Physics Department Compact 2002
October 15, 2002

I. Overview of Department and Summary of 1999 Compact Initiatives

NC State's Physics Department aims to educate and train research physicists for industry, academia, and government; to produce broadly educated, versatile baccalaureate graduates for a diverse spread of careers; to produce internationally recognized research of value to the advancement of human knowledge and to the economic development of North Carolina; and to deliver to thousands of students in other disciplines the fundamental knowledge of the physical world and its mathematical representation.

By quantitative measures, the Physics Department has had substantial success in all these areas. The Department consistently ranks in the top three at NC State in competitive federal funding ($8.7M in FY01). We were number 24 nationally in the most recent NSF survey of research expenditures, sixth among NC State's seventeen peer institutions. The junior-senior enrollment of physics majors ranks fifth among the peer institutions and our 83 graduate students (01-02 enrolment) represent one of the largest programs in the Southeast (ninth among the peer institutions). Most importantly for students, graduates of the Department easily find excellent employment: BS recipients in the last two years received average offers of over $40K/yr, and Ph.D's were sought after in industry and elsewhere. Bachelor's recipients who choose graduate school do well; our graduates can be found in 10 of the top 20 physics Ph.D. programs in the US. And they are satisfied; 90% of graduates polled in the last two years would choose physics, and NC State, again. In service teaching, the Department ranks ninth nationally in the number of students taught (fifth among the peer institutions). This is performed efficiently (our faculty size was only 35th nationally and seventh among the peer institutions in the last NRC survey), and well: in spring 2002, 88% of students polled found the instruction to be satisfactory, and 82% would recommend their instructor to other students.

Our Departmental goals are to build on these strengths, with an important metric of our success being a move into the top 25% of physics departments nationwide. Consistent with our 2000 strategic plan, developed in response to the Department's 1999 external review by a National Academy group of scientists, we plan to hire faculty in exciting forefront research areas of physics, and to develop cross-disciplinary collaborations across campus where physics is a central component. We have diversified our program with a new BA degree. We will continue to build on our extremely successful Physics Education research initiatives to develop new introductory curricula, also expanding our inquiry-based learning and Web-based delivery of educational services.

The previous cycle of compact planning was very valuable for us. We achieved a number of goals and successes in the eleven items represented in our plan. Foremost among these was the allocation of outstanding new space in Riddick, Partners III and the Undergraduate Science Teaching Laboratory for consolidation of the department's teaching and research activities. Our top priority for the next three years is to develop educational and research programs of a caliber to match the quality of the space allocated to us by the University. Our most critical research needs are in experimental nanoscience, biological physics and soft condensed matter physics. Outstanding opportunities exist for linkages across campus in all these areas. We are actively seeking top quality candidates who can take advantage of the opportunities opening up for us in these facilities. Startup issues continue to be a concern. At the same time, we must also relocate the laboratories of our existing faculty into these facilities, with minimal disruption to their highly productive research programs.

The status of the eleven items in our 1999 compact plan is summarized below:

1. Building an inclusive campus community: achieved enhanced success rates for women and minority

students in SCALEUP calculus-based physics; with three recent hires we now have the second highest number of women among top-50 physics departments

2. Reform of Undergraduate Science Math and Engineering Education: SCALEUP classroom now fully utilized by physics, math and chemistry; new faculty members hired in physics education research.
3. High Performance Scientific Computing: Three new faculty hired; major research funding achieved from ITR program at NSF; Center planning ongoing.
4. Nanoscale Initiative: Successful campus-wide workshop, individual success with funding through the national nanoscale initiative. On the negative side, offers to nationally prominent scientists have been unsuccessful. However, we anticipate the opening of the top quality research space in Partners III and Riddick will make us fully competitive as long as we can also match startup requirements.
5. Polymer Center: Relocated lab space in Cox; individual success in funding; continue to develop strong linkages with chemistry and chemical engineering.
6. Partnerships with Oak Ridge National Laboratory: successful joint hire in computation sciences and numerous collaborations in computational materials and astrophysics; co-sponsored three workshops in the Triangle and at Oak Ridge in neutron physics; search now underway for a joint position in SNS-related neutron physics.
7. Space and fragmentation initiative: Allocation of space in Riddick, Partners III, and the USTL substantially solves what had been far-and-away the main impediment to us in functioning as a nationally competitive physics department.
8. New faculty start up resources: Space issues resolved with Riddick and Partners III. Costs of equipment needed for competitive programs in nanoscale, soft condensed matter and biological continue to escalate (now approaching $500K even for junior candidates). Startup concerns were an issue in our unsuccessful offers in nano/bio areas even though we think we made competitive offers in line with the expectations of the candidates.
9. Networking in the Bureau of Mines: not approved by DOI, project terminated.
10. Undergraduate enrollment: twenty majors a year for the last three years puts us in the top twenty of US physics departments; on track to meet our aspirational targets (this year enrolled 22 versus a target of 23).
11. Graduate enrollment: on track to meet aspirational targets (this year enrolled 25 versus a target of 18)

A. Initiatives Supporting University Goals

A1: Recruitment of under-represented groups in Physics

(University goal: Building a diverse and inclusive campus community)

The goals of the Physics Department's diversity effort are: to recruit, retain, and foster the careers of faculty from under-represented groups; to recruit, retain, and graduate a students from diverse backgrounds – in particular those from groups underrepresented in physics; to build a diverse university department that respects and responds to a variety of learning styles.

Specific Plans:

1. The department has charged its personnel committee to identify and recruit faculty from historically under-represented groups. In physics faculties, this suggests efforts to attract women and African-American faculty. Our department has been particularly successful in the former- we are now ranked 2nd nationally in number of women faculty members in the top fifty research universities- and we continue to try to recruit outstanding candidates. Effort has recently focused on attracting African-American faculty members and we are pursuing two strategies suggested by the President of the National Society of Black Physicists, Keith Jackson on a visit: postdoctoral positions for potential junior candidates, and sabbatical leave support for potential senior candidates. As a compact initiative item we request support for minority postdoctoral visitors and minority sabbatical leave visitors.
2. The department proposes to continue supporting Project Preserve – our multifaceted effort designed at recruiting, retaining, and graduating students from diverse backgrounds. The success of the program is manifest in the eight African-American and one native American graduate students currently enrolled. Ultimately the deliverables are graduate degrees for these students, so the project has instituted several programs to achieve this end.
   a. mentoring of at risk students through faculty recitation sessions associated with each of the three 500-level core courses.
   b. providing tuition and TA positions to at-risk students in the summer before their matriculation into the graduate program so that they may take Math 501, *Mathematics for Scientists and Engineers*; (This feature has been instrumental in providing such students with a solid start in their graduate studies.)
   c. increasing the department's profile through recruiting visits to Historically Black Colleges and Universities and at the annual meetings of the National Society of Black Physicists, and the Society for the Advancement of Chicanos and Native Americans in Science.

Outcomes and Assessment: The desired outcomes include increased diversity in the faculty and in the undergraduate and graduate student bodies. While we currently enjoy considerable success in some of these areas – faculty women, and minority graduate students – we seek to bring all other subsets to representation levels well above national averages for physics departments.

Resources: Minority postdoctoral candidate support ($40K + fb per year for 2 years), Minority candidate sabbatical leave support ($40K +fb for one year), Project Preserve tuition support, instructor support, recruitment budget ($50K per year)

A2. Kenan Center for High-Performance Simulations (CHiPS)

(University goal: fostering internal and external partnerships)

The Physics Department possesses major strengths in computational physics and the use of high-performance computing. According to recent Federal reports, high performance computing (HPC) is one of the key high-visibility IT areas that are expected to undergo a very rapid expansion in the next decade, fueled by breakthroughs in several key areas including computer architectures, nanotechnology, genomics, and climate modeling. We will establish the Center for High Performance Simulations in order to (i) consolidate and further develop the formidable expertise in this area already represented at NC State and elsewhere, (ii) nurture interdisciplinary synergistic interactions between the basic and the applied sciences, and (iii) develop and support advanced training and education at the undergraduate and graduate levels. Such a center will also facilitate competitive proposals for large Federal HPC grants. Cross-disciplinary educational tracks will be established for both undergraduates and graduate students, which will include the physical sciences, computer science, and mathematics. The Center will also be actively involved in recruitment of students. All NC State faculty with research activities in computational sciences, including the relevant areas of computer science and mathematics, will be encouraged to join the center, exchange ideas, and ultimately team up in pursuit of grants from large-scale government initiatives, such as the NSF's ITR, IGERT, and Nanoscale Programs, DoE SCIDAC and E Earth Simulator Response, NASA, DARPA and NIH.

The Center will be organized along multidisciplinary thrust areas, which will jointly develop a common core curriculum in HPC. The initial thrusts will be in: (i) materials/biomaterials, (ii) computational fluid mechanics, and (iii) computer science and applied mathematics. In each area we already have enough well-recognized faculty to form nationally competitive teams. However, the long-term interdisciplinary impact will be greatly enhanced by adding faculty who will apply HPC techniques in various Departments in the College and the University, and by the formation of other thrusts. The Center will actively participate in recruiting efforts and work jointly with the relevant Departments. The Center will be operated jointly by PAMS and COE. Additional support for the first five years will be provided by the Kenan Foundation. The PAMS part of the budget has been approved, while the COE contribution is still under discussion. Startup support for the Center will come from the Office of the Vice-Chancellor for Research, after a formal request is made by the Deans of COE and PAMS.

Specific Plans:
2003: Once the COE part of the budget has been approved, the Center will file for "Permission to Form", and aims to begin operations in the upcoming spring.
2004-2005**:** The Nanomaterials group in Physics will consolidate its space and computer equipment in Partners III. Appropriate undergraduate and graduate curricula will be developed and new, multidisciplinary team-taught courses in computational sciences will be given. Strong collaborative plans will be developed with ORNL's Center for Computational Sciences, potentially including additional faculty in joint positions.

*Outcomes and Assessment***:** Success in bringing together faculty from different departments to develop an educational plan. Recognition of the center by experts as a leader in high-performance computing anchored in the thrust areas in which we excel. Increased scientific accomplishments, research grants and publications. Enrollment of graduate students in the program. Success in developing collaborative plans with ORNL.

Resources: Start up funds for a visualization facility (see above), technical support person ($40K +fb/yr), relocation costs associated with the move to Partners III ($30K)

A3 Nanotechnology and Nanoscale Science Initiative (NNI)
(University goal: fostering internal and external partnerships)

Traditional Solid State materials research has increasingly involved structures and phenomena at the Nanoscale (less than one micron) and many NCSU research groups are already active in this area. The goal of this initiative is to foster emerging research and enhance existing capabilities in the area of nanotechnology and nanoscale science, an area identified as a National Budget Priority. The Nanotechnology and Nanoscale Science Initiative (NNI) will provide a focus for new research initiatives and a new group of courses/degrees at NCSU for educating students both in science and non-science areas to learn about such new phenomena and applications. It is anticipated that current efforts in the College of PAMS, the College of Engineering and possibly other units will be involved. Thus existing research groups in Physics, Electrical Engineering, Chemical Engineering, Materials Science, Chemistry and Math that work on Electronic Materials, MEMS/NEMS, Surfaces/Interfaces and related areas are expected to participate in the NNI. Jacqueline Krim (Physics) will serve as the organizational point of contact for PAMS. Gregory Parsons (Chemical Engineering) will serve as the organizational point of contact for the College of Engineering.

Specific Plans:

- Initiate a Nanotechnology Program at NCSU (J. Krim and G. Parsons, coordinators), analogous to the existing Biotechnology Program (www.ncsu.edu/biotechnology). The Program will foster and promote interdisciplinary research interaction between scientists and students across campus and within the community in areas related to nanotechnology and nanoscience. This will include workshops, conferences, and participation in multi-discipline research Centers.
- The Nanotechnology Program will provide courses, teaching laboratories, internet links, and other educational resources for undergraduate, graduate, and post-doctoral students. Existing courses on Nanotechnology and Science (already compiled in the report on the Nanoscale Strategic Planning workshop) will be coordinated within the Nanotechnology Program. A new minor in nanotechnology for graduate and/or undergraduate students will be considered.
- Within the Nanotechnology Program, a new course "Introduction to Nanotechnology", open to both undergraduate and graduate students will be initiated. The course will include a lab component and will have dedicated lab space and laboratory equipment.
- The Nanotechnology Program will act to catalyze and coordinate interdisciplinary interactions between faculty that will lead to successful proposals for Centers.
- The Nanotechnology Program will enhance hiring efforts in this key area. For example, biotechnology at the nanoscale is expected to be a strong component of the Nanotechnology Program, Biotechnology and Nanotechnology Programs would work together to identify opportunities for growth on campus in this area. Over the long term, we would anticipate the need for approximately 10 new hires in Nanotechnology campus-wide, spread over the next 7-10 years.
- For the future, the Nanotechnology Program will provide the infrastructure needed to expand the education and outreach mission, to include for example, courses for industrial scientists, technicians, and managers, as well as K-12 educators within the local community.

Outcomes and Assessment:

- A minor in nanotechnology will be instituted for both graduate and undergraduate students.
- New courses in nanotechnology will be established.
- New hires of outstanding faculty.
- Increased funding and visibility of NCSU in the area of nanoscale science and technology at the international and national level.

Resources: Startup and equipment up-fit funds for faculty occupying the nanoscience laboratories being designed for Partners III. Technician to support the experimental nanosciences groups in Parners III ($40K +fb/yr), relocation costs associated with the moves of the Krim and Nemanich laboratories to Partners III ($50K).

A4: Biophysics Initiative

(University goal: fostering internal and external partnerships)

One of the most promising and challenging research directions in modern science is the physics of biological systems. The role of (bio)physics is to establish a fundamental knowledge base (key quantities, laws and models) in terms of classical, statistical and quantum physics, field theory, etc. The key problems in research of biosystems have a strong overlap with a number of directions in modern physical thinking. This includes:

- *non-equilibrium phenomena* (virtually all biosystems operate at non-equilibrium with continuous exchange of energy and matter with the environment)
- *physics of complexity* (see, for example, the celebrated paper by the physics Nobel laureate P. W. Anderson: “More is different”)
- *quantum nature of many biological processes* (zero-point motion, competition of short- and long-range interactions, quantum dynamics, thresholds between classical and quantum behavior)
- *physics of nanosystems and mesoscopic systems*
- *soft condensed matter* (biosystems = water, colloids, gels, polymers and crystallites)
- *multi-scale/multi-physics* effects in many biological systems up to the cell and tissue level.

The importance of nurturing the underpinning sciences --and physics in particular-- for biology, biomedicine and other related “bios” was emphasized in 1999 by several prominent science officers at the time such as Harold Varmus (director of NIH), Rita Colwell (director of NSF), Neal Lane (President Clinton's science adviser) as well as the Federation of American Societies for Experimental Biology in *Molecular Medicine 2020*. [See also *Strengthening biomedicine's roots*, Nature 400, 309 (1999)]. The National Institute of Health (NIH) has several initiatives designed to bring physical sciences into biology, and an NSF program funds mathematical and physical scientists to collaborate with scientists at NIH. The Sloan Foundation with the DOE funds fellowships for physical scientists in computational molecular biology, and the Burroughs Wellcome fund gives five-year grants to institutions that provide graduate and postdoctoral training at the physics-biology interface. Our peer institutions are establishing major thrusts in this direction, for example, UC San Diego’s $10M for an NSF Center for Theoretical Biological Physics - http://www.npaci.edu/online/v6.20/UCSD_Biological_Physics.html.

NCSU has already a well-established presence in the bio disciplines and sciences, and a major biomedical engineering initiative is underway. Yet, a fundamental biophysics program is still lacking on campus despite recent efforts by the Biochemistry Department to develop a multi-disciplinary graduate program. With recent hires, the Physics Department is exceptionally well-positioned to nucleate a strong biophysics program. Several PY faculty (Sagui, Hallen, Sayers, Mitas, Bernholc, Roland) have current efforts in biophysics, including a substantial NSF grant for biosimulations. The faculty interests elucidate the breadth of the biophysics discipline, from molecular, through cellular, to imaging and tissue-level studies. Other researchers on campus have expressed desire to collaborate with physics: Nina Allen and Eric Davies in Botany, Troy Nagle in ECE (BME), Carol Hall in CHE, faculty in Biochemistry and faculty in the college of Veterinary Medicine.

Specific plans:

- Recruit new faculty members in biological physics, specifically in experimental areas that complement campus-wide initiatives
- Establish joint research activities with faculty in CALS, CVM and the new BME department.
- Recruit a faculty member to lead a program focused on biological applications of neutron scattering at NIST, HIFR and the SNS.
- Develop an educational curriculum in biophysics.

Outcomes: Establish a dynamic and nationally recognized biophysics program on campus, complementing the existing strengths in biological sciences and biotechnology, and leading to increased graduate enrollment college-wide. Increased funding in the biophysics area, particularly from NIH. Increased competitiveness with peer institutions for students.

Resources: Startup and equipment up-fit funds for faculty occupying the biophysics laboratories being designed for Riddick; technician to support experimental biophysics programs in Riddick ($40K +fb/yr); relocation costs associated with the move of the Hallen laboratory to Riddick ($30K).

A5: Polymer/Macromolecular/Soft-Condensed Matter Physics Center
(University goal: fostering internal and external partnerships)

Macromolecules are ubiquitous in Nature, and constitute a central element of soft-condensed matter physics. Macromolecules range from the industrially important polymer materials, to biologically active proteins which are essential to life itself. They have been steadily gaining in technological importance, in many cases replacing many of the more traditional materials (e.g., polymer and carbon composites are now routinely used in the manufacture of a car's body parts instead of steel). Macromolecular physics and chemistry is by its very nature interdisciplinary encompassing topics such as complex fluids, non-equilibrium phenomena, colloids, gels, glasses, membranes – both artificial and biological, polymers, carbon nanotubes, dentrimers, proteins physics, and so forth. Most recently, the advent of nanotechnology has highlighted a growing need to understand processes of self-assembly and growth of these important new classes of materials.

A polymer/macromolecular/soft-condensed matter physics center would provide an opportunity for interested faculty from across college boundaries to pool their expertise and develop a critical mass for the pursuit of large-scale funding initiatives. This is particularly important because investigations of macromolecular molecular systems often require special experimental characterization tools and techniques. The center will be a joint activity with Chemistry, Materials Science and Engineering and Chemical Engineering.

Specific Plans: Recruit a new faculty member in polymer/macromolecular physics/soft condensed matter physics; seek funds from NIH and other agencies; explore the possibilities for collaborations at Oak Ridge through a possible joint faculty hire.

Outcomes: Expected outcomes include the nucleation of a new soft-condensed matter-macromolecular center with extensive interdisciplinary ties to Chemistry, Chemical Engineering and Materials Science and Engineering. Over time, Center faculty will develop courses and a new graduate educational program.

Resources: Startup and equipment up-fit funds for faculty occupying the polymer/soft condensed matter laboratories being designed for Riddick. Relocation costs associated with the moves of the Ade and Sayers laboratories to Riddick ($50K). Technician to support experimental programs in Riddick ($40K +fb/yr)

A6: An Ultra-Cold Neutron Source at the PULSTAR Reactor
(University goal: fostering internal and external partnerships)

Groups in the physics department and the nuclear engineering department are collaborating to construct a world-class ultra-cold neutron source at the PULSTAR reactor. If such a source is constructed, it would immediately see use for fundamental neutron research (for example, in studies of neutron- antineutron oscillations) and for applied research (for example, in studies of the dynamics of biological macro-molecules). The local user group includes nuclear physicists from University of North Carolina and Duke University as well as NC State, and the applied physics programs involve collaborators from as far afield as the Hahn-Meitner Institute in Berlin.

A source of this kind serves several important roles. It provides a significant boost in the research capabilities of both the nuclear and physics departments, it provides an excellent magnet for attracting local students into programs of national significance, and it strengthens connections between NC State and other local universities. Unusual for this campus, it will provide a facility that exists no where else in the world and which will therefore draw national and international attention to NC State.

Support for equipment and operation is being sought through external funding agencies (for example, the DOE INIE program). However, this project also requires a significant investment in infrastructure, to relocate old pumps and renovate space for the experimental hall. An assessment of the required facilities modifications is underway, and should be available late in the fall of 2002. A university commitment to provide the necessary infrastructure changes will be crucial in obtaining the support to finish construction of a UCN source and begin using it for experiments. The estimated costs for the infrastructure upfit are in the range \$100K-\$300K.

Specific plans: undertake a detailed facility design; seek external funding for the UCN source, obtain grant support for a distinguished visiting international scientist who has expressed interest in joining the effort to construct a UCN source at NC State

Outcomes: Creation of a unique facility for neutron research, taking advantage of the existing infrastructure at the NCSU nuclear reactor; increased visibility for the NC State in the neutron research community, increased funding opportunities in basic and applied neutron physics; increased linkage to the Oak Ridge SNS project through possible joint hire (see A7)

Resources: facility design fee (\$20K), half support for two years for a distinguished visiting scientist (\$50K +fb/ yr), infrastructure up-fit cost (\$100K approx.)

A7: **UT/Battelle – NC State joint faculty positions with Oak Ridge National Lab.**
(University goal: fostering internal and external partnerships)

ORNL's strengths in nuclear science, materials science, and computational science are well matched to the interests of the Physics Department and to NC State University. The completion of the Spallation Neutron Source (SNS) in 2006 will also provide unprecedented opportunities for research collaborations using neutron beams. As a member of the core university group, NC State committed to joint positions under a proposed 1/4 university, 1/4 department, 1/2 ORNL funding arrangement. Areas specifically targeted included computational astrophysics, computational materials, polymer and materials science, SNS related fundamental neutron physics, and SNS related biological physics.

The department has already made one very successful joint hire (in computational materials) and will seek to make additional joint hires. We have agreement from the ORNL Physics division to support an SNS-related neutron science hire and a search is currently underway. Additionally, the director of the Center for Nanophase Materials Sciences (CNMS) has recently expressed interest in a joint experimental hire with us in the general area of nanotubes, nanowires, quantum dots, and quantum transport. We plan to pursue both of these opportunities, and others as they may arise in the areas of interest to the department.

Outcomes and assessment: Partnership with ORNL will enhance NC State's position as a national leader in science and technology, and will enhance the Department's national reputation in computational science, materials science and neutron science. The success of this partnership will be assessed by the scientific productivity of the new collaborations.

Resources: Support for ¼ position for each of two candidates, and startup funds for equipment, students and travel.

B Initiatives Contributing to the University's Planning for "Students Learning in a Technology-Rich Environment."

B1: Introductory physics curriculum development, 3D visualization, and intelligent tutoring

We are implementing a new, modern, introductory physics curriculum, *Matter & Interactions*. This curriculum integrates 20th century physics, especially atomic-level models of matter, into the study of basic physics principles. It engages students in the process of modeling messy real-world systems while stressing the macro-micro connections that are crucial to modern applications. The curriculum provides a strong foundation for later work in such areas as nanotechnology, materials science, and computational science, all of which are strategic areas for the University. Instruction involves students in writing computer programs to explore the application of physics principles to systems too complex to be treated analytically at this level. The curriculum is currently being piloted in the SCALE-UP setting, and we plan a pilot test in a more traditional lecture setting beginning in Fall 2003.

Faculty engaged in Physics Education Research will be responsible for developing the program. In the initial stage, they will train TAA's (teaching assistant assistants) who have successfully completed the course. The TAAs will assist in laboratories, in programming, and in problem-solving sessions. The program will require sufficient computers to allow students in lab sections to do serious computer modeling in class (1 computer for every 2 students).

A related research thrust will explore the role of 3D visualization in helping students learn physics. Visualization is increasingly important in science and engineering, and there is some initial evidence that 3D is important for many students. This component of the curriculum requires adequate access to computers in classrooms, computer projection capability, and the availability of an easy-to-use 3D programming language. VPython has emerged as a powerful tool for 3D simulation and with support from an NSF grant, the VPython project is now housed at NC State. Scientists and engineers nationwide are beginning to use VPython as an easy programmatic way to look at data in 3D and national interest is expected to grow.

A final thrust area involves instruction of multi-step problem solving. If students are asked to solve more complex, multi-step problems, it will be necessary to provide adequate practice in a supportive environment, with prompt and adequate feedback. There now exist real-world implementations of artificial-intelligence-based "intelligent tutoring systems" (ITS), deployed in educational settings, which can to a significant extent solve problems themselves (expert systems), track student reasoning in multistep problems, and provide detailed coaching and feedback. An ITS for introductory physics could address known student weaknesses in formal manipulations, interpreting symbolic formulas, working with vectors, etc. We propose to host a seminar series to explore the possibilities of developing and using such tutors in introductory physics; the series would bring in ITS experts whose tutors are currently in use in real educational settings. Various interested groups on campus, including DELTA, would be invited to co-sponsor the series.

Outcomes: The desired outcome of the program will be measured in student performance and satisfaction. The former will be measured by student success in examinations which test their ability to analyze novel situations involving the atomic nature of matter, macro-micro connections, and basic concepts of computational physics (the College of Engineering is already engaged in studies on this issue). The latter will be measured in student surveys.

Resources: Undergraduate TAA grading support ($30K/yr); computer hardware, computer software and 3D computer projection equipment (est. $50K); support for hosting a seminar series on intelligent tutoring systems ($10K)

B2: Graduate curriculum development: quantum computing initiative

Quantum Mechanics has revolutionalized our understanding of the universe, and currently permeates all aspects of modern technology. During the past two decades, it has become clear that quantum mechanics may well revolutionalize yet another field, namely that of computing. The basic idea, as first pointed out by R.P. Feynman and others, is that one can take advantage of the superposition of many quantum states to form a qubit, which allows for parallel computations on many different quantum states simultaneously. Hence, quantum computing should – in principle – allow for exponential gains in computational power. To date quantum computing as a field is still very much in its infancy, and many of the ideas exist as theory only. Despite several recent "proof of principle" experiments, it is currently unclear whether scalable quantum computing will ever become a reality. Nevertheless, quantum computing as a subfield of Physics is being treated seriously by the major funding agencies (including NSF, DARPA, and DOE), which all have special initiatives out on this topic. Given the strategic advantage and high impact that any gains in quantum computing will have on society, it is important for NC State to gain a presence in this emerging discipline.

Specific Plans: As a first step, the Physics Department will participate in development a one semester graduate level special topics course on quantum computing. Topics discussed could include, but not be limited to, quantum coherence and decoherence, qubits, spintronics, quantum dots, quantum cryptography algorithms, and molecular electronic systems. No additional resources beyond faculty release time would be required. Potential overlaps with faculty in chemistry (NMR) and mathematics (algebra) will be explored, and a campus-wide seminar series will be planned to introduce the topics to interested researchers.

Outcomes and Assessment: In addition to adding breadth to the graduate-level curriculum, this will enable the department to assess for itself the relative merits of quantum computing as a viable discipline of Physics in which further investment may, or may not be warranted.

Resources: Support for a seminar series in quantum computing ($10K)