take its allowances as a given. Just as children in a hunting society play with bows and arrows, children of an information culture play with information appliances and social networks. Current research suggests that young people get their news from different channels, engage with information in different ways than previous generations. Yet, despite a lack of interest in traditional news, they consistently score high on tests measuring their recognition and recall of information about current events. Increasingly, we are taking the skills we master through play and redirecting them to our civic lives.

How do youth make sense of the world around them? In the words of journalism scholar Michael Schudson, they have become "monitorial citizens" – counting on each other to keep them informed about pressing matters. Most often, they do so by forming what cybertheorist Pierre Levy calls knowledge communities – that is, social organizations which are structured around the pursuit, sharing, and evaluation of relevant information. These knowledge cultures are taking on some of the key functions that were played historically by the writers of newspapers and magazines. Rather than seeking information from a bound publication, new citizens enter into a social space where information is received and processed in a more dynamic and participatory process.

Blogging and podcasting are part of this process by which young people collect, evaluate, and act upon information about the world, but it is only the beginning. We are already seeing sites such as Flickr and YouTube take advantage of a world where people carry cameras and camcorders – built conveniently into their cell phones – to document and transmit what has become a routine part of their daily lives. Traditional journalists play an active role in this process but the status of newscasters and reporters has shifted. Young people now assert their own agendas and priorities rather than trust editors to tell them what news is fit to print. They are seeking out diverse, sometimes unconventional perspectives on the world rather than returning again and again to the same sources.

Both Comparative Media Studies and the Media Lab have long histories of supporting and studying innovative uses of new media technologies by children and teens. These projects have yielded important new insights into how young people learn about the world and share what they learn with each other through a range of different media technologies. These insights can, in turn, inform the design of new communications platforms and the development of new journalistic practices. For example, the Computer Clubhouse project, founded by C4FCM co-director Mitchel Resnick, has established a network of after-school centers for youth in low-income communities, now serving more than 20,000 youth in 100 communities in 20 countries [http://www.computerclubhouse.org/]. Each Clubhouse offers a unique, locally-specific approach to engaging young people in creative learning experiences with new media. These centers have served as testbeds for countless projects in technology and education, with a strong emphasis on media education and literacy.

Hot (off the press)

We are purposefully using the term civic media, rather than citizen journalism: by civic media, we mean any form of communication that strengthens the social bonds within a community or creates a strong sense of civic engagement among the area's residents. There can be no civic engagement without a reliable system of news gathering and reporting, but the role of civic media goes beyond that. Civic media helps provide people with the skills they need to process, evaluate, and act upon the knowledge in circulation and insures the diversity of inputs and mutual respect necessary for democratic deliberation. Some of what emerges here looks like traditional journalism; some it may pull in radically new directions.

We are proposing an intellectual center, a laboratory for next generation technologies and practices, a sustained forum for international dialogue on best practices, and a mechanism for longitudinal testing in multiple communities. Of course, we have many ideas for projects, but it is important to recognize that the best projects from C4FCM may be generated by students who have not yet been admitted to MIT, but who come because of the Center. Nonetheless, there are many current projects that may give a sense of the Center's direction, some of which may seem quite far outside the purview of journalism: in one project, graduate students are developing networks for sharing information on community dumpsters, looking to create new forms of gathering for sustenance. By charting and forecasting yields and optimal times of harvest, they have created dramatic efficiencies, feeding hundreds of people for free weekly. Others are working on ways to keep track of local government policies and officials in a "Wikipedia" style of citizen informants. Similar attempts to reinvent classifieds, "lights and sirens," reviews, and other sections of newspapers are also of active interest to our students. While such applications may at first seem of interest only to a relatively small community of campus radicals, the technique and underlying technologies may, with a slight inflection of use, be of value to any local group within a specific area.

Many existing projects at MIT would fit well within a Center for Future Civic Media, and profit from its new dialogue and direction. For example, some existing projects work to situate information technologies in civic physical spaces like parks, playgrounds, and city halls. Soap doesn't come in boxes anymore, and public speech can take new forms. The word "tagging" is used in the graffiti community to describe the marking off of physical territory, and in various Web 2.0 applications, to describe the shared annotation of information. If we fuse these two meanings of the word, we can provide informational annotations on physical spaces that can be accessed via various mobile devices.

Many of the roles played by traditional journalism in reporting on construction, planning, or development issues – bringing attention to problems, iniquities, or even just everyday politics – can be served by such

informational systems. Aggregated, communities can see what's happening in similar communities around the country. Citizens should not have to depend on access to computers (or expensive devices), office-based interfaces, or even specific levels of literacy in order to actively participate in community life. In fact, one Media Lab student researcher has been working with the community in Lawrence, MA to develop a platform for teen event planning. Combining a web site, voicemail interface, and social networks of local government and community groups, the platform demonstrates how advanced technologies can be leveraged to provide two-way access to diverse groups using no more than a telephone.

Faculty and students in the Comparative Media Studies Program have been experimenting with the uses of mobile phones and handheld information appliances for the purposes of augmenting the lived experience of moving around the city. These augmented reality systems encourage residents and visitors to look at their communities differently: teachers create class projects where students map local history onto the physical spaces of their towns or neighborhoods; as students work through potential natural disaster or environmental hazard scenarios in their own communities; as people pull up on-the-fly historical photographs and documents to imagine how their neighborhood appeared during earlier eras and even conceive the next phases of an urban renewal project; as schoolchildren in Lexington tap eye-witness accounts of the Battle of Lexington on their handhelds while touring these historic locations to solve who fired the first shot of the American Revolution. From these projects, tools have been developed and tested that can now be more widely deployed.

Imagining ways to make local information easy to post and view on the Internet is, of course, a huge concern to MIT researchers. Locative mapping, storytelling, and monitoring are a natural outgrowth of traditional print journalism. Such systems cannot hope to succeed, however, without careful thought about how such community functions have been fulfilled historically. New tools can enable us to visualize information in new ways, to chart the course of large-scale conversations, and to reflect back recurring themes and concerns.

Tools are often curtailed or re-imagined because each community will utilize them differently in accordance with their changing needs. This is why we call for a feedback loop that combines an understanding of social and cultural processes with an ability to refine our tools and technologies to reflect those understandings. It is immensely valuable to monitor how any given community takes up and deploys these emerging tools; it is even more valuable to be able to think comparatively across multiple communities and see what kinds of commonalities and differences emerge in their use of these technologies. Finally, it is important to see how these effects play out over time: The ability to study multiple communities longitudinally constitutes the comparative advantage of a center as opposed to a series of isolated projects.

Transforming civic knowledge into civic action is an essential part of democracy. And as with investigative journalism, the most delicate and important work can often focus on leaders and institutions that abuse the trust of the communities they serve. MIT students have experimented with a variety of new techniques for civic action, from technologies for protests and civil disobedience to systems that allow democratic votes on trivial everyday activities, like what restaurant a few people might choose for lunch.

Csikszentmihályi's Computing Culture Group at the Media Lab has been working to develop next generation techniques for civic engagement, from helping a tele-operated war journalist defend his first amendment rights in Afghanistan to constructing a massive online system that allows American citizens to spy on government officials, thereby turning the tables on the NSA wiretapping program. The latter system attracted millions of users around the country, from US Army Generals at West Point needing information on the next move by a reticent Executive Branch, to liberals looking to pry information from a secretive government. While such projects have often focused on both local and national levels, both real and protest communities, we would embrace the opportunity to focus on grounded local communities. Indeed, the technologies we developed for protest are now used by local Critical Mass groups in cities and neighborhoods around the country, and were even imported to Ukraine and used extensively during the Orange Revolution. While MIT developed the codes, each of these systems has been established and administered locally.

Finally, while the Internet was designed to link computers and users across the world as easily as if next door neighbors, new generations of fundamental technologies need development to serve local communities. Current models favor centralization, and are based on corporate or government infrastructure; yet are these necessary in the case of community media? For instance, the $100 Laptop project, which grew out of the Media Lab, has shown how peer-to-peer wifi networks can create active Internet access hundreds of miles from an ISP, by allowing the laptops themselves to act as repeaters. In many cases, local information can travel locally, never needing to travel on the Internet, with huge implications for privacy and community independence. Many more research questions need to be answered: How should local networks form? How can they be designed to avoid centralized surveillance, or monopoly access? How can information travel anonymously and securely at a local level? These questions are likely to be addressed, in part, through the Center's interaction with a massive MIT project titled "Living the Future" (described in depth later), an experiment that will situate user-programmable communications technologies throughout the entire Cambridge, Massachusetts community.

Local Loopback

In addition to having developed many projects around communities, from Computer Clubhouses around the world, to translation networks for Chinatowns, to physically based historical video games in Lexington, CMS and the Media Lab are well situated to implement new systems and techniques in a variety of ways and places. For example, Living the Future, mentioned above, will be a major MIT initiative to develop the next generation of communications technologies. The Internet gave us the Web, and the Web gave us the more participatory, democratic Web 2.0. Living the Future aims to redesign the Internet, mobile devices, and consumer electronics – anything with juice – to work in this more participatory, democratic fashion. Based in the Media Lab but involving faculty from all parts of the institute including CMS, extending around the MIT campus and throughout the entire town of Cambridge (itself an economically, racially, and socially diverse burg), Living the Future will focus on enabling the next generation of technologies to be hackable, informationally promiscuous, and democratic. This will be a natural ally to C4FCM, and will allow us to multiply our effects.

In addition, MIT has a longstanding relationship with Lawrence, Massachusetts, a former mill town that has seen massive changes from thriving industrial hub, to depressed rustbelt shell, to depressed rustbelt shell attracting next-generation genomics firms. A complicated community, it has been the site of diverse longitudinal studies and programs.

The MIT@Lawrence program [http://web.mit.edu/mitpsc/funding/lawrence.shtml] offers funding and infrastructure for research in urbanism, community development, and technology. In addition to a community that actively seeks engagement, Lawrence also presents a community of active researchers, and that combined wisdom allows for engagements that are at once agile, systematic, and committed. Already, Media Lab researchers have worked with community organizations in Lawrence to design and implement an innovative phone-based news system, which enables local youth to organize and publicize events aimed to strengthen connections within the community.

Deliverables

We anticipate that C4FCM would engage 3-5 MIT Faculty, 1-2 post-docs, one administrator, and between 10-15 graduate researchers. At any time, several projects would be in active development and field-testing. There would be a regular speaking series, a yearly conference on civic media, and several courses per year taught in the Media Lab and CMS, all designed to immerse project participants in civic engagement literature and best practices of other efforts in order to prepare them for their own research efforts. The Center would utilize existing infrastructure in CMS and the MIT Media Lab, and work in conjunction with projects in the Department of Urban Studies and Planning, Architecture, and the Living the Future project.

Deliverables of the Center would include:

1. Develop new technologies to support/foster civic journalism
    * Next-generation software tools to gather/edit/display community news
    * Device-based community-news tools, leveraging ubiquity of phones, PDAs, music players, and cameras
    * New ways to map debates/discussions in online communities
    * Tools to help people graphically represent/visualize/change their communities, both online and in public spaces
    * Tools to enable citizens to collect/share information on political leaders and legislation
    * Low-level technical protocols – a new Internet – optimized for the local, proximal, community level

2. Serve as international center for study/discussion of civic media
    * Fellows program for citizen journalists (analogous to Nieman/Knight Fellows)
    * Colloquia and symposium series on civic media and citizen journalism
    * Summer workshops for journalists and community representatives
    * K-12, college, and community group curricula based on best practices in civic media and citizen journalism
    * All public events widely disseminated in a variety of channels and formats for audiences worldwide
    * Curricula published and open-sourced

3. Organize community-based testbeds
    * Build on previous work to create new models of interaction between community members
    * Create new civic-media initiatives at local institutions such as community centers, bus stops, and town squares that encourage a participatory culture and empower the fifth estate
    * Work directly with local high schools (and collaborate with national groups such as Student Press Association) to rethink nature of student journalism
    * Community-wide initiatives (all ages) in Lawrence, MA
    * Collaborate with Computer Clubhouses on youth-based civic-media projects – with special focus on Computer Clubhouses in Knight communities (Detroit, Miami, and San Jose)
    * City-wide technology development platform of Cambridge, Massachusetts
    * Potential for trials using the One Laptop per Child initiatives in Nigeria, Brazil, Libya, and other countries
    * Collect best practices, principles and techniques for using media and disseminating them
    * Engage local journalists and citizens in learning new forms and applications of civic media

Henry Jenkins is the Director of the MIT Comparative Media Studies Program and the Peter de Florez Professor of Humanities. He is the author and/or editor of eleven books on various aspects of media and popular culture, including *Textual Poachers: Television Fans and Participatory Culture, Hop on Pop: The Politics and Pleasures of Popular Culture*, *Democracy and New Media*, and *From Barbie to Mortal Kombat: Gender and Computer Games.* His most recent books include *Convergence Culture: Where Old and New Media Collide* and *Fans, Bloggers and Gamers: Exploring Participatory Culture.* He is one of the principal investigators for The Education Arcade, a consortium of educators and business leaders working to promote the educational use of computer and video games. He is the principal investigator of Project nml (New Media Literacies), funded by the John D. and Catherine MacArthur Foundation to promote the social skills and cultural competencies required to insure that every young person is able to fully participate in the new media landscape. He has testified before the U.S. Senate Commerce Committee, the Federal Communications Commission, and the Governor's Board of the World Economic Forum and serves on the advisory board of the Free Expression Network. Jenkins has a MA in Communication Studies from the University of Iowa and a PhD in Communication Arts from the University of Wisconsin-Madison.

Mitchel Resnick, Professor of Learning Research at the MIT Media Laboratory, develops new technologies and activities to help people (especially children) learn new things in new ways. Resnick's Lifelong Kindergarten research group developed ideas and technologies underlying the LEGO Mindstorms and PicoCricket construction kits. He co-founded the Computer Clubhouse project, a network of after-school centers where youth from low-income communities learn to express themselves creatively with new technologies. Resnick earned a BA in physics at Princeton University (1978), and MS and PhD degrees in computer science at MIT (1988, 1992). Resnick has consulted throughout the world on the use of computers in education. He is author of *Turtles, Termites, and Traffic Jams* (1994), co-editor of *Constructionism in Practice* (1996), and co-author of *Adventures in Modeling* (2001). Resnick is director of the Okawa Center for Future Children, and serves on the Board of Trustees of the Boston Museum of Science.

Chris Csikszentmihályi, Murial Cooper Associate Professor of Media Arts and Science, directs the Media Lab's Computing Culture research group, which creates unique media technologies for cultural applications. He has worked in the intersection of new technologies, media, and the arts for 13 years, lecturing, showing new media work, and presenting installations in Asia, Africa, Europe and the Americas. Csikszentmihályi is a 2005 Rockefeller New Media Fellow, author of *Skin | Control* (2005), and recently finished a solo exhibition at the Location One Gallery in New York's Soho. He developed the world's first robot journalist for battlefield reporting, the Afghan eXplorer, and the first robotic hip-hop dj, the DJ I, Robot Sound System. He is currently at work on an inexpensive Unmanned Aerial Vehicle for journalists doing war reporting, and a set of robots to explore and report information from Guantanamo.

MIT Comparative Media Studies

The Comparative Media Studies Program (CMS) at MIT is an international center for the study of media technologies, exploring the cultural, social, political, ethical, legal and economic impact of digital technologies and their analog forbearers. Students are encouraged to develop a broad understanding of key issues surrounding media change which cut across different national borders and delivery techniques; they are also encouraged to develop an in-depth understanding of multiple media traditions, old and new, and to use this knowledge to develop new models of digital media usage. CMS works with foundations and industry to guide their understanding of shifting models of media production, circulation and consumption that impact their day-to day operations. Central to this vision is the ideal of applied humanities, putting knowledge about media change and its impact on the culture to work to solve real world challenges. The CMS program has done groundbreaking work in the fields of humanities databases (MetaMedia, Repertoire), augmented reality and serious games (The Education Arcade), youth and digital learning (the New Media Literacies Project), and consumer relations (The Convergence Culture Consortium).

MIT Media Laboratory

In the more than two decades since the MIT Media Laboratory opened its doors in 1985, faculty members, research staff, and students have enjoyed a reputation for innovation that, while initially considered unorthodox, has found its way into the most conventional – and useful – of applications. The Lab's extremely diverse faculty and research staff have helped to create now-familiar areas such as digital video, multimedia, and wearable computing, and have brought together disciplines such as cognition, electronic music, graphic design, video, and holography, as well as pioneering work in computation and human-machine interfaces. Faculty and graduates have started more than 60 companies since the Lab began.

The Media Lab houses an experimental, gigabit fiberoptic plant that connects a heterogeneous network of computers, ranging from fine-grained, embedded processors to mesh networks. Rapid prototyping resources include 3-D printing, injection molding, and PC board fabrication. There are studios for audio and video, and laboratories for DNA labeling, new sensors, micro-encapsulation, and perceptual studies.