

Department of Physics 2008 Program Review Self-Study

Question 1: *Unit Overview* Provide an overview of your unit, including a summary of the resource requests justified elsewhere in the reporting.

The Department of Physics has made remarkable strides since the last Program Review in 2001. Our aspirations in the two most recent program reviews (1993 and 2001) were to build ourselves into a top-ten public physics department. We have accomplished that goal with the help of strategic investment by the university in hiring and retaining an excellent faculty. The Department of Physics has demonstrated that it is now, arguably, the best department at the University of Colorado.

Evidence of our accomplishments since the 2001 Program Review include:

- Two Nobel Prizes awarded to three faculty: Eric Cornell and Carl Wieman (2001) and Jan Hall (2005).
- Three faculty elected to the National Academy of Sciences: Noel Clark (2007), Deborah Jin (2005) and Margaret Murnane (2004). They join Eric Cornell (2000), John Hall (1984) and Carl Wieman (1995)
- Fourteen faculty members have been awarded the leading international research prize or prizes in their research field: Dana Anderson, Noel Clark, Eric Cornell, Jim Faller, Bill Ford, Chris Greene, Deborah Jin, Jan Hall, Henry Kapteyn, Margaret Murnane, John Wahr, Carl Wieman, Jun Ye, and Shijie Zhong.
- Seven assistant professors hired since 2001 have won the leading federal grants for outstanding young faculty (NSF CAREER, and DOE and Air Force Young Investigator grants): Meredith Betterton, Noah Finkelstein, Victor Gurarie, Michael Hermele, Heather Lewandowski, Tobin Munsat, and Ivan Smalyukh.
- Five faculty members have won leading national teaching awards: Michael Dubson, Deborah Jin, Margaret Murnane, Steven Pollock and Carl Wieman.
- Extramural research funding to physics faculty members has increased from \$13M to \$23M.
- Our national and international reputation has grown dramatically. The U.S. News reputational ranking of graduate physics programs now ranks us as tied for tenth among public institutions, up from 15th in 1999. Our overall ranking of public and private institutions is tied for 20th, up from 26th. U.S News ranks our atomic, molecular and optical physics program as the best graduate program the nation, with quantum physics and plasma physics ranked 4th and 10th respectively.

- The gender diversity of the faculty has improved dramatically. In 2001 there were four women on the physics faculty. In 2009/10 the faculty will include nine women, four full professors: Patricia Rankin, Anna Hasenfratz, Margaret Murnane, and Deborah Jin, and five assistant professors: Meredith Betterton, Heather Lewandowski, Alysia Marino, Minhyea Lee and Cindy Regal.
- Two new national research centers were funded since 2001: the Center for Extreme Ultraviolet Science and Technology (at CU and CSU) and the Colorado Center for Lunar Dust and Atmospheric Studies. These are in addition to the highly regarded Liquid Crystal Materials Research Center founded in 1995.
- Our physics Ph.D. program has grown from 150 to 204. This makes it the sixth largest physics graduate program in the nation. Enrollment in our undergraduate physics majors (physics, engineering physics and astrophysics) has grown from 261 to 442 in the same period, making it also one of the largest in the nation.
- Undergraduate and graduate student credit hours have grown from 20,708 in 2001 to 27,286 in 2009, a 31.7% increase. Campus credit hours increased by 15.5% during the same period.
- Physics has the highest percentage of Latin Honors graduates in the university, 23% over last ten years. The average across the College of Arts and Sciences is 6.3%.
- CU Physics is now a national leader in physics education research (PER) and innovations in science, technology, engineering and mathematics (STEM) education. The department's investment in a new physics education research group in 2003. The PER group quickly became nationally recognized has provided the nucleus for our department's leadership in many campus-wide science education programs: iSTEM, CUTeach, Science Education Initiative, and campus-wide lower and upper division teaching innovations using research-based learning methods such as peer learning/concept test/clickers, simulations and other interactive learning methods.
- The department has won several CU and national awards: CU President's Award for best graduate program as measured by student success, and Science Magazine Interactive Multimedia Award and Merlot Award for the Physics Education Technology Project.
- In its unit merit review of departments last year, the College of Arts and Sciences ranked Physics as the best department in the college in both research **and** teaching.
- Four faculty members have won major CU Awards since 2001: Distinguished Professor (Margaret Murnane), Presidential Teaching Scholar (Steven Pollock),

Professor of Distinction (John Wahr) and the Hazel Barnes Prize (Uriel Nauenberg).

While we are very proud of our successes and thankful for the strong support we have received from the Dean of the College of Arts and Sciences, the Provost and the Chancellor, we would like to focus on several critical challenges that now face us in continuing our trajectory of success. Becoming a top ten department has a tangible cost as it puts us in direct competition with the best physics departments in the nation for recruiting and retaining outstanding faculty and graduate students.

Resource Requests detailed elsewhere in the report

Space: The need for new space for the department has gone from problematic in recent decades to critical. The creation of new laboratory, office and teaching space was our highest priority in the 1993 and 2001 Program Reviews.

The Duane Physical Laboratory was completed in 1972. Since 1972 the university has grown by 35%. The departments, centers and institutes in Duane have all grown even more in every measure: faculty, funding, graduate program, undergraduate enrollments, etc. yet we still occupy the same physical space.

Physics has 76,800 assignable square feet in Duane, which has remained essentially constant for the last 20 years. The department has 8600 square feet of office, laboratory and high bay construction space in the Nuclear Physics Laboratory on the East Campus. Most all of that is now dedicated the Colorado Center for Lunar Dust and Atmospheric Studies. An additional 8000 square feet of laboratory and office and laboratory space in the Nuclear Physics Laboratory which used to be assigned to physics is now occupied by Science Discovery and the Program for Teaching East Asia, two campus outreach programs.

Since the last Program Review the physics tenure-track faculty has grown from 44 FTE to 49.9 FTE with corresponding growth in need for laboratory, office, conference and teaching spaces.

The Department of Physics is essentially out of assignable laboratory space with equally critical needs for office space. We are currently converting office space for graduate teaching assistants into laboratory space to meet the needs of new faculty who are about to arrive. Office space for graduate research assistants is nearly non-existent. Nearly all experimental graduate students have their desks inside their advisors' laboratories. This takes up additional valuable laboratory space and interferes with the safe operation of the laboratory. Teaching space in Duane is also in very short supply. As our graduate and undergraduate programs have grown, suitable classroom and teaching laboratory space in the building is now critically short. Physics classes, especially undergraduate classes, need to be held in close proximity to our lecture demonstration area in the basement of Duane so moving our classes to other buildings is not feasible.

This critical lack of space obstructs our ability to follow our strategic hiring plan for replacing faculty as they retire, much less acting on opportunities to grow into new research areas. Only three of the ten faculty likely to retire in the next decade have any assigned laboratory space. If our pattern of hiring roughly equal numbers of experimentalists and theorists continues, we will be unable to provide necessary laboratory space to meet even the minimal requirements for new faculty. To be competitive in hiring a new experimental scientist, one needs to provide, depending on research area, 500-2000 square feet of high quality laboratory space. Furthermore, as young faculty become successful, new extramural research grants create additional space needs for additional equipment, graduate students and postdocs. It is not unusual for successful faculty at peer institutions to be offered 5,000-10,000 additional square feet of laboratory space to meet their growing research needs. We are not currently able to even remotely meet this need. Theoretical scientists also require substantial office space, conference room and computing system space for their graduate students and postdocs.

We conducted a web search of the top 30 physics programs in the U.S. News survey of graduate programs in physics. All eight of the ten private universities ranked above us and four of the nine public universities ranked above us have new physics buildings or additions, or have major construction projects underway. In addition, three of the five public universities ranked immediately below CU in the rankings have major new construction projects for their physics departments. A fourth is housed in a building completed in 1994.

For over twenty-five years, the campus has been considering the construction of a addition attached to the east end of Duane, the so-called H-Wing. Planning for that 80,000 assignable square foot project included space for four departments, atmospheric sciences (ATOC), applied mathematics (APPM), astrophysics (APS) and physics. Only 20% of the total new space was to be assigned to the Department of Physics. Backfill space from units that moved out of disconnected space in Duane into contiguous space in the new wing was discussed, but with no assurance that space suitable for new laboratories would be included. Due to the rapid growth and success of the Department of Physics, even our minimal need for additional space would not be satisfied by that plan.

The Department of Physics desperately urges the campus to approve and fund a Program Plan to increase the space assigned to the Department of Physics by 100,000 assignable square feet. That space needs to be on the main campus as contiguous as possible with JILA, APS and other physical science units. The department would be delighted to cooperate with other physical science units to design, fundraise and construct a major new physical sciences complex on the main campus to meet the needs of our outstanding departments. Without new physical sciences teaching and research space, our Physics will quickly begin to lose out to other leading physics departments in recruiting, supporting and retaining an outstanding faculty.

Startup packages: The current distribution of fields in the department and our strategic investments in new areas have led to a dramatic increase in the cost of startup packages

for new faculty. Since the mid 1990's, the cost of startup packages for new faculty has more than doubled in most research areas and is 3-5 times higher in some areas. This applies to both experimental and theoretical scientists. The budgetary mechanism for funding startups changed in the 1990's when budget cuts forced departments to fund up to half of startup packages from their Departmental Administrative Indirect Cost Recovery (DAICR). In addition to startups, DAICR is intended to fund:

- administrative staff to support contract and grant accounting and administration,
- matching funds required on many extramural research grants, and
- maintenance and renovation of laboratory and research office space.

The 29% of ICR that is allocated to departments DAICR (before campus skims) was set long before departments were expected to cost-share substantially in startup packages. Startups have grown much faster even than grant funding so the current budget model is not sustainable. A new faculty member may need to raise \$10M or more in extramural funding before the department's share of a startup in many fields will be paid back via DAICR. Even our most successful young faculty will take a substantial fraction their careers to accomplish this. Even a department as successful as Physics is now set to incur over \$1M in debt for just the four most recent faculty hires. With other necessary costs that have to be funded from DAICR, the department will be in debt for five or more years even if we conducted no new hires during that period. In effect, departments are asked to play the role of investment bankers. Either a much larger fraction of startup costs should be funded centrally or the percentage of ICR that is distributed back to departments should be substantially increased.

Instructional support staff: The rapid growth in the number of undergraduate students in our physics majors and in student credit hours our in lower division service courses has resulted in the immediate need for two FTE of instructional support staff:

- 1 FTE dedicated to logistical management of the large service courses, including assisting faculty and coordinating instructional technology support.
- 1 FTE to maintain the junior/senior advanced labs for majors and provide additional assistance to maintain the freshmen/sophomore labs.

Endowed chairs: The Department of Physics, remarkably, does not have any endowed chairs or professorships. (Eric Cornell is a Marsico Chair, but that is based on an endowment to the President's office, not to Physics or JILA.) While this might not have been a major factor in retaining outstanding faculty when we were competing with top twenty public universities, this has become a significant hindrance now that we compete with the top ten public and private universities in the nation. We recommend that the Dean, Provost and Chancellor set endowed chairs for physics as a primary fundraising goal and work very closely with physics faculty to encourage donors to support this flagship department.

Graduate research fellowships: Graduate physics programs at peer institutions regularly often offer multiple year \$5-10K per year graduate fellowships to their top graduate student prospects. We need to be able to offer similar fellowships in order to

compete against the top ten public and private physics programs for the best US and international students. The department has been successful the last few years in fundraising for several new endowments for graduate fellowships but we need the support of the administration to continue this fund-raising effort.

Learning Assistants: Our lower division introductory calculus-based physics classes were dramatically restructured in recent years. The department made several research-based changes but the most dramatic was the replacement of recitations by one hour per week tutorials. The tutorials use a research-based curriculum that requires students to interact with each other and with the instructors in a Socratic learning environment. Research studies of this course show that students demonstrate very large learning gains on conceptual standardized physics – higher than in any other published study. A key component of the course transformation is that each tutorial section is staffed by a graduate teaching assistant (TA) and an undergraduate learning assistant (LA) trained to implement a Socratic learning environment. The LAs are selected from undergraduates who did well in the same class the year or so before. While our TAs are funded from the department's base budget, the LAs have been funded by one-time funding from the university and by NSF funding to CUTeach. The funding for LAs is not scheduled to be renewed by the NSF. Rather it was designed to be replaced by based university-based funds if the program was successful. The program has been extremely successful based on the large learning gains in the courses and has provided an important pipeline of students seeking K12 science teaching certification through CUTeach. The funding per student is small and the benefits large. We request that LA funding be added to the department's base budget in order for us to sustain our teaching successes.

Faculty lines: The Department of Physics has been extraordinarily successful in recent hires and we would like to continue to strategically invest in new areas, such as biophysics, optics and energy and materials research without negatively impacting our outstanding existing research areas. This will require a university investment of faculty lines to supplement the hiring we expect to be able to conduct in the next decade based on faculty retirements.

To reiterate, our most critical and pressing need is new assignable space for research laboratories, teaching laboratories, offices and classrooms. Our success in all other initiatives depends on this.

College of Natural Sciences: Many natural science faculty believe that it is time to reconsider the organizational structure of the College of Arts and Sciences. This is not a reflection on the current or recent administration. Rather, we believe that the huge size, complexity and diverse missions of the departments in the College disadvantages Arts and Sciences in the campus budgeting process, limits the Dean's flexibility in managing resources and inhibits the natural science departments from competing most effectively for campus and extramural resources. The College of Arts and Sciences is nearly twice the size of all of the other schools and colleges put together. The natural science division of Arts and Sciences alone is larger than any other school or college on the campus and, we believe, represents the strongest collection of faculty on the campus.

We request the administration conduct a high-level discussion in consultation with the faculty of how changes to the current administrative structure would allow the natural science departments and institutes to work with each other and with the other schools and colleges more effectively. This might involve creation of separate colleges of natural sciences, social sciences and humanities and arts, or an administrative restructuring that would allow divisions within a larger college to be budgeted separately and act much more independently. We have heard that the faculty in the humanities and arts, and the social sciences would also welcome such a discussion. Smaller and more homogeneous colleges containing departments with similar needs and expectations would offer many benefits to all of the departments and to the University as a whole.