

STRATEGIC PLANNING PROCESS

The **Engineering Science and Mechanics (ESM) 2008-2013 Strategic Plan**, approved in April 2008, built on initiatives in the documents (1) **ESM 2005-2008 Strategic Plan** and (2) **Accomplishments from the 2005 to 2008 Strategic Plan**. Progress in meeting strategic planning goals is reviewed annually by ESM faculty at retreats and in faculty meetings, the ESM Graduate and Undergraduate Student Councils, ESM staff, the ESM Industrial and Professional Advisory Council (IPAC), and by the ESM Alumni Advisory Board (AAB). Future initiatives are aligned with the College of Engineering and the University Strategic Plans, and with state, national and international priorities in Engineering and Science. The 2008-2013 Strategic Planning Committee is led by Professor Bernhard Tittmann. This document presents an updated version of the ESM 2008-2013 Strategic Plan that was approved by the faculty in Fall 2011. The Plan is an evolving document that will be reviewed and updated annually in accordance with ESM's evaluation and assessment plans for the Accreditation Board for Engineering and Technology (ABET).

The ESM Department extends sincere thanks to the Strategic Planning Committee, the IPAC and the AAB for their leadership in developing this strategic plan:

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EXECUTIVE SUMMARY

The Engineering Science and Mechanics Department has seen remarkable advancement since 2005, with the Engineering Science undergraduate program rising to fifth/sixth place rankings nationally by US News and World Reports in years 2007-2011. Benchmarking shows that the department's research productivity continues to place ESM among the top Engineering Science and Mechanics/Engineering Physics programs. ESM has invested in the highest caliber faculty, students and staff, engaged with its alumni, corporate and philanthropic partners, and partnered with US and international institutions to develop major research and educational initiatives. Our faculty is now leading/co-leading nine highly interdisciplinary centers including the:

- The NSF National Center for Nanotechnology Applications and Career Knowledge (NACK);
- The Center for Innovative Sintered Products (CISP);
- A University-wide Center for Neural Engineering (CNE);
- The Ben Franklin Center of Excellence in Structural Health Monitoring (CSHM);
- The Composites Manufacturing Technology Center;
- The Center for Multiscale Wave-Materials Interactions (CMWMI);
- The Engineering Nano Characterization Center;
- The Microwave Processing and Engineering Center; and
- The Center for Dielectric Studies.

In the next five years, the ESM Department will take a leadership position in “*Engineering Science for Society*.” We will create innovative “*Engineered Solutions*” in nanotechnology, health care, energy utilization, advanced materials, and mechanics that are supported by pioneering educational initiatives, our Honors undergraduate program, and outstanding graduate students, faculty and staff. We will continue towards our goal of becoming nationally and internationally recognized for our interdisciplinary programs in Engineering Science and Mechanics.

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VISION

The Department of Engineering Science and Mechanics (ESM) will be an internationally distinguished department that is recognized for its globally competitive excellence in engineering and scientific accomplishments, research and educational leadership. ESM will create and transform the latest developments in the physical, biological and engineering sciences into enabling discoveries, innovations and new technologies.

MISSION

To develop future state, national and international leaders of scientific and engineering endeavors, industry, the professions (including law, medicine and business), politics, governments, and public service, who apply a solid foundation in engineering and scientific principles to impact the well-being of the global society, its environment, and future frontiers yet to be discovered;

To provide a setting where education, research, outreach and innovations in the engineering, life and physical sciences are integrated; and

To train future leaders who will provide comprehensive technological solutions for tomorrow.

GOALS

- Enhance ESM's position as the Honors Program for the College of Engineering;
- Improve the ESM undergraduate and graduate programs through continual assessment.
- Create new paradigms for delivery and dissemination of engineering science education;
- Advance the frontiers of engineering and science;
- Be multidisciplinary *and* interdisciplinary
- Develop the theoretical underpinnings of scientific phenomena and their engineering applications;
- Create new and enabling tools of scientific engineering discoveries;
- Lead in anticipating and pioneering the technologies of the future; and
- Transfer leading-edge technologies to industry;

CORE VALUE

The ESM department will provide a welcoming and respectful climate for a diverse community of students, faculty and staff, recognizing accomplishment and fostering creativity, innovation, intellectual growth, professional development and internationally distinguished leadership.

THE ENVIRONMENT FOR ENGINEERING SCIENCE AND MECHANICS

The dawn of the 21st century is providing unprecedented opportunities for interdisciplinary Engineering Science and Mechanics programs to address societies' problems on a global scale. In only three years since the ESM 2005-2008 strategic plan, a suite of new issues with far reaching implications for our research and educational initiatives has emerged. Thomas Friedman¹, in his book *"The World is Flat: A Brief History of the Twenty-First Century"* highlights the "flattening" of the international economic playing field, enhanced global competition, and questions the readiness of the US to meet these challenges. Reports from The National Academies^{2,3,4,5,6,7,8,9} reinforce the impact of globalization on our technologies, outsourcing, spread of disease, security, communications, and research, education and workforce infrastructures. New dialogues have opened regarding the multiple energy sources we will develop and utilize over the next decades. ASEE has taken important steps to address innovation in engineering education¹⁰ and MIT has proposed a new model of "convergence" to address the challenges facing health care¹¹.

In order to address these challenges on a global scale and compete in the international arena, we must prepare a new generation of science and technology leaders, who are not only well grounded in disciplinary fundamentals, but also have with interdisciplinary perspectives and the leadership and innovation skills required for success in our rapidly changing world. As advancement opportunities for engineers accelerate across the globe, we must educate a workforce of the future that welcomes all people irrespective of gender, ethnicity, religion or culture. Our students must be aware of the world, solidly grounded, technically broad, effective in group operations, versatile, and customer oriented – indeed they must be World Class Engineers.

The strategic initiatives adopted in the ESM 2005-2008 Strategic Plan provide a strong foundation for agile responses to these global challenges and for future growth of our faculty, student bodies and research. Building on the strengths in our new centers, we plan new thrusts related to energy, nanotechnology, neural engineering, structural health monitoring, materials and mechanics. Within Penn State we will partner with all facets of the University, and particularly the College of Medicine. Nationally and internationally, we will continue to develop memoranda of understanding with partner institutions to promote research collaborations and

¹ T. L. Friedman, *The World is Flat: A Brief History of the Twenty-First Century*, New York: Farrar, Straus and Giroux, 2005.

² *Rising Above the Gathering Storm, 2006: Energizing and Employing America for a Brighter Economic Future* (2006)

³ *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* (2005)

⁴ *The Engineer of 2020: Visions of Engineering in the New Century* (2004)

⁵ *The Impact of Globalization on Infectious Disease Emergence and Control* (2006)

⁶ *Frontiers of Engineering: Reports on Leading Edge Engineering from the 2005 Symposium* (2006)

⁷ *Energy Research and America's Future: Meeting the Challenges of the Global Economy* (2005)

⁸ *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering* (2007)

⁹ *Emerging Technologies and Ethical Issues in Engineering* (2004)

¹⁰ *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education*, ASEE, 2009

¹¹ *The Third Revolution: The Convergence of the Life Sciences, Physical Sciences and Engineering*.

exchanges of students and faculty. In addition to our activities in Europe, Asia, Australia and the Americas, we plan new programs in Africa and the Middle East.

In the last five years, the ESM undergraduate program has grown well beyond our target of 40 juniors and 40 seniors. Indeed, in Fall 2011, there were 131 junior and senior students and a total of 185 students in all four years, more than doubling our numbers since 2002. While we will continue the growth of our undergraduate honors program, we will also focus on expanding our graduate program, particularly as we develop opportunities for distance education. We will invite our Alumni Advisory Board to lead our ESM alumni in promoting the advancement of the department. We will engage in the highest level of scholarship in research, education, outreach and service to meet the high demand for ESM students by academia, government and industry.

ESM DEPARTMENT PROFILE

The ESM Department comprises 30 tenure and tenure-track faculty (20 Full Professors, 7 Associate Professors and 3 Assistant Professors totaling 25.4 full time equivalent [FTE] positions), 2 fixed-term graduate faculty, 8 affiliated graduate faculty (with units such as ARL, Electro-Optics Center, Materials Research Laboratory, etc.), 14 emeritus faculty, 15 staff (9 administrative, 1 alumni and development, 5 technical and 2 part time faculty support staff), 185 undergraduates (including first- and second-year students) and 130 graduate students. The Full Professors hold one Department Head Chair (Breneman), five named Chairs/Professorships (Brush, Kunkle, Morrow, Schell, Binder) and two Distinguished Professorships. As Assistant Professors, Drs. Demirel and Huang held a Pearce Development Professorship and a James Henderson Professorship, respectively. Sixteen faculty members are recognized as 31 Fellows in 19 professional societies and Prof. Awadelkarim is a Jefferson Fellow with the U. S. Department of State.

ESM faculty members currently lead the following research centers:

Professor Fonash is the Director of the NSF National Center for Nanotechnology Applications and Career Knowledge (NACK). He also leads the Advanced Technology Education program and the flagship Nanomanufacturing Technology program for the Commonwealth of Pennsylvania;



Nanotechnology Camps for High School Students and Teachers

Professor Schiff is the Director of the Center for Neural Engineering (CNE), which conducts interdisciplinary research with faculty from the Colleges of Engineering, Medicine, Science, Health and Human Development, Earth and Mineral Sciences, as well as the Penn State Institute for the Neurosciences, Materials Research Institute, Huck Institutes for the Life Sciences and Institute for Computational Sciences;

Professor Bakis is the Director of the Composites Manufacturing Technology Center, formed in 1988 to solve fundamental problems in composite materials and structures manufacturing technology;

Professor Lissenden is the Director of the Ben Franklin Center of Excellence in Structural Health Monitoring (SHM), a collaboration with the Departments of Aerospace, Civil and Environmental, and Mechanical and Nuclear Engineering, the Acoustics program, and the Pennsylvania Transportation Institute, and is conducting research, educational outreach and workforce development;

Professor Heaney is Director of the Center for Innovative Sintered Products (CISP), a unique partnership between universities, industry, government agencies and professional and trade associations. CISP develops cutting-edge technology for the processing of sintered materials;

Professor Todd is Director of the Center for Multiscale Wave-Materials Interaction (CMWMI), founded in 2004 with support from the Applied Research Laboratory, College of Engineering, Electro-Optics Center and Materials Research Institute, to explore the interactions of multiple energy sources with materials;

Professor Tittmann is Director of the Engineering Nano Characterization Center to teach and engage in research for materials characterization, wave mechanics, and nondestructive evaluation with an emphasis on nanotechnology

Professor Lanagan is Associate Director of the Center for Dielectric Studies, which plays a leadership role in the development of next generation electronic components and in the creation of scientific training opportunities to advance the understanding of dielectric materials and devices;

Professor Agrawal is Director of the Microwave Processing and Engineering Center

ESM research expenditures reported to ASEE have ranged from \$10,000,000 to \$12,000,000 over the last four years. ESM faculty and students published 212 refereed journal and conference papers in 2009, 127 co-authored with graduate students and several with undergraduates. This is a typical journal publication rate. The faculty has filed numerous invention disclosures and has been awarded more than 36 patents since 2002.

Approximately seventy students are currently enrolled in the Mechanics Minor and 588 students have graduated with the undergraduate Mechanics Minor since 2002. The Nanotechnology Minor, introduced in 2006, is growing and has graduated 35 students since Spring 2007. Initially attractive to Engineering Science majors, since Spring 2010, students from chemical, electrical, mechanical, nuclear and bioengineering and materials science and engineering have also graduated with this minor.

With the introduction of the course E SC 544 - Laser Laboratory in 2010, all courses in the new Post-Baccalaureate Certificate in Laser Materials Processing have been offered and the first students have completed the program.

Enrollments in the service courses on statics; dynamics; strength of materials; mechanical response of engineering materials, and engineering applications of materials are continuing to increase exponentially. The mechanics service courses were taught to approximately 3,500 students in the 2010-2011 academic year compared to 3056 students in 2007-2008.

The ESM graduate program is supporting up to ~130 students per year compared to 114 students in 2008. This is a great tribute to our faculty and their new research initiatives.

BENCHMARKING DATA

Prior to 2006 Engineering Science/Engineering Physics undergraduate programs were not ranked. Graduate programs are still not ranked. In 2010, ASEE reported 41 universities offering B.S. degrees, 20 offering M.S. degrees, and 18 offering Ph.D. degrees in Engineering Science/Engineering Physics. In 2007, Penn State Engineering Science (undergraduate) was ranked in ninth place and rose to fifth place in 2008 and 2009, as shown in Table I.

TABLE I: 2007 TO 2011 RANKINGS OF ENGINEERING SCIENCE/ENGINEERING PHYSICS PROGRAMS BY U. S. NEWS AND WORLD REPORT

Ranking	2007	2008	2009	2010	2011
1	Cornell	Cornell	CalTech	CalTech	CalTech
2	UIUC	U.C. Berkeley	Cornell	UIUC	Cornell UIUC
3	Stanford	UIUC	U.C. Berkeley	Cornell	
4	Harvard Princeton	CalTech	UIUC	U. C. Berkeley	
5		PSU Princeton Michigan	MIT PSU	Virginia Tech	
6	U.C. Berkeley Michigan CalTech			PSU	
7					
8		Harvard Virginia Tech			
9	PSU Yale				

Penn State Engineering Science remained in fifth or sixth place each year until 2011, when U. S. News and World Report chose to rank only three programs, placing CalTech in first place and Cornell University and the University of Illinois-Urbana Champaign tied for second place.

STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS (SWOT)

Table II presents the ESM Department's updated SWOT table that reflects new opportunities for growth and additional pressures experienced in these uncertain economic times.

SWOT TABLE 2008-13

Strengths	Weaknesses
<ul style="list-style-type: none"> • World-class distinguished, collegial faculty • Leaders in research, outreach, education and innovation • Well-equipped facilities for teaching and research • Highly interdisciplinary faculty • Excellent perception of faculty dedication to teaching by PSU students • Honors undergraduate program • Small class sizes for instruction • Individualized academic and research advising • The E SC undergraduate program provides excellent preparation for graduate school, life-long learning and a wide range of employers' needs • Undergraduate and graduate enrollments are increasing 	<ul style="list-style-type: none"> • Identity and visibility of ESM programs • Need improved web communications and professional networking (e.g. LinkedIn) • Limited resources to support faculty and students in emerging science and technology areas • Teaching laboratories need updating and new instrumentation • Reward structure for preparing and updating new essential classes • Resources needed for proposal writing, major proposal/center development • Class sizes in mechanics service courses and honors courses are increasing excessively due to insufficient teaching budget.
Opportunities	Threats
<ul style="list-style-type: none"> • Major funding for multi-institution grants • New research initiatives for growth: bio-nanotechnology, medicine, health monitoring, energy, mechanics, etc. • Integration of research, education and outreach in engineering, life and physical sciences and biomedicine • New curricular initiatives for growth: grad minors in neural engineering, mechanics, nanotechnology, Joint E SC/MBA, M.D./-Ph.D. degrees, professional World Campus M. Eng. degree in ESMCH. • Host conferences in strategic areas • Development Campaign – <i>For the Future of ESM</i> • Continual assessment and improvement of ESM programs • New faculty hires • Revenue generation (short/summer courses, distance learning, conferences, workshops) 	<ul style="list-style-type: none"> • Permanent cuts have reduced the department budget to minimal discretionary funds • Budget model is zero growth • Federal and State regulations have placed increased budget obligations on Department, College and University budgets • Federal proposal matching fund requirements exceed our resources • Reduced ability to provide competitive start-up packages for new faculty • Long visa application process for international visiting scholars and students • Competition to recruit highest quality graduate and undergraduate students • Obsolescence of capital equipment • Skyrocketing enrollments in mechanics service courses and in honors courses require permanent investment to maintain the quality of ESM courses and education • Untimely budget decisions threaten the high quality of ESM education • Intellectual property issues suppress innovation and technology transfer • ITAR concerns are restricting proposals and publications related to perceived dual-purpose technologies

GUIDING PRINCIPLES

A key opportunity that has emerged in the last three years is the creation of novel interdisciplinary programs across the University and with colleagues at national and international institutions. These opportunities led to the addition of the new guiding principle, A) to previously stated principles B) through E).

- A) *Lead the integration of education, research and outreach in the engineering, life, and physical sciences and biomedicine to create interdisciplinary technology leaders and provide innovative and translational technological solutions for tomorrow;*
- B) *Advance our local, state, national and global communities by **Engineering Science for Society***
- C) *Attract and develop the highest quality faculty, students and staff in a supportive teaching, learning and working environment;*
- D) *Create the very finest educational, research and outreach programs; and*
- E) *Promote a culture of open communication, mutual trust and respect, professionalism, teamwork and superior service.*



The Society of Engineering Science students place second in Penn State's 2011 Rube Goldberg competition

2008-2013 CRITICAL ISSUES AND STRATEGIC GOALS

CRITICAL ISSUE 1: RESEARCH

Growth of ESM's research programs will require new multidisciplinary research initiatives.



STRATEGIC GOAL 1: Develop new research initiatives that position ESM and Penn State as leaders in the international community.

CRITICAL ISSUE 3: IDENTITY AND COMMUNICATIONS

The Engineering Science and Mechanics fields are less well-recognized than the traditional engineering disciplines.



STRATEGIC GOAL 3: Improve the recognition of the Engineering Science and Mechanics fields by academia, the professions, industry and government through enhanced communications.

CRITICAL ISSUE 5: DEVELOPMENT AND ALUMNI RELATIONS

ESM's alumni, corporate and foundation relations activities and philanthropic support bases need to be strengthened.



STRATEGIC GOAL 5: Enhance our alumni, corporate and foundation relations, development and marketing activities to increase support for key ESM initiatives.

CRITICAL ISSUE 2: EDUCATION AND OUTREACH

New educational and outreach initiatives must be developed to support our new research areas.



STRATEGIC GOAL 2: Enhance the Engineering Science curriculum by developing innovative, nationally recognized education programs that are disseminated to the widest possible audience.

CRITICAL ISSUE 4: RECRUITMENT, RETENTION, PLACEMENT

Economic and global factors create an uncertain climate for recruitment and retention of faculty and students.



STRATEGIC GOAL 4: Develop new strategies to recruit and retain faculty, students and staff and enhance placement of ESM students.

CRITICAL ISSUE 6: ADMINISTRATION AND ORGANIZATION

Streamlined organization and effective administration can be realized through continuous quality improvement.



STRATEGIC GOAL 6: Implement new administrative and organizational practices in accordance with ESM's strategic plan.

2008-2013 STRATEGIC GOALS AND ACTION PLANS

In the following sections, the 2008-13 Strategic Goals will be presented with updates as appropriate.

Strategic Goal 1:

Develop Research Initiatives that Position ESM and Penn State as Leaders in the International Community

During the next five years, the ESM Department's priorities are to:

- build our newly-formed and existing centers to international prominence;
- develop new *Engineered Health Solutions* in collaboration with the Huck Institutes for the Life Sciences, College of Medicine, Materials Research Institute, Social Science Research Institute, and Health and Human Development;
- focus current strengths in photovoltaics, biodiesel, fuel cells, materials and energy infrastructure towards new strategic energy initiatives (e.g. solar, fossil, nuclear);
- develop a strategic thrust in imaging science;
- underpin our research initiatives with strong foundations in mechanics, materials, nanotechnology, and new areas of design; and
- promote translational research programs that develop new technologies and products for the well being of society.

The Engineering Science and Mechanics Department is strategically positioned to contribute to the health and well being of our society. Two of our new Centers focus on health – the Center for Neural Engineering (CNE) focuses on people, and Center for Structural Health Monitoring (CSHM) focuses on our infrastructure. Ultimately, these foci have the potential to converge in a major center focusing on Health Monitoring – *for structures, systems and people*. Growth of both Centers presents a major opportunity to realize this goal.

The **Center for Neural Engineering (CNE)** moved to the new Millennium Science Complex in the Fall semester 2011, enabling significant expansion of the group. The ESM goal of recruiting a new faculty member to contribute to the growth of CNE and ESM's proposed thrust in imaging sciences was realized in July, 2010, when the department hired Dr. Patrick Drew as Assistant Professor of ESM with a courtesy appointment in Neurosurgery. Dr. Drew, an expert in two-photon, laser-scanning microscopy, has pioneered a cranial window technique which enables him to image cranial blood flow and neuronal development in awake mice. His research makes an important contribution to CNE's strategic thrust – **The Material Brain Project**, which recognizes that neurons and their networks are embedded within a complex multiscale material whose electro-mechanical properties determine how those networks function, how we think, and how we are affected by disease. CNE proposes to create the infrastructure to initiate the first realistic multiscale electro-mechanical model of the brain in order to develop a wide range of feasible medical therapies. New initiatives in modeling, control engineering of the nervous system, the mechanics of hydrocephalus, and electrode development will be undertaken towards treatment of epilepsy, Parkinson's, Alzheimer's, and other brain diseases. Towards these goals, Dr. Steven Schiff published a new book on *Neural Control Engineering*, MIT Press, in 2011.

A second faculty member, Dr. Mohammad Abidian, was recruited by the Bioengineering Department as a member of CNE, and physician scientists from the College of Medicine are contributing to the growth of CNE activities in collaboration with HUCK, COE, the Social Science Research Institute (SSRI) and the College of Health and Human Development (HHD). CNE is one of the Centers in the Penn State Institutes for the Neurosciences, led by Dr. Harbaugh, Head of the Department of Neurosurgery and an ESM faculty member.

CNE's second strategic thrust in **Health Engineering for Sustainable Medicine** has also made major progress in the investigation of a bacterial basis for hydrocephalus in Ugandan infants and the correlation of the disease with the rainfall cycles. Collaborations for pediatric epilepsy have already been established with Uganda and Zambia, and are being explored in Sub-Saharan Africa for meningitis in newborns. A second aim is to develop low cost imaging and image analysis tools, and care units for use in rural communities in Pennsylvania and in developing countries. This will include using low cost (a) computer tomography (CT) images to substitute for magnetic resonance imaging (MRI) for the diagnosis of epilepsy and hydrocephalus; and (b) XO laptops from the "One Laptop per Child" program for epilepsy monitoring and for cardiac, post anesthesia and trauma care units.

The Ben Franklin Center for Structural Health Monitoring (CSHM) is growing rapidly with new projects on "Sensors for Tomography", "Detection of Fiber-Metal Laminate Damage" (ALCOA), and "Relationships between Damage State Variables and Measurable Quantities" (Siemens). GE has donated a Phaser System, and is exploring a new program for Nondestructive Evaluation (NDE) workforce development with CSHM. Critical to the growth of the Center is expertise in sensing technologies, signal processing, prognostics, and wireless communications for the interrogation and remediation of smart structures. CSHM will play an important role in ESM's strategic thrusts related to **energy**. Many of the current generation of US nuclear, fossil and petrochemical plants, and pipelines, are well beyond their design lives, and next-generation infrastructures will require advanced materials and health monitoring technologies for even more extreme environments. The recent San Bruno gas pipeline accident makes the assessment of our aging infrastructure more critical than ever. ESM proposes to build on our strengths in health monitoring to develop solutions for energy infrastructure assessment and management using predictive and early warning technologies. Internal collaborators in this initiative will include the departments of aerospace, civil, electrical, and mechanical and nuclear engineering, the acoustics program and the Applied Research Laboratory. At the faculty retreat in August 2011, the ESM faculty re-emphasized that a new faculty hire for this **energy infrastructure initiative**, in collaboration with PSIEE, was a very high priority for the department.

Imaging Science is critical to both CNE and CSHM. ESM proposes to build on its strengths in wave mechanics, image analysis and interpretation, and to team with the Bioengineering Department, HUCK and COM to recruit two faculty members in this area (one BIOE, one ESM). We propose to align our hires with the development of a University-wide Imaging Sciences Center, which will bring major facilities together to establish Penn State as a leader in imaging sciences.

Nanotechnology research is ubiquitous among ESM faculty and in the **Center for Nanotechnology Education and Utilization**. Applications include biomolecular machines, sculptured thin films, photonics, phononics, molecular simulation, metamaterials, nanomechanics and the bio-nano interface. Our pioneering contributions to electronic materials, nano- and micro-electronic devices and solar cells, position us to make major contributions to the exponentially growing **photovoltaics** industry. Here, the focus will be on developing energy-saving materials and low power consumption devices (for example, high efficiency light emitting diodes [LED]) and systems, and advanced solar cells. At the faculty retreat in August 2011, a future faculty hire in the areas of photovoltaics and photonics emerged as a very high priority for ESM's strategic **energy-related research**.

The **Center for Multiscale Wave-Materials Interactions (CMWMI)** has initiated new programs of laser sustained plasma research, ceramic machining, biophotonics research, and multi-physics modeling, in addition to acquiring an impressive array of laser facilities. Located next to the ARL Laser Laboratory, one of the best facilities in the country, we now have the capability to go all the way from basic research programs to prototype development and even to transition new technologies to military applications via our ARL and Electro-Optics Center (EOC) partners. We are creating a unique facility in the nation, with a very strong and growing core of faculty. There is now a critical need to develop major funding to focus faculty interests and support new students. In 2011, an NSF Science and Technology Center pre-proposal *The Center for Harnessing Light* was submitted focusing on advanced Photonic technologies. While the proposal did not succeed to the second round, it successfully established multiple new collaborations with our partner institutions. To further advance this area, Professors Lakhtakia and Todd will Co-Chair an invited Symposium on Photonic Innovations and Solutions for Complex Environments and Systems at the SPIE meeting on August 12, 2012 in San Diego. In collaboration with ARL and EOC, it is proposed to recruit a senior faculty member with expertise in **photonics**, optics, lasers and materials processing to lead our future efforts.

Composites Manufacturing Technologies: Composite materials are becoming increasingly important in next-generation military and civilian aircraft, energy storage systems including batteries, fly-wheels and wind turbines, durable civil structures, and lightweight space structures. ARL and ESM are established leaders in the development of new composite materials, the modeling of composite material behavior, prototype and full component development, and inspections technologies. ESM continues to attract support for state-of-the-art facilities for composites research. Demand for even higher performance composites in extreme environments is high. Faculty retirements have left ESM below critical mass in this area. ESM proposes to collaborate with ARL and PSIEE in attracting a new faculty member to contribute to our strategic initiative in energy-efficient materials development.

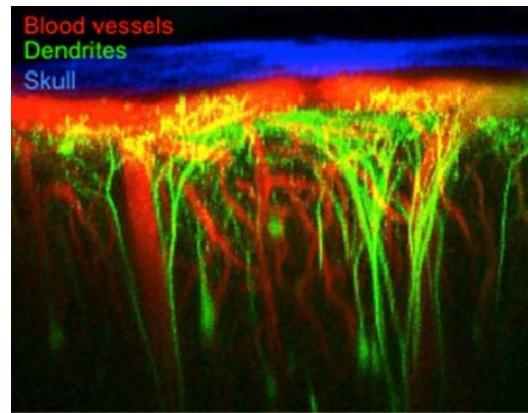
The **Center for Innovative Sintered Products** will continue to provide expertise in sintering and powdered material products to industry in the Commonwealth of Pennsylvania and across the nation. CISP will develop niche applications in refractory and hard materials and novel nanocomposites materials, and has acquired a spark plasma sintering unit to establish Penn State

as a leader in this field. New faculty associates in the Materials Research Institute and the Applied Research Laboratory will add to CISP's capabilities. A new faculty appointment will be considered if the industry base expands.

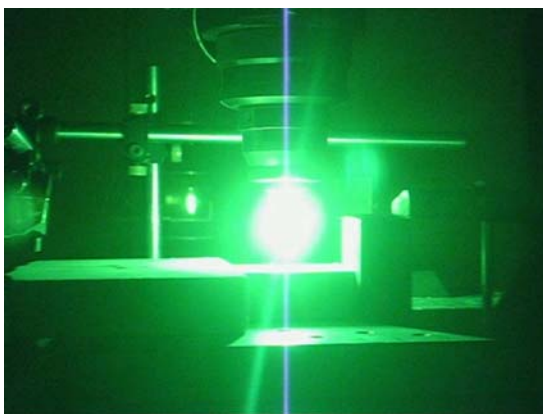
Design is an important component of the Engineering Science curriculum. Looking long term, ESM has interest in appointing a senior faculty member in this field, potentially in collaboration with the School of Engineering Design Technology and Professional Programs. Dr. Renata Engel, who fulfilled this role for many years, is now Associate Dean for Academic Programs in the College of Engineering, and a full time administrator. Many of the interdisciplinary problems being addressed by ESM faculty are **Complex Systems** engineering issues – ranging from the safe design of our energy infrastructure, neural prosthetic devices, health monitoring systems, photovoltaic and photonic systems. A faculty member in the area of Complex Systems engineering could strengthen several of ESM's strategic research areas.



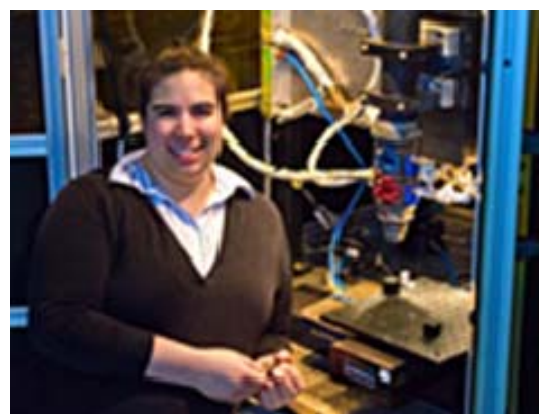
Pipeline health monitoring



In-vivo two-photon imaging of an awake mouse
Blue = bone; green = GFP expressing neurons;
Red = vasculature



Laser sustained plasma research



NSF Graduate Fellow, Amber Black, in the
laser laboratory

Strategic Goal 2: Enhance the Engineering Science Curriculum by Developing Innovative, Nationally Recognized Education Programs that are Disseminated to the Widest Possible Audience

The ESM curricula will be updated annually in support of our ABET assessment procedures, research, recruitment and retention initiatives.

Honors Education

ESM will continue to provide the highest quality Honors Education for Engineering Science majors. Schreyer Honors Scholars who conduct their thesis research in a second branch of engineering will be eligible to graduate with Honors in both Engineering Science and the second discipline. The program will continue to emphasize interdisciplinary education and individually customized curricular and research and design projects. Our proposal to build towards a total of 80 students in the major (40 juniors, 40 seniors) and a total of at least 120 students in all four years, was surpassed in the Fall semester 2010, necessitating dual sections of honors courses just to support our own students. It should be noted that students from other departments also enroll in ESM's honors courses. While teaching resources are currently being addressed on a year-by-year basis, permanent support will be required if our growth trends continue.

Undergraduate Curriculum

Undergraduate program objectives, course offerings and course contents are made annually, in accordance with College of Engineering guidelines and the review and assessment of our program for ABET. The review includes assessments by the ESM Curriculum Assessment Team, ESM Portfolio Subcommittee, ESM Senior Research and Design Project Subcommittee, student reflections on the program, and exit interviews. Improvements in our programs will be based on survey and quantifiable outcomes from these assessments. The Department will continue to collaborate with the Leonhard Center to prepare World Class Engineers for the future. ESM is committed to integrating professional components that include ethics, diversity, teamwork, global awareness, safety, sustainability, communications and environmental impact issues throughout our curriculum.

In the Fall semester 2011, and in response to requests in the student exit interviews, ESM initiated an undergraduate course, E SC 497 – *Interdisciplinary Design Project*, to give students real-life design exposure to industry identified design challenges. Here, interdisciplinary teams of up to four students worked on five projects sponsored by industry to develop innovative design solutions. ESM's team for the Concentrated Photovoltaic Project (CPV) won a 2nd place award at the showcase in the "Best Project" category. The course will be offered in the Spring semester 2012 and each semester thereafter as student interest increases.

New educational initiatives at the undergraduate level will include courses on *Brain Machine Interfaces* and *Neural Engineering Control Theory* to be taught in the new *Brain Machine Interface teaching and research laboratory*, now housed in the Millennium Science Complex. The Center for Neural Engineering occupies 22,000 square feet, custom designed for up to 12 faculty, and includes the following facilities: electrical equipment construction and testing; laser

optical imaging suite; open space for neurophysiology experimental stations; behavioral maze testing; confocal microscopy; computerized microscopy: neurofluidics and stereology; histology; and a machine shop. It is envisaged that these new courses will provide the foundation for either an undergraduate or a graduate minor in neural engineering, administered by ESM.

In 2008, the **Center for Nanotechnology Education and Utilization** successfully competed for the NSF *National Center for Nanotechnology Applications and Career Knowledge* (NACK) to provide **national** coordination of micro- and nanofabrication workforce development. Core partners included Central New Mexico Community College, the Minnesota Nanotechnology Workforce Initiative, the NSF Nanoscale Informal Science Education Network, the Maricopa Advanced Technological Education Center, the National Coalition for Advanced Manufacturing, the National Center for Learning and Teaching in Nanoscale Science and Engineering, SciWords LLC, and the University of Puerto Rico, Humarao. This Center establishes ESM and Penn State as a World leader in nanofabrication education, faculty and curriculum development, workforce education, job placement, and establishing national skills standards certification. A new 18-credit certificate program has been developed with the first two courses to be offered via distance education in Spring 2012.

Drs. Gary Gray and Francesco Costanzo, in collaboration with Dr. Michael Plesha, University of Wisconsin, Madison, published new textbooks (McGraw-Hill) on “*Statics*”, “*Dynamics*”, and “*Statics and Dynamics*” in 2009-2010. These texts include problem-based learning, concept questions and are accompanied with a suite of web-based animations and visualizations. The materials were discussed with faculty who teach mechanics at 18 Penn State campuses during the ESM annual mechanics faculty retreat, and are being used at University Park.

Globalization of the curriculum through both non-travel and travel-based initiatives will be an important focus in this strategic planning period. ESM will work actively with COE and the University to determine how best to introduce new curricular initiatives and identify and implement new communication vehicles for delivery of such education. It should be noted that several ESM students annually participate in study abroad semesters and particularly in global internships and employment during the summer semester. In 2011, ESM hosted 40 visiting scholars from across the globe.

Graduate Curriculum

A complete review of the ESM graduate courses and curriculum will be undertaken. A Ph.D. track in Neural Engineering has been approved. Plans to introduce a new Joint M.D./Ph.D. in Engineering Science and Mechanics Degree Program have progressed to the point where the proposal is under review by the Graduate School. It is proposed that this ESM Joint M.D.-Ph.D. Program proposal should serve as a model for any other engineering or science department wishing to introduce such a Joint degree program.

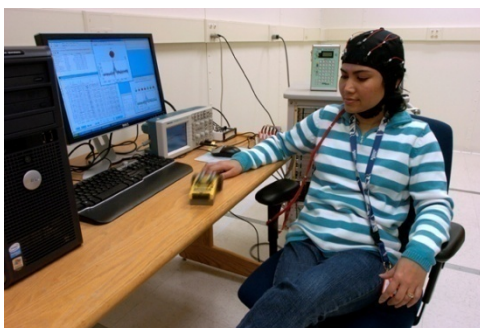
Plans to unify the M.S. degrees in Engineering Science and in Engineering Mechanics into a M.S. degree in Engineering Science and Mechanics have been approved by the Graduate School and are now under consideration by the Faculty Senate.

ESM is currently discussing the development of distance education graduate certificates to be offered via the World Campus as a first step towards the introduction of a professional M.S. degree in Engineering Science and Mechanics. A proposal to renew and rename the Post-Baccalaureate Certificate in Laser Materials Processing as a Graduate Certificate in Laser Materials Processing has been submitted through the course proposal system. ESM is currently considering the development of graduate certificates in nanotechnology, neural engineering, and mechanics. These programs would be administered by ESM.

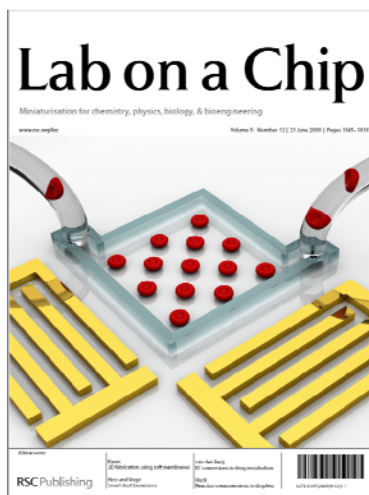
ESM will continue educational **outreach** programs to industry and the profession through short courses in *Corrosion* offered by Professor Shaw and in *Sintered Materials* offered by CISP, the nanotechnology education certificate and through new on-line course offerings. ESM is committed to enhancing our educational outreach to a diverse community of high school and college students through individual and multi-investigator research grants and new ESM initiatives.



Neural engineering education and research in Uganda



Brain-machine interface laboratory



Microfluidics Lab-on-a-chip

Strategic Goal 3: Improve the Recognition of the Engineering Science and Mechanics Fields by Academia, the Professions, Industry and Government through Enhanced Communication

The fifth place ranking of the Engineering Science program in the 2008 and 2009 editions of U. S. News and World Reports America's Best Colleges positioned ESM as a top choice for honors quality undergraduate students interested in flexible, rigorous, research-oriented and individually tailored undergraduate experiences. Student applications and enquiries have grown remarkably and have not yet plateaued. New promotional materials, including a student video and Penn State's first pod cast, were produced and web updates are ongoing. Participation of the faculty is critical to our future communications activities.

The Communications Committee of the ESM Alumni Advisory Board (AAB), formed in 2007, has been critical to the development of ESM's communications materials. A two-page "Profiler" was developed with their guidance and targeted towards industry recruiters. Additional profilers are planned for undergraduate and graduate students. A new newsletter, *ESM Connections*, was developed with an alumni focus and has resulted in significantly increased alumni engagement with the department, increased philanthropy, alumni recruiting ESM undergraduates and graduate students, alumni visiting campus to talk to students, and alumni engaged in mentoring students. A new ESM LinkedIn professional networking site with a mentoring sub-group was introduced in 2011 at the request of the undergraduates. Input from the Alumni Advisory Board and ESM's Industrial and Professional Advisory Council is sought annually as we develop these materials.

ESM's AAB ambassadors have very actively participated in career fairs and industry days to ensure that companies, and particularly their human resources departments, are aware of the unique nature of the Engineering Science major and qualifications of our undergraduate and graduate students.

Our Undergraduate Council and Society of Engineering Science students have engaged in high school visits, meetings with prospective students and their families and in developing events such as the Rube Goldberg competition that reach out to High School students. The Graduate Student Council has launched a graduate symposium, *ESM Today*, to promote University-wide communication of our research programs and develop a book of research abstracts for the web that will highlight our research programs to an international audience.

ESM is now refocusing efforts on improving the recognition and quality of the graduate program. Past recruitment has depended heavily on individual faculty contacts rather than a very high applicant pool. ESM is currently expanding our Memoranda of Agreement with targeted institutions nationally and internationally (India, China, Africa and the Middle East) as a vehicle for strategic recruitment.

Recognition of our students, faculty, staff and alumni is ongoing to showcase the high quality of the ESM Department.

Strategic Goal 4: Develop Strategies to Recruit and Retain Faculty, Students and Staff and Enhance Placement of ESM Students

Faculty: The research initiatives described in Strategic Goal I have identified two high priority hires in the areas of structural health monitoring and photovoltaics/photonics, with additional hires in the areas of imaging, optics/lasers, composites and complex systems design, as opportunities present themselves. Although these may seem ambitious goals, experience shows that ESM has lost 12 faculty members (and hired 11) since 2002, with potential additional losses in the next five years. While ESM will place major emphasis on retaining our exceptional faculty members, it is important that we continue to build and maintain critical mass in our existing and strategic new research areas. We will continue to build our faculty in collaboration with the College of Medicine, Huck Institutes for the Life Sciences, Penn State Institutes for Energy and the Environment, Materials Research Institute, Institute for Computational Sciences, and the Larson Transportation Institute.

Students: Alliances and memoranda of agreement with national and international institutions will be actively pursued to provide high quality students for our undergraduate and graduate programs. Alliances with specific high schools will increase the pipeline of high quality undergraduates in our program. In order to grow our graduate program ESM must grow its faculty and identify new sources of graduate support. ESM will aggressively pursue major block funding awards, industry fellowships, new research programs, and philanthropic support in order to attract new students. Indeed, new sources of support will be essential to increase our student stipends to a level that will make us competitive with institutions across the nation.

Retention: Retention of undergraduate and graduate students remains high. The more important area is retention of the staff. While ESM has been very successful in staff awards, staff promotions require an increase in duties of 30% in order to qualify for one grade level increase. Consequently, by the second promotion, position responsibilities reflect enormous overload, even when efficiencies have been introduced. It is more attractive for qualified staff to move to an even higher graded position in another unit than to stay.

Placement: Between 50-70% of ESM undergraduates continue to graduate school and 30-50% accept positions in industry and government laboratories. Our graduate students find positions in academia (~33%) and industry (~67%). Both undergraduates and graduates rapidly assume leadership positions.

Diversity and Globalization: During this strategic planning period, ESM will make every effort to diversify our faculty, staff and student bodies. In 2010, ESM was fortunate to hire Dr. Reginald Hamilton to our mechanics and advanced materials faculty. Dr. Hamilton is currently serving as Faculty advisor to Engineering House. ESM will continue its open faculty search process to facilitate opportunity hires. We will also work with our new global partners in India, China and Africa, to enhance faculty and student research collaborations and exchanges. We will strategically target urban schools and universities in our undergraduate and graduate programs to grow a diverse and welcoming community of students.

Strategic Goal 5: Enhance Our Alumni, Corporate and Foundation Relations and Development Activities to Increase Support for Key ESM Initiatives

In order to grow our faculty, undergraduate and graduate programs, ESM must significantly increase its philanthropic, corporate and endowment support base. The College of Engineering appointed Maureen Macaleer, Director of Major Gifts, to lead ESM's development activities. In 2007, ESM appointed Jason Lyons as Coordinator for Alumni, Development, and Advancement. The ESM Alumni Advisory Board has constituted a development committee to help us with our development activities. The initial Campaign for ESM, aligned with the University Campaign "*For the Future*", proposed a Campaign fundraising goal of \$3,000,000 excluding endowed Chairs. This goal will be re-evaluated in Spring 2012, with the announcement of a major gift that will bring our Campaign total beyond the \$3 million goal. ESM will work with Ms. Macaleer, the College and University to identify alumni, corporations, foundations and associations with interests matching those of the ESM Department and to develop strategies for presenting them with our initiatives.

ESM is committed to working with the College and University to provide diligent stewardship and being a prudent investment for the department's donors. ESM will continue a stewardship plan that includes an annual review of expenditures; development of an annual report for our donors; and enhanced communications among ESM's students, faculty and benefactors.

Strategic Goal 6: Implement Administrative and Organizational Practices to Support ESM's Strategic Plan

The administrative load and new College/University initiatives carried by the departments, staff and faculty continue to increase. Examples include new development activities within each unit, computer security, increased documentation of faculty compliance with policies and procedures (research, purchasing, intellectual property, conflict of interest, International Traffic and Arms Regulations, export of technology, etc.) human resource documentation, new travel accounting system, faculty self report system, etc. In their infancy, several of these systems are increasing the administrative burden. ESM will work with the College to identify opportunities for enhanced work flow, optimized web applications, increased efficiencies, and recognition that these activities contribute to enhanced job competency and staff performance.

ESM will expand the role of the IT database manager, particularly with respect to student recruitment, diversity and development activities and in liaising with the department's Undergraduate and Graduate Program Officers and their assistants. The ESM IT staff will continue to develop many database innovations and web-based efficiencies that keep the ESM Department at the forefront of computer operations in the College of Engineering. Plans for upgrading ESM infrastructure, facilities, laboratories, equipment and implementing new safety procedures will be vigorously pursued.

The ESM staff were invited to contribute to the Strategic Plan and provided the following recommendations.

Potential ESM Staff Contributions to the 2008-2013 Strategic Plan

Goal 1: Enhance Student Success

- Attend/Participate in student-focused training sessions developed by HRDC, COE Office for Undergraduate Students, or University Level.

Goal 2: Advance Academic Excellence and Research Prominence

- Increase focus on faculty and student **What's New** web articles that publicize the department's wide range of research activities

Goal 3: Realize Penn State's Potential as a Global University

- Increase focus on faculty and student What's New articles that publicize the department's wide range of global activities
- Mail hardcopies of department newsletter (*ESM Connections*) to those schools with whom we have international agreements; maintain a contacts list for each institution and e-mail the link for each newsletter to the contact

Goal 4: Maintain Access/Affordability and Enhance Diversity

- Develop a "My Story" on the department website that lets the international student tell what they are doing; how ESM is good for international students, etc.
- Hire a minority or an international student to work as an intern to help write *ESM Connections* articles (advertise in Marketing, Communications, Journalist, etc).

Goal 5: Serve the People of the Commonwealth and Beyond

- Develop student-centered brochures that can be used for recruiting students at commonwealth campuses
 - In-depth on the senior capstone design project, access to state-of-the-art student labs and access to interdisciplinary faculty

Goal 6: Use Technology to Expand Access and Opportunities

- Keep anti-virus software, spyware detection software, and adware detection software installed on department computers
- Explore full-disk drive encryption for faculty laptops
- Have department bookkeepers develop a listing of departmental vendors who are non-Payment Card Industry (pCI) compliant; encourage faculty who buy services from these vendors to seek others vendors
 - Require all faculty to become Payment Card Industry compliant (one or two still have not gotten a P-card).

Goal 7: Control Costs and Generate Additional Efficiencies

- Continue to pursue staff cross-training initiatives
- Continue to require staff to document desk job descriptions
- Electronic archival of former student records
 - Serves also as an opportunity to remove SS# from our records
- Move Wage Payroll process from paper driven to electronic driven
- Seek ways to cut costs (green initiatives)
 - Request OPP to install light motion sensors in building public places that are not subject to safety requirements (i.e. ESM Common Rooms, Conference Rooms, Mailroom, Student Lounge, laboratories, etc.).
 - Request OPP to install energy efficient lights in large laboratories
 - Reduce paper consumption through use of .pdf files for student advising
 - Explore use of "cloud" computers (instead of staff each having a PC move to centralized software applications and storage)
- Award prize to faculty who improve in advance planning of projects vs. inefficient procrastination practices.
- Develop Continuous Quality Improvement teams to address to develop additional efficiency solutions

Other:

- Award four Department Head Staff Awards to those individuals who excel at above:
 - Outstanding Staff Award for Creativity and Organization
 - Outstanding Staff Award for Planning and Organizational Effectiveness
 - Outstanding Staff Award for Management
 - Outstanding Staff Award for Diversity and Citizenship
- If appropriate, staff would help maintain local metrics as identified in the University's 2009-14 Strategic Plan

FIVE -YEAR STRATEGIC PLAN IMPACT

The initiatives described in the strategic plan are required to maintain ESM's recognition as one of the nation's top Engineering Science and Mechanics Departments. The plan will increase the tenure-track/tenured faculty from 30 to 32 in the near future and introduce new research areas that will lay the foundations for supporting our undergraduate and graduate student bodies. As the new faculty and ESM initiatives develop, a significant increase in research expenditures is expected. By 2013, a premier neural engineering program will be in place and we will be recognized for our pre-med and M.D.-Ph.D. programs. Engineering Science will be recognized as a world-leader for its interdisciplinary research and education. The ESM Development, Alumni and Corporate Relations Plan will be making significant strides in increasing ESM's endowed support for its growing body of faculty and students.

RESOURCES TO SUPPORT FIVE-YEAR STRATEGIC INITIATIVES

The ESM Department will continue collaboration with the Materials Research Institute, the Huck Life Sciences Institute, the Penn State Institutes for Energy and the Environment, the College of Medicine, the College of Engineering, the Applied Research Laboratory and the Electro-Optics Center to support partial salaries and start-up packages for new faculty positions. This support will enable the ESM department, College and University to provide well-equipped facilities to support multidisciplinary programs and faculty. New revenue streams must be generated to grow the graduate student body. Such revenues will be leveraged by: the faculty teaming internally at Penn State and with external institutions to develop large, long-range research programs with high visibility; revenue generating activities such as distance education programs; increased collaborations with industry; and enhanced philanthropic support.

Additional support for special initiatives, for example, the ESM Distinguished Professor Research Awards, ESM Faculty Travel Awards, ESM Today Research Awards, will be made available through the P. B. Breneman Department Head Chair endowment. ESM will work closely with the College of Engineering and the University to increase our endowment and attract philanthropic support for our strategic initiatives.

FIVE-YEAR RECYCLING PLAN

ESM's major investment over the next five years will be in hiring new faculty and establishing their new laboratories and research programs. Recycling funds made available to ESM from the College of Engineering will be invested in recruiting the highest caliber faculty and ensuring that they have the resources needed to be successful in their careers. In the unfortunate event of a 1 percent budget cut for each of the next five years, the ESM Financial Strategic Planning Team, comprising the Department Head, Administrative Assistant and Business Coordinator, would apply new ESM financial models to maximize economies in our operations. Budget cuts beyond these economies may result in a delay in hiring new faculty.



The E SC graduating class at the 2011 ESM Graduation Ceremony