CHAPTER 1

Transformative Interdisciplinary Research Achievements

The National Science Foundation must support the most innovative and potentially transformative research, research that has the capacity to revolutionize existing fields, create new sub fields, cause paradigm shifts, support discovery, and lead to radically new technologies... The Foundation must create an environment that is more open to and encourages transformative research proposals from the research community.

– National Science Board, 2020 Vision for the National Science Foundation, 2005

"Discovery increasingly requires the expertise of individuals with different perspectives—from different disciplines.... working together to accommodate the extraordinary complexity of today's science and engineering challenges."[1] With this as a starting point, all IGERTs address the NSF strategic outcome of Discovery and all of its five sub-goals.

Promoting Transformational and Multidisciplinary Research

All IGERTs promote transformational and multidisciplinary research. The 136 IGERT projects submitting annual reports in 2006-2007 reported a total of 335 distinct research achievements. These achievements are defined as accomplishments of significant impact of the projects as pertains to the interdisciplinary research of each IGERT and cut across all the Directorates of the NSF. Overall, the objective indicators of these achievements are a total of 811 journal publications, 345 conference publications, 1,171 conference presentations, 52 book chapters and 14 books.

Further U.S. Economic Competitiveness

Of the 136 IGERT projects submitting annual reports in 2006-2007, 13% directly involve aspects of entrepreneurialism and 18.1% have formal industry interactions. 35 patents and 61 patent applications arose from IGERT interdisciplinary research across a wide variety of fields and topics.

The remainder of this chapter summarizes each of the technology themes as reported by all IGERTs for year 2006-2007 both qualitatively (with examples) and quantitatively (in terms of counts and percentages reporting) and relates them to NSF's strategic plan and IGERT's solicitation. Table 1 summarizes the breadth of the IGERT thematic experience in terms of both the number and percentage of IGERTs involved with a given theme, and academic achievements associated with the research themes of the IGERT.

NSF Strategic Outcome: Discovery

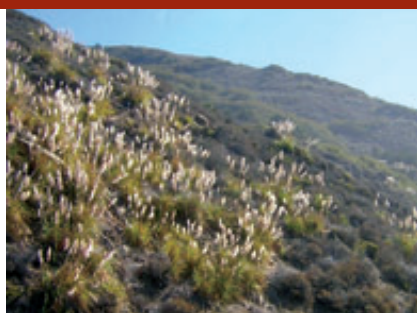
Foster research that will advance the frontiers of knowledge, emphasizing areas of greatest opportunity and potential benefit and establishing the nation as a global leader in fundamental and transformational science and engineering.

[1] National Science Foundation. (2006.) Investing in America's Future. Strategic Plan, FY 2006-2011. NSF Publication Number 06-48.

Table 1: Breadth of Thematic Experiences and Academic Achievements

TOPICS	# IGERTS	% IGERTS	# Journal Articles	# Conference Publications	# Conference Presentations	# Book Chapters	# Books
Sustainability: ecology and the environment	38	28	211	58	313	7	4
Computational science and engineering	48	35	188	110	252	18	1
Human and social dimensions of new knowledge and technology	44	32	188	72	403	26	6
Nanoscience: engineering and technology	23	17	188	87	254	6	4
Energy: alternate and renewable resources and conservation	4	3	21	6	12	0	1
Materials science and engineering	27	20	219	101	200	4	3
Bioinformatics	11	8	62	3	57	0	1
Civil infrastructure monitoring and improvement	2	1	36	2	45	2	0
Entrepreneurialism	17	13	109	93	181	5	3
Neuroscience: biology and psychology	10	7	24	14	55	2	0
Climate change: impacts and factors	6	4	55	27	116	2	0
Biological evolution and development	11	8	58	33	88	7	0
Diverse device development	24	17	123	56	108	8	3
Sensing, signals, imaging and signal processing	14	10	83	55	107	9	2

Sustainability: Ecology and the Environment



Thirty-eight (38) of the 136 IGERTs reporting in 2006-2007 address the NSF strategic investment goal of discovery, fostering research that improves our ability to live sustainably on earth. Examples of projects that strengthen our understanding of the links between human actions and natural processes range from developing a knowledge base for policy creation and decision making to restoring wetlands that were formerly part of a U.S. Army base.

The interdisciplinary skills involved with the training in these IGERTs are setting the platform for developing a new cadre of scientists and engineers conversant both in science and its communication and societal impacts. The publications and conference presentations associated with this theme are in Table 1. Examples of the research achievements include:

☐ Openlands, a Chicago area conservation group, invited an IGERT project to participate in the restoration and management of a lakefront preserve on the former Fort Sheridan Army base including more than one mile of undeveloped Lake Michigan shoreline and one of the last remaining bluff/ravine ecosystems in Illinois. (0549245: Ashley, University of Illinois Chicago)

☐ Working in conjunction with Ceres, a Boston-based nongovernmental organization (NGO), during an internship, an IGERT trainee worked to form a relationship between U.S. financial management/corporate organizations and the U.S. Congress to aid in developing a suite of national policies to mitigate carbon emissions into the atmosphere. (0504103: August, University of Rhode Island)

☐ By integrating several sources of social-ecological sustainability theory, one IGERT is developing new participatory methods for engaging local indigenous communities on research in ways Alaska and other such environments can enhance the sustainability of various human-impacted systems. (0114423: Chapin, University of Alaska Fairbanks)

☐ A publication resulting from an IGERT summer course involved collaborations among ecologists, engineers, and chemists. It demonstrated that micro-organisms use chemical means to compete with macro-organisms, that this may significantly affect energy and nutrient flow, and that microbes need to be considered as competitors with large animals in marine food webs. This unification of the disciplines of chemistry, microbiology, food-web theory, and ecosystem level processes was broadly covered by the press – including the journal *Nature*, and various radio, web, and print based media. (0114400: Hay, Georgia Tech Research Corporation - GIT)

☐ While studying the transport of toxic heavy metals in Clark Fork River, IGERT researchers discovered that heavy metal containing mineral nanoparticles, not previously known to exist in river systems, appeared to be responsible for transporting lead, copper, zinc, and arsenic down river hundreds of miles from the source of the initial contamination. (0504196: Hochella, Virginia Polytechnic Institute & State University)

☐ An IGERT student had the opportunity to study molybdenum isotopes during an international internship to Lake Tanganyika in Tanzania. The lake, with oxygenated surface waters and sulfidic bottom waters, provided a unique system for testing her hypothesis that molybdenum isotopes behave differently depending on whether or not the overlying water has sulfide present. She sampled sedimentary deposits in the lake's freshwater system for comparison with the marine environment. The results to date suggest that molybdenum isotopes may be useful for quantifying carbon flux through time. (0114427: Myrold, Oregon State University)

Computational Science and Engineering: Applied and Interdisciplinary Mathematics

Forty-eight (48) of the 136 IGERTs reporting in 2006-2007 addressed the NSF strategic investment priority of advancing fundamental research in computational science and engineering, and in fundamental, applied and interdisciplinary mathematics and statistics. From linguistics to interactive digital media to assessing changes in coastal ecosystems, IGERT projects have developed and used computational tools to further our knowledge in a range of research covering all NSF Directorates.

The publications and conference presentations associated with this theme are in Table 1. Examples of the research achievements include:

☐ A team of four trainees with backgrounds in microbiology, ecology, math and computer science performed a collaborative study that integrates global information system (GIS) data, climate change models, and on-the-ground presence data for plague to predict how current models of climate change will affect the distribution of plague in the U.S. in the future. Preliminary results suggest that the range of distribution will likely shrink. (0504628: Holben, University of Montana)

☐ An "open channel" protocol for email was proposed and investigated and conditions were discovered under which offering such a channel in parallel to a spam-filtered "closed channel" would reduce the total amount of spam sent and increase the quality of commercial advertising information conveyed in spam, thus benefiting both senders and receivers of spam advertising. (0114368: Mackie-Mason, University of Michigan)

☐ A collaboration of geology, industrial and system engineering IGERT trainees and faculty developed an ontology on natural disaster effects and responses that would improve decision-support and information interoperability between emergency responders. The specific case study was focused on the October 2006 snow storm in Erie County New York and used cognitive systems engineering methods and the philosophical notion of ontology to conceptualize work flow and information flow. (0333417: Mark, State University of New York Buffalo)

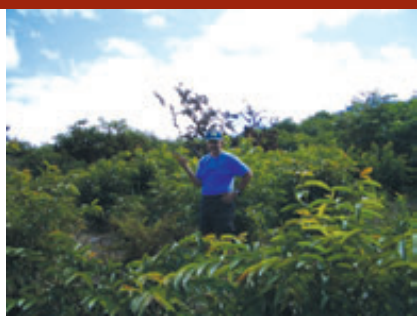
☐ Novel media systems for interactive rehabilitation are under development. The systems integrate task specific motor skill training, associated sensory and cognitive stimuli, and stress monitoring within interactive, multimodal environments. The environments provide purposeful, engaging audiovisual scenes in which stroke survivors practice functional movement tasks, while receiving multimodal feedback indicating measures of performance and results, promoting neural plasticity and encouraging improvement. The system was successfully tested this year with three stroke patients, each patient undergoing six training sessions with the system. Initial results show that the system has strong potential to increase functional recovery of patients. Developing this system requires interdisciplinary interaction to integrate sophisticated information analysis, sensing and feedback systems and medical technologies (team includes 14 members spanning these disciplines). (0504647: Rikakis, Arizona State University)

☐ The integration of mathematical linguistics and theoretical linguistics via an IGERT-developed computational track has shown how the general properties of neural network self-organization can explain

pervasive patterns found in the inventories of vowels and syllables in the world's languages. (0549379: Smolensky, Johns Hopkins University)

☐ An IGERT trainee is developing a high-spatial/temporal numerical model for simulating the hydrodynamics in the lower Mississippi River. High resolution unstructured finite element mesh of the Bird's Foot Delta in the Lower Mississippi River Delta using the Surface Water Modeling Software (SMS) has been developed. The intent is to develop new methods of visualization and hydrodynamic modeling of saltwater intrusion. (0504507: Acharya, Louisiana State University & A&M College)

Human and Social Dimensions of New Knowledge and Technology



Forty-four (44) of the 136 IGERTs reporting in 2006-2007 directly address the human and social dimensions of new knowledge and technology, a strategic goal of the NSF. The range of the research from the impact of toxic wastes in streams to the socioeconomic modeling of crop planting and its impact on maintaining biodiversity to contributions to our understanding of HIV/AIDS spread under conditions of rapid economic and social change gives a glimpse into the breadth of the IGERT trainee research and training experience. Trainees and their mentors address fundamental challenges faced by humans and the planet resulting from the ever changing landscape of human interaction with science and technology.

Table 1 summarizes the number of journal articles, conference publications, conference presentations, book chapters and books reported by IGERTs associated with human and social dimensions of new knowledge and technology in 2006-2007. Examples of the research achievements of the 44 IGERTs involved with human dimensions of science and technology include:

☐ New methods have been developed and tested for monitoring and motivating people recovering from stroke using cameras and computer vision technology to measure movement characteristics in stroke survivors in the home. The work has resulted in methods for aiding patients to regain greater strength more quickly after experiencing strokes. (0333420: Atkeson, Carnegie Mellon University)

☐ Trainees working in Idaho's conifer forests developed simulations to explore the implications of present and future residential patterns and forest thinning based on landowner and stakeholder interviews and shared their results with land managers and decision makers in the region. (0114304: Bosque-Perez, University of Idaho)

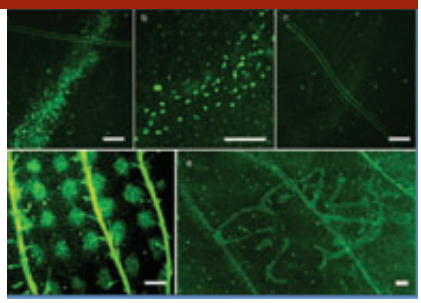
☐ Two books: *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools and Societies* by Scott Page and *Complex Adaptive Systems: An Introduction to Computational Models of Social Life* by John Miller and Scott Page contributed substantially to our understanding of human dynamics and social systems. (0221611: Page, University of Michigan)

☐ Research on security and intellectual property issues associated with synthetic biology has found that intellectual property conflicts and the lack of a U.S. research exemption threaten development of the field. This work has led to collaboration with Department of Homeland Security contractors assessing screening systems for DNA synthesis orders. (0333010: Hastings, Massachusetts Institute of Technology)

☐ Many plants that invade natural areas were introduced as garden ornamentals; our 2003 cohort studied the role of the horticultural trade in establishing invasive species. In a telephone survey of 54 nursery professionals, trainees found that 100% of respondents thought that invasive species pose a problem; 80% thought that nurseries contribute to the spread of invasives; but 83% had not heard of voluntary codes of conduct developed by industry professionals in collaboration with researchers, with the goal of reducing the spread of invasive plants through nurseries. Voluntary initiatives have become increasingly popular as an alternative to government regulation, but may be less effective in an industry that lacks centralized control. Open access of the publication has led to its posting on the U.S. Department of Agriculture (USDA) website, as well as on the web pages of the Center for Invasive Plant Management, and the Great Plains Noxious and Invasive Weeds. (0114432: Strauss, University of California Davis)

☐ In a series of papers it has been shown that complexity is a serious obstacle to both efficiency and equity in the distribution of student aid, disproportionately burdening those with the least ability to pay. These results have been covered in the *New York Times*, the *Chronicle of Higher Education*, and other news media. (0333403: Wilson, Harvard University)

Nanoscience Engineering and Technology



Twenty-three (23) of the 136 IGERTs reporting in 2006-2007 directly address the breadth and interdisciplinary nature inherent in nanoscience engineering and its application technology to help further U.S. economic competitiveness. IGERTs on topics ranging from developing fundamental understanding of nanostructures to using this knowledge to improve manufacturing processes to help move nanotechnologies to aid U.S. economic competitiveness and address the America Competes Initiative are all within the scope of the IGERTs in this theme.

The publications and conference presentations associated with this theme are in Table 1. Examples of the research achievements include:

☐ Plasmonic properties of metallic nanostructures using dark-field microspectroscopy are being investigated for a wide range of nanostructures, including nanoshell dimers, nanorice (prolate-spheriodal nanoshells), and nanoholes in a gold film. This work includes studying the polarization-dependent microspectroscopy of an individual nanoshell dimer compared with a nanoshell monomer. This ability to see the dependence of a structure's spectrum on the polarization orientation is invaluable for characterization of the plasmonic properties of nanostructures. (0504425: Halas, William Marsh Rice University)

☐ An interdisciplinary team demonstrated continuous-flow production of small gold nanoparticles in a simple microcapillary system. Production rates are at least a gram/hour (>10 times higher than batch) and waste is reduced by a factor of 10. While the system and method have not been optimized, this is an impressive result that is a significant step toward high-volume production of nanoparticles. The final experiments are underway and a manuscript is being drafted. The work is the result of a multi-institution collaboration between chemists and engineers. (0549503: Johnson, University of Oregon Eugene)

☐ A project on nanoparticle photovoltaics involved the development of the first reported quantum dot sensitized nanowire solar cell, based on CdSe nanocrystals attached to an array of ZnO nanowires. After incident photons are absorbed by the nanocrystals, electrons are transferred into the ZnO nanowires, while the holes travel in a hole conductor to the opposite terminal of the solar cell. This solar cell improves on another low-cost solar cell, the so called dye-sensitized cell, in two ways: First, it replaces the light-absorbing organic dye, which has stability issues on long-term exposure to light, with more stable, inorganic quantum dots. Second, it uses an array of nanowires for the electron transport instead of a network of abutted nanoparticles with frequent, inhibiting grain boundaries. This project involves four IGERT students and five faculty members from three different fields: Chemistry, Chemical Engineering and Materials Science, and Mechanical Engineering. (0114372: Kortshagen, University of Minnesota Twin Cities)

☐ A dual magnetic resonance/optical detectable nanoprobe capable of reaching medulloblastoma (MB) tumors behind the blood brain barrier has been developed. During thorough testing it was shown to be capable of selectively binding MB cells and enable delineation of tumor boundaries through MR and optical imaging. (0504573: Olmstead, University of Washington)

☐ Interdisciplinary work involving several labs has demonstrated for the first time that an electric field used to macroscopically align polymer nanofibers (300 nm diameter) can also align polymer chains parallel to the fiber axis. This important result indicates that anisotropic structural properties (mechanical, electrical, etc.) can be induced in polymer nanofibers during the electrospinning process. Such uniaxially oriented nanofibers exhibit a variety of potential applications in biomedicine, microelectronics and optics. A simple technique of vertical electrospinning with electric field induced, stationary collection was employed to obtain the molecular orientation in polymer nanofibers. (0221651: Robinson, University of Delaware)

☐ An IGERT trainee used quantum dots to image the distribution of T cell receptors (TCRs) on T cell surfaces in vivo. This newly developed technique relies on the stochastic "blinking" of single quantum dots to determine the clustering of TCRs following the activation of a T cell by antigen exposure. Previously, it had been shown in vitro and by indirect methods that, following activation, TCRs cluster together to form larger patches on the surface, which increases the sensitivity of TCRs and, hence, T cells to antigens. The research allows for visualizing this process in vivo, tagging TCRs with conjugated IgG molecules, and using biotinylated quantum dots as a secondary antibody. Using this method the clustering of TCRs in activated T cells, as well as the subsequent "deactivation" or declustering of TCRs which occurs in the absence of continuous stimuli, were observed. (0549350: Stebe, Johns Hopkins University)

Energy: Alternate and Renewable Resources and Conservation

Four (4) of the 136 IGERTs are directly related to the production of alternate energy sources and the concomitant basic science and engineering required for their successful implementation. Addressing NSF strategic priorities of fostering research to improve our ability to live sustainably on earth coupled with improving our economic competitiveness, these IGERTs range from solar energy to wind energy to fuel cell improvement. Their interdisciplinary success is further interwoven with elements of nanotechnology and cutting edge material science.

The publications and conference presentations associated with this theme are in Table 1. Examples of the research achievements include:

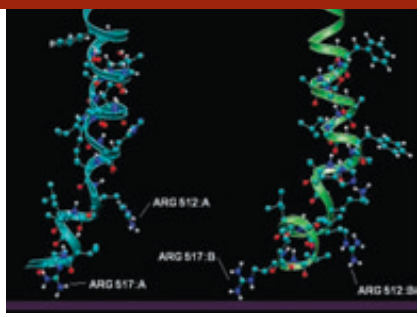
☐ IGERT trainees have been involved in the potential applications for solar hydrogen and the way in which limited surface area places a premium on achieving high efficiency photovoltaics (PV). An approach to high efficiency PV is to use nano-structured materials, such as quantum dots, to allow efficiencies above that of a single junction. By developing band structure models for nanostructured solar cells, our IGERT students from across the disciplines have identified materials which can be used to achieve >50% thermodynamic efficiencies by using GaAsSb/InAs barrier/dot material systems. (0549399: Honsberg, University of Delaware)

☐ Low temperature polymer electrolyte membrane (PEM) fuel cells suffer from their dependence on water. Water is required in order to reach peak proton conductivity of the membrane, but too much water can result in liquid water formation in unwanted regions. A full understanding of the behavior of water within the various portions of the fuel cell must be understood in order to balance these two effects. Researchers (mechanical engineers, electrochemists, physicists) have performed direct in-situ water distribution measurements in the membrane, electrodes, and gas diffusion layers using neutron imaging. These measurements are the first of their kind and are being used to test the few existing hydration-conductivity theories, some of which have been relied on for decades by the fuel cell community. (0504361: Jensen, Rensselaer Polytechnic Institute)

☐ A computational framework for multiscale modeling of the thermal degradation of lubricating oils was developed. Multiscale models of lubricant degradation connect atomic-level details such as elementary reaction rates to macroscopic properties of lubricant degradation such as the "total acid number" or "oxidation induction time." The key pieces of the model include a systematic methodology for producing structure-reactivity relationships from quantum chemistry and transition-state theory and reaction. These new models are helping to unravel the complex reaction mechanisms that govern lubricant degradation, and a consistent picture of the dominant reaction pathways involved is emerging. Furthermore, this new simulation framework has been extended to incorporate the action of free-radical scavenging antioxidants such as hindered phenols. Students from Chemistry, Chemical and Biological Engineering, and Mechanical Engineering have all contributed to this project. (0114429: Keer, Northwestern University)

☐ Hourly-averaged data from the wind-center research center's 200m tower is used to examine static atmospheric stability as a governor of speed and direction shear during day time and night time hours in the atmospheric boundary layer. Large magnitudes of direction shear are found to occur concurrently with wind speed greater than 8 m/s. Joint probability distributions of speed and direction shear measured at Lubbock, Texas show, through numerical simulation, that power loss can be 0.5%. Over the 20-year lifetime of a 100 MW wind power plant this translates to a $3.5 million loss in project revenue.(0221688: Mehta, Texas Tech University)

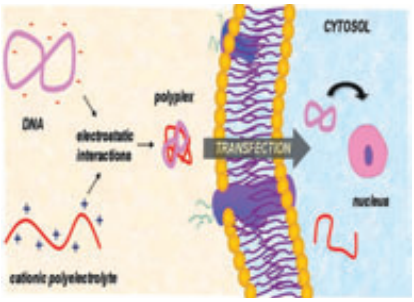
Materials Science and Engineering



Twenty-seven (27) of the 136 IGERT projects reporting in 2006-2007 address the broad aspects from discovery to development of new materials with potential applications that range from oxygen sensors to materials for supercapacitors—from the nanoscale to macroscale. All of these projects address the NSF strategic investment priority of discovery in promoting transformational, interdisciplinary research and fostering U.S. economic competitiveness.

The publications and conference presentations associated with this theme are in Table 1.
Examples of the research achievements include:

☐ An IGERT team developed new materials for oxygen sensing by sequestering the luminophore tris(4,7-diphenyl-1,10-phenanthroline)ruthenium(II) ([Ru(dpp)(3)](2+)) within hybrid xerogels that are composed of two of the following methoxysilanes: tetramethoxysilane, n-propyl-trimethoxysilane, 3,3,3-trifluoropropyl-trimethoxysilane, phenethyl-trimethoxysilane, and pentafluorophenylpropyl-trimethoxysilane. Steady-state



and time-resolved luminescence measurements were used to investigate these hybrid xerogel-based sensor materials and elucidate the reasons for the observed performance. These composites form visually uniform, crack-free xerogel films that can be used to construct oxygen sensors that have linear calibration curves and excellent long-term stability. The [Ru(dpp)(3)](2+)-doped fluorinated hybrid xerogels exhibit the highest oxygen sensitivity of any reported [Ru(dpp)(3)](2+)-based sensor platform. (0114330: Cartwright, State University of New York Buffalo)

☐ IGERT trainees and faculty from engineering and chemistry have demonstrated the effect on nanoscale polymer thin film properties of coordinative crosslinking. The result offers the possibility for very fine control of nanoscale mechanics, building on related work on the macroscale already completed. (0221632: Clark, Duke University)

☐ An IGERT trainee and colleagues in the United States and France published the first paper in *Science* magazine related to supercapacitors (anamolous increase in carbon capacitance at pore sizes less than 1 nanometer). The work deals with the design of porous carbon material which can be used as electrodes in supercapacitors. Historically, the design protocol for supercapacitor carbons was to produce the largest surface area with the largest pore size possible. According to this work, however, decreasing the electrode pores below 1 nm can lead to smaller, lighter, more powerful supercapacitor devices. (0221664: Gogotsi, Drexel University)

☐ IGERT researchers are spearheading the development of powerful new "metrology" of cell-biomaterial interactions. Traditional methods study cell properties on only one or a few biomaterials at a time, which is inefficient and qualitative. The Rutgers IGERT "Cell Profiling Tool-Box" quantifies cellular processes simultaneously on multiple materials. (i) Large libraries of biomaterials are created with differing chemical and mechanical properties. (ii) Cells are engineered with living fluorescent reporters whose organization changes upon cell contact with a biomaterial. (iii) Image analysis, with additional computer modeling and bioinformatics, correlates the fluorescent images to biomaterial properties and cell functions. Information thus generated can help accelerate the design of improved biomaterials targeting important applications,

such as control of stem cell differentiation toward specific lineages (bone, cancer). (0333196: Moghe, Rutgers University New Brunswick)

☐ One IGERT has focused on the design of small particles that carry imaging agents to developing heart disease plaque, and trainees have successfully formulated and delivered microparticles containing magnetic resonance imaging agents to plaques likely to cause complications in order to more clearly picture the areas using magnetic resonance imaging (MRI). The ultimate goal is to impact personalized patient care. (0333080: Peppas, University of Texas Austin)

☐ By developing and subsequently utilizing a novel resonant-cavity-enhanced absorption technique, record cooling temperatures and cooling power in a crystalline solid have been achieved. This has paved the way for attaining the ultimate goal of cryogenic temperature operation of solid-state laser cooling. Led by an IGERT trainee, the research involved multidisciplinary teams from our University of New Mexico's Center for High Technology Materials (involving IGERT faculty participants), Los Alamos National Laboratory, and a crystal growth group from Italy. The research achievement itself will have broader impact as it will be applicable to high-sensitivity spectroscopy and detection of chemical and biological systems. (0114319: Rudolph, University of New Mexico)

Bioinformatics

Eleven (11) of the 136 IGERTs reporting in 2006-2007 address the inherently interdisciplinary field of bioinformatics. By combining computational skills with data set analysis, IGERT trainees are developing unique skills that can impact everything from our ability to live sustainably on earth to advancing fundamental computational computer science, as trainees and IGERT faculty strive to push the limits of algorithm development and utilization.

The publications and conference presentations associated with this theme are in Table 1.
Examples of the research achievements include:

☐ Interdisciplinary teams of IGERT trainees and associates developed a synthetic understanding of the wildlife management issues surrounding population dynamics of elephants and their impacts on the ecological and social fabric of the Okavango Delta watershed during the summer program in Africa. Students developed a series of simulation models that tested hypotheses regarding the causes and effects of increased elephant populations. The models show long-term trends about which local wildlife and natural resource managers could only speculate but now can communicate to local populations the underlying causes of increased elephant numbers and the effects on local economies. The multidisciplinary approach explored diverse aspects of the elephant population explosion, including effects on tourism and economies, impacts of increased salinization from elephant damage to trees, competition with other grazers, and interactions with livestock livelihood systems. (0504422: Brown, University of Florida)

☐ A trainee-organized research project: Does exclusion of random error alter model inference? A case study using grizzly bears (*Ursus arctos*) of the Greater Yellowstone Ecosystem (GYE) resulted in a study on the effects of including error source terms on model selection and inference in population dynamics. The team used both frequentist and Bayesian model selection approaches to investigate the effect of errors on the inferences made from population data. The results of the analysis show that expanding models to include error

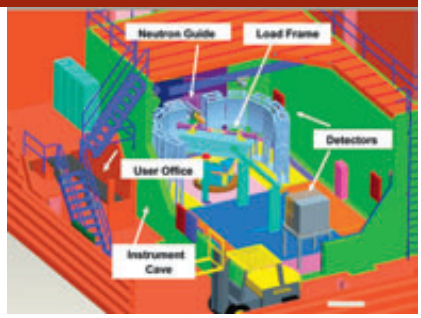
terms leads to more robust decisions about delisting of the GYE grizzly bears (*Ursus arctos*) from the Endangered Species list. (0221595: Davis, Colorado State University)

☐ An IGERT trainee in conjunction with IGERT faculty is developing mathematical models for within-host dynamics of three infections: (i) influenza, (ii) Streptococcus pneumoniae, and (iii) influenza followed by S. pneumoniae. Using experimental data, the team is quantifying infection parameters, investigating treatment strategies, and testing mechanisms of interaction between influenza and S. pneumoniae and each of their interactions with the immune system. (0217424: Keener, University of Utah)

☐ Three IGERT trainees, each from a different department (Ecology and Evolutionary Biology, Plant Sciences, and Computer Science) formed a collaboration on a research project several years ago that explored the relationship between rates of protein evolution and gene expression evolution in Drosophila. They discovered a positive correlation between rates of protein evolution and rates of expression divergence. By testing for evidence of positive selection, they showed that the correlation between expression and protein divergence is probably due to underlying variation in the level of selective constraint, challenging a widely held view in the field. (0114420: Nachman, University of Arizona)

☐ The program, Development and Release of Garli: A genetic algorithm for phylogenetic inference using maximum likelihood criteria is a result of several years of collaborations between biologists and computer scientists for an IGERT. The program uses a genetic algorithm to solve a difficult computational program of interest to many biologists: the phylogenetic analysis of trees of many thousands of DNA sequences, under a model-based maximum likelihood criterion. This program cuts analysis time by at least 10-fold over previous programs. The final program was written by an IGERT trainee with input from many IGERT faculty and trainees. The program is available for free download at http://www.zo.utexas.edu/faculty/antisense/garli/Garli.html. It has quickly become the primary program used by biologists around the world for phylogenetic analysis under maximum likelihood. (0114387: Hillis, University of Texas Austin)

Civil Infrastructure: Monitoring and Improvement



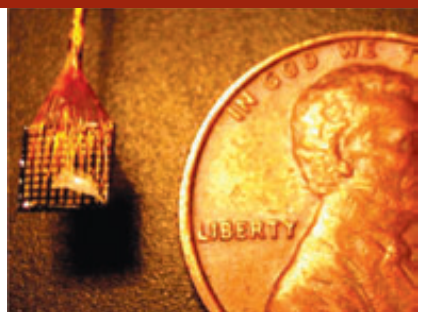
Two (2) of the 136 IGERTs reporting in 2006-2007 directly address infrastructure monitoring from aspects of engineering, corrosion science, and computational modeling, all aimed at improving our understanding of the lifetime, usage and reliability of materials. The interdisciplinary theme addresses NSF discovery strategic investment priorities of promoting transformational and interdisciplinary research and improving our ability to live sustainably on earth.

The publications and conference presentations associated with this theme are in Table 1.
Examples of the research achievements include:

☐ A new multidisciplinary research group named Systems Health Monitoring was formed, bringing together the disciplines of civil engineering and computer science. This effort is leading to the transfer of computer engineering fault detection methods to mechanical and multidisciplinary systems in aerospace vehicles, and is a new extension of the IGERT research theme not envisioned earlier, but made possible due to the interdisciplinary teamwork. (0114329: Mahadevan, Vanderbilt University)

☐ By studying the resistance of Haynes C2000 to corrosion in both static and mechanically-dynamic conditions and comparing the findings with nano nickel-based materials and bulk metallic glasses, a refined model was proposed to predict the lifetime of the nickel-based materials subjected to corrosion fatigue. In addition, nano Ni-Fe and Ni-Co materials were studied to gain insight about their corrosion behavior. (9987548:Liaw, University of Tennessee Knoxville)

Neuroscience: Biology and Psychology



Ten (10) of the 136 IGERTs reporting in 2006-2007 addressed the interdisciplinary theme of neuroscience. Involving statistics, computational science, neuroscience, imaging, and psychology, these projects have led to discoveries from visual imaging to mechanisms of contextual decision making. The theme addresses many of the discovery intensive NSF strategic investment priorities, including promoting transformational interdisciplinary research and advancing research in math and applied statistics.

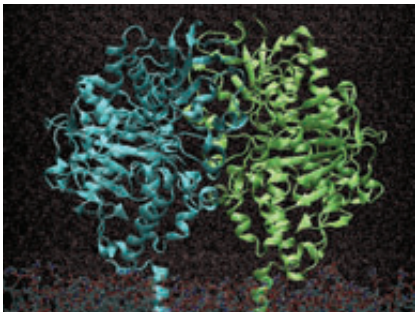
The publications and conference presentations associated with this theme are in Table 1.
Examples of the research achievements include:

☐ An IGERT trainee at the University of California, San Diego's Vision and Learning in Humans and Machines IGERT discovered that Bayesian optimal experimental design principles could be used to design informative experiments to help reveal the intuitive value of information. The work is helping to clarify what information people believe to be most informative on a variety of learning tasks. One such

task is categorization. Other relevant tasks include scientific hypothesis testing and medical diagnosis. In every case, information is not inherently valuable, but valuable as a function of the probabilities in the world it helps a person learn what they need to carry out a task. (0333451: de Sa, University of California San Diego)

☐ An IGERT trainee has been working on an interdisciplinary project involving statistics and neuroscience. The goal of the project is to develop an algorithm for optimizing data collection during neurophysiology experiments. Since neural systems are highly-dimensional, complex systems, each experiment typically provides only a little information regarding the hypothesis or question to be answered. By modifying the design of the experiments as data are collected, one can potentially conduct more pertinent experiments based on the hypothesis. The algorithm combines ideas from information theory, control theory, and computational neuroscience. Simulations show that the algorithm collects information more efficiently than traditional random experimental design. The algorithm is also efficient enough to work in high-dimensional real time applications. (0333411: DeWeerth, Georgia Tech Research Corporation-GIT)

☐ The Science of Learning: This interdisciplinary collaboration between faculty and students in psychology, neurosciences, cell biology and physiology, computer science and engineering, and geology is a direct result of the IGERT activities. The team is studying the connections among human development, learning, memory, thinking, attention, motor skills, etc. Of particular interest is perceptual motor skill development as a new paradigm for learning abilities and disabilities. (0504438: Flach, Wright State University)



☐ To address the goal of enabling direct comparison of human and monkey neuroimaging experiments, an IGERT has developed computer hardware and software and modified the monkey imaging setup so that monkey experiments parallel human experiments as well as having developed new stimulus presentation equipment so monkeys experience the same visual stimuli as humans. Technologies needed to begin our novel monkey neuroimaging to parallel human studies have been established. Comparisons with monkey neurophysiology will provide novel insights into how individual neuronal activity underlies functional brain imaging. (0548890: Thoroughman, Washington University School of Medicine)

☐ IGERT trainees and faculty have used functional neuroimaging to shed light on an important perceptual puzzle: despite constantly changing images on the retina as the eyes move, the world appears still. It was shown that voxels in the right hemisphere, which encode the initial retinal location of a stimulus, are active prior to eye movement, but when the eyes move, voxels in the left parietal cortex become active even though no physical stimulus ever appeared in the right visual field. This demonstrates "spatial updating" in human parietal cortex. New Bayesian statistical methods were developed to assess this updating. It was discovered that updating is present even in the earliest stages of processing, indicating that motor signals from eye movement commands are used throughout the visual system as part of the circuit that keeps the world still. (9987588: Touretzky, Carnegie Mellon University)

☐ An IGERT trainee has begun to develop a mathematical model of real-time sentence comprehension to simulate some of the online eye movement results from a psycholinguistic experiment recently completed. Simulations are being done within the framework of the interdisciplinary coursework developed by the IGERT. (0504487: Trueswell, University of Pennsylvania)

Climate Change: Impacts and Factors

Six (6) of the 136 IGERT projects reporting in 2006-2007 directly address climate change, ranging from its impact on tree species survival to developing data-based scales to measuring the intensity of tornadoes. Each IGERT in this area directly addresses the NSF strategic investment priority of fostering interdisciplinary research to improve our ability to live sustainably on earth.

The publications and conference presentations associated with this theme are in Table 1. Examples of the research achievements include:

☐ An IGERT trainee studied the response of northern hardwood tree species to atmospheric carbon dioxide and nitrogen (N) deposition. The research was conducted to determine how these global change factors might impact future forest functioning. Results indicated that N deposition and atmospheric carbon dioxide (CO_2) will interact to influence understory seedling survival and plants exposed to elevated CO_2 and high N deposition had the greatest survival rates (among the plants studied). Results also indicate that CO_2, N deposition and understory light availability will interact and strongly impact symbiotic arbuscular mycorrhizal fungi associations. It was concluded that increases in atmospheric CO_2 and reactive N deposition will enhance seedling photosynthesis and survival in N-limited temperate forests because seedlings will use these atmospheric compounds as additional plant resources. (0504552: Carroll, University of Michigan)

☐ Faculty and trainees of an IGERT have developed the Enhanced Fujita (EF) scale to rate intensity of tornadoes. IGERT students provided input to this project by using it and validating it in the field for wind storm damage documentation and analysis. Meteorologists and engineers developed 26 damage indicators of buildings and structures. Each damage indicator is divided into several Degrees of Damage (DOD). An expert panel was used to assign wind speed to each DOD to cause that damage. The EF-scale was reviewed through several National Weather Service (NWS) committees. After developing training material for operational personnel, the EF-scale to rate intensity of tornadoes was implemented by the NWS beginning February 2007. (0221688: Mehta, Texas Tech University)

☐ A major focus of another IGERT is the reconstruction of past climate and environments utilizing Tree Ring Research, that has been at the center of a recent National Academies report warning that long-term patterns of variation in the Colorado River basin raise concerns for continued urban growth in the states that depend on Colorado River water. (0221594: Olsen, University of Arizona)

☐ An IGERT trainee presented at the 2007 American Geophysical Union (AGU) Joint Assembly in Mexico on her work assessing the usefulness of the cosmogenic isotope beryllium-10 as a proxy for solar irradiance changes. By using the Goddard Institute for Space Studies Model E general circulation model, she is working to develop a better understanding of how climate-related and production-related changes in the isotope record can be calibrated to solar climate forcings. (0221041: Polvani, Columbia University)

☐ A recently graduated IGERT trainee is beginning a congressional internship on climate change issues and alternate energy based on her IGERT experience in freshwater sciences. (9972810: Ward, University of Alabama Tuscaloosa)

Biological Evolution and Development

Eleven (11) of the 136 IGERTs reporting in 2006-2007 address the theme of evolution and development covering a wide range of disciplines and approaches to solving the riddle of how inhabiting species exist, develop, and evolve on this planet. The theme addressed the discovery NSF strategic investment priorities of transformational, interdisciplinary research and fostering our ability to live sustainably on earth.

The publications and conference presentations associated with this theme are in Table 1. Examples of the research achievements include:

☐ An interdisciplinary project at the fossil hominin site of Laetoli in Tanzania represents one of the most comprehensive studies of an African paleoanthropological site. The international team includes more than 40 scientists from Africa, Europe, and the United States, with expertise in paleontology, geology, palynology, botany, and ecology. The main goals of the project are to recover additional fossil hominins and to better understand their geological and paleoecological context. These data have provided an important building block in a broader understanding of habitat diversity, climate change, and macroevolutionary models in relation to human evolution in East Africa. (0333415: Delson, City University of New York Graduate School)

☐ IGERT trainees have published research demonstrating that fish extinctions impact nutrient recycling in tropical streams and lakes. They combined field data from Lake Tanganyika, Africa, and Venezuelan streams with modeling to examine the impact of fishing removal of major species on nutrient cycling. In both of these species-rich ecosystems, recycling was dominated by relatively few species, but contributions of individual species differed between nitrogen and phosphorus. Alternative extinction scenarios produced widely divergent patterns. These results are the first to demonstrate the effect of fish species extinctions or manipulations on nutrient processes in this kind of environment, and have important implications for managing freshwater tropical fisheries. (0221658: Derry, Cornell University)

☐ IGERT trainees and faculty have shown the first direct evidence that social bonds have adaptive value for female baboons. Using behavioral and genetic records from the Amboseli Baboon Research Project, they demonstrated that female baboons form close, equitable, and stable social bonds with a small number of preferred partners. Females rely on kin for support in agonistic interactions as well as for more peaceful forms of affiliation. The most sociable females reproduce more successfully. This finding linking social behavior directly to reproductive outcomes provides the most compelling evidence to date that social bonds have adaptive value for nonhuman primates. These results provide a striking parallel to evidence on humans which indicates that social support has beneficial effects on health and well-being across the lifespan. (0504228: Peplau, University of California Los Angeles)

☐ Integrative research from one IGERT is making an impact outside of the evolutionary development world as well. Research by one of the IGERT trainees produced the first genetic linkage map, and identified the first photoperiodic timer quantitative trait loci (QTLs) for any organism. The work is part of a broader research program to understand the evolutionary consequences of global climate change. (0504627: Postlethwait, University of Oregon Eugene)

☐ An IGERT trainee is combining ecology and fracture mechanics to address the form/function relationships between the size and shape of the teeth and the nature of the foods eaten by certain animals. A unique hypothesis has been developed to explain the relationship between the thickness and microstructure of enamel and the nature of the foods processed. (9987590: Wood, George Washington University)

Further U.S. Economic Competitiveness: Diverse Device Development

Twenty-four (24) of the 136 IGERTs directly address the synthesis of interdisciplinary training ranging from chemistry, to biology, materials science, and engineering for developing devices ranging from novel drug delivery to the development of femto-second lasers and mini-spectrometers in the tera-hertz time domain. This area of inherently interdisciplinary research helps to aid our economic competitiveness and to investigate the human and social dimensions of science and technology as it allows us to gain information never before available.

The publications and conference presentations associated with this theme are in Table 1. Examples of the research achievements include:

☐ Novel ways to prepare polymeric vesicles for controlled drug delivery and gene therapy are under development via collaborations of biologists and polymer scientists. It has been found that it is possible to prepare vesicular structures by using alternating copolymers of maleimide and vinyl ether monomers. Upon hydration, vesicles form spontaneously. These are on the average <50 nm in diameter and will soon be used to transfect mammalian cell lines with plasmid DNA. Cells will be transfected with pDNA coding for green fluorescent protein and transfection efficacy will be analyzed via fluorescent microscopy. (0333377: Fried, University of Cincinnati)

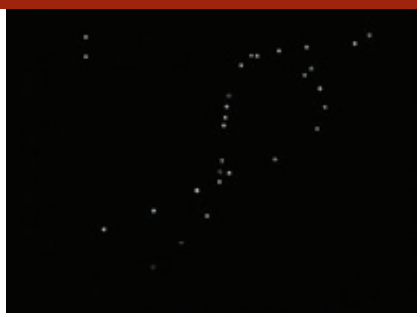
☐ A lab-on-a-chip platform was developed in which liquids are manipulated as droplets on a two-dimensional array, rather than as streams in channels. Students from mechanical engineering and chemistry interacted and identified research problems that subsequently benefited from their combined expertise. These include understanding and facilitating droplet mixing, developing strategies for separating charged particles within a single droplet, and reducing friction by controlling device surface roughness (superhydrophobicity). Success was also achieved in implementing chemical processing functions, such as crystallizations, liquid-liquid extractions, solid-phase extractions, and enzymatic digestions in the devices. (0114443: Garrell, University of California Los Angeles)

☐ An IGERT trainee co-advised by a faculty team with backgrounds in physics and chemistry successfully demonstrated fabrication of waveguides in 3D using femtosecond lasers. These waveguides can be used for interconnection between optical devices. Another IGERT student successfully demonstrated fabrication of quantum dots by etching of quantum well structures for optical switching applications. Progress in optical communications and networking requires breakthroughs at the fundamental device level. Future optical networks will feature more processing in the optical domain. The ability to realize functional devices and interconnect between the devices is critical. (0114418: Li, University of Central Florida)

☐ A group of interdisciplinary scientists and engineers led by an IGERT trainee developed miniature terahertz time domain spectrometer systems for sensing and imaging. These devices require both extensive knowledge and working experience across multiple disciplines. This team developed the "Mini-Z" THz spectrometer which is dramatically smaller and lighter than any previous terahertz time-domain spectroscopic device, and it already has proven its ability to detect cracks in space shuttle foam, measure chemical, biological agents, and explosives and their related compounds. The device, which weighs less than five pounds and fits snugly in a briefcase, could open the door to a wide range of applications in homeland security, biomedical imaging, and nondestructive testing of industrial components. (0333314: Wang, Rensselaer Polytechnic Institute)

☐ Peptide arrays are under development to use as chemical libraries to search for catalysts and for components of artificial antibodies in an approach very similar to the chemistry performed in the DNA chip industry. This approach allows for rational peptide design and synthesis, hundreds of thousands of peptides at a time. An IGERT trainee recently created an array with all possible 6-mers using a set of five amino acids and is exploring the binding of these 6-mers to specific proteins. This array promises to provide a fundamental understanding of molecular recognition properties of short peptides. (0114434: Woodbury, Arizona State University)

Sensing, Signals, Imaging and Signal Processing



Fourteen (14) of the 136 IGERTs reporting in 2006-2007 are involved with the sensing and processing of signals and images. With the need for greater detailed understanding of ever smaller images with greater amounts of information, IGERTs involved with signal processing are transforming our ability to hear and touch and move more effectively to the ability to sense pathogens and hazards. The NSF strategic investment priorities of promoting transformational, interdisciplinary science; fostering our ability to live sustainably on earth; investigating the human and social dimensions of science and technology; and helping the U.S. be more competitive are all addressed in this thematic area of discovery.

The publications and conference presentations associated with this theme are in Table 1.
Examples of the research achievements include:

☐ Optical Science and Engineering Program (OSEP)/IGERT trainees along with their advisors have developed the world's first optoelectronic analog statistical signal processor. The system solves what is popularly referred to as the "cocktail party problem," which refers to the human ability to pay attention to one voice among many despite the presence of noise and other interfering signals. The solution to the problem calls for the descrambling of mixed signals with little or no prior knowledge about the signals or how they are mixed. The human brain seems to do this effortlessly but, when done by machine, it involves a computationally intensive statistical analysis of the incoming signals. Using a creative synthesis of holography, electronics, and nonlinear dynamics, the researchers have developed a system whose dynamics are mediated by input signal statistics in such a way that the system automatically unscrambles incoming mixed audio or radio-frequency signals. (0333453: Anderson, University of Colorado Boulder)

☐ An IGERT trainee has made an important advance in the goal of providing a microarray-based sensor for rapid identification of pathogens by demonstrating, in collaboration with scientists at the National Institutes of Health as well as IGERT faculty in chemistry and chemical engineering, that his research on the modification of surfaces with light can be used to identify immunogenic sugar moieties of *Bacillus anthracis* exosporium by designing and fabricating carbohydrate microarrays. Working with this interdisciplinary team, the trainee created the first method for covalently bonding carbohydrates to surfaces that does not require modification of the carbohydrates. (0221589: Denn, City University of New York City College)

☐ Collaborators in mathematics and mechanical and aerospace engineering have been investigating sensory motor integration in dexterity. The dexterity of individuals is tested as they compress a weak spring that is prone to buckling. Theoretical insights from dynamical systems theory are used to predict aspects of the observed behavior at the threshold for buckling. The experiment is repeated with vision blocked, with tactile sensation blocked and with both vision and tactile sensation blocked. The observed performance gives insight into the way in which sensory information of different modalities is combined in manipulation. This work won the 2006 *Journal of Biomechanics* Award of the American Society for Biomechanics. (0333366: Guckenheimer, Cornell University)

☐ Collaboration among four disciplines is leading to the development of an implantable technology to restore balance. This combines expertise in head and neck surgery, MEMS, and signal processing. This project and collaboration was a direct result of the LifeChips/IGERT sponsored workshop for Head and Neck to bring new collaborations to LifeChips. This collaboration fulfills one of the goals of this IGERT—to initiate new interdisciplinary collaborations in LifeChips research that also provide student training opportunities. (0549479: Li, University of California Irvine)