External Review Committee Report
Physics Department
School of Physics and Astronomy
University of Minnesota

April 23, 2008

Review Committee:

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Assignment: The University of Minnesota has a somewhat unusual structure in which the Physics and Astronomy Departments are combined for the purpose of promotion and tenure into one budgetary entity called the School of Physics and Astronomy; Physics and Astronomy otherwise function as separate Departments. We were charged with reviewing the Physics portion of the school.

Activities: We reviewed documents including the Departmental self-study and long -range plan, and statements of budget and research support. We visited the Department on April 21 and 22, touring the facilities and meeting with a broad cross section of the faculty, with graduate and undergraduate students, with postdoctoral researchers and research scientists and with Department staff. We also met with Chairs and other representatives of other Departments in the Institute of Technology and with one member of the MBBB department in the Institute of Biological Sciences and with members of the administration including Dean Steven Crouch, Vice Provost and Dean of the Graduate School Gail Dubrow, Associate Deans Shirley Ann Garner , Douglas Earnie and Wayne Gladfelter, and Vice President and Vice Provost for Equity and Diversity Rusty Barcelo.

Summary: Physics is a foundational discipline, investigating basic questions from the origin and structure of the universe to the nature of the elementary particles to the physical processes underlying life itself. A strong physics department is an essential component of a first-rate research University both for the fundamental nature of the questions it investigates and because the concepts and techniques it creates and the people it trains have impact on other disciplines.

At the University of Minnesota we found a vital and well functioning Department with strong research and innovative teaching programs, high quality recent hires, good interactions with other departments on campus, a well thought out plan for future development and, at all levels, a high morale and level of enthusiasm. The research productivity and funding level are comparable to that of peer institutions although the faculty size is small relative to peers. We were very favorably impressed by the collegiality and commitment to the Department exhibited by the faculty, students and staff.

However the Department faces significant challenges. The faculty size is smaller than at the time of the previous review (1994) while the number of students at all levels has increased. High-profile faculty have been lost, creating significant gaps in coverage of important areas of the discipline and in the ability to mount a first rate teaching program. An unfavorable age distribution, especially in crucial subfields, increases the severity of the problem while the lack of modern research and instructional laboratory space severely hampers both recruitment and teaching. Departmental space is inadequate. The present building has insufficient research laboratory space to allow the Department to keep up with the trends in the field. Even more important, modern high quality laboratory space with the temperature and environmental control and vibration stability necessary for forefront research seems difficult if not impossible to provide given the present state of the physics building. The instructional space (especially for instructional laboratories) is also inadequate, being both out of date and insufficient for the number of students. Investment in a new building is warranted.
Finally, the financial model under which departments in the Institute of Technology operate has been changed very recently, with consequences which are not yet clear.

State of Department:

The Department has been creative and effective in exploiting opportunities. The proximity to the Soudan mine has been leveraged into a considerable source of strength and support for the high energy experiment group. The successful development of the cosmology group has been aided by synergistic links to other research groups within the Department. The experimental condensed matter program has interacted very well both with nearby companies such as 3M and with other research activities on campus. We were somewhat surprised to learn on the one hand that the interactions between physics and engineering departments are not regarded as interdisciplinary because all of the Departments are in the same administrative unit (IT) but that on the other hand interactions between the newly developed biophysics group and related activities in the medical school and the College of Biological Sciences are inhibited by policies involving the sharing of seed funding across administrative boundaries.

The junior faculty seem generally happy, well treated and well integrated into the program. They receive an appropriate degree of mentoring and (where needed) assistance with teaching. The annual review process seems transparent and provides useful feedback and the Head and relevant senior faculty members display an impressive level of familiarity with the research and teaching programs and strengths and weaknesses of the junior faculty.

The graduate and undergraduate students give very positive reports of their education and integration into research and departmental life. The undergraduate majors speak particularly highly of the advanced laboratory course, of the relatively new courses (such as cosmology) designed to introduce beginning physics majors to forefront areas of research, and of the research opportunities available. Some undergraduates did express the wish that more information be provided about research (and employment) opportunities outside the University, for example about internships at companies. While the undergraduates were in general happy with the advising they have received (both in terms of courses and for post-graduate options), our sense was that the advising was a bit haphazard, most likely because the advising system seems not quite to have caught up with recent increase in the number of majors.

The graduate program seems to be functioning very well. Issues which have caused difficulties at other universities, including the qualifying examination system, the training of teaching assistants and problems with departmental atmosphere, seem not to be present here. Two areas where improvements would be desirable are that the Department does not at present mount all of the advanced graduate courses needed for student training and that the Department does not have enough positions available for research in experimental physics. The former is fundamentally a problem of faculty size, exacerbated by the financial issues related to the University's way of charging for graduate students;
the latter is being addressed by the Department's hiring plan.

Departmental Research and future plans: The Department mounts strong programs in astrophysics/cosmology, condensed matter physics, and high energy particle physics, with smaller-scale efforts in space physics, theoretical nuclear physics and physics education research and has established an impressive effort in biological physics. The Department's long-ranged plan, which we very much endorse, is to maintain a strong presence in the core areas of the discipline: astrophysics/cosmology, condensed matter physics and high energy physics, while continuing to develop their activities in biologically-related physics and maintaining activities in nuclear physics, space research and physics education research. Essential to the future success of the Department is the ability of the University to provide modern laboratory space for forefront research. The present physics building is old and crowded; if nothing is done it will become increasingly difficult to recruit or retain the first-rate faculty on whom the future of the Department depends.

At the time of the previous external review (1994) the Department size was 48. When the self-study was written the Department size was listed as 43 faculty. We may add to this one accepted and several pending offers. Since the self study was written one high profile faculty member (Glazman) resigned to take a position at Yale and two other faculty members (Ghergetta and Grosberg) have received very strong outside offers which, we are told, are likely to be accepted. Overall, the current size of the faculty seems too small. The present vigorous program of searches must be continued and, if possible, expanded.

Hiring over the last decade has been impressive. In the face of a difficult recruitment environment (with many universities searching and very high startup packages being offered) considerable success was achieved. A strong cosmology/astroparticle group has been established, a very promising effort in biologically related physics group has been started. These are not trivial achievements: many universities wish to grow in these areas, and competition for good people is fierce. Key hires have maintained the strength of the other major research groups. The individuals to whom offers have recently been made are of very high caliber. For this reason we have complete confidence that if appropriate resources are provided, they will be used to strengthen substantially the Department and University.

The Department's highest immediate priority is to strengthen experimental condensed matter physics. This is one of the historical strengths of the University of Minnesota, is central to the discipline of physics and is the area with the strongest connection to other scientific disciplines. At this University, as at other universities, condensed matter experimentalists also play important roles in interdisciplinary research centers. For these reasons it also attracts a very high level of student interest. The present size and age distribution of the group and in particular the eventual retirement of Allan Goldman make a recruitment in this area very important. However, hiring in condensed matter experiment can be challenging. Startup packages are very expensive, requirements for laboratory space can be stringent, and many universities are competing for the best candidates. The Department's approach, which is to run a relatively broad search but to favor candidates whose research can generate natural links to research in other IT departments, seems very appropriate to us.

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Biologically Related Physics: The Department has made a very impressive beginning in this field, with a major theorist and two impressive young experimentalists. The experimental effort is now well established, with a good level of external support and a growing collaborative presence within the University. The plans for further expansion have our strong support.

Condensed Matter Experimental (CME): The CME group comprises six professors with active well-funded programs. Research areas include the study of disorder in superconductors, spin transport and dynamics in ferromagnetic semiconductor heterostructures, characterization of domain structure by magnetic force microscopy, properties of thin (two dimensional) liquid crystal films using optics and x-ray diffraction, opto-electronic properties of amorphous semiconductors, pattern formation and dynamics of granular and neurological systems effects of microwave radiation on the linear and nonlinear transport properties of two dimensional electron gases in semiconductors and magnetotransport. Many of these activities have high visibility in the outside scientific community, strong connections to related research activities on campus and provide excellent opportunity for advances in basic scientific understanding and technological application.

The committee feels that the department's efforts to expand the CME effort with additional hires and upgraded facilities are justified for the following reasons: (1) There is a high demand amongst the undergraduate and graduate students for opportunities to work in these fields. (2) These efforts are well coupled to existing campus-wide facilities such as the nanofabrication facility in EE and centralized materials growth capabilities in the Materials Science department. (3) The work couples well to IT initiatives in nanotechnology, energy and device concepts. (4) The existing collaborations among the members of physics, EE and material science departments will be enhanced to the mutual benefit of all participants.

The committee recognizes, as does the department, that Allen Goldman is approaching retirement. Allen's departure will create a large gap in the CME effort that must be offset with strategic hires in areas that complement present activities. The Department's present plan of aggressive hiring at the junior level will help to remediate this loss. The number of mid-career and more senior scientists within this area is adequate at present, but the the loss of even one of these to an outside offer would create a severe weakness. For this reason a senior recruitment could also be justified, but in our judgement would not be likely to succeed until significant new laboratory space becomes available.

Condensed matter theory: The theoretical condensed matter research effort has suffered major losses with the death of Larkin, the loss of Glazman to Yale and the impending loss of Grosberg to NYU. The Department recognizes the need to rebuild, and is taking appropriate action. The presence of the Fine Theoretical Physics Institute, along with the outstanding experimental group, offers a level of intellectual resources which should make it possible to attract theorists of the same outstanding level as those who have left.

Cosmology/Astroparticle Physics: One of the impressive Departmental developments since the previous review is the establishment of a strong cosmology group. This group takes strong advantage of interrelated research in other groups (high energy particle experiment, high energy particle theory, nuclear theory), as well as research by faculty in Astronomy. The range of activities provides a solid foundation in this key subject in both theory and experiment, but is perhaps still below critical mass. The Department's plan for two additional hires in experimental cosmology is therefore a good one that will further enhance strength in this area.

Theoretical High Energy Particle Physics This is a strong group with internationally recognized leadership. The group has broad strength, but has also taken advantage of synergistic relationships with the groups in cosmology and in nuclear physics to create niches of special expertise. The potential departure of Ghergetta, however, would create a significant hole that would need to be filled if the group is to maintain its strength.

Four of the six faculty in this area are also members of Fine Theoretical Physics Institute (TPI), which is a major resource for the Department, IT, and the University. We believe that the maximum potential of this resource has perhaps not yet been achieved, and that its visibility both on campus and in the physics community could be greater. (The recent inauguration of the Misel Family Lecture Series is a strong positive step in this direction.) One suggestion (if sufficient resources are available) would be to have workshops on a broader range of topics through the use of outside organizers who are brought in as short- or long-term visitors.

High Energy Experiment (HEP): The University of Minnesota HEP group has a successful, well funded program which is poised to continue having a strong impact on this core field of Physics. The faculty demographics is balanced. The group efforts covers physics at the energy frontier with the CMS experiment at the Large Hadron Collider in Geneva Switzerland, precision measurement of heavy quarks at CLEO and BESIII, neutrino physics and direct searches for dark matter search at Soudan. The intellectual diversity puts them in a good position to take advantage of new opportunities.

CMS is a large experiment built by an international collaboration of over 2000 physicists. The Minnesota faculty has a leadership role in the collaboration, with particular responsibility for the electromagnetic calorimeter and the data acquisition for the hadron calorimeter. The Minnesota group also played a leadership role in the CLEO experiment and have joined, BES III a high-luminosity e^+e^- experiment in China expecting to start data taking in 2008. Joining BES III is an excellent move for this group.

The Minnesota neutrino group grew out of past efforts to search for proton decay in the Soudan Mine. The group is very prominent and does an excellent job to include graduate and undergraduate students in their research. They were the driving force behind the Soudan 2 experiment which provided some of the earliest evidence for atmospheric neutrino oscillations, and thus of neutrino mass, and played a critical role in the construction of the MINOS experiment. The neutrino group is currently part of the collaboration proposing and designing the NOνA, FermiLab's next major neutrino oscillation experiment. While particle physics is passing through some difficult times, there appears to be a growing consensus that a plan for the field must be formulated that maintains FermiLab as a major center for US physics during the LHC era. FermiLab's recent Steering Group Report identified a phased program of neutrino physics based upon future improvements of the NuMI beam line and new on-axis and off-axis detectors. This puts Minnesota at the center of the Fermilab plan which is critical to particle physics in the US.

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The local group also has a significant program of underground science, including the detection of dark matter particles and the development of new techniques for low-level counting. The group participates in the Cryogenic Dark Matter Search (CDMS) experiment at Soudan. This is one of the leading efforts to identify weakly interacting massive particles, an important class of dark matter candidates. This program could continue in DUSEL, the Deep Underground Science and Engineering Laboratory that the National Science Foundation would like to construct in the Homestake Mine, South Dakota.

Nuclear Theory: The University of Minnesota nuclear theory group is a strong one, with a history of consistent support from the Department of Energy that has allowed it to produce an excellent group of PhDs and to contribute to the mentoring of some of the field's best postdocs. One measure of this record is the success of the eleven thesis students of the group's senior member, Joe Kapusta, seven of whom now hold faculty positions

The group has recently made an interesting transition to establish a new direction, nuclear astrophysics, that nicely aligns with and extends the department's other astrophysics and cosmology interests. This was accomplished by the hiring of two excellent young faculty, Yong-Zhong Qian, who works on nucleosynthesis, galactic chemical evolution, and neutrino and other weak interaction physics important to supernovae; and Alex Heger, who is one of the leading modelers of supernovae, their progenitors, and associated phenomena such as gamma ray bursts. Heger will join the group as a nontenured associate professor later this year. Together with Kapusta's interests in finite-temperature field theory and the quark-gluon plasma, this makes a strong and varied research program. All three members of this group are very productive and recognized as among the best in their areas nationally.

We anticipate that this group will remain very strong for the next decade, the time at which some planning for the retirement of Kapusta will be needed.

Space Plasma Physics: The Space Plasma Physics Group's core effort is in understanding particle acceleration and magnetic field phenomena associated with astrophysical plasmas, particularly as applied to the sun and solar system. The local program has good connections to astronomy, to geophysics and planetology, and to some aspects of galactic chemical evolution of interest to nuclear astrophysics. The group's two instrumentalists are currently building equipment for NASA initiatives STP (Solar Terrestrial Probes) and LWS (Living with a Star). They have strong funding, despite operating in a field that is dominated by very large groups located at centers such as the Space Sciences Laboratory at the University of California, Berkeley.

Space and Physics Building Plans

The plan for maintaining and enhancing the University of Minnesota Physics Department depends heavily on the local experimental effort in fields like condensed matter physics. A strong in-house experimental effort brings many benefits, including improving the research experience for graduate and undergraduate students, and opening new opportunities for on-campus collaborations with fields like engineering, biology, and chemistry. High quality laboratory space will allow Physics to be a strong partner in future campus efforts to establish interdisciplinary centers-of-excellence involving significant facilities investments. The mode of funding in physics is becoming increasingly focused on large facility and collaborative grants, even in traditional single-investigator fields like condensed matter. Thus the quality of a department's laboratory space becomes an important factor in obtaining umbrella grants and thus of ensuring the long-term stability of its various groups.

In the particular case of the University of Minnesota, the department recognizes that it has become a bit overbalance toward theory, and thus would like to begin a period in which experiment is strengthened. The availability of high-quality research space – modern laboratories providing the space, electrical and mechanical stability, and temperature control required for state-of-the-art experimental work – is a crucial ingredient for successful recruiting. By any reasonable measure both the quantity and quality of research space that can presently be offered is substandard. Our committee strongly suspects that an important factor in several recent unsuccessful searches was that lack of competitive space at the University of Minnesota. Some of the universities that won out in these competitions were able to offer more space of significantly higher quality. It is difficult for the University to succeed in recruitment when, during candidate visits, the candidates sees crowded, substandard space, almost all of which is fully occupied by current faculty that will have to be further crowded to make room for new faculty.

This obstacle to increasing the quality of the Physics Department appears to be widely recognized on campus. In our meeting with other department heads of IT, all agreed that Physics needs a new building to remain competitive. This fact is also apparent to the students of all levels that are using Physics space and equipment. In our meeting with undergraduates, one older student from the US Navy who was in Physics to obtain additional training in instrumentation stressed to us how inappropriate he found the space and equipment in Physics. He asked us to do our best to improve the situation, so that students like him could receive training that would be more relevant to their professions.

We understand that this need is also recognized by the University administration, and that improving the Physics Department's facilities is a very high priority on campus. If the University officials in charge of space have not already done so, we would encourage them to examine what other universities have done to modernize their physics facilities, particularly in peer institutions within the Big Ten. Ohio State has recently competed a major research building for physics. The University of Illinois provides another relevant comparison because it has the strongest condensed matter physics effort within the Big Ten. It has succeeded in recruiting new faculty that were also sought by the University of Minnesota. Thus the University should compare the space and facility support that Illinois and Minnesota were able to offer. This will help to define the standards that the University of Minnesota will need to achieve if it wants its Physics effort to be comparable to the best in the Big Ten.

In planning for a new building to sustain the department for the next several decades, the University might take into account several special opportunities to enhance local efforts. One goal might be to help the Fine Theory Institute increase its effectiveness and visibility on campus and nationally. Space designed to promote interactions between visitors and local faculty, postdocs, and students could help this strong Institute reach a new level. For example, we would recommend that University architects examine what has been done recently at UC Berkeley and MIT to create interactive spaces for theory groups and their students and visitors.

We also note elsewhere in this report that the effort to sustain FermiLab over the next two decades may open up outstanding opportunities for the neutrino group in experiments utilizing an enhanced NuMI neutrino beam line and detector facilities associated with the Soudan Mine. This group has creatively utilized facilities outside the physics department in its past efforts on projects like MINOS. However, one should consider the benefits that might come from improving in-house space, such as high-bay areas appropriate for the detector construction. This kind of capacity might also help University of Minnesota assume leadership roles in future large-scale astrophysics efforts, an area of growing emphasis in the department. This could be an area of advantage for the Department, given that it has maintained significant in-house machining capability.

We recognize that a new physics building is a major investment for the state. But we would also recommend that cost be balanced against the importance of adequate high-quality space, given the considerable competition between Big Ten and other top-tier universities. Ohio State new building is perhaps a good indication of current and future competition.

Diversity

Gender and ethnic diversity is a major issue for all physics departments. Because of the very limited number of underrepresented minority PhD's in physics, efforts to improve diversity in physics departments are most often focused on gender. At the University of Minnesota, the number of female faculty in Physics is quite small, just 2 of 43. However, during our visit, we received information (not included in the self-study) that, over the past decade, Physics made 13 faculty offers that were turned down, 6 of which went to women (one of whom was also in the underrepresented minority category). In all these cases, the candidates received other offers from peer institutions that they ultimately chose over Minnesota. We do not have sufficient information to analyze these on a case-by-case basis. In the self-study, the Department pointed to lack of a routine spousal hiring policy as a key issue. The limited information we were able to gather during our visit (we requested, and were granted, an appointment with the Vice President and Vice Provost for Equity and Diversity, Rusty Barcelo) indicates that at least some of the Physics Department's complaints have merit; support for spousal hiring at the University of Minnesota appears to be limited to a rather small amount (in relation to the University-wide need) of short-term bridge funding. There also appears to be no dedicated funding in support of target-of-opportunity hires of women and underrepresented minorities. Many other peer institutions now have policies that are considerably more aggressive and supportive of recruitment of academic couples. We would suggest that the University review its policies in these and related matters (e.g., family-friendly policies such as tenure-clock stoppage for child rearing) to be certain that they are compatible with the best practices of the leading peer institutions. If the University of Minnesota is not competitive in this aspect of academic recruitment and retention, it will be at a definite disadvantage.

Within the Physics Department, we think that more attention could also be given to these issues. Very recent trends are encouraging. The most recent (unfortunately failed) recruitment attempt of a potential female faculty member appears to have involved such best practices as interpreting the search area broadly and introducing the candidate to female peers in the STEM disciplines, but the degree to which the Department as a whole focuses on these issues was not clear to us. In general, greater visibility within Physics of organizations such as the IT-wide group Women in Science and Engineering (WISE); Women in Physics and Astronomy (WIPA), and the IT Program for Women would be beneficial, as would perhaps a greater level of commitment by the University to these organizations. WIPA, for example, could be more actively engaged in recruitment efforts of both faculty and graduate students (of all ethnicities and both genders). The visibility of these organizations sends important signals to prospective recruits at all levels, and should lead to greater engagement and utility of off-campus resources, such as visits by high-profile female and underrepresented minority scientists from other institutions.

The two current female faculty are accomplished scientists whose leadership abilities may be presently underutilized within the Department. (For example, neither currently serves on key departmental committees such as Promotions and Tenure or Long-Range Planning.)

As discussed more generally elsewhere, the climate for students (both graduate and undergraduate) appears to be good. When we raised the topic of gender-related issues, inadequate child-care facilities for graduate students was the only complaint we heard. Still, as mentioned above, more efforts to raise the visibility of a diverse cohort of scientists would be beneficial.

In summary, the Department has a generally good climate for women and (to the limited extent we could examine this issue) underrepresented minorities, but greater efforts towards best practices in the engagement of these groups would provide multiple benefits. Strong leadership from the University administration on key issues such as spousal and target-of-opportunity hires, backed by substantial financial resources, is essential if the University of Minnesota is to maintain its status as one of the top public universities in the nation.

Outreach:

The committee is impressed with the departmental outreach efforts. These efforts are significant and involve a considerable amount of faculty effort and time. The department clearly benefits by promoting physics to a large audience of students and increasing the visibility of the department. The Programs include the NSF supported Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET), the Physics Force demonstration circus, Quarknet, and the APS/NSF supported PhysTEC program. This latter program couples to a faculty member in the School of Education and supports a teacher in residence in the physics department. The departmental outreach efforts are complemented by the physics education research (PER) efforts of a senior faculty member. These efforts concentrate on the techniques for cooperative problem solving and have been described in professional education journals.

Appendix: Answers to Questions Posed by Dean Garner

<u>General</u>

1. *What are the most outstanding departments in physics in the United States, and how would you position this department among them? What are its outstanding features? What are its most problematic features?*

There are a number of formal rankings of physics departments, with the general consensus that the top departments include Harvard, Princeton and MIT are among the best overall. In the 1995 NRC rankings, Minnesota was 23rd. To the extent that such rankings are meaningful, it seems reasonable to place the University of Minnesota Phyiscs Department in the top 20 to 25. The Department has many unique strengths which include: the presence of the Fine Theoretical Physics Institute; proximity to the SOUDAN underground laboratory which provides unique physics opportunities; and the strong interactions of the condensed matter experiment group with other departments and with industry. Problematic features include a relatively small faculty size for the number of students served, and generally aging and inadequate facilities.

2. *Considering faculty, students, curriculum, and resources, how has the profile of the program changed over the past 10 years? What challenges and opportunities does the program face over the next decade? What strategies do you recommend for meeting these opportunities and challenges? Do you see this program positioned to be a leader in education and research?*

The Department has maintained its strengths over the past 10 years, while successfully building in new areas such as cosmology and biological physics. One key challenge over the next decade is the need for state-of-the art laboratory space and adequate teaching space. Recruitment and retention of top-quality faculty in the face of ferocious competition from peer institutions is of course a major issue. Possible strategies include enhancing the already strong connections to the other Departments on campus, both within and outside of IT, and increased efforts to increase diversity, which to be successful will require strong financial support from the administration.

3. *What is your view of the stated strengths and needs of the program to be found in the narrative and tables within the Self-Study Report? Do you think Physics is in a position to maintain or enhance its strengths into the future? What are the plans for maintaining its strengths or enhancing them, and in your opinion, are they appropriate and feasible? Is the program taking a strategic approach to planning its future?*

The *Self-Study Report* provide anaccurate snapshot of the status of the department. We believe that the faculty has taken advantage of key opportunites, and has a plan to continue to do so in the future. The Department's long-range plan well motivated and feasible if the University provides the needed resources.

4. *How well does Physics maintain curricular and research linkages with other units within the Institute of Technology and the University? Is it well connected to other departments or research centers? If not, what linkages might enhance the program's strengths? If so, are these relationships working so as to contribute to the program's strengths?*

The Physics Department has strong and collegial relations with the other units in IT. The physics curriculum is well taught and appears to meet the requirements of the other units within the Institute of Technology and the University. Greater strengthening of some connections would appear to be possible; for example, it may be that Physics could play a stronger role with the Institute for Mathematics and its Application. Administrative barriers to collaborations (either research or teaching) between physics and other units outside of IT should be reduced. These barriers pose particular issues for the new effort in biological physics.

5. *Is there adequate support in Physics and the Institute of Technology for building innovative interdisciplinary relationships with colleagues in other fields?*

Interdisciplinary efforts are typically most successful when built from "the ground up", among individual and small groups of faculty. It seems that efforts across departmental boundaries within IT are sometimes not recognized as interdisciplinary by the higher administration, a notion that is not common at peer institutions. The workshops and visitors programs of the Fine Theoretical Physics Institute seems an underutilized resource in this regard

6. *Are resources (faculty lines, research funding, staff support, space, etc.) adequate for the size of the faculty, the size of the undergraduate and graduate programs, and the number of students served?*

The comparison provided in the *Self-Study Report* clearly indicates that in comparison with similar programs in the Big Ten the Minnesota physics program is short in faculty lines. As previously noted, the space problem in the Physics Department is real. The level of research funding is strong, and the size of the graduate is reasonable; the number of undergraduates is at (or slightly beyond) the limits which can be handled by the existing number of faculty.

7. *Are there other models for graduate and undergraduate curricula in physics that offer broader and richer training?*

The training provided by the department is excellent both at the undergraduate and graduate level. The Physics Research in Education group has provided input that has translated in courses aiming at implementing effective learning techniques into teaching. This benefits both undergraduates who are learning physics well and graduates who are well prepared for teaching. We commend innovative classes such as Methods of Experimental Physics which are designed to teach the students to develop an experiment starting from the proposal stage. Again, the relatively small size of the faculty hampers efforts to enhance the curriculum.

8. *The Self-Study Report describes numerous problems that follow from inadequate space. How do you view their assessment? Do you see additional or different space needs both for teaching and research as this unit compares to our peers and competitors?*

We discuss this issue in the body of our report.

9. *The Self-Study Report also documents difficulties in hiring women and minorities. Are your experiences at your universities similar? If so, do you see difficulties as stemming from the same sources? If you do not experience such difficulties in hiring, do you have suggestions for Physics at this University?*

We discuss this issue in the body of our report.

<u>Faculty</u>

1. *Does the balance of scholarship, teaching, advising, and outreach within Physics seem appropriate?*

The faculty appear to balance their multiple responsibilities effectively.

2. *Do the publications and other forms of productivity of the faculty compare favorably in quantity and quality to those in similar programs elsewhere? Is the faculty's external funding comparable to those at top institutions?*

Yes. The faculty productivity is excellent overall, and compares favorably in terms of publications and funding with other top institutions.

3. *Are the faculty's strengths in the areas among the most significant in the field, or do they represent those where the most important new knowledge is being created? If not, do you have recommendations for change?*

The Department is playing a visible role in the most significant and currently important areas of physics. Their long-range plan is reasonable and would maintain and enhance key strengths.

4. *Is the faculty sufficiently engaged in the governance of the program and in strategic planning to chart its future?*

The faculty is clearly engaged in the governance of the Department and in developing their long range plan. We found the Department to be cohesive and collegial.

<u>Graduate Program and Graduate Students</u>

1. What is your assessment of the quality of the graduate students, their financial support, and the climate in which they do their work?

Our assessment is that the graduate students are good, with adequate financial support and (apart from the poor quality of the building) a very good climate for research. The committee met with 26 graduate students (5 female, 21 male) in an informal setting. The students expressed a general appreciation of the work climate and satisfaction with the financial remuneration. One student expressed concern about family-friendly policies, in particular the long waiting list for University-run child care and lack of assistance with the very high cost of non-University child care services.

2. *Is graduate students' advising satisfactory?*

Yes. A faculty advisor is assigned to each student during orientation and an orientation booklet is provided. Each year a report is provided by the student and his/her advisor. These reports are assessed by the director of graduate studies (DGS) and problems usually resolved at this level. Faculty and University-level resources are available for conflict resolution, if necessary; however the students did not seem to be sufficiently informed about these services.

3. *What is your assessment of the appropriateness of the size of the graduate student body in view of faculty size, job market prospects, and other factors?*

The size of the graduate student body is appropriate with respect to the number of faculty available. All students are productively engaged in research although there were a few students who were unable to work with their first choice of advisors. The graduate students perceived a relative shortage in positions in experimental research especially in condensed matter; the Department is working to address this.

4. Does the graduate student body incorporate the kinds of diversity that are desirable for this discipline? If not, do you have suggestions as to ways the program might enhance the diversity of its students?

Thirteen percent of the graduate students are women. Efforts should be made to increase this number and thus increase diversity. Recruiting more female graduate students would be facilitated by having more women faculty, and by paying a bit mjore attention to the issue during graduate student recruiting (for example by involving the WIPA group more directly in the recruitment process).

5. *A substantial proportion of enrolled students in the Physics graduate program are international students (60 of 130 enrolled students were international students in fall 2007). Is this proportion of international students typical in Physics programs elsewhere? If not, do you see this as problematic, and if so do you have recommendations to address this issue?*

This proportion of international students is not a concern. Except in the University of California (where foreign students are charged high out-of-state tuition rates and cannot become state residents) the proportion of international students is the same or lower than in other universities.

6. *Does the time it takes a student in Physics to complete a degree seem appropriate? Is this time-to-degree typical for comparable programs elsewhere?*

The time-to-degree of 5.9 years is typical for comparable programs elsewhere and does not represent an area of concern.

7. *Do you consider the program's efforts to develop its graduate students professionally, including participation in national/international conferences and journal publications along with assuring that they understand professional ethics and the responsible conduct of research, adequate?*

The department is to be commended for its extensive TA training program. This program is appreciated by the students and provides good training and preparation for their teaching assignments. Some students also participate in the "zeroth year" option where in the pre-fall they join a research group and thus get a jump start on research experience. Departmental funds are made available to all students so that they can present at least one talk on their work at a workshop or conference. Students have additional opportunities to become coauthors on paper and reports and to attend conferences with financial support provide by the grants of their advisors. The department does not provide graduate placement services or explicit Departmentally run professional development programs. Career advice is obtained through one-on-one contact with faculty members. This is typical of Phd programs.

8. *How do you view the quality of graduate students' job placement?*

Job placement for the PhD students appears to be satisfactory. The students find jobs in industry, in government labs and as postdoctoral associates.

9. *What are the strengths and weaknesses of the graduate curriculum in comparison to the graduate programs in the top physics departments nationwide?*

The graduate curriculum is of high quality and appropriate for the size of the department. It could be improved by providing a greater variety of courses including special topic courses which are close to the student's area of concentration. The number of special topics courses is compromised by insufficient numbers of faculty available to teach these courses. All physics departments have similar problems to greater or lesser degree. The committee is concerned that economic pressures to obtain ABD status can deny students learning opportunities. This restrains what the students can do and what the department can offer. To enhance breadth of experience, students suggested that a greater number of lab rotations would be beneficial. This is commonly done in biology and chemistry, but is very rarely done in physics (Stanford is the only example of which we are aware).

10. *How might existing resources be realigned to further increase the competitiveness of the graduate program? If new resources can be secured, what improvements should be a high priority?*

Without additional space to accommodate additional faculty and upgraded facilities there is not much opportunity to increase the competitiveness of the graduate program.

<u>Undergraduate Program and Undergraduate Students</u>

1. *What is the quality of the undergraduate education? What would make the quality of the undergraduate experience in the program extraordinary?*

The committee met with more than thirty undergraduates in an informal setting. Overall they praised the program, especially the research opportunities, the MXP undergraduate lab experience, and the courses such as cosmology which introduce beginning students to forefront research areas The climate appeared to be good. However, since nly two women were present at our meeting, we were not able to explore gender issues in any depth.

2. *Is the curriculum what it should be? If not, what do you recommend to strengthen it?*

The curriculum is under enrollment stress primarily because there are not enough faculty. Since 2000 the demand in the large service courses has increased by 20% but the number of faculty has not changed. If a new course such as cosmology is added, an old course such as special relativity is dropped. Electives such as optics and additional biophysics courses should be taught. There was enthusiastic praise for the methods of experimental physics (MXP) course together with the opportunities to perform individualized experiments. Additional space is needed and outdated equipment needs to be replaced. This is especially true in the freshman laboratories.

3. *Is the Honors experience in Physics sufficiently rich?*

There was general satisfaction with the Honors experience. For the first two years, separate courses containing accelerated material distinguish the honors students. For the third and fourth years there is less distinction and all qualified students (not necessarily honors) are given the opportunity to perform independent research and write a senior thesis. Thus it is better to say that the majors experience in Physics is of very high quality and is indeed sufficiently rich.

4. *How do you view the research opportunities offered undergraduates?*

Research opportunities are plentiful and all students who desire a research experience are able to find one. Undergraduates are also given an opportunity to become TAs after receiving training similar to the training offered to the graduate students. The NSF supported REU program, which provides opportunities for a summer research experience, are available and utilized.

5. *What is your assessment of the service learning courses, internships, learning aboard, etc. that the program offers? Are these opportunities diverse and sufficient in number, and are students taking advantage of them?*

The students in general did not seem to be aware of internship opportunities. The department should make a greater effort in disseminating such information. Some students were aware of a “learning abroad center” but were discouraged from applying with the argument tha because the international curriculum is very different from the US one their progress in physics would be slowed down.

6. *Are undergraduate enrollments appropriate for the size of the faculty and the number of teaching assistants available?*

There are too many students for too few faculty. This situation is described fully in the Self Study.

7. *Does the advising process allow students adequate access to advisors and systematic counseling at all stages of their undergraduate career? Is advising on career options sufficient? How can advising be improved?*

The faculty is perceived by the students to be well connected and “in touch with what is going on”. The students report considerable satisfaction with the informal advice they obtain from Professors whom they know from class or “by knocking on doors” The students have access to an undergraduate advisor and can also participate in student physics society (SPS) activities. The SPS meets one a month and has a faculty advisor. However it is our sense that the formal advising procedure has been somewhat overburdened in most recent years by the increase in the number of majors.

8. *Do the undergraduates want improvements in any aspect of the major?*

Yes: a greater variety of courses, a greater faculty to student ratio in the major courses and more spacious laboratories.

9. *How would you describe the climate in the department for undergraduate majors?*

The climate is healthy and the students are appreciative of the efforts of the faculty and staff to provide them with a quality physics education.