Physics Department Self-study

October, 2017

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I. Executive Summary

The UT Austin Physics Department is among the largest in the U.S. in terms of Bachelors degrees granted, PhDs granted, and external research funding. The department has active research programs in most area of modern physics. While not ranked in the top ten U.S. physics departments, it was ranked fifth among those in public universities (tied with Maryland) by U.S. News and World Reports.

This self-study describes the department, its educational and research programs, its organization and ways of functioning. It discusses the challenges the department faces and the opportunities that we are trying to take advantage of.

The biggest issues that challenge the department are:

- Renewing an ageing faculty
- Strategic recruiting of outstanding physicists to our faculty
- Improving the diversity of the faculty and student bodies (graduate and undergraduate)
- Coping with an ageing building that urgently needs renovation
- Improving the quality of undergraduate teaching
- Significantly increasing endowments to support the department, especially the graduate program

Efforts are underway to address these challenges, and the department welcomes advice on how to improve our efforts.

II. Introduction

The University of Texas at Austin is a public research university. It has the eighth largest single-campus enrollment of any U.S. university (40,168 undergraduates and 11,163 graduate students in Fall 2016). UT consists of 18 colleges and schools providing 156 undergraduate degree programs and 139 graduate degree programs. With a teaching faculty numbering 3,156 (Fall 2016), UT lists over 12,000 courses. U.S. News and World Reports ranks it 18th among public universities in the U.S.

The Physics Department resides in the College of Natural Sciences (CNS), the largest college at UT Austin. CNS has twelve departments, includes the School of Human Ecology, and houses both the Marine Science Institute and the MacDonald Observatory. CNS is home to about 350 tenure-track faculty and a similar number of non-tenure track faculty (mostly lecturers). In Fall 2016 there were 10,975 undergraduates and 1,229 graduate students in CNS. The staff numbers about 1,200.

CNS is led by Dean Linda Hicke. Its mission is: To provide research-enhanced education and to provide educationally-connected research. There are five Associate Deans: Dean Appling, Research and Facilities; Dan Knopf, Graduate Education; Shelley Payne and Natasa Pavlovic, Faculty Affairs; and David Vanden Bout, Undergraduate Education. Other key functions in CNS are managed by five Assistant Deans or Directors: Kelsey Evans, External Relations (includes development); Ricardo Medina, Business Services (includes human resources); Melissa Taylor, Strategy and Planning; Mark McFarland, Information Technology; and Christine Sinatra, Communications. The level and quality of engagement between the Physics Department and all of these CNS leaders is high.

The Physics Department has 48 tenure-track faculty members as of Fall 2017, including one whose appointment is split with Chemical Engineering. There are 449 undergraduate physics majors and 203 graduate students. The American Institute of Physics in 2015 identified our department as the fourth largest source of physics bachelor's degrees in the U.S. The department has active research programs in most areas of modern physics research. In the most recent U.S. News and World Reports ranking of physics graduate programs, it was ranked 14th overall and fifth among physics departments in public universities (tied with Maryland).

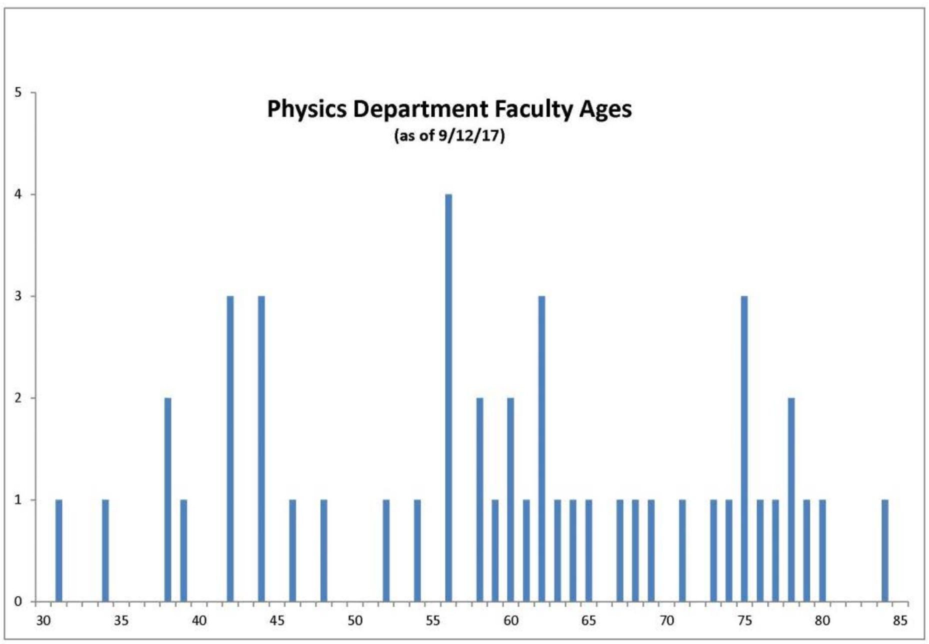
The Physics Department is located in the Robert Lee Moore Hall (RLM), where the Math and Astronomy Departments are also located. RLM includes space for classrooms, as well as Physics Department faculty and other departmental offices, research laboratories, instructional laboratories, and research-related facilities such as the machine shop and cryogenics shop. The Kuehne Physics Mathematics Astronomy Library is also located in RLM. While many physics classes are taught in RLM, two lecture halls located in Painter Hall, each seating about 135 students, are used for the larger physics classes, including introductory classes for physics majors and the introductory (service) courses that are provided for engineering students, pre-med students, and other non-physics majors. Adjoining each of those lecture halls are rooms where extensive collections of lecture demonstration equipment are maintained.

III. Analysis of the Physics Departments Strengths, Weaknesses, and Opportunities

We identify and discuss several major issues for the Physics Department.

Faculty

The greatest strength of our Physics Department is its faculty. However, the age distribution among our faculty is far from ideal. Our faculty includes one Nobel Prize winner (Weinberg), three members of the National Academy of Sciences (MacDonald, Swinney, and Weinberg), and 33 Fellows of the American Physical Society. Our faculty includes a number of outstanding research physicists and physics teachers. However, the mean and median ages of our faculty are 60 years, and 10 faculty members are 75 or more years old. While everyone's contributions to the department are valued, this is not a healthy situation. It does, however, present an opportunity to renew the department as the cohort of older faculty retires.



The figure shows the distribution of faculty ages. One can easily see that the density of the distribution is lower on the left half of the figure. This reflects a relatively low rate of faculty hiring into the Physics Department over a significant period of about 20 years, beginning in approximately 1995. Over this period there has been the gradual reduction in the faculty headcount (i.e., attrition exceeded hiring). The department had 62 faculty members in 1995. Today it has 48.

We are currently authorized to fill five open positions (four senior Faculty Investment Initiative[1] positions and one assistant professor), and these hires will have multiple benefits for our faculty. Nonetheless, we can reasonably anticipate close to a dozen retirements in the next five years. This

[1] The Faculty Investment Initiative will be discussed later in this section.

provides an opportunity to revitalize the department, but it also poses the question of whether the current size of the faculty should be maintained, or allowed to decline further – and if so how would that affect the stature and impact of our department.

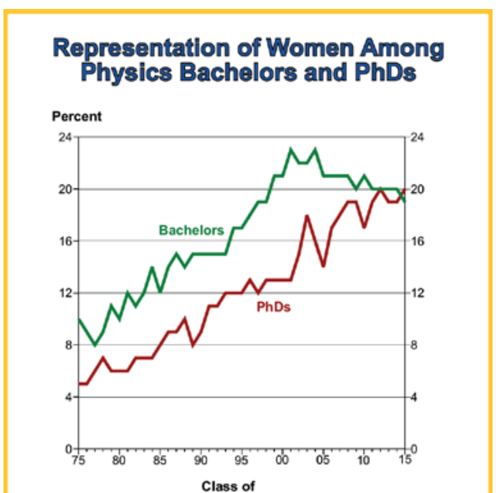
Diversity

Physics as a scientific discipline suffers from low participation by women and minority members. This is a larger problem for physics than other sciences. For instance, about 50% of bachelor's degrees in chemistry go to women, while only 20% go to women in physics.

The fractions of our faculty and students belonging to historically under-represented groups are typical for U.S. physics departments, except for an unusually large fraction (25%) of Hispanic undergraduate physics majors that reflects the significant Hispanic population in Texas. Otherwise, the diversity statistics for our department (shown in the following table) are not impressive. Currently, our faculty of 48 includes six women, two Hispanics, and one African-American.

	Total	Female	African-American	Hispanic
Faculty	48	6	1	2
Grad Students	204	31	1	8
Physics Majors	449	83	7	112

A challenge in faculty hiring of diversity candidates is the small fraction of PhD's going to women and minorities. Nationally, only about 20% of physics PhD's go to women and about 6% to minorities (including Native Americans). Naturally, the best physicists in those groups are highly sought by other physics departments. The American Institute of Physics figure below shows the fraction of physics bachelor's degrees and PhDs going to women versus time. Recently, the fraction of bachelor's degrees has plateaued and may even be declining. This will be reflected in PhD production if it continues.



The number of women receiving physics PhDs and bachelor's degrees are both at all-time highs, 365 and 1,550 respectively. The percentage of physics PhDs awarded to women has been increasing, whereas the percentage of physics bachelors awarded to women has been declining in recent years.

In spite of the difficulties, the department is making a strong push to make diversity faculty hires. Recruitment is underway for two target-of-opportunity diversity hires into senior level positions (full professors). An assistant professor search that is currently underway will follow practices to assure that diversity candidates are not subjected to any implicit biases and that diversity candidates are included in the final short list.

The department's Outreach and Diversity committee, formed in Fall 2015, works to ensure that the environment in the Physics Department is hospitable to women and minority members. There is an active Women in Physics group in the department, participated in mostly by female faculty and graduate students. Also, the department sponsors three outreach programs that are aimed at pre-college students. This is important since young people usually form their attitudes toward physics before they arrive at a university. Outreach activities that bring children and pre-college female and minority students into contact with physics and physicists are critical to making progress.

Our department sponsors the Physics Circus (https://web2.ph.utexas.edu/~circus), a traveling show that takes entertaining physics demonstrations to schools around the Austin area. The graduate student presenters are often female. Circus performances reached over 10,000 local-area students last year, and a similar number are expected this year. Our Alice in Wonderland program (https://sites.cns.utexas.edu/aliceinwonderland/home) brings female high-school students to our department for a few weeks each summer to learn about physics and to participate in research in our laboratories. Our Saturday Physics workshop is designed for secondary school physics teachers and their students. It brings them to campus for a day of lectures and discussions on the latest physics.

Space

The RLM building was completed in 1974, and it is showing its age. Major mechanical systems need to be upgraded. Many basic lab amenities are substandard. For instance the building's chilled water distribution system is barely functional. The overall condition of many parts of the building is poor. In response to an inquiry about faculty research needs, one of our faculty members commented as follows: "We work under conditions of peeling paint, scrounged half-broken furniture, wild temperature swings and constant sordid trials in our lab facilities in RLM. Compared to physics facilities at peer institutions, with which I have collaborated, our lab space is stunningly below par." Conditions in RLM make recruiting new faculty more difficult.

The need for RLM renovation is well understood by the upper administration. An architectural and engineering study is underway, but no timeline for renovation has yet been set. Preliminary plans for RLM renovation emphasize the replacement of obsolete mechanical systems and moving classrooms to the ground floor and first floor (RLM levels 4 and 5). The need for modernizing research laboratories will be partly addressed, but most lab renovations will only be addressed room-by-room as new faculty are hired.

Teaching

Our faculty includes some outstanding educators, including three current faculty members who have received the distinction of being designated a Distinguished Teaching Professor (Downer, J. Markert, and Sitz; emeritus faculty Chiu and Oakes also received this recognition). Several other faculty members have received teaching awards. Many of our faculty members are dedicated teachers. Nonetheless, the department has a reputation for poor teaching. This is primarily the result of low student evaluation scores (so-called Course Instructor Surveys, or CIS scores) in service courses taught to engineers and pre-meds. In addition to the bad reputation for the department, quality of teaching has become an issue in promotion decisions for some Physics faculty recently.

Efforts are in progress to improve our teaching, particularly in the service courses. A new (Fall 2015) Teaching Excellence committee is active. One of its initiatives has been to start conducting universal peer teaching evaluations. That is, now every faculty member will receive a peer evaluation from a faculty colleague (usually a member of this committee) who visits and observes a class. The committee has also developed a standard format and methodology for the evaluations.

The Teaching Excellence committee has recently been asked by the chair to draft a statement on Teaching Expectations for Physics Faculty. This statement will be helpful for new faculty as we pursue aggressive recruiting, and it may encourage some current faculty to be more sensitive to teaching concerns. Over time we also aim to forge a closer linkage between teaching quality and faculty salary increases. Many faculty members are uncomfortable with CIS scores being the sole indicator of teaching quality, but universal peer evaluations over time will provide another indicator to assist with these judgements.

Endowments

The Physics Department depends critically on both endowment income and gifts. The majority of our endowment base is in four large chairs, held by four members of our faculty. Details of our endowments and the resulting funding will be presented in Section V. The current endowments do not meet our needs. The greatest shortfall is in the area of graduate student support.

In addition to being a recruiting tool, graduate student fellowships provide a fallback source of support for graduate students when Teaching Assistant or Graduate Research Assistant appointments are not available. In the last couple of years, about $60-75K per year has been needed for such fallback support. Also, a program called the Graduate Student Investment Initiative (GSII), aimed at attracting top students, was instituted for incoming graduate students in 2015. It provides an attractive package to potential students. Over a five year period our department is scheduled to ramp up to having 30 GSII students. While the majority of the costs of this program are provided from outside the Department, the cost to our department will be $180,000 per year when the ramp-up is completed. All our graduate student endowments combined generate only about $150,000 per year (and some of those have donor restrictions that make them difficult to use). So, our graduate endowments fall short of existing commitments by nearly $100,000 per year. Additional needs will appear soon as new graduate-student friendly policies are being adopted by CNS. In short, there is a pressing need for substantially increased graduate student endowments.

Faculty endowments will be important as we recruit at the senior level. The Department currently has one endowed chair that is not occupied and is targeted for a particular research area (cosmology). It also has one open endowed professorship that has no such restriction. Current CNS policy is that chairs and professorships are awarded for a six-year period, which may be extended after an appropriate review. However, in the past, chairs and professorships were awarded in an essentially open-ended way, which over time may mean they are no longer optimally deployed. A few of our current chairs and professorships may fall into that category.

New Directions

In a physics department as large as ours, new ideas and new initiatives are continually being developed as part of the research process. Nonetheless, the department as a whole has been somewhat static in recent years. While we have made some excellent hires at the assistant professor level, recruiting has not been strategically targeted.

A UT program from the Provost called the Faculty Investment Initiative (FII) has provided an opportunity for strategically targeted recruiting at the senior level. The Physics Department was allocated four senior FII positions to fill, and it is expected that significant resources will be available to support these recruitments.

Two areas of strategic importance are the focus of these recruitments:

- Two FII positions will be used to establish a new research program in Quantum Information (QI). QI is not a new research area (having existed for 20+ years), but it is still under rapid development. QI involves studies of fundamental physics while at the same time its possible applications could be earthshaking. Other UT departments are also interested in QI, particularly Computer Science and Electrical and Computer Engineering. Over a short period of a few years UT may be able to establish a world-class program in QI combining the strengths of multiple departments, with the Physics Department playing a central role.

- It is a strategic goal of our department to recruit a more diverse faculty. Two FII positions are earmarked for hires of outstanding physicists who would bring greater diversity to our faculty. These may be in any area of physics, although it is likely that these hires will complement (or revitalize) existing research groups in the department.

Recruiting on these positions is underway. The status of discussions with potential candidates can be discussed in general terms, but details such as candidate names are confidential.

IV. Strategic Plan

A long-standing goal of the Physics Department has been to move into the top-tier of U.S. physics departments. It is difficult for any public university to support an elite, top-tier physics department. Nonetheless, by taking the actions described below, we will move toward achieving this goal.

ACTION 1: Recruit outstanding and diverse new faculty.

The first Physics Department hiring under Dean Hicke took place in 2015, when we were able to hire three new assistant professors (one of whom has since left). A policy of regular recruiting at the junior level is desirable, and it is likely that we will be able to that do in the future.

A current focus is on senior level hiring enabled by the Faculty Investment Initiative, which is a program initiated by the University's President, Greg Fenves, when he was Provost. The FII program has two components: (1) aggressive recruiting of outstanding mid-career faculty members and (2) significant pre-emptive retention raises salary for top faculty members. Under the FII program the Physics Department was allocated four positions.

The priorities for FII hires are as follows:

- Two positions will be occupied by outstanding researchers in quantum information. Our current thrust is recruiting two leading experimentalists.
- Two positions will be occupied by outstanding researchers who bring additional diversity to our faculty.

Beyond the FII program, continuous recruiting of outstanding and diverse faculty is essential to the success of the Physics Department. With roughly a dozen retirements expected over the next few years, the opportunity exists to not only renew the department but also to significantly increase its quality, impact, and diversity.

ACTION 2: Continuously improve physics education.

Our education mission is central, and any department that aspires to be in the upper echelon of physics departments must demonstrate a strong commitment to teaching excellence. We will endeavor to continuously improve physics teaching in our Department.

In a typical academic year, we have about 100 new physics majors, and we teach introductory physics courses to about 1000 engineering students, about 1000 students with majors in other CNS departments, and about 200 students with majors outside CNS. These are different student communities with different needs. We must approach each group in a way that is tuned to those needs.

We must stay abreast of the results of research on physics education and evaluate (and consider adopting) new teaching techniques as they are developed.

An important facet of achieving teaching excellence is motivating our faculty. This means rewarding excellent teaching, both through appropriate recognition (e.g., awards) and weighing teaching performance in the determination of merit raises, and it means making sure faculty are held accountable when teaching quality falls short. Also, the Department needs to provide support and assistance to help our faculty improve their teaching and employ classroom best-practices.

A new departmental committee, the Committee on Teaching Excellence, promotes strategies to continuously improve physics teaching at both the undergraduate and graduate levels.   It will provide feedback, suggestions, and advice to help faculty members improve their teaching. It will monitor CIS rankings and student complaints to identify instructors to may need assistance. It will stay abreast of research on physics education and the lessons from other physics departments, and it will promulgate teaching best-practices within our faculty.

ACTION 3: Increase Physics Department endowments by a significant amount.

The Physics Department relies on endowments and endowment income for several critical purposes. These include: graduate student recruitment, graduate student fellowships, faculty recruitment and retention, undergraduate scholarships, visiting lectureships, and departmental activities that cannot be supported with state funds. Our current graduate-student endowments are insufficient to meet current commitments to GSII students after the program is fully implemented, and other critical fellowship needs may not be met.   Faculty recruiting may be constrained by inadequate availability of endowed chairs and professorships. Worthy outreach activities, such as the Physics Circus, may not be possible in the future without donor support.   Also, we would greatly benefit from having a named post-doctoral fellowship program similar to those in some top Physics departments. To achieve our goal of moving our department into the top-tier, we will need a significantly larger endowment base.

Our development efforts are coordinated with the CNS development staff.   The department has an Advisory Council consisting of some alumni and other friends of the department. Effort is underway to engage the Advisory Council more effectively in the development process and to refresh the membership to assist with that effort.

ACTION 4: Sustain a collegial Department that supports our faculty, students, and staff while operating in an efficient and cost-effective manner.

Our Department generally provides a collegial environment for faculty, students, and staff, but we cannot afford to be complacent.   We need to develop a culture that is open to change. Our procedures for tracking faculty career advancement, including third-year reviews of assistant professors to comprehensive period reviews (aka post-tenure) of senior faculty, can be improved. We must make sure that the Department is allocating resources based on priorities. For instance, some laboratory space assignments made many years ago may not make the best use of the space today. Organizational structures created long ago prevent the most efficient deployment of administrative staff.

We have initiated steps to streamline the Department's management and to provide more professional supervision of administrative staff. The committee on Faculty Advancement, whose members are among our most productive faculty, now advises the Chair on faculty workload issues and oversees systematic 3rd-year and comprehensive periodic reviews. When new research opportunities arise, lab space and other resources will be redirected.

ACTION 5: Operate high-quality facilities for the benefit of the Department and the College.

We believe the Physics Department machine shop is one of the best in the country and that maintaining its high level of quality and capability is important for our department and others in CNS. In September, 2014, it became a service center with a $20 per hour charge. Currently it is a CNS core facility that is available to all CNS departments. It provides high-quality and high-capacity capabilities for the fabrication of scientific instruments for all CNS departments. This charge is billed for all jobs, including those from Physics faculty. For the Physics Department, this is an important research resource for our experimental faculty, and it is valuable as a recruiting tool as well.

The Physics machine shop is part of a long tradition in our Department. It has a full complement of modern machine tools (e.g., three CNCs and an EDM), and it is managed with commitment to customer service. This is reinforced by a high level of involvement from the experimentalists in the Physics faculty who feel a strong sense of responsibility for the health of the shop.

Summary

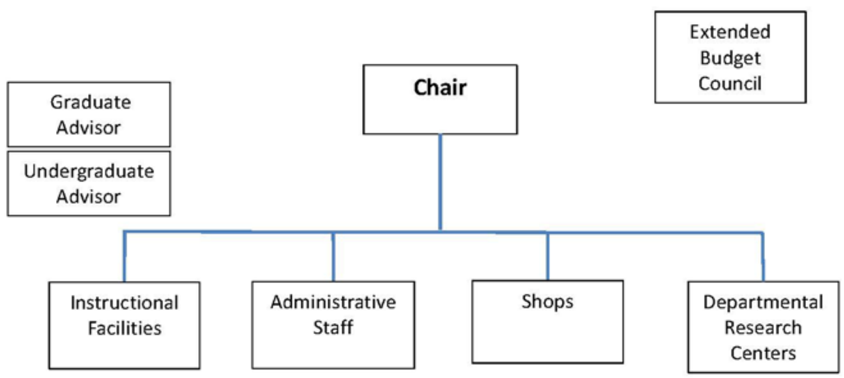
Moving our Physics Department into the top tier will require recruiting outstanding new faculty, both senior and junior, as many current faculty members retire, and we must make sure that new faculty members increase the diversity of our faculty. It will require focused attention on delivering the highest quality teaching to our students, both undergraduate and graduate. It will require maintaining excellent facilities and staff to support our faculty and students. And, it will require finding sources of support outside the University, especially new endowments.

V. Organization and Governance

Organizational Structure

The Physics Department is managed by a Chair, who is appointed by the Dean to terms of four years. The roles and responsibilities of a department chair in CNS are listed at the following link: https://cns.utexas.edu/images/CNS/Deans_Office/Faculty_Affairs/Chairs_Handbook/02_Role_and_responsibilities.pdf. Most administrative personnel and functions are overseen by an administrative staff person with the job title Assistant Director, who reports to the Chair. The Chair may appoint, with the concurrence of the Dean, up to two Associate Chairs. The prior Chair delegated responsibilities to four associate chairs, but that arrangement predated the current Dean. There is no currently serving Associate Chair, although the hope is to enlist a suitable faculty member soon. The current organization is illustrated in the chart.

DEPARTMENT OF PHYSICS ORGANIZATIONAL CHART



The Chair currently has four direct staff reports: the Assistant Director (Chris Lynch); the shops supervisor (Allan Schroeder); the RLM building manager (Ben Costello), who also manages our instructional labs and lab support staff; and the lecture demonstrations supervisor (Andrew Yue), who is based in Painter Hall. The Assistant Director supervises the administrative staff of the Physics Department, oversees finances and budget, interfaces with the College and other parts of UT, and provides direct support to the Chair on a wide range of issues. The shops supervisor supervises the machinists in the Machine Shop, the technician in the Cryogenics Shop, and an electronics technician. A detailed organization chart for administrative and technical staff appears in Appendix D.

Most student related matters fall under the purview of either the Undergraduate Advisor (Greg Sitz) or the Graduate Advisor (John Keto). The chair of the Graduate Studies Committee (Sonia Paban) also plays a key role in graduate student issues. Teaching assignments for graduate and undergraduate courses are made by committees (discussed later), subject to Chair approval.

In the past the Physics Department included several Organized Research Units (ORUs) whose directors reported to the Provost through the Dean. Under Dean Hicke the ORUs were reconstituted as non-ORU centers, which we refer to as departmental centers or departmental research centers. The directors now report to the Chair. The centers will be discussed in a later section, along with some history and how the current structure works.

Governance, Policies, and Procedures

The Physics Department has traditionally followed the Extended Budget Council mode of governance, in which the Budget Council consists of all tenured faculty (both Associate Professors and Professors). The governance policy is renewed every three years with a vote of the Budget Council, in accordance with the Handbook of Operating Procedures (2-1310). The department chair serves as chair of the Budget Council. Budget Council meetings are called by the Chair when needed, usually two or three times each semester. (Other faculty meetings are called for purposes of sharing information or discussion, also a few times per semester.) Budget Council votes are taken on recommendations for faculty hiring, tenure, promotion, and faculty salary raise evaluations. Associate Professors may not vote on matters affecting faculty members of their own or higher rank.

The department has a standing committee called the Budget Council Advisory Committee (BCAC), which serves in an advisory capacity to the Budget Council and the Chair. The full faculty (including Assistant Professors) elects this six-member committee, with two new members being elected to three-year terms each year. All tenured faculty members are eligible for BCAC membership, but five members must be full professors at any given time. The BCAC follows its own by-laws. The Chair is an ex-officio non-voting member. Most motions for Budget Council voting originate in the BCAC (e.g., motions for faculty hiring, tenure, promotion, salary raises).

A number of policies and procedures are discussed below.

<u>Annual and Comprehensive Periodic Review of Faculty</u>

The Budget Council makes annual faculty evaluations. These may be based on the same review process it uses for merit raises. The Chair may make separate recommendations.

Mid-probationary and comprehensive periodic reviews are performed by ad hoc sub-committees of the Budget Council consisting of three full professors.

<u>Merit Raises</u>

Each Spring the Budget Council Advisory Committee goes through a faculty review process that results in a set of faculty evaluations that are the basis for raise recommendations that are submitted to the Budget Council for approval. Those Budget Council recommendations for faculty merit raises are communicated to the Dean. The Chair, at the Dean's request, makes separate recommendations. The BCAC evaluations are also used as the basis for the Budget Council's annual faculty evaluations which are reported in the following Fall semester.

Faculty Recruiting

Faculty recruiting is one of the responsibilities of the Chair. The Chair may appoint ad hoc committees to assist with faculty searches and recruiting. Hiring diversity is a departmental priority. The Department maintains and executes a Diversity Hiring Plan which outlines the procedures to be followed during faculty searches to improve the diversity of our faculty. The Diversity Hiring Plan must be approved each year by the Dean prior to receiving authorization for faculty recruiting.

Faculty Retention

Faculty retention cases are addressed by the Chair, in consultation with the BCAC, and the Dean.

Faculty Mentoring

Assistant professors are assigned both a teaching mentor and a research mentor. The Chair meets once each semester with each assistant professor to discuss progress and any issues that need to be addressed. Assistant professors give a status report to the BCAC each year, providing an opportunity for wider discussion and feedback. Mentoring of associate professors has been less formal in the past, although the Chair meets with associate professors occasionally to discuss their progress toward promotion. In fact, mentoring of all faculty throughout their careers needs more attention. This was one reason for the creation of the Faculty Advancement Committee in September 2015.

Diversity and Gender Equity

Achieving increased diversity and gender equity is the responsibility of the Chair and of all faculty members. The entire faculty has been charged with helping to make contacts with promising women and minority physicists to encourage them to apply during future faculty searches. The Committee on Outreach and Diversity (formed September, 2015) has been charged by the Chair with helping to improve the environment for women and minority faculty, post-docs, graduate students, and undergraduates in the Department.

Non-Tenure Track Faculty

Non-tenure track (NTT) faculty (typically Lecturers) may participate in faculty meetings and may serve on departmental committees. Evaluation and promotion issues for NTT faculty are addressed by the Chair, in consultation with tenure-track faculty and Dean as needed. The Physics Department currently has only one Lecturer (John Yeazell). Occasionally, to meet teaching needs not covered by the regular faculty, a post-doc may be appointed part-time as a Lecturer, but these appointments are made for only one semester at a time when the need arises. CNS approval and funding is required for those appointments.

Departmental Centers

Research centers have played an important role in the life of the Physics Department over many decades. They were initially constituted as organized research units (ORUs). When Dean Hicke became CNS Dean in 2012, there were seven Physics ORUs: the Center for Complex Quantum Systems, Center for High Energy Density Science, Institute for Fusion Studies, Center for Nonlinear Dynamics, Center for Particles and Fields, Center for Relativity, and the Weinberg Theory Group. The Center for Relativity, the first of the centers created in 1962 and at one time an important force in gravity research, was eliminated since it had diminished over time to having a single faculty member. Primarily because the other ORUs did not meet the current criteria for ORUs at UT (e.g., they did not include faculty members from multiple departments), they have been reconstituted as non-ORU centers, or departmental centers. As such the Chair may select or replace center directors, determine their funding, and may ultimately dissolve the centers if they are not adding value to the Department. Presumably the Chair may also create new departmental centers, although on all major decisions the Dean's concurrence would be solicited.

In the past some of the ORUs had special funding arrangements with the College. Now all funding is derived from indirect cost return (i.e., overhead return). The College receives return of 25% of the overhead generated by grants held by CNS faculty members. CNS returns half of that to the department. In recent years the Department has passed 84% of each center's overhead back to the center, while holding 16% to cover essential departmental needs. Some modification of this policy will result from changes in how centers are staffed.

The centers help to coalesce faculty members with shared physics interests into coherent groups, and in some cases they provide external visibility that is valued by funding agencies. However, with respect to administrative staffing, they have created silos that have led to inefficient use of resources and in some cases poor supervision of staff. Center directors, being faculty members, are not familiar with UT's administrative systems or human-resources policies and best practices. Supervision of administrative staff is best performed by a senior level staff supervisor. As administrative staff retire from centers, they will be replaced by staff who report to the department's assistant director for administration. Lowering the silo boundaries will result in a more efficient management of staff resources. These efficiencies are needed in order to meet the needs of the faculty in an environment in which budgets are tight and can be expected to decline or at best remain constant in spite of rising operating costs (e.g., staff salary increases are frequently "self-funded" by departments, meaning staff raises must be paid for by cutting other costs).

The departmental centers are listed in the following table, along with the center director, and the centers' faculty membership.

Special comment is appropriate in the cases of the Center for High Energy Density Science (CHEDS) and the Institute of Fusion Studies (IFS). Each of these centers is funded primarily through large grants (greater than $2 M/year) from the Department of Energy. The visibility that their center status provides is valued by DOE. CHEDS is funded by the DOE National Nuclear Security Administration to operate the Texas Petawatt Laser. As such, CHEDS has a larger technical staff than other centers. The IFS is funded by the DOE Office of Fusion Energy Studies (in the Office of Science), and it hosts the leading theory group for fusion studies in the U.S. It has a large research staff that includes three Research Professors and several other long-term research staff employees.

	Director	Faculty Membership	Comment
Center for Complex Quantum Systems	Allan MacDonald Linda Reichl, co-director	De Lozanne, Fiete, Lai, Li, MacDonald, J. Markert, Niu, Potter, Reichl, Shih,Tsoi	Mostly condensed matter, theory and experiment
Center for High Energy Density Science	Todd Ditmire	Ditmire, Hegelich, Keto	Operates Texas Petawatt Laser
Institute for Fusion Studies	Francois Waelbroeck	Downer, Gentle, Hazeltine, Morrison, Fitzpatrick	Mostly fusion theory, some experiment
Center for Nonlinear Dynamics	Harry Swinney	Florin,Gordon, Marder, Raizen, Swinney	Includes biophysics and some AMO physics
Center for Particles and Fields	Jack Ritchie	Andeen, Dicus, Lang, C. Markert, Onyisi, Ritchie, Schwitters	Particle and nuclear physics, experimental
Weinberg Theory Group	Steve Weinberg Willy Fischler, assoc dir	Caceres, Distler, Fischler, Kaplunovsky, Kilic, Matzner, Paban, Weinberg	Particle theory, cosmology

Departmental Committees

Much of the work of the department is performed by faculty committees. The current membership of each of the standing committee is provided in Appendix E. A brief description of the committees and their missions follows.

- Budget Council Advisory Committee – members are elected by the full faculty to staggered three year terms; advisory to the Chair and Budget Council

- Colloquium Committee – oversees scheduling of the departmental colloquia

- Faculty Advancement Committee – advises Chair on issues concerning faculty career issues and mentoring; organizes post-tenure reviews (now called comprehensive periodic reviews); organizes mid-probationary reviews (3rd year review of assistant professors); advises Chair on faculty workload policy and assessments.

- Graduate Studies Sub-Committee (GSSC) – oversees the graduate program, responds to petitions from graduate students; has authority to act on the behalf of the Graduate Studies Committee on many issues; makes teaching assignments for graduate courses.

- Graduate Student Recruitment Committee – makes decisions on graduate student admissions.

- Graduate Student Welfare – includes graduate students, deals with graduate student issues and concerns.

- International Initiatives – develops and oversees international exchanges for advancing research and both graduate and undergraduate education,

- Committee on Nominations – attempts to bring appropriate recognition to faculty members by nominating them for awards, encouraging nominations, etc.

- Committee on Outreach and Diversity – promotes physics and physics education to the community at large; works to improve access to physics and physics education for under-represented groups; works to eliminate gender biases from the culture and practices of the Department; and works to improve the gender and ethnic balance of the faculty and graduate and undergraduate student bodies.

- Teaching Excellence Committee – seeks to improve teaching quality in our department; includes performing universal peer teaching evaluations.

- Undergraduate Advising Committee – members meet with students for advising (chaired by the Undergraduate Advisor).

- Undergraduate Affairs – oversees the undergraduate program, including making teaching assignments (chaired by the Undergraduate Advisor).

In addition to standing committees, *ad hoc* committees may be established when needed to perform specific functions. For instance, there are three active *ad hoc* committees as of Fall 2017:

- an assistant professor search committee;
- an undergraduate curriculum review committee working within the framework of the Dean's 21st Century Undergraduate Initiative; and
- a graduate curriculum review committee.

Faculty Endowments and Allocation Process

The department has seven endowed faculty chairs and seven endowed faculty professorships. The table lists each chair and professorship, its holder, and the recent endowment amount (market value).

	Holder	Endowment Market Value 8/27/2017
Sid W. Richardson Foundation Regents Chair in Physics #1	Allan MacDonald	$4,530,259
Sid W. Richardson Foundation Regents Chair in Physics #2	Mark Raizen	$4,134,501
Sid W. Richardson Foundation Regents Chair in Physics #3	Harry Swinney	$4,662,734
Sid W. Richardson Foundation Regents Chair in Physics #4	Roy Schwitters	$5,811,478
Fondren Foundation Centennial Chair in Physics	Daniel Heizen	$2,142,739
Jeff and Gail Kodosky Endowed Chair in Physics	vacant	$1,348,936
Dr. Arnold Romberg Endowed Chair in Physics	Chih-Kang (Ken) Shih	$1,167,669
Professorship in Physics #1	vacant	$603,564
Professorship in Physics #2	Mike Downer	$603,564
Jane and Roland Blumberg Professorship in Physics	Karol Lang	$398,969
Jane and Roland Blumberg Centinnial Professorship in Physics	Willy Fischler	$558,231
Trull Centennial Professorship in Physics #1	Qian Niu	$364,898
Trull Centennial Professorship in Physics #2	James Erskine	$350,236
Texas Atomic Energy Research Foundation Professorship	Richard Hazeltine, Phillip Morrison; Fellows	$802,062

Steven Weinberg holds the Jack S. Josey-Welch Foundation Chair in Science, which is not a Physics Department endowment.

In the past chair and professorship assignments have been open-ended. Current CNS policy is that new assignments will be reviewed by a CNS committee on a six-year cycle. New assignments are based on Chair recommendations to the Dean.

Colloquia, Lecture Series, and Seminars

The Physics Department has a lively schedule of colloquia and seminars. During the 2016-2017 year the departmental calendar listed 290 events. We do not track statistics on these, but that number is probably typical of other years. These events were not all colloquia and seminars. Appendix F lists the events during 2016-2017. The departmental centers sponsor their own seminar series.

Occasionally, a lecture series will be presented by an outside visitor. Every semester the departmental colloquium is scheduled for Wednesday afternoons at 4:00 pm. It rarely misses a week. Two endowed lectureships provide funds that can be used for prestigious speakers. A third endowed lectureship, named in honor of our former faculty colleague Mel Oaks, is used to support a colloquium speaker whose presentation is aimed toward undergraduates.

We circulate weekly event schedules by e-mail and other means. One such schedule for a randomly chosen week from Fall 2016 is shown below. It may not seem random since the colloquium speaker was a Nobel laureate, but such things happen from time to time.

Physics Events for the week of 14-18 November 2016

Monday, 14 November 2016
- QUALIFIER: Lu Zheng, UT-Austin, "Imaging Emergent Phenomena on Ferroelectric Material with Microwave Impedence Microscopy," 11:00am, RLM 11.204
- PHYSICS DEPARTMENT OPEN HOUSE: Come interact with physics faculty and students as the Department of Physics opens its doors, 2:00pm-5:00pm, Throughout RLM (look for signs)
- CENTER FOR PARTICLES AND FIELDS SEMINAR: Jacquelyn Noronha-Hostler, University of Houston; "Finding Missing Resonances using Lattice QCD," 4:00pm, RLM 5.114 (Note room change, this week only.)

Tuesday, 15 November 2016
- THEORY GROUP SEMINAR: Dr. Mehrdad Mirbabayi, Stanford University, "Weinberg Soft Theorems from Weinberg Adiabatic Modes," 2:00pm, RLM 7.104
- PIZZA SEMINAR: Prof. Harry Swinney, Department of Physics, UT-Austin, "Chaos and dynamics of pattern formation: progress and open challenges!" 5:00pm, RLM 7.104

Wednesday 16 November 2016
- QUALIFIER: Dung Duc Phan, UT-Austin, "Sterile Neutrino Search in MINOS+ via Electron Neutrino Appearance," 10:00am, RLM 9.222
- GEOMETRY AND STRING THEORY SEMINAR: Valentin Zakharevich, UT-Austin Mathematics, "Gapped boundary conditions for topological insulators," 12:00pm, RLM 8.136
- THE F.A. MATSEN ENDOWNED REGENTS LECTURESHIP ON THE THEORIES OF MATTER: Dr. David Wineland, NIST, Boulder, "Quantum information processing with trapped atomic ions" 4:00pm, The John A. Wheeler Lecture Hall (RLM 4.102). Coffee and cookies will be served at 3:45pm in RLM 4.102

Thursday 17 November 2016
- QUALIFIER: Igal Bucay, UT-Austin, "Surface and Field Ionization of Atoms," 10:00am, RLM 11.204
- QUALIFIER: Jeffrey Heninger, UT-Austin, "Solving Kinetic Equations with One Velocity Dimension Using an Integral Transform," 12:00pm, RLM 5.112
- COMPLEX QUANTUM SYSTEMS/CONDENSED MATTER SEMINAR: Marco Buongiorno Nardelli, University of North Texas, "High-throughput materials discovery and development: breakthroughs and challenges in the mapping of the materials genome," 12:30pm, RLM 11.204
- THEORY GROUP BROWN BAG MEETING: Members of the Theory Group discuss their work, 12:30pm, RLM 9.222
- RELATIVITY SEMINAR: Group Members meet to discuss their work, 3:30pm, RLM 9.222

Friday, 18 November 2016
- QUALIFIER: Scott V. Luedtke, UT-Austin, "Simulating High-Intensity Laser-Matter Interactions Including QED," 10:00am, RLM 11.204
- FINAL DEFENSE: Nathan Riley, UT-Austin, "Supernova in a Bottle: Experimental Study of Magnetic and Radiative Effects on Scaled Supernova Remnant Shocks," 1:30pm, RLM 7.124
- PHYSICS EDUCATION FORUM: Roundtable Discussion, "Reflections on Education," 3:00pm, RLM 5.114

Staff, Space, and Budget

Physics Department staff consists of research staff, administrative staff, and technical staff. The research staff consists of three Research Professors, three Senior Research Scientists, nine Research Scientists, nine Research Associates, and 30 postdocs.

A detailed organization chart for administrative and technical staff is shown in Appendix D. Technical staff includes the Cryogenics and Machine Shops staff and a few technicians associated with research groups. Appendix G provides a complete list of Physics Department staff along with job titles.

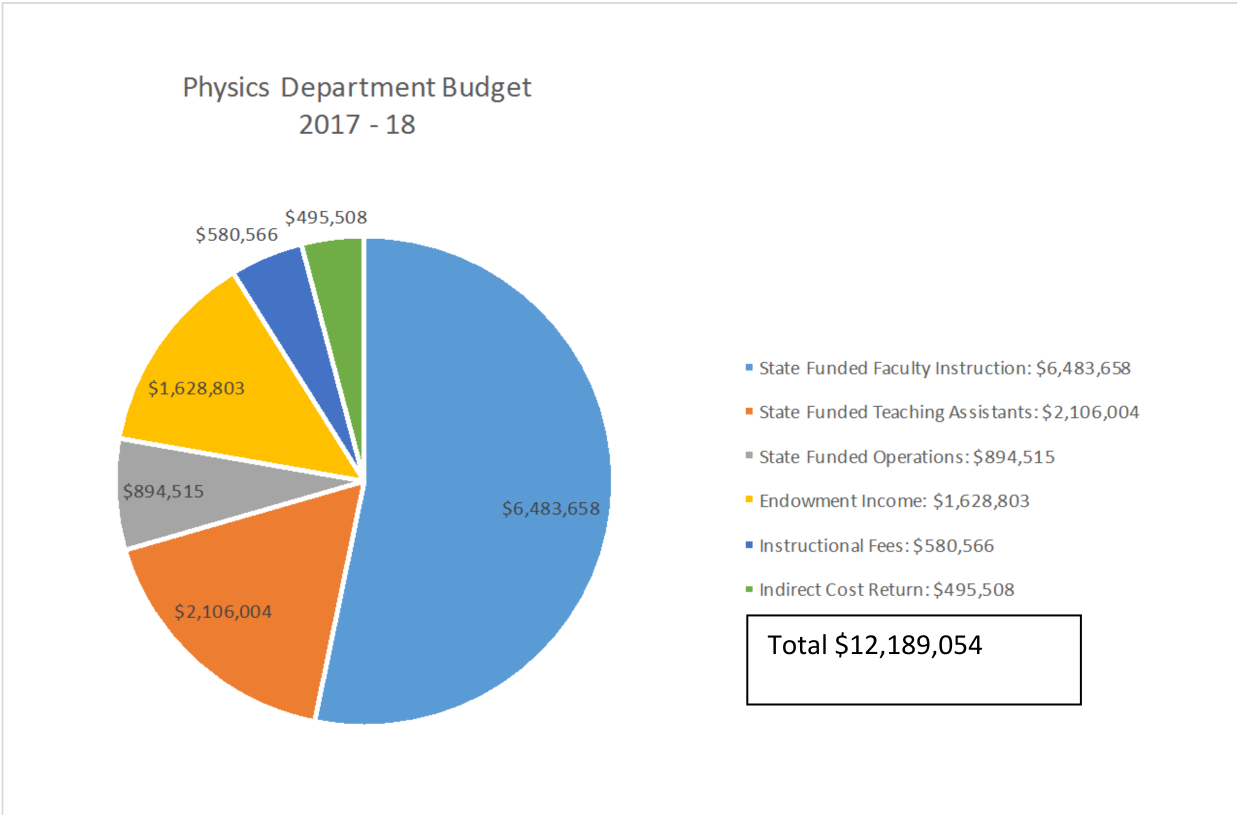
The Physics Department is housed in Robert Lee Moore Hall (RLM). RLM has 17 levels, with level 4 being the ground floor. The Physics Department occupies space on levels 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. The Astronomy and Math Departments are also housed in RLM. The Kuehn Physics Math Astronomy library and the Wheeler Auditorium (a general purpose classroom, used for the departmental colloquia) are on level 4.

As discussed elsewhere, the condition of RLM is substandard in some respects. The building's mechanical systems are old and unreliable. Air flow and cooling are poor in some parts of the building. The appearance of many rooms, including classrooms, offices and labs, is shabby. This makes successful recruiting of new faculty more difficult.

The Physics Department's budget is fairly simple, with funds coming in the following main categories:

- State funds (includes faculty salaries, teaching-assistant salaries)
- Instructional fees
- Indirect cost return (aka overhead return)
- Endowment payouts and gifts

When combined, these will provide about $12.2 M for Physics Department operations in 2017-2018. The following pie chart shows the breakdown of the $12.2 M into categories.



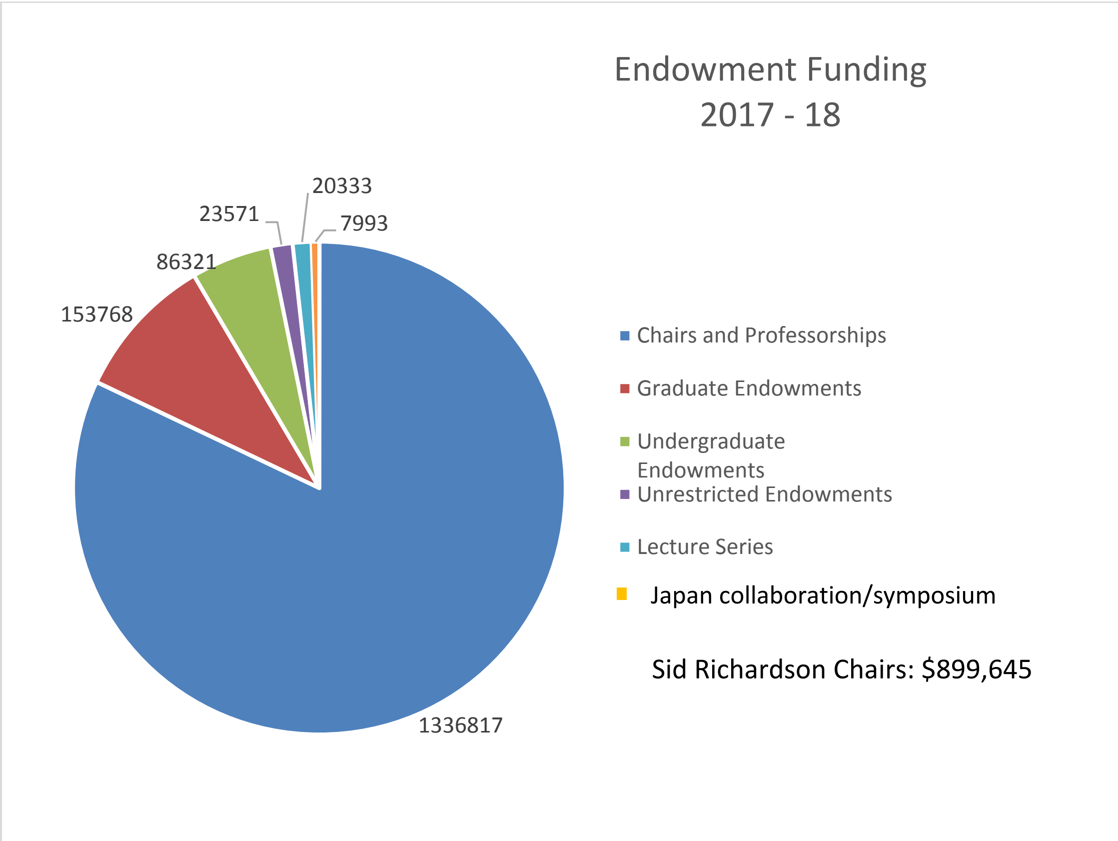
In addition, the department operates two service centers (Machine Shop and Cryogenics Shop) which bill customers for services or supplies. The service centers are discussed in Section VII. The Department also receives a small amount of royalty income (about $4K/yr) from the sales of Lab Manuals for our instructional lab courses.

The largest part of our budget, by far, is faculty salaries. The next largest part is stipends for graduate student Teaching Assistants and Assistant Instructors. Those TA/AI funds are referred to by CNS as the "instructional budget."

The State Funded Operations of $894,515 is dominated (77%) by salaries of Physics Department staff, including some of the machinists. The other significant components are Maintenance and Operations (8%) and a supplement to defray faculty machine shop charges (10%). The machine shop supplement will be discussed in Section VII. The remaining funds provide wages for student employees including the graduate students who conduct the Physics Circus performances. CNS funding of $20,000 that is earmarked for Circus support is included in this part of our budget.

The Instructional Fees part of the budget supports staff whose jobs are primarily student-related, such as our Graduate Coordinator and Undergraduate Coordinator, the person who manages our instructional labs in RLM, the person who manages our Lecture Demonstration operation in Painter Hall, and wages of student workers who support the instructional labs and lecture demos. It also includes Maintenance and Operations funds necessary to keep those operations going (supplies, equipment repairs, etc.).

A breakdown of endowment-generated funding is shown in the following pie chart. The majority of the funds from endowments come to the holders of four large Sid Richardson Chairs (MacDonald, Raizen, Schwitters, and Swinney). The chair holders have discretion over about 80% those funds, with the remainder being used to provide part of their 9-month salaries.



As discussed earlier, the endowment funding for graduate student support is a modest amount of $154K. That is significantly below our need.

Our experience is that we have sufficient funds for undergraduate scholarships. While having the ability to make larger awards would be desirable, we are able to award scholarships to most undergraduate students who apply for them.

In addition to endowment payouts, the Department receives some donations, typically in the form of small gifts ($100-$2000), some through the CNS Annual Giving campaigns. The total amount fluctuates year-to-year around the ballpark of $25K when the suggested contributions of Advisory Council members are included.

Indirect Cost Return represents 12.5% of the overhead generated from grants held by Physics Department faculty. There are a few complicating relationships that a few faculty members have with organized research units (ORUs) that direct their indirect cost return to the ORUs. CNS has typically negotiated at least partial return of those funds to Physics. In the current year, the Physics Department's IDC budget is $495,508. The chair will distribute something in the range of 75-85% of those funds to the departmental research centers which generated the overhead. Almost all centers pay salaries to administrative staff, and typically other funds are used to fund visitor travel for seminars and similar research-related activities.

The IDC funds held by department represent the major part of the funds over which the chair has discretion. They are used to cover critical expenses that arise throughout the year, provide small matches for faculty grant proposals, etc.

VI. Undergraduate Program

A Bachelors degree in physics is good preparation not only for postgraduate study in physics, but also for careers in the private sector and government in which quantitative reasoning is important.

Undergraduate Curriculum (degree options)

Undergraduate students majoring in physics have two primary options in terms of the degree they pursue and then several choices once this main option is selected. The two main options are the Bachelor of Science (BS) and Bachelor of Science and Arts (BSA) degrees.

The BSA requires fewer courses in physics and math relative to the BS. This lower requirement is compensated for by requiring completion of a 'transcript recognized certificate' (TRC) or minor comprising a block of typically five courses packaged by the offering department in a single subject area. The minor must be outside of a STEM area but the TRC can be in any field. The BSA replaces the Bachelor of Arts (BA) degree previously offered and is modeled on the more traditional BA in allowing for a combination of concentrations in both science and liberal arts. Roughly 20 percent of physics students pursue the BSA.

The BS degree is our workhorse degree with a relatively heavy slate of required physics and math courses. Students take a total of six math courses at the level of calculus and above and 10 or 11 physics courses (some of which have associated labs or are themselves 3 or 4 credit hour advanced labs). Within the BS track there are 7 possible options. Option 1 is designed to give students a strong foundation as a basis for further study in physics or work in a wide variety of fields. The other options subtract some of the option 1 requirements and add a corresponding number of courses in a targeted field closely tied to physics. The other six options are:

- Computation,
- Radiation Physics (connected with Mechanical Engineering),
- Space Sciences (connected with Aerospace Engineering),
- Teaching (connected with the College's UTeach program),
- Honors (through the College's Dean's Scholars program), and
- Biophysics.

Roughly 60 percent of the BS students pursue option 1 with the remainder spread out over the other options.

The curriculum can be roughly broken down into three parts. First, students take four courses at an introductory level in Mechanics, Electricity and Magnetism, Waves and Optics, and Modern Physics. Next students take more advanced courses in Classical Dynamics, Electrodynamics, a lab in Modern Physics, Quantum Mechanics (2 or 3 courses), Thermal and Statistical Physics, and, for most degree options, an Advanced Lab. These classes are all offered every semester. Finally, students have the option to take topical courses in Solid State, General Relativity, Biophysics, Electronics, and selected other topics. We are able to offer each topics class approximately once per year. Students also can take an independent study course and study a topic outside of our formal course offerings or pursue a research project (more on this below). Students on the BSA track do not take all of these courses.

For all degree options students must complete a legislatively mandated set of core courses as well as a number of courses satisfying university designated flags. The core consists of a total of 42 credit hours distributed amongst English, Government, History, Social Sciences, Mathematics, Natural Science, and Visual and Performing Arts. The flags (and number of required courses) are in Writing (2), Quantitative Reasoning (1), Global Cultures (1), Cultural Diversity (1), Ethics and Leadership (1) and Independent Inquiry (1).

Number of Majors and Graduates

The number of physics graduates and declared majors over the previous 5 years: Academic Year (number of degrees, number of majors)

	Graduates	Majors
2012-13	72	466
2013-14	79	496
2014-15	81	499
2015-16	96	471
2016-17	86	476

These numbers place UT amongst the largest programs in the United States in terms of the size of the undergraduate program (top six based on single year 2015 graduation data from the American Institute of Physics). They also represent substantial growth from years prior: the number of declared majors by year were 2008-09 (225), 2009-10 (278), 2010-11 (324), 2012-13 (342).

Trends in Undergraduate Enrollment and Seats Taught

Numbers are given in the following table for each academic year, first for the four introductory level courses, and then for five advanced courses that are taken by all students seeking a physics degree (and many Astronomy students).

	301 Mechanics	316 E & M	315 Waves	355 Modern	336K Dynamics	352K Electrodynamics	373 Quantum	369 Thermo	353L Modern Lab
2012-13	310	193	174	184	108	102	100	83	111
2013-14	378	230	213	223	96	112	102	92	110
2014-15	333	197	204	199	155	139	109	85	110
2015-16	272	164	160	211	155	97	140	135	97
2016-17	309	184	194	162	122	148	120	114	96

Undergraduate Educational Opportunities

Physics students have numerous opportunities to participate in research activities, including the Freshman Research Initiative (FRI), participation in active research programs both on and off campus, a summer exchange program with Wurzburg University in Germany, and a well-organized Study Abroad program. A brief description of each of these is given below.

As indicated by the title, the FRI program is aimed at getting freshman involved in and thinking about research from the start of the college careers. Students start with a general Research Methods course before joining a group focused on a specific topic. Projects, or 'streams' as they are called, are proposed and run by faculty in one or more departments. Students spend semesters 2 and 3 working within the 'stream.' A typical stream will have either 15 or 30 students working on individual projects. Students need not work in a stream within their major although many do. Physics has had one stream since the beginning of the FRI program focused on magnetic materials that accommodates 12-15 students. A second stream involving the Physics and Computer Science Departments as well as staff at the Advance Research Lab (ARL) dealing with Quantum Computing and Quantum Information is set to come on line in the Fall of 2017. Roughly one-third of freshman physics majors participate in the FRI.

For a number of years now physics students have the opportunity to spend 10 weeks at Wurzburg University in Germany working in an active research group in physics. They receive credit for our Advanced Lab as a result of this activity. They also receive partial travel support through the Department. Typically 5-10 students go each summer. Returning students uniformly rate this as a tremendously positive experience.

Many physics students also spend a semester or a year in the Study Abroad program. This program is run at the level of the Provost and as such is University wide. There are currently some 13 CNS premier partners in physics with which course equivalencies are pre-approved and a well-organized exchange program is in place. Included are institutions in Europe, South Africa, Australia, and others.

One other opportunity of note is the Department's offering of undergraduate 'Learning Assistant' (LA) or 'Peer Assistant' positions (also referred to as undergraduate teaching assistants, UGTAs). These are paid positions in which undergraduates help with our teaching mission. They typically hold office hours, lead discussion sessions and help with in-class activities. The number of such positions has fluctuated, but with a recent commitment of additional resources from the College, we expect to be able to offer 30 or so positions each semester. The activities are of substantial benefit to both the students in the class and to LA's themselves.

Curriculum reform

In May of 2106 a College of Natural Sciences committee completed a report entitled “Vision and Recommendations for 21st Century Undergraduate Education.” One recommendation was that Departments within the College: “Establish experiential learning as the central theme of undergraduate education in the College of Natural Sciences.” The report outlined several concepts that this goal would encompass including increased emphasis on involvement in research and a more curiosity driven element in classroom and laboratory instruction. This inquiry-based learning has been demonstrated to offer significantly improved learning outcomes.

Exercises and projects more connected with real world applications are seen as a hallmark of this approach. Physics is one of three departments selected to consider the committee's recommendations in its curriculum. A Physics Department committee will begin this process in the Fall of 2017.

Teaching (TT and NTT faculty)

A large majority of physics classes at UT are taught by tenure track faculty with only occasional teaching by non-tenure track faculty or lecturers. A table summarizing the number of faculty teaching at a given level is given below for the prior five academic years (tenure track with nontenure track faculty in parenthesis).

Academic Year	2012-13	2013-14	2014-15	2015-16	2016-17
Lower Division, non majors	28(10)	29(7)	34(4)	28(3)	27(1)
Lower Division, physics majors	8(0)	8(1)	8(0)	8(0)	8(0)
Upper Division, non majors	3(1)	4(0)	4(0)	4(0)	4(0)
Upper Division, physics majors	25(0)	23(0)	25(0)	23(0)	25(0)

These numbers are for faculty members, not courses taught. That is, some faculty members teach more than one course in a semester, particularly in the most recent two years tabulated.

Instruction Staffing and Budget Management

The Department submits a proposed set of course offerings to the College in the late fall for the following Fall and subsequent Spring semesters. This is followed in the Spring by a meeting of the Physics Department chair, the undergraduate advisor, the Associate Dean for Undergraduate Affairs, and the Assistant Dean for Strategy and Planning, where the courses and faculty allocations are finalized and where appropriate support in the form of teaching assistants and non-tenure track faculty are authorized. The large majority of physics courses are taught by tenure track faculty with an average of only one or two per semester non-tenure track.

Advising, Scheduling and Enrollment Infrastructure

Students entering UT are invited to attend two day orientation sessions which are offered weekly during the first six weeks of the summer. As part of this process, the students meet individually with College of Natural Sciences staff advisors to discuss degree plans and potential courses. They then meet with the Department's undergraduate advisor (a faculty member) for further discussion. In addition, a question and answer session is held with the undergraduate advisor and several current students in which issues such as participation in departmental student organizations and general student life are addressed. At the end, students register for Fall classes. A similar though less extensive structure is in place for transfer students.

For returning students, an advising period followed by preregistration takes place at roughly the two-thirds point in each Fall or Spring semester. During this period, students must meet with a staff advisor and a faculty advisor before being allowed to preregister for the upcoming semester. These meetings allow for a detailed check of student's progress as well as affording the student the opportunity to discuss bigger issues, such as degree progress, research opportunities, post-graduate options and the like.

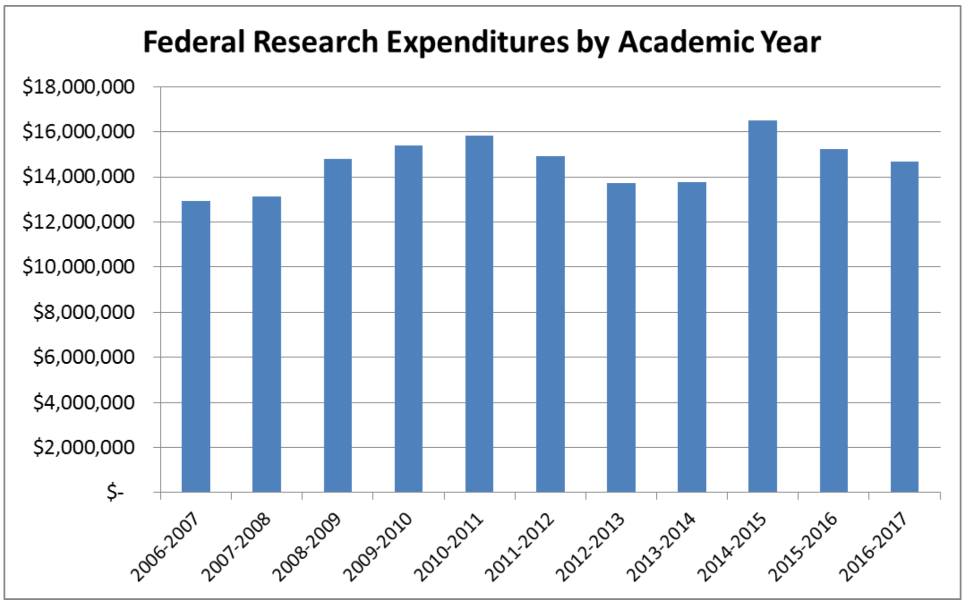
Course scheduling and instructor assignments are handled by staff working with the Department's undergraduate committee. This occurs in the mid-Fall in order to submit a proposed set of course offerings for the following year to the College by late Fall. Historically, course availability has not been a problem, although in recent years the situation has tightened up due in part to an increase in the number of physics majors and in part to a decrease in faculty. This has been felt particularly in our Modern and Advanced Labs where seats are limited. Supported by the College, we have been able to offer the Modern Lab during the Summer for the last five years (and filled all available seats).

VII. Research Support and Facilities

Research Support

Most funding support for research come from external sources, especially Federal research grants. The quantity that is most straightforward to track is research-related expenditures rather than the amount of funding awarded. The figure below shows Physics Department research expenditures for an eleven year period. In the 2016-2017 year, Physics research expenditures amounted to $14.7 M. This is about $306 K per faculty member. Since some of our faculty are no longer research-active and do not have external research support, the average for research-active faculty is higher.

Data from the NSF's Center for Science Engineering Statistics indicate that during the period 2012-2015 UT Austin was one of the top six institutions of higher education for Federal funding of physics research.



Internal funding for research derives primarily from indirect cost return, either from the 12.5% of IDC withheld by the College or the 12.5% returned to the Physics Department. For example, those funds are sometimes used to provide cost-sharing in grant proposals. They are also used by some departmental research centers to fund administrative support staff.

In addition, some research support is provided by the College through the Physics Department operating budget which pays costs associated with operating the Physics Department Machine Shop, which is an important facility for our experimental programs.

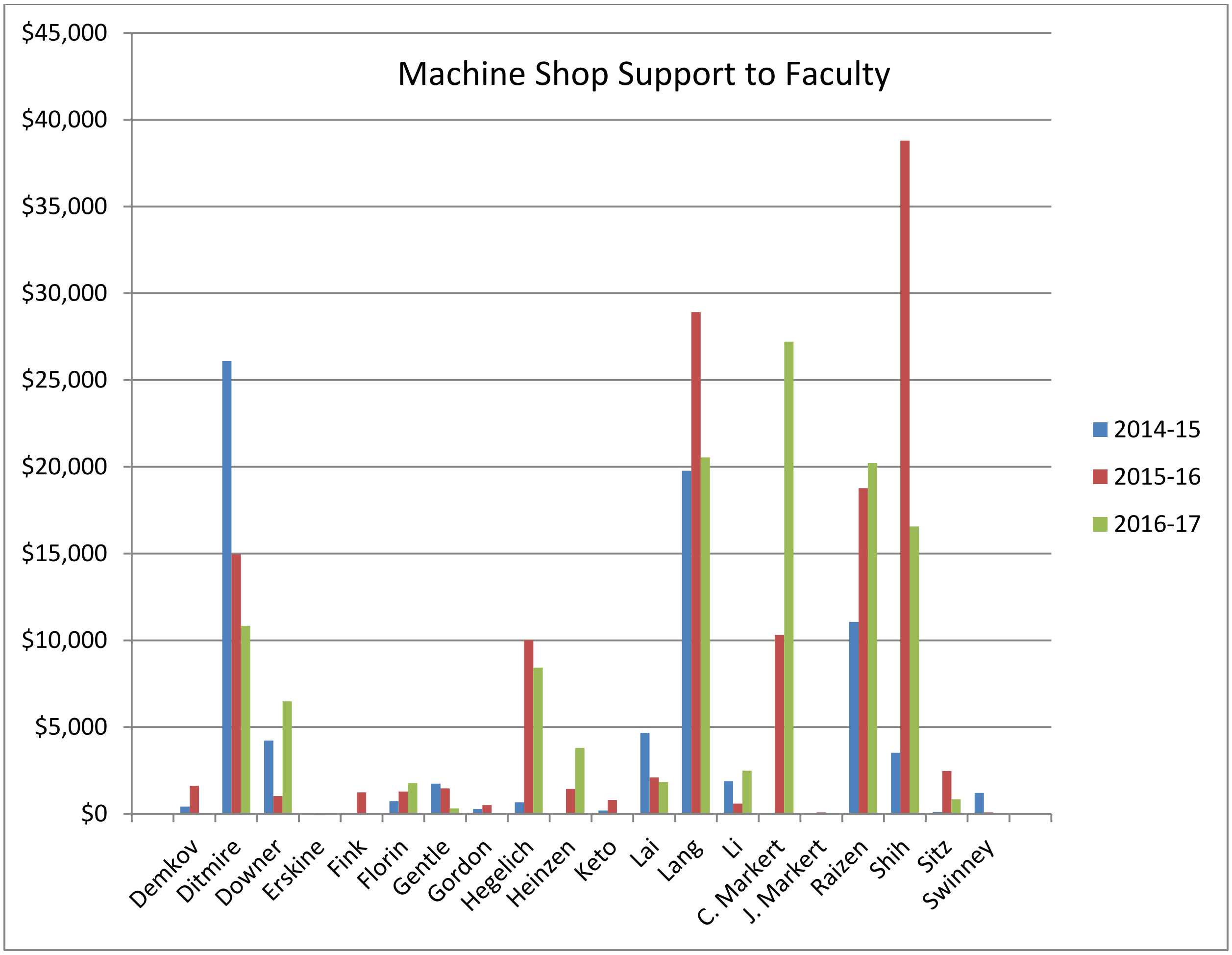
Machine Shop

The Physics Machine Shop is a core facility in the College for Natural Sciences. Its main function is to fabricate instruments for research labs in the College. Most of the work supports research in the Physics Department, but all CNS departments are welcome to take advantage of the capabilities of this facility. Many of the instruments that are constructed in the Machine Shop are unique and could not be realistically obtained from other sources. Faculty and students work directly with instrument makers when projects are in progress. This interaction, especially with students, gives the students valuable knowledge about design, the techniques used to construct their instruments, and how to create usable drawings. Students also have the option of constructing their own instruments in the Physics Student Shop, where proper training and attention to safety is the highest priority.

The Physics Machine Shop is staffed by the supervisor, Allan Schroeder, and nine full-time machinists. Each project that is submitted to the shop poses different problems that challenge the instrument makers. Because of their many years of combined experience and knowledge of machinery and materials, specialized research equipment and devices are always constructed very accurately and efficiently.

The Physics Department machine shop is a deeply valued facility by the experimental faculty of our department. It is a well-managed facility that does excellent work. Prior to September, 2014, use of this faculty was free for Physics faculty. That is, it was supported entirely by the College through the Physics operating budget. As such it provided a competitive advantage to our experimentalists since most university-based machine shops have a significant labor charge. It was also a recruiting tool for experimental faculty. Beginning in September, 2014, the Physics Machine Shop became a CNS core facility. Some other departmental machine shops were closed in recognition of the role of the Physics shop as a CNS core facility. The Machine Shop is now managed by the Physics Department as a service center with a labor charge of $20/hour. That still low in comparison to most other institutions. Currently, about 20% of the billed-hours are for work outside of the Physics Department. It would be straightforward for the Physics Machine Shop to absorb other remaining machine shop facilities within the College.

The Physics Department chair at the time of the conversion to a service center decided to use department operating funds to subsidize the use of the Machine Shop by Physics faculty. In particular, since the $20/hour charge was instituted, the Department has paid $15/hour, leaving individual faculty members to cover a $5/hour charge from their research grants. Needless to say, this softened the transition from a free shop. The effect of this supplement has been to subsidize the research of some of our most active faculty members. That is, the support does not benefit faculty uniformly. Almost all of the support has gone to six faculty members, as can be seen in the following figure which shows the total support by faculty over the three full years the Machine Shop has been a service center.



This rate of support for Physics faculty is unsustainable. The budgeted amount of $88 K/year for this purpose falls short of the actual cost, so that departmental reserves have been depleted to maintain it. The chair will reduce the supplement to most $10/hr in the near future, requiring Physics faculty users to pay $10/hr. This will reduce the cost to the department to approximately the budgeted amount.

Critical departmental needs may force further reduction, or even elimination, of the faculty supplement in the future. For instance, as noted in Section III, current graduate student endowments cannot support the full cost of the Graduate Student Investment Initiative (GSII) program once it reaches the full complement of 30 students. If our graduate student endowments do not grow fast enough and by a sufficient amount, departmental operating funds may need to be shifted from research support to graduate student support. (Even so, we would still need additional endowments to meet all the needs of our graduate program.) Our goal, of course, is to succeed in developing significant new endowment resources to fully meet the needs of our graduate program.

Cryogenics Shop

The Physics Cryogenics Shop is an important resource for research and teaching labs needing various high-pressure gases and liquids, leak detection, metal deposition, and maintenance of vacuum pumps for research. The main product is liquid helium, which is produced on site. The current charge for liquid helium is $10.10 per liter. Some of the labs in RLM are equipped with a helium recovery system that returns helium to the Shop after use. Other products include liquid nitrogen and a variety of high-pressure gases.

The Cryo Shop is operated as a service center on a full cost recovery basis. The Cryo Shop is staffed by single staff member, although backup support is provided by the shops supervisor. The cryo technician's salary is part of the service center budget.

The Cryo Shop has the capability to test vacuum chambers and components for leaks, using helium leak detectors for ultra-high vacuum applications. The technician works directly with faculty, students, and other staff when preparing and testing research apparatus for leaks.

VII. Research Overview

New Initiatives

Two new research initiatives will be highlighted: developing a quantum information research program and upgrading the existing Texas Petawatt Laser facility with substantial new capabilities.

Quantum Information

The interest and effort directed toward the broad field of quantum information (QI) has exploded in recent years, yet our Department has been largely uninvolved. This hole provides an opportunity to create a new research program that will bring attention to our department and also have side benefits such as revitalizing our AMO program, bringing our AMO and condensed matter groups closer together, and forging collaborations with faculty in other UT departments – especially Computer Science and Electrical and Computer Engineering.

On the theory side, our department did play a somewhat seminal role in developing this field. In the late 1970's, John Wheeler came to Texas, and at the time he was interested in and helped to revitalize quantum measurement theory. Several important QI physicists were educated at UT during that period. Benjamin Schumacher (who coined the term "qubit"), Wojciech Zurek (the cofounder of decoherence theory and quantum error-correction), and William Wootters (of the no-cloning theorem and quantum teleportation) received their Ph.D.'s from our Department in that era. More recently, the Computer Science Department has recruited Scott Aaronson, a leading theorist in the area of quantum computing.

The importance of quantum mechanics in practical modern devices cannot be questioned, from the semiconductor devices that power modern computing, atomic clocks that enable GPS navigation, and MRI systems that help to diagnose medical conditions, quantum-based technologies are ubiquitous. Progress in QI involves studies of physics systems that can store and manipulate quantum information, from single qubits to linked networks of qubits, where phenomena such as superposition and entanglement open the door to ways of processing and transmitting information that far exceed current capabilities. Progress in QI involves work on fundamental physics, and it has potential applications that are far-reaching – in sensing and metrology, communications, simulations of quantum systems, and ultra-fast computing.

The Physics Department is receiving strong support to establish a QI program. While this will ultimately involve recruiting both experimental and theoretical faculty, our initial thrust is on the former – in a sense because that is harder. If we successfully establish a visible and productive experimental program, scaling it up and broadening it to include theory will not be hard. Thus, we are currently recruiting toward hires of two "mid-career" experimenters into Faculty Investment Initiative positions.

A Multi-petawatt Laser

Another new initiative in our department involves building upon an existing facility, the Texas Petawatt Laser (TPW). The TPW was for a time the most powerful short-pulse (femptosecond) laser in the world and it continues to be the most powerful in the U.S.. It supports a vigorous research program that studies hot, dense plasmas, shock compressed gasses and solids, particle acceleration by intense ultrafast lasers, and electromagnetic wave interactions at ultrahigh intensities. However, outside the U.S., higher power multi-petawatt facilities exist and more are being built.

An opportunity to upgrade the TWP to the multi-petawatt range at low cost (approximately 5 PW, with up to 10 PW possible at higher cost) has come about because the Los Alamos National Laboratory recently awarded the Trident laser, which it recently decommissioned, to UT. Shipping of Trident components will be completed by October 1. This provides our laser group will approximately $20 M in equipment, which will be the basis of a significant upgrade to the TPW. This new instrument will advance cutting-edge research at electric and magnetic field strengths that are unprecedented.

In short, large-scale initiatives are underway that will significantly enhance the research in our department.

Atomic Molecular and Optical Physics

Research in Atomic, Molecular, and Optical (AMO) physics has been dramatically transformed by the development of powerful experimental tools, including high-resolution, ultra-fast, and ultra-powerful lasers, and new methods to cool, trap, and manipulate atoms and molecules. AMO is naturally interdisciplinary because the topics touch on fundamental questions in quantum mechanics as well as materials physics, plasma physics, and even biophysics. The Physics Department has had active research programs in AMO physics for many decades. The boundaries between AMO and some other research areas are fuzzy, so there is no distinct separation between this group and others in the Department. Nonetheless, the faculty participants in this research are primarily Mike Downer, Manfred Fink, Dan Heinzen, John Keto, Mark Raizen, and Greg Sitz.

A brief summary of AMO research in the department follows.

Mike Downer's main area of research is intense laser plasma and laser solid interaction experiments. His main current interest is in developing laser and particle beam driven plasma electron accelerators, and exploring their potential as future compact coherent light sources and colliders. His current and near future experiments are visualizing and monitoring plasma-based accelerator structures, accelerating electrons to multi-GeV energies, deriving and using secondary secondary X-ray and gamma-ray radiation from these accelerators, and exploring terawatt mid-infrared lasers as drivers. He also pursues a parallel research program on unique optical properties of surfaces and interfaces, including semiconductor nano-structures, thin-film ferroelectrics, and organic composites.

Manfred Fink for decades worked to understand molecular structure using precision electron scattering experiments. He also has pursued development of a tritium beta decay experiment on campus. His current effort aims to use positrons as detectors to develop procedures to help the semiconductor industry find the defect sites, understand their origin and facilitate their removal. This technology is particularly suitable for probing a variety of depth and for selected atomic species. Most of these techniques are well established and need only to be modified to accommodate the space and the availability of a monochromized intense positron beam. This research takes advantage of a research reactor on the Pickle research campus about 10 miles from the main campus.

Dan Heinzen's research uses ultra cold atoms to address various issues. One goal is to search for an intrinsic electron electric dipole moment (edm). Such a moment would violate time-reversal symmetry and is forbidden to exist at observable levels within the standard model, but is allowed in many extensions of the standard model at the level of 10^{-26} e·cm. The idea behind the experiment is that if the electron has a dipole moment, the atom has one also. The atomic levels would then shift due to the first order interaction between the atomic dipole moment and the electric field.

John Keto co-invented a process for generating nanoparticless by laser ablation of microparticles in a flowing powder aerosol. His research investigates techniques for assembling nanostructured materials from these nanoparticles. He has also studied the explosion of strongly-coupled nanoplasmas produced in rare-gas clusters and metallic nanoparticles using high-intensity XUV light. Light sources have included high-harmonic XUV generation from 30 fs, 100 TW lasers and the free-electron laser at SLAC.

Mark Raizen's group pioneered the study of quantum chaos with ultra-cold atoms. In a recent study of short-time Brownian motion, Mark and his group verified a prediction by Einstein from 1907 and established a new testing ground for fluid dynamics on the microscale. He developed general methods of cooling and trapping of atoms as an alternative to laser cooling, which has been limited to a small set of elements. The two-step approach uses a series of pulsed electromagnetic coils to stop atoms in a supersonic beam. Atoms that are magnetically trapped can be further cooled by a one-way wall for atoms, a direct realization of Maxwell's Demon from 1871. This recent work opens the door to trapping and cooling of most elements in the periodic table and many molecules.

Greg Sitz uses a combination of nonlinear optics, molecular beams and ultrahigh vacuum surface science to study the dynamics of molecule-surface interactions. The emphasis is on the role that the internal rotational and vibrational quantum state of the molecule plays in the interaction. Such measurements play a crucial role in testing the validity of current theory in this field.

Biophysics

The faculty members who are active in biophysics research are E.L. Florin, Vernita Gordon, and Harry Swinney. This work is carried out within the Center for Nonlinear Dynamics in the Physics Department. Florin and Gordon are also members of the Institute for Cellular and Molecular Biology, which includes faculty from a wide range of science and engineering departments.

Recent research achievements include:

- Demonstration that *Pseudomonas aeruginosa*, an opportunistic human pathogen that is widely used as a model organism for biofilm development, senses mechanical stress as a cue to initiate biofilm development (Rodesney *et al.*, 2017 Proceedings of the National Academy of Sciences of the USA). Little is known about how bacteria sense surfaces, and almost nothing is known about bacterial mechanosensing and mechanobiology, so this is a significant step forward.
- Development and demonstration of quantitative thermal noise imaging, a three-dimensional scanning probe technique that allows imaging of soft, optically heterogeneous, porous structures with resolution of ~10 nanometers, and measurements of structural dynamics with 50 kHz bandwidths and <1 nanometer amplitudes (Bartsch *et al.*, 2016 Nature Communications). This circumvents many prior difficulties in imaging important living systems, such as tissues and the cytoskeleton.

Dr. Gordon's research focuses primarily on biofilms. Biofilms are interacting communities of bacteria and other microbes that are bound to each other, and often to a surface, by a matrix of polymer and proteins. As a result, biofilms are characterized by spatial and mechanical properties that are not present for microbes in liquid suspension, which is the condition under which most traditional microbiological studies have been done. Even in the absence of genotypic changes, being in a biofilm state results in phenotypic changes that, in infections, make constituent microbes more resistant to antibiotics and the immune system and more damaging to host tissue. In built structures, biofilms cause biofouling, with consequent loss of efficiency and increased fuel use, and biocorrosion. The harms done by biofilms are closely connected to their spatial structure and mechanical integrity, yet very few specifics are known. The primary thrust of research in the Gordon lab is to determine the causative links between physical properties and biology of biofilms, with a view toward identifying new, physics-based targets for preventing and ameliorating harmful biofilms.

The Gordon lab investigates the mechanics of single bacteria by using optical microscopy to track the motion of cells on a surface, and by using atomic force microscopy to measure the adhesive forces binding cells to surfaces and the cohesive forces binding cells to each other (Cooley *et al.*, 2013 Soft Matter). The Gordon lab measures the mechanics of the mature biofilm by using a rheometer - a device which can apply strain at controlled amounts to a material in order to measure that material's response, and thereby its viscoelastic properties. Dr. Gordon has recently found that different polymers have different impacts on the mechanics of biofilm and that multiple polymers can combine to have synergistic effects on biofilm mechanics (Kovach *et al.*, 2017 npj Biofilms and Microbiomes). A stiffer biofilm may increase bacteria survivability because the human immune system cannot perform phagocytosis, or cellular "eating", to neutralize the threat. Understanding the role mechanics plays in bacterial infections, as Dr. Gordon is working to do, will open the way for better treatment designed to alter biofilm mechanics to make the immune system better able to defend the human host. Future approaches will use microrheology, both passive and active, and atomic force microscopy to study variations in biofilm microstructure and composition, and associated heterogeneities in mechanics.

Another thread of Dr. Gordon's research studies how the structure of bacterial populations contributes to their growth and resistance to antibiotics (Kaushik *et al.*, 2015 J. Royal Society Interface and 2016 npj Biofilms and Microbiomes; Kragh *et al.*, 2016 mBio; Hutchison *et al.*, 2014 Langmuir). The team is extending their findings to medicine by working in collaboration with the College of Pharmacy at UT Austin and the School of Medicine at Texas Tech University Health Sciences Center.

E.L Florin's research in biophysics centers on the development of new types of instrumentation to achieve measurements of biological systems with very high temporal and spatial resolution. One notable example is the thermal noise imaging discussed in the second bullet point above. Another example, that also takes advantage of the energy input as a consequence of being at finite temperature, is the development of a new approach that allows the direct observation of intermediate states in membrane fusion (Keidel *et al.*, 2016 Scientific Reports). Membrane fusion is a multi-step process that is essential for many life processes, including all sexual reproduction and many intracellular dynamics. The technique developed by Dr. Florin allows fusion dynamics to be measured at the single-vesicle level, with high temporal and spatial resolution that can distinguish steps in this process, along with instantaneous measurement of the energy barriers separating intermediate steps in the fusion pathway. This could not be done using previously-extant techniques.

Dr. Florin has also extended his research to larger-scale measurements of the dynamics of biological systems. Notable work along these lines includes development of a new, more-naturalistic approach to molecular motor studies (Bartsch *et al.*, 2013 Biophysical Journal) and studies of large numbers of actively-moving and –growing bacteria (Be’er *et al.*, 2013 Journal of Bacteriology, 2011 mBio, 2010 Proceedings of the National Academy of Sciences of the USA; Zhang *et al*., 2010 Proceedings of the National Academy of Sciences of the USA).

Complexity and Nonlinear Systems

Complexity and nonlinear systems research developed in UT physics in the 1980s with studies of diverse nonlinear phenomena by Professors Swinney, Marder, McCormick, and Swift and several visiting professors and UT collaborators from math, chemistry, and engineering. In 1985 the UT administration established the Center for Nonlinear Dynamics, and by the late 1990s the complexity and nonlinear systems program was annually first or tied for first in the US News and World Report rankings of graduate programs in nonlinear dynamics (this ranking category ended in 2002). In the past three decades the UT research on complexity and nonlinear systems has included chaos in chemical and physical systems, methods for characterizing chaos, quantum chaos in optical systems, fracture in solids, scaling properties of turbulence, chemical spatial patterns (predicted in 1952 by Alan Turing, observed in Center experiments in 1991), geophysical flow phenomena (e.g., a model of Jupiter's Great Red Spot, super-diffusive transport in oceanic flows, atmospheric blocking of weather patterns), patterns in vibrating sand, and fractal growth processes in leaves.

Complexity and nonlinear dynamics research in the past decade has continued to involve close interaction between experiment (Florin, Raizen, Swinney) and theory (Marder and collaborators in other departments and universities). Florin and Swinney examined growing bacterial colonies and the swimming of individual bacteria. Fluctuations in the number N of bacteria/volume were found to scale as $N^{3/4}$ rather than the $N^{1/2}$ scaling of fluctuations in systems in thermodynamic equilibrium. Further, the velocity correlations for the swimming bacteria were found to behave in the same way as in bird flocks, even though viscous forces dominate inertia for the bacteria while the reverse is true for birds.

Current research by Swinney is examining the generation and transport of energy in internal gravity waves in the oceans. These waves comprise more than half of the energy in the oceans and comprise an important component of the earth's energy budget, but the complex wave-wave and wave-topography interactions make an accurate estimate of the energy difficult. The current UT research is conducted in collaboration with Professor Morrison at UT and oceanographers at Woods Hole Oceanographic Institute. One project is using dynamical systems methods to quantify transport of biota and sediments by internal waves shoaling up the continental slopes. A laboratory study examined shoaling internal wave intensity as a function of topographic slope angle and discovered a resonance phenomenon that provided an explanation for the angle of the oceans' continental slopes, typically only around 3 degrees, which is an order of magnitude smaller than the angle of repose.

A current study with Prof. Charles Radin (Math) of a container of 50000 nearly identical glass spheres was motivated by a half century of experiments on the packing of spheres: in 1960 G.D. Scott reported in *Nature* that he found, in a large number of trials of pouring ball bearings into a container, the upper limit of the volume fraction was 64%, well below the 74% volume fraction of spheres in a hexagonal close packed (HCP) or face center cubic (FCC) lattice. Many subsequent experiments supported but did not explain the "random close packed" volume fraction of 64%. In the present granular experiment the container of spheres was subjected to slow small amplitude oscillating shear. The 64% volume fraction was reached at about 20000 shear cycles, remained unchanged for the next 50000 shear cycles, and then slowly began to increase. Accurate measurements of the central 20000 sphere positions after successive shear cycles revealed a first order phase transition at 64% volume fraction, where crystallites began to form and grow.

Marder's theoretical research in nonlinear systems has involved application of concepts of the discipline to a wide-ranging collection of problems. Much of the work has concerned nonlinear dynamics of solids, particularly fracture and friction. Experimental systems considered in these studies have ranged from rubber to graphene.

For friction, the main finding of the last decade was that frictional slipping motion of silicon on nanometer scales obeys laws of rate and state friction established for friction between rocks on much large space and time scales. A new phenomenon was established for the fracture of rubber, in collaboration with the group of K Ravi-Chandar. Above a critical extension, the fracture toughness of rubber increases several thousand-fold. This leads to the curious phenomenon that pulling harder on a sample can actually stop a running crack in its track. Another recent accomplishment is the complete analytical solution for the motion of every atom in a planar crystal as a crack moves by at a steady velocity.

Marder's current research is focusing on two areas. The first is the application of ideas from nonlinear dynamics to petroleum extraction. This work is done in collaboration with colleagues in Petroleum Engineering including Patzek, Lake, and Torres-Verdin and at the Bureau of Economic Geology, including Tinker and Male. One accomplishment was to show that the fracking process creates conditions under which the history of gas production from wells in a given field should follow a universal scaling curve. This theory was first compared with thousands of wells in the Barnett shale, and subsequently has become part of a standard analysis of other shale fields including the Haynesville, Fayetteville, Eagle Ford, and Marcellus. The development of the scaling curve relies upon a physical picture in which gas is recovered from a network of parallel collection planes, spaced at a typical scale. Current work is making use of very late time behavior of wells to provide more precise measurements of this scale. Other current projects include analysis of diffusion into sinks with fractal structure, and multi-phase flow in highly heterogeneous materials.

The second area of Marder's research involves application of nonlinear dynamics and statistical mechanics to analysis of high-stakes test scores. This became possible after 2002 when states were required to test all students in many consecutive years in math and reading. Thus it became possible to treat test scores with ideas such as coarse-graining, Markov models, and visualization. One of the findings was that an educational intervention in Texas on which the state spent approximately half a billion dollars had changed the pattern by which low-income students flowed through grades 3 through 11 in a very positive way. The state's own analysis did not try to follow individual students over time, concluded that the program had no effect, and this led to its cancellation. Work in progress aims to improve the possibility of predicting at the state level students' progress through school based upon the minimum possible number of years of data. This application is quite recognizable as nonlinear dynamics, but it has implications for the educational future of the country.

Condensed Matter Physics

The condensed matter physics group consists of 12 faculty - six specialized in theory and six in experiment. The main goals of the group are to advance the “hard” condensed matter field (“soft” condensed matter falls mainly under the non-linear dynamics area at UT), and to introduce interested undergraduate and graduate students to the field’s very broad subject matter. UT is now established as an important center of condensed matter physics research. For example, the 2014 International Conference for the Physics of Semiconductors—the largest and most prestigious semiconductor meeting—was held in Austin, with the main organizers UT physics faculty. From September of 2017, the University will host an NSF Materials Research Science and Engineering Center (MRSEC)—a $16M program—for at least 6 years. Roughly half of the MRSEC will have its intellectual home in the physics department. Members of the condensed matter group participate in the Center for Complex Quantum Systems, which serves as an important organizing umbrella for the group (also overlaps AMO areas), runs a weekly seminar series, and occasionally funds small focused workshops. Group members maintain deep and active collaborations with other faculty in the College of Natural Sciences and the School of Engineering. Some research highlights follow.

Computational Materials Physics

The application of massively parallel computer calculations to the fundamental quantum mechanical descriptions of materials is a relatively new and exciting field. The goals are achieved by combining techniques developed from both physical and computational sciences, and lie at the intersection of physics, chemistry, and engineering. The grand challenge of this research program is to answer the following question: Can one predict and understand the structure and properties of materials solely from knowledge of the atomic constituents? An affirmative answer to this question would permit one to design and understand materials without resorting to experiment. This is particularly important for newly discovered materials such as topological insulators, artificially layered oxides, metal nanowires, and nanoparticles. These new materials have inspired research programs aimed at fabricating novel electronic and magnetic (including spintronic) devices. The chief impediment to the successful implementation of these massive computations to quantum theory is the difficulty involved in a direct solution of the Schrodinger equation. However, through the extensive computational facilities available at UT Austin [Texas Advanced Computing Center (TACC)], and the study and development of algorithms targeted to solving these quantum problems, significant progress has been achieved. Computational Physics Professors Chelikowsky and Demkov are also members of the multi-disciplinary UT Institute for Computational Engineering and Sciences.

Experimental Physics

Recent experimental studies have developed novel microscopes to study the magnetic, superconducting, and other electronic properties of new materials down to the atomic scale. UT faculty have expertise in scanning tunneling microscopy (STM), atomic force microscopy (AFM), and microwave impedence microscopy (MIM). Researchers in the group study a wide range of materials and low-temperature phase transitions.

The de Lozanne group microscopes can look at the magnetic properties of a sample or image its surface potential in fields up to 8 Tesla and temperatures down to 4K. They have measured high temperature superconductors, magnetic nanocrystals, magnetite (a common mineral with fascinating phases), ferroelectrics, manganite materials that show colossal magnetoresistance, and diluted magnetic semiconductors. A class of materials, dubbed multiferroics, combines the properties of magnetic and ferroelectric materials. The capabilities developed in the de Lozanne lab are unique in the world, leading to many collaborations in the US and abroad. Their current project is to build a spin-polarized scanning tunneling microscope (8 Tesla and 4K) that will enhance capabilities by providing a map of the spin-dependent local density of states down to the atomic level.

The philosophy of atomic scale control of materials to explore and harness novel quantum phenomena is also exemplified by recent work from the Shih group, which has focused on thin film superconductivity and thin film topological insulators probed by STM. The group also has angle-resolved photoemission (ARPES) capability, and an effort in nanoplasmonics.

The Lai group uses MIM to image a wide class of systems, including correlated oxides, thin film topological insulators, and transition metal dichalcogenides. Focus topics include the metal-insulator transition, spatial mapping of chemical processes, domain wall properties, and photoconductivity imaging.

The Markert group focuses on magnetic and superconducting phenomena involving reduced dimensionality: layered or chain structures, interfaces, and thin films. Flux and electrolytic crystal growth have more recently been complemented by electron-beam and pulsed laser ablation depositions of epitaxial films and multilayers. His work aims to correlate composition and structure with magnetic, electronic, and thermal properties using cryogenic transport, susceptibility, heat capacity, mechanical oscillator, and magnetic resonance techniques. One recent specialty is in the novel field of force-detected nuclear magnetic resonance microscopy. Current work involves iron-chalcogenide superconductors and two-dimensional conducting interfaces between insulating oxides. He leads the physics stream of UT's Freshman Research Initiative.

The Tsoi group is focused on spintronics, in which the spin of the electron is exploited for information processing in a revolutionary new class of electronic devices. The goal of this research is an active control and manipulation of spin distributions, e.g. by electrical means like in the spin-transfer torque (STT) phenomenon. A special focus is on the new field of antiferromagnetic (AFM) spintronics, because AFM materials are especially interesting for high-speed applications thanks to their high natural frequencies.

The Li group uses a variety of advanced nonlinear optical spectroscopy techniques, including pump-probe, four-wave-mixing and two-dimensional (2D) Fourier transform spectroscopy to study the coupling between vibrational, rotational, and electronic resonances on femtosecond time scales. Her group also uses light scattering techniques to study fundamental excitations in solids, such as phonons and magnons. The knowledge obtained from optical spectroscopic studies complement those obtained from other techniques and provide a more accurate picture of system dynamics. Materials of interest range from semiconductor nanostructures to magnetic materials.

Condensed Matter Theory

Professors Fiete, MacDonald, Niu, and Potter maintain broad interconnected research programs across a wide variety of topics in condensed matter theory. Professor Niu is a leading expert on the wide variety of physics related to momentum space Berry phases. Work in the UT physics department on the role of Berry phases in Hall physics helped usher in the current interest in topological insulators. Professor MacDonald has been active in advancing understanding of the electronic properties of graphene two- dimensional electron systems. Professor Fiete's group has been studying the properties correlated electron systems and topological insulators. Professor Potter's group has focused on fundamental questions in topological systems and driven, interacting many-particle systems. All theory faculty use theoretical methods ranging from numerics to powerful analytical, non-perturbative techniques and are strongly motivated by new experimental discoveries and predictions of new phenomena. Faculty in condensed matter theory interact extensively with each other, with UT experimenters, and with colleagues at other institutions

Materials Synthesis

The growth of new materials is the life blood of condensed matter science. The condensed matter group hosts efforts in the lab of Professor Demkov on oxide molecular beam epitaxy (MBE) combined with *in-situ* materials characterization, and in the lab of Professor Markert on sputtered thin films of oxide materials. The interest in oxides is motivated by "emergent phenomena" that appear due to strong correlation effects and are manifested in magnetic, semiconducting, superconducting and optical properties. In Shih's lab, MBE of 2D electronic materials including topological insulators (e.g. Bi_2Se_3) and transition metal dichalcogenides (e.g. $MoSe_2$) are being pursued, in addition to using MBE as an integral part of atomic scale control of novel materials properties of ultra-thin epitaxial metals on semiconductors.

Statistical Physics

While not strictly condensed matter physics, Professor Reichl 's research is describe here owing to her long association with the Center for Complex Quantum Systems. Her research has ranged over a variety of topics in statistical physics and nonlinear dynamics. These have included the theory of low temperature Fermi liquids, quantum transport theory, and the transition to chaos in classical and quantum mechanical conservative systems, among others. Recently her work has focused on superfluid transport theory, quantum control, quantum scattering theory, and the theory of open quantum systems.

Cosmology and Particle Theory

Research on cosmology and particle theory in the Physics Department is centered in the Theory Group. The Group is composed of eight faculty: Weinberg, Fischler, Kaplunovsky, Distler, Paban, Kilic, Matzner joined in the Fall 2016 and Caceres started in Fall 2017. The group has one postdoctoral fellow, and 12 active research students.

The work done by the group ranges from physics at the most fundamental level to computations relevant to current observations in particle physics and cosmology. They pursue their quest for a deeper understanding of the various challenges confronting Theoretical Physics. These challenges range from combining quantum mechanics and gravity including cosmology, to the phenomenology of particle physics. Making progress in these areas requires a many-pronged approach, using insight gained from existing concepts like holography, developing a deeper mathematical understanding including new tools in field theory and string theory, building models beyond the Standard Model in order to address open questions in particle physics, and making proposals to improve the sensitivity of experiments to new physics.

The group was founded by Professor Steven Weinberg in 1982 and, since its inception, has been recognized for significant contributions to our understanding of the most fundamental issues of theoretical physics. Since coming to Texas, Weinberg has made important contributions in various areas of theoretical physics. In particular his seminal proposition for an anthropic bound to the value of the cosmological constant generated tremendous interest over the years. Fischler, the co-inventor of the invisible axion and pioneering work on the use of supersymmetry to solve outstanding problems in the standard model of particle physics, in collaboration with Banks, Susskind, and Shenker gave the first proposal for a complete formulation of string theory in a widely known paper published in 1997. Known as Matrix Theory, it gave rise to many later developments. He was among the founders of the idea of the holographic principle as applied to the universe. Distler is known for his pioneering work on heterotic string compactification and 2D quantum gravity. His focus lies in the nexus between string theory, quantum field theory and mathematics. Kaplunovsky is best-known for his pioneering work on the low-energy phenomenology arising out of string theory. Paban has worked on a wide range of topic, from string theory to phenomenology. With Fischler and students, she realized the important implications that an accelerating universe has for string theory. Kilic's speciality is in phenomenology, centered on both the LHC and dark matter experiments. Matzner works in the field of numerical relativity, relevant to gravitational wave experiments, and Caceres is well-known for her work on AdS/CFT.

More recently, the members of the Theory Group have continued to extend their contributions and build new areas of study. In a series of papers, Weinberg has worked on various aspects of measurement theory in quantum mechanics and has studied the implications of the presence of goldstone bosons during the pre-recombination era. He is also pursuing new approaches to quantum measurement theory and investigating alternative regularization schemes for cosmological perturbation theory. Fischler has worked on a new theoretical framework, holographic spacetime and studied its implications for black holes and cosmology. He continues to work on holographic spacetime and on applying the AdS-CFT connection to strongly interacting field theories in various environments, black holes and quantum computational complexity. With students, he studied the implications of dark sectors both in astrophysics and cosmology and is exploring new approaches to dark matter. With one of his students he worked out the implications of electromagnetic and gravitational theta angles for observers hovering at a fixed distance to a black hole or cosmological horizon. Distler has developed powerful methods for classifying N=2 superconformal theories called “tinkertoys”. In addition to work on superconformal field theories, Distler has been involved in various aspects of string theory. Kaplunovsky and collaborators worked on holographic models of hadrons and nuclear matter. He also has continued work on heterotic M-theory. Paban has continued her research on cosmology and focused on various aspects of inflation ranging from the implications of the initial conditions and their signatures for the CMB to studies of tunneling in the context of the “landscape”. With Distler she has also worked on aspects of measurement theory in quantum mechanics. Kilic is primarily focused on the extensions of the Standard Model of particle physics, with an emphasis on their experimental signatures, specifically at collider experiments such as the Large Hadron Collider and in dark matter searches. Matzner continues his research in areas spanning General Relativity and Cosmology, Kinetic Theory, Black Hole Physics, Gravitational Radiation. Caceres is pursuing her work on various applications of the AdS-CFT connection.

High Energy Density and High Intensity Laser Physics

We have in the department a vigorous research program in high energy density plasma physics and complementary physics of high intensity laser matter interactions. The centerpiece of this predominantly experimental effort is the Texas Petawatt Laser (TPW), which is located in a large laboratory on the first level of the RLM building. The TPW is currently the highest power laser in the US and is operated is by the Center for High Energy Density Science (CHEDS) for internal and external experimenters. A "User-Collaborator program" has been implemented within CHEDS which has facilitated collaborative experiments with dozens of outside institutions. Four Physics faculty members are principal participants in this research: Todd Ditmire (CHEDS director), Manuel Hegelich, John Keto and Mike Downer.

The kind of research we do: Using high peak power lasers, we create plasmas and shock compressed materials in the lab with temperatures from a few eV up to over 10 keV at densities of 10^{19} cm^{-3} to well over solid density. CHEDS research has four specific thrusts: (1) study of the properties of hot, dense plasmas, (2) study of shock compressed gasses and solids and (3) study of high energy particle acceleration by intense ultrafast lasers, and (4) most recently an effort to study electromagnetic wave interactions at ultrahigh intensities (>10^{22} W/cm^2).

The first thrust involves using high intensity femtosecond laser pulses to create hot dense plasmas by rapid heating of solid targets and diagnosing the properties of these plasmas. These temperatures and densities are unique in that plasmas are "non-ideal"; they are strongly coupled and are often affected by quantum and complex ionization physics. We develop new ultrafast diagnostics to probe the equation of state, the conductivity and other properties of these unique plasmas. The second thrust involves using high energy laser pulses to drive shock waves at pressures from 100 kbar to > 1 Mbar. Some of these experiments are motivated by astrophysical problems, such as how radiation transport affects the dynamics of shock waves in supernovae, while others are motivated by need to understand the behavior of solid materials at high compression strain rates. Recent progress in the thrust has involved introducing external magnetic fields to make deeper ties to astrophysical phenomena. The third research thrust centers on accelerating electrons and protons in the plasmas that can be created by intense lasers. We study proton acceleration by intense irradiation of thin solid density targets and the wakefield acceleration of electrons by the creation of plasma waves with an intense ultrafast laser pulse in a low density gas. Finally, the fourth thrust exploits recent upgrades to the TPW laser enabling very tight focusing of the petawatt pulses. We are attempting to examine ionization of very highly charge ions at these ultrahigh field strengths and study the effects of radiation reaction and even QED effects in laser plasmas subject to these exotic intensities

The experimental work in CHEDS uses a number of small to large scale laser facilities at UT and around the US. We have at UT a suite of table-top scale lasers with peak power of 20-50 TW. These lasers complement the large scale TPW facility acting as a good local to train new students and test experimental ideas before proposing a full scale experiment on the TPW. In addition to these lasers, CHEDS students often perform experiments on lasers at the national labs including the Z-Beamlet laser at Sandia and the Janus and Titan lasers at LLNL.

Plans for the future:

1) **installation of the Trident laser:** CHEDS recently competed successfully to host the transfer of the Trident laser from Los Alamos to an outside lab. This transfer will allow CHEDS to install Trident within the same experimental bay as the TPW in newly expanded and renovated space. This will greatly augment the current CHEDS experimental capabilities and make CHEDS one of the world's leading HED laser facilities. Of particular interest is the opportunity to use Trident to pump amplifiers that will allow multi-PW laser operation. This will constitute a new world leading capability. This laser will enable new experiments in astro and particle physics, as well as quantum field theory. Development of an ultra-short pulse beamline that uses one Trident beam as a pump source will yield a 5PW, 100J, 20fs laser pulse that can be used in conjunction with the existing Texas Petawatt and the remaining Trident beams. This new instrument will advance cutting-edge research at electric and magnetic field strengths that are unprecedented. It will enable the explicit exploration of the interface between classical and quantum theories by probing non-perturbative quantum effects in strong classical potentials, staging the first controlled laboratory experiments on this topic. The experiments will combine elements of strong field physics, laser-matter interaction, astrophysics and particle physics. Coupled with the existing TPW laser this new system will enable strong field experiments with GeV electron bunches as well, accessing fields in the electron rest frame that well exceed the critical (Schwinger) field.

2) **Coupling of a strong magnetic field driver with the TPW**. In collaboration with Sandia, we have an ongoing effort to integrate a 2 mega-amp pulse power driver with the TPW laser. This driver will allow laser plasma experiments in external magnetic fields up to 100 Tesla. This is a new avenue of high energy density physics research accessing an explored regime. Applications here include understanding the evolution of supernovae explosions, fundamental plasma evolution in strong fields and possibly novel confinement methods using laser produced fusion plasmas.

Particle and Nuclear Physics

The experimental particle physics group consists of the following faculty: Tim Andeen (assistant professor), Karol Lang (professor), Peter Onyisi (assistant professor), Jack Ritchie (professor), and Roy Schwitters (professor). Christina Marker (associate professor) is an experimentalist in the closely allied field of relativistic heavy ion physics. In addition, Duane Dicus (professor) is a particle physics phenomenologist who is associated with this group. These faculty comprise the Center for Particles and Fields, a departmental research center. The Center for Particles and Fields uses indirect cost return to support half the salary of a highly skilled technician ("supertech"), Marek Proga. The other half of his support comes from direct grant funding or from the endowed chair occupied by Schwitters. Research by this group addresses topical issues at the forefronts of particle and nuclear physics.

Properties of neutrinos

With the discovery of neutrino oscillations in the late 1990's, it became clear that neutrinos have non-zero masses. Our neutrino group (led by Karol Lang) was central to the long-baseline neutrino oscillation experiment, MINOS, at Fermilab. MINOS made the most precise measurement of the so-called ``atmospheric" mass difference. This experiment has continued until recently, in the form of the MINOS+ experiment, which took data with a modified beam configuration that provided higher intensity and higher energy. With completion of the MINOS program nearing, Lang has shifted focus to the NOvA experiment, which will measure electron-neutrino appearance in a muon-neutrino beam, a probe into CP-violation in the lepton sector. NOvA is the current flagship experiment at Fermilab, and it will be a major research thrust for the immediate future. Longer-term, the new DUNE project will inherit the flagship role in U.S. neutrino physics, and Lang and his group are actively involved in R&D for DUNE.

In parallel with the work at Fermilab, Lang's group is working on underground experiments in France (NEMO3 and SuperNEMO in the Frejus Underground Laboratory) that searche for the neutrino-less double beta decay process. If observed, this will answer one of the most basic questions about neutrinos, are they Dirac or Majorana particles? (I.e., are they like electrons, for which the anti-particle is a distinct particle, or are they like neutral pions, for which the particle and anti-particle are the same?) A measurement of neutrino-less double beta decay will also help to measure the absolute mass of neutrinos and to understand the ordering of the mass eigenstates.

Rare quark-flavor changing processes

Rare processes, through the effects of virtual particles, are sensitive to high mass scales. Many discoveries in particle physics over many decades have come from experiments that exploited this fact, and such experiments have been the focus of Ritchie's research. This has included studies of rare kaon decays at the Brookhaven National Laboratory and more recently studies of B mesons in the *BABAR* experiment at the SLAC National Accelerator Laboratory. While studies of muons represents a departure from rare meson decays, Ritchie's current research focus is the Fermilab Muon g-2 experiment, which will improve the current muon g-2 measurement (i.e., the precise value of the muon’s magnetic moment). The best prior measurement of muon g-2 hinted at new physics, but more precision is needed to draw a definite conclusion.

Fundamental properties of Quantum Chromodynamics

High energy collisions of relativistic heavy ions provide access to studies of fundamental quantum chromodynamics (QCD). Christina Markert’s research in this area has included the STAR experiment at the RHIC collider at BNL, and currently is focused on the ALICE experiment at the CERN LHC. QCD presents difficult computational challenges, particularly for phenomena that occur in the non-perturbative regime (i.e., all phenomena excluding only very hard collisions). QCD seems to predict the existence of a new state of matter, a quark-gluon plasma, that would only exist under conditions of extreme temperature and density, such as immediately after the Big Bang. Markert’s current focus is the study of resonance production at ALICE to study the evolution of the hot, dense fireball produced in relativistic heavy ion collisions.

Studies of the Higgs boson and Searches for Exotic States

The CERN LHC provides the highest energy proton-proton collisions to date and it is host to a large international program of forefront particle physics research. Andeen and Onyisi are collaborators on the ATLAS experiment at the LHC. Onyisis data-analysis focus is to measure the properties of the Higgs boson, in particular its couplings to other quarks – with emphasis on the top quark. These studies are needed to determine if it is a Standard Model Higgs. Andeen’s data-analysis focus is the search for new, heavy quarks. In addition, Andeen is developing new data -acquisition electronics for the ATLAS liquid argon calorimeter in order to manage higher rates of interactions when LHC luminosity upgrades are implemented.

In addition to these mainstream particle/nuclear physics experiments, Roy Schwitters has been pursuing a novel application of particle physics detector techniques to explore a Maya pyramid in the jungle of Belize. This involves using cosmic ray muons to ``X-ray" the pyramid by reconstructing a three dimensional image from the scattering of through-going muons that are observed in detectors that are buried below ground level. This effort takes advantage of scintillators developed for the MINOS experiment and electronics developed for the ATLAS experiment at the LHC.

Duane Dicus conducts theoretical particle physics research, primarily addressing phenomenological topics related to the Higgs boson and properties of neutrinos.

Plasma Physics and Fusion

The intellectual excitement of plasma physics—a discipline with high intrinsic scientific interest as well as importance to various applications (notably fusion energy)—has led the University of Texas to be a major participant in this area of research for several decades. In 1980 the US Department of Energy decided to insure that the best physics be brought to bear on the quest for thermonuclear energy by establishing a center of excellence in fusion science. After a nation-wide competition, the University of Texas was selected as the site for this center, named the Institute for Fusion Studies. Since then the IFS has gained and maintained an international reputation for first-rate scientific achievements. The IFS is unique in the fusion program for its nature as a departmental center within the Physics Department: this circumstance is central to the role it plays in enabling the fusion program to benefit from the latest advances in physics, and vice versa.

The research being pursued at the IFS is diverse, including plasma turbulence, transport theory, kinetic theory, plasma-boundary interaction, stability theory, and nonlinear plasma dynamics. In addition to the principal application to fusion energy science, theoretical tools developed at the IFS have been applied to a broad range of laboratory and naturally occurring plasmas.

Members of the IFS are involved in many local, national, and international collaborations. These include collaborations with other groups in the Department, including the Center for Nonlinear Dynamics and the Center for High Energy Density Physics. The IFS also has a vigorous advanced computation program in collaboration with the Mathematics Department and the University's Institute for Computational and Engineering Sciences. It is the lead institution in one SciDAC center (Scientific Discovery through Applied Computation) studying turbulence in fusion devices and is a participant in two others (studying runaway electrons and turbulence in the edge of fusion experiments). It is also a key participant in the Exascale Computing Project where it is responsible for the core turbulence component of an integrated model of tokamak turbulent transport.

The IFS has an active experimental program. It leads a consortium that is designing the electron temperature diagnostic system for ITER (based on cyclotron emission), operates diagnostics on the DIII-D tokamak in San Diego and the EAST tokamak in China, and conducts research on JTEXT (China) and KSTAR (Korea). It specializes in the study of turbulent transport, especially in the electron channel, and the interaction of plasma waves (used for heating and current drive) with plasma turbulence.

During the past three years, IFS scientists authored 180 papers in refereed journals. IFS work is regularly selected for invited talks at major national and international conferences. For example, at the 2016 American Physical Society Division of Plasma Physics annual meeting IFS scientists presented three invited talks including a plenary review talk. At the prestigious biennial IAEA Fusion Energy Conference held in 2016 in Kyoto, we presented one plenary overview, four lead-author and seven co-author papers. This representation is typical of IFS participation at the principal plasma meetings throughout the years.

Recent significant IFS contributions to fundamental understanding and innovative ideas in plasma and fusion energy science include the following:

- Study of structure preserving algorithms in plasma physics based on Hamiltonian and action principle formulations of plasma physics
- Application of the discontinuous Galerkin method to plasma simulation for both fluid and kinetic (Vlasov) models.
- Clarification of the role of damped modes in plasma turbulence
- Explanation for turbulence-induced bifurcations in the evolution of magnetic islands
- Detailed analysis of runaway electron dynamics during plasma disruptions
- Explanation for confinement degradation in the pedestal of the Joint European Torus (JET) in the presence of a metal wall.

IFS plans to further grow its research program in the high-interest areas of advanced computation. IFS will also continue to increase its emphasis on scientific research that is relevant to burning plasma through the development of new conceptual tools and the testing of innovative ideas.

In addition to its research role, the IFS also serves as a center for information exchange about fusion plasma science, nationally and internationally, by arranging visits of scientists and students, joint collaborations, and conferences. It is the principal site for fusion theory collaboration activities between the United States and Japan. The IFS also has a strong educational role, in teaching courses, writing textbooks, and training students and young scientists. IFS scientists are active in teaching courses, guiding student thesis research, and training postdocs and young scientists. To date, IFS scientists have written 18 books, some of which have become standard texts in graduate physics courses.

IX. THE GRADUATE PROGRAM

A. Narrative Description

The Department of Physics offers three graduate degrees: a Master of Arts (M.A.) in Physics, a Master of Science (M.S.) in Applied Physics, and a Ph.D. in Physics. Our primary mission is the Ph.D. program. The Department has 203 graduate students; among them only two are seeking a terminal master's degree. Some Ph.D. students receive an M.A. degree while pursuing the Ph.D.

The Department only offers financial support to students seeking the Ph.D. degree; this support takes the form of a Teaching Assistantship (TA), Graduate Research Assistantship (GRA), or fellowship.

As the above enrollment figures indicate, the graduate program is large. According to the most recent American Institute of Physics report on the subject, of the 201 U.S. institutions that offer a Ph.D. in Physics, our program ranks among the largest, each of which has more than 200 graduate students. Our graduate program is #3 by doctoral degrees granted in 2014–15 (36) and #7 by total graduate enrollment in Fall 2015 (205). The seven-year (2011–2017) total of doctoral degrees awarded was 208 for an average of 29.7 per year.

After graduation, more than half of our Ph.D. graduates continue their research work in postdoctoral positions at research universities or other research institutions. About a quarter go to industry. Among 274 (2005–2013) graduates we could trace, 28 (10%) are now professors at research universities/research institutions.

(a) Graduate Degree Requirements

Master of Arts

The M.A. degree requires 30 hours of credit, including six hours of thesis. Of the remaining 24 hours, 18 credit hours must be in physics and at least six hours must be in supporting work outside of physics. All requirements must be completed within a six-year period. The M.A. degree is not required of Ph.D. candidates, but a few students earn the M.A. degree while pursuing the Ph.D.

Master of Science in Applied Physics

The program was introduced in 1995 and is designed to provide students with a broad background of graduate-level courses in physics and related fields with an emphasis on those aspects of science most used in an industry setting. The requirements are 30 hours of credit, six of which are obtained by preparation of the required thesis. The course work must include graduate level physics courses in experimental physics, quantum mechanics, classical electrodynamics, the physics of sensors and a technical seminar. Supporting work must be chosen from courses in engineering, chemistry, or geological science.

Doctor of Philosophy

There are three steps in the program leading to the Ph.D. degree. The first is the qualifying process. Prior to being admitted to candidacy for the Ph.D. degree, the student must:

1. Take the four “core” courses, i.e., quantum mechanics, electricity and magnetism, classical mechanics, and statistical mechanics, with a grade-point average of B+ (3.33).

2. Show evidence of exposure to modern methods of experimental physics through participation in an experimental research program or by taking the graduate course in experimental physics.

3. Present a seminar, within 27 months after entering the program, on a proposed research topic, followed by an oral examination.

After satisfying the three requirements listed above the student prepares a "program of work" for the Ph.D. degree. This program of work lists the courses the student has completed and those that will be taken to satisfy the requirements for the Ph.D. The doctoral degree must include at least four advanced physics courses (with a letter grade of at least B-), at least one of which must be in a specialty other than that of the student's dissertation. The Program of Work must include three courses outside the student's area of specialization. One of these must be an advanced physics course; another must be outside the Department of Physics; the third may be either outside the area of specialization or a course outside the Department of Physics. The Program of Work must be approved by the Graduate Advisor in the Physics department. Following this approval, the student is admitted to candidacy for the Ph.D. degree. For clarification, see Table I, below.

Table I: Model Course of Study for a Condensed Matter Experimentalist.

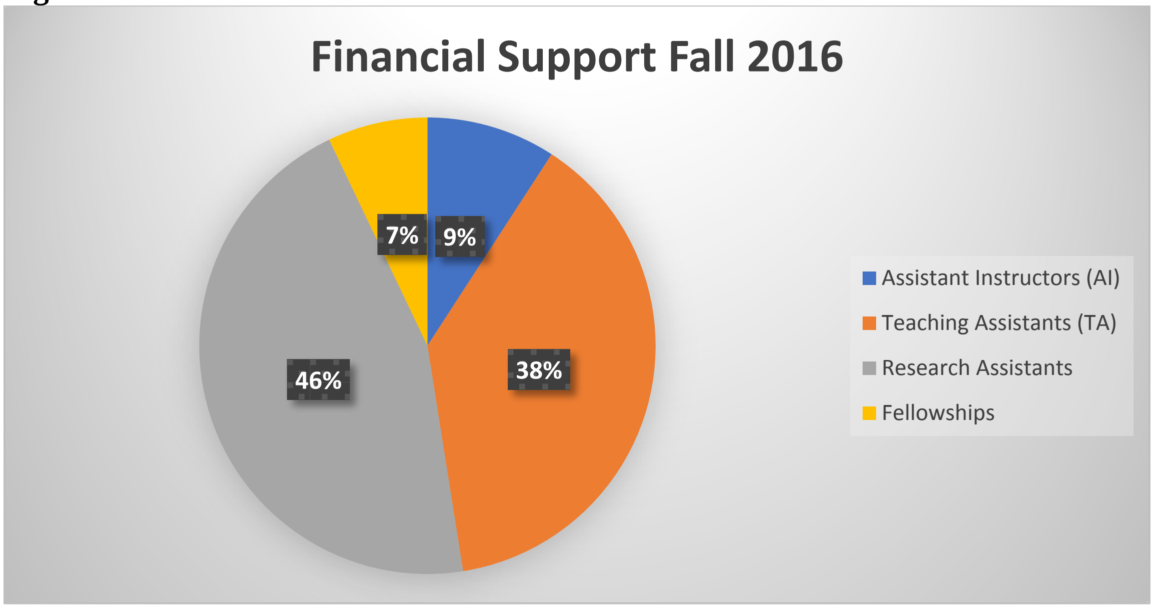
Major Work	
The Core Courses	PHY 385K Classical Mechanics
	PHY 385L Statistical Mechanics
	PHY 387K Electromagnetic Theory I
	PHY 389K Quantum Mechanics I
In-Field Advanced Courses	PHY 392K Solid-State Physics I
	PHY 392L Solid-State Physics II
	PHY 392N Many-Body Theory
Dissertation Hours	
Supporting Work	
Out-of-Field Advanced Course	PHY 395K Nonlinear Optics and Lasers
Out of Department Supporting Course	M E 387R Practical Electron Microscopy
Out of Department or Out-of-Field Supporting Course	CSE 392 Parallel Algorithms in Scientific Computing

The last step in the process is the preparation of a dissertation based on original research. The research leading to the dissertation is done under the supervision of a faculty committee chaired by the student's dissertation supervisor. This is certainly the most rewarding and most time-consuming part of the degree program. Approval of the dissertation follows a final oral examination covering the dissertation and related topics in physics. The median number of years for earning a Ph.D. is from 5 to 7 depending on the sub-field.

(b) Available Financial Support

Students are supported as Assistant Instructors (AIs), Teaching Assistants (TAs), and Research Assistants (GRAs) with a few students holding University, NSF, or DOE Fellowships. The funding types are shown in Table I by year of recruitment. The majority of the first-year students are supported as TAs.

Figure 1.



Salaries for TAs and RAs are shown in Table III. For TAs, the Legislature provides $3,784 per long semester and $1,892 in summer in remission of their tuition and fees (called a Tuition Reduction Benefit, also known as TRB). For the GRAs, the sponsoring faculty member provides the same/similar amount of support for tuition and fees. Fringe benefits are provided by either the University in the case of the TAs, or a principle investigator in the case of GRAs.

The level of AI is attained by senior students having appropriate teaching experience. AIs have independent responsibility in the design and teaching in their course, Physical Science 303/304. This experience is excellent for those who wish a teaching career in Physics at colleges.

The University maintains a competitive scholarship program. Every year the Graduate School asks each graduate program to nominate three graduate students for a Continuing Fellowship award. The stipend for 2017-2018 is $28,000 with a $2,185 supplement to help with medical insurance premiums along with full tuition support.

We ask faculty to nominate their best students for this award. The nominations are then reviewed by the Graduate Studies Subcommittee, ranked, and forwarded to the Graduate School where the final decision is made. Typically we receive 1–2 of these fellowships per year.

Table II: Number of Students by Funding Type & Semester, 2011–2017.

	2011	2012	2013	2014	2015	2016	2017
Fall							
TA/AI	120.5	120.5	120	124	114	108	--
GRA	87.5	84.5	79	80	74	81	--
Fellowship	12	17	14	15	15	16	--
Self-Supporting	2	3	2	2	2	4	
Spring							
TA/AI	--	122.5	120	118	115	112.5	100
GRA	--	85.5	85	81	89	75.5	89
Fellowship	--	12	17	14	15	15	16
Self-Supporting		2	3	2	2	2	4

Table III: Graduate Student Salaries for 2017-2018.

Job Title	*20-Hour Appointment / 1-Month Salary*
Teaching Assistant (TA)	$2,250
Assistant Instructor (AI)	$2,385
Graduate Research Assistant (GRA)	$2,250

c. Program Size

Table IV shows the numbers for enrollments and M.A., M.S., and Ph.D. degrees granted in the past 7 years (2010–2017). The number of students enrolled was larger than 200 for many years. Our current enrollment has been controlled partly by the number of offers made during recruitment with a target number determined by surveys of our research groups and by the number of TA positions available. This trend is very much the same as the national trend. The current enrollment is 203 as of September 2017, and the student to faculty ratio is 4.23 (=203/48). Some further decline in the number of students is likely in the next few years as admissions are more closely linked to the availability of external research funding.

The number of Ph.D. degrees granted changes considerably from year to year, but on average stays flat with an average of 28/year.

Table IV: Enrollments and Degrees Granted, 2010–2017.

Academic Year	**2010–11**	**2011–12**	**2012–13**	**2013–14**	**2014–15**	**2015–16**	**2016–17**
Total Enrollment*	225	222	225	215	221	205	209
Doctoral Degees	29	31	24	27	36	23	28
M.A. Degrees	2	4	6	4	7	5	2
M.S. Degrees	1	0	0	0	0	0	0

*Totals are as of September 1st of the indicated year.

The distribution of the students enrolled in the Fall of 2016 and degrees granted in the period 2012-2016 into different research fields are shown in Table V, together with the number of faculty.

In the past seven years (2011–2017), the Department produced 208 doctoral degrees and the number of incoming Ph.D. students over the same period was 238. A measure of our production rate is thus 208/238=87.39%.

Table V: Faculty, Enrollments, and Degrees Granted by Sub-Field.

Research Specialty	2016-17 Faculty	Enrollment* Fall 2016-17		No. of Degrees Granted 2016-17 (2010-16)		
		Master's	Doctoral	Master's	Terminal Master's	Doctoral
Atomic, Molecular, & Optical Physics	8	31	19	0 (2)	1 (5)	5 (29)
Biophysics	2	7	7	0 (1)	0 (3)	2 (11)
Condensed Matter Physics	14	32	38	0 (7)	0 (3)	8 (53)
Cosmology & String Theory	6	11	7	0 (2)	0 (3)	2 (18)
High Energy Physics	7	13	4	0 (1)	0 (1)	2 (16)
Nonlinear Dynamics	2	1	4	0 (0)	0 (2)	1 (6)
Plasma & Fusion	5	13	14	0 (3)	0 (2)	7 (22)
Relativistic Heavy Ion Physics	2	2	1	0 (1)	0 (0)	0 (4)
Relativity & Gravitation	1	0	3	0 (0)	0 (0)	2 (5)
Statistical & Thermal	1	1	0	0 (0)	0 (1)	0 (5)
Non-Specialized	0	0	0	0 (0)	0 (0)	0 (0)
TOTALS:	**48**	**111**	**97**	**0 (17)**	**1 (20)**	**29 (169)**
Full-Time Graduate Students		110	93			
Part-Time Graduate Students		1	4			
First-Year Graduate Students		37	0			

*Students not yet committed to a research specialty are entered under non-specialized.

(d) Admissions Process

The numbers of applicants, TA/GRA positions offered and accepted, and the total number of incoming students in the past seven years (2011-2017) are listed in Table VI. The average number of applicants per year over the same period was 376 (the median was 384). For comparison the average from (2006-2010) was 429.

The average number of incoming students for the Ph.D. program is 36. The average ratio of international to US students during the same years is 1.37 to 1. The selection of the students from the applicant pool is made by the Graduate Recruitment Committee.

The quality of the incoming students is one of the primary concerns of the Department. It has improved recently, but progress in this regard is not as noticeable as the Department would hope. The average yield rate for 2011-2017 was 36%, and the average selectivity was 25% (see Table IV, above, for details). There are two reasons for this:

- Better prospective students tend to go to prestigious schools in the East or West.

- The low amount of financial support the Department has offered to TAs and GRAs. This has improved significantly over the past three years, from a 9-month stipend of $18,000 to a 12-month stipend of $27,000.

In 2001, a Doctoral Harrington Recruitment Fellowship was established at the University with a stipend of $33,000 (TA/GRA salary is $27,000) in addition to full tuition and fees, student medical insurance, and an allowance of $2,000/year for travel, equipment, books, or other professional expenses for five years. The Department has offered one of the Fellowships to a prospective student every year since, but the recipients have turned down the offers to go to more prestigious institutions. The university also established the Provost's Graduate Excellence Fellowships (PGEF). The stipend for these fellowships is $30,000 (TA/GRA salary is $27,000) per year, for a period of five years, an allowance of $2,000/year for professional expenses, tuition, and medical insurance. The program provides two years of fellowship, one year of TA, and two years as an RA. The TA/GRA salaries are augmented to raise them to the $30,000 level of the fellowship years. The target for the physics department is to recruit 6 of these fellowships per year. We attempt to make 20 offers per year, limited by the number of GRA positions available from the faculty. In the first three years of this fellowship, we have recruited 4, 4, and 5 students, respectively.

In addition to these recruitment fellowships, we also have fellowship funds provided by donors to honor past faculty. Currently we have Antoniewicz, Biedenharn, Boner, Downer, Lane, Leonard, Little, Lockenvitz, Matsen, Naito, Riley, Rudmose, and Wheeler fellowships. Part of these endowment funds contribute to the PGEF, but there is sufficient funds for ~10 summer fellowships which are combined with summer TAs (currently ~13) for summer support. New applicants supported on TAs are promised 12-month support for a five-year period.

Table VI: Recruitment, 2011–2017.

	2011*		**2012***		**2013***		**2014***		**2015***		**2016***		**2017**	
	U.S.	*Int'l*	*U.S.*	*Int'l*	*U.S.*	*Int'l*	*U.S.*	*Int'l*	*U.S.*	*Int'l*	*U.S.*	*Int'l*	*U.S.*	*Int'l*
Applicant Pool	**348**		**407**		**361**		**399**		**384**		**410**		**321**	
	136	212	189	218	158	203	166	233	143	241	173	237	150	171
Offers	**62**	**39**	**66**	**42**	**57**	**36**	**44**	**43**	**36**	**48**	**62**	**36**	**45**	**36**
TA	31	28	33	35	12	33	8	33	17	38	32	29	26	30
GRA	1	0	1	0	2	1	3	0	0	1	1	2	3	0
Fellowships														
TA + Fellow	29	8	29	4	43	0	33	7	9	7	15	0	N/A	N/A
Full Fellow	1	0	1	0	N/A	N/A	N/A	N/A	10	1	13	3	16	5
Other	0	0	0	0	0	0	0	0	0	0	1	2	0	1
*No Aid***	0	3	2	3	0	2	0	3	0	1	0	0	0	0
Acceptances	**38**		**39**		**28**		**40**		**34**		**37**		**26**	
	17	**20**	**17**	**22**	**17**	**13**	**19**	**16**	**14**	**18**	**20**	**17**	**16**	**10**
TA	9	14	10	18	5	11	4	11	7	12	13	13	11	9
GRA	1	0	1	0	1	0	1	0	0	1	1	2	1	0
Fellowship														
TA + Fellow	29	8	6	2	11	0	14	2	4	3	3	0	N/A	N/A
Full Fellow	0	0	0	0	N/A	N/A	N/A	N/A	3	1	3	1	4	1
Other	0	0	0	0	0	0	0	0	0	1	0	1	0	0
*No Aid***	0	3	0	2	0	2	0	3	0	1	0	0	0	0
Selectivity (%)	**29.0**		**26.5**		**25.8**		**21.8**		**21.9**		**23.9**		**25.2**	
	37.4	16.7	39.8	18.0	34.3	15.5	26.5	18.5	21.7	20.6	37.4	15.5	27.1	15.5
Yield (%)	**36.6**		**36.1**		**32.3**		**40.2**		**38.1**		**37.8**		**32.1**	
	27.4	51.3	25.8	524	29.8	36.1	43.2	37.2	38.9	37.5	32.3	47.3	35.6	27.8

*From 2011 to 2014, all students receiving fellowship offers received a TA with it. In 2015 and 2016, we began offering a number of full fellowships, and thus a portion of fellowship offers were these and the rest were as in 2011–14. In 2017 all fellowships were full fellowships and, thus, no combined TA + fellowship offers were made.

**U.S. students not offered Aid of any kind were typically those seeking a terminal master's degree. International students not offered Aid of any kind were typically participants in the Würzburg Exchange Program.

For the recruitment of students from Underrepresented Minority (URM) backgrounds the College of Natural Sciences, with the support of the Provost's Office, has, for the past two years, awarded ten inclusivity fellowships. The awardees receive:

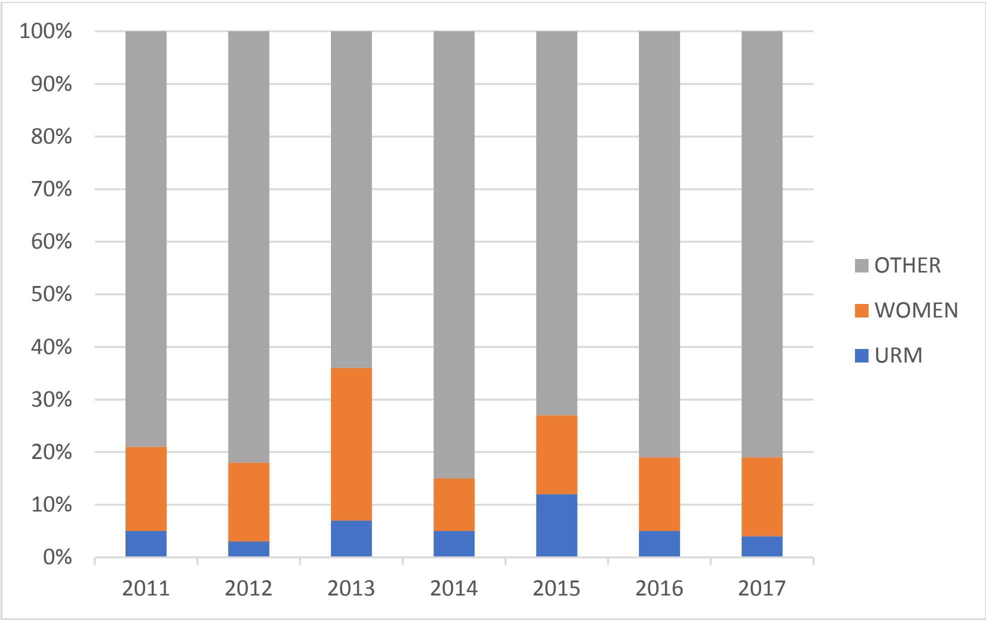
- Year 1: Full fellowship including annual stipend of $31K, full tuition support, and one-time payments (at the beginning of each long semester) to cover the cost of staff (UT Select, employee only) health insurance.
- Years 2-5: $4,000 annually in GRA/TA "bump-up" fellowships. The students are appointed as a GRA or TA with full tuition support for 12 months at an annual rate of $27K. The fellowship will bring the total annual stipend to $31K.

For the 2017-2018 class Physics was awarded three fellowships, but all the offers were declined.

Previously, the graduate school had two types of Diversity fellowships. The mentoring fellowship with a stipend of $16,000 (over 9 months), tuition assistance of $3,784 per semester and a $1,100 supplement for medical insurance. This program also provided travel grants for student recruitment. For the 2016 recruitment year the department offered two-year diversity fellowships to two black students. One student rejected our offer; the other has deferred.

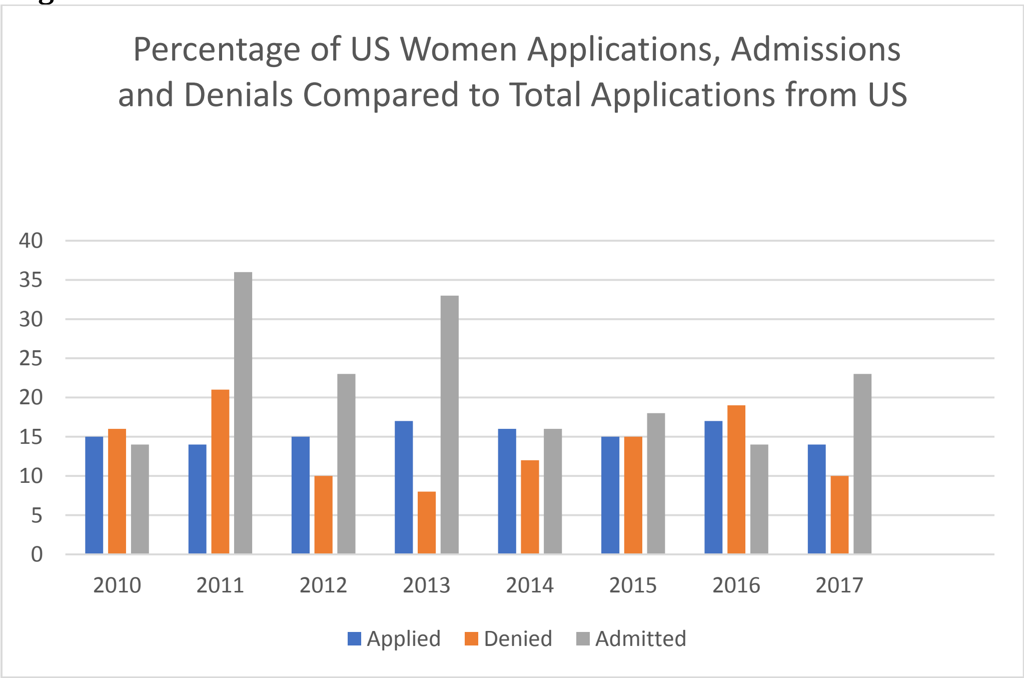
We also make a concerted effort to recruit women physicists. The Rudmose fellowship program is used to augment the TA stipend of women applicants, typically by $6,000. The percentage of women and URM admitted during the period 2011-2017 is displayed in the figure, below.

Figure 2.



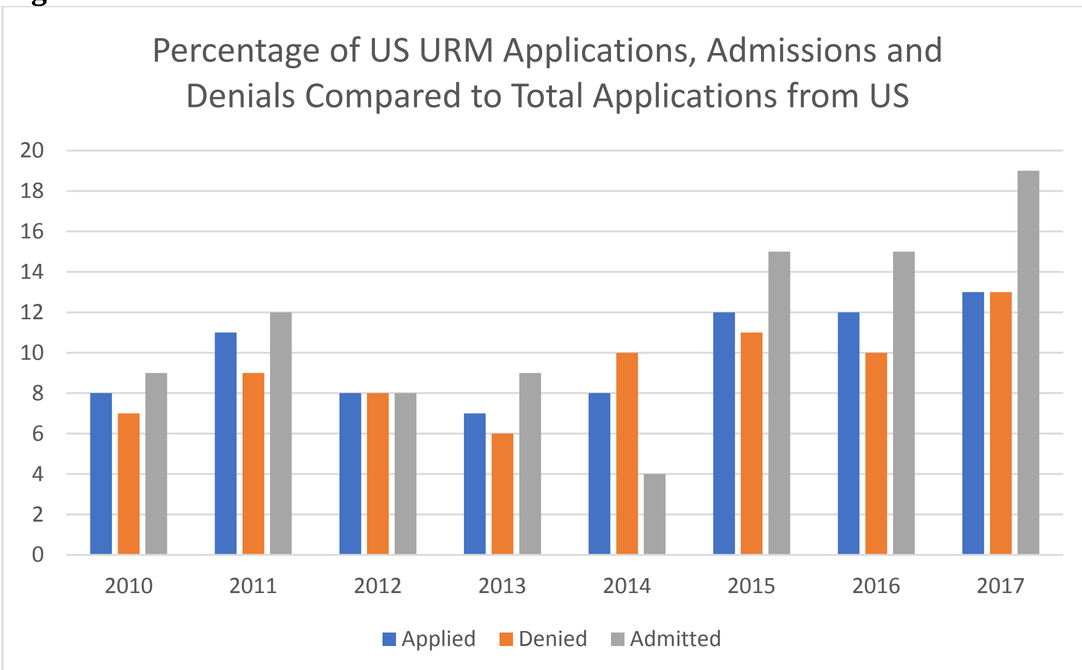
In Figure 3 we compare the number of US women that applied to our graduate program and were admitted or denied admission from 2011-2017. The percentages in these three categories show no negative bias in the admissions process. The statistics for international women applications were not available.

Figure 3.



In Figure 4 we compare the number of US URM that applied to our graduate program, were admitted or denied admissions from 2011-2017. The percentages in these three categories show no negative bias in the admissions process.

Figure 4.



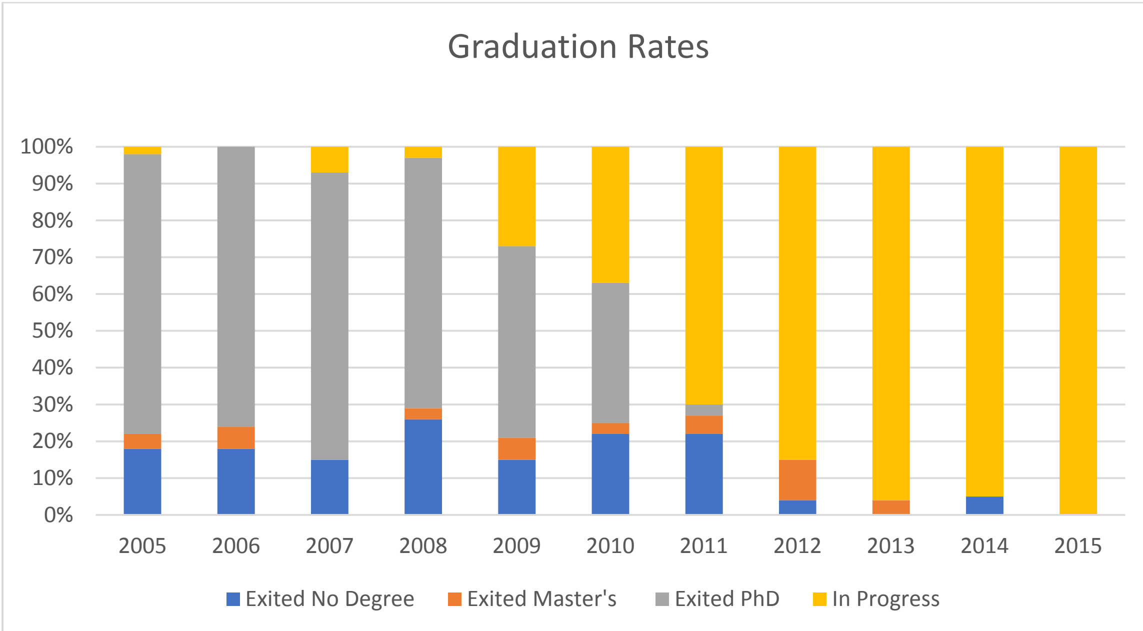
Our averages for URM (6.2%) and women graduate students (16.5%) are close to the national average, respectively (APS: ~6%, ~20%), but as a large public university in a diverse state we would like to do better. This year only one of the students is an URM in spite of making three diversity fellowship offers and admitting a record number of URM (see Figure 4).

Since March 1995, the Department has held an Open House Recruitment event every year, inviting ~60 of the top applicants residing in the United States (both US and international). It is held in late February. In the evening of arrival, we hold a poster session at the AT&T center where the students are housed. The posters are presented by our graduate students who also answer questions regarding their research. Faculty are also available to answer questions, and a buffet is provided. In the morning, we have an organized session where a representative of each of our research groups, who may be faculty, a student or both, introduces their research program in a 20-30 minute presentation. The afternoon is devoted to meetings with faculty and the laboratory tours. In the evening, we invite the attendants to a dinner, which is also attended by members of the Recruitment Committee of the Department, some of our faculty, and students. The next day, Committee members and students take the applicants on tours of Austin to show them the city and surrounding areas.

e) Degree Completion Rates, and Time-to-Degree

For each cohort, the Graduate School tracks the number of students that exit without a degree, those that exit with a Master's and those that complete a PhD. The percentages for each class are displayed in Figure 5.

Figure 5.



The average time to degree, as computed by the Graduate School, for the Ph.D. and Master's programs as well as the average time a student takes to exit the program without a degree is given in Table VII. Unfortunately, this average is for the period 1989–2015.

Table VII: Time to Degree (1989-2015).

	Exited No Degree	Exited Master's	Exited Ph.D.
Average Years	2.06	3.78	6.8
Median Years	2	3	7

(f) TA Workoad Policies

Before graduate students can have contact with students in a classroom they must pass written and oral exams on their fluency in the English language. If they fail this exam they are required to take the appropriate courses in English as a Second Language until they pass the exams. Teaching assistants are also required to take PHY 398T, Supervised Teaching in Physics. This course presents recent techniques developed to improve the teaching of physics. In addition to teaching strategies the course covers administrative procedures, and classroom responsibilities including the university non-discrimination and harassment polices. It also includes a module on scientific ethics as required by the National Science Foundation and the National Institutes of Health. Students are required to prepare model classroom lectures and present them to the class, where they then receive feedback on improving their lectures.

Teaching assistants teach physics laboratory courses, discussion/problem sessions, and they grade upper division physics courses and the core graduate classes.

We have developed written work load specifications for all of their responsibilities. For the teaching of elementary physics laboratories they are responsible for two three-hour laboratories or three two-hour laboratories. The work load includes time for preparation, instructional meetings for teaching the labs, office hours, and the grading of lab reports. The total workload is estimated at 15-20 hours depending on the TA's experience and efficiency of grading. Techniques for improving grading are also taught in TA meetings.

Discussion sections also require 5-6 contact hours and the workload includes homework preparation, attendance at lectures, and proctoring of exams. Grading for courses with discussion sessions is computerized and the TA's responsibility is mostly helping with problem selection.

In 2017 the College of Natural Sciences has established a new policy limiting the total numbers of semesters that students may be supported as TAs. The motivation is to improve the graduate experience. The limit will be 6 semesters of TA support for experimentalists and 8 semesters for theorists. While this may not be a major problem for most experimental research programs where GRA funding is available it does limit the flexibility of the department to fund students in areas where funding is lost. In theoretical particle physics the NSF/DOE funding provides ~1/3 of the GRA cost per investigator per year. The particle Theory Group has used this funding for summer support. The proposed reduction from 12 semesters of TA support to 8 semesters could over a period of years force a significant reduction in the number of graduate students that the Theory Group can admit as it is unlikely that the students will graduate in 4 years. The average time to degree for Particle Theory Students in our department for the period 2007-2013 was 6.3 years while in the top 15 institutions the average was 5.9 years. See table from a recent NSF-sponsored study on time-to-degree in the Appendices to this report. This concern may be addressed through increased endowment support. This one reason why obtaining new graduate student endowments is the highest development priority for the Physics Department. Obtaining additional graduate student endowments is also the highest priority for the College's development effort.

(g) Graduate Student Professional Development Opportunities

In early 1980, our graduates obtained employment largely in industry. A significant change has taken place since then; now, more than half of our graduates are employed either as postdoctoral fellows at research universities/research institutions, or as teachers at liberal arts colleges. Employment in industry accounts for about a quarter. Table VIII shows the details of the employment of our graduates just after graduation. It is notable that a large portion of the MA/MS graduates enter the Ph.D. program.

The College of Natural Sciences provides access to a Career Development Specialist to graduate students in all CNS departments. The specialist consults on a wide range of matters, including career exploration, non-academic job searches, academic job searches, converting a CV to a resume, interview preparation, and others. Since April 2014 and October 2017, 49 Physics graduate students have taken advantage of these services. Also, eight postdocs from our Department have as well. Most often the graduate students have consulted on career exploration, resume and cover letters, and job/internship searches.

Table VIII: Placement Information, 2005–2014.

		Three-Year Period: 2005–2008	Three-Year Period: 2008–2011	Three-Year Period: 2011–2014	Totals	Percentages
Education	University Faculty	3 (12)	4 (6)	4 (10)	11 (28)	4.01% (10.22%)
	University Non-Faculty*	47 (40)	45 (40)	38 (27)	130 (107)	47.45% (39.05%)
	Secondary Teaching	2 (1)	1 (0)	1 (1)	4 (2)	1.46% (0.73%)
National Laboratories & Research Institutes		27 (25)	17 (17)	6 (7)	50 (49)	18.25% (17.88%)
Private Sector	Research	13 (12)	18 (15)	15 (16)	46 (43)	16.79% (15.69%)
	Non-Research	2 (4)	5 (9)	7 (7)	14 (20)	5.11% (7.30%)
Other		2 (2)	0 (0)	1 (1)	3 (3)	1.09% (1.09%)
Unknown		3 (3)	3 (6)	10 (13)	16 (22)	5.84% (8.03%)

*Figures outside parentheses are for Initial Posting; those inside parentheses are for Current Posting (where available)

Table VIII also shows where our Ph.D. graduates are now, separately for those that graduated on or after 2005 and before 2014. Among 274 Ph.D. graduates we could confirm, 28 (10%) are now professors at research universities/research institutions. Almost the same number of graduates are employed in industry. The rest are postdoctoral fellows at research universities/research laboratories or are teaching faculty at liberal arts colleges. (The appendix of this report contains lists of places where our students have been placed, together with their sub-fields, for the period 2001–2017).

For the most part, the professional development of our students has been traditional. They receive support to go to conferences/school both through research grants and through limited funding from the graduate school, asked to give internal seminars presentations and they are motivated to find internships in industry. To encourage the latter, every Spring semester, the Physics Department runs the Technical Seminar which invites physicists from industry to share their research and experiences with our students. This seminar also provides a networking opportunity. Approximately two years ago the College of Natural Sciences hired a Graduate Student and Postdoctoral Career Development Specialist who works with our students to find options outside academia. Although not all students are aware of this opportunity, a good fraction of physics graduate students have already taken advantage of his expertise.

In 2015-16, the College of Natural Sciences convened a 21st Century Graduate Education Working Group and charged that committee to make bold and innovative recommendations about the future of graduate education in the College. In 2016-17 an Implementation Task Force was formed to determine what the College should do in response to the report, how to facilitate programmatic innovation to effect recommended improvements, and how to evaluate effects of these changes. Among new professional development programing under development of discussion are:

- A 3-course Teaching & Mentoring Concentration currently being piloted within the College for PhD students interested in pedagogics;
- A concentration in Communications
- A concentration in Leadership & Administration
- Scaling statistics and coding workshops to serve more students
- A Public Policy Concentration