UNIVERSITY OF SAN FRANCISCO
COLLEGE OF ARTS AND SCIENCES

# DEPARTMENT OF PHYSICS & ASTRONOMY

## Self-Study for
## Departmental Program Review

February 2011

## Contents

## 1. Introduction: Department's Mission and Goals

The Physics & Astronomy Department at the University of San Francisco blends the ideals of a rigorous foundational physics and astronomy curriculum with the principles of Jesuit higher education.

Our mission is to provide students with a solid foundation in the fundamental concepts of classical and modern physics; to expose them to the scientific methodology of hypothesis testing; and to help them develop their technical skills using a variety of tools including abstract thought, experimentation, and mathematical and computer modeling. This is accomplished in our department via a comprehensive coverage of experimental, theoretical, and computational physics, and by combining coursework together with on- and off-campus research and exposure to cutting-edge equipment and laboratory techniques. Our emphasis on rigorous physics foundations is centered on the premise that physics deals with the most basic principles that describe all phenomena in the universe, i.e., the fundamental properties of space, time, energy, and matter; and with their interrelationships leading to multiple levels of beauty, simplicity, and interconnectedness. In this view, astronomy plays an essential role as a central field within contemporary physics.

As an integral part of a Jesuit institution of liberal learning, the Physics and Astronomy Department seeks to provide students—both science and non-science majors—with: (i) an appreciation for science and its relation with and responsibility toward society; (ii) the understanding that a college degree is not an end in and of itself, but only the beginning of a person's journey through a life of learning and service. Most importantly, in terms of our various service courses, and major and minor programs, we provide the fundamental knowledge and the practical tools of a *rigorous science-based education that will help our students be players and leaders in shaping a more humane world.*

The comprehensive foundation of our major program ideally prepares students for graduate studies in any discipline within fundamental or applied science (physics, astronomy, mathematics, chemistry, biology, etc); in any of the standard engineering fields; in education; in medicine and related disciplines; and many other fields, such as law or financial analysis. Our physics-major tracks, and most especially the 3/2 Physics-Engineering and Materials Physics programs, were designed to enhance the academic and professional skills and knowledge of USF students, preparing them for positions in the high-technology sector of the global economy—thus furthering the University's mission of educating leaders who will make a societal difference.

## 2. Physics & Astronomy Programs and Curriculum

### 2.1 General Overview

The Physics & Astronomy Department academic offerings include a physics major with several tracks, as well as a flexible set of minors. Our expanding set of offerings is expected to provide multiple paths for subsequent development, as outlined in the Introduction. In addition to the Physics Major and Honors Major Programs, we offer tracks leading to technology-related fields via the 3/2 Physics-Engineering and Materials Physics Programs.

Three minor programs: in physics, astronomy, and astrophysics, complete our current list of offerings.

### 2.2 Physics Major Program

The major in physics leads to a BS degree that involves a number of physics and mathematics courses. These are equivalent to the physics-program standards adopted at most US colleges and universities. Within those constraints, at USF, we offer a minimalist version (based on "core physics courses"), in addition to an expanded version with additional requirements (see below).

#### 2.2.1 Major in Physics

The basic major in physics consists of a minimum core of physics and mathematics courses. It provides a rigorous background combined with maximum flexibility for students who have a strong interest in an additional field of study. The major program requires completion of a total of fifty-six (56) units, of which forty-four (44) units correspond to Physics, and 12 to Mathematics support courses, as follows:

- MATH supporting courses (12 units):
  Three semesters of Calculus and Analytical Geometry (MATH 109, 110, 311).
- Lower-division required PHYS courses (12 units):
  - General Physics I (PHYS 110);
  - General Physics II (PHYS 210);
  - Modern Physics (PHYS 240).
- Upper-division required PHYS courses (32 units):
  - Computational Physics (PHYS 301);
  - Analytical Mechanics (PHYS 310);
  - Statistical and Thermal Physics (PHYS 312);
  - Electromagnetism (PHYS 320);
  - Quantum Mechanics (PHYS 330);
  - Optics (PHYS 340);
  - Upper-Division Laboratory I (PHYS 341) or Upper-Division Laboratory II (PHYS 342) (2 units are required, 4 are recommended);
  - Physics Colloquium (PHYS 350; two units are required);
  - Methods of Mathematical Physics (PHYS 371).

As outlined above, this program covers all basic areas of physics (both classical and quantum; and theoretical, computational and experimental). A peculiar feature of this program is that the Upper-Division Lab I and II are listed as having 2 units only. This is merely an artifact of the evolution of our program—especially via programmatic changes

driven by core-curriculum changes a few years ago. However, in practice, the department has continued offering an Upper-Division Lab as a 4-unit course (essentially a merger of the above); in addition, we encourage the students to take an Electronics course. It has already been agreed at the departmental level that the Upper-Division Lab unit enhancement will be officially implemented pending approval by the College Curriculum Committee. Moreover, a number of ideas are currently being discussed to further enhance the academic standards and usefulness of the degree (see Section 3).

In terms of the logistics of program implementation, the required upper-division courses (with the exception of PHYS 371, which is taken during a typical sophomore year) are offered in two-year cycles. However, due to understaffing and rapidly changing student enrollments, various modifications of the cycles have been implemented over the past few years.

### 2.2.2 Honors Major in Physics

The Honors track of the physics major is recommended for students choosing physics as their main professional field, or students planning to pursue graduate studies in physics or related fields. This track requires the completion of ten (10) additional units and research, above and beyond the requirements of the basics major in physics. The additional units involve a minimum of: 2 extra units of Upper-Division Laboratory (usually, both PHYS 341 and 342); 2 units of Directed Research for Advanced Undergraduates (PHYS 299 or 399); 2 extra units of Physics Colloquium (PHYS 350); and 4 units of an upper-division elective, from at least one of the following offerings: Nuclear Physics (PHYS 332); Solid State Physics (PHYS 333); Astrophysics (PHYS 343); Foundations of Computational Neuroscience (PHYS 380); Advanced Classical Dynamics (PHYS 410); Advanced Electrodynamics (PHYS 420); General Relativity (PHYS 422); Advanced Quantum Mechanics (PHYS 430); or Advanced Materials (PHYS 450).

The electives listed above are only offered intermittently, with the possible exception of PHYS 422 (which is linked to the astrophysics minor in two-year cycles).

A significant component of research is expected as an outgrowth of the scheduled Directed Research course. This work often leads to an undergraduate thesis—an increasingly favored model (currently being encouraged but not yet required).

## 2.3 The 3/2 Physics-Engineering Dual-Degree Program

The 3/2 Physics-Engineering Program is administered jointly by the University of San Francisco and the University of Southern California (USC), following an articulation agreement in effect since 1997. Under this program, an undergraduate student attends USF for typically three (3) academic years and USC for approximately two (2) academic years—the actual times vary according to pre-existing transfer credits and satisfactory progress. This is a dual degree program: after satisfying the academic requirements of these two institutions, the student is awarded two BS degrees: one in physics from USF and one of the several designated degrees in engineering by USC.

Students satisfy USF's 3/2 physics/engineering requirements for the BS degree in physics by successfully completing all the requirements for our regular Major in Physics.

Additional courses required for the successful continuation of the dual degree program at USC are specified for some majors (Chemical and Computer Engineering); moreover, other adjustments are made on a case-by-case basis. The general outlines of the program, including specific physics requirements at USF, have remained basically unchanged over the years (simply adjusting to our minimal PHYS major requirements, with a minor change made in AY 2002-2003 with the introduction of the new university-wide core curriculum). More substantial changes have taken place at the level of USC, especially in terms of their admission requirements (globally, with all of their 3/2 programs). Originally, the agreement guaranteed admission with a 3.0 GPA; currently, every case is examined individually, a 3.0 GPA is recommended as a minimum in the science courses, and satisfactory performance in their final year at USF is scrutinized closely. In all cases, a recommendation from the pre-engineering advisor at USF is still required (in the form of a diagnostic letter summarizing the student's academic record).

Currently, 3/2 dual degree candidates are eligible to seek any of the following majors from USC: Aerospace Engineering, Chemical Engineering, Civil Engineering, Computer Engineering, Electrical Engineering, Industrial and Systems Engineering, and Mechanical Engineering. The rigorous nature of this academic program is noteworthy. In addition to a standard physics training at USF, our students complete their engineering requirements in the final two years at USC—their engineering school is ranked among the top fifteen in the nation. Our goal is to provide a thorough physics background: unlike the typical 3/2 programs of liberal arts colleges, the USF part of the degree is comparable to that of a typical B.S. degree in physics, with the same required courses as in our regular degree program (thus, the integrity of our BS degree is fully preserved). As a result, this program leaves no room for electives (either at USF or at USC); the only additional course that our students can and should take is General Chemistry, as required by the engineering school. From the administrative viewpoint, this constrained sequence leads to increased enrollments in our required upper-division courses, which is a highly desirable departmental outcome.

### 2.4 Materials Physics Program

The Materials Physics track differs from the regular Physics Major in the following ways:

- Students are required to take the following additional courses: Solid State Physics (PHYS 333), Electronics (PHYS 215), Advanced Materials (PHYS 450), General Chemistry I, and Computer Science I.

- Students are *not* required to take the following courses: Statistical and Thermal Physics, Computational Physics, and Analytical Mechanics. However, these courses are "recommended electives."

- An internship is required in the summer following their junior year. Internships should be in either an industrial setting or an academic setting that relates to advanced materials.

Despite its initial promise, the future of this program is uncertain at best, due to lack of student interest.

### 2.5 Minor Programs

#### 2.5.1 Physics Minor

The Minor in Physics requires the completion of twenty (20) Physics units, as follows:

- PHYS lower-division core (12 units): General Physics I (PHYS 110); General Physics II (PHYS 210); Modern Physics (PHYS 240).
- 8 units of upper-division PHYS courses.

The minor in Physics is conceived to enhance the career options of other science majors; in practice, due to curriculum overlaps, it is usually pursued by a Mathematics or Chemistry majors.

#### 2.5.2 Astrophysics Minor

The Minor in Astrophysics (ASTO) requires the completion of twenty (20) Physics units, as follows:

- Foundational Physics Sequence (12 units): General Physics I (PHYS 110); General Physics II (PHYS 210); Modern Physics (PHYS 240).
- 8 units of upper-division PHYS courses selected from the following astrophysics-related courses: Astrophysics (PHYS 343); General Relativity (PHYS 422); or Special Topics in Physics Courses (with a focus on major topics in Astrophysics, PHYS 386).

#### 2.5.3 Astronomy Minor

The Minor in Astronomy (ASTR) requires the completion of twenty (20) units of Physics and Astronomy courses, as follows:

- Astronomy Core Courses (12 units):
  - Astronomy: From the Earth to the Cosmos (PHYS 120);
  - Planetary Astronomy (PHYS 121);
  - The Geometry of the Cosmos: Einstein, Black Holes, and the Big Bang (PHYS 122).
- Physics/Astronomy Elective courses (8 units): selected from any two courses from the intro physics menu consisting of Introductory Physics I (PHYS 100); Introductory Physics II (PHYS 101); General Physics I (PHYS 110); Concepts in Physics (PHYS 130); Physics by Inquiry (PHYS 201); General Physics II (PHYS 210).

The astronomy core courses are supplemented by observing nights that offer direct exposure to observational techniques, using the telescopes and other high-quality instruments in our Fromm observatory.

The elective courses provide a deeper insight into the physical basis of contemporary astronomy as grounded in the universal laws of nature. The most appropriate combination of courses from this menu is selected in consultation with an advisor, depending on background and interests.

### 2.6 Physics & Astronomy Service Courses and the Core Curriculum

The Physics & Astronomy Department offers introductory physics courses for all the other science programs (Biology, Environmental Science, Chemistry, Mathematics, Computer Science, and Exercise and Sport Science) and for the Architecture program; and physics and astronomy courses for non-science majors.

In terms of course offerings, the most important curricular constraint is set by the university Core Curriculum. This is a learning-outcomes-based set of "general-education" requirements that includes 6 major areas; of these, area B corresponds to science in two forms: B-1 (math) and B-2 (laboratory science). The Physics & Astronomy Department offers courses in both, as it is uniquely positioned at the interface between lab science and math. Indeed, most of the service courses also apply to the USF core, science area, either B-1 or B-2. In what follows the courses will be listed in three categories: targeted to specific programs, "Astronomy core courses," and other service courses.

First, our current list of courses targeted to specific programs consists of:

- Introductory Physics I and II (PHYS 100/101):
  the standard two-semester algebra-based introductory physics sequence. It serves as the default intro physics sequence, especially for the life sciences—required or recommended as part of the Biology, Environmental Science, and Exercise and Sport Science programs [PHYS 100 earns B-2 core credit].
- General Physics I and II (PHYS 110/210):
  the standard two-semester calculus-based introductory physics sequence (modern physics excluded), which serves mainly the Chemistry and Physics programs, and to a lesser extent the Mathematics and Computer Science programs (their students can satisfy the lab science requirements from a menu of courses from all science departments) [PHYS 110 earns B-2 core credit].
- Concepts in Physics (PHYS 130):
  a mostly conceptual introductory physics course, which serves the Architecture track within the Fine and Performing Arts program [earns B-2 core credit].

Second, a special dual role is played by the "Astronomy Core courses:"

- Astronomy: From the Earth to the Cosmos (PHYS 120)
  introductory topics plus stellar, galactic and extragalactic astronomy [earns B-2 core credit].
- Planetary Astronomy (PHYS 121)
  introductory topics plus astronomy of the solar system and other planetary systems [earns B-2 core credit].
- The Geometry of the Cosmos: Einstein, Black Holes, and the Big Bang (PHYS 122).
  mostly conceptual introduction to special and general relativity, with astrophysics and cosmology applications [earns B-1 core credit].

In their dual role, these three courses: (i)provide a much sought-after path for completion of core B credit among non-science majors; (ii) in addition, they form the core of our

Astronomy Minor. At present, PHYS 120 and 121 are offered every semester each (with numerous lab sections, and often with multiple lecture sections); PHYS 122 is typically offered once a year. The record enrollment numbers in the astronomy courses provide a significant fraction of the student credit hours (and account for about half of the increase in SCHs within the past decade).

Finally, other physics courses taken by students from other majors (and with core credit) include:

- Masterpiece Physics (PHYS 135):
  a conceptual physics course, with some math and lab exercises, using art and music as central themes—with emphasis on the concepts of sound, light, color, and how the brain perceives them; and applications to musical instruments, photographic cameras, and paintings [earns B-1 or B-2 core credit].
- Physics by Inquiry (PHYS 201)
  a step-by-step introduction to physics and the physical sciences. From their own observations, students develop basic concepts for simple physical systems and their interactions, interpret different forms of scientific representations, and construct explanatory models with predictive capability [earns B-2 core credit].

Physics by Inquiry is typically taught once a year during one of the Summer sessions—this current scheduling scheme proves convenient for the departmental distribution of courses. Masterpiece Physics was offered a few times by Prof. Marcelo Camperi (who singlehandedly developed course), but has not been offered more recently due to his appointment at the Dean's Office.

## 3. Curriculum Delivery and Statistics

### 3.1 Student Numbers

The Physics & Astronomy Department student numbers, both SCHs and numbers of majors, are discussed below; and detailed tables are shown in Appendix A, providing a historical and university-wide perspective to appreciate the tremendous progress made by our Department in recent years. As the statistics reveal, *we are the only department in the sciences with huge increases in the two critical numbers (SCHs and number of majors)* in the seven-year time window since the 2004 Program Review—both numbers essentially doubled in that period.

#### 3.1.1 Student Credit Hours

The total number of student credit hours (SCHs)—associated with all courses taught in our Department—has markedly and steadily increased over the years. Table 1 displays the statistics over the past fifteen years, including absolute numbers for all departments and the percentage of physics SCHs compared to the total SCHs in the sciences.

For a long time through the 1990s, the number was well below 1,000 SCHs and did not pass that mark until after our 2004 Program Review. It should be highlighted that the

number has essentially *doubled* since then, in only seven years (no other science department, except Computer Science, has experienced a similar percent rise in SCHs). The percentages (relative to the science totals) also reveal the same trend, but they do not reflect the whole magnitude of this phenomenon—in large part due to the significant increase in mathematics SCHs (an increase in an already large number deflates the percentage) and the addition of a new science department (ESS, Exercise and Sports Science). Accounting for all of these factors, the climb in student numbers is significant and impressive—our challenge will now become to maintain such high numbers in the foreseeable future.

Parenthetically, there is a curious pattern associated with science enrollments (science majors taking introductory physics courses) that leads to larger Fall and smaller Spring numbers. We now seem to have reached a Fall target number of approximately 1,800 SCHs and a somewhat lower Spring number. However, this semester (Spring 2011), we are already above the 1,700-SCH threshold. Thus, if we count using a more meaningful averaging period, i.e., by academic years, we currently seem to be at approximately 3,500 annual SCHs compared to 3,300 SCHs last year; approximately 3,100 SCHs two years ago; and 2,300 SCHs three years ago. This suggests that the year 2008 was a sort of turning point.

Looking at the SCH numbers compared to the 2004 Program Review, the year 2008 was a turning point because we finally succeeded (by channeling our resources) to cross the threshold of 200 introductory astronomy students per semester. Earlier targets had been closer to 100 students per semester, thus leading to a net increase close to 400 SCHs. Additional nontrivial gains came from the introductory physics courses (algebra- and calculus-based, adding up to a total of at least 200 SCHs) and from our increased physics-major population (adding up to an increase close to 200 SCHs per semester).

In short, the factors behind this remarkable increase can be easily identified:

- A systematic departmental effort to maximize the astronomy-related SCHs (via introductory astronomy). This departmental goal involved a calculated strategy of unprecedented lab expansion (almost doubled the number of lab sections to the current number of 15 to 20).

- An increase in the introductory physics numbers (algebra- and calculus-based). While this is mostly due to external factors, we have made an effort to retain those students in the appropriate courses. It turns out that many international students prefer to take physics for their science requirement and we certainly welcome them in both introductory sequences.

- The significant increase in the number of majors. The physics courses are no longer small and they add up. At the time of the last program review (2004), we used to regard the range from 7 to 9 students for a sophomore-level or upper-division class as a desirable "high number." Not surprisingly, that situation was unstable and led to predictable discussions with the Dean's Office every semester. By contrast, within the past year, all of our upper-division courses have comfortably exceeded 10

students, typically around 15, and in some cases over 20 students (for example, our upper-division Electromagnetism class has 24 enrolled students after Census Date).

The current numbers, if maintained, place the Department of Physics & Astronomy in a comfortable position among all science departments. After the very large Biology and Mathematics SCH numbers, we compete tightly for the third position with Exercise and Sports Science (slightly ahead of us) and Chemistry (slightly behind of us).

### 3.1.2 Number of Majors

The number of physics majors at USF is given in Tables 2 and 3; in addition, Table 4 gives the breakdown by gender. While the number of majors was in the teens in the 1990s, it had reached a relatively steady plateau in the mid- to upper twenties by the time of our last Program Review (2004). Remarkably, in the past 3 years we have seen a significant rise in the numbers that is now reflected in record enrollments (of about 20 or more students) in some upper-division courses.

The current number after the Census Date, Spring 2011 is:

*48 PHYS majors*
(38 males and 10 females)

Incidentally, the Department currently has 1 physics minor, 4 astronomy minors, and 9 astrophysics minors.

Tables 2 and 3 serve as tools for comparison against other majors. What comes out of this analysis is the observation that physics used to be one of the smallest majors at USF the 1990s. The Department was in a precarious position, and the administration wisely invested resources to revamp the program. These efforts were successful but only to a degree: by this count, and despite the increased numbers, the physics major still remained small at the time of the 2004 Program Review. However, at present we can depict a much improved situation with almost twice as many majors; and with absolute numbers comparable to some of the traditionally thriving programs—for example, physics is only slightly behind chemistry in number of majors at this time. To be more specific, within the sciences, the most relevant comparison is against the two disciplines most closely related to physics: mathematics and chemistry—and on this front, the progress is truly noteworthy. In comparison to the whole College, the undergraduate physics major population today is about 1.4%, while it was only about 0.6% in the 1990s and 0.9% in 2004.

The upward trend is probably due to a multiplicity of factors, as follows:

- Renewed interest in the engineering program
  (after several years with very low numbers of 3/2 physics-engineering students).

- The fact that the physics major seems to be intrinsically more appealing. Appreciation of its value and usefulness appear to be on the rise, based on anecdotal evidence, but this is in agreement with a similar national trend in the past few years.

- Increased visibility of the Department and USF *vis-á-vis* Admissions.
  As a result of these three factors, the number of students who declare a physics major

at the time they are admitted to USF has increased substantially. We have had two consecutive years with freshman classes of approximately 15 already-declared physics majors.

- Sustained efforts to recruit students. While this component was in place before, it now seems that there is a more receptive population of students.

- Retention is facilitated by a much-improved departmental atmosphere, from the efficiency of Physics & Astronomy Office to the overall physical appearance of the department, including the hallways and the labs. Significant resources were invested to this effect within the past two years. In addition, social departmental gatherings (beginning and end of the semester, and Coffee Hour) have become the norm and the additional opportunities of student involvement (through student assistantships and in research) are provided.

### 3.2 Advising

Our Department has a long tradition of one-on-one student-faculty interaction: advising of majors is given high departmental priority. Physics juniors and seniors benefit from this system, particularly when planning their post-USF careers. All in all, advising has been typically conducted in a sort of informal manner, without a centralized assignment of students to faculty advisors.

This advising system is being revised as part of the major structural changes due to our recent and ongoing rapid expansion. While the quality of the one-on-one advising is not expected to change, we do need to develop the guidelines of a new advising system—in synch with similar upgrades at the College and University levels.

It is anticipated that a more systematic approach will be conducted via the Physics & Astronomy Office. Currently discussions are underway at the departmental faculty level and steps are being taken via the Program Assistant. It is understood that in the near future, though, the faculty collectively and/or the Department Chair individually will have to deal with numerous cases of "exceptions" (i.e., substitutions and waivers) to facilitate graduation within a reasonable time framework despite the current faculty understaffing and curricular restrictions (motivated by administrative and financial constraints).

### 3.3 Assessment

The Physics Assessment Plan was developed and implemented as a three-year cyclic plan starting in early 2009, as per WASC accreditation guidelines. Our plan, which specifically applies only to the Physics Major program, is described in Appendix B.

The basic principles of our current assessment plan are the use of objective evaluation through embedded questions in exams and lab reports; and the identification of three major areas (one per year) within a three-year cycle: skills, knowledge, and laboratory techniques.

We are nearing the end of the three-year cycle, and there have been faculty discussions to identify areas for improvement (including a departmental retreat in May 2010). At the moment, two major related initiatives are being considered: (i) the use of the ETS "Field

Test" in Physics; and (ii) a strengthening of the physics major curriculum in specific areas already identified (laboratory work and mathematical background). While point (i) above is a possible integral element of a future assessment plan, point (ii) is partly due to the discussions triggered by the already existing plan.

Specifically, the Physics major program participated in a pilot version of the ETS Field Test in May 2010. At the time, to enhance the numbers, we developed a dual system whereby students would take the test twice (at the end of their general physics sequence and at the time of graduation). No decision has been made yet on this issue; it is possible that with the enhanced number of majors, we may agree to the use of this objective standard.

### 3.4 On the Growth of the Astronomy Component of the Program

The Astronomy part of the program started in 1998 with the introduction of Astronomy: From the Earth to the Cosmos (PHYS 120) by Profs. Camblong and Camperi. The course rapidly became one of the most popular science courses for nonscience majors. Due to departmental understaffing, the planned growth of enrollments was built sequentially and was conditional on other departmental constraints. Several faculty were involved in this program over the years. When the enrollments reached approximately 100 students per semester in AY 2004-2005, it was decided that the course would be split into a two-semester pair of introductory courses, one dealing with stellar, galactic and extragalactic astronomy and cosmology; and the other one focused on planetary astronomy and the solar system. The discussed were initiated by the 2004 Program Review, which included a strong recommendation for the hiring of a faculty member with expertise in astrophysics. With the approval of a faculty position in the astrophysics area in 2005, our intended implementation of the two introductory astronomy courses within a larger program was postponed until after the arrival of Prof. Venkatesan (2006). As a result, Planetary Astronomy (PHYS 121) was first offered in Spring 2008. In addition to PHYS 120 and 121, a third course, Geometry of the Cosmos (PHYS 122), was launched in Fall 2008, thus completing the triad of required courses for an astronomy minor. With the continuously growing success of the astronomy courses, the enrollment numbers have recently reached over 200 students per semester, with the simultaneous offering of multiple sections.

The curricula of the two new minors (in astronomy and astrophysics) were fully worked out and approved in the Fall 2009 semester. This development coincided fortuitously with the celebration of the International Year of Astronomy (IYA), which we used as platform to raise the visibility of the Physics & Astronomy Department. At the moment, it is too early to fully assess the success of the initiatives. The astrophysics minor is attractive and about 20% of our physics students have already signed up for it. The astronomy minor has a smaller numbers (4 students) and we are trying to identify problem areas and possible improvements. Along these lines, Profs. Camblong, Venkatesan and Frye now plan to work closely together to develop new courses such as: lower-division astrobiology, upper-division courses on modern cosmology and other topics, archaeoastronomy, and and an upper-division astronomy Lab. Such courses combined with research opportunities have the potential to position us to introduce an astronomy major within the next 5 years; its feasibility will be assessed in the near future.

## 4. Facilities & Physical Equipment

The Physics & Astronomy faculty offices and facilities are located on the first floor of the Harney Science Center (HR). Additional state-of-the-art laboratories will be housed in the Center for Science and Innovation (subsection 4.7).

### 4.1 Physics & Astronomy Lecture Classrooms

Physics and astronomy instruction for lecture courses is conducted in two classrooms, Harney 127 and Harney 143. The strategic location of these rooms on the Physics & Astronomy level of Harney is ideal for the consistent use of lecture demonstrations, with easy access to the physics equipment stored in HR 129 (prep room) and 136 (stockroom). HR 127 is the main Physics & Astronomy Lecture Hall, with theater-style seating capacity of 154, mainly used for the large introductory classes; while HR 143, with a seating capacity of approximately 30, is used for small- to medium-sized lecture classes. The demos are usually planned and set up ahead of time in the prep room, with direct access to HR 127. To facilitate the delivery of demos, both HR 127 and 143 have a built-in lecture bench with electrical outlets (AC and DC), a sink, and compressed air. In addition, they are both smart classrooms with multimedia presentation tools (lcd projector, computer with Windows XP and Mac OS, laptop-ready capabilities, DVD/VHS player, and other features). The classrooms are shown in Figures 1 and 2 in Appendix D.

Physics and astronomy courses have been given priority for the assignment of HR 127 and 143 through the Dean's office. However, in recent years, a few small- to medium-sized courses have been scheduled elsewhere or in the Department's own rooms (including the labs and the "conference room," HR 140-A). With the growth of the Physics & Astronomy program (larger upper-division courses and increased occupancy of the labs), the use of alternative rooms is no longer satisfactory.

A generic problem with Harney is the growing need for maintenance. This is especially evident in some rooms, HR 127 being an obvious example. Despite some of the convenient features described above, including its conversion to a smart classroom, it has an unattractive look and its chairs are falling apart, noisy, and uncomfortable. A comparison standard is HR 232, which is an equivalent classroom (similar capacity and geometry, but with much better physical look and quality of chairs). Incidentally, for this and other logistical reasons, the Physics Colloquium Series in now held in HR 232 rather than 127.

### 4.2 Lower-Division Laboratories

Laboratory instruction for physics and astronomy lower-division courses is conducted in three dedicated rooms: Harney 104 for the algebra-based Introductory Physics sequence, Harney 133 for the calculus-based General Physics sequence, and Harney 109 for the introductory astronomy courses. For logistical reasons and computer accessibility, the Concepts in Physics labs are also conducted in HR 133. The lab rooms have provision for water, steam, compressed air, and gas; they also have a common built-in variable output power supply, which can supply the Department with DC or AC current in any room. Over-

lapping equipment is used for many experiments in HR 133 and 104, especially for both physics sequences, requiring careful planning and coordination.

In addition, HR 109 and 133 are each equipped with 10 iMac computers connected by a wireless network (Apples Airport Extreme) and a shared printer. Each computer has Microsoft Office and instructional lab-specific programs. For General Physics in HR 133, each computer serves as a platform for Pascos Science Workshop software with an SW 500 Interface and its assortment of probe ware and associated equipment; computer data acquisition and analysis are used in most experiments. At present, HR 104 lacks any computer infrastructure, but this is likely to change in the near future, along with a revision of the Introductory Physics labs.

Due to the continued growth of the introductory astronomy courses, HR 109 has been recently converted to a full-time astronomy lab. The roles of HR 133 and 109 were switched in 2009, with the rationale that HR 109 is a larger room (this allows for astronomy lab caps of up to 30 students in a typical semester). The HR 109 computers (described above) have various astronomy simulation software, such as CLEA (Contemporary Laboratory Experiences in Astronomy), and internet access for online astronomy tutorials (Mastering Astronomy). In addition to these computer based laboratory equipment, the astronomy lab contains all the resources of the other labs, allowing for more traditional physics experiments to be used in this course, as well as hands-on (more elementary) labs. At present, both the Astronomy: Earth/Cosmos and Planetary Astronomy classes share this lab, with typical scheduling of 8 to 10 lab sections per semester.

For the past three consecutive summers (since 2008), departmental resources have been channeled with the support of the Dean's Office to revamp our lower-division labs. This job has been undertaken by Dr. Terrence Mulera with feedback from the instructors involved in the various courses and the Department Chair. They have included the introduction of the Planetary Astronomy labs and additions and improvements to the Astronomy: Earth/Cosmos labs; and a significant upgrade of the General Physics, with a few new experiments and increased emphasis on proper error analysis of experimental data. In all cases, the lab manuals were modified and an ongoing fine-tuning of experiments and lab manuals has been undertaken. It is anticipated that, starting in the summer of 2011, significant revamping of the Introductory Physics labs will be undertaken (including the likely use of computers).

### 4.3 Upper-Division & Electronics Laboratory

Laboratory instruction for upper-division physics is conducted in one dedicated rooms: Harney 139, with adjacent spaces for storage of equipment and additional activities. The courses taught in this space are the Upper-Division Laboratory and Electronics.

The Upper-Division Laboratory underwent two major upgrades in the past decade. First, with the acquisition of advanced laboratory equipment from a Fletcher-Jones Grant (close to $800,000) and related developmental work by Prof. Brown, with materials physics emphasis; and second with the developmental work done by Prof. Böttger (he took over the Upper-Division Lab after our 2004 Program Review). During the first phase an array of experiments were introduced, including film-deposition experiments and X-ray diffrac-

tion. These experiments, in addition to the earlier existing gamma-ray spectroscopy and speed of light labs, are still used as part of a significantly expanded menu. For the second phase, in the past few years, the following labs have been added and are routinely conducted: Fabry-Perot cavities, Frequency Modulation spectroscopy, Optical Amplifier, Erbium doped fiber laser, Michelson Interferometer, Reflection and Refraction on an optical interface, Saturation absorption spectroscopy of Rubidium atoms, Laser frequency stabilization, Data storage on a CD and DVD, Principles of optical wave guiding, and Optical communications. Details of these experiments are given in Appendix C.

Finally, for the electronics course, the Department owns 5 digital Techtronics oscilloscopes, computers with data acquisition software for the oscilloscopes (GPIB), electronic bread board trainers, digital millimeters, probes, a large assortment of electronic components (IC and passive), and other basic electronics tools (soldering irons, alligator clips, power supplies, variable resistance boards, variable capacitance boards, wire cutters, needle nose pliers, and various cables. HR 139 also contains a variable ac/dc supply that feeds outlets at every lab station.

### 4.4 Computational Physics Laboratory

The Computational Physics Laboratory, in Harney 101, is a multipurpose room that doubles up as physics smart classroom and computational laboratory for our upper-division physics majors, in addition to supporting computational research. It is currently equipped with 14 high-end Macintosh dual boot imacs, a laser printer, one document camera, and one ceiling-mounted projector connected to the server and the document camera. All computers are networked through a fast-Ethernet switch and behind a firewall that shields the local network from outside traffic. Thus, the array of computers can be used as cluster for parallel computations, and has been used for faculty and student research. The laboratory holds site licenses of the packages Mathematica and Matlab, as well as an assortment of useful programs.

This laboratory was introduced by Professor Camperi in the late 1990s, along with the Computational Physics upper-division course, and also used for Computational Neuroscience. Over the years, the computer inventory has been upgraded and expanded: originally intended for upper-division courses, ideally with enrollments no higher than 8 to 10 students, it has now been pushed to its useful limit (which is arguably of the order of 15 students). Due to faculty understaffing during a period of aggressive program expansion, the Computational Physics course could not be offered in 2007-2009 (course substitutions were made for physics majors). With its revival in 2010, the addition of computers and the introduction of Matlab, the lab is entering a new phase: it has now been released gradually as a facility accessible to upper-division majors on an ongoing basis; and the Computational Physics course is already being offered every year (instead of every other year) due to our recent increases in enrollments (around 20 or more for some upper-division courses). The decision to give Matlab priority as a computational program has been favored by some faculty, and has been stressed as a high-priority recommendation by our 3/2 program USC coordinating officers (as their engineering program uses Matlab as the primary computing language for most engineering courses).

### 4.5 Fromm Observatory and Astronomical Equipment

Our current observation facility is the Fromm observatory, which is essentially an observing platform that extends over a large open area with a fairly unobstructed view of the sky. It is located on the rooftop of the Fromm Hall (located on the main campus, near Harney and next to the Gleeson Library). We primarily use this facility for course-related observations by astronomy students and training of our observation teaching assistants (mainly physics majors).

Near the observing areas, an array of electrical outlets is available for telescope use, along with a protected storage shed for our telescopes and other astronomical equipment. The facility opened in 2005, following an unfortunate sequence of events that disrupted our earlier observing platform in Lone Mountain (originally established in 1998 along with the start of the astronomy part of the program). Several upgrades and the addition of new instruments followed, especially with the acquisition of a large NASA grant specifically secured for this purpose.

The storage shed is a controlled environment, with weather sealing and a dehumidifier running continuously. This protective, low-humidity, low-dust environment was carefully planned to extend the lifetime of our telescopes and other sensitive astronomical equipment.

A partial list of our current astronomical equipment includes: three 12-inch Meade LX200-ACF (Advanced Coma-Free optics); one 1- inch Celestron Newtonian reflector; one 4-inch Questar; one 7-inch Questar; one 6-inch refracting Celestron; one 8-inch Meade LXD55 refracting telescope; and a large number of binoculars (various magnifications and fields), two CCD cameras (one research-grade), and various accessories.

In addition, we currently own a 20-inch RC (Ritchey-Chrétien) telescope with Astro-Physics 3600GTO German Equatorial Mount, and a dome, which are temporarily located in an off-campus storage space until the new USF Observatory is built. Finally, we have received an offer from The Villages Radio Astronomy Club to install a 12-foot radio dish and mount (from SETI) on our campus; details are being worked out and its installation on our Fromm Observatory is being considered.

### 4.6 Stockroom, Prep Room, and Shops

Harney 129 is the Physics & Astronomy Department's "demo prep room" and the main office for our Physics & Astronomy Instrumentation Technician and laboratory student assistants. As mentioned in subsection 4.1, it is located adjacent to our main Physics & Astronomy lecture hall HR127. All of the department's demonstrations are stored and set up in this room prior to lecture time. The basic demonstration equipment is organized according to subject matter. In addition to the physical equipment, the department also keeps a large library of DVDs, laserdiscs, and VHS tapes in HR 129, including most of the well-known educational physics and astronomy series and documentaries (such NOVA documentaries, Cosmos, The Mechanical Universe, and The Video Encyclopedia of Physics Demonstrations, among many others).

Harney 107 is the Physics & Astronomy Department's stockroom. This facility serves as main organizational storage unit for all equipment of the physics and astronomy lower-

division labs, as well as generic multipurpose and old equipment, and miscellaneous supplies. The equipment is organized by subject matter in several large cabinets.

There are also two machine shops in our Physics & Astronomy area: a metalworking shop and a woodworking (and plastic) shop. HR 107 connects through an internal door to the Physics Metalworking Shop, which contains miscellaneous tools for repairing or building laboratory equipment, including two lathes, a milling machine, and two bandsaws. Due to changing space needs, the Woodworking Shop, which has several tools and a table saw, has been moved a number of times within the past decade, and is now in HR 111. The shops can be used as needed by the technicians in all science departments.

Incidentally, there is no separate electronics shop where faculty, technicians, and students can repair and fabricate electronic circuits, although its need has been discussed in the past, and may be a justified addition to the facilities as the experimental part of the program expands (as we anticipate from the direction taken by our curricular discussions).

### 4.7 Center for Science and Innovation: Space Planning and Future of the Science Facilities at USF

Starting in the year of our last program review (2004), USF began in earnest to investigate the addition of new science facilities. This process responded not only to the previous Physics program review, where facilities and space were cited as significant challenges, but also to similar reviews of all science departments at the University.

At present, planning is complete for a new 57,000-square-foot new laboratory facility that will connect to existing Harney Science Center. The University has just held a formal groundbreaking ceremony, after hiring a general contractor and obtaining final permits. Construction will start in earnest in May, 2011, and take approximately 30 months. We anticipate that, at least by Fall 2014 at the latest, we should have both new physics-specific teaching spaces in a state-of-the-art facility but also interdisciplinary spaces where we can more properly pursue topics like computational physics.

#### 4.7.1 Department Specific Spaces

Figure 3 in Appendix D shows the floorplan of level G1 of the planned new science center. The two new spaces for our department are both housed on this level, which lines up with our current floor of the Harney Science Center.

- Lower-Division Laboratory.
  After much study and discussion, the department decided to prioritize a new lower-division laboratory. The flexible space resulting should serve all of the 100-level laboratory courses as we see fit (see Figure 4.) We particularly hope to prioritize our General Physics sequence (calculus-based, for physics and chemistry majors) for this space, in an effort to attract, impress and retain new physics majors. For the first time, such a laboratory will have a dedicated preparation and storage space adjacent to it. And for the first time, such a laboratory will feature flexible, movable furniture to maximize the number of distinct laboratory activities (or even departmental functions) that can be carried out in the space.

The square footage of this space (over 1200 sq. ft.) dwarves our existing lower-division laboratories, that average just over 900 square feet. Therefore, lab sections of, say, 20-24 students (and even 30 in extreme cases) can be held with little trouble.

- Upper-Division Laboratory.
  The second highest priority for the department is an upper-division laboratory space that conforms to modern standards and supports modern advanced techniques. We are delighted that the new center will feature a dedicated space for this purpose as well (see Figure 5).

  Primary upgrades to the existing space for upper-division laboratory (Harney 139) include most notably:

  - Vibration isolation plate for optical measurements.
  - A fume hood.
  - Dedicated storage and preparation space.
  - Access to advanced instrumentation from other departments—see instrument corridor in figure.
  - Deionized water supply.
  - Proper bench depths for modern instruments.

### 4.8 Future USF Observatory: Options and Planning

The medium- to long-term goal of the Physics & Astronomy Department is to set up a new USF astronomical observatory which will operate *in addition to the existing Fromm Observatory* (discussed in Sec. 4.5). The new observatory would have a dome (already purchased) and house our recently purchased research-grade 20-inch optical telescope and some of our other equipment. This would serve as a critical avenue for student research, collaborative partnerships, and for inviting the local community and the citys residents for public observing nights.

With the current emphasis on undergraduate research, we hope the future USF astronomical observatory would significantly contribute to this end. As one of San Franciscos largest optical telescopes, our 20-inch telescope has excellent potential for student projects on transients, variable stars, supernovae remnants, and possibly extrasolar planets. In advance of using data from the USF observatory, we have obtained accounts on the Global Telescope Network (GTU, http://gtn.sonoma.edu), operated through Sonoma State University. This will provide increased scientific and education and public outreach collaborative opportunities through this network of 16-inch remotely-operated optical telescopes around the USA and the world—including the dark-site 16-inch telescope operated by SSU about 1.5 hours north of San Francisco.

Following discussions among the Physics & Astronomy faculty, and exchanges with the Dean's Office and Facilities Management, a number of on- and off-campus options are being discussed. A summary of the status of our discussions and conclusions to date can read

from Table 5 in Appendix D. In the meantime, both the dome and the 20-inch telescope have been moved to a downtown storage facility.

On-campus sites being considered (after ruling out other options) include: (i) a Lone Mountain ground site, (ii) a Lone Mountain rooftop, and (iii) the current Fromm rooftop observing area (with the dome being an addition to the existing facility). Construction and structural analysis costs are potential stumbling blocks unless additional funding is secured; from this perspective, the site that enjoys the best observing conditions [one of the Lone Mountain rooftops, category (ii) above] may be out of reach, though it has not been ruled out completely.

A possible off-campus site under consideration is described in Table 5: The Villages Radio Astronomy Club—a private 550-acre country club that has an established radio astronomy amateur group with an array of radio telescopes. They already the wiring and internet services for telescope and remote operation, and they have an established public outreach program. In this specific off-campus option being considered, they would offer us a dedicated private dark site near San Jose (only twenty minutes by car), as well as access to their radio telescopes and data, no site usage fees, and possibly a support staff person. In general (with details that need to be worked out), the installation cost would be limited to basic construction and wiring of services.

## 5. Faculty

### 5.1 Full-Time Faculty

Currently, the Physics & Astronomy Department has seven full-time faculty: Eugene V. Benton (since 1969), Thomas Böttger (since 2003), Brandon Brown (since 1998), Horacio E. Camblong (since 1993), Marcelo F. Camperi (since 1996), Brenda L. Frye (since 2010), and Aparna Venkatesan (since 2006). However, one of them holds a full-time administrative job (Marcelo Camperi, Dean of Arts and Sciences) and another one (Brandon Brown, Director of External Affairs in Arts and Sciences) currently has a half-time administrative appointment. Thus, our faculty understaffing in recent years has led us to not offer all the required courses in rational cycles, to rely on a large pool of part-timers, and even to enlist one of the full-time mathematics faculty members (Stephen Yeung) for a yearly upper-division course.

The full-time faculty research interests and other relevant information are listed below.

#### 5.1.1 Eugene V. Benton

Professor Benton's research interests in the field of radiation physics include the design and analysis of experiments to determine the health effects of ionizing radiation. His early work on the effects of astronauts' radiation exposure during space flight led him to the establishment of the Radiation Physics Laboratory (RPL) at USF in 1969. In collaboration with NASA and other space agencies, the RPL performed experiments in the Apollo missions, the NASA Space Shuttles, the Russian Mir Orbital Station, and the International Space Station. Other RPL experiments were carried out in high-energy particle accelerators at the Lawrence Berkeley National Laboratory, the Brookhaven National Laboratory,

the Japanese National Institute for Radiological Sciences, and CERN. The nuclear track detector-based dosimetry system developed by Professor Benton is routinely used for radon dosimetry in buildings and for neutron dosimetry at nuclear power plants and high-energy physics laboratories. Recent research work has focused on the radiation dosimetry of civilian and military pilots and flight attendants, and the use of accelerated proton beams for cancer therapy at the Loma Linda University Medical Center.

### 5.1.2 Thomas Böttger

Professor Böttger studies optical, dynamical, and magnetic properties of solids, specifically optical materials doped with rare earth ions. This work is centered on understanding the fundamental material physics at the microscopic scale but also geared towards the development of optical materials for optical signal processing, optical memories, quantum computing, and laser frequency stabilization. He has been specifically interested in Erbium doped materials as they enable optical devices operating at the fiber telecommunication wavelength. This work is carried out using a variety of linear and nonlinear optical methods, such as stimulated photon echoes, spectral holeburning, time-resolved spectroscopy and more conventional methods such as optical absorption spectroscopy. He is also interested in laser development and has worked on the technique of frequency stabilizing external cavity diode lasers to the narrow frequency references found in rare-earth-doped materials. By locking the laser frequency to an ultra-narrow spectral hole, experiments have reached the limits of precision in the optical spectroscopy of solids.

### 5.1.3 Brandon R. Brown

Professor Brown's early research dealt with superconductivity and low-temperature physics. His recent work brings techniques and ideas from the field of condensed matter physics to biological studies of the electric sense. This work has centered on two main problems in recent years: (1) since the electrical sense organs are filled with a clear gel, what does that gel do? and (2) since sharks have hundreds of these little sense organs all over their heads, how do they use all these organs in concert to see the world electrically. Thanks in large part to his research work, along with that of his students and some collaborators, these questions are much better understood now than they were even a few years ago. Recently, follow-up work has branched into a more traditional project in bioinformatics, seeking certain protein channels within the electrosensors, along with a new project investigating the mechanisms of the magnetic sense (primarily in insects).
Professor Brown is currently the Director of External Affairs in the College of Arts and Sciences and has played a pivotal role in planning and fundraising for the new science building: the Center for Science and Innovation (CSI).

### 5.1.4 Horacio E. Camblong

Professor Camblong's research deals with miscellaneous topics in quantum field theory, gravitational physics, and many-body theory. His most recent work involves two major (related) areas: black hole thermodynamics and singular quantum mechanics, which involve collaborative work with scientists and students at the University of Houston and

Universidad Nacional de La Plata. The latter is an outgrowth of his earlier discovery of a quantum anomaly in molecular physics (for dipole-bound anions) and in the three-body Efimov effect, using effective-field theory concepts for conformal quantum mechanics; this work has recently led him to the study of broader unitarity issues in singular quantum systems. The work on black holes involves overlapping results with singular quantum mechanics, but more fundamentally provides a deeper insight into the quantum nature of gravity and black holes. Ultimately, the goal of this research is to shed light on the emergence of black hole thermodynamics and the emission of Hawking radiation from the near-horizon conformal symmetry of black holes.
Professor Camblong is is currently the Department Chair.

### 5.1.5 Marcelo F. Camperi

Professor Camperi's early research involved topological field theory and some phenomenology of elementary particles. He subsequently became interested in the study of the brain from a physicists' point of view. In recent years, he has worked on various topics in the field of computational neuroscience, including the simulation of very large network of biologically feasible neurons using parallel computer architectures, the development of models of prey detection and navigation in elasmobranch, and the use of information theory for networks of neurons. He is also interested in computational physics, mathematical physics, and in computers in education.
Professor Camperi currently holds the position of Dean of Arts and Sciences.

### 5.1.6 Brenda L. Frye

Professor Frye's research interests include extragalactic astronomy and observational cosmology, galaxy formation and evolution, protoclusters, galactic structures, high-redshift galaxies, the galaxy-IGM interface, gravitational lensing, and the intergalactic medium. She makes use of large ground- and space-based telescopes (including the Hubble Space Telescope) to study physical environments and conditions in galaxies dating back to when the universe was only 900 million years old.

### 5.1.7 Aparna Venkatesan

Professor Venkatesan's research lies primarily in theoretical cosmology, including studies of the first stars and quasars in the universe, the cosmic microwave background, dark matter, and gravitational lensing. She has also worked on high-energy astrophysics (gamma-ray bursts and cosmic rays) as well as extensive data analysis in planetary astronomy. Her current interests include constraining the duration of first-generation star formation through semi-analytic and numerical methods; the evolution of cosmic star formation and related observational signatures, such as the hydrogen/helium reionization and the metal enrichment of the high-redshift universe; models for the cosmological transport of metals; feedback from the first stars and supernovae on the cosmic microwave background and on the physics and chemistry of early halos and the intergalactic medium; the cosmic synthesis of the biogenic elements at early times in the universe; and, predictions for detecting the first objects through the next generation of instruments and satellites.

### 5.2 Part-Time Faculty

A number of part-time instructors are critically needed every semester to deliver our whole program of courses. They are enlisted from a pool that mostly includes continuing instructors (with extensive teaching experience) and applicants through the USF/UCSF Partnership for Undergraduate Mentoring and Teaching (PUMT). Two of the continuing instructors, Dr. Terrence Mulera and Ms. Hana Mori Böttger, have been teaching in the Department for several years and have become an integral part of our academic program.

Dr. Mulera has taught a broad range of courses from introductory physics to Modern Physics, and most of the laboratories. In recent years, he has taken the role of laboratory coordinator and has helped with the redesign and upgrade all of our lower-division labs. With an early research career in experimental elementary particle physics (with research interests in strong interaction dynamics, spin dependence in the strong interactions, relativistic heavy ion collisions, neutrino oscillations and rare decays of the pion), he came to the USF Physics & Astronomy Department after working in the semiconductor industry—and he is also teaching modern physics courses at the USF-affiliated Fromm Institute for Lifelong Learning.

Hana Mori Böttger has been a key player in the development of the minor in architectural engineering at USF. In the Physics & Astronomy program, she teaches the Concepts in Physics course for the architecture students every Fall (along with its lab sections)—this is in addition to occasional other physics labs and her teaching in the Architecture program at USF. Her research interests include structural materials analysis, seismic behavior of adobe brick wall systems, and engineering education.

A third instructor who has been routinely teaching in our department in recent years (since 2007) is Dr. William Golightly—he has regularly taught Modern Physics, and occasionally an upper-division course and some labs. With a background in laser physics, he has extensive teaching experience at several Bay Area institutions, including UC Berkeley.

Finally, the PUMT partnership with the University of California, San Francisco (UCSF)—alternatively called Preparing Future Faculty-Teaching Apprentice Program (PFF-TAP)—has consistently provided (since 2007) a large pool of UCSF graduate students and post-doctoral researchers/clinicians, hired as part-time faculty for Biology, Chemistry, and Physics & Astronomy. The stated goal of the program is to give the PFF-TAP instructors a valuable teaching experience at the undergraduate level. The USF Physics & Astronomy Chair works closely with the PFF-TAP coordinator at the UCSF Office of Career and Professional Development to hire qualified instructors from this pool for physics and astronomy labs, and occasionally for lecture courses. In practical terms, this program has made it possible for our department to significantly increase the SCHs, offering a broad range of courses and 15 to 20 lab sections every semester (while a small number of these lab sections are staffed with undergraduate TAs, most of them are taught by our continuing part-time faculty and PFF-TAP instructors, and a few by our full-time faculty).

### 5.3 Other Faculty

As mentioned above, Stephen Yeung, full-time faculty in the Department of Mathematics

has been teaching the Methods of Mathematical Physics (PHYS 371) course every Spring since 2007 (five years in a row). Professor Yeung' s background at the interface of applied math and physics have made him a valuable partner in the delivery of our physics program. His research interests are in dynamical systems theory, including coupled oscillators, Josephson junction arrays, injection lasers, sigma-delta data converters, and algorithmic analysis of microarray data.

This appointment has allowed us to shift priorities accordingly—before that, physics faculty had been teaching the course continuously once a year, for a decade. While this appointment has been obviously made with the prior approval of the Mathematics Department in the past few years (on a yearly basis), it is nothing more than a temporary, informal agreement, and is likely to be discontinued in the near future.

## 6. Administrative Support Staff

The Department's day-to-day operations critically rely on the support personnel. Our support staff includes our full-time Physics & Astronomy Instrumentation Technician (Mr. Patrick McNeff) and our full-time Program Assistant (Ms. Melody Kirk)—in addition to the student assistants supervised by them for specific tasks. Thanks to their work ethics, diligence and skills, we currently enjoy a smooth and efficient working environment. To a great extent, this environment is based on the principle that team work is encouraged and practiced at all departmental levels. Ms. Kirk took her current position in late 2006 and Mr. McNeff (a USF alumn) in 2005.

The Physics & Astronomy Instrumentation Technician has an open-ended job description centered on all experimental and technical aspects of the delivery of the physics and astronomy curriculum: laboratories, lecture demos, and ongoing organization and maintenance of the equipment in a managerial role. Day-to-day tasks include assembling lecture demonstrations, repairing equipment, taking inventory of supplies and equipment, ordering routine supplies for laboratories, setting up and taking down laboratories, and providing minimal computer support within the Department. Many of these tasks are implemented under his supervision by one or two student assistants. In addition, our technician has successfully provided infrastructural assistance to our various research programs; and also provided support for astronomy-related activities.

As a side historical note, for many years over the past two decades the technician had reported not to the head of the Physics Department, but to the manager of technical operations. This situation was already in transition at the time of our 2004 Program Review, with the Physics Department having priority of work assignments; however, the rules at that time were a bit vague. Over the years, the situation has evolved towards a logical distribution of tasks within Physics & Astronomy, which has become a much larger program—but in the spirit of collegiality, our technician still provides assistance for targeted tasks outside Physics & Astronomy on a non-priority basis.

An interesting development in recent years has been a trend towards departmental integration of tasks, whereby our Program Assistant and Instrumentation Technician work as a team to help resolve new problems and challenges under the supervision of the De-

partment Chair. This development has been further strengthened by the recent addition of Harney 136 as an expansion of the Physics & Astronomy Office, and the hire of student assistants for specific and generic tasks, both in HR 136 and in HR 129. As a result, we enjoy a relatively efficient environment, with a smooth delivery of routine departmental tasks.

## 7. Students and Departmental Activities

Students are offered many opportunities for active participation in our program, as described below. The "Departmental Activities" mentioned below integrate students and faculty in a nurturing, interactive environment.

### 7.1 Student Teaching Assistantships and Graderships

We employ students as teaching, administrative, and research assistants, as is common practice in most Physics Departments. The research kind is usually covered via other sources of funding (Faculty Development or grants), but the teaching and administrative appointments are arranged at the departmental level. Specifically, the delivery of our curriculum involves student assistants as an integral part of the educational experience for targeted courses (mainly lower-division, introductory physics and astronomy). This system facilitates the smooth delivery of our courses (including covering all the lab sections); and it also provides invaluable training and teaching experience for our students.

The available positions are announced at the end of the semester prior to the hiring and decisions are made based on experience, GPA, and other factors leading to an optimal distribution of limited resources. The available positions typically involve:

- Laboratory teaching assistantships: for lower-division introductory physics and astronomy courses (PHYS 100, 101, 120, 121, 130, 135, 210)
- Problem-discussion teaching assistantships ("recitation instructors"): for the introductory physics courses (PHYS 100, 101, 110, 210).
- Graderships ("readerships"): most or all lower-division courses with sufficiently large enrollments.
- Observation teaching assistantships: for sessions at the Fromm observatory, linked to PHYS 120/121.
- Administrative student assistantships: for the Physics & Astronomy Office and for the Stockroom/Lab management (under the supervision of the Technician and the Department Chair).

Over the past three years the Department has developed a systematic procedure for the hiring of TAs (as described above). The increase in the number of majors has helped rationalize the process, and the hiring of instructors from UCSF has allowed a considerable expansion of the lab hiring while still providing targeted opportunities for our students.

Currently, of the 15 to 20 labs offered every semester, most of them are taught by part-time faculty (including UCSF instructors) and a few by full-time faculty, usually leaving 2 or 3 sections for undergraduate laboratory teaching assistantships.

### 7.2 Student Research

Exposure to active research is a very important aspect of undergraduate education in our Department. Our undergraduate students have engaged in research projects in our on-campus labs as well as off-campus. A number of examples are listed below.

Besides on-campus research, students have been encouraged and supported to participate in NSF's Research Experience for Undergraduate students program (REU). Over the years, several of our students successfully completed intense 10-week summer REU programs; a partial list includes: Gregory Zicarelli (Montana State University—2004); Patrick McNeff (Argonne National Laboratory—2004); Alexandra Polosukhina (University of California Santa Barbara—2005; University of Wisconsin—2006); Ben Westbrook (Lawrence Livermore National Lab—2006 & 2007); Daniel Merthe (Sandia National Laboratory—2008, 2009); and Joseph Lussier (University of Nevada at Las Vegas—2010). Students reflected positively on these programs, and many of them have been admitted to prestigious graduate programs; a partial list follows: Danien Scipio (California Institute of Technology, 2009), Ben Westbrook, and Alexandra Polosukhina (University of California Berkeley, 2007), De Phuoc Ly and Gregory Zicarelli (University of California Irvine, 2007), and Dustin Kerksieck (Boston College, 2006).

A chronological list of students who worked in Prof. Böttger's USF laser spectroscopy lab follows: Gregory Zicarelli, *High Finesse Interferometer for 793 nm Tunable Diode Laser* (2003-2005, graduated in 2005); Patrick McNeff, *Precision Michelson Interferometer/Wavemeter* (2003-2004, graduated in 2005); Ben Westbrook, *Construction and Characterization of a High-Finesse Fabry-Perot Cavity for Laser Frequency Stabilization* (2005-2007, graduated in 2007 with the Honors major); Danien Scipio, *Cavity Ring-down Spectroscopy* (2007-2008, graduated in 2008); Daniel Merthe, *High Resolution Spectroscopy of Atomic Rubidium* (2007-2009, graduated in 2009 with the Honors major).

Other students have been recently working under the supervision of Prof. Venkatesan. Two sophomore undergraduate students worked in 2009 on theoretical astrophysics projects in helium reionization (but unfortunately transferred to the UC system due to financial problems). She is currently training a group of three physics majors who will work with her on projects in cosmology and astrobiology.

Professor Brown has led two undergraduates in active research projects. One student, Kara Scanlon, has conducted a series of exploratory experiments seeking to refine a quantitative understanding of the magnetic sensing abilities of various species of ants (in a collaboration with San Francisco State University). Another student, a biology major, has conducted a series of molecular biology assays in conjunction with bioinformatics efforts, seeking to identify key proteins in the electrosensors of paddlefish.

### 7.3 Departmental Activities

Regular departmental activities organized by faculty, students, and/or the Department's

Office include the Physics & Astronomy Colloquium Series, the Physics & Astronomy Coffee Hour, activities of the Astronomy Club, and various social events hosted at the beginning and end of each semester and around special events (visitors and annual info session on the 3/2 Program).

The Coffee Hour is held on Thursdays during the official university "activity hour" (around noon, with no classes scheduled). This social event is usually tied to meetings and informal discussions of the newly established Astronomy Club (which also organizes other astronomy-related events). We also have a local chapter of the Society of Physics Students (SPS), which has been active intermittently.

The Physics & Astronomy Colloquium Series follows a long-standing tradition of physics departments around the world: to provide an ongoing series of talks for the faculty and the students. Unlike highly specialized seminars, the physics colloquia are intended to cover a broad spectrum of physics topics at a reduced technical level. Moreover, because of the size of our department and the nature of our curricular offerings (only undergraduate), our invited speakers are given explicit instructions to make their talks accessible to as wide an audience as possible. First conceived as a "Physics Colloquium Series" in 1994, it has been organized (at different times) by most of our faculty; in 2009, it was renamed (along with the Department's name change) "Physics and Astronomy Colloquium." With over 200 speakers to date, we have hosted 5 Nobel laureates and many other world-renowned scientists. All in all, the Colloquia constitute an important series of events that give our department visibility within the university and in the Bay Area. They also provide our students with an overview of current physics research and with invaluable opportunities to meet informally with a variety of scientists—we know such contacts have been critical for many students later pursuing summer research opportunities, internships, and graduate school work.

## 8. Conclusions and Recommendations

Since the 2004 Program Review, our Physics & Astronomy Department has taken huge steps towards becoming a strong academic unit with a thriving program. Navigating through a climate of financial crisis, we succeeded in doubling both the SCHs and the number of majors—like no other department in the sciences. Along the way we have taken concrete steps to implement the recommendations of the 2004 Program Review, with emphasis on realizing the following goals:

- Increase the number of majors and all-around departmental numbers.
- Expand the introductory astronomy component of the program (by increasing the number of individual courses and the total SCHs).
- Develop new minors in astronomy and astrophysics (including course development).
- Expand and diversify the faculty.
- Enhance the visibility of our Department by multiple means, including the Physics Colloquium Series.

- Strengthen the academic program at all levels, including a systematic revision and upgrade of upper-division experimental physics.
- Implement an ongoing laboratory upgrade and development plan of lower-division labs.
- Continue expanding and upgrading the departmental computing facilities.
- Develop a more nurturing and efficient working environment through improvements in the physical appearance of classrooms, labs, and hallways; and by fostering team work with the faculty, staff, and students.

More than at any other time in USF history, the Physics & Astronomy Department displays growing student numbers that place it in a strong position within the sciences. Our academic program has a rigorous and modern undergraduate curriculum in physics, and is expanding in astronomy as well; and our research programs are strong and offer some opportunities of undergraduate research for our students.

We do face a number of challenges, and we are are already pondering various strategies for improvement. The following list is incomplete, but representative of our current strategic thinking for the next fe years.

1. Departmental Numbers.
   The departmental numbers are solid, but we cannot be complacent. We face the challenge of maintaining the current momentum, both in terms of the all-important SCHs and the number of majors. The Department needs to continue making this agenda item the highest priority for long-term administrative strength.

2. Physics Curriculum.
   Centered on our assessment follow-up discussions, we are planning to enhance our physics major. Several ideas are being considered, but there is consensus that additional math (linear algebra and differential equations) and a stronger laboratory foundation (sophomore and upper-division) are needed. For the latter, the addition of labs to Modern Physics, a two-semester sequence of Upper-Division Lab and Electronics are being considered. More radical proposals are also being entertained.

3. 3/2 Physics Engineering Curriculum.
   Given the current level of student interest in engineering, it may be due time to make the program a bit more flexible while retaining its academic integrity. This initiative would offer the potential to attract even larger numbers of students into our program.

   Incidentally, there may be ways of combining this goal with a revamping of the Material Physics major.

4. Astronomy/Astrophysics Curriculum.
   We intend to expand the menu of offerings for both minors and take the necessary steps to make the "non-technical" astronomy minor more appealing to the USF non-science population. With the addition of new courses, especially in astrophysics, we intend to assess the feasibility of an astronomy major within the next few years.

5. Undergraduate Research.
   Following similar trends nationwide, USF is placing higher emphasis on undergraduate research. While the recent history of our Department shows an excellent record of a few high-caliber undergraduate theses, we do not have a systematic approach to date to encourage this kind of work. We hope to integrate this activity into our enhanced physics major or honors major.

6. Faculty Hires.
   Professor Benton will retire at the end this academic year. With the current numbers and ongoing faculty understaffing, we believe that this position needs to be replaced. The replacement position should go back to experimental physics and help strengthen the curriculum and the undergraduate research opportunities in that area.

   Beyond that, to function optimally and deliver the curriculum, we would need an additional position. While the recent numbers have been fantastic, the work behind the scenes that allows students to graduate (e.g., substitutions) is not the trademark of a high-quality education.

7. Facilities.
   A decision needs to be made in the near future regarding the location new Observatory, including financial and logistical details.

   Longer term, as the CSI becomes a reality, some changes occur with the Harney facilites; thus, appropriate strategic planning for the future teaching and research vitality of the Physics & Astronomy program is imperative.

APPENDICES.

# A. Physics Department and Physics Major Statistics

## A.1 Physics & Astronomy Department Student Credit Hours (SCHs) & Comparison within the Sciences—Timeline.

| Dept / TERM | BIOL | CHEM | CS | ENVS | ESS | MATH | NASC | PHYS | PHYS (%) | Grand Total by Term |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996F | 1730 | 2091 | 670 | 56 | | 2679 | 1062 | 555 | 6% | 8843 |
| 1997S | 2290 | 1336 | 740 | 73 | | 1740 | 1215 | 428 | 5% | 7822 |
| 1997F | 1895 | 2043 | 817 | 50 | | 2337 | 1089 | 647 | 7% | 8878 |
| 1998S | 2108 | 1312 | 808 | 100 | | 1881 | 1203 | 481 | 6% | 7893 |
| 1998F | 1818 | 1860 | 986 | 80 | | 2550 | 1089 | 703 | 8% | 9086 |
| 1999S | 1918 | 1361 | 1000 | 87 | | 1839 | 897 | 610 | 8% | 7712 |
| 1999F | 1807 | 1718 | 1233 | 68 | | 2852 | 927 | 742 | 8% | 9347 |
| 2000S | 1899 | 1212 | 1200 | 66 | | 2164 | 900 | 662 | 8% | 8103 |
| 2000F | 1477 | 1695 | 1320 | 49 | | 2871 | 723 | 931 | 10% | 9066 |
| 2001S | 1718 | 1286 | 1212 | 43 | | 2166 | 885 | 674 | 8% | 7984 |
| 2001F | 1586 | 1719 | 984 | 104 | | 2988 | 864 | 859 | 9% | 9104 |
| 2002S | 1757 | 1222 | 880 | 155 | | 2061 | 891 | 587 | 8% | 7553 |
| 2002F | 2116 | 1442 | 887 | 267 | | 2310 | 399 | 760 | 9% | 8181 |
| 2003S | 2260 | 1211 | 959 | 242 | | 2045 | 256 | 592 | 8% | 7565 |
| 2003F | 2844 | 1627 | 703 | 458 | | 2323 | | 959 | 11% | 8914 |
| 2004S | 2921 | 1154 | 854 | 302 | | 2228 | | 876 | 11% | 8335 |
| 2004F | 3126 | 1700 | 601 | 518 | | 2596 | | 956 | 10% | 9497 |
| 2005S | 3089 | 1328 | 625 | 349 | | 2227 | | 1126 | 13% | 8744 |
| 2005F | 2840 | 1562 | 407 | 536 | | 2943 | | 1140 | 12% | 9428 |
| 2006S | 2809 | 1287 | 690 | 340 | | 2260 | | 1079 | 13% | 8465 |
| 2006F | 3158 | 1811 | 682 | 536 | | 3120 | | 1071 | 10% | 10378 |
| 2007S | 3138 | 1499 | 727 | 456 | | 2366 | | 872 | 10% | 9058 |
| 2007F | 2896 | 1592 | 705 | 552 | | 3202 | | 1191 | 12% | 10138 |
| 2008S | 2814 | 1484 | 905 | 460 | 1765 | 2562 | | 1117 | 10% | 11107 |
| 2008F | 2725 | 1549 | 704 | 620 | 1808 | 3048 | | 1537 | 13% | 11991 |
| 2009S | 2788 | 1318 | 807 | 508 | 2117 | 2400 | | 1533 | 13% | 11471 |
| 2009F | 2968 | 1769 | 821 | 572 | 1530 | 2726 | | 1820 | 15% | 12206 |
| 2010S | 2759 | 1360 | 891 | 560 | 1979 | 2300 | | 1514 | 13% | 11363 |
| 2010F | 3246 | 1724 | 1147 | 912 | 1894 | 3170 | | 1794 | 13% | 13887 |
| Grand Total by DEPT | 70500 | 44272 | 24965 | 9119 | 11093 | 71954 | 12400 | 27816 | | 272119 |

**Table 1: Student Credit Hours (SCHs) of science departments for the last 15 years at USF. NASC stands for natural science (obsolete unit).**

### A.2 Number of Physics Majors & Comparison within the Sciences—Timeline.

| Major / TERM | BIOL | CHEM | CS | ENVS | ESS | MATH | UNSC | PHYS | PHYS (%) | Grand Total by Term |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996F | 264 | 38 | 67 | 26 | | 27 | 89 | 12 | 2% | 523 |
| 1997S | 244 | 30 | 60 | 24 | | 27 | 77 | 13 | 3% | 475 |
| 1997F | 263 | 38 | 67 | 28 | | 17 | 98 | 19 | 4% | 530 |
| 1998S | 243 | 38 | 70 | 29 | | 13 | 76 | 20 | 4% | 489 |
| 1998F | 267 | 38 | 97 | 28 | | 12 | 95 | 18 | 3% | 555 |
| 1999S | 233 | 38 | 96 | 26 | | 21 | 75 | 20 | 4% | 509 |
| 1999F | 231 | 38 | 117 | 22 | | 25 | 104 | 25 | 4% | 562 |
| 2000S | 206 | 38 | 115 | 18 | | 26 | 87 | 26 | 5% | 516 |
| 2000F | 214 | 42 | 140 | 17 | | 28 | 114 | 27 | 5% | 582 |
| 2001S | 202 | 50 | 128 | 13 | | 27 | 90 | 26 | 5% | 536 |
| 2001F | 205 | 55 | 129 | 21 | | 30 | 117 | 27 | 5% | 584 |
| 2002S | 186 | 50 | 113 | 22 | | 32 | 85 | 24 | 5% | 512 |
| 2002F | 217 | 56 | 90 | 21 | | 38 | 132 | 20 | 3% | 574 |
| 2003S | 202 | 52 | 76 | 23 | | 35 | 102 | 22 | 4% | 512 |
| 2003F | 237 | 53 | 63 | 23 | | 29 | 122 | 20 | 4% | 547 |
| 2004S | 220 | 49 | 56 | 23 | | 32 | 93 | 28 | 6% | 501 |
| 2004F | 246 | 47 | 53 | 20 | | 33 | 121 | 24 | 4% | 544 |
| 2005S | 221 | 52 | 49 | 19 | | 32 | 82 | 26 | 5% | 481 |
| 2005F | 250 | 36 | 44 | 16 | | 36 | 108 | 24 | 5% | 514 |
| 2006S | 238 | 37 | 34 | 16 | | 35 | 82 | 24 | 5% | 466 |
| 2006F | 273 | 43 | 36 | 21 | | 36 | 130 | 23 | 4% | 562 |
| 2007S | 252 | 41 | 34 | 22 | | 36 | 95 | 20 | 4% | 500 |
| 2007F | 244 | 39 | 37 | 25 | | 31 | 109 | 25 | 5% | 510 |
| 2008S | 219 | 48 | 33 | 27 | 75 | 25 | 79 | 25 | 5% | 531 |
| 2008F | 232 | 56 | 34 | 29 | 83 | 34 | 94 | 36 | 6% | 598 |
| 2009S | 221 | 56 | 30 | 25 | 85 | 29 | 71 | 30 | 5% | 547 |
| 2009F | 239 | 64 | 29 | 30 | 69 | 21 | 133 | 39 | 6% | 624 |
| 2010S | 238 | 64 | 35 | 33 | 69 | 20 | 84 | 34 | 6% | 577 |
| 2010F | 284 | 65 | 51 | 43 | 70 | 27 | 123 | 46 | 6% | 709 |
| Grand Total by Major | 6791 | 1351 | 1983 | 690 | 451 | 814 | | 723 | | 12803 |

**Table 2: Student Credit Hours (SCHs) of science departments for the last 15 years at USF. UNSC stands for undeclared science.**

## A.3 Number of Majors of All USF Programs—Timeline.

| | | 96F | 97S | 97F | 98S | 98F | 99S | 99F | 00S | 00F | 01S | 01F | 02S | 02F | 03S | 03F | 04S | 04F | 05S | 05F | 06S | 06F | 07S | 07F | 08S | 08F | 09S | 09F | 10S | 10F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Arts and Sciences: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| BA | Advertising | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 11 | 26 | 38 |
| BAR/JDP | Architecture | - | - | - | - | - | - | 15 | 17 | 29 | 23 | 42 | 40 | 48 | 39 | 37 | 32 | 26 | 23 | 17 | 17 | 9 | 8 | 2 | 1 | 0 | 1 | 0 | 103 | |
| BA | Architecture and Comm. Dsgn (BAVA) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 18 | 20 | 38 | 29 | 47 | 50 | 62 | 64 | 86 | 90 | 104 | 104 | 107 | 0 | 116 |
| BA | Art History/Arts Mgt (BAVA) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 8 | 11 | 18 | 18 | 25 | 32 | 51 | 54 | 60 | 59 | 59 | 56 | 64 | 61 | 59 |
| BA | Arts Education (BAVA) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 6 | 8 | 8 | 9 | 9 | 4 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | |
| BA | Asian Studies | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 2 | 4 | 5 | 6 | 6 | 6 | 7 | 8 | 10 | 12 |
| BS | Biol/Bioc/Biop | 264 | 244 | 263 | 243 | 267 | 233 | 231 | 206 | 214 | 202 | 205 | 186 | 217 | 202 | 237 | 220 | 246 | 221 | 250 | 238 | 273 | 252 | 244 | 219 | 232 | 221 | 239 | 238 | 284 |
| BS | Chemistry | 38 | 30 | 38 | 38 | 38 | 38 | 38 | 38 | 42 | 50 | 55 | 50 | 56 | 52 | 53 | 49 | 47 | 52 | 36 | 37 | 43 | 41 | 39 | 48 | 56 | 56 | 64 | 64 | 65 |
| BA | Communication/Comm Studies | 247 | 239 | 263 | 268 | 257 | 228 | 250 | 243 | 225 | 216 | 209 | 197 | 202 | 195 | 203 | 198 | 194 | 180 | 208 | 209 | 248 | 233 | 253 | 247 | 232 | 231 | 216 | 225 | 229 |
| BA | Comparative Lit and Culture | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 4 | 10 | 12 | 10 | 8 | 9 | 10 | 12 |
| BS | Computer Sci | 67 | 60 | 67 | 70 | 97 | 96 | 117 | 115 | 140 | 128 | 129 | 113 | 90 | 76 | 63 | 56 | 53 | 49 | 44 | 34 | 36 | 34 | 37 | 33 | 34 | 30 | 29 | 35 | 51 |
| BS | Computer Science 4+1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 2 | 2 | 2 | 2 | 4 | 5 | 3 | 2 | 1 |
| BA | Design | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 19 | 29 | 46 | 56 | 68 |
| BFA/JDP | Drawing | - | - | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BA | Economics | 38 | 31 | 32 | 32 | 36 | 31 | 35 | 34 | 30 | 34 | 40 | 52 | 48 | 40 | 40 | 35 | 43 | 45 | 47 | 46 | 50 | 44 | 52 | 46 | 50 | 55 | 58 | 65 | 74 |
| BA | Economics 4+1 | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 10 | 11 | 11 | 11 | 5 | 6 | 7 | 6 | 5 | 3 | 1 |
| BA | English | 146 | 134 | 128 | 131 | 129 | 117 | 132 | 120 | 133 | 121 | 132 | 123 | 132 | 126 | 143 | 134 | 125 | 120 | 150 | 156 | 174 | 168 | 174 | 169 | 178 | 179 | 163 | 167 | 158 |
| BS | Environ Sci | 26 | 24 | 28 | 29 | 28 | 26 | 22 | 18 | 17 | 13 | 21 | 22 | 21 | 23 | 23 | 23 | 20 | 19 | 16 | 16 | 21 | 22 | 25 | 27 | 29 | 25 | 30 | 33 | 43 |
| BA | Environmental Studies | - | - | - | - | - | - | - | - | - | - | 1 | 2 | 7 | 7 | 11 | 12 | 16 | 16 | 12 | 14 | 20 | 24 | 33 | 28 | 35 | 37 | 53 | 59 | 64 |
| BA | Ex. and Sport Sci. | 173 | 160 | 157 | 137 | 140 | 119 | 126 | 100 | 100 | 87 | 81 | 63 | 64 | 59 | 62 | 56 | 62 | 65 | 72 | 71 | 83 | 78 | 87 | 75 | 83 | 85 | 69 | 69 | 70 |
| BS | Exercise & Sport Sci | - | 5 | 5 | 16 | 16 | 34 | 30 | 34 | 27 | 26 | 29 | 26 | 21 | 40 | 37 | 46 | 52 | 60 | 53 | 56 | 62 | 66 | 77 | 78 | 87 | 76 | 88 | 94 | 101 |
| BFA/JDP | Fashion Design | - | - | 5 | 8 | 20 | 18 | 27 | 23 | 31 | 25 | 47 | 43 | 29 | 27 | 19 | 19 | 5 | 5 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFA/AA | Fine Arts | 28 | 18 | 13 | 11 | 8 | 8 | 4 | 7 | 4 | 2 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BA | Fine Arts (BAVA) | - | - | - | - | - | - | - | - | - | - | - | - | 19 | 16 | 21 | 18 | 34 | 34 | 57 | 56 | 53 | 53 | 40 | 32 | 52 | 43 | 48 | 49 | 48 |
| BFA/AA | Graphic Design | 27 | 26 | 14 | 11 | 7 | 6 | 3 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFA/JDP | Graphic Design | - | - | 14 | 20 | 38 | 37 | 54 | 47 | 58 | 52 | 57 | 46 | 34 | 28 | 19 | 13 | 7 | 8 | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BA | Graphic Design (BAVA) | - | - | - | - | - | - | - | - | - | - | - | - | 25 | 23 | 36 | 40 | 47 | 56 | 71 | 73 | 78 | 80 | 84 | 82 | 65 | 52 | 38 | 29 | 18 |
| BA | History | 87 | 84 | 95 | 94 | 97 | 99 | 99 | 93 | 85 | 83 | 75 | 81 | 95 | 90 | 94 | 92 | 99 | 104 | 109 | 107 | 98 | 94 | 96 | 95 | 96 | 93 | 90 | 104 | 117 |
| BFA/AA | Illustration | 11 | 8 | 7 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFA/JDP | Illustration | - | - | 1 | 1 | 4 | 6 | 7 | 5 | 7 | 12 | 11 | 12 | 12 | 11 | 10 | 9 | 6 | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFA/JDP | Industrial Design | - | - | 1 | 4 | 3 | 1 | 7 | 5 | 8 | 8 | 11 | 10 | 9 | 9 | 9 | 9 | 7 | 6 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFA/JDP | Interior Architecture | - | - | 9 | 6 | 14 | 17 | 17 | 18 | 14 | 11 | 10 | 10 | 7 | 6 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFA/AA | Interior Design | 13 | 11 | 8 | 5 | 5 | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFA/JDP | Interior Design | - | - | - | - | - | - | - | - | - | - | 8 | 10 | 8 | 8 | 9 | 8 | 8 | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BA | International Studies | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 17 | 29 | 50 | 58 | 115 | 122 | 149 | 150 | 176 | 178 | 204 | 214 | 228 |
| BA | Int'l and Devel. Econ 4+1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 3 | 4 | 3 | 3 | 6 | 2 | 6 | 4 | 3 | 1 | 2 | 1 | 1 | 2 | 0 |
| BA | Japanese Studies | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | 6 | 7 | 6 | 10 | 10 | 14 | 13 | 13 | 15 | 14 |
| BA | Languages (French and Spanish) | 32 | 26 | 18 | 22 | 23 | 23 | 25 | 25 | 19 | 20 | 28 | 27 | 23 | 23 | 18 | 16 | 15 | 23 | 22 | 14 | 15 | 13 | 17 | 12 | 15 | 14 | 16 | 16 | 18 |
| BA | Latin American Studies | - | - | - | - | - | - | - | - | - | - | 3 | 4 | 8 | 10 | 12 | 9 | 8 | 11 | 10 | 13 | 12 | 13 | 11 | 12 | 11 | 9 | 9 | 12 | 13 |
| BS | Math | 27 | 27 | 17 | 13 | 12 | 21 | 25 | 26 | 28 | 27 | 30 | 32 | 38 | 35 | 29 | 32 | 33 | 32 | 36 | 35 | 36 | 36 | 31 | 25 | 34 | 29 | 21 | 20 | 27 |
| BA | Media Studies | - | - | - | - | - | - | 1 | 15 | 44 | 51 | 74 | 84 | 105 | 105 | 109 | 128 | 128 | 127 | 125 | 125 | 123 | 130 | 141 | 145 | 155 | 159 | 171 | 165 | 158 |
| BFA/JDP | Paint/Draw | - | - | - | - | - | 4 | 11 | 8 | 17 | 11 | 13 | 11 | 7 | 4 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFA/JDP | Painting | - | - | 2 | 1 | 7 | 4 | 3 | 3 | 3 | 4 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BA | Performing Arts and Soc. Just. | - | - | - | - | - | - | 5 | 5 | 12 | 14 | 23 | 22 | 37 | 39 | 44 | 39 | 51 | 48 | 57 | 53 | 56 | 53 | 52 | 50 | 44 | 43 | 45 | 43 | 50 |
| BA | Philosophy | 23 | 31 | 36 | 37 | 38 | 41 | 36 | 38 | 33 | 35 | 35 | 42 | 45 | 40 | 35 | 39 | 40 | 45 | 36 | 44 | 45 | 50 | 42 | 52 | 54 | 50 | 38 | 43 | 45 |
| BS | Physics | 12 | 13 | 19 | 20 | 18 | 20 | 25 | 26 | 27 | 26 | 27 | 24 | 20 | 22 | 20 | 28 | 24 | 26 | 24 | 24 | 23 | 20 | 25 | 25 | 36 | 30 | 39 | 34 | 46 |
| BA | Politics | 130 | 119 | 111 | 101 | 95 | 97 | 100 | 97 | 107 | 113 | 128 | 146 | 182 | 192 | 200 | 196 | 212 | 203 | 213 | 208 | 212 | 214 | 194 | 194 | 179 | 194 | 199 | 191 | 183 |
| BA | Psych/PSer/PAR | 262 | 269 | 284 | 267 | 315 | 300 | 293 | 274 | 299 | 286 | 292 | 277 | 299 | 279 | 328 | 338 | 357 | 351 | 358 | 330 | 339 | 303 | 314 | 300 | 344 | 321 | 350 | 326 | 349 |
| BA | Sociology | 82 | 89 | 76 | 79 | 87 | 89 | 89 | 86 | 84 | 93 | 101 | 95 | 108 | 111 | 105 | 104 | 126 | 136 | 145 | 155 | 158 | 151 | 139 | 129 | 120 | 110 | 109 | 116 | 121 |
| BA | Theology/Rel Stu | 7 | 5 | 9 | 12 | 9 | 7 | 10 | 9 | 14 | 12 | 15 | 19 | 13 | 12 | 10 | 13 | 10 | 11 | 14 | 17 | 16 | 15 | 15 | 13 | 15 | 15 | 15 | 18 | 18 |
| BA | Undeclared Arts | 157 | 137 | 184 | 142 | 177 | 145 | 182 | 160 | 240 | 195 | 286 | 233 | 282 | 209 | 324 | 228 | 314 | 230 | 297 | 213 | 268 | 190 | 287 | 191 | 251 | 169 | 251 | 173 | 261 |
| BS | Undeclared Sciences | 89 | 77 | 98 | 76 | 95 | 75 | 104 | 87 | 114 | 90 | 117 | 85 | 132 | 102 | 122 | 93 | 121 | 82 | 108 | 82 | 130 | 95 | 109 | 79 | 94 | 71 | 133 | 84 | 123 |
| BA | Visual Arts (BAVA) | - | - | - | - | - | - | - | 2 | 3 | 6 | 12 | 17 | 57 | 68 | 65 | 63 | 50 | 36 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 1 | 0 |
| | Total Arts and Sciences | 2036 | 1913 | 2031 | 1919 | 2100 | 1960 | 2133 | 1992 | 2213 | 2080 | 2355 | 2210 | 2503 | 2335 | 2592 | 2447 | 2678 | 2533 | 2753 | 2614 | 2942 | 2754 | 2952 | 2744 | 2982 | 2809 | 3056 | 2975 | 3283 |
| | Business and Professional Studies: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Business: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Accounting | 90 | 90 | 110 | 102 | 115 | 105 | 97 | 88 | 88 | 86 | 93 | 97 | 100 | 95 | 98 | 102 | 109 | 127 | 115 | 117 | 115 | 121 | 133 | 143 | 143 | 145 | 144 | 147 | 151 |
| | Business Admin | 401 | 361 | 367 | 321 | 331 | 291 | 342 | 320 | 375 | 326 | 378 | 363 | 394 | 343 | 374 | 351 | 410 | 372 | 410 | 383 | 450 | 419 | 488 | 432 | 477 | 431 | 376 | 365 | 352 |
| | Business Admin (3+1) | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| | Entrepreneurship | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 6 | 18 | 38 | 43 | 71 | 73 | 84 | 83 | 76 | 69 | 42 |
| | Entrepreneurship and Innovation | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 8 | 30 |
| | Finance | 96 | 100 | 98 | 108 | 104 | 103 | 127 | 125 | 128 | 132 | 139 | 125 | 121 | 122 | 116 | 117 | 103 | 107 | 105 | 104 | 119 | 137 | 137 | 159 | 166 | 183 | 159 | 157 | 175 |
| | Hospitality Industry Mgmt | 61 | 64 | 62 | 58 | 69 | 70 | 75 | 60 | 70 | 58 | 54 | 60 | 73 | 69 | 63 | 62 | 78 | 78 | 73 | 75 | 83 | 84 | 81 | 91 | 103 | 100 | 84 | 101 | 107 |
| | International Bus | 137 | 139 | 180 | 175 | 211 | 199 | 226 | 206 | 239 | 214 | 213 | 188 | 187 | 185 | 188 | 168 | 174 | 169 | 171 | 162 | 178 | 163 | 166 | 153 | 158 | 162 | 142 | 143 | 140 |
| | Management | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 31 | 35 | 48 | 54 | 58 | 54 | 59 | 47 | 29 | 19 | 11 |
| | Marketing | 77 | 97 | 121 | 113 | 134 | 130 | 158 | 154 | 162 | 154 | 169 | 163 | 170 | 157 | 172 | 168 | 187 | 173 | 192 | 182 | 195 | 190 | 184 | 164 | 157 | 156 | 152 | 151 | 158 |
| | Personnel | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| | Undeclared Business | 7 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 22 | 23 | 144 | 123 | 221 |
| | Total Business | 920 | 882 | 949 | 881 | 964 | 898 | 1025 | 953 | 1062 | 970 | 1046 | 996 | 1045 | 972 | 1011 | 968 | 1061 | 1029 | 1103 | 1076 | 1226 | 1211 | 1318 | 1269 | 1369 | 1330 | 1306 | 1283 | 1388 |
| | Professional Studies: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | American Studies | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 11 | 10 | 9 | 6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | Applied Economics | 72 | 60 | 80 | 79 | 51 | 87 | 85 | 94 | 57 | 94 | 63 | 90 | 81 | 78 | 96 | 96 | 123 | 100 | 125 | 101 | 110 | 100 | 85 | 73 | 92 | 105 | 104 | 115 | 0 |
| | Business Economics | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 92 |
| | Health Svcs | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 14 | 27 | 41 | 37 |
| | Info Systems | - | - | - | - | - | - | - | - | - | - | 22 | 93 | 164 | 210 | 155 | 177 | 159 | 149 | 133 | 104 | 87 | 63 | 81 | 75 | 74 | 75 | 71 | 70 | 55 |
| | Info Systems Mgt | 366 | 285 | 368 | 324 | 324 | 342 | 310 | 317 | 292 | 343 | 300 | 219 | 85 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Law Enfrcmt Ldrshp | - | - | 4 | 6 | 16 | 35 | 49 | 43 | 41 | 37 | 37 | 37 | 34 | 38 | 26 | 27 | 18 | 12 | 15 | 9 | 9 | 8 | 12 | 15 | 15 | 24 | 22 | 21 | 16 |
| | Non-Profit Admin | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 3 | 9 | 14 | 18 | 13 | 14 | 15 | 21 | 17 | 15 | 14 | 10 | 11 | 14 | 15 | 9 |
| | Org'l Behavior | 384 | 309 | 361 | 318 | 289 | 316 | 286 | 284 | 233 | 231 | 174 | 198 | 203 | 186 | 201 | 198 | 207 | 187 | 217 | 182 | 175 | 119 | 61 | 23 | 3 | 3 | 1 | 1 | 0 |
| | Org'l Behavior and Ldrshp | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 24 | 111 | 154 | 190 | 175 | 179 | 151 | 153 |
| | Public Admin | 53 | 37 | 67 | 56 | 49 | 40 | 33 | 27 | 30 | 43 | 50 | 52 | 54 | 64 | 60 | 77 | 41 | 33 | 49 | 44 | 38 | 36 | 44 | 43 | 48 | 47 | 27 | 40 | 29 |
| | Total | 875 | 691 | 880 | 783 | 729 | 820 | 763 | 765 | 653 | 748 | 646 | 689 | 624 | 581 | 548 | 590 | 567 | 494 | 564 | 465 | 449 | 373 | 409 | 397 | 433 | 454 | 445 | 454 | 483 |
| | Total Busn. and Professional Studies | 1795 | 1573 | 1829 | 1664 | 1693 | 1718 | 1788 | 1718 | 1715 | 1718 | 1692 | 1685 | 1669 | 1553 | 1559 | 1558 | 1628 | 1523 | 1667 | 1541 | 1675 | 1584 | 1727 | 1666 | 1802 | 1784 | 1751 | 1737 | 1871 |
| | Nursing: | 666 | 581 | 592 | 489 | 473 | 413 | 352 | 305 | 304 | 281 | 296 | 270 | 322 | 305 | 423 | 423 | 535 | 508 | 592 | 576 | 625 | 584 | 599 | 578 | 578 | 594 | 625 | 639 | 656 |
| | Grand Total | 4497 | 4067 | 4452 | 4072 | 4266 | 4091 | 4273 | 4015 | 4232 | 4079 | 4343 | 4165 | 4494 | 4193 | 4574 | 4428 | 4841 | 4564 | 5012 | 4731 | 5242 | 4922 | 5278 | 4988 | 5362 | 5187 | 5432 | 5351 | 5810 |

**Table 3: Number of majors of all USF programs for the last 15 years (Physics is highlighted).**

| Count of ID | | GENDER | | |
|---|---|---|---|---|
| MAJC | ACADEMIC_PERIOD | M | F | Grand Total |
| PHYS | 199640 | 10 | 5 | 15 |
| | 199720 | 12 | 5 | 17 |
| | 199740 | 15 | 9 | 24 |
| | 199820 | 15 | 8 | 23 |
| | 199840 | 13 | 9 | 22 |
| | 199920 | 12 | 8 | 20 |
| | 199940 | 16 | 17 | 33 |
| | 200020 | 16 | 16 | 32 |
| | 200040 | 15 | 18 | 33 |
| | 200120 | 14 | 17 | 31 |
| | 200140 | 13 | 13 | 26 |
| | 200220 | 15 | 10 | 25 |
| | 200240 | 14 | 7 | 21 |
| | 200320 | 15 | 9 | 24 |
| | 200340 | 15 | 10 | 25 |
| | 200420 | 16 | 12 | 28 |
| | 200440 | 19 | 5 | 24 |
| | 200520 | 24 | 4 | 28 |
| | 200540 | 23 | 5 | 28 |
| | 200620 | 19 | 5 | 24 |
| | 200640 | 19 | 7 | 26 |
| | 200720 | 18 | 6 | 24 |
| | 200740 | 19 | 6 | 25 |
| | 200820 | 21 | 5 | 26 |
| | 200840 | 30 | 6 | 36 |
| | 200920 | 24 | 6 | 30 |
| | 200940 | 28 | 10 | 38 |
| | 201020 | 26 | 8 | 34 |
| | 201040 | 36 | 11 | 47 |
| PHYS Total | | 532 | 257 | 789 |
| Grand Total | | 532 | 257 | 789 |

**Table 4: Number of USF Physics Majors—Breakdown By Gender.**

## B. Assessment

The text below is a shorthand version of the comprehensive document that our Department adopted for the Physics Major assessment.

### B.1 Physics Program Learning Goals

Upon completion of the Bachelor of Science degree in Physics, graduates will be able to:

- LEARNING GOAL 1.
  Demonstrate proficiency in the basic subfields of physics (classical mechanics, electromagnetism, quantum mechanics, statistical mechanics, and thermodynamics) as well as areas of application (e.g., solid state physics, astrophysics, etc).
- LEARNING GOAL 2.
  Apply physical principles to novel situations, both in the classroom and in research settings, through critical thinking, problem solving, mathematical and computer modeling, and laboratory experimentation.
- LEARNING GOAL 3.
  Construct and assemble experimental apparatuses, conduct and analyze measurements of physical phenomena, and make meaningful comparisons between experiment and theory.

### B.2 Physics Program Learning Outcomes

Upon completion of the Bachelor of Science degree in Physics, graduates will be able to:

1. - LEARNING OUTCOME 1 (a).
     *Demonstrate* mastery of the core concepts and general principles of physics.
   - LEARNING OUTCOME 1 (b).
     *Demonstrate* competent knowledge of the specific concepts, principles, and problems of each of the basic subfields and some areas of application in physics.
2. - LEARNING OUTCOME 2 (a).
     *Formulate, solve, and interpret* problems by the use of physical principles, via mathematical and computational techniques.
   - LEARNING OUTCOME 2 (b).
     *Describe and discuss* the formulation, solution, and interpretation of a problem, by the use of physical principles, via a seminar presentation.
3. - LEARNING OUTCOME 3 (a).
     *Conduct* experiments with the proper use of equipment for a detailed comparison with physical models and theories.

- LEARNING OUTCOME 3 (b).
  *Examine* the results of experiments with the statistical methods of error analysis, including the assessment of experimental uncertainties.

### B.3 Physics Program Assessment Methods

The Physics & Astronomy Department will use *direct (objective) measures* for the evaluation of all Program Learning Outcomes and Rubrics. The direct measures to be used are different forms of course-embedded assessment: embedded questions and problems, laboratory reports, and seminar presentation outlines. The final results are organized according to a ternary scale.

#### B.3.1 Curriculum Map

In the table below, LO stands for "Learning Outcome" with the corresponding enumeration [i.e., 1 (a), 1 (b), etc] defined in Section 2; an abbreviated description is also provided for easy reading. The check-mark symbol ✓ is used to indicate the applicable Learning Outcomes for each required course.

| **PHYS COURSE NUMBER** | LO 1 (a) **Demonstrate** concepts & principles | LO 1 (b) **Demonstrate** specific knowledge | LO 2 (a) **Solve problems:** mathematical & computational | LO 2 (b) **Describe** problems in seminars | LO 3 (a) **Conduct** experiments: equipment | LO 3 (b) **Examine** experiments: error analysis |
|---|---|---|---|---|---|---|
| **PHYS 110** | ✓ | ✓ | ✓ | | ✓ | ✓ |
| **PHYS 210** | ✓ | ✓ | ✓ | | ✓ | ✓ |
| **PHYS 240** | ✓ | ✓ | ✓ | | | |
| **PHYS 301** | | | ✓ | | | |
| **PHYS 310** | ✓ | ✓ | ✓ | | | |
| **PHYS 312** | ✓ | ✓ | ✓ | | | |
| **PHYS 320** | ✓ | ✓ | ✓ | | | |
| **PHYS 330** | ✓ | ✓ | ✓ | | | |
| **PHYS 340** | ✓ | ✓ | ✓ | | | |
| **PHYS 341** | | | | | ✓ | ✓ |
| **PHYS 342** | | | | | ✓ | ✓ |
| **PHYS 350** | | | | ✓ | | |
| **PHYS 371** | ✓ | ✓ | ✓ | | | |

### B.4 Physics Program Assessment Time Frame

For the three-year cycle 2008-2011, the following time frame is planned. Given three major program learning goals, the corresponding outcomes are evaluated according to the rule: one goal per academic year (AY 2008-09: goal 2; AY 2009-10: goal 1; AY 2010-11: goal 3)

### B.5 Physics Program Assessment Implementation

The Physics Program Assessment will be conducted by the Physics & Astronomy Department Chair in coordination with the instructors involved with the relevant courses. Representative forms of course-embedded assessment (questions, problems, reports, etc) will be prepared by the instructor and final decision will be made in a consultative manner. Whenever needed or deemed appropriate, a coordinator other than the Physics Chair may be appointed to further provide support through the assessment process.

## C. New Upper-Division Lab Experiments

As discussed in Section 4.3, the following advanced experiments have been introduced since our program review. They are an integral part of the upper-division curriculum, whose experimental part we intend to further upgrade; and they provide a good platform for subsequent student research.

1. Fabry-Perot cavities.

   Fabry-Perot (FP) cavities are ubiquitous elements in optical physics, and are used for applications such as optical spectrum analysis, sensitive frequency discrimination for laser frequency stabilization, building up large field intensities with low input powers (for instance in continuous wave Raman lasers), as frequency rulers to calibrate spectra, etc. In this lab students investigate two kinds of FP cavities  a low finesse cavity where the mirror separation is fixed and a high finesse cavity where one of the mirrors is mounted on a piezoelectric actuator (PZT). Students learn how to quickly set up a low finesse cavity and use it as a frequency ruler that can be used to calibrate laser scans. Here the transmission peaks of the cavity can be used as frequency rulings and their separation can be adjusted by changing the mirror separation (length of the cavity). In the next part, students set up a cavity of higher finesse, determine the mirror separation and study the cavity spectrum described by the Airy function. Then they investigate a high  finesse confocal cavity, which students use as an optical spectrum analyzer. This instrument is also actively used in the research lab as a diagnostic to measure the spectral content of a laser as it gives the information on whether the laser is running single mode or multimode.

2. Frequency modulation spectroscopy.

   In this laboratory, students explore the basics of a technique called frequency modulation or FM spectroscopy. Most students are already aware of frequency modulation (FM) radio broadcasting, where the radio carrier frequency of typically 100 MHz is modulated. In the optical domain, a similar technique exists. However, here the carrier frequency is boosted to optical laser frequencies which are on the order of 500 THz. The resulting optical analog has many powerful applications, commercially the most dominant one being fiber-optic communications (see separate laboratory on this). This lab focuses more on the scientific applications. FM-spectroscopy was invented about 20 years ago by Gary Bjorklund to sensitively detect weak absorption features and independently by Jan Hall (Nobel price in Physics 2001) in the context of servo locking a tunable laser to a high finesse cavity. Both techniques are closely related optical analogs of methods developed in the microwave region by Pound in the 1940s. In this lab, students focus on the frequency modulation of the laser and investigate the resulting laser spectrum using the confocal optical cavity as a spectrum analyzer as it allows observing sidebands on the laser output when rapidly modulating the lasers phase with an external electro  optic modulator. Besides the experimental investigation, students calculate the expected FM  lineshapes for the confocal high  finesse cavity and then experimentally reproduce these lineshapes.

3. Optical Amplifier.

   With the ever growing widespread use of Erbium Doped Fiber Amplifiers (EDFA) and lasers, it is important for the students to have a good working understanding of optical amplifiers. In this lab, students investigate the basic properties of an EDFA. They measure the amplifier output power as a function of input power for the regions of small signal gain and signal saturation. Students determine small signal gain, gain, pump saturation and saturation output powers. Furthermore, students take measurements of the output power and gain as a function of pump power. Students analyze their data. An extension of the lab is the investigation of amplified spontaneous emission and the noise characteristics of the amplifier.

4. Erbium doped fiber ring laser.

   This laboratory builds upon the Optical Amplifier laboratory as prerequisite. The laser was first invented in the 1960s and nowadays laser usage permeates consumer applications such as laser printers, bar code readers and CD and DVD players. Modern laser applications enhance our daily lives in areas such as telecommunications, medicine, and optical instrumentation. Students therefore benefit from a good working knowledge and understanding of the basic principles of lasers. In this laboratory students build a fiber ring laser and gain practical experience and understanding of the basic operation and efficiency of an optical oscillator (i.e. a laser), examining the output power, threshold and slope efficiency and their dependencies on gain, intra-cavity loss and output coupling ratio.

5. Michelson Interferometer.

   The Michelson Interferometer is historically important, and also provides a simple interferometric configuration for introducing basic principles. Students can measure the wavelength of light and the indices of refraction of air and its dependence on pressure as well as other substances. This lab was developed with the help of USF physics student Patrick McNeff.

6. Reflection and Refraction on an optical interface.

   The boundary (optical interface) between any two transparent optical materials of different refractive index acts as a partial transmitter and reflector of light. The reflectance and transmittance vary as a function of angle of incidence as described by the Fresnel equations and depend on the relative refractive indices of the two materials, the polarization of the incident light and the side of the interface the light is coming from. Reflected light emerges at an angle equal to the angle of incidence and transmitted light is bent relative to the surface normal, emerging at an angle determined by the relative indices of the materials and the incidence angle. The laboratory provides students the opportunity to investigate many aspects of reflection and refraction of light at an optical interface and provide the foundations for the study of applications such as the design of polarizers, reflection elements and optical waveguides.

7. Saturation absorption spectroscopy of Rubidium atoms.

   In this experiment students use a diode laser to carry out laser spectroscopy of rubidium atoms. They study the Doppler broadened optical absorption lines, and then use the technique of saturated absorption spectroscopy to study the lines with resolution beyond the Doppler limit. This will enable the students to measure the hyperfine splittings of one of the excited states of rubidium. Students use a Michelson interferometer (see separate experiment) to calibrate the frequency scale for this measurement. This experiment was originally developed by Nobel laureate Carl Wieman and uses techniques currently in use in his and other research laboratories at the University of Colorado.

8. Laser frequency stabilization.

   This laboratory builds upon the Fabry-Perot cavities and Frequency Modulation Spectroscopy laboratory as prerequisite. In many precision optical measurements it is desirable to have a laser with a well-defined frequency. For example, atomic physics experiments often require lasers with frequencies fixed at or near the frequencies of atomic resonance lines. For tunable lasers it is therefore necessary to have a means of controlling the lasers operating frequency, and of locking it at a desired value. In this lab students investigate methods for achieving this, and focus on one particularly powerful technique known as the Pound-Drever-Hall method (named after R. V. Pound, who first used the technique to stabilize microwave oscillators in the 1940s, and Caltech professor R. W. P. Drever, who extended the ideas to the optical domain in the early 1980s, as well as Jan Hall at the University of Colorado, who is considered a pioneer in laser frequency stabilization).

9. Data storage on a CD and DVD.

   In this lab students design an experiment to measure the grating period of a CD and a DVD based on the physics of a diffraction grating. Students convert the grating period to data density and check whether the result agrees with real values (a CD can store typically store 700MB of data and the storage capacity of a DVD is several times higher).

10. Principles of optical waveguiding.

    Optical fiber communication is based on the cylindrical dielectric waveguide in the form of an optical fiber. Fiber optic cables are being used for long distance, high data rate telecommunications even across continents. The demand for processing optical signals in such systems has also prompted the development of a large number of waveguide devices and components, such as power splitters, multiplexers, filters, and modulators. In this lab students are introduced to optical wave guiding to fully appreciate the principles and design rules of optical waveguides. Students investigate the step index and graded index planar waveguide and learn about the principles of modes, mode effective index, mode cut-off thickness, single mode operation and basic waveguide design. These are the fundamentals to understanding light propagation in

optical fibers and the design of waveguide devices. Students have already carried out the experiment on reflection and refraction on an optical interface and have covered Fresnels equations and total internal reflection as a precursor to this experiment.

11. Optical communications.

    Optical fiber links are ambivalent everywhere and have penetrated into the access and local area networks and even private homes. This experiment expedites the development of the necessary hands on skills and introduces the student to the bigger picture behind an optical fiber communication link, which involves the design, installation, and operation the individual components. Specifically, in this experiment students characterize all of the major components of a fiber optic telecommunication system, such as the transmitter, the optical fiber, and the receiver. Then the students build a simple point to point fiber optic link and experimentally assess the performance of that link including the determination of the upper limits on the link length, bit rate and analog bandwidth as defined by fiber attenuation and dispersion.

## D. Facilities

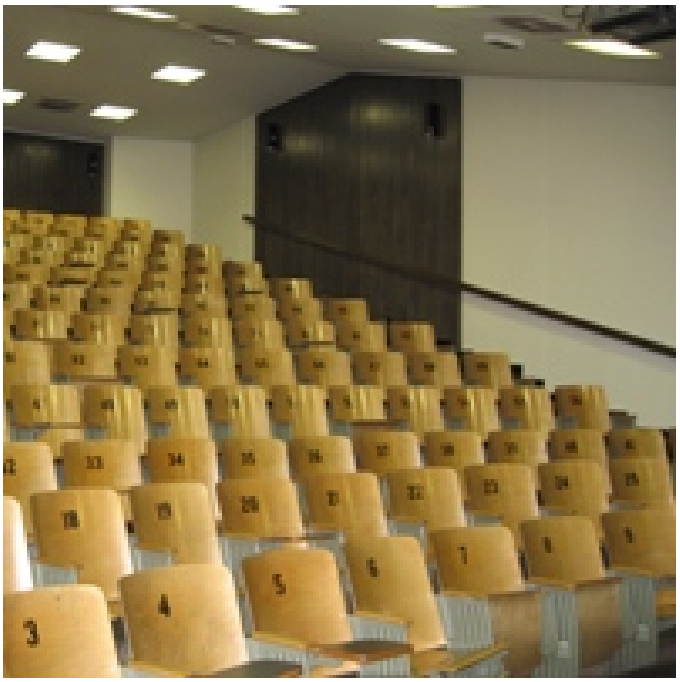

**Figure 1: Our large Physics & Astronomy lecture hall: Harney 127.**

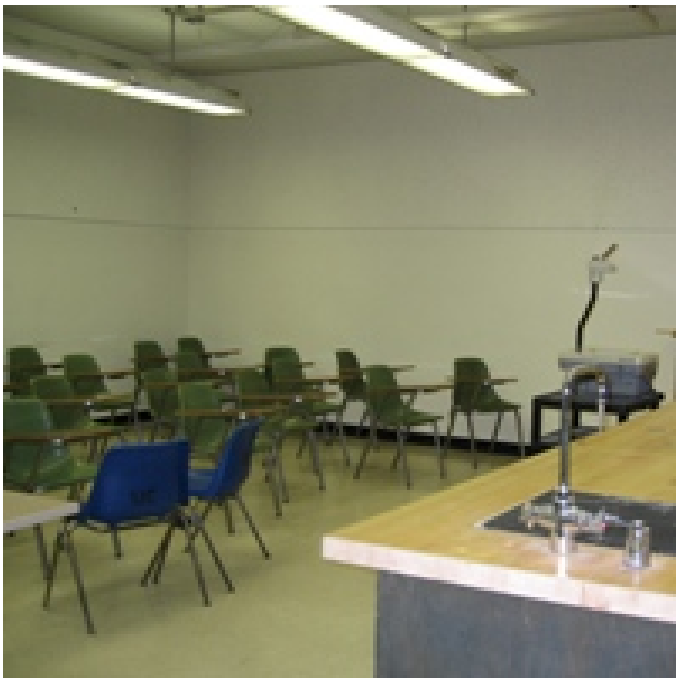

**Figure 2: The classroom for small- and medium-sized Physics & Astronomy lecture courses: Harney 143.**

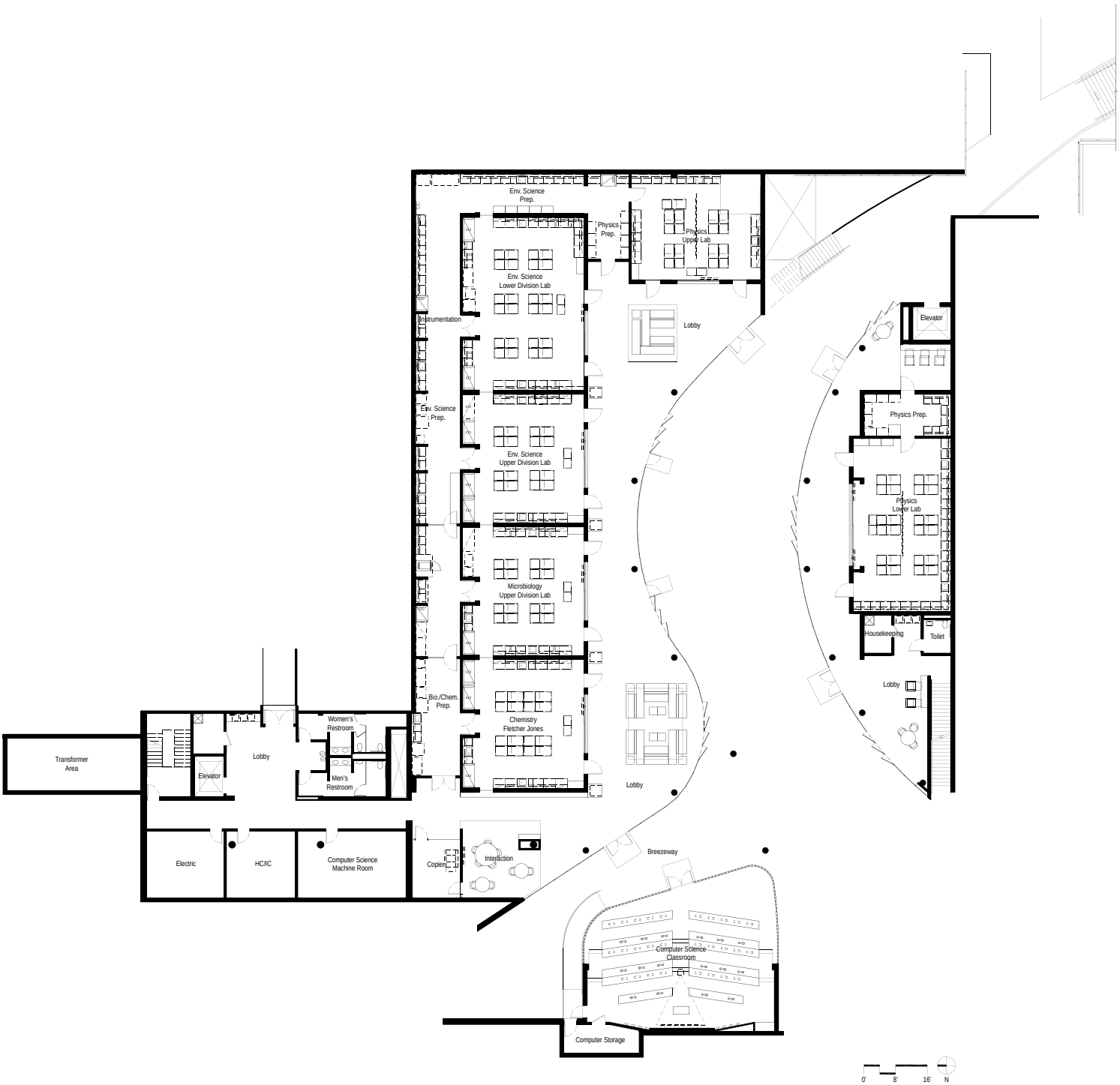


**Figure 3: Floorplan of level G1 of the planned Center for Science and Innovation.**

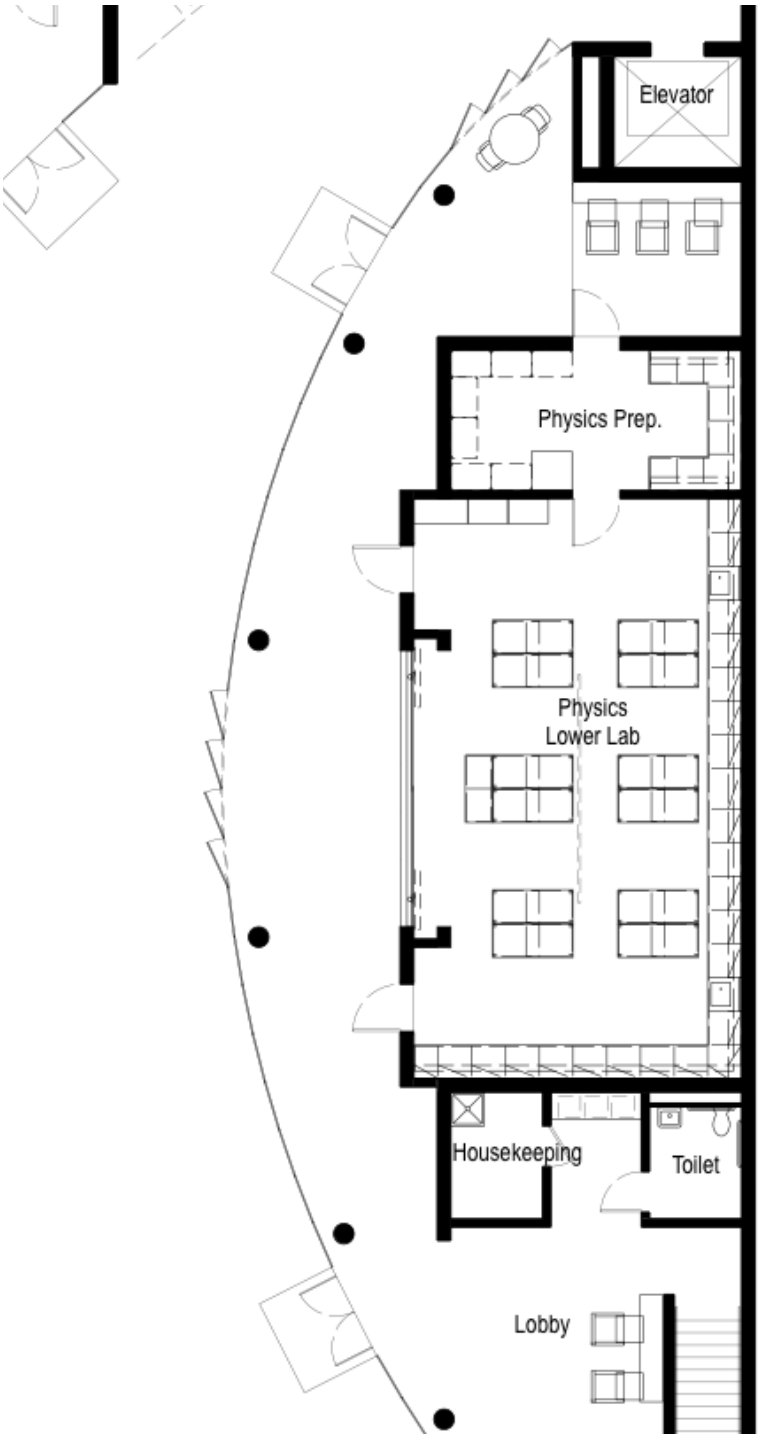


**Figure 4: Detail of Introductory Physics Laboratory at the G1 level of the Center for Science and Innovation.**

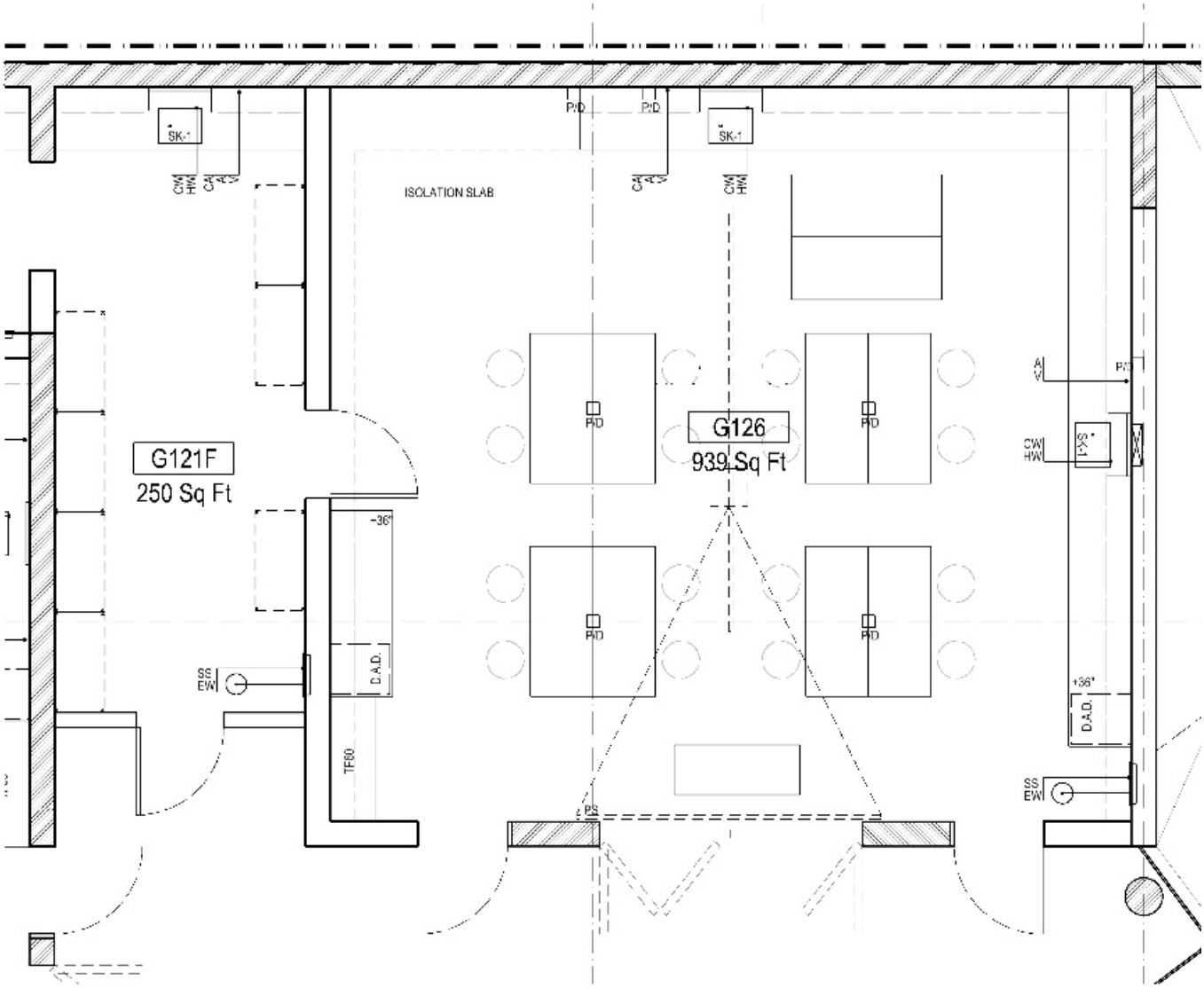


**Figure 5: Detail of Upper-Division Physics Laboratory at the G1 level of the Center for Science and Innovation.**

**USF Observatory operated through the Department of Physics and Astronomy**
**20-inch RC Optical telescope with 14-foot Ash Dome, CCD camera,**
**and 3600GTO German Equatorial Mount**

| LOCATION OF OBSERVATORY | ADVANTAGES | DRAWBACKS |
|---|---|---|
| (A) ON CAMPUS<br>(Lone Mountain Ground, Lone Mountain rooftop, or Fromm Rooftop)<br><br>Cost of St. Mary's observatory[1]: Maintenance: 1 course release per year +$5000 per year maintenance/supplies (underestimate according to Prof. Ron Olowin at St. Mary's) | Easy access for department's faculty, majors/minors and nonmajors. Important recruiting tool. Public outreach activities with free talks and observing for alumni, trustees, and the general public. Good avenue to increase USF's Bay Area visibility. Would be set up to operate remotely. | Weather (rain/wind) and fog are often issues; also a bright site (light pollution). Our 20-inch optical telescope (high-quality optics) would have limited science capacity. Potentially enough science projects to keep undergraduates busy with differential photometry of all the planets, asteroids & comets, ~1000 stars, many quasars, & transitory phenomena. Model: St. Mary's College (they achieve 17$^{th}$ mag but have a darker site) |
| (B) OFF CAMPUS<br>(Bay Area sites, e.g., at The Villages Radio Astronomy Club[4] near San Jose) – this would be set up to operate remotely with our automated telescope mount<br><br>Cost of Sonoma State Observatory: Telescope/dome/pre-fab. shed out of a kit ~$30K. Maintenance approx. ½ time FTE per year (more in first year, less so when established) | Dark site with improved science capacity, good scientific and collaborative outreach options with Bay Area institutions and groups, partnership opportunities with national/worldwide observatory networks using automated astronomy education and research facilities[2,3]. Good avenue to increase USF's Greater Bay Area visibility. Would be set up to operate remotely. | No immediate access for faculty/students, limited opportunities for visits, outreach perhaps aimed more at South Bay public/schools rather than SF public, funding and support staff required for equipment maintenance and upgrades, value of our own off-site observatory when we have access to comparable facilities in Bay Area (Sonoma State, St. Mary's) |

**Table 5: Planning of Future USF Observatory.**

[1] The Geissberger Observatory at St. Marys College (Moraga, CA): http://physics.stmarys-ca.edu/classes/Observatory/ObsIndex.html (with a 16-inch Meade optical telescope with Paramount robotic mount).

[2] Global Telescope Network (GTN): already have an account (for use of 14-inch optical telescope with remote observation capacity).
http://gtn.sonoma.edu/gort/index.php

[3] Sierra Stars Observatory Network: http://www.sierrastars.com/

[4] The Villages Radio Astronomy Club:
http://thevillagesastronomyclub.homestead.com/index.html
See description in Subsection 4.8 of the main text.