Department of Physics Strategic Plan

(Draft Version 0.41)

Department Vision Statement [*in progress*]

The Department's goal, and vision, for the year 2010 is to have the quality, resources, and recognition of a top 20 department. Indeed, moving into this group is "a very worthy and achievable goal", as stated in the report of the 2005 Physics External Review Committee. Our faculty will have a broad array of coherent, cohesive, interdisciplinary programs based on fundamentally strong core research areas. Our department will have become, through extensive visitor and workshop programs, a key stopping point for young physicists on their way up in their careers. And, our undergraduate program will provide a substantive research experience for all physics majors and provide exposure to state of the art physics and measurement techniques for all students studying physics. Quantitative attributes of increased stature will be 1) major roles in two or more nationally funded centers, 2) external funding of $15M/year, or 50% more than currently, 3) 100 graduate students on GRA's, a nearly 100% increase, and 4) at least three full time faculty who have won national awards. The number of bachelor's degrees in physics and engineering physics will have doubled.

Self-Appraisal [*in progress*]

We have a strong, broadly based research effort. The 1995 NAS rankings report and subsequent US News reports (the last in 2002) have consistently ranked OSU at about 24th in the nation and 13th among physics departments at public universities. Among subfields, our Condensed matter Physics effort was ranked 15th in the 2002 US News ranking, 7th among publics.

Table 1 (see Appendix B) provides benchmarking data for our department as compared with other top 20 public university physics departments. The data clearly indicate that we belong in this group. They also suggest goals if we are to be at the average in the elite group of 12 above us. Our faculty size is at about the average for this group. Yet, our external funding lags the average by $4.7M/year. Both our total number of GRA's and our number of GRA's per faculty member are slightly less than half the average, a discrepancy only partly accounted for by our external funding level. We have slightly more than the average number of postdocs, attesting to the vibrant research programs in the Department. The number of NAS members on our faculty, one, is one-fifth of the average for the elite group, but only six of the elite departments have more than two. The data for the departments ranked with or below us suggest that Penn State and Michigan State are serious competitors.

We lack nationally funded centers based substantially in our department. The 12 departments ranked above us have among them seven NSF Physics Frontier Centers, eight NSF Materials Research Science and Engineering Centers (MRSEC) and an array of associated national facilities. The report of the 2005 Physics Department External Review Committee states "If Ohio State is to be in the top twenty surely the materials effort must be one of the winners of a NSF MRSEC grant since there are about twenty seven universities that have such grants." Additionally, the infrastructure required for a serious national presence in nanoscience is lacking at OSU. In large part because of this we were unable to recruit two excellent condensed matter experimentalists last year, not the first year we have lost excellent potential hires in this way. It is clear that important progress in terms of national center awards and in nanoscience infrastructure will be crucial to our aspirations.

Overview of Strategic Plan for Research

The report of the External Review Committee applauded the hiring program of the last few years and recognized the quality of the faculty, but commented generally that "the whole does not add up to more than the sum of the parts." They advised the creation of intellectually focused groups, often interdisciplinary, that can become leading centers of excellence in the country. They further noted that internal resources under control of the chair could be redirected to help achieve the overall goal of moving the Department into the ranks of the top twenty. The report had specific comments directed at each of the traditional subgroups in physics.

The Physics Department seeks to increase the impact of our faculty, including that of the individuals with existing programs of established world wide excellence, through development of larger cooperative and coherent programs with even greater visibility and impact. Recognizing the importance of being awarded a federally funded Center, the Department places a high priority upon creating the conditions that will enhance our ability to compete for and maintain such a Center. This would include support for early-stage Center formation, and assistance with essential infrastructure and other supports (educational outreach, etc.) that successful Centers require.

This strategic plan proposes procedural changes that will direct internal resources to seed the formation of focused groups or provide support to take existing groups to the next level. The first round of solicited proposals ("Letters of Intent"), currently in the evaluation stage, reveal that the bulk of the faculty is exploring initiatives to move in this direction. These proposals provide a context for responding to comments, criticisms, and suggestions directed by the review committee at the traditional subgroups in the Department.

A large and highly ranked Physics Department must have more than one or two areas of excellence. The plan sets up mechanisms for improvement across the spectrum, large and small, of current and future activities in the Department, and does so based on current Departmental resources. However, this plan also identifies programs that are primed, based on current faculty, to make additional significant jumps (e.g., to national centers) if new outside resources become available. With time and successful outcomes, this list will grow.

Principles and New Procedures

The strategic plan embodies a general theme of using resources to seed initiatives rather than subsidize or simply bankroll them. In implementing this seeding, the following principles are recognized:

- Departmental resources should generally be allocated for limited duration (e.g., one to three years). Long-term investments, such as faculty positions and certain elements of infrastructure, should be consistent with other elements of the strategic plan.
- Progress will be evaluated against clear milestones in both the short term and long term. The formulation of these milestones should involve comparisons with the Department's aspirational peers.

- Some type of matching will be generally required (which could be in forms other than money).
- This must be an ongoing process, not a one-time lottery for Departmental resources. The plan should provide opportunities for groups with good ideas in 6 months, one year, or five years from now to move toward "best-in-class" physics and develop self-sufficient external resources. The limited duration of resource allocation is essential if the process is to be ongoing.
- The reallocation of Departmental resources and the emphasis/de-emphasis of research efforts should be driven by the initiative of faculty members and subsequent success in achieving milestones.

To achieve the efficient and effective allocation of resources that allow this seeding, various long-standing Departmental procedures are being or have been modified. In particular:

- The uniform distribution of Departmental research allocations (that is, separately uniform among experimentalists and theorists) has been replaced by a differential allocation system that rewards the funding of GRA's.
- Charges for the shops, which have been almost fully subsidized in the past, will be phased in over several years. One use of shop charge income will be to improve and expand the Department shop facilities to match the growing demand that will result from our increased research activities.
- An enhanced visitors program will focus on bringing in people to help develop proposals and/or launch new initiatives. The new building has already proven through the OCTS to be an attractive venue for productive workshops.
- Matching resources will be available for proposals aligned with this strategic plan. These can include money, equipment, or support for students and postdocs,
- Release time will be awarded for proposal writing and to launch new initiatives.
- Assistance with proposal writing and financial management will be provided for complex centers/grants.
- In the new building, the allocation of office and laboratory space will be flexible and driven by demonstrated need rather than entitlements.

To initiate discussions and create a base of proposals, a call for one-page "Letters of Intent" (LOI) consistent with the goals of achieving "best-in-class"-level physics and enhancing interdisciplinary efforts was made in July, 2005. This call led to twelve proposals. A strategic planning committee (SPC) for the Department consisting of nine representative senior faculty members plus the Chair and Vice-chairs as ex officio members was appointed and, based on the LOI's, the SPC enumerated questions for each of the LOI proposers. Presentations to the entire faculty (about 45 minutes each) discussing physics, resources and the SPC questions were made in a series of lunchtime meetings in August, 2005. The original LOI's, presentations in electronic form, and questions/answers are available to all Physics faculty on the Departmental planning web pages. As the proposals evolve, updates are to be posted.

Letters of Intent

The twelve 2005 LOI's are entitled:

1. “Advanced Multifunctional Materials and Interfaces with Nanoscale Controlled Spin and Charge”
2. “Black Holes and String Theory”
3. “Center for Cosmology and AstroParticle Physics (CCAPP)”
4. “Coupling Science on Relevant Length and Time Scales”
5. “Frontiers in Medical Imaging Laboratory”
6. “Interdisciplinary Center on Quantum Gases”
7. “Institute for Hyper-Fast, Ultra-Intense Laser Science”
8. “LHC Discovery Center”
9. “Microscopic Mechanisms of Molecular Machines”
10. “Particle and Astrophysics Analysis Center”
11. “Physics Education Research Group Strategic Plan”
12. “Research Center for High-Energy Density Physics (HEDP)”

All of the proposals address at one level or another the call for focused groups of excellence. The proposals include many interdepartmental, programmatic efforts, with half of the proposed programs involving direct collaboration with other Departments inside and outside of MAPS (#1, #3, #4, #5, #9, #11). Several of the others within the Department span traditional group boundaries to capitalize on Department strengths to form coherent initiatives (#6, #12).

The writers of the LOI’s were instructed to identify resources needed for success according to the “best in class” goal. The sum of these resources is, not unexpectedly, far beyond what is available from Departmental resources. Thus, they generally serve at this stage as guides to potential seed areas rather than specific blueprints for the allocation of resources. With this in mind, we step through the proposals in Appendix A to indicate the plans for exploiting the proposed changes in Departmental procedures, some of the milestones toward excellence, and how the Department proposes to address the more focused comments of the external review. The LOI’s are grouped according to some basic themes, but are not assigned priorities. The individual discussions are necessarily brief; more detailed plans and milestones can be found in the planning web pages.

Two of the LOI’s (#1 and #3) present large-scale efforts that involve many Physics faculty members and span departments in the College and beyond. Other proposals consolidate existing faculty to achieve “wholes greater than the sum of parts”. Another class of proposals would use seed resources to perform proof-of-principle investigations, which might be in the form of computational physics techniques or demonstration projects, or to explore the possible payoff of unconventional or path-breaking collaborations. Several of the first-round LOI’s fall into this category. Finally, while the goal of building coherent efforts was highlighted in the 2005 call for LOI’s, the Department should not omit the support of individual efforts of excellence that reach best-in-class status (e.g., LOI #2).

The LOI process itself has already been successful in spawning interactions and creative ideas on how current expertise can be used in coherent efforts. These initiatives will not all succeed, but predicting winners ahead of time is prone to error. Instead, we let the successes drive the allocation. While the LOI's put forward this year cover a very wide range of physics efforts in the Department, they are not exhaustive. Other efforts include the experimental program of de Lucia and the theoretical program of Herbst, which are both already world class. We expect that the proposed changes will naturally support the continued excellence of these efforts. The on-going nature of the LOI procedure leaves open this option for the future.

Hiring [*in progress*]

Within the LOI's are proposals for specific hiring in the short term (the current year) and the future (i.e., the next five years). In contrast to the limited duration of other resources discussed above, faculty positions represent long-term, high-level investments. This plan gives recommendations (subject to faculty approval) for the short term and lays out some scenarios for hiring in the longer term.

The Department instigated three targeted searches in 2004-2005, in biophysics, physics education, and condensed matter experiment. The first two were successful while the third failed to attract either of two strong candidates. The present limitations in infrastructure at OSU was a major factor in these failures. Continuing this targeted search in an area consistent with LOI #1 will enhance that effort, with the coordinated plan for infrastructure used as a recruiting tool. Recommendations for hiring in the short term:

- Continue the targeted search for a condensed matter experimentalist.
- Search for a high-energy LHC phenomenologist (see the discussion in Appendix A about LOI #8).
- Continue to seek opportunities to hire highly qualified women or minorities.

[To be developed after faculty discussion: Scenarios for the longer term.]

Graduate Program

The Department of Physics is committed to increasing the quality of our graduate students and supporting graduate students in a fiscally responsible way, especially to expedite their transition from department support to support on research grants as GRAs. As a first step in accomplishing these goals, the department has instituted a new policy in which advanced students are required to be supported on GRAs. It is our practice in Physics that grant requests for which students will be supported on GRAs are required to include tuition and fees, which will be feasible as long as these costs are substantially rebated to the PI's. As another means of controlling the number of our students on GTAs, in the short term we plan to admit smaller classes of higher-quality students. We do not foresee having to adjust our instructional patterns as a consequence of the smaller classes. This plan has already been implemented for the Autumn 2005 incoming class which has about 20 students, which is significantly lower than our usual entering classes of 30-35 students. This class is mostly composed of domestic students, includes an NSF Fellow and several University Fellows, and has an average physics GRE score of 700, well above that which we normally have for domestic students.

Undergraduate Education and Outreach [*in progress*]

Understanding the fundamental physical processes in the universe creates a foundation of knowledge from which all technology emerges. The department of physics is designing a new educational approach for ALL students involving state-of-the-art technology and measurement techniques coupled with state-of-the-art educational pedagogy. The ultimate goal of this new educational paradigm is twofold:
1) Provide a substantive research experience for ALL physics majors beginning with exposure in the freshman year to state-of-the-art measurement techniques.
2) Provide exposure to state-of-the-art physics and measurement techniques for ALL introductory students.

On a recent trip to China Will Saam and Lei Bao visited nine universities and learned about the latest efforts in laboratory instruction. Using Bao's relationship with the Physics Education Research (PER) Groups in China, our own PER efforts, and the Office of Undergraduate Studies, we are developing an educational plan for physics that will usher in a new era of instruction. In all cases the PER group will work closely with the instructional staff to use improved methods of instruction consisting of inquiry, studio classrooms, integrated computer exercises, etc. The plan will call for the development of a Technology Team (TT) comprised of technical staff, instructors and students to provide a common technology base for all laboratory experiences.

[*An outline of the programmatic changes for majors and introductory students, along with a timeline for implementation, is available on the planning website. This has not yet been reviewed by the Undergraduate Studies Committee.*]

Staff [*in progress*]

Staff resources are presently strongly directed toward administrative, instructional and research support, with significant personnel associated with the electronics, machine, low temperature, and computing shops.

- Only one staff person is associated with the materials preparation shop, which may see expansion with the new building's clean room facilities and the proposed interdisciplinary materials center. Departmental support of a staff person whose emphasis would be on support of clean-room based materials research would be needed until the center's funding is established.
- The growth and vitality of the undergraduate majors program will benefit from addition of a dedicated staff person associated with recruiting, advising, and outreach. With the significant changes planned for the format and equipment used in many of the undergraduate courses, we anticipate adding the equivalent of one FTE to support this curriculum and technology development. Support of this has been identified under our prior funded technology fee proposals.
- Proposed center initiatives involve administrative support of operational, visitor, and workshop activities. Such would be temporarily supplied by the department until external center funding became available to sustain it.

While evaluation of current shop needs will continue, funding for these particular changes can in part also be associated with a reduction in our temporary lecturer costs due to recent increases in the number of faculty available to teach.

Appendix A: LOI's

Two of the LOI's present large-scale efforts that involve many Physics faculty members and span departments in the College and beyond.

* As stressed in the external review, if the Department is to break into the top twenty, the faculty in condensed matter must rise even higher, and to do so must become more collaborative. The "Advanced Multifunctional Materials . . ." proposal (LOI #1) lays out a strategy to achieve a coherent effort while addressing the need for facilities and support to fabricate nanostructures and devices. It will function at more than one level, as a critical component of a university-wide effort to develop a first-class materials program (if such an effort materializes), while concentrating on developing thrusts within and close to Physics on novel multicomponent material systems that can become best-in-class with sufficient investment (which goes well beyond what the Department alone can provide). The majority of the condensed matter faculty are involved. The external review commented on the apparent lack of interaction of condensed matter theorists with their experimental colleagues; this problem is ameliorated with the addition of new senior faculty (Randeria and Trivedi). Important milestones are collaborative publications and block funding.

* The proposed "Center for Cosmology and AstroParticle Physics" (CCAPP) described in LOI #3 will focus the efforts of the astrophysics theory group and the various experimental astrophysics efforts with compatible thrusts in the Astronomy Department, with the ultimate goal of a nationally funded center. This directly addresses the call for coherence from the external review committee; a draft proposal with Astronomy has been under development since the review. The proposal exploits the rare combination of a significant share of the LBT, large and strong cosmology theory group, a strong presence on two important astroparticle experiments (AUGER and GLAST), and a strong subset of the high energy experimentalists migrating to experimental astrophysics. The faculty involved have already benefited from new interactions and will profit additionally from the "branding" of their efforts. Space and infrastructure are the immediate needs, with faculty hires possible with demonstrated success.

Other proposals consolidate existing faculty to achieve "wholes greater than the sum of parts".

* The "Institute for Hyper-Fast, Ultra-Intense Laser Science" (LOI #7) builds upon the "best-in-class" atto-second laser capabilities of DiMauro and Agostini, but will provide a collaborate environment for other laser faculty (van Woerkom and Schumacher). Ultimately there may be a combination with an OSU high-intensity laser initiative. The awarding of an MRI is a promising early success. A main objective of the Institute is to attract agency funding in the new collaborative funding model, and become a springboard for a national center. DiMauro's external contacts with the FOCUS center at Michigan are very promising and may lead to future expansion. The effort also reaches beyond the Department with cost-sharing arrangements with outside collaborators at various national labs. In the short term, the main seeding would be in the form of moderate facilities and postdoc support.

* The physics of cold quantum gases has been one of the most active and widely publicized fields in recent years, with no sign that it has peaked. This field has attracted the interest

of a wide range of theorists in atomic, condensed matter, particle, and nuclear theory. The Department has one of the strongest collections of such theorists in the world (Braaten, Furnstahl, Ho, Randeria, Trivedi). The "Interdisciplinary Center on Quantum Gases" discussed in LOI #6 would capitalize on this expertise. The Department made an all-out effort to hire two experimentalists in this field in 2003, but ultimately three generous offers were declined. A renewed effort as proposed in LOI #6 would require a major commitment from the Department and the College. In the meantime, a newly formed Midwest Cold Atoms Consortium is meeting in November, 2005 to plan future joint activities (including workshops and schools) and to develop plans for seeking collective funding. This Consortium could be the springboard for building the case for additional resources to hire experimentalists.

* The biophysics group was criticized in the external review as being a small cluster of isolated research projects, which did not address forefront problems. The former criticism is valid at present, while the latter is questionable. The "Microscopic Mechanisms of Molecular Machines" (LOI #9) outlines a strategy whereby the three junior faculty (Poirer joining in 2006) can combine in a coherent project developing a novel approach to understanding the working of protein complexes, which harness the chemical energy of ATP to perform mechanical tasks. Achievement of best-in-class status in five years is not practical, but success will provide a foundation for further advancement and heighten the probability of attracting a strong senior biophysicist. Coordination with chemical biophysics and biochemistry efforts at OSU is under development, and milestones center on achieving group NIH funding.

* The external review identified gaps in the Departmental high-energy effort in Large Hadron Collider (LHC) physics, which will be one of the major frontiers in particle physics for the next decade and more. The "LHC Discovery Center" LOI (#8) is a proposal to address both the experimental and theoretical gaps with a major new investment in faculty and technical support. In the absence of substantial outside resources, the hire of a LHC phenomenologist who would interact substantially with the experimentalists as they shift from construction to physics analysis, mortgaged against the retirement of an high-energy theorist, could provide maximum leverage on the Department's LHC investment.

Another class of proposals would use seed resources to perform proof-of-principle investigations, which might be in the form of computational physics techniques or demonstration projects, or to explore the possible payoff of unconventional or path-breaking collaborations. Several of the first-round LOI's fall into this category.

* The "Coupling Science on Relevant Length and Time Scales" (LOI #4) addresses the currently unsolved problem of simulating multiscale dynamics from quantum mechanical through classical regimes, which arises in physical systems from materials to fast excitations of atomic processes to examples in the biological, medical, and agricultural sciences. The new simulation paradigm proposed would incorporate dynamic coupling of scales, whose development requires a team effort spanning Physics, Material Science Engineering, and Computer Science to attack a problem spanning large length and time scales as a proof of principle. The resources needed are a team of postdocs (one funded from MPS) and space to house them in close proximity.

* The "Frontiers in Medical Imaging Laboratory" (LOI #5) combines two existing Departmental initiatives (involving three faculty members) on medical imaging, which exploit

expertise from detector technology in high energy and condensed matter experiment. While this is not a major research thrust for any of the participants, a proposed joint project on combining PET and MRI (also in collaboration with faculty in Radiology and the Wright Center), if successful, would be widely noticed and have significant societal benefit. The goal is the development of successful demonstration projects, which is a *de facto* prerequisite for NIH funding (the National Institute of Biomedical Imaging and Bioengineering has a $300M/year budget). To carry this out, support for people (postdocs and students) is key. A valuable spinoff to this departmental expertise could be a GEC course on the physics of medical devices.

* The "Research Center for High-Energy Density Physics (HEDP)" (LOI #12) is not in the short term a proposal to develop a center, but rather to explore through expert visitors and focused workshops if the Department can be a pioneer in an identified national scientific field (e.g., in the "Physics in a New Era" report). This involves three existing strong groups in the Department that do not presently collaborate (relativistic heavy-ion nuclear physics, astrophysics, and high-intensity laser physics), but each explores physics that falls under the HEDP banner. If the fact-finding results are promising, a proposal for a center, which might incorporate the Laser Institute, will be developed.

* New generations of large-scale physics experiments, such as the Large Hadron Collider (LHC), generate enormous cumulative data volumes analyzed using teraflops of processing power, which requires a new generation of computing resources and strategies. The "Particle and Astrophysics Analysis Center" (LOI #10) proposes teaming with the Ohio Supercomputing Center (OSC) to compete for Tier 1 (ALICE) and Tier 2 (ATLAS) computing centers using grid computing technology. The ALICE effort is the front runner for a Tier 1 center, and mock LHC data challenges have been conducted with OSC (itself a member of the ALICE collaboration) for the last three years. The external review notes that "this would be a great opportunity for OSU, although it will require substantial resources."

The Department's mission includes goals in research, teaching, and service. The interdependence of efforts in these areas are most evident in the Physics Education Research group, which is now restored to its historical size of two faculty members. Further, as education is inherently interdisciplinary, the PER activities and expertise link to many areas of the Department, College, University, and the public. The Physics Education LOI (#11) outlines a strategic plan to multiply the impact of the group on the rest of the department while enhancing the research effort on educational technology. Because of the small number of PER groups nationally, becoming truly best-in-class in educational technology is a reachable goal. The group can become a focus for Department outreach through "broad impact" requirements, COSI, and more. Support for the requested technology specialist might come from restructuring UG instructional resources (such as the technology fee funds).

The goal of building coherent efforts was highlighted in the 2005 call for LOI's. However, the Department should not omit the seeding of individual efforts of excellence that reach best-in-class status. The "Black Holes and String Theory" LOI (#2) proposes such an opportunity, with success being noted throughout the physics community and among the general public, which is fascinated by black holes and Stephen Hawking. Resolution of the "information paradox" has been designated one of the top 10 unsolved high-energy physics problems. Progress by Mathur and collaborators over the last six years coupled with a concrete plan imply a reasonable probability of success. In allocating resources for this project, the principle of limited duration must apply. While success in this project is not expected to generate additional national agency funding, the high profile produced could very well attract private funding.

Appendix B: Peer Comparison Table

Table 1 **Top 20 Public University Physics Departments**

Data from AIP 2005 Graduate Programs in Physics

Rank [1] (US News 2002)	Public University	# Faculty	Other Faculty [2]	# NAS members	# GRA's	# GRA's per faculty	# postdocs	# postdocs per GRA	# Ph.D's in 2003-04	# B.S.'s in 2003-04	National Centers [3]	External Funding (in $M)
3	UC Berkeley	51		22	190	3.7	22	0.1	21	69	LBL	$4.6 [4]
9	U of Illinois	66	8	6	125	1.9	89	0.7	17	40	DOE MRL	$17.9
10	UCSB	44	5	11	68	1.5	23	0.3	17	39	PFC, MRSEC	$13.9 [5]
13	U of Maryland	75	36	1	127	1.7	45	0.4	33	39	MRSEC	$19.6
13	U of Michigan	68		1	82	1.2	43	0.5	11	26	PRC	$13.4
13	U of Texas	56	1	2	112	2.0	34	0.3	31	40		$13.6
16	UCLA	65	34	0	75	1.2	42	0.6	9	45		$18.8
16	UCSD	50	8	5	77	1.5	34	0.4	12	29	2 PFC's	19.3 [5]
16	U of Washington	45	30	7	69	1.5	25	0.4	22	70	DOE INT	$11.2
16	U of Wisconsin	50		2	108	2.2	19	0.2	19	26	PFC, 2 MRSEC	$17.0
20	U of Colorado	56	40	4	182	3.3	60	0.3	13	41	JILA, NIST	$12.1 [6]
23	SUNY Stony Brook	59	44	2	106	1.8	35	0.3	15	9	2 MRSEC's	$14.0
24	Ohio State U	58	12	1	51	0.9	40	0.8	14	30		$9.9
24	Rutgers	70		4	36	0.5	57	1.6	17	33		$8.5
24	U of Minnesota	45	4	0	44	1.0	27	0.6	13	24	MRSEC	$13.4
27	Penn State U	48		2	64	1.3	49	0.8	16	25	PFC, MRSEC	$26.3
28	Michigan State U	66	7	0	90	1.4	26	0.3	12	14	PFC, NSCL	$25.8
32	Georgia Tech	29	9	0	41	1.4	12	0.3	7	26		$4.5
32	Indiana U	35		0	53	1.5	18	0.3	11	9	IUCF	$11.4
32	Purdue U	43		1	33	0.8	13	0.4	7	16		$7.3
Average for the 12 Public Universities		57.1		5.3	110.1	2.0	39.3	0.4	18.3	39.4		$14.6
	Ranked above OSU											
Average for Top 20 Public Universities		54.1		3.6	87.8	1.6	35.8	0.5	16.0	32.8		$14.1

Notes:

1. Rank includes private universities (not shown)
2. "Other Faculty" are engaged in separately budgeted research (joint and adjunct appointments)
3. PFC = NSF Physics Frontier Center; MRSEC = NSF Materials Research Science and Engineering Center
4. UC Berkeley external funding does not include $138M in physics related research outside dept. (from LBL, etc.)
5. UCSB and UCSD external funding each includes $8.7M for institutes