

Physics Department Compact Plan

I. RESEARCH INITIATIVES

- A. Nano-bio
- B. Training High School Teachers
- C. Energy Initiatives
- D. High Performance Computing

II. ENROLLMENT GROWTH

Professional Science Masters Program

The physics department compact plan involves two separate thrusts: one focused on research initiatives, and one concerning enrollment growth. The research section identifies four thrust arenas listed in order of decreasing priority.

I. RESEARCH INITIATIVES

A. Nano-bio sciences

Nanoscience and bioscience are two rapidly advancing fields that are having major impacts on modern society. Nanoscience exploits the emergence of unique material properties and new physical phenomena that occur when dimensions are scaled down into the nanometer range. The rich variety of natural biological phenomena arises from the assembly of nano-sized building blocks at a scale where entropy, fluctuations and viscous damping are dominant.

In the future there will be increasing overlap and interaction between nanoscience and bioscience. Lessons from biological systems will inspire new engineering paradigms at the nanoscale, whereas application of new tools from nanoscience will accelerate our understanding and control of biological systems, eventually leading to new devices and medical therapies. This initiative focuses on enhancing the Physics Department's contribution to nano-bio science.

Nanoscience, biological physics and soft condensed matter have been a longstanding focus for the Physics Department. In particular, each of these areas was highlighted in the 2002 compact plan. In the interval since the last compact plan, 5 junior faculty members (Clarke, Daniels, Pearl, Riehn, and Weninger) have been added who enhance the Department's presence in these high priority areas. The boundary where nanoscience meets biological sciences is especially active. As part of this initiative the physics department will continue to strengthen its efforts in these directions individually and at the interface of these fields. Furthermore, efforts in nano-bio science directly support the energy initiative highlighted independently within this compact plan.

The Physics Department's focus on nano-bio science matches priorities of PAMS, NCSU and the state of North Carolina. **In particular, we strongly support the efforts of the nano-science working group headed by Professor Greg Parsons of the Chemical and Biomolecular Engineering Department to establish a nano-science Institute. The**

ambitious vision that this working group proposes will allow NC State faculty to flourish as the university develops more and more world-class programs in nano-science. The April 2006 report “A roadmap for nanotechnology in North Carolina’s 21st century economy” from the Governor’s Task Force on Nanotechnology and North Carolina’s economy recommends a strategy that emphasizes relationships between nanotechnology, bio-science, and other emerging fields. The Physics Department will coordinate our nano-bio efforts with University-wide efforts by sharing this initiative with the North Carolina State University Nanoscale Steering Committee.

Development of graduate degree-granting programs in nano-bio science will enhance the University’s position in this field. Nano-bio science is highly interdisciplinary, drawing expertise from physics, chemistry, computing, mathematics, engineering and all of the biological disciplines. Graduate degree granting programs will provide a curriculum that crosses department and college lines to educate students in a highly flexible environment.

Specific Plans:

- Recruit new faculty to support research in nanoscience, biological physics and soft condensed matter.
- Encourage collaborative efforts between nanoscience and bioscience groups.
- Explore the feasibility of graduate degree-granting programs in the nano-bio sciences and investigate external funding opportunities to support such programs.
- Develop advanced courses that will be required for graduate student training in nano-bio sciences

Outcomes:

- Establish a nationally respected interdisciplinary program in nano-bio sciences. This initiative will increase overall graduate enrollment in the University, as well as foster collaborations that cross department and college boundaries. It will support the efforts of the state of North Carolina for economic development in the areas of nanoscience and biotechnology.

Resources:

- Startup support of order \$750,000 and high quality laboratory space for each new physics department faculty member hired for nanoscale and biophysical research.
- Administrative support for the exploration of graduate programs in nano-bio sciences. If such programs are to be enacted, then substantial support for administration will be required.

B. Training High School Physics Teachers

In North Carolina and nationally there is a great need for teachers prepared to teach high school physics. North Carolina students enroll for high school physics courses at half of the national rate. One cause is that there are few teachers qualified to teach physics courses that motivate and engage students. Annually only a handful of new

teachers take the Physics Praxis II exam to certify their command of physics content and pedagogy. The Physics Department is concerned that the current state of high school physics will decrease the preparedness of NC State freshmen for science/engineering courses, and decrease the pool of students motivated to study in STEM disciplines. The Physics Department, because of its Physics Education Research group and its close collaboration with The Science House, is uniquely prepared to address the physics teacher shortage.

The American Physical Society leads a national consortium of universities working to increase physics teacher graduation rates. The successful Physics Teacher Education Coalition (www.PhysTec.org) programs share some common features. These features are mirrored in the specific plans outlined below.

Specific Plans:

- From the freshman year STEM majors are encouraged to explore high school teaching as a career choice and opportunity.
- STEM majors are provided opportunities to serve as teaching assistants in laboratories, courses and summer student programs.
- Future physics teachers take a special capstone course that helps the future teachers assimilate the physics they have learned in an inquiry-based environment.
- A physics faculty member is charged with recruiting possible future teachers from the physics majors classes and mentoring them through their college career.

We propose that these steps could be carried out at NC State for a modest cost that would have large returns for NC schools and for NC State. We will work with The Science House and join the PhysTec Coalition to develop a program that incorporates the elements described above. If this proposed project produced five new qualified physics teachers per year, the extra cost per teacher would be about \$28,000. This compares favorably with the costs incurred by NC school systems to recruit, train and retain less qualified teachers for high school physics courses.

Resources:

- Student opportunities to participate in mentored teaching internships (salaries) \$28 K/yr ongoing
[(10stud)x(10 hrs/stud wk)x(\$10/hr)x(14wks/sem)x(2sem/yr) = \$28k/yr]
- Physics Education Research Faculty position to develop and oversee capstone courses, interface with College of Education and school systems, to serve as Future Physics Teacher Advisor and to travel to PhysTec annual meeting \$100 K/yr ongoing.
- Funds for development and delivery of a junior/senior level two-semester capstone physics course for future physics teachers \$20k/yr for 2 yrs.
- Staff time for Science House staff to supervise students during summer programs. (\$10 K/year ongoing.)

C. Energy Initiatives

The creation of clean and safe renewable energy is one of the greatest challenges in science and engineering in the 21st century. We have come to expect and rely on clean, available energy every day, but there are currently few education and research programs at NC State focused on key problems and issues in the science and technology of energy generation, utilization, and impact. Energy is the world's largest industry, and the growing demands for electrical, chemical, and petrochemical energy supplies, and the impact of those demands on environmental quality are beginning to affect the economy of our Nation and State. Significant advances in materials and chemical technologies, including for example recent rapid progress in biotechnology and nanotechnology, can bring new knowledge and potential revolutionary new solutions to this long-standing problem. However, to date there are not broadly available funds to support a significant research effort that brings together researchers in these previously disconnected areas to focus specifically on problems in alternative energy technology. We clearly envision a strong overlap and interaction with the nano/bio initiative highlighted independently within this compact plan

The Department of Physics at North Carolina State University has broad expertise in many areas related to energy science and technology, and the merging of these currently disparate efforts into a unified research thrust could yield significant progress in emerging technologies, as well as produce even more powerful yet unforeseen revolutionary advances.

North Carolina State University has a vibrant collection of ongoing efforts in the development, utilization, and management of alternative energy sources and energy storage. This includes novel nanostructured materials and synthesis, characterization methods, and computational modeling with specific applications towards thermionic, photovoltaic, thermoelectric, thermophotovoltaic, and non-equilibrium thermodynamic effects. Mutual interests exist across multiple disciplinary and field boundaries. A recent workshop, entitled "Nanotechnology for Energy and Environment" (sponsored jointly by NC State University and ORNL with funds made available from the NCSU/UT-Battelle Core University Contract) reflected the mutual interests of research efforts at NCSU and began to establish connections with industrial, commercial, and energy policy initiatives. The workshop also identified key areas of expertise available at NC State University, including:

- Materials Synthesis and Processes: There is broad expertise in methodologies to form assemblies and compositions including nanomaterials processing, molecular synthesis, catalytic and photocatalytic processes with desired functionalities for new and emerging forms of renewable energy devices. There is expert proficiency in thermoelectric ceramics, compound semiconductors, organic and chemically tuned films as active media, as well as biological and biomimetic components for applications such as organic photovoltaics, catalysis for biomass conversion, thermoelectric energy conversion. A key area of expertise is in biological toxicity of advanced

functional nanoscale materials and structures, to more fully understand the broader aspects of advanced materials in the environment.

- *Characterization and Simulation*: Novel spectroscopic, optical, electronic and acoustic analysis techniques can be combined with first-principles calculations to provide selfconsistent models of functionalities. A broad and comprehensive effort is required with regards to characterization which will include use complementary experimental tools as well as correlated studies with computational models.

- *Invention and Development*: Significant expertise is available to invent and demonstrate new functional device structures and understand issues related to scale-up, commercialization, and transition to manufacturing.
- *Extension, Outreach and Workforce Training*: Extension and outreach to potential end-users of the technology will be a key factor built into the earliest stages of the research effort, led by the NCSU Solar Center in conjunction with programs in CALS, CNR, COE and Design and coordinated with the state Community College system where appropriate. Work will be coordinated with other energy activities at NCSU including for example the Applied Energy Research Laboratory in Mechanical Engineering. The Physics Department will coordinate our energy efforts with University-wide efforts by sharing this initiative with the North Carolina State University Nanoscale Steering Committee.

We envision a broad scope for a future NCSU leadership in the field of novel and renewable energy science, with particular emphasis building upon current expertise. Specifically in PAMS, we propose to focus on the area of ***Materials and devices for energy technology***. This thrust encompasses the broad field of materials-by-design for energy applications, including:

- *New materials and devices for solar energy conversion*, including molecular and bio-molecular photovoltaics, and inorganic/organic photo-electrochemistry, where molecular and inorganic superstructures are designed from first principles to enable collection and direct conversion of sunlight into clean electric power. The focus will be on low cost materials and processes to go well beyond current silicon-based photovoltaics technology.

- *Materials for thermal energy conversion*, where novel materials, including nanowires, metal-semiconductor composites, and crystalline diamond films, will be employed to efficiently convert heat directly into electrical power. With these materials, the thermoelectric effect, or the thermal emission of electrons or photons will be used to achieve conversion efficiencies greater than 20%, well beyond current state of the art, and will impact applications such as highly efficient electrical power plants, efficient remote power generation, and improved efficiency of systems which generate waste heat such as automobile and jet engines.

- *Advanced fuel cell materials and devices*, using novel nanotechnology-based patterning and deposition techniques to create new fuel cell membranes and integrated catalyst materials to enhance efficiency, and improve structure and design, to realize the full potential for clean fuel cell systems in transportation and other technologies.

We propose to expand the education programs at NC State to focused on key problems and issues in the science and technology of energy generation, utilization, and impact. The development of a strong program on “Clean and Renewable Energy and Environment” at NC State would be beneficial for the society at large, including *pure scientific advancement*, the *training and education of a skilled workforce*, *new industrial extension*, and fostering of *new entrepreneurial activities*. There will be large dividends in the training of new generations of scientists. The scope of our activities will likewise include broad outreach and education through partnerships with extant programs in place at NCSU, including the Science House, the Solar Center, and the Colleges of Design, Natural Resources and Agriculture and Life Sciences.

Specific Plans:

- Recruit new faculty members in energy sciences, both in experimental and theoretical areas that complement campus-wide initiatives.
- Establish joint research activities with faculty in other colleges and with wider initiatives at the national level (Oak Ridge National Lab., etc.)
- Develop an educational curriculum in energy sciences and nanotechnology.

Resources:

- Support of a successful energy initiative will require start-up packages and salary lines commensurate with recruited faculty. Amounts will depend on the nature of the discipline and the level of the hires.
- The development of an educational curriculum in energy sciences will require administrative support and release time for course development.

D. High-Performance Computing

High-performance computing (HPC) has emerged as one of key expanding areas in science and technology. A recent NSF Blue Ribbon Advisory Committee summarized: “[E]nvironments and organizations, enabled by cyberinfrastructure, are increasingly required to address national and global priorities, such as understanding global climate change, protecting our natural environment, applying genomics-proteomics to human health, maintaining national security, mastering the world of nanotechnology, and predicting and protecting against natural and human disasters, as well as to address some of our most fundamental intellectual questions such as the formation of the universe and the fundamental character of matter.” HPC is viewed as an essential, enabling technology for science, technology, defense and biomedicine, with national investment in excess of \$1B, an expected increase in high-end computational capability by a factor 10-100 in the next 5 years. Several of our peer institutions, including those in the Southeast, are

proceeding with faculty and infrastructure investments in excess of \$100M, spread over 7-10 years. Given the high level of national investment and the support for computational sciences and engineering in the region, NCSU may be able to substantially increase its standing in all science and engineering areas where advanced computing can have an impact.

NCSU is already participating in key national initiatives in HPC, as a strong partner of ORNL, which has become the largest site for open-science computing in world. ORNL is currently the flagship DOE computing site (leadership computing facility, LCF). It has a 54 teraflops Cray XT3 and a 18.5 teraflops Cray X1E, and it is scheduled to field a petaflops DOE-funded computer in 2008. NCSU has been a high-level participant in the LCF proposal, and is currently a high-level contributor to ORNL-led NSF proposal for a *sustained* petaflops supercomputer. Our high-level of involvement provides NCSU with a unique opportunity for significantly raising its stature in major HPC-supported areas for a relatively modest investment. In particular, the development and application of petascale computing is an area where NCSU's investments could be matched by ORNL, both in cash and in kind.

Specific plans:

- One joint NCSU/ORNL faculty or research faculty position in nanophysics, devoted to development of nanoscale applications on the emerging petascale supercomputers.
- 1-2 additional positions in petascale physics over the next 7 years.
- Several positions in applied mathematics, devoted to petascale algorithm development
- Several positions in petascale computer science.

Resources:

- The joint NCSU/ORNL position will require \$45K/y ongoing.
- Each additional faculty position will require \$90K/ongoing and \$50K startup funds.

II. Enrollment Growth

In recent years, a new type of degree is being offered by an increasing number of institutions nationwide. This degree, the Professional Science Master's (or PSM) is a graduate professional degree in science or mathematics for students interested in a wider variety of career options than provided by current graduate programs. Information on these programs can be found at <http://www.sciencemasters.com/>. Typically open to bachelor's degree holders in the sciences, mathematics, or engineering, the new self-contained PSM degree programs prepare students for work in fields such as consulting, research management and technology transfer. The New York-based Alfred P. Sloan Foundation has helped launch new PSM degrees in 45 institutions with strong graduate programs in the sciences and mathematics. All have been developed in concert with industry and are designed to dovetail into present and future professional career opportunities. Programs typically consist of two years of training in an emerging or

interdisciplinary area. Many include internships and "cross-training" in business and communications.

In the fall term of 2005, an ad hoc committee of the Physics Department investigated the advisability of developing a PSM degree in the physics department. The committee surveyed the situation nationally, regionally, and locally and found that...

- there is a market for a properly constructed PSM degree offered by the Physics Department;
- there is an infrastructure already in place in the College of Management and in PAMS that would support the academic aspects of the program;
- if such a program were to be initiated in North Carolina, NC State should be the institution that offers it; and
- a commitment to begin the program would require identification of a faculty champion who would have to spend at least two years of full time effort establishing the program. Ongoing administration of an established program would probably require at least a half-time commitment of a faculty member.

The faculty received and discussed the report. The general sentiment at the meeting was that although the PSM seems to be a good idea for us, until a champion can be identified the notion to establish a program should be tabled.

Now in late 2006, with the advent of the Kauffman task force, with the rewriting of the college Compact Plan, and with the identification of possible champions, the Physics Department is prepared to propose development of a PSM degree program. At this stage the particulars of the program are not in place, but the funding of a planning effort is in order and is presented here as part of our Compact Plan.

Specific plans:

- Designate a faculty member to direct planning for a PSM degree program.
- Outline an academic program and develop courses as needed.
- Identify industrial sponsors who might provide internship opportunities.
- Propose a complete program to the appropriate department, college, and university bodies.

Resources:

- While the level of funding will depend on matching from sources such as the Kauffman Program, initial support of a faculty member in the planning stages may be \$30k/yr. for two years.
- Administrative support for items such as such as publicity, travel, and office assistance may be on the order of \$15k/yr. for two years.