

Department of Physics Strategic Plan

Charge (Jan. 2000): In consultation with all Physics Department stakeholders, develop a ten-year strategic plan for the Physics Department consisting of three parts: a) A vision statement and goals for the coming decade. b) Assessment indices comparing the Department with aspirational peer institutions c) An implementation strategy for achieving our ten year goals.

Charge (Sept. 2005): Revisit the department's ten-year Strategic Plan to assess the record at the five-year midpoint. Based on this assessment, the current environment, and the goals for continued growth, present a vision of the department's future in terms of the Plan and, if necessary, propose a refocused document.

Original submitted by the Strategic Planning Committee January 10, 2000, endorsed by faculty vote January 12, 2000.

Revised version submitted by the Strategic Planning Committee October 4, 2006, endorsed by faculty vote February 7, 2007.

Strategic Planning Committee (2000)

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Executive Summary

In its Strategic Plan the Physics Department of NCSU has set a vision of sharply increased recognition for its research and educational programs and improved service to the State of North Carolina by 2016. The implementation plan outlines the steps that we believe are needed to implement the Strategic Plan and accomplish the Physics Department vision. It will cover both general and specific aspects of faculty development, describe creative approaches for taking advantage of new opportunities in education, and outline goals for developing the undergraduate and graduate programs. It will also cover both short- and long-term space needs and proposed additions to the staff and the operational budget. The guiding principles and action items for each part of the plan are summarized here.

Faculty Development

Guiding Principles:

1. Hiring within the department will not be driven by the concept of simply “replacing” a retiring or leaving faculty member.
2. Hiring within a particular targeted research area will occur over an extended time period to secure a superior candidate. The department will continue to employ a combination of open searches, targeted searches, and targets of opportunity hires to increase its faculty size.
3. The fact that a target area has been specified in no way guarantees that we will hire in that area.
4. The faculty reserves for itself the right to examine and consider for hire faculty from under-represented groups, as well as other “targets of opportunity”.
5. Decisions on hiring new faculty and promoting existing faculty will incorporate our commitment to excellence in undergraduate and graduate teaching.
6. The distribution of faculty research areas will reflect a balance between fundamental, applied, and interdisciplinary areas of physics, as set forth in this Strategic Plan.
7. The plan will be reviewed on a regular basis, in conformity with the Compact planning process and in consultation with an External Advisory Committee.

Action Items:

1. Continue to improve the performance, promote and enhance faculty prominence.
2. Identify, sustain, and enhance the most vital research programs, as outlined.
3. Increase the number of tenure track faculty from 34 to 43.
4. Continue with a standing faculty search committee, whose composition will be adjusted annually to reflect the either open or targeted searches to be undertaken.
5. Increase the NRC rating of faculty quality.

Instruction and Student Development

Guiding Principles:

1. We will remain aware of the needs of the students and provide learning opportunities that make our students maximally competitive upon graduation.
2. We will continue to improve teaching effectiveness through the use of innovative approaches and the implementation of new technologies.
3. We aim to raise awareness of science, particularly physics, in K-12 education.
4. We will find and enroll the best undergraduate and graduate students.

Action items, instruction:

1. Development:

- a. We reaffirm our commitment to Physics Education, and will continue to test and develop innovative instructional methods as they are developing.
 - b. We aim to collaborate with other departments to extend teaching innovations to related areas.
 - c. Continue to promote additional versions of physics courses that appeal to nonscience majors.
 - d. Expand current levels of instructional support as we improve instructional approaches and deal with increasing student enrollment.
2. Research:
- a. Continue developing innovative approaches to teaching, including organization and presentation of material as well as the use of developing technologies.
 - b. Continue testing these approaches by performing regular assessments of learning for comparison to national norms and innovative classes.
3. Outreach:
- a. Expand collaborations with the College of Education and Psychology to train pre-service and in-service teachers.
 - b. Continue support of Science House programs.
 - c. Promote faculty outreach to area schools.
 - d. Expand Public Demonstration Shows.

Action items, Undergraduate Program:

- 1. Increase the graduating students by 50%, from 16 per year now to 24 per year.
- 2. Increase both the number and size of scholarships and awards.
- 3. Enhance recruiting efforts, stepping up contacts with local high school guidance counselors.
- 4. Continue to promote the BA as a second degree.
- 5. Examine the feasibility and implement a “study abroad” program.
- 6. Continue to develop the curriculum to meet current needs.
- 7.

Action items, Graduate Program:

- 1. Improve the quality of the graduate students.
- 2. Continue to increase the number of graduate students.
- 3. Continue to enhance the effectiveness of the recruiting process.
- 4. Revamp and continuously update the department website.
- 5. Increase the number of special topic courses offered in the various subfields of physics.
- 6. Ensure that we are providing the best education for our students.

Infrastructure

(a) Space

Guiding Principles:

- 1. We shall seek to use existing space as effectively as possible.

2. We shall seek means of generating more space and seek to continue to consolidate our fragmented department, most likely in the Riddick Building under current renovations.

Action items:

1. We will continue with a standing space committee.
2. The space committee will continue to examine how space needs to be allocated in order to ensure its most effective use.

(b) Support Personnel and Services:

Guiding Principle:

As the size of teaching and research operation of the department continues to grow, there is recognition that increased support operations (both administrative and technical) may be needed in order to help the department fulfill its mission and vision.

Action Items, Support Personnel and Services:

Continue to press the administration for increased support staff and services, especially as the number of students and faculty continues to grow. Continue to seek the ways and means to improve current and future support operations (e.g., the demo room, lab and TA support, IT operations, etc), so as to ensure that professional services are delivered to the department in a timely manner.

(c) Budget:

Action Items, budget

While the faculty continues to obtain research funding, it is the perception that relatively little of the overhead generated has actually been returned to the Department, let alone the PIs. It is recommended that the departmental administration continue to press the College and the University on this issue, so that the Department can successfully implement its stated mission and vision.

Strategic Plan

October 2006

Mission: The Physics Department faculty is committed to providing outstanding educational and research opportunities. Our highest priority is to help all students achieve their educational objectives. We serve the people of the State of North Carolina by:

- providing educational opportunities to undergraduate and graduate students in physics, through high quality curricula, faculty, and research facilities
- developing world-class research programs that advance scientific knowledge, contributing to the needs of the Nation and the State, and meriting national and international recognition for their high quality
- providing high-quality physics instruction to the University community
- supporting outreach activity that fosters improved public awareness and understanding of science

Vision: The Department of Physics at North Carolina State University will become a national model among public universities for its approach to and innovations in education, its excellent and diverse faculty and graduates, the significance of its research, and its contributions to other disciplines and to society in general. The Department will continue to improve its national and international stature and will be considered among the top ranked departments in the nation.

Long Term Goals (to be achieved by 2016):

General Goal: The department will raise its standing as evidenced by recognized measures such as the National Research Council (NRC) rankings. In the 1993 NRC rankings of Physics Departments, NCSU was ranked 51 out of 147 departments. By 2016, our goal is to be ranked in the top 30. The department will strive to become a model for public universities in the quality and diversity of its research, particularly seeking to develop new interdisciplinary partnerships, and for its innovations in education and teaching, to the benefit of students not majoring in physics as well as physics majors.

Faculty Development:

1. Increase the number of tenure track faculty from about 33 to about 43, in part by increasing the diversity of the faculty by hiring in new fields of research and from under-represented groups.
2. Increase faculty quality by hiring new faculty with excellent potential or experience and supporting the continued development of existing faculty.
3. Enhance and sustain the most vital research programs by allocating available positions and providing the necessary space and start-up resources for new faculty.

4. Find resources to retain and develop existing faculty through investment in selected programs chosen on the basis of the departmental goals and the faculty member's career development plans.
5. Promote and increase the prominence of the faculty as evidenced by membership in the National Academy of Science, fellowships and elected positions in professional societies, and awards.

Instruction and Student Development:

1. Develop a nationally recognized research and development center for physics education aimed at improving methods for instruction, particularly in the introductory physics courses.
2. Increase the quality and quantity of the graduate program by:
 - a. Increasing the quality of the students
 - b. Increasing the entering graduate class from about 15 per year to 25 per year in step with the development of the faculty size. and anticipated funding levels
 - c. Increasing the number of fellowships to graduate students.
 - d. Increasing the number of Research Assistants funded from grants.
3. Increase the number of graduating physics majors and double majors from about 16 per year to about 24 per year by:
 - a. Increasing the number of scholarships and fellowships available.
 - b. Continuing the development of the major curriculum to reflect changes in the field and in our students.
 - c. Promoting the BA in physics.
 - d. Continue to develop the undergraduate program offerings.
 - e. Develop and foster the possibilities of a “study abroad” program for physics

Infrastructure

(a) Space: Develop adequate space which will be appropriate for the size and quality of the department including:

Consolidating space among existing programs and developing additional space for new faculty and expanded research programs in Riddick Hall currently under renovation, or on Centennial Campus.

(b) Support Personnel and Services: Increase the infrastructure support for the department, in both quality and quantity, as the teaching and research mission of the department continues to grow and expand. Continue to seek the ways and means in order to improve current and future support operations, so that the services reach the appropriate faculty in a timely manner.

Department of Physics

North Carolina State University

I. Introduction:

The 1960's marked a period of dramatic growth of physics departments nationwide. As a result, the approaching decade will mark a period of unprecedented retirements around the country and at North Carolina State University (NCSU) in particular. Indeed, based on past retirement profiles, our Department will diminish from its present size of about 34 to 19 members by 2016 if no further hires are made. At the same time the nature of physics research is itself changing. Funding from Government agencies such as NSF is shifting away from core disciplines and the type of classical electronic-materials research that has supported physics departments for the last 30 years into new areas such as nanostructures, bioinformatics, interdisciplinary research, education, and "soft" materials including for example bio-electronic interfaces.

Consequently, the years from 2000 to 2016 will see a major reordering, restructuring, and reranking of physics departments nationwide. While the ever-increasing demand for technology will ensure that physics will continue to play a major role in research and education, competition within the physics community for new faculty and adequate funding will be intense. Visionary planning and disciplined implementation of plans will be required to meet this challenge, to make the most of this opportunity, and to emerge stronger at the end of the next decade.

Physics has been termed "the basic science" and, as such, seeks to find a unified set of laws governing matter, motion, and energy from the subatomic domain to the largest distances known. In recent years physics has not only emphasized its core knowledge but has played a major role in applying this knowledge to other disciplines. This has not only led to the formation of separate disciplines such as astrophysics, biophysics, geophysics, etc., but also to increasingly interdisciplinary research in many of the core areas that are still contained in traditional physics departments. In addition to the important knowledge involved in the study of physics, the problem-solving approaches that are emphasized provide vital skills for any college-educated person in this society.

In its Strategic Plan the Physics Department of NCSU has set a vision of sharply increased recognition for its research and educational programs and improved service to the State of North Carolina by 2016. The keys will be faculty development, both of existing faculty and new hires, and student development, through aggressive recruiting and the development of enhanced curricula and research programs, since it is the quality of the faculty as defined by their research and teaching accomplishments and the students as defined by the positions in which they can be placed that determine the quality of any academic department.

The present document outlines the steps that we believe are needed to implement the Strategic Plan and accomplish the Physics Department vision. It will cover both general and specific aspects of faculty development, describe creative approaches for taking advantage of new opportunities in education, and outline goals for developing the undergraduate and graduate programs. It will also cover both short- and long-term space needs and proposed additions to the staff and the operational budget.

In developing this plan several assumptions have been made. The first is that physics and a strong Physics Department will be a vital part of the NCSU of the future. Traditionally, physics is one of the few disciplines with an unusually high correlation between the ranking of the department and the overall ranking of the institution itself. Because of fundamental nature of physics and the linkage that it provides between basic knowledge and applied research, that correlation is expected to be true in the future.

The second is that the fundamental changes that have occurred in the discipline in terms of funding and the interest of students in pursuing education in physics will continue to evolve. The end of the cold war with its emphasis on technologies closely coupled to physics and the emergence of information and computer science, and modern molecular biology, have led to a strong competition for the brightest young students. The net result of these factors has been some renormalization of the discipline regarding both size and emphasis. While this will result in a different way of “doing” physics in a university setting, it does not mean that physics will not and should not play a central role in the university of the future. This is particularly true at an institution where physics has established itself as one of the most successful departments, and particularly in an institution like NCSU with its land-grant tradition and its focus on science and technology.

The goal, then, of significantly increasing the ranking of the Physics Department seems to be reasonable and has been encouraged by the recent external review of the Department as well as by the Dean of PAMS. To accomplish this increase the Department has determined that it should evolve to a point where it serves as a model for how physics departments should function within the university of the future. In research this means maintaining a solid core of the basic disciplines with a balance of experiment, theory, and computation, while at the same time expanding relevant existing areas and developing new areas, in particular areas that emphasize interdisciplinary activities and/or those connected with new technology, especially those areas that can have the greatest impact on the State of North Carolina. In education, for both non-majors as well as majors, we need to continue to develop new ways of teaching students that emphasize interactive learning and improved problem-solving skills.

Our assumptions concerning the specific areas of emphasis and the numbers of people needed to have the impact that is our goal leads us to recommend that the Department be expanded from its present size of 34 to about 43. This appears to be a conservative number. It is also consistent with the sizes of departments that are currently ranked at the level that we seek to reach. Of course, if we are not able to expand as we propose, the general criteria of seeking excellent new faculty members and of striking a proper balance between traditional core and newer interdisciplinary areas of research still apply, but the results will almost certainly be less than to what we aspire.

II. Guiding Principles

In order to achieve its goals and vision, the original Strategic Plan (Jan. 2000) set forth a series of guiding principles in the areas of faculty development, instructional development, and the use of departmental resources. We have subsequently re-examined these guiding principles (Sept. 2006), and found that they have served the department well. Consequently, these guiding principles, as summarized here, shall remain in force during the upcoming years 2006 – 2016.

A. Faculty Development—Guiding Principles:

- 1. The concept of “replacing” a faculty member who is leaving will be abandoned.**

To “replace” a faculty member who is retiring or resigning is to emulate the past. Furthermore, there is no guarantee that a particular slot will be reallocated by the university administration. Future hiring will be determined by the needs and aspirations of the department and the quality of the available applicants.

- 2. Hiring within a particular targeted research area will occur over an extended time period to secure a superior candidate. The department will continue to employ a combination of open searches, target searches, and target of opportunity hires to increase the size of its faculty.**

Our hiring procedures will change. Predetermined target areas will be defined based on the needs and goals of the department. Individual research groups will be encouraged to search on a continuing basis for faculty in the targeted areas to locate superior candidates. This is in contrast to hiring the “best” (or perhaps the second or third best) candidate in a particular field in a given year.

- 3. The fact that a target area has been specified in no way guarantees that we will hire in that area.**

All new faculty hiring must clearly enhance the reputation, vitality, and future interests of our department. Faculty hiring in non-targeted areas will always be considered if the candidate clearly represents a special opportunity to strengthen the Department.

- 4. Faculty from under-represented groups, as well as other “targets of opportunity”, is welcomed at any time.**
- 5. Decisions on hiring new faculty and promoting existing faculty will incorporate our commitment to excellence in undergraduate and graduate teaching.**
- 6. The distribution of faculty research areas will reflect a balance between fundamental, applied, and interdisciplinary areas of physics.**
- 7. The plan will be reviewed on a regular basis, in connection with Compact planning and in consultation with an External Advisory Committee.**

B. Instruction and Student Development—Guiding Principles.

- 1. We will remain continually aware of the needs of the students and provide learning opportunities that make our students maximally competitive upon graduation.**

The objectives of a University education are to broaden one's horizons and improve one's economic position. This means not only providing our physics students with the tools needed for critical thinking but also being continually aware of the job market and the needs of the local as well as the national economy. The same applies to the students taking the service courses that we teach. Consequently, we need to regularly evaluate the effectiveness of all courses. We note that this goal is completely consistent with the expanding role of land-grant institutions in the 21st

century, which will turn increasingly to enhancing our store of knowledge and improving its application in technology.

2. We will seek to improve teaching effectiveness through the use of innovative approaches and the implementation of new technologies.

Evolving computer, display, communications, and information technology are providing new challenges but at the same time presenting new opportunities to universities in general. For example the development of the Internet leads to new possibilities in "distance" learning and at the same time new mechanisms by which other institutions can compete. The uniquely fundamental position of Physics in science positions us excellently well to attack these challenges and to provide creative solutions through Physics Education Research, where we are currently exploring new approaches toward presenting physics material and also innovative ways of using evolving technology. WebAssign and Scale-Up represent two such examples.

3. We will seek to raise awareness of science in general and physics in particular in K-12 education.

It is generally accepted that to function effectively a society has to be literate. It is less well accepted that to function effectively a society now has to be scientifically and technologically literate as well. Yet it is clear that scientific and technological literacy will become increasingly important. Thus our current emphasis on carrying science to the K-12 arena, as exemplified e.g. by Science House, not only needs to be continued but to be enhanced.

4. We will find and enroll the best undergraduate and graduate students.

The quality of the Department is dependent on the quality of the students as well as that of the faculty. As we act to improve the quality of our faculty, we will also act to improve the quality of our students.

C. Infrastructure

(a) Space—Guiding Principles:

1. We shall seek to use existing space as effectively as possible.

While expansion is ideal, we recognize that it is also the easy way out, and that constraints outside our control often dictate the amount of space allocated. Thus it becomes important to ensure that we are using the space already allocated efficiently and effectively.

2. We shall seek means of generating more space, ideally to consolidate our currently fragmented Department.

Our research program was the second best-funded among all NCSU departments over the past two decades. Quality research space is required if we are to continue this record of remarkable growth in sponsored research, and to enhance our competitiveness and participation in interdisciplinary research.

(b) Other Infrastructure - Personnel and Budget—Guiding Principles:

There is a recognition, that as the teaching and research mission of the department continues to grow and expand, there is a need for increasing the both the quality and quantity of the support operations. The department will continue to seek the ways and means for improving the operation of such support systems – whether they are of an administrative or technical nature – so that the services are delivered to the appropriate faculty in a timely and professional manner.

III. Implementation Plan:

A. Advancing Research in the Department of Physics

In developing new research areas, the NC State Physics faculty have a tradition of developing significant and multifaceted programs with potential for collaboration and opportunities for students to interact with multiple faculty. The development of these program in general requires a continuous effort to recruit new faculty and to provide the resources and the environment for their success.

The plan presented here is organized to unify broadly similar areas of physics in ways that will enhance development of new programs that span traditional areas of physics. Only four areas have been identified, and one of these is Education and Society impact which would largely be developed with graduate students outside of the physics department. The other three areas are, 1) Physics of the Universe, which ranges from nuclear and subatomic physics to astrophysics, 2) Quantum, Molecular, Nanoscale and Materials Physics, and 3) Biological, Complex and Nonlinear Phenomena and Materials.

Each of the four areas is similarly organized with a general description of the focus at NC State, a description of the Significant Current Initiatives and collaborative projects, a vision for the future, and a bulleted list of required faculty lines and resources.

These plans were developed with a vision to bring national research leadership in carefully selected specific topical areas which would also broadly span physics. The goal is to simultaneously enable excellence, leadership, impact and breadth.

Our plan proposes to recruit 23 new faculty over the next ten years. We may anticipate that 14 of the current faculty would possibly retire during this period which would boost the department to about 43 faculty, a number that had been discussed in the prior strategic plan developed in 2000, and in the last round of compact planning.

In addition, our plan presents several initiatives to implement centers of excellence that will enhance collaborations and enable the faculty to develop new initiatives to lead the development of the specific fields.

Physics of the Universe: From Quarks to the Cosmos

Faculty list:*

John Blondin, Kazimierz Borkowski, **David Brown**, **Steve Cotanch**, **Don Ellison**, Robert Golub, **Chris Gould**, **Dave Haase**, **Paul Huffman**, **Chueng Ji**, John Kelley, **Dean Lee**, **Gail McLaughlin**, Gary Mitchell, **Steve Reynolds**, **Thomas Schaefer**, **Albert Young**.

Summary of current research perspectives:

Particle physics, nuclear physics, and astrophysics have seen stunning progress in their realms over the past decades. A recent report by the National Research Council (NRC) "Connecting Quarks to the Cosmos: Eleven Science Questions for the New Century" argues that the advances made by physicists in understanding the deepest workings of matter, space, and time and by astronomers in understanding the universe as a whole have brought these sciences together in a new way. The report lists eleven questions that highlight the way in which questions about the very large and the very small are inextricably intertwined. We have a good chance of answering at least some of these questions in the near future, and the answers will profoundly affect the way we think about our universe.

Nuclear, particle and astrophysicists at North Carolina State work intensively on at least six of these questions:

- What are the masses of neutrinos, and how have they shaped the evolution of the universe?
- How do cosmic accelerators work, and what are they accelerating?
- Are there new states of matter at exceedingly high density and temperature?
- Is a new theory of matter and light needed at the highest energies?
- How are the elements from iron to uranium made?
- What is dark matter?

Other questions that are being investigated at North Carolina State relate to the problem of how the interaction between quarks and gluons generates the ordinary, visible, mass in the universe, how the tiny asymmetry between matter and anti-matter came about, and what the mechanism of supernova explosions is. Progress in answering these questions will require research at the frontiers of nuclear, particle, and astrophysics, as well as new ways of bringing these different fields of physics together.

Work at N.C. State continues to expand our knowledge of fundamental physical processes from the smallest nuclear scales to cosmic scales. In the following we will summarize the active research efforts in these areas and then outline our vision for the future.

Nuclear Experiment: Faculty at North Carolina State (Gould, Golub, Haase, Huffman, Mitchell, and Young) maintain a strong collaborative program centered around their involvement in the Triangle Universities Nuclear Laboratory (TUNL). This Department of Energy *Center of*

* Tenured or tenure-track faculty whose main research interests are in a given area are listed in bold.

Excellence is an inter-institutional consortium of three major universities in the Research Triangle area: Duke University, University of North Carolina at Chapel Hill, and N.C. State. As part of the TUNL program and through individual National Science Foundation grant, N.C. State has initiated a world-class program in low energy nuclear and particle physics using cold and ultracold neutrons. Initiatives in this area include the development of an ultracold neutron (UCN) source at the North Carolina State nuclear reactor for use in experiments to test the Standard Model, in studies of material properties, and for neutron moderator development. The construction of an experiment to measure the neutron electric dipole moment (EDM) at the fundamental physics neutron beam line at the Oak Ridge Spallation Neutron Source (SNS) is underway. In addition, separate programs to measure both the neutron lifetime and beta-decay asymmetry coefficients are in progress at the National Institute of Standards and Technology and Los Alamos National Laboratory (LANL) respectively. Neutron EDM, lifetime, and beta-asymmetry measurements provide important information about the breaking of the symmetry between left and right, and between matter and anti-matter in our universe. N.C. State nuclear scientists are also involved in measurements and analysis of nuclear reaction data taken with gamma ray arrays at LANL, measurement of the neutron-neutron scattering length, and several other measurements involving neutron capture, proton resonances, radiative strength functions and level densities. N.C. State and TUNL faculty are among the founders of the Majorana collaboration, a group that seeks to determine the symmetry properties of the neutrino.

Astrophysics: Blondin, Borkowski, Ellison and Reynolds study a wide range of astrophysical phenomena using large-scale computer simulations, more traditional computational techniques, and the collection and interpretation of data from space and ground-based telescopes. Current projects include (i) large-scale computer modeling of the core-collapse supernova explosion mechanism, (ii) computer modeling of compact objects including accretion disks around massive black holes, binary neutron stars, and pulsars, (iii) the hydrodynamics of supernova remnants and the nonlinear coupling of the hydrodynamics to the production of cosmic rays, (iv) the study of pulsar-wind nebulae, (v) radiative processes in hot plasmas including emission from hot dust, (vi) fundamental nonlinear processes in shock acceleration with applications to gamma-ray bursts and collisionless shocks elsewhere in astrophysics, and (vii) the collection and interpretation of data from various telescopes including space-based observatories *Chandra* (X-rays), *XMM-Newton* (X-rays), *Spitzer* (Infrared), INTEGRAL (gamma rays), the Hubble Space Telescope, and ground-based radio telescopes. An important element of our work is to study fundamental astrophysics in objects where good data and observations exist and then establish connections to more exotic, less well studied objects. As an example, our models for thermal emission from plasmas far from ionization equilibrium, and for synchrotron emission from realistic electron distributions, are distributed globally through the most widely used software for X-ray spectroscopy of cosmic plasmas. We have demonstrated the use of these tools with our own observational studies, and the international community of X-ray astronomers makes extensive use of them.

Brown studies numerical general relativity with application to gravitational wave emission and detection. Computational strategies being investigated include variational and symplectic integration techniques and constrained evolution schemes. The primary goal of these projects is to model the binary black hole problem. Work is also done to model the gravitational wave signals from core-collapse supernovae. The numerical techniques used here include finite

differencing and spectral methods, as applied to both hyperbolic and elliptic partial differential equations.

McLaughlin investigates R-process nucleosynthesis (responsible for the formation of the heaviest elements), the role of neutrinos in astrophysical environments such as supernovae, gamma ray bursts, and black hole accretion disks, and neutrino-nucleus reactions, relevant to the detection of neutrinos on earth.

Nuclear/Particle Theory: Cotanch, Ji, Lee, and Schaefer study QCD, the theory of quarks and gluons, which provides the fundamental description of all strongly interacting matter. QCD studies focus on the mechanism of confinement and chiral symmetry breaking, the structure of hadrons, and the search for exotic hadrons such as bound states of pure glue or hybrid states of quarks and excited glue. We also study new states of matter that are predicted to exist under extreme conditions of temperature and density. This includes the properties of the quark-gluon plasma at very high temperature, and the structure of color superconducting quark matter at very high density. These efforts are related to the ongoing experimental program at Jefferson Lab and the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Lab. Research into the structure of heavy hadrons involving bottom or charm quarks makes important contributions to the search for violations of fundamental symmetries, and research into quantum field theory contributes to our understanding of neutrino or neutron-anti-neutron oscillations. We have also initiated a program in computational nuclear many body physics aimed at exploring the equation of state of nuclear matter at densities relevant to the outer crust of neutron stars. Our research involves a number of interdisciplinary efforts. The study of dense matter has important connections to the physics of neutron stars, and the rapidly evolving field of cold atomic gases.

Estimates on the current number of physics students/postdocs in all three areas (Astrophysics, Nuclear Experiments and Nuclear/Particle Theory) are 7 undergraduates, 20 graduates and 6 postdocs from our department.

Significant Current Initiatives and Collaborative Projects:

Nuclear experimentalists are in the process of ramping up TUNL's involvement in the neutron EDM experiment. This is an approximately \$20M construction project that will eventually take data at the SNS. N.C. State/TUNL has committed to build the cryogenic portion of the experiment and oversee the integration of all the components.

Upon completion of the ultracold neutron source presently being constructed at the nuclear reactor on campus, NC State will be home to a world-class facility ready to perform both fundamental and applied physics experiments with neutron.

NCSU played a key role in the highly successful Terascale Supernova Initiative lead by ORNL and funded by the DOE SciDAC Program at \$10M. NCSU-based supernova simulations were one of only four projects given initial use of the Cray X1E supercomputer at the new National Leadership Computing Facility at ORNL.

Nuclear theorists at NCSU are currently funded through two grants from the Department of Energy, an umbrella grant involving Cotanch, Ji, Lee, and Schaefer and a separate grant

supporting McLaughlin. Together, these two efforts will generate close to \$1.0M over the next 3 years.

In addition to these larger scale projects, theory faculty have extensive external collaborations throughout the world.

Vision for the future:

North Carolina State has strong, internationally recognized groups in experimental and theoretical nuclear physics and in theoretical astrophysics. We believe the department should capitalize on the existing strengths and engage in a program of strategic hiring that will reinforce the existing connections between the different efforts, add breadth to the theory effort by adding theorists working on physics at the very shortest and the very largest length scales, and strengthen and broaden the astrophysics program. We feel that these measures are essential in order to improve the ranking of the physics department, to attract more as well as more highly qualified graduate students, and to attract additional outside funding in the form of topical centers, centers of excellence, or initiatives in computational physics.

The experimental nuclear physics program has a strong core effort in cold neutron physics led by two recent hires, Huffman and Young. However, the remaining TUNL group (Gould, Haase, Mitchell) has taken on significant administrative or outreach responsibilities and several may be nearing retirement. There is now an opportunity to expand the current program to address the questions in nuclear astrophysics and/or neutrino physics would align our aspirations with national priorities at DOE and significantly strengthen the overlap between theory and experiment in this area.

The nuclear theory groups have strong programs in QCD, computational many body physics and nuclear astrophysics. We believe that we should expand this effort in the direction of physics at shorter distances and higher energies. There are many areas of opportunity that would add breadth and at the same time strengthen the existing links between nuclear/particle physics and astrophysics. One field of interest is astro-particle physics with an emphasis on high energy cosmic rays, neutrino physics or dark matter. A new faculty member in this area would add new competence in particle physics and strengthen the connections between nuclear astrophysics and computational astrophysics. Similarly, a high energy theorist working on duality between string theories and strongly interacting gauge theories would tie the QCD effort to the physics of the universe, and a particle phenomenologist working on heavy hadrons and fundamental symmetries violating processes would provide support to the existing theory program or cold neutron program, respectively.

The astrophysics group at N.C. State has developed great depth in the study of supernova explosions and the remnants they leave behind and is widely considered a world leader in this field. While the physics essential for understanding supernovae has broad application in many areas of astrophysics, the current strength and international reputation of our astrophysics group offers an opportunity to attract exceptional new faculty and expand into exciting, emerging fields. There is also an opportunity for a connection and even integration of the astrophysics and the nuclear/particle astrophysics to solve NRC's questions for the new century by connecting

Quarks to the Cosmos. If astrophysics at N.C. State is to enter a new, brighter phase, we believe two new faculty are required in the short term. Our fundamental work on particle acceleration, radiative processes, and astrophysical hydrodynamics has applications all across the Universe, in particular in extragalactic astronomy. Individuals working with these ideas in connection with the formation of large-scale structure, galaxy formation and evolution, and active galactic nuclei would extend the range of our efforts greatly, while maintaining appropriate areas of overlap with current faculty. However, the nature of astrophysics, with unexpected discoveries occurring at an amazing frequency, suggests that we not overly restrict a faculty search to a particular field, but search for the best person who would flourish here.

Specific Recommendations:

2006-2009

- Search for two faculty in the areas of theoretical astrophysics and theoretical astrophysics-nuclear-particle physics.
- Develop a plan for a Center on Neutron Science and Applications

2009-2012

- Search for one faculty in the areas of Astro-theorist, Particle theorist, Computational extra-galactic astrophysicist, and one experimentalist in the area of experimental nuclear physics.

2012-2016

- Search for two more faculty in this area

Required Resources:

Faculty lines: 6 new faculty lines (against 6 possible retirements)
Staff: 1 Admin for Neutron Science Center

Faculty Expertise:

John Blondin: Computational gas dynamics applied to astrophysical objects, including core-collapse supernovae, supernova remnants, pulsar wind bubbles, planetary nebulae, interacting binary stars, and accretion disks. Much of this work focuses on fluid instabilities and their role in forming the observed spatial structure seen in these systems.

David Brown: Gravitational physics and the development of numerical algorithms for solving Einstein's equations. The primary goal of these projects is to model gravitational wave signals from binary black holes and core-collapse supernovae.

Steve Cotanch: Cotanch's research broadly addresses theoretical structure and reaction studies of hadrons, hadronic systems and nuclei. The goal is comprehensive insight by confronting fundamental field theoretical QCD calculations incorporating important symmetries with precision data from new and existing accelerators, CEBAF at Jefferson Lab where he is a

consultant, and RHIC at Brookhaven Lab. Also many-body and new computational techniques for diagonalizing effective Hamiltonians for both hadron and nuclear structure studies as well as condensed matter systems.

Don Ellison: Modeling of particle acceleration in astrophysical shock waves. Shocks are responsible for most of the nonthermal particle distributions (such as cosmic rays) seen in astrophysics. The process by which shocks place a sizable fraction of their kinetic energy into individual particle energy is complex and nonlinear. This theory has been developed with the help of computer simulations, including particle-in-cell plasma codes and Monte Carlo particle codes. Besides applications to cosmic-ray production and photon observations of young supernova remnants, extensive modeling of shocks in the heliosphere has been performed.

Robert Golub: Tests of the Standard Model using ultracold neutrons (UCN). Development of neutron scattering instruments, in particular the neutron spin-echo device. Studies of the systematic effects in electric dipole moment searches.

Chris Gould: Tests of parity and time reversal violation in the nucleon-nucleon interaction. The design and planning of beam lines for nuclear physics at the Spallation Neutron Source. The study of the properties of the neutrino using the Kamland detector. Measurement of the electric dipole moment of the neutron.

Dave Haase: Measurement of the electric dipole moment of the neutron using ultracold neutrons in a cryogenic environment. Improvement of K-12 science education through statewide and national programs of The Science House.

Paul Huffman: Low-energy particle physics studies using cold and ultracold neutrons. Development of techniques for magnetic trapping of ultracold neutrons for an improved measurement of the neutron lifetime. Search for a non-zero neutron electric dipole moment. Development of an ultracold neutron source at the N.C. State nuclear reactor.

Chuang Ji: has focused on the novel and accurate theoretical predictions of the hadron structures and spectra including the study of heavy meson decays and exotic hybrid and glueball components. In order to construct a realistic hadron model consistent with the precision experimental data envisioned at JLAB, the program emphasizes relativity by taking advantage of the lightcone and investigates the fundamental symmetries of the Standard Model. Perturbative QCD is applied to analyze the short distance nature of the generalized parton distributions and the hadronic wavefunctions.

Dean Lee: focuses on interesting quantum phenomena that are universal in character. For example neutrons at low temperature and density are close to a special point where the range of the interaction goes to zero and the scattering length goes infinity. This same physics can be seen in trapped Li-6 and K-40 experiments done at Duke, JILA, MIT, and Innsbruck. My current interest is in the condensation of fermion pairs and superfluidity at the boundary between Bose-Einstein condensation and Bardeen-Cooper-Schrieffer theory.

Gail McLaughlin: works in nuclear and particle astrophysics and the study of astrophysical phenomenon such as gamma ray bursts, supernova and the big bang. I examine the microphysics of these environments, particularly the effects of newly discovered particle physics, such as neutrino oscillations. I also study the origin of the elements.

Gary Mitchell: Measurement and analysis of nuclear reaction data taken with gamma ray arrays located at Los Alamos National Laboratory—focus on level densities, cross sections and strength functions, Measurement of neutron-neutron scattering length—experiment at Snezhinsk, Russia, Measurement of neutron capture with two step cascade method—experiment at Rez Nuclear Institute, Czech Republic, Measurement of acoustic resonances in vibrating plates—experiment at Sao Paulo, Brazil, Measurement of electromagnetic resonances in microwave cavities—experiment at Darmstadt, Germany, Measurement of Radiative Strength Functions and Level Densities—experiment mainly at Oslo University, Norway, Measurement of Proton Resonances—experiments at TUNL.

Steve Reynolds: Theoretical modeling and observations of astrophysical shock waves and supernova remnants; particle acceleration; radio, X-ray, and infrared observations. Pulsar interactions with surroundings.

Thomas Schaefer: works on strong interactions and QCD. I am interested in the phase diagram of strongly interacting matter and in the behavior of matter at high temperature and baryon density. I am also interested in the structure of hadrons and the mechanism of chiral symmetry breaking and confinement. This research is relevant to the ongoing experimental program at Jlab and RHIC.

Albert Young: The study of fundamental symmetries and particularly the search for new physics beyond the Standard Model at low energies. Measurement of the beta-asymmetry coefficient in neutron decay. Development of an ultracold neutron source at the N.C. State nuclear reactor. Tests of time-reversal invariance using UCN. Measuring the intrinsic properties of the neutrino as part of the Majorana project.

Quantum, Molecular, Nanoscale and Materials Physics

Faculty list:

Harald Ade, David Aspnes, Jerry Bernholc, Jason Bochinski, Marco Buongiorno Nardelli, Laura Clarke, Hans Hallen, Gerry Lucovsky, Jacqueline Krim, Wenchang Lu, Lubos Mitas, Robert Nemanich, Thomas Pearl, Michael Paesler, Christopher Roland, Celeste Sagui

Summary of current research and scholarship perspectives:

For the past twenty-five years, the materials physics program at NCSU has had national visibility particularly in electronic and optoelectronic materials, surfaces and interfaces, amorphous semiconductors, theory and simulation, and more recently in the area of nanoscale friction. The research has evolved to include a significant focus on nanostructures and dynamics at the nanoscale. Faculty and researchers from the physics department have been leaders in the advancement of nanoscience and nanotechnology and have brought significant attention to this

field at NC State. The success of these efforts have set the stage for significant expansion in this research area. Moreover, several of the research programs are developing significant programs and collaborations that focus on the interface of solid materials and biological molecules.

The research has had an essential interdisciplinary character, with many programs supporting collaborations with faculty in Electrical Engineering, Chemical Engineering, Materials Science, and Chemistry. In fact, students from these departments are often co-supervised during their graduate studies by faculty from physics, and conversely, physics graduate students are often co-supervised by faculty from other departments.

The program on theory and simulation has been particularly successful in developing a broad and cohesive effort. This effort, which spans the full range of materials to biological phenomena forms a critical component of the Center for High Performance Computing. The theory program has a significant collaboration with ORNL which includes two joint faculty positions.

The faculty from physics have led or substantially contributed to the leadership of several significant multi-investigator, interdisciplinary programs. These programs address complex scientific and technological problems that are typically beyond the scope of single investigator research efforts. In addition to these large interdisciplinary programs, most faculty have individual research programs through various agencies and also industrial collaborations that blend basic and applied research and expose students to technology transfer opportunities.

The experimental research program involves 15 physics undergraduates, 33 physics graduate students 4 postdocs, 4 interdisciplinary undergraduates, 11 interdisciplinary graduate students. The theoretical research program involves 1 physics undergraduate, 13 physics graduate students 12 postdocs, and 4 interdisciplinary graduate students.

Significant Current Initiatives and Collaborative Projects:

Center for High Performance Simulations (CHiPS) has 26 faculty as members, drawn from the departments of Biochemistry, Bioengineering, Chemical Engineering, Chemistry, Civil Engineering, Computer Science, Electrical and Computer Engineering, Genetics, Marine and Earth and Atmospheric Sciences, Mechanical and Aerospace Engineering, Materials Science and Engineering, Nuclear Engineering and Physics. The external funding of the members exceeded \$8M in FY06. As the Center evolves, the multidisciplinary interactions will strengthen and will eventually enable large-scale proposals in key thrust areas. The Center sponsors Visiting Scientists and Seminar Speakers who are leaders in these areas and plans to develop appropriate courses at both undergraduate and graduate levels. CHiPS also plans to facilitate and organize meetings, conferences and workshops related to the computational sciences.

Extreme Friction MURI: *Multi-functional Extreme Environment Surfaces: Nanotribology for Air and Space*, DoD MURI 2004 program solicitation, J. Krim, PI, with 7 co-PI's at NCSU, UC Irvine and the Naval Academy. (5/1/2004 – 4/30/2009) \$5.5 M

Polarity NIRT: (NSF NIRT: Configurable Nano Patterned Polar Surfaces for Molecular Pattern Formation and Transfer): involves polarity domains of patterned ferroelectric surfaces to drive

selective deposition, self assembly and selective chemical reactions. (PI: Nemanich, Co-PI's: Gruverman, Pearl, Clarke, Gorman, Kingon, Oliver-Hoyo)

AEMP: Transition Center for Front End Processing (SRC and Sematech): studies of band alignment and internal fields in high-k – metal gate stack structures. (PI: Osburn, NCSU Co-PIs: Nemanich, Whitten, Lucovsky, Parsons, Misra, Kingon, Maria)

Laboratories and Facilities:

Cox: CHIPS, Clarke, Hallen,
Partners III: CHIPS, Krim, Pearl, Nemanich
RBII: Aspnes

Vision for the future:

The strong and broad programs in materials physics are expected to continue and grow in the future. The expectation is that the research will grow along three significant directions: 1) quantum electronics, 2) nanodynamics, and 3) nano-bio interfaces. Moreover, it will be necessary to develop significant efforts leading to broader impact and also to develop approaches to consider societal impact at the early stages of technology development.

The quantum electronics efforts have involved experimental programs of Aspnes, Hallen, Lucovsky, and Nemanich and theory and simulation programs of Bernholc, Buongiorno Nardelli, and Roland. These programs have in the past focused on the properties of interfaces of electronic materials. The programs are expected to grow in nanoelectronics, single electron and spin based electronics, plasmon systems, and molecular electronics. In fact, the theory programs have already evolved along these directions, with significant contributions in the areas nano and molecular electronics. The electronics program at NC State has been dominated by the Center for Advanced Electronic Materials Processing (AEMP) which has been largely directed by ECE faculty. This program appears to have ended, and there is now a tremendous need and opportunity for new leadership and new research directions. We propose developing a new nanoelectronics program based on single electron and spin based electronics, plasmon systems, and/or molecular electronics. It would be most appropriate if this program was developed in the RBII area since the facilities seem appropriate.

The research in nanoscale science and technology in physics has broad and significant achievements that can be generally classified as nanodynamics. Topics include nano polymer composites, nanofriction, molecular rotators, optoelectronic molecular nano patterned surfaces, carbon nanostructures, nanochemical reactions, and nanotransport. Researchers have also been involved in significant advances in new characterization techniques to enable characterization of nano materials (FEL-PEEM, QCM-STM, x-ray microscopy). The nanoscience program is poised to achieve national and international recognition and leadership. We are proposing two significant steps to enhance the overall impact of the programs:

- 1) The formation of a Center on Nano Dynamics. This center would bring together the leading faculty working in nanoscience and technology into a functional unit which would manage information, support facilities, develop an industrial affiliates, develop effective broader impact and education collaborations, and develop collaborations focused on societal impact. The development for such a center should move forward with

a commitment for three to six new faculty which could fall in physics or chemistry or shared positions between the two departments.

- 2) Development of an NC State degree granting program on Nanoscale Science and Technology (NST). The impact of the research could be substantially magnified with the development of a degree program to both provide a knowledge foundation for our 'nano' research graduate students but more importantly to offer undergraduate courses and training courses to science and engineering and non-science majors. The program could also offer opportunities for seminar based courses to develop concepts related to societal impact.

The area of nano-bio is most likely going to be the next large growth area in physics. We expect that the proposed center for nanodynamics will include a significant nano bio component. The vision for growth in this research area is described more completely in the section on Biophysics, Complex and Non-linear Phenomena.

Specific Recommendations:

2006-2009

- Search for four junior faculty in the areas of experimental quantum/molecular electronics, nanodynamics or Nano-bio. Develop a cluster hire strategy with Chemistry or other departments involved in advancing nanoscience at NCSU.
- Develop a plan for a Center on Nanoscale Dynamics
- Develop a plan for an NC State degree granting program on Nanoscale Science and Technology (NST).

2009-2012

- Search for two junior faculty (theory or experiment).

2012-2016

- Search for two junior faculty (theory or experiment).

Required Resources:

Faculty lines: 8 new faculty lines (against 4 possible retirements)

Staff: 1 Admin for Center of Nanoscale Dynamics, 1 Admin for NST Program

Laboratories and Facilities: Renovate laboratories in RBII for three faculty. Provide laboratories in PIII or Riddick for three new faculty.

Faculty Expertise:

Harald Ade: Development of characterization techniques with compositional sensitivity and 10-20 nm spatial resolution, primarily NEXAFS microscopy and resonant x-ray scattering. Applications of these techniques to macromolecular materials.

David Aspnes: Condensed-matter physics, specializing in linear and nonlinear optics and applications of same to materials deposition and analysis

Jerry Bernholc: Theoretical condensed matter physics, materials science and chemistry; computational physics, nanoscale science and technology. Current research focuses on fundamental processes in molecular and nanoelectronics, new theoretical methods, low-dimensional transport in nanotube and graphene-based materials and devices, novel ferroelectric polymers, multiscale simulations of solvated biomolecules and petascale computing.,

Jason Bochinski: Novel, optics-based experiments designed to elucidate the underlying physics occurring at the nanoscale level, characteristically utilizing light as a non-contact probe. Current projects include observing hindered molecular motion within self-assembled monolayers via fluorescence anisotropy measurements, as well as spectrally-resolved fluorescence quenching studies for investigating optimization of electron transfer between excited chromophores and small ligand-stabilized gold nanoparticles.

Marco Buongiorno Nardelli: application of ab initio electronic structure techniques to the theoretical study of the physics of materials and nanostructures. Current research programs carried out in a collaborative environment at NCSU and ORNL focus on various aspects in the fields of computational materials and high performance simulations. Examples include: molecular electronics at the nanoscale and quantum transport in molecules and molecular materials; design of novel electronic devices; physics and chemistry at interfaces and surfaces; theoretical developments of ab initio quantum transport, DFT-based methods and multiscale computational techniques.

Laura Clarke: Electrical, dielectric and optical measurements of organic molecules, macromolecules or biomolecules on surfaces. Our group is focused on the study of fundamental physics (i.e., phase transitions, electron transfer dynamics, and wave propagation) in systems built using organic chemistry; for instance, probing rotator phases in self-assembled monolayers and exploring two-dimensional glass transitions in a sheet of rotating dipoles.

Hans Hallen: projects in nanoscale characterization with scanning proximal probe microscopes utilizing optical, electrical, and photoemission probes. Oriented molecular deposition, scanning nano-transport microscopy, surface modification for functionality, and research efforts in biophysics (nanoprobe for nucleus manipulation and intracellular signaling studies), lidar (deep UV and multistatic), and wireless communications (UWB propagation, long range prediction).

Jacqueline Krim: research seeks to measure friction in controlled environmental conditions and atomically well-defined contact geometries. Projects are in progress to explore model lubrication systems, the fundamental mechanisms of energy transfer at a sliding interface, the possibility of transporting surface atoms via the frictional drag forces of electrical currents, and superconductivity-dependent friction.

Wenchang Lu: Current research activities are focused on the first-principles studies of nanoscale systems, such as molecular electronics, organics/semiconductor, and organics/metal nanostructures. The structural, electronic, optical, and quantum transport properties are investigated within density functional theory (DFT) and beyond. $O(N)$ methodology for

electronic and quantum transport calculations is developed to deal with systems consisting of several hundreds to thousands of atoms.

Lubos Mitas: Electronic structure of new materials such as nanosystems, clusters and solids; computational many-body methods for quantum systems such as quantum Monte Carlo and path integrals; electronic structure of biomolecules, especially, metallic reaction centers; mathematical and theoretical physics of quantum many-body systems.

Robert Nemanich: research is focused on growth, processing and characterization of surfaces, interfaces, epitaxial films and nanostructures. The emphasis is on electronic and optoelectronic materials, polar materials, and carbon based nanostructures. The goal is to determine new approaches to design functionality through control of interface structure and nanoscale patterning.

Thomas Pearl: studies of interactions between surface and adsorbate properties that induce morphological transitions, change electronic characteristics, and determine growth and ordering. Particular interest lies in studies utilizing scanning probe microscopies to elucidate mechanisms for surface driven phenomena, single molecule behavior, and molecular junction characteristics.

Michael Paesler: studies of the amorphous-crystalline phase change by investigating local atomic bonding configurations including x-ray absorption studies of chalcogenide materials for reconfigurable interconnect technology. Informal collaborate with colleagues at the NC Natural Science Museum on studies of paleophysics.

Christopher Roland: Theoretical condensed matter physics, materials science, statistical mechanics, and biophysics. Examples of current projects include first principles simulations of nanoscale devices, quantum transport, antibiotics, solvated systems, surface science systems, multiscale methods and phase field modeling of nanopatterning.

Celeste Sagui: Theoretical biophysics, statistical mechanics, and condensed matter physics. Current work is focusing on new methods and algorithms for biomolecular simulations, biochemical reactions, multiscale modeling, biopolymers, protein folding, antibiotics, molecular electronics and dynamics of phase transitions,

Biophysics and Soft-condensed Matter Physics

Faculty list:

Harald Ade, Jerry Bernholc, **Karen Daniels**, **Hans Hallen**, Lubos Mitas, Robert Nemanich, **Robert Riehn**, Christopher Roland, **Celeste Sagui**, and **Keith Weninger**

Summary of current research perspectives:

Emergent phenomena, both biological and physical, arise and are governed by the subtle balance between many factors and small forces. The chemical, thermal, electrostatic and mechanical energies converge on the nanometer lengths scale (see Fig. 1), which is thus the natural length scale where this subtle competition occurs. While many systems are out of equilibrium, they can nonetheless exhibit steady state behavior. Both dynamical and statistical characterizations play important roles. Quite often, the system size is large and the physics required for description has to include “entropic” contributions, i.e. consider the Gibb’s Free energy, rather than provide a description purely based on energies and potentials. With the emergence of biology and nanotechnology as key drivers of the scientific enterprise addressing some of the most fascinating scientific questions and technological challenges, an opportunity arises for the physics community to make important contributions.

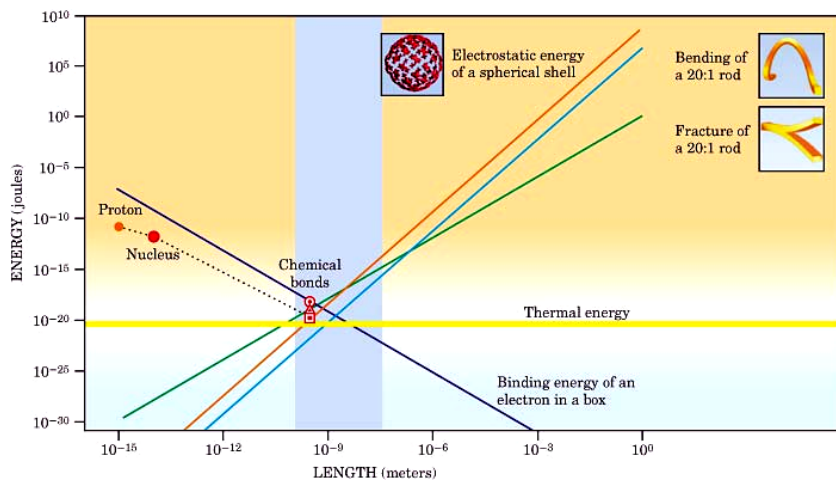


Fig. 1. Confluence of energy: Scaling of thermal, chemical, mechanical and electrostatic energy scale with object size (From “The biological frontier of Physics”, R. Phillips and S. R. Quake, *Physics Today*, May 2006).

Already, with the decoding of various genomes, an unprecedented explosion of biological information is becoming available to scientists, whose significance needs to be understood, classified and systematized. Physicists—in interdisciplinary collaborations with biochemists, chemists, biologists, materials scientists and medical doctors—are poised to play a significant role in this process, and can already claim success through the development of fundamental experimental tools such as X-ray diffraction and NMR techniques, which are currently invaluable for the understanding of biomolecular structure and function. Our role is not just limited to development of these tools. Physicists are also poised to make direct contribution to the physics of biology and soft condensed matter through novel experiments and sophisticated simulations. The study of biomaterials and the combination of biomolecules with nanotechnology furthermore holds forth the promise of new technologies.

“Biophysics and Soft-condensed matter physics” should here be interpreted broadly, and encompasses “complex and nonlinear phenomena” of materials, as well.

The research programs presently involve 2 physics undergraduates, 11 physics graduate students 4 postdocs, 3 interdisciplinary undergraduates, 3 interdisciplinary graduate students.

Significant Current Initiatives and Collaborative Projects:

Through the prior departmental strategic planning and the compact planning process of the university, the Physics Department has committed itself to establish a research group of critical

size in Biophysics. A graduate level biophysics course (PY590) will be taught for the first time in the spring of 2007 by K. Weninger.

ITR/AP: Tools and methods for multiscale biomolecular simulations – NSF (PIs- Celeste Sagui, Jerry Bernholc, Lubos Mitas, Christopher Roland (NC State Physics), Lee Pedersen (UNC-CH Chemistry), John Board (Duke –Computer Science), Tom Darden (NIEHS)) This collaboration is aimed at developing science and codes for large-scale biomolecular simulations and feed into the AMBER consortia.

In addition, Celeste Sagui has significant ties with the local NIEHS and aim to foster and enhance these with time.

Keith Weninger participates in collaborative projects studying regulation of neurotransmitter release (George Augustine, Neurobiology, Duke University), DNA mismatch repair proteins (Dorothy Erie, Chemistry, UNC-Chapel Hill), viral infection pathways (Dennis Brown, Biochemistry, NCSU) and the molecular actions of scorpion toxin (Paul Fletcher, Biochemistry, East Carolina University).

Harald Ade is a member of the Garcia MRSEC “Polymers at Engineered Interfaces”, and collaborates on polymer clay nanocomposites/polymer thin films with Prof. Rafailovich and Sokolov, Materials Science, Stony Brook University. He also collaborates to use advanced synchrotron radiation tools (NEXAFS, NEXAFS microscopy, resonant scattering) and has a 15 year collaboration with Dow Chemical.

Karin Daniels present collaborates on phase transitions in granular materials (Bob Behringer, Physics, Duke University), size-segregation in sheared granular materials (Michael Shearer, Mathematics, NCSU), instabilities of droplets spreading on compliant substrates (M. Shearer & B. Behringer), and seismological and geological implications of granular behavior, (Peter Malin and Nick Hayman, Earth and Ocean Sciences, Duke University).

Vision for the future:

Given the increasing importance of bio- and soft-condensed matter physics as an active component of physics research, the Department of Physics aims to play a leadership role in nucleating and developing a Biophysics and Soft Materials effort here at NC State.

Several critical areas need to be addressed to achieve critical mass and critical presence vis a vis students, other campus units and the outside research community:

- Faculty hires: The department aims to build up the strength of the experimental biophysics effort from currently one to at least three faculty in the next few years. In addition, the hiring of two experimental, soft-condensed matter physicists (e.g. nanofluidics, colloids, membranes, gels, etc.) who can effectively bridge the gap between biophysics and our solid-state physics/nano efforts would help solidify NC State in a leadership position.
- Student growth/curriculum development: The physics background required for biophysics and soft condensed matter research is often neglected and not taught well in many undergraduate and graduate programs, including ours. A set of new undergraduate and

graduate courses will be developed to rectify this problem. This might include a tailored undergraduate course in Thermodynamics for Physics majors, a general education course at the 100 or 200 level, a graduate level introductory course as well as some specialized graduate courses. Only the right mix of courses will support growth in the number of students working in and being educated in this research area.

- A truly interdisciplinary biophysics/bioscience program that draws upon the expertise and background of faculty and students from other departments needs to be established.
- Sharing of tools/techniques/knowledge: Collocation of faculty in this research area in Riddick is highly desirable to allow for the efficient sharing of tools and knowledge. A biophysics/Gibb's Free Energy physics research group that couples effectively to the nano-physics activities should be established in Riddick, enhanced by a Shared User Facility that is supported by the department.
- A biophysics/soft matter seminar series, drawn primarily from local expertise, would further enhance communication and enhance graduate education.
- The theoretical and experimental efforts should be overlapping as much as possible.

This research area currently lacks critical mass, partly due to its diversity of efforts. Achieving critical mass and critical focus, particularly in biophysics, should be a relatively high priority of the department.

Specific Recommendations:

2006-2009

- Search for three junior faculty in the areas of experimental and/or theoretical biological and soft-condensed matter physics. Develop a cluster hire strategy with Microbiology or other departments involved in advancing biological physics at NCSU.
- Develop additional undergraduate and graduate courses in this area

2009-2012

- Search for two junior faculty in the areas of experimental and/or theoretical biological and soft-condensed matter physics.

2012-2016

- Search for two junior faculty in the area of experimental and/or theoretical biological and soft-condensed matter physics.

Required Resources:

Faculty lines: 7 new faculty lines (against no anticipated retirements)

Staff: Support staff to help maintain and operate shared experimental facilities in Riddick.

Laboratories and Facilities: Provide laboratories in PIII or Riddick for new faculty.

Faculty Expertise:

Harald Ade: Development of characterization techniques with compositional sensitivity and

10-20 nm spatial resolution, primarily NEXAFS microscopy and resonant X-ray scattering. Applications of these techniques to soft-condensed matter and macromolecular materials.

Karen Daniels: Experimental studies of model nonequilibrium and nonlinear systems. Recent areas of interest include dynamics of size segregation in granular materials, granular-like behavior in earthquakes and faults, statistical mechanics of granular materials, and interfacial/morphological instabilities in complex fluids

Hans Hallen: Experimental nano- and biophysics. Active projects in nanoscale characterization with scanning proximal probe microscopes utilizing optical, electrical and photoemission probes, Oriented molecular deposition, scanning nanotransport microscopy, surface modification for functionality and nanopores for cellular nucleus manipulation and intercellular signaling studies.

Robert Riehn: Experimental bio- and nanophysics. Physics of polymers and polyelectrolytes, especially biomolecules such as DNA under nanoconfinement. Investigations of genetic information on DNA using nanochannels (<100 nm wide) and fluorescence microscopy. Direct electrical detection of DNA in nanochannels, active nanoplumbers, on-chip near-field Raman.

Celeste Sagui: Theoretical biophysics, statistical mechanics, and condensed matter physics. Current work is focused on new methods and algorithms for biomolecular simulations, biochemical reaction, multiscale modeling, DNA, biopolymers, protein folding, and antibiotics.

Keith Weninger: Experimental biophysics. Current research focus is on revealing molecular mechanics at work in complex biomolecular systems with the use of single molecule, optical spectroscopy. Current efforts are addressing questions in protein folding, enzymatic function, and viral infection in living cells. Of interest are also membrane phenomena, including membrane fusion and protein translocation.

Education and Societal Impact

Faculty list:

Robert Beichner, Ruth Chabay, David Haase, John Risley, Bruce Sherwood.

Summary of current research perspectives:

Education in science and technology has taken new meaning with recent reports that suggest that the US leadership in many technology areas will be challenged in the very near future. Moreover, scientific and technological advances impact our society in a multitude of ways ranging from science policy to training our workforce to educating our society of benefits, risks and security measures. Funding agencies such as the National Science Foundation have sought broader impact to research programs and have specifically encouraged the integration of education and research. This perspective has now been further broadened to include the integration of researchers and sociologists to develop strategies for societal impact.

The education and societal impact program in physics has had two primary focuses: 1) physics education in introductory physics courses and 2) developing partnerships with K-12 science and mathematics teachers across the state to enhance teacher effectiveness, and to increase the number of physics teachers generated within North Carolina.

The Physics Education Research Group is engaged in research and development of improved pedagogy and content in physics education, with emphasis on introductory-level college physics and the application of instructional technologies for problem solving, simulation, and visualization. The approach involves theory, scholarship, and experiment.

The introductory physics component has included the development of a broad based introductory physics curriculum that includes modernized content (Matter and Interactions), student oriented software for modeling physical phenomena (Vpython), a student centered classroom environment that integrated laboratory and lecture (SCALE-UP), and a web-based homework delivery system that offers instant feedback to students (WebAssign).

The mission of The Science House is to partner with teachers to emphasize hands-on learning in science and mathematics. The program has a strong commitment to underrepresented groups with the Imhotep Academy as a specific example. Through school demonstration programs, student science camps, teacher workshops and innovative laboratory training, and support projects, The Science House annually reaches over 3,000 teachers and 25,000 students in 60 North Carolina counties.

The research program involves 1 undergraduate, 3 graduate students and 1 postdoc. The Science House has a professional staff of 10.

Significant Current Initiatives and Collaborative Projects:

SCALE-UP: Student-Centered Activities for Large Enrollment Undergraduate Programs

(Beichner & Risley) There is an extensive SCALE-UP collaboration effort, involving approximately three dozen institutions. The pedagogy and classroom environment has been adopted and adapted (or funding to being actively pursued) in at least 35 US institutions. SCALE-UP is also being adopted in Mexico and Israel. Moreover, the list is certainly growing.

Matter & Interactions (Chabay & Sherwood) the Matter & Interactions curriculum has been adopted at a growing number of institutions and significant collaboration with faculty at several institutions. Revisions to an existing textbook are underway.

Matter & Interactions for high school teachers (Sherwood) is a distance learning version of the Matter & Interactions course offered to in-service high school physics teachers with the goal of deepening their knowledge of physics from a contemporary point of view, coupled with discussion and reflection on the impact on their own teaching. Teachers who have taken the course have been extremely enthusiastic. The course has pioneered the technological innovation of interactive video lectures.

VPython (Chabay & Sherwood) is an open-source software project housed in the Physics Education (PER) group which has integrated contributions from the Australian National University and elsewhere.

WebAssign (Risley) is a commercial web-based homework delivery system that grew out of a research project. It continues to function as a research tool as well as the most widely-used such system in the sciences. It is used by 160,000 students at 615 schools around the world.

Physical Review Special Topics-Physics Education Research (Beichner) is a journal that is edited by Beichner. It is the newest member of the Physical Review series offered by the American Physical Society. Editorial offices are located on campus, administration is handled by APS in Long Island.

PER-Central (Beichner) is a web-based collection serving the physics education research community. Editing is carried out on campus with web service provided via the Compadre digital library system of the American Association of Physics Teachers in College Park, Maryland.

The Imhotep Academy, Photonics Xplorers and Photonics Leaders (Haase) are a sequence of year-round hand-on science and technology programs, grades 6-12, that encourage and mentor students from groups underrepresented in the sciences toward STEM careers.

The Science House

- **The Science on the Road Program** (Haase) brings lively physics, chemistry and earth science demonstration programs to schools across the state.
- **The Science House Website** (Haase) is a rich resource of student-learning activities and teaching ideas that draws over 60,000 visits per month.
- **The Rural Schools Projects** (Haase) help middle school mathematics and science teachers across North Carolina to use computer-based laboratory technology in their classrooms. These activities are led by Science House professionals located at five regional satellite offices.
- **Conferences on K-12 Outreach from University Science Departments** (Haase) The Science House has annually hosted conferences of scientists and science educators to discuss issues in how university and corporate laboratories can contribute to the improvement of STEM education.
- **Outreach from NSF Research Centers** (Haase) The Science House leads K-12 education outreach programs for two NSF-supported multi-campus scientific research centers. The programs include teacher training workshops and curriculum materials distribution in four states.

Laboratories and Facilities:

Interview rooms, 5th floor of Cox

SCALE-UP classroom, Fox labs

The Science House includes classrooms, a teaching laboratory, and a computer-learning center plus five regional offices in Asheville, Lenoir, Fayetteville, Jacksonville and Edenton.

Vision for the future:

The NCSU PER group is a leader in its field, is highly visible, and brings sustained recognition to the Department. Its work has been cited in *Physics Today* and *Science*. The department head attends a prestigious annual national meeting of top physics departments as a result of the PER group's reputation. We hope to continue being a leader in the field and to produce innovative, effective curricular materials. The University has proposed to establish a center for discipline-based education research. The researchers in physics should expect to play a key role in the development of this center activity. With these opportunities it would be important to embrace

these activities with two (possibly joint) positions that would be associated with the center for discipline based research and/or with collaborative programs with the college of education.

The Science House is a learning outreach project of the University. Their mission is to work in partnership with K12 teachers to increase the use and impact of hands-on learning technologies in mathematics and science. During the past 15 years, the program has evolved from a department initiative to a college-level initiative, and is recognized as a model for how the research university can interface with K-12 education. The Science House has extensive collaborations across NC State and across the University system in North Carolina. The Science House will continue to expand its reach to science and mathematics teachers across the state, especially in the rural areas, and into neighboring states. The Science House is an effective conduit for the science education research of the university to be ported to the K-12 environment, to provide K-12 connections for disciplinary education research, and to facilitate the research-education collaboratives that address the Broader Impacts criteria of the federal funding agencies.

There is an opportunity need to conserve the intellectual investment and leadership of the Physics Education Group by hiring at least one new PER faculty in the near future. This is motivated by the impending reassignment/redirection of two senior PER faculty. The new faculty member(s) could be mentored and supported by the senior faculty in development of new research initiatives.

The group also sees the opportunity for a disciplinary education research cluster hire strategy that would broaden this effort across campus and integrate education programs in PAMS, CALS, Engineering, Education, Design and The Science House.

Specific Recommendations:

2006-20012

- Search for one junior faculty in the areas of physics education. Consider developing a cluster hire strategy that would integrate education programs across integrate education programs in PAMS, CALS, Engineering, Education, Design and The Science House.

Required Resources:

Faculty lines: 1 new faculty line (against 3 possible retirements/transfers)

Faculty Expertise:

Robert Beichner is an Alumni Distinguished Undergraduate Teaching Professor of Physics at NC State and coordinates the University's Science, Technology, Engineering, and Math educational innovation efforts for the Provost's office. He is founding editor of *Physical Review Special Topics: Physics Education Research* and was co-author of the leading introductory physics textbook. He has given 120 invited talks and colloquia. His research and development work includes the SCALE-UP project for collaborative, interactive learning in large classes, instructional technology, and assessment instrument design.

Ruth Chabay is co-author of the *Matter & Interactions* textbook which incorporates a contemporary view of introductory physics. She has done research on student learning in introductory physics courses and has also studied motivation in computer-assisted learning. She has over 30 years of experience in the use of computers in science education, has published award-winning educational software, and has contributed to the development of system software.

David Haase is an Alumni Distinguished Undergraduate Teaching Professor of Physics at NC State and Director of The Science House. He has worked with teacher-training programs for twenty-six years and has published over 120 papers on topics in physics research and science education.

John Risley is engaged in research and development on the effective utilization of online homework systems for physics instruction. He started the Courseware Review column in the *Physics Teachers*, is the founding editor of *Physics Academic Software* and founder and president of Advanced Instructional Systems, Inc. – the home of WebAssign, and has conducted many teacher education workshops during the past 23 years and was the PI for the Physics Teacher Institute held in the 1990s at NC State. He has published many papers in physics research and physics education.

Bruce Sherwood is co-author of the *Matter & Interactions* textbook which incorporates a contemporary view of introductory physics. He has over thirty years experience in the use of computers in physics education in a variety of modes and has played major roles in the development of four programming environments (TUTOR, MicroTutor, cT, and VPython). He has done research on student learning in introductory physics courses. He has published 70 papers and in the last 5 years has given 30 invited talks and workshops.

B. Advancing the Physics Undergraduate Program:

1. Increase the number of graduating students by 50%, from 16 per year in 2000 to 24 per year by 2016.

There are four main reasons for doing this: (1) internal allocation of resources requires that students demonstrate interest in our programs; (2) external recognition is partly linked to program size; (3) some of our best graduate students historically have been NC State undergraduates who chose to stay; and (4) we can provide an excellent educational experience that would be of great benefit to more students than now take advantage of it.

This goal is extremely ambitious, but one that we believe is attainable through more vigorous recruiting and more extensive (and better advertised) financial aid. However, in-state recruiting has almost reached saturation, and further progress will require attracting top out-of-state students and nontraditional physics students.

2. Increase both the number and size of scholarships and awards.

This is particularly desirable. Current scholarships of \$1000/yr are too small to provide a significant recruiting edge and need to be increased to at least \$2000/yr. Adding awards for

continuing students will target transfers. If we wish to attract out-of-state students for whom the annual cost is about \$18,000, we need at least one or two awards to bridge the gap between in-state and out-of-state tuition. Work-experience awards offer another alternative, with an added publicity advantage if they involve research.

3. Enhance recruiting efforts.

We can increase the pool of interested students by (1) increasing the number of visits of faculty to (mostly local) target high schools; (2) improving our website, for example by listing student careers and salaries and by providing contact information for Department graduates willing to talk about our programs with prospective students; (3) developing new materials that stress employment and career opportunities for bachelors' graduates, thereby overcoming the general idea that "there are no jobs in physics"; (4) working more closely with local organizations such as the AAPT section, NC Science Teachers Association to publicize our programs and distribute materials; and (5) using summer programs to bring in strong high-school students from selected out-of-state schools such as Thomas Jefferson High School in Alexandria. Yields from these programs are quite high.

4. Promote the BA as a second degree, with Science Education as well as with any engineering degree.

Work with Engineering representatives to allow the maximal amount of equivalencies and double counting consistent with our delivering a respectable physics degree.

5. Continue to develop the curriculum to meet current needs.

It is essential to keep our programs up-to-date and to add new options that will make them attractive to nontraditional as well as traditional physics students. This will require (1) reviewing the BS curriculum; (2) add/ rearrange junior courses; (3) continue to develop informal junior-year laboratory exercises; (4) consider adding new BA-specific courses; and (5) plan new undergraduate programs such as applied physics.

6. Examine the feasibility and perhaps implement a "study abroad" program.

There is considerable merit – both as a way recruitment and as an educational tool – in having a one-year "study physics abroad" program. Currently, a nascent program is being set up with NCSU's Prague Institute. It will be interesting to see the student and faculty response to such a program. If found to be useful, such programs should be integrated into the current physics undergraduate program.

C. Advancing the Physics Graduate Program:

1. Increase the quality of the graduate students

The continued investment in research active faculty during the last 10-15 years has resulted in a significant improvement in faculty quality. In contrast, the quality of the students has not

proportionally improved and a gap between the quality of faculty and student has opened up. Consequently any improvement in student quality could substantially leverage the prior investment in the faculty. Graduating students are also one of the most visible products of our activities. Improvements in the quality of students will be vital for the further advancement of our Department. Unfortunately, it will be a complex and time consuming task to achieve such improvements without a clear path to success. A strategy will be developed by the Director of Graduate Programs that includes a number of incentive and fellowship packages to attract a few very highly qualified students each year.

2. Increase the number of graduate students.

This is a complex issue relative to the undergraduate situation, owing to the need to provide support through fellowships or teaching or research assistantships, and the need for the faculty to generate enough support and positions. Graduate education is significantly more highly specialized, with research topics that can change substantially according to federal funding. To justify a broad spectrum of graduate-level courses a critical mass of graduate students (and of faculty) is required. The optimum number of graduate students is therefore critically connected to the number of graduate faculty.

The graduate program currently fits the research needs of the Department fairly well. Most Physics Department research programs use physics graduate students, although some of our larger applied programs are using degree candidates from other departments, often engineering. Thus some growth in the graduate student population is warranted. This fact, along with the plans to add to the faculty size, result in a goal of increasing the number of entering graduate students from about 15 per year to about 25 per year to achieve a total enrollment of about 120 students.

Assuming that the faculty size increases as planned under Faculty Development, we can increase the number of graduate students by (1) actively recruiting in the new research areas of the department; (2) increasing the number of fellowships and research assistantships; (3) expanding the positions supported by the graduate school tuition remission policy; and (4) adding degree options such as instrumentation or applied physics.

3. Enhance the effectiveness of the recruiting process.

We have studied our market by surveying students who enter our program and those who do not. This analysis shows that our recruiting resources are best spent on two items: a) maintaining an attractive up-to-date webpage; and b) bringing prospective candidates to NCSU for a campus visit. If we are willing to change the student demographic profile, we can follow the recent advice of our visiting committee and accept highly qualified foreign students. Although it is not clear how much this can be supported by the graduate school tuition remission plan, we have decided to move in this direction. In particular, we are attempting to increase the number of fellowships available to graduate students by seeking funding from NSF, private foundations, and industry.

4. Revamp and continuously update the departmental website

The departmental website is a crucial element of our projection to the outside world, not only locally in terms of North Carolina but also internationally. It is therefore a key element for enhancing the status and visibility of the department, as well as an important recruiting tool. It is therefore absolutely crucial that the website be revamped to reflect the current department and be continuously revamped.

5. Ensure that we are providing the best education for our students.

We approach this by examining course profiles on the transcripts of recent graduates to determine the breadth and depth of the education these students have received and are considering changes in academic policy to ensure that the proper breadth and depth are manifest in all our graduates. Finally, we are examining our testing policy to determine if the departmental qualifying examination properly fulfills its goals.

Nevertheless, we lose a substantial fraction of our students to other disciplines and career paths. We are currently considering changes that can prevent this, a physics instrumentation degree, most likely at the MS level, and an applied physics degree. Above all we cannot dilute our degree program so as to impugn its academic integrity.

D. Infrastructure

(a) Advancing the Department's space needs.

Space is a critical resource required for the development of faculty, education, research, and developing a sense of community. The Department currently has 58,008 sq. ft. allocated to it in seven buildings on both North and Centennial Campuses. The department is about to undertake a major space move, which will result in the allocation of about 55000 sq. ft. in Riddick Hall, 9050 sq. ft. in Fox, 13,170 sq. ft. in Partners III, 32,093 sq. ft. in other North Campus buildings, and 4196 sq. ft. in other Centennial Campus buildings. The space in the 'other' buildings would be lost as the faculty using that space retire. Division across both campuses makes it difficult to maintain the collegial interactions and coherence needed to develop a first-rate department, but the space in Riddick alone is not quite sufficient for the department even at its present size and even if the entire building was allocated to Physics. The most critical short-term space need is to move the teaching laboratories currently in Fox closer to the faculty in Riddick. For this to happen, Physics must control the entire Riddick building. The next most critical space need is to reduce the rental costs associated with space to the college so that we receive more overhead return so that we can grow our faculty as we propose. We must make an effective case to the Dean and Provost that space needs are an integral part of our development plan.

In the short term, based on the number of new hires and the proportion of experimentalists to theorists the Department will need to provide about 25,000 sq. ft. of research and office space for the new faculty. While faculty projected to retire by 2016 currently occupy about 16,000 sq. ft., more than half of that will not become available until the last half of this period. The short-term need is therefore for about 5,000 sq. ft. of space, much of which for research laboratories.

In the long term, space needs will have to focus on placing Physics at a location near the hub of science research at the University. The desired goal of NCSU to be considered among the top tier

academic institutions cannot be achieved by advancing only the engineering and technology sectors alone, but by advancing the mathematical, physical, and natural sciences in parallel. Toward this end an 87,000 sq. ft. Physical Sciences Research Building (formally requested by the Department in the late 1980s) is now a candidate for the Bond 2 package. It would provide much-needed, high quality research lab and office space adjacent to Riddick Hall, and would enhance the interdisciplinary interactions of the departmental faculty with faculty in other units at NCSU.

Action items:

- 1. We will continue with an ad hoc space committee which will continuously examine how space needs are to be allocated in order to ensure its most effective use.**

Among other tasks this Committee will develop a cross department/cross college effort to find strategies for advancing the institution as a whole so that our competition is viewed as lying primarily outside NCSU. We will also remain aware of what's going on regarding relevant issues within the University, State, and Nation so as to be able to respond in a timely and effective manner.

- 2. We will continue to press the College and the University for a solution to the Centennial Campus rent problem.**

We will do this effectively, by assisting the Dean in making the case, and moving faculty as needed to other high quality, well-located space.

(b). Support Personnel and Services:

As of July 2006, we had 8 administrative/secretarial positions, 2 teaching support positions plus partial support for one-quarter of a position, 2 technical positions supporting the general department, and 2 technical support positions assigned to specific research programs funded by state appropriations or overhead. During the 2000-2006 period, the department added only a single EPA position.

As the number of students and faculty continues to grow and expand, there is a recognition that support personnel and support operations will also need to grow and improve, so that the department can fulfill its teaching and research vision. The support operations envisioned here include not only the administrative staff, but also the demo room operation, the lab and TA support, the shop, departmental IT support, etc. The department will continue to seek the ways and means for improving these operations, so that the needed support reaches the appropriate faculty in a timely and professional manner.

Action Items, personnel:

Continue to press the administration for increased support staff and operations, especially as the number of students and faculty continues to grow.

(c). Operating Budget:

Although the department has increased its budget, the department is currently financially strained because of start-up commitments and state-budget cuts. This is despite efforts by the faculty, who has increased the amount of overhead generated by the department from about \$900,000 to about \$1,900,000 in 2006.

Action Items, budget:

While the faculty continues their efforts to obtain research funding, relatively little of the overhead has actually been returned to the department, let alone the PIs. It is recommended that the departmental administration continue to press the College and University on this issue, so that the Department can successfully implement its stated mission and vision.