# Department of Physics & Astronomy

# Program Review
# Self-Study Report
# 2015

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SONOMA STATE UNIVERSITY

School of Science and Technology

**Department of Physics and Astronomy Self-Study Report**
**Executive Summary**

The Sonoma State University Department of Physics & Astronomy (P&A) has a small well-functioning faculty led by its well renowned Chair, Dr. Lynn Cominsky. Remarkable for graduating approximately ten Physics majors a year, it ranks in the 88$^{th}$ percentile of bachelor's granting institutions. Counting the AY 2015-2016 hire of Dr. Tom Targett, it has five faculty members and 6 part-time lecturers. Hosting a popular series of Astronomy general education courses, Physics service courses, and a strong major curriculum, the department serves an annual headcount of over 1,000 students. This results in 200 Full Time Equivalent Students (FTEF) per semester, and a Student to Faculty Ratio (SFR) of 34.

The P&A program offers 34 distinct courses: 11 include lab components, and 13 satisfy GE requirements. The department's degree programs include two BS and two BA programs. It is the recommendation of the self-study to replace the Applied BS with an Astrophysics BS to leverage the strength of the department in this area. It is also recommended to replace the BA-Trig with a BA-Physical Science, addressing the STEM teacher shortage and providing another degree program with growth potential. The Department of Physics & Astronomy uses teaching methods based on Physics Education Research, including think-pair-share, the flipped classroom, clickers, inquiry, peer-mentoring, the Skills Lab, and Supplemental Instructors in a Learning Assistant model. The department has an unparalleled connection to alumni, with survey data of 88% of our graduates and our production of a popular annual Newsletter. See: http://www.phys-astro.sonoma.edu/ourgraduates.shtml and http://www.phys-astro.sonoma.edu/newsletter .

The defining educational element of our program is the skill-based growth of our students. The curriculum nurtures a set of student real-world experimental and communication skills. This culminates in the Senior Capstone which includes research with a faculty advisor, and the preparation of a talk for the department's Senior Seminar and a poster for the school's Science Symposium. The Capstone serves as the final assessment of our students' learning and an ongoing one of the department. A robust 36% of our students enter graduate study. Many of them go on in physics and astronomy, but an equal number in in a wide variety of disciplines including: engineering, education, and other science fields. Ours is an inclusive department, addressing diversity in multiple ways including: the selection of diverse voices in our popular public lecture series (http://www.phys-astro.sonoma.edu/wpd); the historically strong inclusion of female leadership of the active Society of Physics Students (SPS) and the department; and the many allied programs of the university including MESA, DSS, McNair etc.

The Department is active in research (materials science and astrophysics), service, and grants acquisition. Examples include: an NSF STEM Talent Expansion Program (STEP) grant and its freshman Science 120 course; a $3M Department of Education curriculum grant, "Learning by Making"; an NSF LIGO outreach grant; the EPO programs for the NuSTAR, Fermi, Swift and XMM-Newton spacecraft; "Big Ideas in Cosmology", an online Astronomy and Cosmology curriculum; a PhysTEC teacher education grant; the development of an NSF-funded astronomical adaptive optics system; an active satellite (CubeSat) program; popular public observatory and lecture programs; and the supervision of a multiple grant-winning Society of Physics Students club.

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## A. Physics and Astronomy Program Introduction and Recent History

Let us begin by presenting a high-level snapshot of the Sonoma State University Department of Physics & Astronomy at the time of this review.
The Department of Physics & Astronomy:

- Offers BA and BS degrees in Physics (2 plans each)
- Offers minors in both Physics and Astronomy
- Major/Minor Student Breakdown
    - 51 Majors
        - 42 B.S.
        - 9 B.A.
    - 21 Minors
        - 16 Astronomy (including 6 physics majors)
        - 5 Physics
    - 3 additional Postbacc. Students taking undergraduate physics classes.
    - 9.6 graduates/year (2007-2014)
- Course offerings
    - 26 distinct physics courses, 8 including lab components
        - 11 lower division, 15 upper division
        - 8 satisfy General Education requirements
        - Introductory calculus and algebra/trigonometry sequences (2 semesters each) are also service classes to allied degree programs.
    - 8 distinct astronomy courses, 3 including lab components
        - 5 satisfy General Education Requirements
    - Majors required to complete capstone course
        - Research done under supervision of a faculty advisor
        - Students present a poster at SSU Research Symposium
        - Students give talk at Physics & Astronomy Symposium
    - Student research taken as special studies, and a popular seminar series round out our offerings
- Students served in Academic Year 2014-2015:
    - Total Student headcount in P&A courses: 1146
    - 405 FTES[1]
        - 224 Astronomy (187 in Astronomy 100), 181 Physics
- Faculty in Academic Year 2014-2015
    - 4 Tenure-Track Faculty in 2014-2015, 5 in 2015.
        - Currently two Full and two Associate Professors, we are adding one Assistant Professor in fall.
        - Core specialties of department are Materials Science and Astronomy

[1] FTES - Full-time equivalent students. A student whose class schedule totals 15 units in a given term = 1.0 FTES

    - 2.4 FTEF[2] among the 3 tenured faculty with teaching responsibilities, with the balance of WTU (weighted teaching units) in grant-related work
  - 6 Part-Time Faculty (3 w/ Ph.D.)
    - One moves to tenure tenure-track in fall as noted above.
    - 3.7 FTEF
- SFR[3] = 33.2
- Staff: 0.5 Administrative Coordinator, 1 Laboratory Technician
- Operating Expenses Budget 2014-2015 Academic Year: $9,380
- The Department of Physics & Astronomy is active in research, service, and grants acquisition. Examples: NSF STEM Talent Expansion Program (STEP) grant and the related freshman-cohort Science 120 course; Department of Education curriculum grant, "Learning by Making"; NSF Ligo outreach grant; the Education and Public Outreach programs for the NuSTAR, Fermi and Swift spacecraft; "Big Ideas in Cosmology", a new, online Astronomy and Cosmology curriculum; a PhysTEC teacher education grant; the development of an NSF-funded astronomical adaptive optics system, KAPAO; public programs such as observatory viewing nights and the 'What Physicists Do' public lecture series; and an active Society of Physics Students club which has been successful in acquiring SPS national Marsh White Grants for outreach activities and has developed a Skills Lab system of upper-division students teaching lower-division students key research skills.

**Goals:** The primary goal of the Department of Physics & Astronomy is the education of our students. This includes teaching three different, but aligned populations of students: the preparation of our majors for a broad array of pathways to careers in industry, research, and teaching; the training in the processes of physics of students in aligned STEM fields; and providing the student body with a rich set of General Education courses to serve as a lasting impression in how science works as part of our SSU tradition as a public Liberal Arts institution. Central to the education of the majors, and enriching the experience of the other two populations, is our goal to conduct student-centered authentic research directed by our faculty and incorporated in our degree programs via our intermediate and advanced laboratories, our special studies programs, and culminating in a senior Capstone research experience. Our final goal is centered upon sharing the processes and discoveries of physics and astronomy in ways that involve the broader campus and community.

**Recent History:** To place the findings of this Program Review in context, we will present a short history of the department. We begin by reflecting on the period of time since the last Program Review in 2008. A Program Review serves different

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[2] FTEF - Full-time equivalent faculty. TT Faculty: 1 FTEF = workload of 12 weighted teaching units in class and 3 indirect WTU. Part-time faculty – 15 in class teaching WTU.
[3] SFR: Student to Faculty Ratio, the number of full-time equivalent students to full-time equivalent faculty (FTES per semester/FTEF)

constituencies in different ways. For the department it serves as a reflective document on setting and adjusting goals, measuring progress and delineating resources necessary to achieve these goals. For the administration it serves an assessment of the health of the department focusing on evidence-based assessment of student learning outcomes; alignment of a program's mission and goals with those of the university; relation of curriculum to student learning; quality and diversity of faculty, staff, and curriculum; service and contributions to community; recruitment, retention and support for students and faculty; resource allocation; and administrative support. The process at SSU includes an external reviewer, a review by the Dean, then the Educational Policies Committee of the Academic Senate (EPC), and finally the Provost.

The Department of Physics & Astronomy last underwent a program review in 2008. The EPC summarized the review thusly:

> *Physics employs a range of assessment instruments: student exit interviews, alumni interviews, standardized competence tests. Based on these instruments, the department has made or is making the following revisions: create small-group and interactive activities in lecture courses, adopt on-line homework tutorials to supplement first-year physics sequence of courses, redesigning lower-division labs to include inquiry based assignments focused on doing science, require all students in capstone projects and special studies to meet at least once per month.*

Additionally, the Department's 2008 action plan, made in correspondence with the external reviewer's report, highlighted several other items: adjusting the curriculum to engage majors in the department earlier should they not be math qualified for the calculus-based introductory series; address the then-recent faculty turnover by seeking additional hires and including the junior faculty in department governance; reevaluating advising on an ongoing basis; and seeking support for release time for probationary faculty to pursue their scholarship. As we will see herein, all of these issues within the purview of the Department of Physics & Astronomy have been acted upon. Additionally, during the last year we have seen our first new tenure-track hire since the 2008 review, and the hire has been awarded a stronger release time package than the previous round. The period of time since the last review has proven to be a remarkable one.

Since 2008, the department has seen:

1. California Budget Crisis[4]
2. Retirements of faculty who were in the Faculty Early Retirement Program: Joe Tenn, Bryant Hichwa, and Gordon Spear.
3. Hongtao Shi promotion to Associate and then Full Professor.
4. Promotion to Associate Professor for Jeremy Qualls and Scott Severson.
5. Continuous leadership under the Department Chair and senior faculty member Lynn Cominsky.
6. The AY 2013-2014 hire of a visiting then adjunct (2014-2015) professor, Tom Targett to a new tenure track position within the Department beginning Fall 2015.

[4] "Higher Education Funding and Mission in Crisis" - http://www.calstate.edu/budget/fybudget/2012-2013/executive-summary/funding.shtml

7. Continued excellence in physics education through the offering of an impressive array of courses, growth of the Senior Capstone research experiences (both in breadth and depth, example projects: Cube-Sat satellite development; Water harvest form the atmosphere; Materials Science research into organic crystals, ZnO UV photodiodes, and carbon nanotubes; and astronomical Adaptive Optics), and research-proven pedagogical techniques.
8. Success in grant acquisition including the S3 STEM education grant, an NSF-MRI grant for the KAPAO Adaptive Optics System, and the continual excellence of Chair Cominsky's EPO program including several NASA grants (e.g. as Co-Investigator on Swift, Fermi, and NuSTAR) and the recent "Learning by Making" Department of Education grant (totaling $3 Million over 5 years).
9. Active service efforts, including faculty service at the Departmental, School and University levels, as well as a diverse set of public programs: alumni outreach through an annual newsletter, an active SPS club chapter, a public lecture series that involves multiple faculty members and a team of student assistants, and a venerable public lecture series that has entered the "YouTube" era.

**History of Degree Programs**

The history of the degree programs offered in the Department of Physics & Astronomy is as follows. Since 1971 the Department has offered both Bachelor of Science (B.S.) and Bachelor of Arts (B.A.) degrees. The B.S. has been the conventional physics degree offered by most American universities and has provided excellent preparation for graduate school. According to our graduates (see Appendix B) it also provides a firm foundation for working in technical fields.

The B.A. has been more flexible, offering a way for students not intending to become physicists to earn a bachelor's degree in the subject. Originally there were versions at three different mathematical levels: descriptive, algebra & trigonometry, and calculus. All versions of the B.A. have always required 12 units in one other subject and have a relatively low number of total units required, so that the degree can readily be combined with another in a double major. The descriptive B.A. worked for a time, but was dropped in 1988, with the algebra based sequence setting the minimal mathematical rigor within our degrees.

As the number of noncalculus courses offered decreased, the number of students in the algebra & trig-based B.A. has declined. Only eight out of 92 graduates in the past decade have chosen it. At one time it was a common double major with business, but the business degree now has so many units in it that few students have time for double majors.

In 1985 the Department began offering a concentration in applied physics within the B.S. program. This program has always required more laboratory courses and fewer courses in theory and in chemistry and mathematics than the "straight B.S." Until 2004 the B.S.-Applied was also distinguished by requiring a "capstone course" called Senior Design Project. Since then all the major programs have required capstone courses.

For basic statistical data for enrollments in Physics and Astronomy Department courses and majors, please see Appendix A.

Recent changes are described below:

**Major changes in 2004-2006 catalog:** All four degree programs — the B.S., the B.S. with a concentration in applied physics, the B.A. with calculus, and the B.A. with algebra and trigonometry —now required a two-unit "capstone course." This course could be chosen from an instructional design project in physics or astronomy, undergraduate research in physics or astronomy, or a senior design project.

Upper division laboratory courses Introductory Quantum Laboratory (P316), Precision Machining for Experimental Physics (P333), X-Ray Analysis (P384), Lasers and Holography Laboratory (P447), Fiber Optics and Detectors Laboratory (P449), and Applied Nuclear Chemistry and Physics Laboratory (P482) were deleted from the catalog, and were replaced by two new courses, Physics 366 Intermediate Experimental Physics and Physics 466 Advanced Experimental Physics. Several experiments from the deleted courses, as well as new ones making use of the equipment in the Cerent Laboratories, were incorporated into the new courses.

A few lecture courses, including Applied Nuclear Chemistry and Physics (P481), were also dropped. We retained Photonics (445) and Semiconductors (475) lecture courses from the previous catalog.

The first course in electronics, and its associated laboratory, were given new numbers (Physics 230 and 231), revised slightly in content, and moved from fall to spring. This was intended to facilitate coordination with the then forthcoming B.S. in engineering sciences program. The second courses in electronics, Physics 413 and 413L, were also revised.

The differences between B.S. and B.S.-Applied became: B.S.-Applied requires P475 (Theory of Semiconductors) and does not require Calculus III (Math 241), Analytical Mechanics (P320) or Chem 115B (second semester General Chemistry) Also B.S.-Applied majors cannot choose A380 (Astrophysics) as an upper division elective course, but they have more elective units available. Both B.S. programs require P366.

**2006-2008 catalog**: No significant changes in Physics degree programs since 2004-2006 catalog. Chem 115A/B (four units each) and Chem 116A/B (recitation, 1 unit each) combined to be two 5-unit classes, Chem 115A/B. The Mathematics Department eliminated its confusing numbering system by dropping the terms Calculus III and Calculus IV. Math 241 is now titled Differential Equations with Linear Algebra, and Math 261 is now called Multivariable Calculus.

**2008-2010 catalog:** Physics 230/231 went back to being called Physics 313/L, and returned to their former content, since coordination with the Engineering Science program did not work out. We eliminated Physics 413/L, due to its content being incorporated into our two lab classes. Astronomy course descriptions were re-written to update the content in alignment with the findings and priorities of the current state of the field. Physics 100, Descriptive Physics, was added to the advanced electives of the major in response to the program review in order to provide majors without adequate math preparation an incentive for taking courses within the department while they worked through the first semester of calculus. This has been an attempt to prevent loss of declared majors during this early period of math preparation while they otherwise had little contact with the Physics & Astronomy department.

**2012-2014 catalog:** Astronomy 303 was changed from “Extraterrestrial Intelligence and Interstellar Travel” to “Life in the Universe” to reflect the emergence of a discipline within astronomy that provides an appraisal of the possibilities and prospects for life in the universe and travel beyond our Solar System. Topics of the course include: the nature of life, habitability of Earth and other worlds within our Solar System, detection of planets beyond our Solar System, the search for life beyond Earth, and space travel.

**2014-2016 catalog:** The Department responded to the Chancellor’s mandate for all CSU majors to be within a 120-unit cap. Reworking our two BS degree plans that were over this cap, we eliminated general elective units to bring them down to 120 units. No changes were necessary to major core or supporting courses.

# B. Physics and Astronomy Program Objectives

## B.1 Learning Objectives for Courses in Physics and Astronomy

The following are the learning objectives for the Physics and Astronomy courses and degree programs. These learning objectives are found on our departmental website: http://phys-astro.sonoma.edu/learningobjectives.doc and our class syllabi reference these learning objectives.

### B.1.a. Learning Objectives

*Objectives Specific to Physics and Astronomy discipline courses*

Students are required to demonstrate:
1) Knowledge, understanding and use of the principles of physics and/or astronomy
2) Ability to use reasoning and logic to define a problem in terms of principles of physics
3) Ability to use mathematics and computer applications to solve physics and/or astronomy problems
4) Ability to design and/or conduct experiments and/or observations using principles of physics and/or astronomy and physics or astronomical instrumentation
5) Ability to properly analyze and interpret data and experimental uncertainty in order to make meaningful comparisons between experimental measurements or observation and theory

*General Skills for all Physics and Astronomy courses*

Students are expected to acquire:

6) Critical Thinking Abilities
7) Quantitative Skills
8) Communication Skills

Since all courses are expected to incorporate these learning objectives, they are not indicated in the matrix below.

### B.1.b. Aligning Physics Courses with Learning Objectives

**Major Courses**

| Courses/ Objectives | P114 | P116 | P210A/B | P209A/B | P214 | P216 | P313 | P313L | P314 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | X | X | X | X | X | X | X | X | X |
| 2 | X | | X | | X | | X | | X |
| 3 | X | | X | | X | | X | X | X |
| 4 | | X | | X | | X | | X | |
| 5 | | X | | X | | X | | X | |

| Courses/ Objectives | P 320 | P325 | P340 | P366 | P381 | P430 |
|---|---|---|---|---|---|---|
| 1 | X | X | X | X | X | X |
| 2 | X | X | X | | X | X |
| 3 | X | X | X | | X | X |
| 4 | | | | X | | |
| 5 | | | | X | | |

| Courses/ Objectives | P445 | P450 | P460 | P466 | P475 | P492 | P493 |
|---|---|---|---|---|---|---|---|
| 1 | X | X | X | X | X | X | X |
| 2 | X | X | X | | X | X | X |
| 3 | X | X | X | X | X | X | X |
| 4 | | | | X | | X | X |
| 5 | X | | | X | | X | X |

| Courses/ Objectives | P497 | A331 | A380 | A482 | A492 | A497 |
|---|---|---|---|---|---|---|
| 1 | X | X | X | X | X | X |
| 2 | X | | X | | X | X |
| 3 | X | | X | | X | X |
| 4 | X | X | | X | X | X |
| 5 | X | X | | X | X | X |

**General Education Courses:**

| Courses/ Objectives | P100 | P102 | P300 | P342 | A100 | A231 | A303 | A305 | A350 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | X | X | X | X | X | X | X | X | X |
| 2 | | X | X | X | | X | X | X | X |
| 3 | | X | | | | X | | | |
| 4 | | X | | | | X | | | |
| 5 | | | | | | | | | |

1) Knowledge, understanding and use of the principles of physics and/or astronomy
2) Ability to use reasoning and logic to define a problem in terms of principles of physics
3) Ability to use mathematics and computer applications to solve physics and/or astronomy problems
4) Ability to design and/or conduct experiments and/or observations using principles of physics and/or astronomy and physics or astronomical instrumentation
5) Ability to properly analyze and interpret data and experimental uncertainty in order to make meaningful comparisons between experimental measurements or observation and theory

## B.2 Standards and Trends in the Discipline

The physics curriculum at SSU is aligned with the common curriculum that has been developed by consensus throughout the US. According to a special study funded by the NSF and conducted through the American Institute of Physics (http://www.aapt.org/Projects/upload/SPIN-UP-Final-Report.pdf) :

> "The commonality among physics departments lies in the physics curriculum. Most college level introductory physics courses across the country cover a common set of standard topics, usually in a one-year course (two semesters or three quarters), including classical mechanics (roughly the first half of the course), and electricity and magnetism (roughly the second half).These courses are generally taught in the traditional lecture/lab/recitation format. A mix of "modern physics" topics, including special relativity and quantum physics, is often covered in an additional semester or quarter. The "core" upper-level courses (advanced mechanics, advanced electricity and magnetism, and quantum mechanics) are even more homogeneous with a relatively small number of standard textbooks used across the country. This homogeneity in curriculum is somewhat surprising because, unlike chemistry and engineering, the physics community has no formal certification or accrediting program for undergraduate programs. The situation in physics is more akin to that in mathematics in which the community of faculty has over the years reached an informal consensus about what constitutes the core of an undergraduate program. The undergraduate physics program, at least for those students who are considering graduate work in physics, is remarkably uniform."

Survey data from the SPIN-UP report ant presented in the American Association of Physics Teachers publication "Guidelines for Self-Study and External Evaluation of Undergraduate Physics Programs" (http://www.aapt.org/Resources/upload/Guide_undergrad.pdf has been added to corresponding information four our department in the following table:

Course Requirements and Undergraduate Degree Program

| | National | | SSU | | | |
|---|---|---|---|---|---|---|
| Required Course | BS | BA | BS | BS-A | BA-C | BA-T |
| Introductory classical physics | 99% | 99% | R | R | R | R |
| Intermediate classical mechanics | 97% | 88% | R | E | E | - |
| Introductory modern physics | 95% | 94% | R | R | R | R |
| Intermediate electromagnetism | 96% | 88% | R | R | R | - |
| Advanced laboratory | 90% | 74% | R | R | R | - |
| Quantum mechanics | 88% | 74% | R | R | R | - |
| Thermal and/or statistical physics | 82% | 57% | R | R | R | - |
| Mathematical physics | 45% | 38% | R | R | E | - |
| Optics | 46% | 24% | R | R | R | R* |
| Other physics courses | 85% | 82% | R | R | R | R |
| | | | | | | |
| Number of survey respondents | 387 | 92 | | | | |

The survey data is presented in the first two columns as percentages of programs requiring this course. The last four columns represent the (R) required, (-) not required, and (E) elective courses for our BS, BS-Applied, BA-Calculus, and BA-Trig. And algebra.

*Modern Physics and Optics at the BA-Trig and Algebra level is addressed in the Astronomy 305, Frontiers in Astronomy, and Physics 342, Light and Color courses respectively.

Comparing the courses required in our B.S. major curriculum to several other roughly equivalent universities, we find:

| Courses | P114 | P116 | P214 | P216 | P313 | P313L | P314 |
|---|---|---|---|---|---|---|---|
| Universities | First year course including Lab: Mechanics and E&M | | | | Electronics & Lab | | Modern Physics |
| Humboldt State Univ. | R | R | R | R | R 2 semesters | | R |
| CSU East Bay | 1Q@5 | | 1Q@5 | | 1Q@4 | | 1Q@3 |
| College of Charleston | R | R | R | R | E | E | R |
| SUNY Geneseo (BS Appl.) | R | R | R | R | E | E | 2 semesters |

| Courses | P 320 | P325 | P340 | P366 | P381 | P430 | P450 | P460 |
|---|---|---|---|---|---|---|---|---|
| Universities | Adv. Mech. | Math. Phys. | Optics | Inter. Lab | Comp. Pgm. | Adv. E&M | Stat. Mech. | Adv. QM |
| Humboldt State Univ. | R | R | R | R | R | R 2 sem. | R | R |
| CSU East Bay | 2Q@3 | - | 1Q@3 | 2Q@4 | 1Q@4 | 3Q@3 | 2Q@3 | 3Q@3 |
| College of Charleston | R | - | E/Pho-tonics | R | - | R | E | R |
| SUNY Geneseo (BS Appl.) | R | R | Incl. with Mod. | R | 2 sem. in CS | E | E | E |

In the above table, "R" means required, "E" means elective, "-" means not required or elective. Note that CSU East Bay is on the quarter system, so the number of quarters and hours per quarter are indicated, e.g. 2Q@3 means two quarters at 3 hours per quarter.

These Universities were chosen because they are similar to SSU (within the CSU, both Humboldt and East Bay do not have large engineering programs) in size and mission, and SUNY Geneseo and College of Charleston are fellow COPLAC Universities with combined Physics and Astronomy Departments. SUNY Geneseo was studied by the NSF/AIP task force as an example of a "thriving department" and College of Charleston has a much higher percentage of physics majors compared to the nation-wide average.

### B.3 Comparisons to Similar Programs at Comparable Universities:

*Electronics and intermediate laboratory work:* Humboldt State requires two semesters of electronics and instrumentation work, with laboratory, but does not require an intermediate laboratory class. At both College of Charleston and SUNY Geneseo, Electronics is a strongly-recommended elective for BS physics majors, but is not required. Intermediate laboratory classes are required at both, however. Nine of twelve programs reporting to a CSU Physics Chairs meeting require an electronics class.

*Mathematical Physics:* Three of the four comparable universities do not offer a Mathematical Physics class within the department, but assume the students will obtain sufficient mathematical background through the co-curricular requirements in Mathematics. This has not been our experience, which is why we moved the class to a 300-level several years ago – our students need the extra mathematics preparation in order to succeed in the upper division classes. Six of twelve programs reporting to a CSU Physics Chairs meeting require a Mathematical Physics course.

*Computational Skills:* Two of the four universities require comparable courses to our Physics 381, Computer Programming for Scientists, while one requires that two semesters be taken in the computer science department, and the other has no specific requirement. Three of twelve programs reporting to a CSU Physics Chairs meeting require a Computational Skills course.

*Advanced Electricity and Magnetism:* Humboldt State requires a three-semester sequence of Advanced E&M, CSU East Bay requires three quarters of Advanced E&M, College of Charleston requires one semester and does not appear to regularly offer the second semester, while SUNY Geneseo offers two semesters of this class as electives. SSU used to offer two semesters of Advanced E&M, however this was dropped several years ago as a result of pressure to lower the total number of units in the major. All of twelve programs reporting to a CSU Physics Chairs meeting require this course and nine of twelve require two or more semesters.

*Advanced Quantum Mechanics*: Humboldt State requires one semester of Advanced QM, CSU East Bay requires three quarters of Advanced QM, College of Charleston requires one semester and offers the second semester every other year as electives, while SUNY Geneseo considers this course an elective for their BS/Applied degree, and regularly offers the first semester of this class, with the second semester offered in alternate years. SSU used to offer two semesters of Advanced QM, however this was also dropped several years ago as a result of pressure to lower the total number of units in the major. All of twelve programs reporting to a CSU Physics Chairs meeting require this course and five of twelve require two or more semesters.

### B.4 Surveys of Alumni Used to Assess Educational Effectiveness

Each year we have asked all of our graduates to keep in touch with the Department and to report their contact information, achievements, and comments on their education at SSU. Prior to our last program review in 2008 we added four questions on the questionnaire (which may be seen at http://www.phys-astro.sonoma.edu/gradupdate.shtml):

THE FOUR QUESTIONS:

a) “Skills”: What technical skills do you use in your daily job that you can attribute to your SSU physics education?

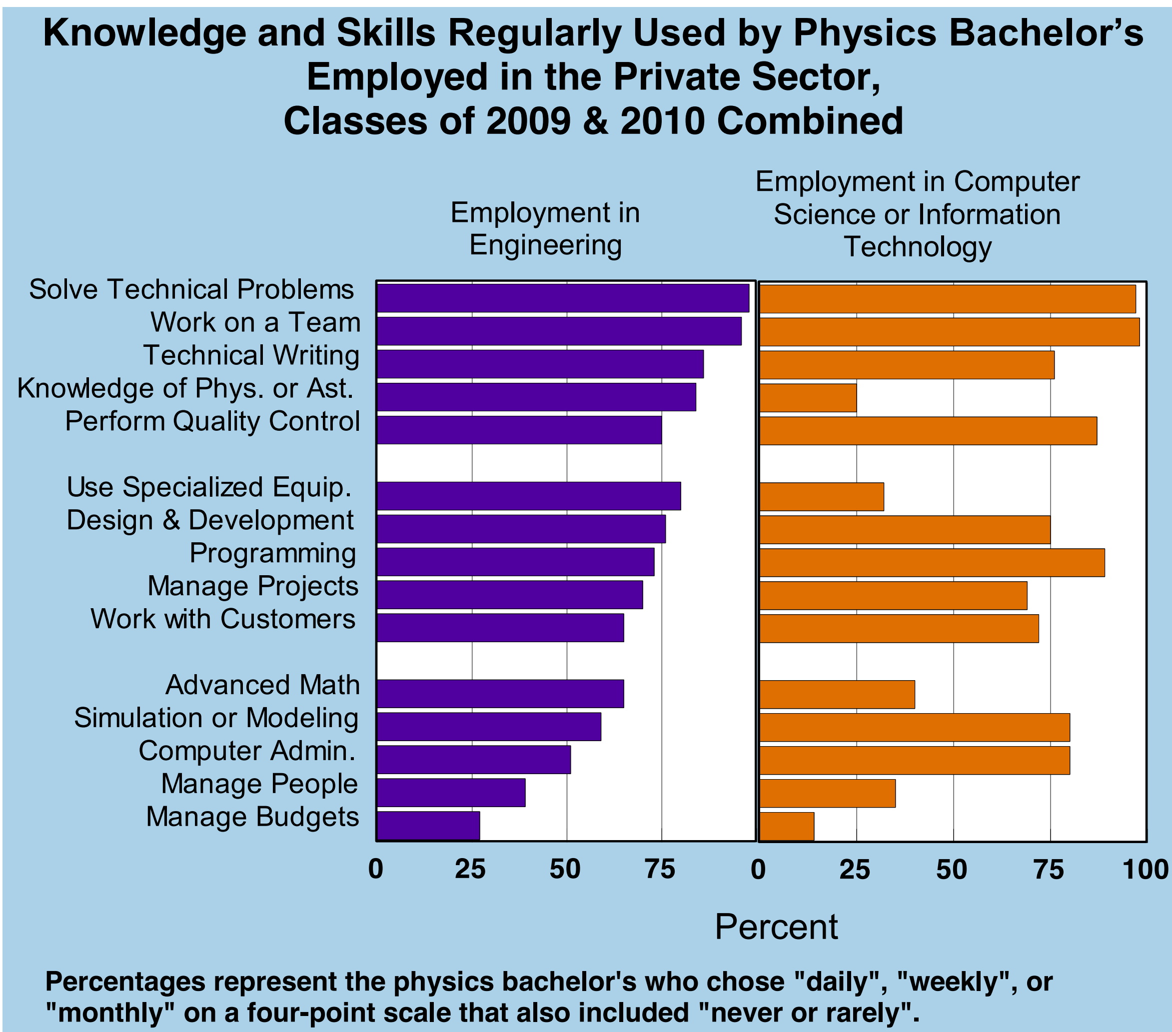
b) “Lacking”: As you look back at your SSU physics education, what one or two skills did you find lacking?

c) “Impact”: What impact did your SSU education in physics have on your subsequent career and life?

d) “News”: Other news

Answers to the "News" question were used to write the paragraphs which appear on the Department website at http://www.phys-astro.sonoma.edu/gradsAchievements.shtml and are reproduced in Appendix B. Answers to the remaining questions received during the 2007-08 and 2006-07 academic years are summarized here. Some of our graduates from the earlier years of the department's existence report that they feel that they lack adequate modeling capabilities as well as computer programming experience. Others have noted that they wished they had more experience in writing and oral presentation. We have worked during the history of the department to realign some of our upper division courses to address these skills deficits. Although we do not have quantitative data to compare to the AIP data summarized below, we carefully read the annual responses from our graduates and have considered these in updating the alignment of skills with respect to our curriculum (Section B.5). Changes in the program resulting from this analysis are discussed in section G.3 below.

The figure below from the American Institute of Physics (http://www.aip.org/statistics/data/employment) shows the importance placed on various skills used by physics bachelors employed by the private sector.



## B.5 Skills Development for Degree Programs in Physics and Astronomy

### B.5.a. Academic Programs

The Physics and Astronomy program offers four different degree programs and two minors. A general description of the goals for each program is given below. For details of the actual courses required for each degree program, see our catalog (Appendix K). For reference, we include a brief summary of the proposed changes to each degree program as put forward in our Section H: Action Plan.

**a)** **B.S. degree:** The B.S. program is a thorough introduction to the principles of physics, providing a strong foundation for graduate study or industrial research. It is also intended for those students who wish to prepare for interdisciplinary studies on the graduate level in fields such as astronomy, atmospheric science, biophysics, environmental science, geophysics, materials science, and physical oceanography

**b)** Currently: **B.S. Applied:** Students may earn a B.S. in physics with a concentration in applied physics. This program is intended for those students who desire an emphasis on laboratory work. It provides a rigorous, yet slightly less theoretical course of study, and a greater selection of hands-on electives. It is a good choice for students who wish to continue their studies in graduate engineering programs, or who wish to work in industry in engineering or computationally oriented positions. Ultimately, this is not sufficiently different enough from standard B.S. and we recommend replacing it.

Becomes (See Section H: Action Plan): **B.S. Applied: Astrophysics**: Students may earn a B.S. in physics with a concentration in Astrophysics. This program is intended for those students who are motivated to study physics through their interest in Astronomy, an area of growth in the major we recognize. It provides a rigorous, yet astronomically themed, course of study. The selection of electives allows the student to choose physics classes to round out preparation for graduate study, or to focus on our upper division general education Astronomy electives for an emphasis on the classes that motivate their pursuit of a rigorous STEM program.

**c)** Was: **B.A. – Calculus (B.A.-C):** Students who choose this advisory plan have the prerequisites to take nearly all of the courses in the department. They find employment in scientific and engineering fields. Some go on to graduate school in interdisciplinary sciences. This degree program is appropriate for those who wish to earn a California Science Teaching Credential with a concentration in Physics.

Becomes (See Section H: Action Plan): **B.A. – Physics:** This suggested change is a “re-branding” of this degree to remove the awkward listing of the mathematical rigor. It remains as a flexible but rigorous program that pairs well with multiple career pathways.

**d)** Currently: **B.A. – Algebra/Trignometry (B.A.-T):** Students may select from upper-division courses, appropriate to careers as science or technical writers, scientific sales personnel, technicians, programmers, or other technical specialists. There is opportunity to take courses that lead to careers in the health sciences or environmental fields. This degree program is appropriate for those who wish to earn a California Multiple Subject Teaching Credential. This advisory plan is often taken as part of a double major.

Becomes (See Section H: Action Plan): **B.A. – Physical Science:** Motivated by the lack of interest in the B.A.-T, the small number of upper-division electives taught without calculus, and the desire to produce more well-trained middle school STEM educators, we propose replacing it with this program. This degree program is offers a pathway to serve as a Foundational Science waiver, and is a strong STEM-focused liberal arts degree.

e) **Minor in Physics:** The minor in physics is often combined with other B.S. degrees, such as Mathematics. It is useful for chemistry majors, health science majors, and business majors who wish to work in the high-tech industry. It also provides deeper insight into te physical world as well as enhanced quantitative reasoning and problem solving skills.

f) **Minor in Astronomy:** The Astronomy minor has been paired with our Physics B.S. as a preparation for astronomy graduate school, or taken by students in other disciplines to pursue their passion in this area and generate a set of STEM skills outside of their primary degree. It serves as a low-barrier entry into our program and we have seen it paired with an incredible array of major programs: business, psychology, theater arts just to name a few. Career fields for which an astronomy minor would be beneficial include aerospace, astronomy, atmospheric science, education, planetary geology, and geophysics.

### B.5.b Skills Assessment Matrices

Our skills Assessment matrices date back to 2003. Then, the Department held a retreat in which we first discussed the skills that we wanted to develop for each degree program, and in which classes these skills would be taught and then used. We realize that course content for upper division physics lecture courses is fairly standardized (see Section B.2). However, even though the ability to solve physics problems is necessary, it is not sufficient to produce employable physics graduates, or to develop research capabilities for those who wish to attend graduate school or work in highly technical fields.

As part of our prior 2008 self study, we revised the Skills Assessment charts to include several items that our Alumni Survey (see Section B.4) indicated were important: presentation skills, oral speaking skills, and writing skills. For this self-study, we once again revamped the Skills Assessment charts to: update the skill listings; group them according to thematic areas,; and reassess where these skill are taught within the curriculum.

*Table B-1. Skills Assessment vs. Academic Knowledge Base* shows a summary of the ratings by the five participating tenured and adjunct faculty of the courses in which the particular skills should be taught and then used. (The first course in the sequence that uses this skill should be the one in which the skill is first taught, so that subsequent courses can assume that the students possess the skill, with perhaps some refreshing.) The skills are then shaded to show where a skill is addressed in that class. For example, the Department has agreed to ensure that all lower division students are taught to use Excel in both lecture and laboratory courses in the algebra-trig and calculus-based first year sequence. Laboratory interface, multimeter and oscilloscope skills, as well as error analysis, curve fitting and regression and graphics and plotting will be taught and used beginning in lower division laboratory courses. General programming and symbolic languages will be used in upper division physics major courses, and will be specifically taught in Physics 381 (Computer Applications for Scientists). Dimensional analysis as well as problem solving logic will be taught and used in each physics and astronomy course, including general education classes. Our Intermediate Lab class (P366) will be the first class to heavily use research skills, including literature searches, annotated bibliographies, and data evaluation. These skills will also be required for the capstone courses in both physics and astronomy. Practical astronomy skills will be concentrated in Astronomy 231, 331 and 482 as well as the astronomy capstone courses. The table is broken into three portions for clarity: lower-division physics courses, upper division physics course and astronomy courses.

We also place importance on communications skills, to be developed through GE and majors courses, so that by the time the students are doing their capstone experiences, they will have developed the ability to speak, write and do oral presentations. Of additional importance to the capstone projects is the ability to do literature searches, annotated bibliographies and data evaluation. These latter skills are key for the intermediate and advanced laboratory courses which lead up to the capstone experience.

And last but not least, the ability to solve second order differential equations analytically as well as numerically is an important proxy that represents the level of mathematical ability that we expect from our students, especially in the upper division theory courses.

**Table B-1. Skills Assessment vs. Academic Knowledge Base**

| Skill Assessment & Academic Knowledge Base Category | Skill | PHYS 100 | PHYS 102 | PHYS 114 | PHYS 116 | PHYS 209A | PHYS 209B | PHYS 210A | PHYS 210B | PHYS 214 | PHYS 216 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Critical Thinking | Logic | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Problem Solving | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Math | Statistics & Probability | 0 | 0 | 1 | ■ | ■ | ■ | 0 | 0 | 0 | ■ |
| | Basic Analytical | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Advanced Analytical | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ■ | ■ |
| | Computational & Numerical | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Estimation & Order of Magnitude | ■ | 1 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Basic Laboratory Skill | Lab Safety | 0 | ■ | 0 | ■ | ■ | ■ | 0 | 0 | 0 | ■ |
| | Lab Notebook & Note Taking | 0 | ■ | 0 | ■ | ■ | ■ | 0 | 0 | 0 | ■ |
| | Error Analysis | 0 | ■ | 0 | ■ | ■ | ■ | 0 | 0 | 0 | ■ |
| | Electronic: Soldering | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ■ |
| | Electronic: Multimeter | 0 | ■ | 0 | 0 | 0 | ■ | 0 | 0 | 0 | ■ |
| | Electronic: Function Generator | 0 | 0 | 0 | 0 | 0 | ■ | 0 | 0 | 0 | ■ |
| | Electronic: Oscilloscope | 0 | 0 | 0 | 0 | 0 | ■ | 0 | 0 | 0 | ■ |
| | Electronic: AC/DC Circuitry | 0 | ■ | 0 | 0 | 0 | ■ | 0 | 0 | 0 | ■ |
| | Magnetism | 0 | ■ | 0 | 0 | 0 | ■ | 0 | 0 | 0 | ■ |
| | Optics | 0 | ■ | 0 | 0 | 0 | ■ | 0 | 0 | 0 | ■ |
| | Mechanics | 0 | ■ | ■ | ■ | ■ | 1 | ■ | 0 | 0 | 1 |
| Advanced Lab Skill | 3D Printing | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | AutoCAD & 3D Modeling | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Cryogenics | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Spectroscopy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SEM-AFM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | X-ray Diffraction | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Semiconductor Principles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Magnetometry | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Materials Processing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Thin film coating/Masking/Etching | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Wavefront Sensing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Wave Optics | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Telescope Control | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DataAcquisition and Manipulation | Mathematica | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | EXCEL | 0 | ■ | ■ | ■ | ■ | ■ | 0 | 0 | 0 | ■ |
| | MathCad | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | MatLab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Interface (Labview) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Interface (PASCO) | 0 | ■ | 0 | ■ | ■ | ■ | 0 | 0 | 0 | ■ |
| | Unit Analysis | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Graphing & Data Plotting | 0 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Curve Fitting & Regression | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | ■ |
| | Fourier Analysis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | Image Processing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Information Literacy | Literature Search | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Preparing Annotated Bibliographies | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Scientific Writing | 0 | ■ | 0 | ■ | ■ | ■ | 0 | 0 | 0 | ■ |
| Social | Cooperative Skills | 1 | ■ | 0 | ■ | ■ | ■ | ■ | ■ | 0 | ■ |
| | Leadership | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Ability to Explain | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Ability to Critique | 1 | ■ | 1 | 0 | 0 | 1 | 0 | 0 | 0 | ■ |
| | Presentation Skills (Oral & Poster) | 0 | ■ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Skill Assessment & Academic Knowledge Base Category | Skill | PHYS 300 | PHYS 313 | PHYS 313L | PHYS 314 | PHYS 320 | PHYS 325 | PHYS 340 | PHYS 342 | PHYS 366 | PHYS 381 | PHYS 430 | PHYS 445 | PHYS 450 | PHYS 460 | PHYS 466 | PHYS 475 | PHYS 492 | PHYS 493 | PHYS 495 | PHYS 497 | PHYS 494 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Critical Thinking | Logic | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| | Problem Solving | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Math | Statistics & Probability | | | X | X | | X | X | X | X | X | | X | X | X | X | X | | X | X | X | |
| | Basic Analytical | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | |
| | Advanced Analytical | | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | | X | X | X | |
| | Computational & Numerical | | X | X | X | X | X | X | | X | X | X | X | X | X | | X | | X | X | X | |
| | Estimation & Order of Magnitude | | X | X | X | X | X | X | | X | | | | X | X | | | | | | | |
| Basic Laboratory Skill | Lab Safety | | | X | | | | | | X | | | X | | | X | | | X | X | X | |
| | Lab Notebook & Note Taking | | | X | | | | | | X | | | | | | X | | X | X | X | X | |
| | Error Analysis | | | X | | | | | | X | X | | | | | X | | X | X | X | X | |
| | Electronic: Soldering | | | X | | | | | | X | | | | | | X | | | X | X | X | |
| | Electronic: Multimeter | | | X | | | | | | X | | | | | | X | | | X | X | X | |
| | Electronic: Function Generator | | | X | | | | | | X | | | | | | X | | | X | X | X | |
| | Electronic: Oscilloscope | | | X | | | | | | X | | | | | | X | | | X | X | X | |
| | Electronic: AC/DC Circuitry | | | X | | | | | | X | | X | | | | X | | | X | X | X | |
| | Magnetism | | | X | | | | | | X | | X | | | | X | | | X | X | X | |
| | Optics | | | | | | | X | X | X | | | X | | | X | | | X | X | X | |
| | Mechanics | | | | | X | | | | X | | | | | | X | | | X | X | X | |
| Advanced Lab Skill | 3D Printing | | | | | | | | | | | | | | | | | | X | X | X | |
| | AutoCAD & 3D Modeling | | | | | | | | | | | | | | | | | | X | X | X | |
| | Cryogenics | | | | | | | | | X | | | | | | X | | | X | X | X | |
| | Spectroscopy | | | | | | | | | X | | | | | | | | | X | X | X | |
| | SEM-AFM | | | | | | | | | X | | | | | | | | | X | X | X | |
| | X-ray Diffraction | | | | | | | | | X | | | | | | | | | X | X | X | |
| | Semiconductor Principles | | | | | | | | | X | | | X | | | | X | | X | X | X | |
| | Magnetometry | | | | | | | | | X | | | | | | X | | | X | X | X | |
| | Materials Processing | | | | | | | | | X | | | | | | X | X | | X | X | X | |
| | Thin film coating/Masking/Etching | | | | | | | | | X | | | X | | | | X | | X | X | X | |
| | Wavefront Sensing | | | | | | | | | | | | | | | X | | | X | X | X | |
| | Wave Optics | | | | | | | X | | | | | X | | | X | | | X | X | X | |
| | Telescope Control | | | | | | | | | | | | | | | | | | | | | |
| DataAcquisition and Manipulation | Mathematica | | X | X | X | X | X | X | | | X | X | X | X | X | | | | X | X | X | |
| | EXCEL | | X | X | X | | X | X | | X | X | | | X | | | | X | X | X | X | |
| | MathCad | | X | | X | X | X | | | X | X | X | | | | | | | | | | |
| | MatLab | | X | | | X | X | | | | X | | | | | | | | | | | |
| | Interface (Labview) | | | | | | | | | X | X | | | | | X | | | | | | |
| | Interface (PASCO) | | X | X | | | | | | | | | | | | X | | | | | | |
| | Unit Analysis | X | X | X | X | X | X | X | X | X | X | X | X | X | | X | X | | X | X | X | |
| | Graphing & Data Plotting | X | X | X | X | X | X | X | | X | X | | X | X | | X | X | X | X | X | X | |
| | Curve Fitting & Regression | | X | X | | | X | X | | X | X | | | X | | X | X | | | X | X | |
| | Fourier Analysis | X | X | X | | | X | X | | | X | | X | | | | | | | | | |
| | Image Processing | | | | | | | X | | | | | | | | X | | | | | | |
| Information Literacy | Literature Search | | | | | | | | | | | | | | | X | | X | X | X | X | X |
| | Preparing Annotated Bibliographies | | | | | | | | | | | | | | | X | | X | X | X | X | X |
| | Scientific Writing | X | | X | | | | | | X | | | | | | X | | X | X | X | X | X |
| Social | Cooperative Skills | X | | X | | | X | | X | X | X | | | | | X | | X | X | X | X | |
| | Leadership | | | | | | | | | X | | | | | | X | | X | X | X | X | |
| | Ability to Explain | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| | Ability to Critique | | | X | | X | X | | X | X | X | X | | | X | X | X | X | X | X | X | X |
| | Presentation Skills (Oral & Poster) | | | | | | | | X | X | | | | | | X | | X | X | X | X | |

| Skill Assessment & Academic Knowledge Base Category | Skill | ASTR 100 | ASTR 231 | ASTR 303 | ASTR 305 | ASTR 331 | ASTR 350 | ASTR 380 | ASTR 396 | ASTR 482 | ASTR 492 | ASTR 495 | ASTR 497 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Critical Thinking | Logic | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Problem Solving | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Math | Statistics & Probability | 0 | ■ | 0 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Basic Analytical | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Advanced Analytical | 0 | 0 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Computational & Numerical | 0 | ■ | 0 | 0 | ■ | ■ | ■ | ■ | ■ | 0 | ■ | ■ |
| | Estimation & Order of Magnitude | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 0 | ■ | ■ |
| Basic Laboratory Skill | Lab Safety | 0 | ■ | 0 | 0 | ■ | 0 | 0 | 0 | ■ | ■ | ■ | ■ |
| | Lab Notebook & Note Taking | 0 | ■ | 0 | 0 | ■ | 0 | 0 | 0 | ■ | ■ | ■ | ■ |
| | Error Analysis | 0 | ■ | 0 | 0 | ■ | 0 | 0 | 0 | ■ | ■ | ■ | ■ |
| | Electronic: Soldering | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ■ | ■ |
| | Electronic: Multimeter | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ■ | ■ |
| | Electronic: Function Generator | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Electronic: Oscilloscope | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Electronic: AC/DC Circuitry | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ■ | ■ |
| | Magnetism | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Optics | 0 | 0 | 0 | 0 | ■ | 0 | 0 | 0 | ■ | 0 | ■ | ■ |
| | Mechanics | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Advanced Lab Skill | 3D Printing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ■ | ■ |
| | AutoCAD & 3D Modeling | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Cryogenics | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Spectroscopy | 0 | ■ | 0 | 0 | 0 | 0 | 0 | 0 | ■ | 0 | ■ | ■ |
| | SEM-AFM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | X-ray Diffraction | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Semiconductor Principles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Magnetometry | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Materials Processing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Thin film coating/Masking/Etching | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ■ | ■ |
| | Wavefront Sensing | 0 | 0 | 0 | 0 | ■ | 0 | 0 | 0 | ■ | 0 | ■ | ■ |
| | Wave Optics | 0 | ■ | 0 | 0 | ■ | 0 | 0 | 0 | ■ | 0 | ■ | ■ |
| | Telescope Control | 0 | ■ | 0 | 0 | ■ | 0 | 0 | 0 | ■ | 0 | ■ | ■ |
| DataAcquisition | Mathematica | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| and Manipulation | EXCEL | 0 | ■ | 0 | 0 | ■ | 0 | 0 | 0 | ■ | ■ | ■ | ■ |
| | MathCad | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | MatLab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Interface (Labview) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Interface (PASCO) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Unit Analysis | ■ | ■ | 0 | ■ | 0 | ■ | 0 | 0 | 0 | 0 | ■ | ■ |
| | Graphing & Data Plotting | 0 | ■ | 0 | ■ | ■ | ■ | 0 | 0 | ■ | ■ | ■ | ■ |
| | Curve Fitting & Regression | 0 | ■ | 0 | 0 | ■ | ■ | 0 | 0 | ■ | 0 | ■ | ■ |
| | Fourier Analysis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ■ | 0 | ■ | ■ |
| | Image Processing | 0 | ■ | 0 | 0 | ■ | 0 | 0 | 0 | ■ | 0 | ■ | ■ |
| Information Literacy | Literature Search | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 0 | ■ | ■ | ■ | ■ |
| | Preparing Annotated Bibliographies | 0 | ■ | ■ | ■ | ■ | ■ | ■ | 0 | ■ | ■ | ■ | ■ |
| | Scientific Writing | 0 | ■ | ■ | ■ | ■ | ■ | ■ | 0 | ■ | ■ | ■ | ■ |
| Social | Cooperative Skills | 0 | ■ | ■ | ■ | ■ | ■ | ■ | 0 | ■ | 0 | ■ | ■ |
| | Leadership | 0 | ■ | 0 | ■ | ■ | 0 | 0 | 0 | ■ | 0 | ■ | ■ |
| | Ability to Explain | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 0 | ■ | ■ | ■ | ■ |
| | Ability to Critique | 0 | ■ | ■ | ■ | ■ | ■ | ■ | 0 | ■ | ■ | ■ | ■ |
| | Presentation Skills (Oral & Poster) | 0 | ■ | ■ | ■ | ■ | ■ | ■ | 0 | ■ | ■ | ■ | ■ |

## B.6 General Education and Service Courses

### B.6.a. General Education Requirements

During the period since our last Program Review in 2008 Sonoma State University established learning objectives for the GE requirements. The Department of Physics and Astronomy maintained a representative at the University level during the process of drafting and ratifying the GE learning objectives and outcomes. The results of these effort are shown in Section B.6.c below.

The Department of Physics and Astronomy offers a number of courses that satisfy the physical science requirements (Area B1 and B3). From the original General Education-Breath Requirements established in executive order No. 595 from the California State University Chancellor in 1993 (http://calstate.edu/EO/EO-595.pdf):

> "Area B: A minimum of twelve semester units or eighteen quarter units to include inquiry into the physical universe and its life forms, with some immediate participation in laboratory activity, and into mathematical concepts and quantitative reasoning and their applications. Instruction approved for the fulfillment of this requirement is intended to impart knowledge of the facts and principles which form the foundations of living and non-living systems. Such studies should promote understanding and appreciation of the methodologies of science as investigative tools, the

> limitations of scientific endeavors: namely, what is the evidence and how was it derived? In addition, particular attention should be given to the influence which the acquisition of scientific knowledge has had on the development of the world's civilizations, not only as expressed in the past but also in present times. The nature and extent of laboratory experience is to be determined by each campus through its established curricular procedures. In specifying inquiry into mathematical concepts and quantitative reasoning and their application, the intention is not to imply merely basic computational skills, but to encourage as well the understanding of basic mathematical concepts."

On the SSU campus, Area B has been divided into 4 areas; (P&A areas shown in **bold**)

- **B1: 3 units of lower division physical science**
- B2: 3 units of lower division life science
- **B3: 3 more units of science, which could be any B1 course or any of several others, some of them upper division**
- B4: Mathematics

### B.6.b General Education Courses Offered

The Department of Physics and Astronomy offers courses to satisfy the B1 and B3 requirements.

The B1 courses offered include:

ASTR 100 Descriptive Astronomy
ASTR 231 Introductory Observational Astronomy
PHYS 100 Descriptive Physics
PHYS 102 Descriptive Physics Lab
PHYS 114 Introduction to Physics
PHYS 116 Introductory Laboratory Experience
PHYS 209A General Physics Laboratory
PHYS 210A General Physics

The B3 courses offered include all of the above and:

ASTR 303Life in the Universe
ASTR 305 Frontiers in Astronomy
ASTR 350 Cosmology
PHYS 300 Physics of Music
PHYS 342 Light and Color

Under a broader auspice of General Education, the Department of Physics & Astronomy has been instrumental in the offering of Science 120: A Watershed Year, a STEM First Year Experience course. This is discussed in detail in Appendix G. The course combines biology, math modeling, and critical thinking to address issues surrounding the local Russian River watershed while facilitating strong personal connections with SSU. It augments its innovative pedagogical approach with supplemental instruction and additional academic and career advising, tutoring, and undergraduate research opportunities for students. All of this is done to help retain students in STEM.

### B.6.c. SSU General Education Learning Objectives

SSU redefined the learning objectives for Area B in October 2008. The new overall Area B learning objectives are listed below and our current offered courses are aligned with and meet the current learning objectives.

**AREA B** (Final)

In natural sciences, humans use their perceptions and quantitative reasoning to discover the principles and rules that govern how the universe works. Courses in this area of general education examine important theories of the natural sciences, and methods and models by which scientific investigation proceeds. They also seek to increase scientific understanding and to imbue students with the sense of curiosity and wonder about the natural world that inspires scientists and mathematicians in their work.

1. Students will develop knowledge of scientific theories, concepts, and data about living and non-living systems.

2. Students will understand how the scientific method is used to develop scientific principles and interpret evidence.

3. Students will appreciate the value systems and ethics associated with scientific inquiry, and the potential limits of scientific endeavors.

4. Students will demonstrate understanding of the scientific method through laboratory exercises.

5. Students will be able to read and understand mathematical arguments and data, and use mathematics effectively to analyze and solve problems that arise in ordinary and professional life.

*(Authored by Jim Christmann, Karin Jaffe, Matt James, Jeremy Qualls, Ben Ford)*

**Area B1** (Final)

1. Students will gain an understanding of the fundamental laws and principles governing the behavior of the physical world.

2. Students will understand the physical world through interpretation of results from experimentation and/or observation.

3. Students will learn that there are interactions between matter and energy and use this knowledge to understand physical, chemical, or geological phenomena.

4. Students will develop a basic understanding of physical matter and the scientific method so that they can apply this understanding to more complex systems.

*(Authored by Matt James, Jeremy Qualls, Carmen Works)*

**Area B3** (Final)

1. Students will improve their understanding of the concepts and theories of science and technology

2. Students will understand the interconnected and every-changing relationships among the natural, physical, and technological sciences

3. Students will critically assess the social and ethical implications of science and technology in relations to their daily lives.

4. Students will improve problem solving and critical thinking skills through application of scientific knowledge using hands-on activities.

*(Authored by Jeremy Qualls, Dolly Freidel, Tia Watts, Jagan Agrawal, Matt James, Nick Geist, Karin Jaffe)*

**B.6.d. Service Courses**

The Physics and Astronomy Department teaches a variety of “service courses” that primarily serve other departments. The courses described in this section are also GE courses that serve areas B1 and/or B3.

The classes described below satisfy general GE learning objectives including critical thinking abilities, quantitative skills and communication skills, however most do this within a descriptive and conceptual framework. The calculus and algebra-trig based sequences meet the general GE learning objectives, but require more rigorous problem solving and mathematical skills. Enrollment totals for many of these classes are summarized in a table presented in Appendix A. Learning objectives and/or syllabi for these courses are given in Appendix J.

***Introductory physics courses*****:** We offer three levels of first-semester physics courses. *Introductory Physics* (P114) is our calculus-based first semester course, P210A is our algebra-trig based first semester course, and P100 is our Descriptive Physics course. All three of these courses meet the B1 General Education requirement, however P114 is taken primarily by physics, engineering science, and mathematics majors, plus a few B.S. chemists and biologists. It has an accompanying laboratory class, P116, which is not required for the mathematics majors. P114/116 are part of a year-long sequence with P214/216. We offer both P114/P116 and P214/216 each semester.

*General Physics* (P210A), which uses algebra and trigonometry, is taken by the bulk of the biology and geology majors, along with environmental studies majors, B.A. chemists, and kinesiology majors who intend to go into physical therapy. It has an accompanying laboratory course, P209A, which is required for most of the students who take P210A. These courses are part of a year-long sequence, with P210B and 209B. We offer both P210A/209A and P210B/209B each semester.

*Descriptive Physics* (P100) is taken by an assortment of majors, as a lower division GE requirement. We also offer the P102 laboratory, as a separate 1-unit course, which fulfills the GE lab requirement. This has proven to be a popular course for those who do not wish to take 3 or 5 unit biology or chemistry classes to get that one unit of laboratory..

We have previously noted a significant drop-off in enrollment for the second semester course in both the algebra-trig sequence and the calculus sequence, as neither are required for some of the majors. For example, in the calculus-based sequence, the second semester is not required for mathematics majors. For the algebra-trig based sequence, the second-semester course is not required for some concentrations within the Kinesiology major or for the B.A. degree in Biology, and the laboratory courses are not required for the B.S. degree from Environmental Studies and Planning.

***Lower Division Astronomy General Education courses*:**

*Descriptive Astronomy* (A100) is our most popular course, accounting for basically 50% of our department's FTES each semester. It meets the B1 and B3 General Education requirement, and the variations in enrollment reflect the number of sections that we have the budget and personnel to offer. It almost always fills whatever rooms we are able to teach it in. Due to the extremely large size of these lecture classes testing is of the machine-scored multiple choice type and writing assignments are graded with the assistance of course management software assignment upload and TurnItIn originality checks. It is taken by many first time freshmen and we try to recruit physics majors and astronomy minors from each section of this class each semester.

The structure of the course may vary from instructor to instructor, but key components of this class are a survey of the composition, history and fate of the Universe, an appreciation of the underlying physics (gravity, light, atomic structure) and an emphasis on the processes of science (the scientific method, hypotheses, the scientific definition of "Theory" etc.). This course, due to its size and student composition, presents some unique pedagogical challenges and we have just re-introduced a "Supplemental Instruction" section in Spring 2015. We had tried this in 2008 but found the constraints in the model of the SI program then (limited contact between the SI tutor and the course instructor) limiting. With the recent PhysTEC teacher recruitment grant, we reached out to the new head of the SI program and found it to me much more friendly to faculty direction of the SI student activities. This program creates an organized and regular "study group" attached to certain SSU courses with high faculty-to-student ratios. The section is taught by an upper-division Physics major paid by the SSU Tutorial Program. This in essence adds a Teaching Assistant and creates an extra session that may be taken with or without additional credit. Our goal in re-introducing this section is to provide students with alternate avenues to learning the course material with a lower student to instructor ratio.

*Introductory Observational Astronomy* (A231) is also a very popular course, but due to the laboratory component, has rather limited enrollment. In order to accommodate the increased demand, we now offer this three times a year, up from 1x/year pre-2008, and 2x year until the hire of our visiting, soon to be tenure-track hire. The class always fills up (24 students maximum). This course satisfies areas B1 or B3, as well as the GE laboratory requirement. This class is supposed to be taken after or concurrently with A100 and is also a potential source of new minors or majors. There are many sophomores who take this course, but it is also taken by students who are trying to finish their GE lab requirement.

This course is organized around the introduction to the actual techniques used by astronomers to obtain information about celestial objects. Each week one or more topics related to this theme ise discussed and then put into practice. These practical applications may be indoors using existing data, or outdoors using data obtained from the sky. The course also makes extensive useof software and data analysis techniques to explore the course themes.

***Upper Division GE courses in Physics and Astronomy:***

*Life in the Universe* (A303) is offered each fall and satisfies area B3. The course is an appraisal of the possibilities and prospects for life in the universe and travel to the stars. Topics covered include: the nature of life, habitability of Earth and other worlds within our Solar System, detection of planets beyond our Solar System, the search for life beyond Earth, and space travel. This course emphasizes the scientific method, especially the development of scientific theories founded in observational and experimental evidence. Students come to understand that science is a creative process of discovery -- with new knowledge built on observations, evidence, and logical reasoning – and the are able to describe evidence that supports major scientific understandings as well as lack of evidence for ideas that are not founded in science.

*Frontiers in Astronomy* (A305) is offered each fall and satisfies area B3. The course presents a survey of recent developments in astronomy and explains how these breakthroughs are made: the discovery of planets orbiting other stars; the explosive deaths of stars and the creation of neutron stars and black holes; and the study of the origin and fate of the Universe, including mysterious "dark matter" and "dark energy". The course has a pre-requisite of A100 and can thus cover topical material in greater depth, while retaining a General Education perspective. The course is constructed to enhance student's science literacy through a mix of reading and writing exercises that vary in format and difficulty. Core concepts are reinforced through small-group work that focuses on selection and evaluation of reference material, data analysis, problem-solving, and communicating results. The course attracts both from the broad GE audience and from Physics Majors and Astronomy Minors. The emphasis on topical research, critical thinking and communication skills provides a common ground for students with such a disparity in their educational goals and backgrounds.

*Cosmology* (A350) is offered in the spring and satisfies area B3. The course describes what we know about the Universe and how scientists have learned it. Topics include the Big Bang, cosmic inflation, surveys of galaxies, the origin and evolution of structure in the Universe, dark matter, and dark energy. The course emphasizes the scientific method and how our knowledge of the Universe has changed over time and will continue to change, but the method continues to work. There are usually two or three physics majors in this class, with the remainder being students who liked their first course in astronomy and want to go deeper into the subject while meeting both GE category B3 and an upper division GE requirement. This course is taught in a flipped class format and uses the "Big Ideas in Cosmology" an online text developed by a team led by Dr. Lynn Cominsky. The text and related materials place a focus on student interaction with real data and critical thinking. For more details see section E.1.

*Physics of Music* (P300) is was offered typically in the spring, but with the recent completion of the Green Music Center, interest in the course has increased and it is offered most semesters. It satisfies area B3. The course presents an introduction to physical principles encountered in the study of music; applicable laws of mechanics and acoustics; harmonic analysis; musical scales; sound production in musical instruments; and elements of electronic music. It also attempts to build a bridge between the modern world of technology and the historical roots of the many forms of music in our diverse societies. The course explores the science of sound and the relationship to the human voice, the various families of musical instruments including their historical evolution and the current methods to synthesize even the most complex of musical forms. It often appeals to music majors and is taken by B.A.-T physics majors.

*Light and Color* (P342) is offered in the fall, and satisfies area B3. This course is a descriptive, nonmathematical, but analytical treatment of the physical properties of light, the camera, telescope, microscope and laser; holography, mirages, rainbows and the blue sky; colors in flowers, gems and pigments; human and animal vision and visual perception. It often appeals to art majors, biology majors and is taken by B.A.-T physics majors.

**B.6.e. Summary of Departmental Discussion about Service and GE courses**

We are happy with our current mix of GE courses; however their existence is reliant on the stability of the requirements and offerings of the SSU GE program. This has currently been very stable following the 2008 specification of the SSU GE learning objectives. We feel that our mix of courses offers many options to students at different levels of mathematical preparation and the Department believes itself well-qualified to present GE courses in Area B, which is "the physical universe and its life forms." We have reviewed the teaching strategies and learning objectives for all the courses described above and note that they are appropriate and aligned with the overall GE requirements.

*Use of On-line Tutorials and Homework in Lecture Classes*: We discussed the use of Wiley Plus (Halliday, Resnick and Walker) and WebAssign (Serway) in P114/214. They have been used several times now, with mixed results. The ease of use and convenience to the students was good, but content errors (especially in Wiley Plus) were annoying, and may be less problematic in WebAssign. The A100 classes used to use Mastering Astronomy with reasonable results and recently switched to a lower cost textbook/online homework solution, SmartWork. This system is not as mature, but has proven an acceptable trade-off with cost for the near-term. The tutorials and self-guided study of both are considered good. Most students seemed to like the online homework. Most faculty set a specific number of times that an assignment can be repeated for credit, with certain time limits (which can be individually varied if students have really good excuses.) Solutions are made available after the homework is due for the entire class.

*Physics courses:* We made Physics 100 available as an advanced elective for our majors as part of our last Program Review Action Plan. This was done to encourage freshmen who were not mathematically ready to engage our introductory series courses to take a class within the major and get to know the department. It has been used in this manner, but it also has had several students thinking they could take it later in the program sequence as an “easy” elective. This was not our intent, and we have had to address the occasional upper-division enrollee in the class and direct them towards a more appropriate offering.

We are happy with the current strategy for teaching P210A, the algebra and trigonometry based introductory series course that has a large number of students taking it as a requirement in another allied STEM degree program. It is probably the hardest course to teach in the department. We have noticed that the students in this sequence are bimodally distributed with respect to their skills, and it creates a challenge to teach them. There are a number of occasions when the students in the lecture class seem to “gang up” on the instructor in an effort to address their cognitive difficulty with the course. This phenomenon has not been noted in other classes to this same extent. Currently we have an excellent and organized adjunct instructor for the class, and his student evaluations are exemplary. Faculty have also found P210B rather challenging, and it takes lots of extra office hour time with the weaker students. We would like to be able to afford to teach no more than 60 people in this class, and if the campus population grows and funding is available, we would like to split P210A in half. Both of these courses may benefit by the inclusion of a student Supplemental Instructor, and we have one in P210A in the current semester with plans to expand our use of this program in the future.

*Laboratory courses:* Following the prior Program Review, we moved P116 and P216 to something intermediate between inquiry based and cookbook labs. They now include a strong basis in the process of doing science and are more directly tied to the corresponding P114/214 syllabi. The labs concentrate on recognizing and using basic concepts. The P209A/B lab classes, as currently taught, are very popular and we don't see any reason to change them at the present time.

*Astronomy courses:* Astronomy 100 is taught by three different instructors, and all of the sections fill and have strong student evaluation scores. The courses have settled on using the same textbook, and we will use this textbook while adding an additional mathematical treatment in a new, more rigorous, introductory course, Astronomy 150, Astronomy for Scientists. We decided on adding this course, both as a requirement of a new Physics B.S. concentration, but as a way to recruit interested students with the mathematical background to transition to a physics major. We have two instructors teaching the Astronomy 231 lab, and the courses are similar, with computer and telescope-based labs that are made available as pdfs on the course management website. The upper-division general education courses are very popular, and provide a diverse set of topics and pedagogical experiences for students. Taking them in combination with the introductory course is a straightforward pathway for students to complete an Astronomy minor and progress towards SSU upper-division GE requirements and this is reflected in the growth of the minor in recent years. We are committed to providing writing experiences in all of our Astronomy General Education courses from observing writing assignments in Astronomy 100, to the series of papers required in a course like Frontiers in Astronomy.

# C. Diversity

*Explain how your program…*
**C.1.a Addresses the cultural, ethnic and social diversity of the SSU student body in the curriculum.**

The traditional physics and astronomy curriculum is content rich, consistent with that offered nationally, and therefore not directly related to the SSU student body. We do feature scientists that are culturally diverse, as appropriate, in historical contexts that relate to the establishment of physical and astronomical principles. For example, a particular component to our Astronomy 100 course is the exploration of stellar classification and pioneering female astronomer Henrietta Swan Leavitt is featured. Similarly, the contributions to early astronomy by the Polynesians, Mayans, Persians and other cultures are discussed.

In addition, in our What Physicists Do colloquium series which first started in 1971 and is now in its 89th series (see http://www.phys-astro.sonoma.edu/wpd), we try to include lectures by physicists and astronomers from many different cultural and ethnic backgrounds. For example: the 2014-2015 WPD series has had 7 women speakers out of 20 total. This rate (35%) is above the percentage of women graduating with PhDs in physics (17%) and astronomy (33%) and well above their representation in faculty positions in physics (14%) and astronomy (19%)[1].

**C.1.b. Accommodates differences in student preparation and access in educational opportunities.**

We offer many different levels of physics and astronomy at the introductory levels: Descriptive Physics (P100) and Descriptive Astronomy (A100) are two introductory classes that do not require more than GE-level mathematics. We are usually able to recruit physics majors from both of these classes, despite the lack of preparation and background for most of the enrollees.

Each physics major is advised individually, each semester. In this way, we are able to recommend specialized course schedules to accommodate differences in preparation. An example solution to a lack of student preparation in prerequisite math is enrollment in Math 161X, a 6-unit version of first semester calculus for students who feel that they need to refresh their algebra skills.

The Society of Physics Students club offers free tutoring for students in lower-division courses who need extra help. This club is also good for ensuring that the physics majors can "peer tutor" each other and do homework together in challenging upper-division classes.

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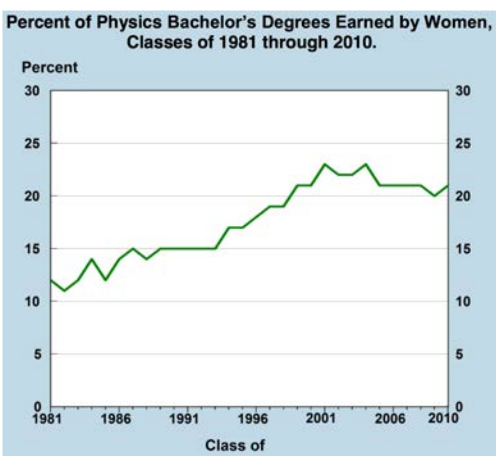
[1] http://www.aip.org/statistics/women

We also advise students to seek help through SSU's tutoring center, when appropriate. We are using student "Supplemental Instructors" in some of our very large introductory lecture courses, in addition to on-line tutorials that are available through textbook publishers. On-line tutorial approach is also being used in several lower-division courses, such as Physics 114, Physics 210A, Physics 214 and Astronomy 100. This helps to level the playing field by giving the students the opportunity to do as much or as little work as they feel they need to do to accomplish the classes' learning objectives.

**C.1.c. Shows leadership in recruiting and retaining diverse faculty and students, without reliance on discriminatory preferences.**

According to the American Institute of Physics, the percentage of women earning Bachelor's degrees in physics has risen through the years, and in 2012 was approximately 21%. The percentage of minority students (including Asian-American) earning bachelor's degrees in physics was about 19% total. See the figure and table below from http://www.aip.org .




**Minority and Ethnic Profile of Physics Bachelor's, Classes of 2008 through 2010. (3-Year Average)**

| | Number | Percent of all Physics Bachelor's |
|---|---|---|
| White | 4,808 | 81 |
| Asian American | 310 | 5 |
| Hispanic American | 221 | 4 |
| African American | 157 | 3 |
| Other US citizens | 70 | 1 |
| Non-US citizens | 333 | 6 |
| Total | 5,899 | 100% |

In SSU's Department of Physics and Astronomy, we have graduated 457 students in the past ~45 years. Of these graduates, approximately 20 percent (85 out of 457) are women. This includes 12 of the first 100 (1967-80), 19 of the second 100 (1980-88), 18 of the third 100 (1988-96), 25 of the next 100 (1996-2008) and 11 of the last 57 (2008-2014). The Society of Physics Students (SPS) always has women in leadership roles and the department has been sending our female students to the annual APS Undergraduate Women in Physics Regional Conference. We do not compile data on the ethnicity or race of our students. We have several programs in place to recruit and retain students from diverse backgrounds as we will describe below.

Through leadership and funding provided by Prof. Cominsky's Education and Public Outreach (E/PO) group, SSU has established a MESA (Math, Engineering Science Achievement) chapter to focus on supporting self-selected under-represented students who are interested in any of the STEM (Science, Technology, Engineering and Mathematics) fields. MESA is a nation-wide program that provides co-curricular support, tutoring, activities, competitions and other activities to support under-represented STEM students. Dr. Carolyn Peruta an employee od the E/PO group is the MESA Program Director. (See: http://mesa.sonoma.edu )

The E/PO group's efforts in bringing science to underserved areas is exemplified by the "Learning by Making" program to develop a two-year science-driven computational-thinking integrated STEM curriculum that improves mathematical and science proficiency for 485 high-needs ruralstudents in six Mendocino County, California high schools/ (http://galaxy.sonoma.edu/i3/) The E/PO group also has a long-standing partnership with Roseland University Prep, a charter public high-school in Santa Rosa, and encourages RUP seniors to attend SSU and to study science and mathematics. We have had an after-school science club at RUP since 2005. In January 2008, the E/PO group began working with the students at Cali Calmecac, a public charter K-8 dual-immersion school in Windsor. We also participate regularly in the Science Fair sponsored by the Sonoma County Office of Education, and in the yearly Expanding Your Horizons program for 7th and 8th grade girls. Faculty members in the Department of Physics & Astronomy regularly serve as research advisors as part of the SHIP Summer High School Internship program. (http://www.sonoma.edu/scitech/hs/) This work places high-achieving high school students as interns in our research laboratories over the summer.

We are increasing our recruiting efforts in a manner to reach our service community and encourage students of all backgrounds to attend SSU. This includes the recently awarded PhysTEC (Physics Teacher Education Coalition) recruiting grant and its funded effort to reconnectwith the physics educators at local high schools and the Santa Rosa Junior College. We are also recruiting in the Physics 100 and Astronomy 100 classrooms, as well as the Science 120 cohort of science-interested freshmen. We routinely tryi to find qualified students to participate in two campus programs that assist low-income or ethnically under-represented students: the Louis Stokes Alliance for Minority Participation program (https://www.sonoma.edu/math/lsamp/), and the McNair's Scholar program (http://www.sonoma.edu/mcnair/).

**Percentage of Physics Faculty Members Who Are Women**

| | Year 1998 | 2002 | 2006 | 2010 |
|---|---|---|---|---|
| **by Academic Rank** | (%) | (%) | (%) | (%) |
| Full Professor | 3 | 5 | 6 | 8 |
| Associate Professor | 10 | 11 | 14 | 15 |
| Assistant Professor | 17 | 16 | 17 | 22 |
| Instructor / Adjunct | * | 16 | 19 | 21 |
| Other ranks | 13 | 15 | 12 | 18 |
| **by Highest Degree Offered by Department** | (%) | (%) | (%) | (%) |
| PhD | 6 | 7 | 10 | 12 |
| Master's | 9 | 13 | 14 | 15 |
| Bachelor's | 11 | 14 | 15 | 17 |
| **OVERALL** | **8** | **10** | **12** | **14** |

The year in the table refers to the spring semester; for example, 2010 represents the 2009-10 academic year.

* These data were not collected in this survey year.

Regarding the diversity of the SSU Physics and Astronomy faculty: the faculty consists of 4 (soon to be 5) tenure-line positions and 6 (soon to be 5) lecturers. Prof. Lynn Cominsky is the department chair and the most senior member of the department. We also have three additional women hired as lecturers (two with Ph.D. degrees), for a total of 4 women in 10 positions. In addition, we have one tenure-line faculty member who is from China, and one of the female lecturers who is from South Korea. Thus half of our faculty are individuals who add to the diversity of the SSU faculty as a whole. It is particularly noteworthy that we have a much higher percentage of women faculty than the national average of recent Ph.D. recipients, and that our most senior faculty member is female. This compares very favorably to AIP statistics that in 2010, only 8% of all full professors were female, and that 17% of all faculty in Bachelor's degree-granting departments were female.

### C.1.d. Addresses diversity issues in its advising, mentoring and career development

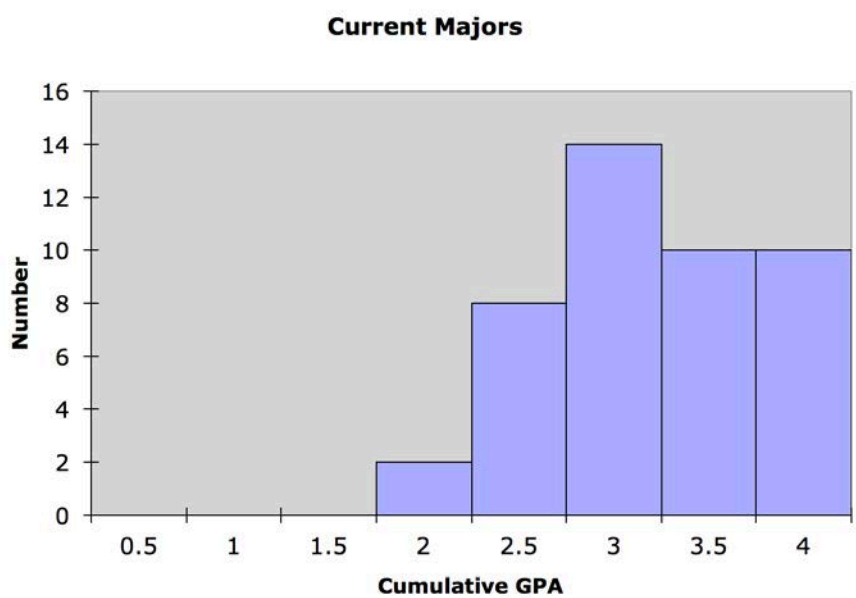
Our department has long had a policy of mandatory advising, with the student matched to an individual faculty advisor. This ensures that we offer a personalized approach so that each student can receive consistent advice and mentoring that is best suited to his or her particular needs. In addition, all students are required to work with a faculty member to do a capstone project, and thus enter into a personalized mentoring relationship that also facilitates career development.

# D. Student Body and Advising

## Student Body

The Department of Physics and Astronomy serves students in the major and in the broader general education community of Sonoma State University. The University is a campus of the California State University system, is accredited by the Western Association of Schools and Colleges and is a member of the Council of Public Liberal Arts Colleges. Sonoma State University has an enrollment of 9,300 students (8,500 undergraduates) with a relatively large residential population, housing 3,100 students in on-campus housing. The student body is predominately female with a proportion of 63% female and 37% male students. The ethnicity is 58% Caucasian, 21% Hispanic with the balance being multiple ethnicity, Asian, African American and Other in that order. Newly enrolled students used to come in roughly equal proportion from transfer admissions and first-time freshmen but this has been shifting to predominately first-time freshmen over the years . For example, this ratio was 863/1120 in 2001 whereas it was 545/1330 in 2008. For further details on the makeup of the general student body please see: http://sonoma.edu/about/facts/.

The following statistical breakdown of our current declared Physics major population will be presented with the equivalent 2008 Program Review numbers shown in parenthesis for comparison. There are currently 45 (37) students with a declared major in Physics, 36 (26) pursuing a B.S. and 9 (11) pursuing a B.A. degree. There are an additional 5 (1) students with a declared minor in Physics, and 16 (4) with a declared minor in Astronomy. The trends show a growing Physics major (+22% in 7 years) and a popular Astronomy minor (+300% in 7 years). Women comprise 18% (20%) of our major, but over 60% of our Astronomy minors. A histogram of the individual cumulative GPA of our majors is presented below. The mean GPA is 2.99 (2.86) with a standard deviation of 0.55 (0.58). The trends show a *growing Physics major* (+22% in 7 years) and a *popular Astronomy minor* (+300% in 7 years).



Our population of majors reflects the student body at-large, containing a substantial percentage of transfer students. Of a sampling of 100 recent graduates of the Department, 47 have transferred from a 2-year or 4-year college program (see Table D-1 below). This presents some challenges in addressing their educational needs and in the advising process. It is often difficult to address student shortcomings in math preparation with the abbreviated time they are in our program. We generally advise our students to choose degree programs that will enable them to meet their goals. Those intent on graduate school in the physical sciences or engineering are advised to pursue the B.S. Students intent on careers in engineering are encouraged to choose the B.S. or the B.S. with a concentration in applied physics. Students interested in using their physics in some other field are usually advised to choose the B.A., which includes 12 units in another field and requires fewer units of physics. The B.A. with calculus is the best choice for students intending to earn a single subject teaching credential and teach in secondary schools, while the B.A. with algebra and trigonometry is adequate for elementary credential-seekers and those intent on careers in science writing or sales. The advising process with transfer students can become over-involved with administrative matters regarding the applicability of transfer credits. Anecdotally, transfer students can be quite mature and focused in their studies and this can alleviate some of these matters.

| **Table D-1: Educational background of 100 recent graduates** | |
|---|---|
| | |
| **Came from 4-year college or university – 8 Total** | |
| 3 | With BA or BS |
| 5 | Without degree |
| | |
| **Attended community college – 39 Total** | |
| 20 | Santa Rosa Junior College |
| 4 | Mendocino College |
| 3 | Orange Coast College |
| 2 | College of the Redwoods |
| 10 | Other Calif 2-year colleges (1 each) |
| | |
| **First-time Freshmen at SSU – 53 Total** | |

**Advising**

The faculty of the Department of Physics and Astronomy takes seriously the role that faculty have in guiding and advising students within and outside the major. The advising of students within the major makes up the bulk of this work and is described in greater detail below. For students outside of the major or minor, the majority of advising from our faculty comes in the form of interactions with students in office hours and before, during, and after class periods. The SSU advising policies are available at:

http://www.sonoma.edu/UAffairs/Policies/advisingpolicy.htm. Academic advising for undeclared students can be found at: http://www.sonoma.edu/advising/.

The Department has a long-standing tradition of providing excellent web-accessible resources for students:

1. http://www.phys-astro.sonoma.edu/PhysicsLinks.shtml
2. http://www.phys-astro.sonoma.edu/People/Faculty/Tenn/Astronomylinks.html
3. http://www.phys-astro.sonoma.edu/EducationalResources.shtml
4. http://www.phys-astro.sonoma.edu/ScholarshipOpportunities.shtml
5. http://www.phys-astro.sonoma.edu/UndergraduateOpportunities.shtml

The role of advisor within the Department of Physics and Astronomy has historically been filled by a single faculty member. Between Spring 2008 and May 2013, Dr. Severson served as a single advisor handling the administrative responsibilities of the role and scheduling advising sessions with all enrolled majors, once a semester, to review degree process, discuss scholarship and research opportunities and provide an opportunity for discussing long-range plans. As advisor, Dr. Severson streamlined the advising process to help students prepare materials to monitor their degree process and make the scheduled advising sessions as productive as possible. Students had access to a web-based scheduling system to pick their appointment times and were directed to the requirements, degree progress reports and advising forms for their pre-meeting preparation. This method had seen success in keeping administrative tasks in these meetings to a reasonable level, allowing the advisor to address the mentoring aspects of the role.

During the Fall 2013 semester, Dr. Severson went on his sabbatical leave to conduct research off-campus. Drs. Qualls and Shi stepped in to advise physics majors, while Dr. Cominsky served as the advisor of astronomy minors (she also served as the Department advisor for majors in the past). Over the last few years, due to the increase in the total number of physics majors and physics/astronomy minors, as well as the fact that the advising role has seen a decrease in corresponding release time from a peak of 3 Weighted Teaching Units (WTUs) in decades past to the current 0 WTUs, the Department has decided to have multiple faculty members share the role of advisor. Following is the instruction that the Department posts online to inform our majors/minors who his/her advisor is (see http://www.phys-astro.sonoma.edu/advising.shtml ):

1. If you are a Physics B.A. student (advisory plan C(alculus) or T(rignometry)), or an Astronomy minor (REGARDLESS OF YOUR MAJOR), your advisor is Dr. Scott Severson.

2. If you are pursuing a Physics B.S. degree, including B.S. - Applied Physics, AND your last name starts with a letter between A and L, please see Dr. Jeremy Qualls for advising.

3. If you are pursuing a Physics B.S. degree, including B.S. - Applied Physics, AND your last name starts with a letter between M and Z, your advisor is Dr. Hongtao Shi.

4. Please keep in mind that you could have a research advisor that is different from your academic advisor. PeopleSoft only shows the name of your academic advisor.

The Department will make changes in coming years to these assignments once our new B.S. in Astronomy and Physical Science Degree Programs get approved. Dr. Thomas Target will also become an advisor to share the responsibility when he joins the Department as a tenure track assistant professor this fall.

To better manage our student related data, the Department has set up an online paperless library via Dropbox to store all scanned student forms, including advising and degree progresses for each student, degree requirements, as well as detailed description of each capstone project. Each student gets a folder in the library. All scanned data are currently shared by the department chair, Dr. Cominsky, and three advisors, Drs. Qualls, Severson and Shi.

The current advising process is streamlined to help students prepare materials to monitor their degree process and make the scheduled advising sessions as productive as possible. Students are directed to a variety of resources including: the degree requirements and course listings from the General Catalog; the Academic Requirements Report available through the students PeopleSoft login; and our custom advising forms for their course pathway preparation. These documents appear in Appendix L.

Promoting students to be involved in authentic scientific research at the undergraduate level is a major emphasis of our advising program. Students are encouraged to apply for research opportunities both within and outside of the Department. The URLs listed above serve as a common destination for students at SSU and elsewhere looking for summer research opportunities. The development of our capstone project program and the newly established research support and mentoring group are all part of our effort to give our students the experience graduate programs and employers value.

# E. Faculty:

The Mission of the Department of Physics and Astronomy is to provide excellent education to the Sonoma State University student population through general education, support courses and a strong major program. Successful faculty must contribute to this mission with demonstrable quality of instruction, and vibrant scholarship that first and foremost integrates student involvement. Faculty are expected to contribute to the Department, School of Science and Technology, University and Community through service that supports and promotes this mission. In this section we describe the teaching methods, scholarship and service of the members of our Department.

## E.1. Pedagogy

This section is an overview of the key pedagogical underpinnings of instruction within the Physics and Astronomy Department. We then discuss the mechanisms for formal and informal feedback on the quality of faculty instruction.

*Pedagogy.* Our classes fall mainly into two categories; lecture-based and laboratory-based. These distinctions occur both in courses for majors and in GE courses. Within these courses we employ a variety of teaching methods to support student-learning outcomes through the use of best practices. These include lecturing, small group activities, small and large group discussions, guided laboratory activities, and inquiry-based and project-based activities. Our faculty monitor and enhance student learning with appropriate choices in assessment. We employ formative assessment through the use of discussions, ongoing writing assignments, and question and answer sessions in order to give students feedback on their progress and to provide the instructor feedback on what might be done to support student learning throughout a given course. We use summative tasks like exams, problem sets, student presentations and written reports to assess student achievement in reaching our learning objectives.

There are both subtle and striking differences between teaching courses within the major and to the General Education audience. The amount of mathematical rigor is the most obvious, but our learning goals for the students are another difference. Within courses in the major, we stress conceptual development to allow students to go beyond rote memorization of formula and become capable practitioners of science. In a parallel fashion, we want GE students to become conversant in the mechanisms of the physical world, but often stress an understanding of the general principles and processes of science. Our review of courses in the context of a skills matrix (discussed in Section B.5) led to the development of our capstone program within the major. For both audiences, we stress the intertwining of process, content and attitudinal goals as we develop our courses and instruct our students.

*Lectures, Flipped Classes, and Online Learning.*

The department of Physics and Astronomy has recently offered several of its most popular courses in non-traditional formats, such as the “flipped class” and fully online models. Both of these pedagogical styles have been made possible at SSU through the work of Professor Lynn Cominsky and her EPO group on campus. This group developed "Big Ideas in Cosmology", an online resource for teaching introductory and advanced astronomy, with a focus on student interaction with real data and critical thinking.

Using the Big Ideas resource, over the spring and summer of 2014 and now again in 2015, Dr. Thomas Targett offered both "A100: Descriptive Astronomy" and "A350: Cosmology" in traditional classroom settings, as flipped classes, and as fully online courses.

In a flipped class, students read and engage with material and mathematical exercises designed to teach them the core course learning objectives before scheduled class times. With this essential knowledge now in place, lectures no longer server as content delivery, but instead as interactive discussion sessions focused on connecting the basic factual knowledge to the large conceptual implications.

In the fully online classes, students based around the state were set material from the Big Ideas resource to be completed each week. As the participants were never in one place together, mentoring, guidance, and assessment were provided via email or message boards.

Early analysis of student performance indicated positive results where comparison with the traditional classroom setting was conducted (see link below). The success of the flipped class model for the A350: Cosmology course has resulted in its continuing use at SSU during the spring 2015 semester, and as an online offering during Summer 2015.

For a full description of the Big Ideas in Cosmology material and student performance analysis see the following:
http://contentbuilder.merlot.org/toolkit/html/snapshot.php?id=16711931691237

*Feedback and Development.* There are formal and informal mechanisms for instructional feedback within the Physics and Astronomy Department. The development of faculty teaching effectiveness begins with the Retention Tenure and Promotion process and its annual reviews. During this process we are evaluated on our teaching by students and by our peers. Student evaluation is conducted in the form of both standardized effectiveness survey (the Student Evaluation of Teaching Effectiveness, or SETE) and by the submission of written comments. These are reviewed by the faculty member undergoing the RTP process and by the various department, school and university wide RTP committees. This method of student input followed by faculty review and response is an effective way to inform teaching practice. The other formal component of teaching evaluation during the RTP process is peer evaluation. Twice in each annual RTP review, a fellow faculty member observes a class period of instruction. The resulting written comments form an excellent resource for self-reflection on teaching practice and provide the RTP committees an accurate picture of faculty instructional performance. It is important to note that this visit and evaluation by peers provides an invaluable resource by making the broader Department aware of the teaching styles in use by the individual faculty members.

As the RTP process is completed, much of the formal mechanism for faculty assessment and feedback is ended. The SETE surveys are available for faculty self-assessment and full and interim program reviews form a structure during which discussions of best practices and pedagogy occur. On a less formal basis, our department has a supportive and collaborative attitude towards instruction. Our faculty frequently share syllabi, course materials and specific teaching modules. Our regular department meetings may contain a discussion of successes in classes or the sharing of particular instructional problems. The Department of Physics and Astronomy places a strong emphasis of monitoring and developing teaching practices during the impressionable early portion of a faculty member's career, but the reflective nature of that process informs our practices throughout our careers.

**E.2 Participation**

The Physics and Astronomy Department actively involves all faculty and staff in the governing of the department. We hold department meetings on a nearly every week basis and all faculty, staff and lecturers are invited to attend. Almost all departmental issues are resolved in these meetings, but occasionally sub-committees are formed to do additional work on some issue.

Current department faculty are active in School-level governance, including the School of Science & Technology's Curriculum Committee and its Professional Development Committee. In addition, the Department Chair is an active participant in bi-weekly Chairs' meetings. It has not always been possible to place a representative on the School Retention Tenure and Promotion Committee as we do not always have sufficient tenured faculty to populate the Department, School and/or University levels of this committee. Chair Cominsky will be joining the URTP committee next year.

Faculty in our Department routinely seek out professional development opportunities. A recent example is the NSF-funded "Reinventing the College Lecture" project to introduce active learning pedagogies to the STEM classroom. In the first year of this program, Dr. Shi was a member of the faculty cohort. In year two, Drs. Severson and Targett joined the program.

Department faculty have been active in University-level governance. Dr. Cominsky has served on the Vice President's Budget Committee (two terms), the Enterprises Board of Directors, the Commencement Committee, the Scholarship Committee, and the Affirmative Action Committee. Dr. Shi served on the University Structure and Functions Committee, a position that is now held by Dr. Severson. Both Dr. Shi and Dr. Qualls have served on the Faculty Hearing Panel. Dr. Qualls served on the GE learning objectives committee. Dr. Severson has served on the Campus Planning Committee. Dr. Qualls is Chair of the University Program Review committee, and Dr. Targett is currently the Secretary of the Faculty Senate.

Finally, service does not end with these committees. Each member of the department has an exemplary history of service to the community in a variety of ways. Dr. Cominsky has given over 125 invited lectures to scientific and public audiences on topics in high-energy astrophysics. For more than a decade, she served as the Deputy Press Officer for the American Astronomical Society, and currently serves as the Press Officer for the Swift and Fermi missions, explaining scientific topics to the public. Dr. Shi is the advisor of SSU SPS (Society of Physics Students) chapter, which has won several National SPS Awards in the last few years, such as Marsh White Award (three years in a row from 2011 – 2014), Future Faces of Physics, and Undergraduate Physics Research Award. Dr. Qualls serves as director and lecturer for Science 120 for the past three years. This role led to the development and creation of an NSF funded STEM- Freshman year experience which saw a rise in retention and attraction rates of STEM majors. This was a cross disciplinary effort across all STEM fields. Dr. Severson leads two popular public programs, the Public Viewing Nights at the SSU Observatory and the venerable "What Physicists Do" public lecture series. Finally, Dr. Targett serves as faculty advisor to a student computer gaming club, organized the first ever faculty and staff whisky tasting, and is planning a showing of *Back to the Future* in the fall to coincide with the date and time the Delorean arrives in the year 2015.

## E.3. Professional Contributions

*Leadership in the Discipline:* Many of the Department's faculty are recognized nationally for their accomplishments in various sub-disciplines of Physics and Astronomy. For example, Department Chair Lynn Cominsky, is a fellow of the American Physical Society (Education, 2009), of the American Association for the Advancement of Science (Astronomy, 2012) and of the California Council on Science & Technology (2008). She has been on the Executive Committee of the High Energy Astrophysics Division, was (for 10 years) a Deputy Press Officer for the American Astronomical Society and has served on various NASA and NSF advisory committees including one Federal Advisory Committee Act (FACA) committee.

Hongtao Shi has worked extensively with local industry through his role as the Director of SSU's Keck Microanalysis Laboratory; Scott Severson is widely regarded as one of the leaders in the field of developing instrumentation for adaptive optics and has recently completed the KAPAO Adaptive Optics System for Table Mountain Observatory. He also serves as an external advisor for the Institute of Science and Engineer Educators out of UC Santa Cruz. Jeremy Qualls is a leader in studying the properties of materials in strong magnetic fields, who serves as an NSF and NHMFL expert in material science. He also served as content expert and representative for K-University "Vertical Alignment" (Texas), examining what constitutes the basic science concepts needed for modern scientists and college graduates. Dr. Targett is a Member of several international astronomy collaborations: CANDELS, HUGS, & UDF12. He is a frequent speaker in the media on astronomical topics and his YouTube discussion of scientific modeling of the computer game Starcraft went viral.

*Outstanding teaching:* One of the Department's current faculty have won the Excellence in Teaching Award (or its predecessor, the Outstanding Professor award): Lynn Cominsky (1993), and two others have been nominated: Jeremy Qualls and Scott Severson. Lynn Cominsky was named the California Professor of the Year by the Council on the Advancement and Support of Education (CASE, 1993). Our tenured and tenure-track faculty score very well on the SETE evaluations across the board, with average scores over 4.0 in virtually all categories.

*Scholarship and Creative Activity:* The Department's faculty have published widely in refereed journals. Department Chair Lynn Cominsky has been an author on over 120 papers in refereed journals, including *Nature,* and the *Astrophysical Journal* for her work in high-energy astrophysics and science communications. She also leads SSU's NASA-funded Education and Public Outreach group, which has created many educational products and curriculum units, and has trained over 65,000 teachers in deeper content knowledge in the physical sciences. Recently, Cominsky was the lead author of an online cosmology course, "The Big Ideas in Cosmology". Other faculty also have extensive publications records: Hongtao Shi has over 30 papers in refereed journals for his work in studying the magnetic properties of new types of materials in journals such as the *Journal of Applied Physics* and *Physical Review B*, Scott Severson has published extensively in the field of adaptive optics and observational astronomy in journals such as the *Astrophysical Journal* and *Optics Letters*, Jeremy Qualls is an author of approximately 80 papers in refereed journals regarding the behavior of materials in very strong magnetic fields, including *Physical Review Letters* and *Physical Review B,* and Tom Targett is an author on 29 refereed papers on the properties distant of distant galaxies in journals such as *Astrophysical Journal* and *Monthly Notices of the Royal Astronomical Society*.

*External Funding For Individual Or Collaborative Projects:* Prof. Cominsky has received over $12 million in funding from NASA, the State of California and the Department of Education for her scientific research and her work with the Education and Public Outreach group in support of NASA's Swift and GLAST missions, and ESA's XMM-Newton mission (among others.) Professor Hongtao Shi has received external funding from companies that are using the Keck Laboratory, and significant donations of equipment, as well as on-campus RSCAP grants. Associate Professor Scott Severson received an $85,000 grant from the Mt. Cuba Foundation to establish an adaptive optics laboratory at SSU, then a $637,138 NSF MRI grant to build the KAPAO adaptive optics system, as well as $29,889 from PhysTEC to improve Physics Teacher recruitment. Associate Professor Jeremy Qualls brought with him over $400,000 in NSF-funded equipment to SSU, to establish a high-magnetic field laboratory at SSU. He also has served as lead on the NSF STEP program Science 120 Freshman Year program, funded by a $987,153 grant. Finally, soon to be Assistant Professor Tom Targett has been successful in the competitive acquisition of telescope time having been awarded over 50 nights on telescopes including the Keck 10-m telescope, Palomar observatory, and UKIRT.

# F. Institutional Support and Resources

*Assess how the following integrate and contribute to student learning objectives:*

## F.1.a Library

Past program reviews lamented the steady decline of library services at SSU. As budgets decreased the library was forced to cancel subscriptions to most of the major journals in physics and astronomy. The 2008 Program Review noted a reversal in this trend, due to the onset of electronic subscriptions. At the time of the current Program Review however the situation has once again worsened. We lost journals such as *Astrophysical Journal* and *Astronomical Journal* in 2010, and in 2015 we have a crisis in the non-renewal of the Wiley subscription.

> *"Preliminary details of the Wiley subscription cancellation decision have been shared on the Senate list. As you may know, the Library subscribes to over 1,300 academic journals published by John Wiley through a "big deal" package agreement negotiated by the Chancellor's Office, a package subscribed to by nearly all CSU campuses. After extensive negotiations over several months, in mid-December the CSU reluctantly decided against renewing the contract with Wiley due to the unmanageable proposed cost increase of 10-12% (depending on the campus). SSU's access to the Wiley package will end on January 31, 2015."*

While funds for ordering books are still limited, they appear to be adequate for the Department's needs at the present time. At all times the library personnel have been extremely helpful. The library has become one of the brightest spots in the University's support for our educational and research missions.

The library is used by students writing papers for upper and lower division general education courses, by advanced students conducting research in capstone courses, and by faculty for both their courses and their research.

## F.1.b Computer Technology

In 2003 we developed a skills assessment matrix and decided to greatly enhance the integration of computer technology into our courses (see Section B.5.b). Table B-1: Skills Assessment vs. Academic Knowledge Base lists the courses that integrate computer technology under the headings of

- General computer programming
- Basic web programming
- Advanced web programming
- Excel
- Higher symbolic language (e.g. Python)

- Data analysis-curve fitting and regression
- Data analysis graphics and data plotting
- Data analysis Fourier transforms and filtering
- Image processing
- Data analysis astronomical processing software
- Data analysis spectral model fitting
- Solve 2nd order homogenous differential equation numerically
- Solve 2nd order inhomogeneous differential equation numerically
- Hardware Interfacing - LabView Competent
- Powerpoint or other Presentation software
- Laboratory Interface competency

In the disciplines of Physics and Astronomy, the role of computers is prolific. In our program computer technology has become crucial in providing tools for data management, controlling and interfacing data acquisition instruments, analyzing data, simulations and computations, as well as general tools such as word processing and presentations. Section B.1.a lists the learning objectives specific to Physics and Astronomy. Computer technology is utilized to achieve each of the objectives three through five in a number of ways. Objective three clearly states use of computer applications.

Learning Objectives students are required to demonstrate:

3) Ability to use mathematics and computer applications to solve physics and/or astronomy problems
4) Ability to design and/or conduct experiments and/or observations using principles of physics and/or astronomy and physics or astronomical instrumentation
5) Ability to properly analyze and interpret data and experimental uncertainty in order to make meaningful comparisons between experimental measurements or observation and theory

*Learning Objective 3:* Students are introduced to Excel in the first year sequence of lecture/lab series courses (both P114/116 and P209/210) as a spreadsheet tool as well as for data error analysis and curve fitting. In the lab they also use data acquisition software to obtain and display data such as Data Studio and then analyze their data using Excel or Data Logger. As the students progress to upper divisional courses they learn a variety of software packages to assist in problem solving. P381, Computer Applications for Scientists, introduces and develops Python, some C++ programming, MATLAB, Mathematica, and Latex. This set of software applications provides a solid basis for problem solving that will be utilized in advanced courses as well as in graduate school and in future career choices. The University has a site license for Mathematica, and we also have one 12-seat laboratory license for MathCad. The symbolic processing skills are reinforced in upper division courses including P320 Analytical Mechanics, P340 Light and Optics, and P460 Quantum Mechanics. Students can continue with advanced problem solving techniques in independent studies done with individual faculty: in these cases, the computer applications are specialized to suit the individual research projects.

*Learning objective 4:* When conducting observations or experiments, part of the effort includes the use of data acquisition software. Although some instruments have the ability to internally store data, a number of software packages are available to interface to the instrumentation to store data to text or image file. Labview and Datastudio are examples which provide the ability to take data as well as the ability to be custom tailored to meet the needs of the experiment or modifications in the experiment. In some cases experiments can be done based on numerical simulation/computation in which the role of computer technology becomes the dominant factor. In this case, the computer not only will store the data but also generates and displays it. Students make measurements and record their data for analysis in a variety of laboratory classes and through their research capstone projects.

*Learning objective 5*: All students have to analyze data beginning with the first year sequence of lab/lecture classes. For this objective, computer software packages are used almost exclusively. Students are taught how to use these programs to analysis the data for basic trends, error analysis, and to solve for unknown parameters. In addition to the software packages previous mentioned, other software packages used include IGOR pro and Origin to analyze data.

### F.1.c Student support services

There are several student support programs at Sonoma State University that we use to enhance our ability to fulfill student-learning objectives. These include a strong emphasis on assistance outside the classroom. Tutoring and small group instruction is available from several resources listed below. We are also aware that achieving our instructional goals is impacted by events in our students' lives outside the classroom and we rely on and direct students to the counseling and special assistance opportunities the campus provides (see below).

*Tutorial Center*: Our faculty reinforce in class the availability of tutoring through the Sonoma State University Tutorial Center. Our majors (and others) are employed through the center to provide tutoring support. This program provides instructional support and has the benefit of providing financial support for majors. Tutors are provided training in assisting students in a friendly, but challenging manner. Reinforcing active engagement with the course material, tutors help students learn more efficiently. According to the program's philosophy, tutoring methods emphasize the sharing of concepts, problem solving strategies, and feature small group discussions.

*Society of Physics Students*: The SPS club at Sonoma State University is very active and has the strong support of the Department of Physics and Astronomy. There is a faculty advisor to the group and several faculty attend the bi-weekly meetings of the organization. The SPS club provides a social and support network for the students in the major. In addition, SPS members provide invaluable services to the broader student population through tutoring and outreach. The SPS tutoring program is very active and the recent move to a donation-basis "drop-in" structure, currently Thursdays beginning at 6 pm every week, has been very successful.

*Supplemental Instruction*: Supplemental Instruction (SI) through the SSU Tutorial Program provides an alternate learning environment for students to actively engage the course material with student mentoring. These organized and regular "study groups" can be attached to certain SSU courses with high faculty-to-student ratios ("parent courses"). This program is currently in use in Dr. Targett's Astronomy 100 GE course, And Wes Farriss' Physics 201A course. These parent courses have large enrollments. Two upper-division majors are paid by the SSU Tutorial Program for instructing these supplemental sessions. The SI section meets for two one-hour periods a week and students may attend the sessions with or without earning one unit of academic credit by concurrently registering in UNIV 103S and submitting a three-to-four page paper describing their learning process with respect to the parent course. We are monitoring the outcomes of this program as it pertains to large lecture class instruction.

*SSU Writing Center*: The SSU Writing Center is a Sonoma State University service that works with students, staff and faculty to improve their writing. They work with individuals and small groups to develop writing skills and with faculty to improve writing instruction. We often direct students to this service in preparation for course writing assignments or for skill development relating to graduate school and employment applications.

*Undergraduate Research Grant Program*: The Sonoma State University Fee Advisory Committee awards $7,500 to the Undergraduate Research Grant Program to support independent research by undergraduates. These funds assist students to purchase supplies and equipment for their research projects, or may be used to fund travel to professional meetings.

*Disabled Student Services*: Disability Services for Students (DSS) assists in making Sonoma State University's educational and recreational programs accessible to students with disabilities. DSS provides services such as testing accommodation, advising, and assistive technology to students with disabilities. The faculty of the Department of Physics and Astronomy respond to requests from students and DSS to provide educational materials in a variety of accessible formats. We are also proactive in designing accessible instructional materials and encouraging students to seek the services DSS provides.

*Counseling & Psychological Services*: Counseling & Psychological Services attends to the mental health needs of students by offering consultation and counseling. The emotional well being of our students is critical to their happiness and their pursuit of educational goals. We are sensitive to the needs of our students and remain alert for signs of emotional distress. Counseling & Psychological Services is an important resource for our faculty, and we do not hesitate to direct at-risk students there.

### F.1.d Faculty development and support services

There are opportunities and resources for faculty development at Sonoma State University. The writing and counseling resources listed under section F.1.c are available to faculty as well as students. In addition, there is a faculty development seminar series and a variety of faculty development funding opportunities.

*Faculty Center)*: From the website: "The Faculty Center at Sonoma State is an inviting space where faculty are welcome to explore innovative teaching and learning practices supported by instructional technology specialists. Activities include educational technology workshops, SSU Learning Community events, self-service test scanning, screencast recording, and more."

*Office of Research and Sponsored Programs (ORSP)*: The ORSP assists faculty in seeking resources to support research and service projects. This is the administrative body charged with helping faculty in their external grant applications and is a resource for the faculty of the Department of Physics and Astronomy.

*School of Science and Technology Faculty Professional Development Funds*: The SST Faculty Professional DevelopmentCommittee provides some travel funding and small equipment grants to faculty. The program supports faculty as they present research findings and/or attend a conference. Support requests are typically in excess of available funding. Faculty can usually expect to have at least one trip per year supported. The annual maximum per faculty is $2000.

*Research, Scholarship And Creative Activity Program (RSCAP)*: RSCAP funds two programs: Mini-Grants and Summer Fellowships. Mini-Grants and Summer Fellowships may fund research, or activities designed to enhance student learning. Awards fund up to $5000 or one month's summer salary, respectively.

*Describe and assess the adequacy of the following:*

### F.2.a Physical facilities

The Department of Physics and Astronomy is housed on the third floor of the newly renovated Darwin Hall. (Renovations were completed in August 2006.) The resources are focused on undergraduate education and in engaging students from GE courses to advanced research. Departmental facilities include basic resources such as faculty offices as well as research laboratories.

With the exception of some advanced courses, the bulk of the department lectures are taught in multimedia University classrooms. To enhance the effectiveness of lectures, a number of lecture demonstrations have been developed. Our stockroom Darwin 309 has demonstration equipment to cover the entire range of courses offered. A full time technician, Steve Anderson, provides expertise in maintaining equipment as well as developing new infrastructure when needed. Steve Anderson's extensive background and eagerness to assist in the classrooms and laboratories have proven to be extremely valuable.

The department facilities includes faculty offices, a conference room, a student study room (shared with the Chemistry Department), two lower-division teaching labs, a stock room, several advanced research labs, and an on-campus observatory (http://www.phys-astro.sonoma.edu/observatory/). The Keck Microanalysis Lab and Rolf Illsley photonics labs in the Cerent Engineering Science Complex (Salazar 2nd floor) are available for use by students as well. Dr. Shi from the Department of Physics and Astronomy is the director of the Keck Microanalysis Lab.

***Laboratories in Darwin Hall:***

*Lower-division Labs:* The two lower-division teaching labs support 24 seats each (Darwin 308 & 311). These rooms provide eleven to twelve lab sections per week. The first lab is well equipped for classical mechanics experiments and the second is equally well equipped with test equipment for Electricity & Magnetism. The labs include individual dual-boot Mac/PC workstations with data acquisition software such as DataStudio from PASCO as well as analytical software such as Mathematica, MathCAD, LabVIEW, and Data Logger. The instrumentation and lab equipment were significantly updated during the move back into the newly remodeled Darwin Hall (which occurred in the Fall 2006). The equipment provides both breadth for descriptive courses and depth for the upper divisional courses.  Both of these spaces saw recent computing upgrades, Darwin 311 getting new dual-boot iMacs, and Darwin D308 getting hand-me-down iMacs from 2008 which are able to boot the most recent operating systems and support some of our specialized astronomical software.

*Upper-division Labs:* The north side of Darwin Hall houses the advanced and research labs. These labs are equipped for upper division students and include experiments like; the Hall Effect measurement of metals and semiconductors (D305A), the CubeSat, satellite development lab and 3-d printer (D305B), thin film coating (D304), astronomical imaging lab (D-305C), super-conducting magnet  & magnetometer (D-303), adaptive optic and geometric+ wave optics  experiments (D-302) and nano-materials engineering (D-301). These research labs are not only utilized by faculty, but by the students working with them and their collaborators. Students are introduced to the advanced labs in the courses P366 and P466 and then continue to use the labs in the form of senior research and capstone courses. The lab space in D304 serves as a bit of an upper-division student lounge.

*Darwin 301, 305A and 304 as currently operated by Dr. Shi:* Every spring semester Physics 366 students use these facilities to learn how to make their own samples in vacuum systems and then characterize them. Students who do capstone courses with Dr. Shi use these facilities to conduct research related to thin film fabrication and transport property measurement. Other students, staff, faculty, and a few local companies also use them to work on their research projects. The frequency of use depends on the nature of the project. These facilities are crucial to gain hands-on experience and complete capstone projects in the areas of thin films deposition and analysis.  Significant instrumentation includes Varian VE-10 thermal evaporator and an Agilent Hall system.

*Darwin 302 as currently operated by Dr. Severson:* This laboratory is intended to host student and faculty experiments in the fields of astronomical optical systems and interdisciplinary optical research such as for interferometric measurement systems. The laboratory is the home of an Adaptive Optics testbed. This system, funded by an $85,000 grant from the Mt. Cuba Astronomical Foundation, consists of a Shack-Hartmann wavefront sensor and Micro-Electro- Mechanical Systems (MEMS) deformable mirror for wavefront correction run with a closed loop control system. The laboratory is well outfitted with two Newport Optical Tables (4' x 8' x 12") and vibration isolating legs to support these experiments.

*Darwin 303 as currently operated by Dr. Qualls:* This laboratory is intended for uses in Material Science with a focus on electronic and magnetic properties. The laboratory hosts a wide range of capabilities from synthesis to characterization. It is well equipped with a 17 Tesla superconducting magnet system, SQUID magnetometer, and infrastructure for measuring transport and magnetic properties. Other significant instrumentation includes a Vacuum Atmosphere Glovebox, fully functional Wetlab, Helium recovery system and workstation with data acquisition and analysis capabilities. The lab has approximately $400k worth of equipment and was supported by two NSF grants "MRI: Acquisition of Magnetic Field System with SQUID for Material Research" ($236,834) and NIRT: 3D Hierarchical Nanomanufacturing for Active Photonics-on-chip ($100,000).

*Darwin 305c Astronomical Imaging Lab:* This laboratory is filled with computers of various types including Macs, PCs and Unix machines, all of which have different software used for analyzing astronomical data from the SSU Observatory and the NASA/GLAST Optical Robotic Telescope (GORT). It is also possible to control GORT from this facility. The computers in this lab have recently been upgraded.

***Cerent Engineering Science Complex:***
This multi-laboratory facility in Salazar Hall contains over $8 million worth of equipment that can be utilized by physics students in intermediate and advanced laboratory courses, and for experience in undergraduate research, design projects, or special studies.

*The Keck Microanalysis Laboratory* includes a Hitachi S-3000N Scanning electron microscope (SEM), equipped with a Oxford Instruments Electron dispersive X-ray spectrometer (EDX), a Pelco Model 3 Sputter coater (Keck), Pacific Nanotechnology Atomic force (AFM) and magnetic force microscope, a Rigaku D-Max 1000 Powder X-ray diffractometer, a PHI 540A Auger electron spectrometer, an Olympus Confocal microscope, and a Janis Cryostat with low temperature measuring capabilities.

*The Photonics Laboratory* features extensive laser instrumentation as well as telecommunication and fiber optic analysis equipment. A sample of the equipment includes Acterna ANT-20E Advanced Network Tester, AFC UMC1000 AccessMAX, Agilent N4901B Serial Bert 13.5 Gb/s, Agilent 8703A Lightwave Component Analyzer 1550NM / 130MHz-20GHz, Agilent 86100A Wide bandwidth Oscilloscope, Agilent 83480A Digital Communication Analyzers (2), Agilent 86140B and 86142A Optical Spectrum Analyzers (9), Agilent 11896A Polarization Controllers (2), Agilent 83433A

10Gb/s Lightwave Transmitters (2), Agilent 83434A 10Gb/s Lightwave Receiver, Agilent 8594E RF Spectrum Analyzer, Alcatel Litespan-2000 Central Office Terminal, DS Uniphase SWS15100 Swept Wavelength System, Scion Photonics 48-channel Arrayed Waveguides (2), Tellabs Cablespan 2700

***Sonoma State University Observatory:***
Students and faculty at SSU have access to two observatories. The on-campus observatory (SSUO) is a sliding roof structure on the south-east corner of the campus. The location, known as The Stadium, contains an athletic field and a track. The observatory is outside the track in the south-east corner of the field. This location continues to be the darkest location on campus.

The observatory houses two permanently mounted optical telescopes, a 0.36 meter f/11 Schmidt-Cassegrain and a 0.25 meter f/5 Newtonian. Both telescopes are computer controlled and can point to within a few arcminutes of a specified target on the sky. The 0.25 meter telescope is mounted on a fork mount and was custom built by Epoch Instruments in the mid-1980s. This telescope is known as the Epoch. The 0.36 meter telescope is a classic Celestron-14 purchased in 1975. This telescope is now mounted on a modern Mathis Instruments MI-500F fork mount and is known as the Mathis.

The Mathis is used for visual observations and for spectroscopy using an SBIG SGS Spectrograph. The spectrograph can produce a dispersion of up to 0.1 nm/pixel with an achievable resolution of 1 nm. Spectra can conveniently be obtained for stars as faint as $8^{th}$ magnitude. The Epoch is used solely for imaging using an SBIG ST-7 CCD camera with standard BVRI filters. The field of view is approximately 15 arcminutes. A standard BVRI filter set allows measurements of magnitude and color for objects as faint as $16^{th}$ magnitude.

*Adequacy and problems of SSUO:* The on-campus observatory is very convenient for introducing students to what can be seen in the sky, for demonstrating and providing instruction in the use of astronomical telescopes and instrumentation, and for introducing students to the nature of the work done by astronomers. SSUO continues to be adequate and extremely convenient for these purposes. During the time of the last Program Review we identified an issue with the observatory being no longer wheelchair accessible as a result of construction. This issue has been addressed with the construction of an alternate pathway. Continuing issues that remain: light pollution (including nearby street lamps); roof issues; masonry issues; and the need to modernize the equipment and find a permanent mount for the large 16” Newtonian telescope.

**F.2.b. Financial resources**

*Operating Expenses:* Our Department receives $9380 per year to cover items such as copying, printing, supplies, repairs and maintenance of equipment and salaries for student assistants to help with grading.

When we moved back into the newly remodeled Darwin Hall, we received a one-time allocation of about $225K to purchase new equipment for our laboratories. Other than this and the additional Darwin 311 computer purchases, we have not received any replacement equipment money for over 20 years. We actively work on acquiring many pieces of equipment through donations from local companies, which we then try to refurbish. For example, the Hall measurement system, the Auger Spectrometer, and various types of deposition equipment.

It is clear from the above that we do not receive adequate funding on a regular basis from the University to maintain our laboratories or facilities. We try to be creative, and to raise funds privately to make up for what the University cannot provide

*IDC rebates:* We now get a rebate based on a combination of grant volume and IDC accrual. Dr. Cominsky has received about $25K each year for the past 3 years, and has used some of it each year to pay for the CubeSat program as well as the 3D printer and student salaries for the CubeSat program.

*Public Programs:* We raise some private funds to support our Department's weekly physics colloquium, "What Physicists Do", but now get most of the funding through the Instructionally Related Activities funds (via a competitive grant process: $6000/yr). This program uses the money to provide honoraria for the speakers, pay for the speaker's dinners, fund a student assistant and print the posters advertising the series. IRA also supports the printing, snacks and student assistants for the Public Viewing Nights at the SSU Observatory (~$3000/yr).

*Student Research Support:* We receive direct annual donations of about $5700 per year to support undergraduate student research from two different sets of donors. Since 2002, $3000 of the annually donated funding comes from Mike and Sheila McQuillen, who support a summer research student called the McQuillen Research Assistant. Starting in 2011, emeritus faculty Bryant Hichwa and his wife Diane began to contribute to a second summer research assistantship. Students for both of these awards are chosen on the basis of a written research proposal to work with one faculty member each summer. More information on the McQuillens and the selected summer research students can be found at: http://phys-astro.sonoma.edu/advisor/McQuillen.html More information on the Hichwas and the selected summer research students can be found at: http://www.phys-astro.sonoma.edu/hichwaassistantship.shtml

We also receive the interest from an endowed account that supports the Horace Newkirk Research Assistant, a student selected (on the basis of a written research proposal) to work with a faculty member each spring. This account was established in the memory of her father by Nadenia Newkirk, and some friends and other relatives after Horace's death in 1995. Horace Newkirk, a retired U.S. Navy physicist, was a regular attendee at our What Physicists Do lecture series and gave a lecture in the series in 1979. Photos of the Newkirk Assistants and more information about this program can be found at: http://phys-astro.sonoma.edu/advisor/Newkirk.html

*Foundation Accounts:*

The following table summarizes the Department's current Foundation accounts as of 1/31/08:

| Number | Name | Balance 04/20/15 |
|---|---|---|
| C0020 | Horace Newkirk Fund | $2904 |
| C0141 | P&A Public Programs | $7661 |
| C0142 | P&A Equipment & Supplies | $3588 |
| C0143 | Observatory Support | $277 |
| C0144 | Student Development Fund | $6093 |

*Travel:* In recent years, there has been a small amount of travel money (typically $10,000) available on a competitive basis through the University to support faculty travel. In addition, the School of Science and Technology has made $25,000 available for travel funding for faculty professional development. It is unclear at this time whether or not any of these funds will be available next year, due to the budget situation.

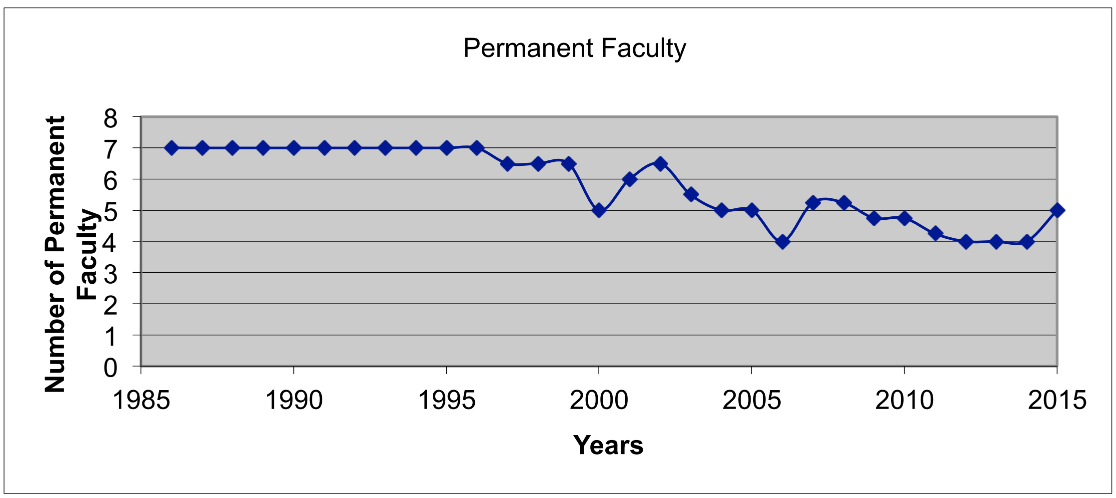
*Summary:* We actively work to augment the extremely meager funding provided by the University, by raising funds to support our Public Programs, undergraduate research, and equipment needs. We do not have guaranteed access to funding for faculty or staff professional development, and we have no regular supply of replacement equipment for instruction.

**F.2.c. Human resources (include workload analysis for both faculty and staff)**

*Permanent Faculty.* From 1986 – 1997, the Physics and Astronomy Department permanent faculty were remarkably stable. Permanent faculty consisted of Duncan Poland, Sam Greene, Joe Tenn, Gordon Spear, John Dunning, Saeid Rahimi and Lynn Cominsky. In Fall 1997, Sam Greene entered the Faculty Early Retirement Program (FERP), and taught half-time for the next five years. In Fall 2000, Duncan Poland entered the FERP, but only taught half-time for one year, retiring completely by the Fall 2001. That same year, Saeid Rahimi became interim Dean of the School of Natural Sciences, and was appointed Dean starting in May 2001. John Dunning entered the Faculty Early Retirement Program in Fall 2001 on a half-time basis. Two successful tenure-track searches during the spring of 2001 led to two new junior faculty joining the Department in the Fall of 2001 (Enrique Izaguirre and Brock Weiss.) Another successful search in the spring of 2002 led to Bryant Hichwa joining the faculty in the Fall of 2002. We were awarded another tenure-track search in the Fall of 2002, but it was cancelled after the telephone interviews, due to budget cuts. By the Fall of 2003 Weiss had departed the

Department, and a successful search during the fall of 2003 led to the appointment of Hongtao Shi in the Fall of 2004. However Izaguirre left during the Fall semester 2004 and Joe Tenn went on half-time FERP. In 2006, John Dunning's FERP ended, and Gordon Spear's half-time FERP began. Two successful tenure-track searches during the Fall of 2006 led to the appointment of Scott Severson and Jeremy Qualls in the Fall of 2007. At that time, Bryant Hichwa went on a quarter-time FERP (teaching half-time in spring semester only.) Gordon Spear lowered his FERP to 0.25 time in the fall of 2009.

Since our last program review, Joe Tenn's FERP ended after spring semester 2009, Gordon Spear's FERP ended after spring semester 2011 and Bryant Hichwa's FERP ended after spring semester 2012. From the fall of 2012 through this present year, we have had four tenure-track or tenured faculty. In the fall of 2009, Hongtao Shi was tenured and promoted to Associate Professor, and in the fall of 2014, promoted to Professor. In the fall of 2011, both Severson and Qualls received tenure and were promoted to Associate Professor. Cominsky has served as Department Chair since 2004.

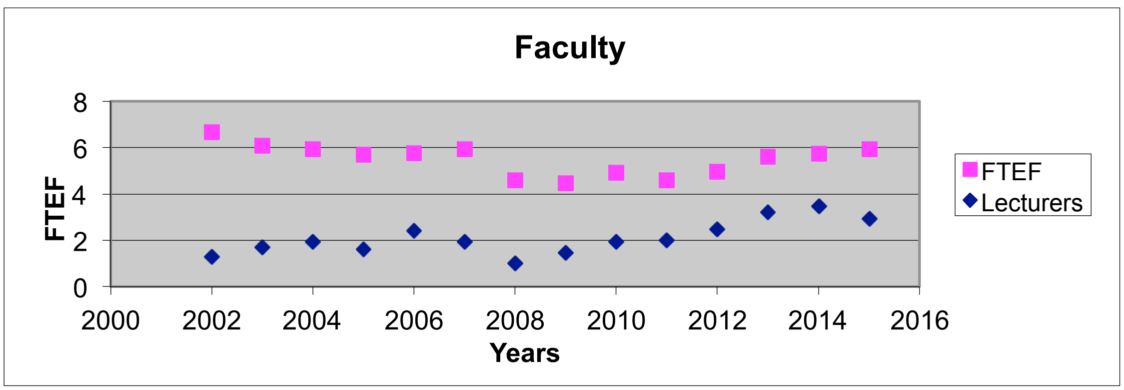



We requested additional faculty hires each year since the parade of FERPs began in 2009. In Fall 2013, Scott Severson went on a full-time one-semester sabbatical leave and we were granted a Visiting Faculty position. Dr. Thomas Targett joined the faculty at that time, and we were able to keep him for a second year as a lecturer in 2014, when we did not received a tenure-track search. His lecturer salary was augmented by Cominsky's NASA funding in order to maintain parity to the Visiting Faculty salary he received the previous year. He helped test out the "Big Ideas in Cosmology" material that was a major project for the NASA group. We finally received a tenure-track search for an Astronomer in 2014, and after a national search, hired Dr. Targett into the position. We will have 5 tenure-line faculty again beginning in Fall 2015. However, it should be noted that Cominsky has not taught in the Department since she became Chair in 2004. The responsibilities of her Education and Public Outreach group have grown to the point where she routinely carries a 25% (paid) overload. Her regular faculty released time supports lecturers in the Department (at about a 2:1 ratio), but that is not an adequate substitute for permanent faculty's contributions to the smooth functioning of the

Department or the award-winning teaching which she previously contributed. However, if she were to return to teaching, the number of courses we can afford to offer would actually decrease, as two lecturers will lose classes for each class that she can offer.

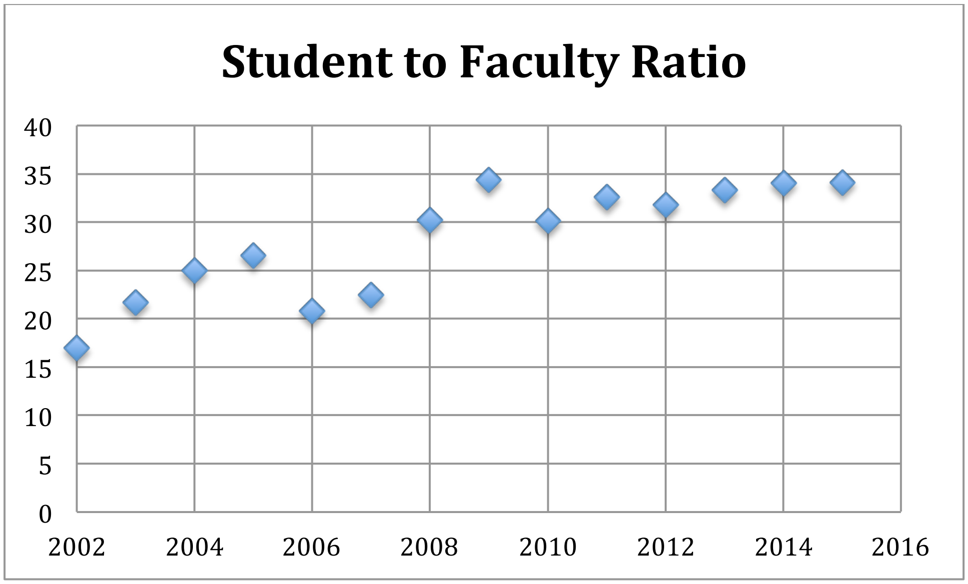
Another problem that currently faces the Department is that there are not enough faculty to staff the RTP committees. This past year, Hongtao Shi chaired the Department RTP committee, and Cominsky served on the School RTP committee. Next year, she will serve on the University RTP committee, the P&A position on the School RTP committee will be vacant, as Shi will chair the RTP committee which oversees the promotion requests for Severson and Qualls, and the probationary review of Targett. The other two committee members will have to come from outside the Department.

*Lecturers:* As can be seen in the following figure, the number of Full Time Equivalent Lecturers has grown steadily since our last program review. With the addition of the new tenure line in Fall of 2015, there is a slight dip in the lecturer assignments.




In this figure, the FTEF series (top series in pink) is the total for both physics and astronomy courses, as reported in Appendix A (which has been averaged between the fall and spring semesters in a given academic year), while the Lecturer series (bottom series in blue) has been calculated from the units taught by lecturers in each semester, added together for fall and spring, and then divided by 30.

The SFR (Student to Faculty Ratio) for our courses, seen in the plot below, show a general increase during the last six years and jumped considerably during AY 2007-2008. The jump corresponded with the transition at the hiring of Drs. Qualls and Severson and and the FERPs and retirement of the then-current faculty. Between 2002 and 2015 we see a doubling of the SFR from 17 to 34.  It is disturbing to note that we are teaching bigger classes, and that these classes are being taught by an increasing percentage of lecturer faculty. The recent hire of Dr. Targett is only one step on a path to reversing this trend.




*Volunteer Faculty:* A new trend since the last program review is the increasing contribution of volunteer faculty to the Department. Most notably, Dr. Garrett Jernigan has been playing an increasingly significant role in mentoring students, supervising student research projects and driving SSU's CubeSat program. Dr. Jernigan (who is also Lynn Cominsky's husband) retired from UC Berkeley, where he was on the research staff at Space Sciences Laboratory for 30 years. He is an expert on computational physics, instrumentation development, and satellite-based astronomy. The Department has now built a CubeSat laboratory in Dar 305b, and Dr. Jernigan can often be found there, working with a wide variety of students. Students working on projects with Dr. Jernigan (and sometimes also with Dr. Cominsky) have won a number of recent awards, including taking first and second place in the SST Science Symposium last year. Jernigan has also volunteered to run a Physics GRE study group with interested students. Another recent volunteer is Dr. Sangyoun Gee, who works at local laser company Raydiance. Dr. Gee is mentoring a capstone student.

*Staff:* Since the return to the newly remodeled Darwin Hall in Fall 2006, our Department has shared an Administrative Coordinator with the Chemistry Department. This has proven to be a less than ideal situation, since the Chemistry courses require considerable AC support as they are frequently oversubscribed. We have had to manage the time of the AC to try to get our fair share, and it has been difficult. The current Administrative Coordinator for Chemistry and Physics & Astronomy is Andrea Cullinen, who has done an admirable job since joining us in Fall 2013.

Our Department has one full-time technician, Steve Anderson, who has served us ably for many years. Steve received the Staff Excellence award in 2013, and it was extremely well deserved. However, with the continued increase in our laboratory sections, and the difficulty in scheduling the labs to avoid conflicts with teaching schedules, he often is called upon to work well past his nominal 430 pm quitting time. (We have evening labs every day of the week except Friday). Additional burdens placed on Steve in the past few years include supporting the Scanning Electron Microscope and other equipment in the

Keck Microanalysis Laboratory, and maintaining the Liquid Nitrogen plant, providing LN to users including Chemistry and the Health Center.

When Cominsky was hired in 1986, the School of Natural Science had a full-time machinist, a full-time electronics technician, and ACs for each department. Those days are long gone, along with the machine shop (many of the larger machines were given to the Art department during the Darwin remodel). Our Department Technician is called upon to cover all aspects of equipment invention, maintenance and repair, to prep an increasing number of lab sections, and support an increasing number of students.

*Overall Summary of Workload Issues:* From the above, we conclude that workloads are increasing for both faculty and staff, the ratio of tenure-track to lecturer faculty is decreasing even as administrative pressure increases to teach larger and larger classes, and the quality of the education that we can provide will therefore continue to deteriorate. These trends have worsened since our last program review. That these factors are universal across the University is no comfort. Our Department has been very entrepreneurial and creative in trying to make the most of what we have, and we are proud of our efforts to maintain the close interactions between students and faculty, and hands-on laboratory experiences that make our program distinctive. The only bright spot is the recent tenure-line hire. However, the external program reviewer for our last program review seven years ago recommended two immediate tenure-track hires. These hires are still badly needed, as is additional technician support.

# G. Assessment and Findings

## G1. Description of the Department assessment plan

Our department uses a mixture of assessment methods to monitor student and faculty/program centered metrics. We present an overview of these in the table below. A primary effort has been in the development of the learning objectives presented in Section B. The combination of these well-delineated content and process goals with the accompanying Skills Matrices allows us to monitor student learning of the content and processes of physics. We supplement this with our support and monitoring of the student community (SPS, and other activities) to gauge student attitudes. As we discuss below, the capstone experience for every major is our culminating assessment of student learning. We combine this with our alumni surveys, which allow us to track our students' persistence in STEM fields.

Faculty- and program-centered assessments are our mechanisms to monitor the three pillars of our Retention, Tenure, and Promotion process; our use of effective pedagogy, our scholarship, and our service to the University and Community. These are discussed in detail in Section E, but deserve mention in our overall assessment plan.

| | Assessment Goal | Tools |
|---|---|---|
| Student Centered | Student learning of content and processes of physics | Learning objectives, grades, GPA, and faculty observation and commentary |
| | Student attitudes and community | Society of Physics Students activity, student participation in extra-curricular activities, pizza-lunches, Public Viewing Nights, and enrollment in seminar series |
| | Mastery of high-level content, and practices of physics research | Capstone course "portfolio" review and assessment of competency in learning objective areas |
| | Persistence in STEM | Long-term tracking through our "About our graduates" surveys |
| Faculty/Program Centered | Effective pedagogy | SETEs, classroom observations, RTP process |
| | Intellectual activity | Grant acquisition, publications, conferences, panels, and depth and breadth of student research opportunities, RTP process |
| | Service | Programs (e.g. S3, EPO, club advising, WPD, PVN etc.), department, school, and university committees, RTP process |
| | Program efficacy beyond the aforementioned | Enrollment, advising, assessment of degree pathways |

We use our capstone projects as a portfolio-type assessment to evaluate each student's ability to achieve our five overarching learning outcomes (see below). All physics majors are required to take one of five courses that are considered to be capstones: Instructional Design Project (A492 or P492), Senior Design Project (P493) or Undergraduate Research (A497 or P497). Demonstrating a thorough knowledge of physics principles, experimental design, research methods and conducting an independent "hands-on" project is a culminating experience for Physics majors who are bound for graduate school or for careers in industry. Demonstrating the ability to contribute to the design of a lecture or laboratory course is a culminating experience for the educationally-oriented Physics major. Competency in our Learning Objective Areas is measured by student performance in the capstone.

Learning Objective Areas:

1. Knowledge, understanding and use of the principles of physics and/or astronomy
2. Ability to use reasoning and logic to define a problem in terms of principles of physics and/or astronomy
3. Ability to use mathematics and computer applications to solve physics or astronomy problems
4. Ability to design and/or conduct experiments and/or observations using principles of physics and/or astronomy and physics or astronomical instrumentation
5. Ability to properly analyze and interpret data and experimental uncertainty in order to make meaningful comparisons between experimental measurements or observation and theory

Section G.3.a presents a table of our student capstone projects since our last Program Review. We used to do exit interviews to assess how well each student was able to do the specific Learning Objectives listed above, but were forced into stopping this following the sharp decrease in our permanent faculty between 1996 when we had seven faculty and today when we have four, soon to be five.

## G.2 Analysis of the educational effectiveness of the program

### G.2.a. Comparisons to other institutions

The defining document in assessing undergraduate physics programs is the Spin-Up Report. This special study funded by the NSF and conducted through the American Institute of Physics (http://www.aapt.org/Projects/upload/SPIN-UP-Final-Report.pdf) states:

> "About 50% of undergraduate physics majors go on to graduate school, about 30% in physics and 20% in other fields. At the introductory physics level, annually about 350,000 students take introductory physics across the country. This number has tracked the general college enrollment for many years. About half of these students take calculus-based physics. Among those in the calculus-based physics course from which most physics majors are recruited, only 3% take another physics course. So, by and large, introductory physics is a service course at most colleges and universities."

The table below summarizes the enrollments in the calculus-based first semester course, the algebra/trig based first semester course, and the one-semester courses in descriptive physics and astronomy the past few years:

| Enrollment in Introductory Courses | | | | |
|---|---|---|---|---|
| Academic Year | 2011-2012 | 2012-2013 | 2013-1014 | 2014-2015 |
| Calc-based Phys | 42 + 42 =84 | 36 + 48 = 84 | 42 + 46 = 88 | 34 + 40 = 74 |
| Alg/Trig Phys | 99 + 118 = 217 | 115 + 111 = 226 | 113 + 100 = 213 | 97 + 104 = 201 |
| Descr Phys | 52 | 50 | 40 + 40 = 80 | 27 + 37 = 64 |
| Descr Astr | 246 + 329 = 575 | 457 + 310 = 767 | 522 + 350 = 872 | 3451 + 486 = 937 |

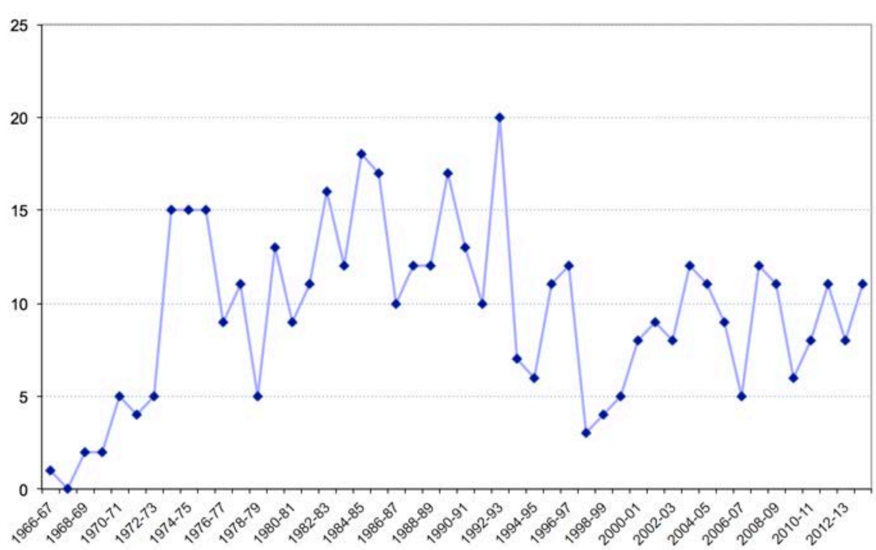
At SSU, we find that the percentage of students who take our introductory physics sequence with calculus is lower than the national average, reflecting the fact that we do not have a large engineering program (which typically requires calculus-based introductory courses). From the data in the table, in 2011 - 2015 we averaged 82.5 students in the first semester calculus course per year, whereas in 2003-2007 we averaged 66.5 students. If 3% of these students continued on to take more physics courses, i.e. became physics majors, we would have only 2.5 students per year majoring in physics. However, we are doing far better than the national average, as we average ~10 students per year in the major. One clear feature is the large growth in the number of students taking an introductory astronomy course, with an all time high in the current academic year of nearly one thousand students taking Descriptive Astronomy.

**G.2.b. Results from analyzing over 45 years of tracking our alumni:**

The graphs and statistics below summarize educational effectiveness by documenting the number and success of our graduates. They were compiled from tracking our alumni on a yearly basis. The narrative comments from these alumni are compiled in Appendix B. Similar statistics appear on our departmental website at:
http://phys-astro.sonoma.edu/people/graduates/index.html

Figure 1 below shows the number of graduates per academic year. During the time from the 2007-2008 AY through the 2013-2014 AY we have averaged 9.6 graduates per year.

**Figure 1 – Number of SSU Physics graduates per year from 1966 - 2014**



The figure at right shows the percentage of physics graduates who have received degrees in each of our programs. The Descriptive BA program (BA-A) was discontinued in 1988. There are 457 graduates as of March 2015. The most popular degree path is the B.S. in Physics; the second most the B.A. with Calculus, with the B.S. Physics – Applied and the B.A. with Trigonometry/Algebra base rounding out our current offerrings.

**Figure 2**

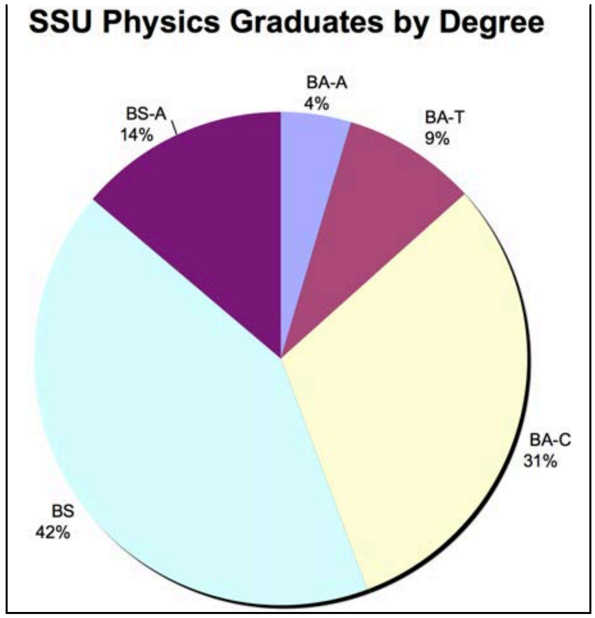



Table 1 below gives the key to this figure and describes the years in which each degree program was offered.

| TABLE 1 – DEGREE PROGRAM DESCRIPTIONS | | |
|---|---|---|
| **Degree** | **Version** | **Offered** |
| BA-A | Descriptive | 1971-88 |
| BA-B (or T) | Algebra & Trig | 1971- |
| BA-C | Calculus | 1971- |
| BS | BS Physics | 1967- |
| BS-A | BS with concentration in applied physics | 1985- |

Figure 3 below shows the types of graduate programs entered by SSU's physics graduates. During 1986-2014, 97 of 271 grads (36%) started graduate school.

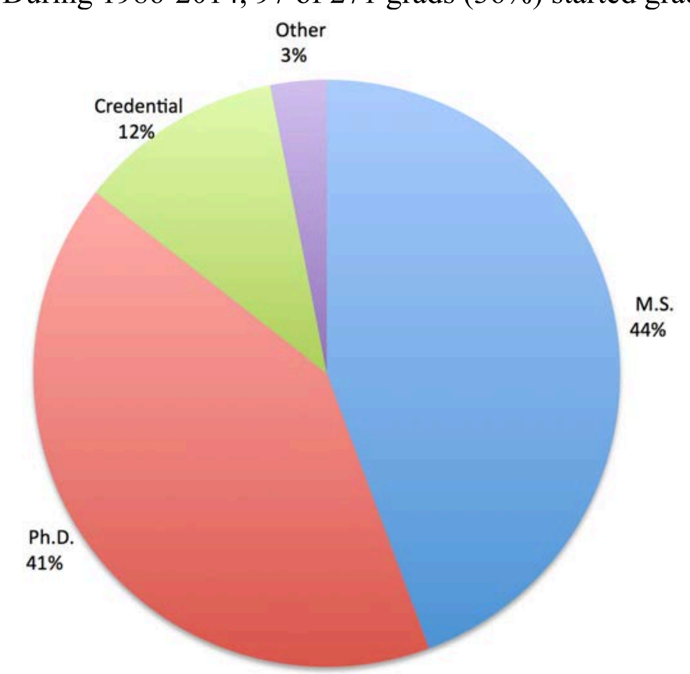



**Figure 3 – Percentage of SSU Physics graduates entering different types of graduate programs (1987-2014)**

Figure 4 below shows what types of graduate programs are entered by SSU's physics graduates. Other includes medicine, math, geography, acting, aging & medical facilities.

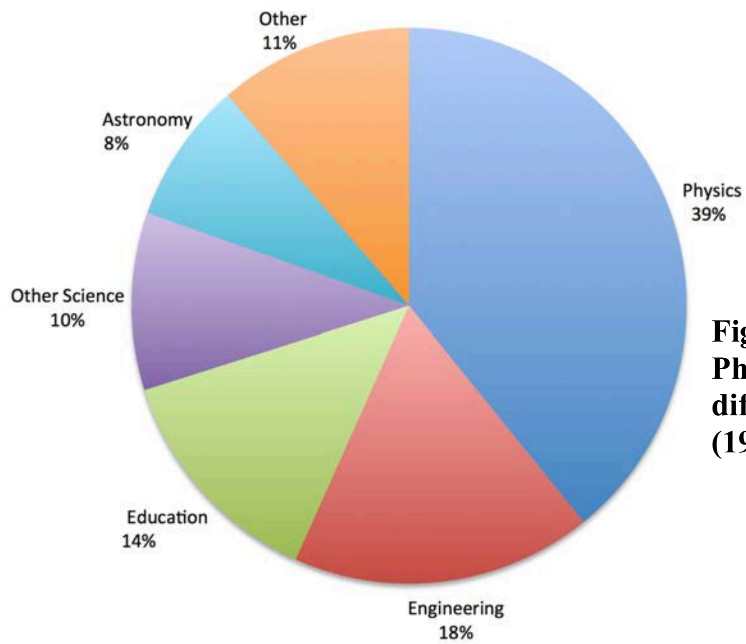



**Figure 4– Percentage of SSU Physics graduates entering different graduate fields of study (1987-2014)**

Figures 3 and 4 above describe the 36% of our graduates who attend graduate school. For the other 64% who do not enter graduate school, most seek work as engineers or programmers or technicians. We are seeing a significant number of graduates spend a year or two traveling or vacationing before seeking employment or else taking up to a year or two to find a suitable job.

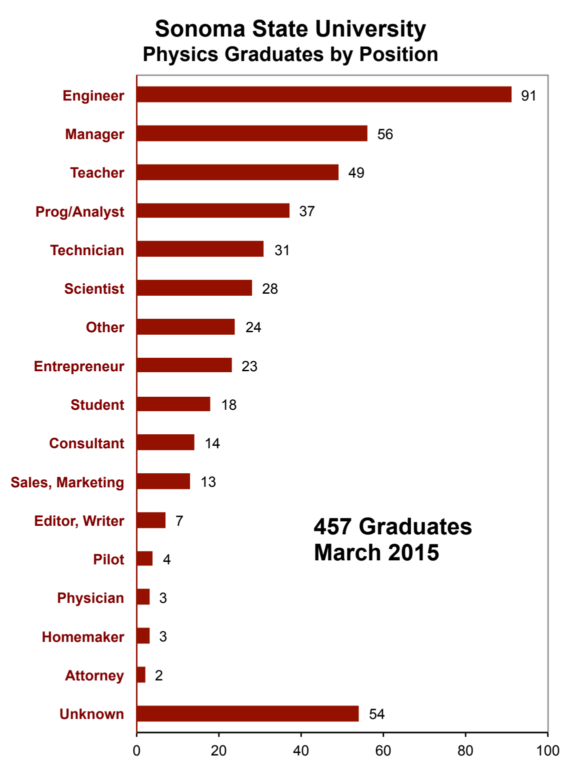



**Figure 5 – SSU graduates by position held.**

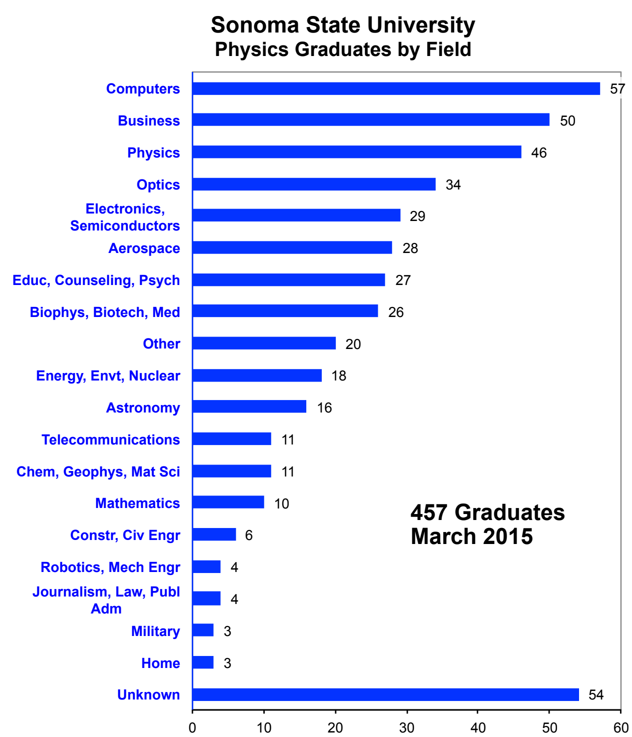



**Figure 6 – SSU graduates by field of work.**

Our graduate survey data is highlighted by Figures 5 and 6 above, where we present data on the careers of 403 out of our 457 graduates to date (88%). The astonishing success in tracking our graduates in their careers is due to the efforts of Professor Emeritus Joe Tenn, who started this tracking decades ago and continues to contact former students. The most common fields for our alumni are computing, business and physics and the post common positions held are engineer, manager, and teacher. These data and short alumni career descriptions and links are presented on our "What Our Graduates Are Doing" page at : http://www.phys-astro.sonoma.edu/ourgraduates.shtml.

### G.2.c. Comparisons to national statistics

The American Institute of Physics collects data from BS-degree granting institutions each year (http://www.aip.org/statistics). The average number of physics bachelors produced by departments where the bachelor's was the highest physics degree offered was 4.9. Sixty-eight percent of physics departments that offer a bachelor's as their highest physics degree averaged five or fewer degrees a year. The figure below shows this distribution, and the location of SSU at 8.7 graduates/year over the same span. This places the SSU Department of Physics & Astronomy in the 88$^{th}$ percentile for number of bachelors produced at institutions offering at the bachelors degree as their highest degree.

**Figure 8**

**Number of Bachelor's-Only Physics Departments by the Average Number of Bachelor's Conferred, Classes of 2008 through 2010.**

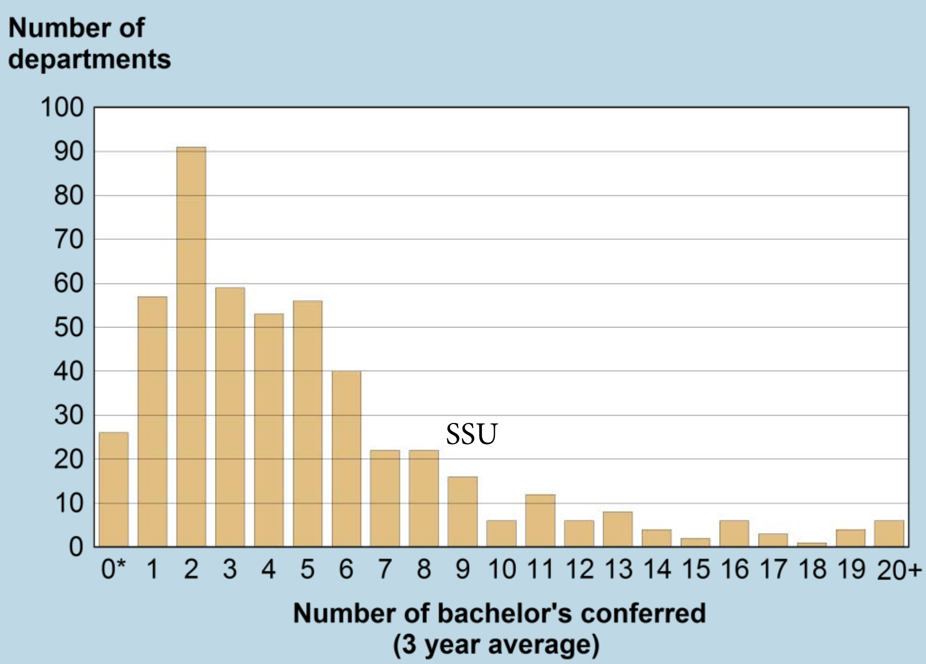
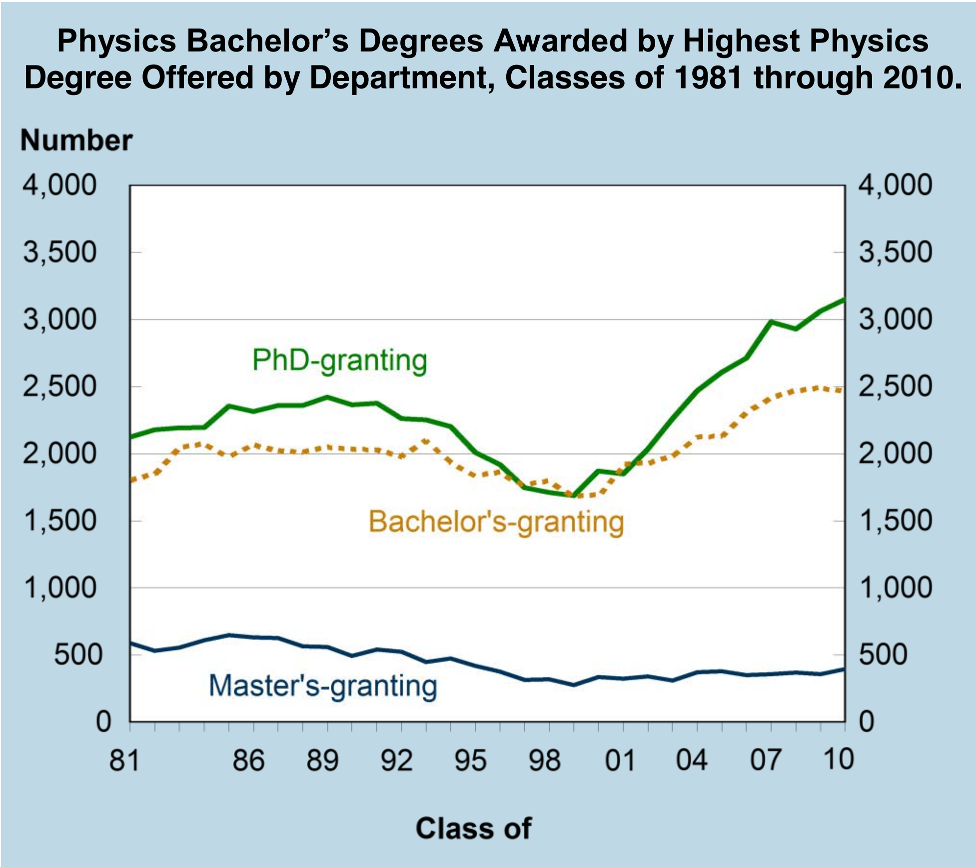



**Figure includes 500 departments where the bachelor's was the highest physics degree offered for all 3 years. Data were estimated for non-responding departments.**

*** Includes 13 departments who conferred one bachelor's degree during the 3 year period.**

The following figure shows that Bachelor's-granting Physics departments have seen a general increase in degrees awarded since a low near the beginning of the millennium, though not as much as at PhD-granting institutions. This corresponds well to the general trend shown in Figure 1, where the SSU Department of Physics & Astronomy had similar low-point in graduating majors from 1998 through 2000 and has shown an increase thereafter.

**Figure 9**




**Bachelor's-, master's-, and PhD-granting refers to the highest physics degree offered by the department.**

The American Institute of Physics also collects national averages to analyze the percentage of physics Bachelor's degree recipients that enter the workforce or graduate school upon graduation. Figure 10 below (from http://www.aip.org/statistics) shows the national statistics. The percentage of SSU physics graduates who enter Physics and Astronomy graduate study is 17% compared to 36% overall and 26% among Bachelor-degree only granting institutions. This most likely reflects the fact that SSU is not a research-first institution, and therefore tends to produce fewer students bound for discipline—based graduate programs. The percentage of SSU physics graduates who enter graduate study in other fields is 19% overall, which is consistent with the national figures (22%). The national statistics showing the variety of graduate programs for which a physics degree is preparation is shown in Figure 11. This is in correspondence with the graduate survey data we presented earlier, where our graduates find work in engineering, optics, physics, astronomy, medicine, computer science, education and many other fields.

**Figure 10**

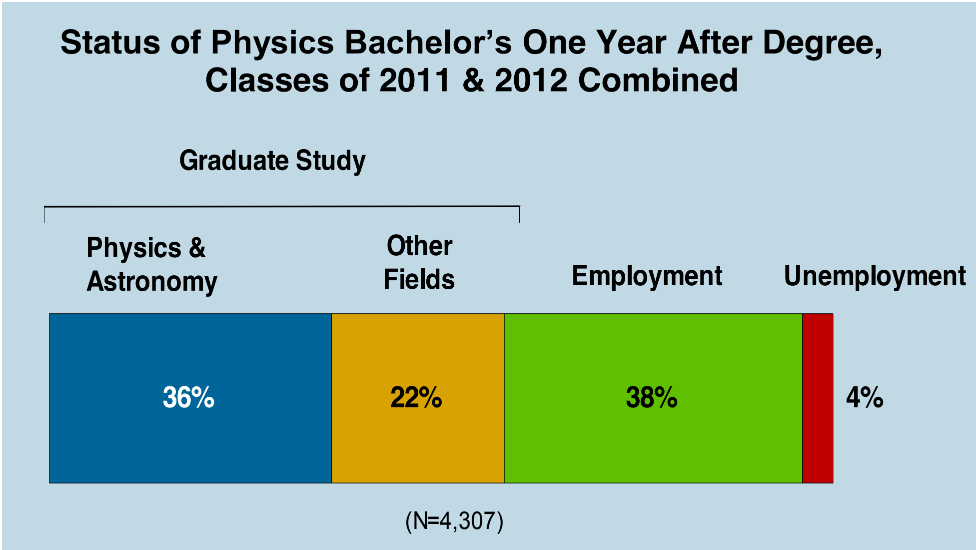
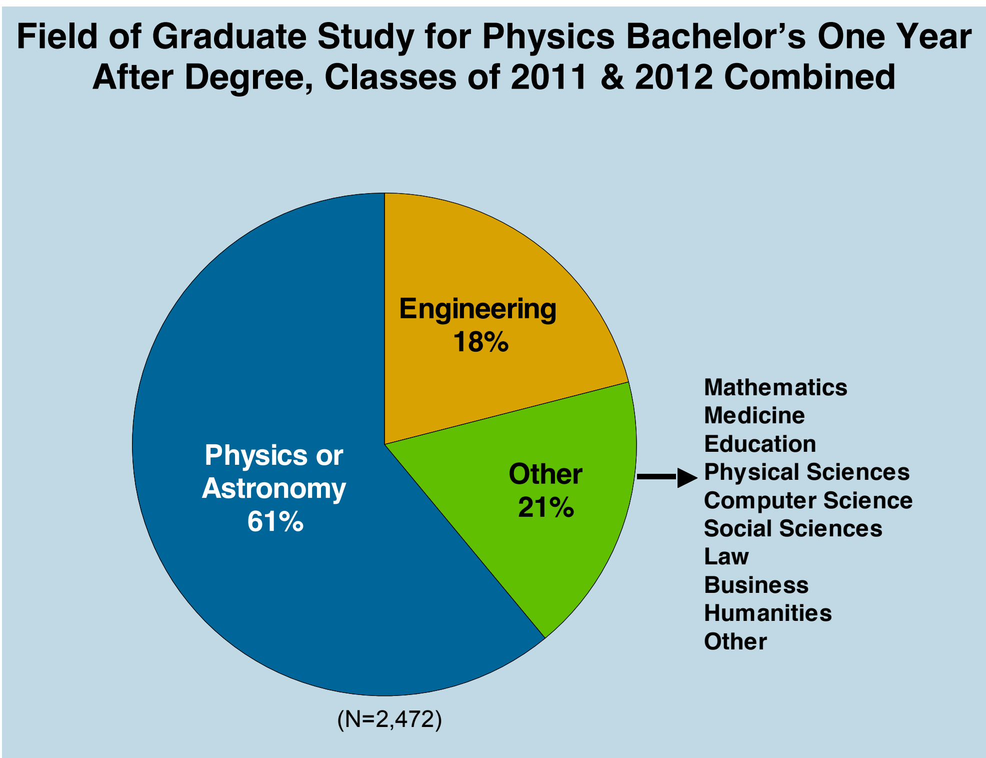



**Figure 11**




Next we compare our program to other Physics programs within the CSU. Using recent data collated in AY 2014-2015 by CSU Physics Chairs we were able to compare three main components of these Bachelor's degree programs. The first is a breakdown of upper division courses required of the major. In a survey of 12 CSU programs offering a B.S. in Physics, they required an average of 36 units in the major in junior and senior-level classes. Sonoma State university requires 34 such units in the B.S. – Physics track. While most programs require a similar set of these courses (i.e. Modern Physics, Mathematical Physics, Mechanics, Electricity & Magnetism, Thermodynamics/Statistical Physics, Electronics and Quantum Physics), there were some differences of note. Some of the 12 reporting CSU Physics programs require two semesters in E&M (9 of 12) and some require two semesters in Quantum Mechanics (5 of 12). SSU does not offer a second semester in these topics. Instead we see that Sonoma State University requires Optics (5 of 12), a Computational Physics class (3 of 12), and a Capstone or Senior research experience (6 of 12). Here the pattern is clear, our program chooses to require a set of courses of the greatest use in entering the STEM job market: authentic experiences in the skills required in local industries. These courses also serve to prepare students for the research required of them when entering graduate studies.

The final two components that we have to compare with other CSU Physics programs are the average number of Bachelor's degrees in Physics and the number of Tenured and Tenure-track faculty. These data are presented in the Table below, which is sorted by Average number of graduates over the 2010-2013 graduating classes. Key takeaways are that the SSU Physics & Astronomy Department falls in the middle of the distribution of graduates, but near the top of similar programs (those outside the Cal Polys and the programs with Master's programs). Even more striking is the size of the Tenured and Tenure-track faculty, which at 4 during the period of interest, is well below the average of 9.7 and only larger than the Physics department at CSU-Channel Island. The ratio of graduates/year to faculty of 1.9 for Sonoma State dwarfs that of any other school, with the CSU average being 0.9 and the next nearest being CSU-LA with a ratio of 1.6.

| INSTITUTION | MS? | AY09-10 | AY10-11 | AY11-12 | AY12-13 | Average | T-TT faculty |
|---|---|---|---|---|---|---|---|
| Cal Poly St U-SLO | | 29 | 27 | 22 | 32 | 27.5 | 26 |
| Cal St Poly U- Pomona | | 15 | 7 | 21 | 20 | 15.8 | 15 |
| San Fransisco St U | Y | 13 | 11 | 20 | 16 | 15.0 | 12 |
| Cal St U- Los Angeles | Y | No report | No report | No report | 14 | 14.0 | 9 |
| Cal St U- Long Beach | Y | 9 | 12 | 11 | 19 | 12.8 | 14 |
| Cal St U- Northridge | Y | 10 | 10 | 8 | 6 | 8.5 | 15 |
| San Jose State U | Y | 12 | 9 | 2 | 10 | 8.3 | 12 |
| San Diego St U | Y | 10 | 7 | 7 | 8 | 8.0 | 14 |
| Cal St U- Fullerton | Y | 11 | 8 | No report | 5 | 8.0 | 11 |
| Cal St U-San Marcos | | - | - | 9 | 7 | 8.0 | 6 |
| **Sonoma State U** | | **6** | **8** | **10** | **7** | **7.8** | **4** |
| Cal St U- Chico | | 8 | No report | No report | 7 | 7.5 | 9 |
| Humboldt State U | | 8 | 8 | 4 | 9 | 7.3 | 5 |
| Cal St U- Sacramento | | 11 | 4 | 5 | 7 | 6.8 | 9 |
| Cal St U- San Bernardino | | 7 | 4 | 5 | 11 | 6.8 | 6 |
| Cal St U- Stanislaus | | 6 | 7 | 6 | 3 | 5.5 | 5 |
| Cal St U- East Bay | | 4 | 6 | No report | No report | 5.0 | 4 |
| Cal St U- Fresno | Y | 4 | 6 | 5 | 2 | 4.3 | 10 |
| Cal St U-Channel Island | | - | - | 3 | No report | 3.0 | 2 |
| Cal St U- Bakersfield | | 2 | 3 | 4 | 2 | 2.8 | 11 |
| Cal St U- Dominguez Hills | | 3 | 1 | 2 | 4 | 2.5 | 4 |
| Total | | 168 | 138 | 144 | 189 | 184.8 | 203 |
| Average | | 9.3 | 8.1 | 8.5 | 9.9 | 8.8 | 9.7 |

### G.2.d. Overall Conclusions

Compared to other institutions without graduate programs, SSU ranks very highly in the production of physics graduates, and compares favorably with respect to students entering graduate programs that are not in physics or astronomy. However, we do not compare well to the overall national average in percentage of students going to graduate school in physics or astronomy, most likely due to the fact that the national data are dominated by Ph.D. granting institutions. We do, however, tend to produce more students who go into STEM fields compared to the national average, and it is noteworthy that a larger percentage of the other technology positions are in energy or environmentally related professions.

### G.3 Discussion of changes necessary to improve effectiveness of the program

The requirement for all of our majors to complete a senior capstone dates back to the planning at a 2003 retreat. The senior capstone project is our most important summative assessment tool, and it has been used to determine how well our graduating seniors have met our discipline-specific learning objectives. As of AY 2003/2004, each senior physics major (in both the BA and BS degree programs) has been required to enroll in one of the following courses:

a) Physics or Astronomy 492: Instructional Design Project
b) Physics 493: Senior Design Project
c) Physics or Astronomy 497: Undergraduate Research

In addition, students are encouraged to enroll in Physics or Astronomy 495, Special Studies in the semester(s) prior to enrolling in the capstone course, in order to more fully develop their project, in consultation with their faculty advisor. The capstone courses require both oral and poster presentation of the project to their peers and the department faculty, prior to graduation. (Oral presentations were first required in May, 2005. Poster presentations have been required since May 2013.)

Our graduating students are required to demonstrate:
1) Knowledge, understanding and use of the principles of physics and/or astronomy
2) Ability to use reasoning and logic to define a problem in terms of principles of physics and/or astronomy
3) Ability to use mathematics and computer applications to solve physics or astronomy problems
4) Ability to design and/or conduct experiments and/or observations using principles of physics and/or astronomy and physics or astronomical instrumentation
5) Ability to properly analyze and interpret data and experimental uncertainty in order to make meaningful comparisons between experimental measurements or observation and theory

### G.3.a. Summary of capstone projects presented to date

The table below summarizes the students, advisors, project titles, course, and learning objectives demonstrated by each student in the self-study period of review (Fall 2008- Fall 2014). For each group of graduating students, the faculty also discussed the capstone experience and performance of the students. These serve as a formative assessment to the operation of the department and a summative assessment for the students.

| Capstone Term | Student | Course Number | Advisor | Graduation Term | Capstone Research Title | Outcomes Tested* |
|---|---|---|---|---|---|---|
| Fall 2008 | Wiedeman, Mark | Phys 493 | Shi | Spring 2009 | Temperature dependent resistance measurement via a cryostat | 1,2,3,4 |
| | Duncan, Michael | Phys 493 | Qualls | Spring 2009 | Sysnthesis and Characterization of 2-D Organic Conductors | 1,2,3,4,5 |
| | Yearwood, Bradley | Phys 493 | Qualls | Spring 2009 | Investigation of Bound States at Interface of Dissimiliar Charge Transfer Salts | 1,2,3,4,5 |
| | Rondeau, Sean | Phys 497 | Qualls | Spring 2009 | Electrical Conductivity of Irregular Shaped Substrates | 1,2,3,4,5 |
| Spring 2009 | Johnson, Christopher | Astr 497 | Spear | Spring 2009 | Color and Time Variability of Supernovae | 1,2,3,4,5 |
| | Wyman, Katherine | Astr 497 | Spear | Spring 2009 | Semi-regular Variable Stars | 1,2,3,4,5 |
| | Bransford, Kevin | Phys 492 | Severson | Spring 2009 | Meaningful Learning in Modern Physics Classrooms | 1,2,4,5 |
| | Hessong, Timothy | Phys 492 | Shi | Spring 2010 | Setting up a photoluminescence system in the laser lab | 1,2,3,4 |
| | Fisher, Winston | Phys 493 | Qualls | Spring 2009 | Analysis of Nanofiber Polyethylene Composites | 1,2,4,5 |
| | Santos, Aimee | Phys 493 | Shi | Spring 2009 | Laser induced breakdown spectroscopy | 1,2,3,4 |
| | Wiedeman, Mark | Phys 493 | Shi | Spring 2009 | Temperature dependent resistance measurement via a cryostat, cont'd | 1,2,3,4 |
| | Lundy, Eric | Phys 497 | Qualls | Spring 2009 | Development of Low Temperature Probe | 1,2,3,4,5 |
| | Yearwood, Bradley | Phys 497 | Qualls | Spring 2009 | Interfacial Metallic Conductivity of TTF/TCNQ: Materials Processing, Continuation | 1,2,3,4,5 |
| | Martineli, Kenneth | Phys 497 | Shi | Spring 2009 | Fabrication of self-assembled alumina films | 1,2,3,4,5 |
| | Dye, Adam | Phys 497 | Severson | Spring 2009 | Adaptive Optics System Calibration | 1,2,3,4,5 |
| Fall 2009 | Young, Ryan | Phys 493 | Severson | Spring 2010 | Atmospheric Seeing at the Galbreath Wildlife Preserve | 1,2,3,4,5 |
| | Hessong, Timothy | Phys 497 | Shi | Spring 2010 | Probing the light emission from zinc oxide (ZnO) thin films | 1,2,3,4,5 |
| Spring 2010 | Salvemini, Rebecca | Phys 492 | Qualls | Spring 2012 | Development of In-Class Demo | 1,2,4 |
| | Adame, Christopher | Phys 493 | Shi | Fall 2010 | Growth and characterization of Co-doped ZnO thin films | 1,2,3,4,5 |
| | Garcia, Bill | Phys 497 | Qualls | Spring 2010 | Assembly and Design of SQUID Magnetometer Insert | 1,2,3,4,5 |
| | Powell, Austin | Phys 497 | Qualls | Spring 2011 | Organic Conductors | 1,2,4,5 |
| | Anderson, Michael | Phys 497 | Severson | Summer 2010 | High Speed Photometry at SSU Observatory | 1,2,3,4 |
| | Gilbreth, Blaine | Phys 497 | Severson | Fall 2010 | Development and Testing of Optical Components in an Adaptive Optics System | 1,2,3,4,5 |
| Fall 2010 | Powell, Austin | Phys 497 | Qualls | Spring 2011 | Electrochemical Syntheis and Vibration Isolation | 1,2,3,4,5 |
| | Barrera, Kalie | Phys 497 | Shi | Fall 2010 | Photoluminescence of ZnO nanowires | 1,2,3,4,5 |
| Spring 2011 | Haley, Luke | Astr 492 | Severson | Summer 2011 | Alternate Approaches To Teaching Physics | 1,2,4,5 |
| | Morrison, Kathleen | Astr 492 | Severson | Spring 2011 | The Cosmological Timeline: An Interactive History of the Universe | 1,2,4,5 |
| | Stortz, Joshua | Phys 492 | Severson | Spring 2012 | Special Relativity Exhibit | 1,2,3,4,5 |
| | Hubbard, Jay | Phys 493 | Qualls | Spring 2011 | Investigation of the Pressure Dependance of Ressistivity in Single Crystal Pyrite | 1,2,3,4,5 |
| | Powell, Austin | Phys 497 | Qualls | Spring 2011 | Synthesis of High Purity Single Crystals of (TMTSF-TTF)2PF6 | 1,2,3,4,5 |
| | Kelley, Daniel | Phys 497 | Severson | Spring 2011 | Meade DS-16 Reecting Telescope | 1,2,3,4,5 |
| Fall 2011 | Pappa, Travis | Phys 492 | Shi | Spring 2013 | Quantum conductance due to nano-contacts | 1,2,3,4,5 |
| | Cassell, Jason | Phys 493 | Severson | Fall 2011 | Simulating Waves | 1,2,3,4,5 |
| | Fahle, Jarod | Phys 493 | Qualls | Spring 2012 | Frequency Response and other Properties of Electric Guitar Pickup | 1,2,3,4,5 |
| | Hanley, Brooks | Phys 493 | Qualls | Spring 2012 | Development of Magnetic Field Proton Precession Magnetometer | 1,2,3,4,5 |
| | Ewen, Crystal | Phys 497 | Qualls | Spring 2012 | Turning and Modeling the Frequency Response of Organic Semiconductors | 1,2,3,4,5 |
| | Fontana, Matthew | Phys 497 | Shi | Spring 2012 | Current-voltage characteristics of ZnO/p-Si junctions | 1,2,3,4,5 |
| Spring 2012 | Miller, Kalie | Astr 492 | Severson | Spring 2012 | Teaching/Creating Lesson Plan for Astronomy Course | 1,2,4,5 |
| | Terrell, Bryce | Astr 497 | Severson | Spring 2012 | Danjon Project | 1,2,3,4,5 |

Capstone Table. Page 1 of 2

| Capstone Term | Student | Course Number | Advisor | Graduation Term | Capstone Research Title | Outcomes Tested* |
|---|---|---|---|---|---|---|
| Spring 2012 | Ewen, Crystal | Phys 497 | Qualls | Spring 2012 | Frequency Response of Organic Semiconductors | 1,2,3,4,5 |
| | Salvemini, Rebecca | Phys 497 | Qualls | Spring 2012 | Creation and Evaluation of Physics Teaching Pedogogy | 1,2,3,4,5 |
| | Alfaro, Cristhyan | Phys 497 | Shi | Spring 2012 | Optical properties of copper doped ZnO | 1,2,3,4,5 |
| Fall 2012 | Pappa, Travis | Phys 492 | Qualls | Spring 2013 | Third World Perspectives and Sustainability | 1,2,4 |
| Spring 2013 | Blumert, John | Astr 492 | Severson | Fall 2014 | Distribution of Celestial Objects | 1,2,4 |
| | Baker, Brandon | Astr 497 | Severson | Spring 2013 | Measuring the Earth's Albedo Using Light Reflected Off the Moon | 1,2,3,4,5 |
| | Horowitz, Jack | Astr 497 | Severson | Spring 2013 | Rotation Curves and Spectroscopy | 1,2,3,4,5 |
| | Neely, Chuck | Astr 497 | Severson | Summer 2013 | Measurement and Modeling of an Eclipsing Binary Star System | 1,2,3,4,5 |
| | Halbert, Stephanie | Phys 493 | Qualls | Not Graduated | Dynamics of Normal Forces in Orbital Roller Coaster | 1,2,3,4,5 |
| | Pappa, Travis | Phys 493 | Qualls | Spring 2013 | Development of Automated Dew Collection System | 1,2,3,4,5 |
| | Rowe, Jude | Phys 497 | Qualls | Spring 2013 | Frequency Response of Plasma Based on Material Interaction | 1,2,3,4,5 |
| | Wojtowicz, Anna | Phys 497 | Qualls | Spring 2013 | High-Temperature Induced Changes of Electronic Properties in Charge Transfer Salts | 1,2,3,4,5 |
| | Badham, Katherine | Phys 497 | Severson | Spring 2013 | Wavefront Sensing in Adaptive Optics | 1,2,3,4,5 |
| Fall 2013 | Cunningham, Benjamin | Phys 493 | Shi | Spring 2014 | Environmental monitoring to quantify experiment and experimenter performance | 1,2,3,4 |
| | Vindiola, Desiree | Phys 497 | Qualls | Spring 2014 | Development of Portable NIRS Unit | 1,2,3,4,5 |
| Spring 2014 | Campion, Jessica | Astr 497 | Severson | Not Graduated | Kepler Objects of Interest with Adaptive Optics | 1,2,3,4 |
| | Ryan, Daniel | Phys 493 | Qualls | Fall 2014 | Water Collection using Condensation and Solar Absorption | 1,2,3,4,5 |
| | Zack, Kevin | Phys 493 | Cominsky | Spring 2014 | Putting Sonoma State Into Space | 1,2,3,4,5 |
| | Cazarez, Antonio | Phys 493 | Shi | Fall 2014 | Design, construction and testing of a DC magnetometer | 1,2,3,4 |
| | Crites, Collin | Phys 497 | Qualls | Spring 2014 | Synthesis of Frustrated Spin System | 1,2,3,4,5 |
| | Lewis, Jacob | Phys 497 | Qualls | Spring 2014 | Concert Hall Acoustics of Weill Hall and Other Campus Venues | 1,2,3,4,5 |
| | Jackowski, Stephan | Phys 497 | Shi | Spring 2014 | Al-doping of ZnO (AZO) via electrochemical deposition | 1,2,3,4,5 |
| | McCready, Jedidiah | Phys 497 | Shi | Spring 2014 | Modelling a damped static pendulum using different numerical integration methods | 1,2,3,4,5 |
| | Mills, Hunter | Phys 497 | Shi | Spring 2014 | 3D coded aperture imaging via Monte Carlo techniques | 1,2,3,4,5 |
| | Wang, Feng | Phys 497 | Shi | Spring 2014 | Determination of electron's charge to mass ratio | 1,2,3,4 |
| Fall 2014 | Halbert, Stephanie | Phys 493 | Qualls | Not Graduated | Development of Graphene Supercapacitors | 1,2,3,4,5 |
| | Baporia, Safura | Phys 497 | Qualls | Fall 2014 | Development of Condensation Testbeds | 1,2,3,4,5 |
| | Sperry, Jordan | Phys 497 | Shi | Fall 2014 | Characterization of ZnO thin films deposited on ITO substrates | 1,2,3,4 |

*Our graduating students are required to demonstrate:

1) Knowledge, understanding and use of the principles of physics and/or astronomy
2) Ability to use reasoning and logic to define a problem in terms of principles of physics and/or astronomy
3) Ability to use mathematics and computer applications to solve physics or astronomy problems
4) Ability to design and/or conduct experiments and/or observations using principles of physics and/or astronomy and physics or astronomical instrumentation
5) Ability to properly analyze and interpret data and experimental uncertainty to make meaningful comparisons between measurements or observation and theory

All of these learning outcomes are utilized to varying degrees in the capstone research and presentations, which remain our most successful assessments.

Capstone Table. Page 2 of 2

### G.3.b. Changes needed to Capstone projects

After continual review of our process, the progress made in these capstone projects, and the comments from our graduates, we decided that we needed to improve our system so that the students enrolled in all of our capstone and Special Studies (A495 or P495) courses would meet as a group at regular intervals to work on developing the abstract for their work, searching the literature to support their projects, developing the experimental methods for their projects, and developing the final presentations. We began the series of monthly capstone meetings in 2008 and now have scheduled meetings every two weeks.

In 2013 we added a poster presentation to the capstones, as part of a new School of Science and Technology Symposium, developed, in part, by our own Dr. Jeremy Qualls. Throughout the development of our capstone program, we have added more and more group time to the process. As part of our self-study, we realized that we should make this portion of the capstone a seminar class. The class should meet weekly and a faculty member should be identified as instructor for the course on a rotating basis, as we will continue to share responsibilities overall.

### G.3.c. Comparison of capstone courses to comparable programs

Humboldt State University has a required 2-unit senior lab class, as well as requiring seniors to enroll in two semesters of Physics Seminar, in which presentations are given by students.

CSU East Bay has a 1-unit physics capstone course which is taken for one quarter immediately preceding graduation.

College of Charleston has a 3-unit senior research project which is required for the BS degree, and can extend for two semesters in the honor program. It is preceded by a 1-unit course in preparing the proposal for the project, which must be approved by the faculty.

SUNY Geneseo has a BS Applied degree, and a minor in either chemistry, biology, geology, mathematics or computer science, or an internship is also required. Their Honors in Physics program is by invitation only, and requires research with a faculty member, oral presentation at a departmental colloquium and a written thesis or professional paper.

*Summary:* We have a program that incorporates several best practices seen as some but by no means all comparable institutions. Our students are well prepared for life after the degree as seen by their comments and life trajectories  they report in our alumni surveys.

### G.4 Dissemination of findings to faculty and staff

Since we began doing Interim Program Reviews in 2005, the results of the reviews have been distributed to the Physics and Astronomy Department faculty and staff, and have been discussed at special department meetings held in the fall after the reports were submitted to the University.

The capstone project presentations are advertised throughout the Department, and students and often their friends and family members attend.

# H. Action Plan

## H.1 Action plan based on findings and recommendations

**(AWAITING EXTERNAL REVIEW REPORT)**

## H.2 Description of Proposed Program revisions

### H.2.a. Teaching-learning methods

- Grow small-group and interactive demonstration use in our lecture courses.
- Adopt "clicker" system where applicable
- Continued use (growth) of on-line homework
- Grow use of "supplemental instruction"
- Continued evaluation of flipped classroom in Cosmology, use elsewhere where appropriate.
- Look at improving presentation and communication lines-of-sight in Darwin lower division lab spaces

### H.2.b. Course content

*Lower division labs:*

- Maintain communication between lecture instructor and lab instructor to keep content aligned
- Continue emphasis on student inquiry, experimental design and data analysis
- Modernize and update apparatus as appropriate
- Sophomore Lab/Sophomore Year Experience. Building on the success of the S3: Stepping up STEM NSF grant and the Science 120 Freshman Year Experience, Dr. Qualls is leading an initiative to bring a Sophomore Year Experience into existence with a focus on teaching students the lab skills necessary for them to move onwards to mastery of research techniques during their upper-division years.

*Lower division lecture classes*:

- Continue with our sequences and textbooks.
- Constantly evaluate on-line homework and tutorial offerings
- Supplemental Instructors (SI) used in a Colorado-model Learning Assistant-like manner
- SI use of lecture tutorials

*Upper division labs:*

- P366 remains an effective overview of the major instruments that we have in the Keck Lab and Darwin (SEM, AFM, etc.)
- Continued emphasis on scientific process skills.

- P466 remains a place to introduce some of faculty's research (e.g. Qualls/Severson in Spring 2015)

*Upper division lectures*:
- Statistical Physics will stay as a 2-unit course, this remains a compromise between depth and breadth of topics within the major.
- Electricity and Magnetism will remain cross-listed with Engineering Studies program, with both departments offering a section a year.

*Capstones:*
- Continue the growth here, this is a priority for us
- Need to move beyond the every other week meetings, and need to honor the volunteer effort of the faculty to make these meeting happen. Split the 2-unit capstone into a 1-unit capstone, plus one unit seminar.
- Students are presenting talks and now additionally posters: continue this.

*GE Courses:*

- We are happy with our current mix of GE courses and feel that we do a very good job of meeting the GE learning objectives
- Large courses now have the option of additional faculty support: units, graders, development money. Monitor this change.

*Astronomy courses*:
- Addition of BS-Astrophysics replacing BS-Applied
- A100 is more integrated amongst faculty (text/online homework)
- Add A150 - Astronomy for Scientists course for new major and recruiting opportunity amongst STEM-inclined students
- Increase and possibly share Supplemental Instructor access amongst sections
- A231 lab development and sharing between instructors
- A331 as lab course for majors and minors
- A482 as advanced lab course segue into research
- A382 added to A380 to add a standard 2-semester astrophysics sequence.

*Service Learning and additional opportunities:*
- SPS club efforts: Marsh White grant with school visits; and Skills Lab training of experimental skills are an important development within the last review period. It is vital to nourish these new platforms for student learning and community building.

**H.2.c. Learning objectives**

- Work on ensuring that all of our courses have there specific learning goals and objectives outlined in the syllabi and available online.
- Our skills matrix (see Section B5) is a map to the process skills we emphasize

### H.2.d. Recruitment and Mentoring

Recruitment of additional physics majors is very important to the Department, and we are addressing this on many fronts.

- “What Physicists Do” our popular physics colloquium series
- Web pages with alumni information and “What Can You Do with a BS in Physics?” links
- Astronomy 150 Astronomy for Scientists
- Astronomy minor information placed in A100 Syllabi
- Restructuring of degree plans
  - BS – Astrophysics (new program replacing BS - Applied)
  - BA Physics (rebranded BA-Physics with Calculus)
  - BA Physical Science (Flexible and accessible degree program replacing BA - Trig)
- Outreach Programs
  - Expanding Your Horizons encourages middle school girls interest in STEM
  - Participation in local science fairs
  - SHIP Summer High School internship program
- MESA (Math, Engineering Science Achievement) program
- PhysTEC recruitment grant
  - Teaching pathways highlighted
  - Close connections with High Schools and Santa Rosa Junior College
  - Recruiting posters
  - Social events and open houses
- Society of Physics Students
  - Tutoring
  - High School classroom visits
  - Social events and tabling

*Mentoring:*

- Change of capstone process, 1-unit research, 1 - unit seminar with weekly discussions
- Continue encouraging students take one or more semesters of Special Studies (P495) leading up to the capstone
- Encouraging and explicit programs in tutoring, supplemental instruction and peer mentoring
- Skills Lab run by SPS students to teach lower division students important research skills

### H.2.e. Assessment

Following the Table that begins Section G, we group our assessment plans into two categories: Student centered, and Faculty/Program Centered.

Student Centered Assessment:
- Learning of content and processes of physics
    - Learning objectives, grades, GPA, and faculty observation and commentary
- Attitudes and community
    - Society of Physics Students activity, student participation in extra-curricular activities, pizza-lunches, Public Viewing Nights, and enrollment in seminar series
- Mastery of high-level content, and practices of physics research
    - Capstone course "portfolio" review and assessment of competency in learning objective areas
    - Capstone projects are our main summative assessment tool
- Persistence in STEM
    - Long-term tracking through our "About our graduates" surveys

Faculty/Program Centered Assessment
- Effective pedagogy
    - SETEs, classroom observations, RTP process
- Intellectual activity
    - Grant acquisition, publications, conferences, panels, and depth and breadth of student research opportunities, RTP process
- Service
    - Programs (e.g. S3, EPO, club advising, WPD, PVN etc.), department, school, and university committees, RTP process
- Program efficacy beyond the aforementioned
    - Enrollment, advising, assessment of degree pathways

**H.2.f. Advising and mentoring in the major**

- We have moved from a singular departmental advising to sharing the advising amongst the active teaching faculty.
- Each student is assigned a faculty advisor
- Resources to assist the students exist and are in use: Academic Progress Reports, our advising forms, our prerequisite flowchart, and a four-year planner (see Appendix L).
- We will look at advising holds to fix the WEPT writing proficiency test issues some of our seniors have

**H.2.g. Tenure track faculty hiring plans**

We are well off of our department faculty high of seven during the eighties and nineties. With four tenured faculty and one tenure-track faculty joining us in the fall we are two faculty down from that baseline. Our Department Chair has no teaching load due to her assigned time for her EPO projects. We need additional faculty to keep pace with the growing number of majors, the extremely high 405 Full time equivalent students in our courses and our resulting Student Faculty Ratio of 66.4.

### H.2.h. New and replacement equipment

We received about $225K for new equipment when we moved back into the newly remodeled Darwin Hall in the Fall of 2006. However, there has been no replacement equipment money for many years, and we need to plan for upgrades and maintenance to our new lower division labs. We did recently get an upgrade to the computing in the Darwin 311 lab, and the Darwin 308 lab needed an upgrade which was accomplished by hand me down computers from 2008 that were modern enough to handle our current software needs, but without much headroom for future growth in computing needs. The lower division labs consistently need replacement equipment that requires us to augment our meager annual OE budget of $9,380 with other sources such as grant overhead reimbursements, the use of equipment auctions for lower priced equivalents, and one-time requests of the School. In addition to these needs, the campus observatory is in need of repairs and some equipment purchases to insure its vitality as a resource for majors, general education course students, the student body and the public.

Add recent equipment request list here.

### H.2.i. Changes to degree programs

Perhaps the main result of this program review is our finding that our degree programs were in need of overhaul. We would like to keep an arrangement of four degree programs, but the nature of two of these programs would change. The Department of Physics and Astronomy currently offers two BS degrees (with or without an Applied Physics Concentration) and two BA degrees (with or without calculus). The BA degrees were established to provide a broader background for students seeking a liberal arts education or those seeking to earn a California Teaching credential. As part of the program review these degrees were reexamined both for their current use and for their potential. The BA calculus based and the BS Physics programs will remain. The BS applied will now be an astrophysics concentration and the BA trigonometry (non-calculus) based will now be transitioned into a BA Physical Science.

| | |
|---|---|
| Bachelor of Science in Physics | Bachelor of Science in Physics *(no change)* |
| Bachelor of Science in Physics with a concentration in Applied Physics | Bachelor of Science in Physics with a concentration in Astrophysics *(new)* |
| Bachelor of Arts in Physics with Advisory Plan C (Calculus) | Bachelor of Arts in Physics *(renamed)* |
| Bachelor of Arts in Physics with Advisory Plan T (Trigonometry) | Bachelor of Arts in Physical Science *(new)* |

The **B.S. in Physics** is a thorough introduction to the principles of physics, providing a strong foundation for graduate study or industrial research, and it is our most popular degree. As such, the degree would not change, modulo any course changes outlined above.

The B.S. in physics with a concentration in applied physics is not sufficiently different enough from standard B.S. and we recommend replacing it. In its place we would add the **B.S. in physics with a concentration in Astrophysics**. This program is intended for those students who are motivated to study physics through their interest in Astronomy, an area of growth in the major we recognize. It provides a rigorous, yet astronomically themed, course of study. The selection of electives allows the student to choose physics classes to round out preparation for graduate study, or to focus on our upper division general education Astronomy electives for an emphasis on the classes that motivate their pursuit of a rigorous STEM program.

The astrophysics program leverages our existing astronomy courses, including our intermediate and advanced labs, to create a course of study matched to our students' interest and one of our department's strengths. There are just two additional courses required. The first is Astronomy 150, Descriptive Astronomy for Scientists. This course fits well with our extremely large interest in the introductory class, creating a new section, but one with an amount of mathematical rigor that will serve well as a source for recruiting interested and able students into the major (or minor). This course will need to be approved for GE credit to attract students outside of the major to take the course instead of Astronomy 100. The second course addition is the second course in astrophysics. The de-facto standard textbook for an upper-division astrophysics course, Carrol & Ostile, *Introduction to Astrophysics*, is meant for two semesters of study, and allows us to cover the physics of galaxies and cosmology a key area of interest for potential majors.

**Bachelor of Science in Physic: Astrophysics Concentration** Advising Dates ____________ ____________

Department of Physics and Astronomy, SSU ____________ ____________

____________ ____________

Name ______________________________ ____________ ____________

Example Starting Sequence: (See advisor for details)

| Semester 1 | → | Semester 2 | → | Semester 3 | → | Semester 4 |
|---|---|---|---|---|---|---|
| Math 161<br>Astr 150 | | Math 211<br>Physics 114<br>Physics 116 | | Math 261<br>Physics 214<br>Physics 216 | | Math 241<br>Physics 314<br>Astr 331 |

**Required Core Courses**

| Course | | Units | Semester ‡ | Grade |
|---|---|---|---|---|
| Astr 150 | Astro for Sci | 3 | F | |
| Astr 331 | Astro Imaging | 2 | S | |
| Astr 380 | Astrophys I | 3 | S | |
| Astr 390 | Astrophys II | 3 | F | |
| Astr 482 | Observ. Astr | 2 | S | |
| Phys 114 | Physics I | 4 | F/S | |
| Phys 116 | Phys I Lab | 1 | F/S | |
| Phys 214 | Physics II | 4 | F/S | |
| Phys 216 | Phys II Lab | 1 | F/S | |
| Phys 314† | Physics III | 4 | S | |
| Phys 325† | Math Physics | 3 | F | |
| Phys 340 | Optics | 3 | S | |
| Phys 381 | Comp. for Sci. | 2 | F | |
| Phys 430 | Elec. And Mag. | 3 | S | |
| Phys 450 | Stat. Physics | 2 | F | |
| Phys 460 | Quantum | 3 | F | |

† Phys 314 and 325 are important prerequisites for most upper-division physics courses, see catalog for details.

**Major Electives - 8 Units Advanced Electives**
**One of the courses must be a capstone (*) course.**

| Course | | Units | Semester ‡ | Grade |
|---|---|---|---|---|
| Astr 303 | Life in the Univ. | 3 | F | |
| Astr 305 | Frontiers in Ast. | 3 | F | |
| Astr 350 | Cosmology | 3 | S | |
| Astr 492* | Instruct. Design | 2 | F/S | |
| Astr 495 | Special Studies | 1-4 | F/S | |
| Astr 497* | Astr. Research | 2 | F/S | |
| Phys 313+L | Electronics+Lab | 3 | F | |
| Phys 320 | Mechanics | 3 | S | |
| Phys 366 | Interm. Lab | 3 | S | |
| Phys 445 | Photonics | 3 | | |
| Phys 466 | Adv. Lab | 3 | | |
| Phys 475 | Semiconductors | 3 | S | |
| Phys 492* | Instruct. Design | 2 | F/S | |
| Phys 493* | Senior Design | 2 | F/S | |
| Phys 494 | Phys. Seminar | 1 (≤3x) | F/S | |
| Phys 495 | Special Studies | 1-4 | F/S | |
| Phys 497* | Phys. Research | 2 | F/S | |

* Capstone courses, preferably taken in final Spring semester.

‡ Semester the course is typically offered is shown in gray type: F=Fall, S=Spring, F/S=both. (Subject to Change.)

**Required Supporting Courses**

| Course | | Units | Semester | Grade |
|---|---|---|---|---|
| Chem 115A | Gen. Chem I | 5 | | |
| Math 161 | Calc. I | 4 | | |
| Math 211 | Calc. II | 4 | | |
| Math 241 | Diff Eq+Lin Alg | 4 | | |
| Math 261 | Multiv. Calc. | 4 | | |

Please take Math in this sequence: 161, 211, 261, then 241

> The Bachelor of Physics: Astrophysics Concentration Degree Program as summarized using one of our advising forms. Key elements are: the way it mirrors the B.S. in Physics with only the drop of the required second chemistry course, mechanics, electronics and intermediate laboratory; the addition of an Astronomy 150 course, available immediately for all math-ready students; the two semester Astrophysics sequence; and the two semesters of astronomical laboratory courses.

There is little to no change in the Bachelor of Arts in Physics with Advisory Plan C (Calculus) other than its renaming to simply the **Bachelor of Arts in Physics**. This suggested change is a “re-branding” of this degree to remove the awkward listing of the mathematical rigor. It remains as a flexible but rigorous program that pairs well with multiple career pathways.

Finally, our least popular major, the Bachelor of Arts in Physics with Advisory Plan T (Trigonometry) becomes **Bachelor of Arts in Physical Science**. This degree addresses our push to produce more and better STEM educators while serving as a strong, yet flexible STEM-focused liberal arts degree. We expect this pathway to grow the major, while retaining the strong laboratory skills and capstone development pathway that defines a Sonoma State University Physics major.

The decision to go with a BA Physical Science was derived from three basic incentives. First, there are too few upper divisional PHYS/ASTRO courses that are not calculus based and the non-calculus BA is extremely limited. Secondly, SSU has revitalized its interest in providing clear paths for future STEM educators with a clear need of a major to facilitate teaching science at the middle school level. Chemistry department has already begun looking for ways to create a science waiver program for students seeking to enter credentialing program. Finally, there are not many students that actually take this major. The SSU Department of Geology's recently created a BA in Earth Science and it has been very successful. A Physical Science BA would be able to attract more majors to our department.

| Course | Title | Unit | GE |
|---|---|---|---|
| ASTR 100 or 150 | Descriptive Astronomy | 3 | B1 |
| ASTR 305 | Frontiers in Astronomy | 3 | B3 |
| PHYS 210AB | General Physics | 6 | |
| PHYS 209AB | General Physics Laboratory | 2 | |
| PHYS 300 | Physics of Music | 3 | |
| PHYS 342 | Light and Color | 3 | |
| PHYS or Astro 492/493/497 | Capstone | 2 | |
| PPHY 494 | Physics Seminar | 1 | |
| PHYS 344* | Practical Physical Science | 3 | |
| GEOL 102 | Our Dynamic Earth | 3 | |
| GEOL 303 | Advanced Principles of Geology | 4 | |
| GEOL 304 | Geological Mapping and Report Writing | 1 | |
| CHEM 115AB | General Chemistry | 10 | |

| | |
|---|---|
| **General Education** | **50** |
| **CoreTotal Units (not GE)** | **38** |
| Upper division units | 20 |
| **Support (Math 160 Pre Calc)** | **4** |
| **Electives in Chem/Phys/Geo/Astro/ES** | **28** |
| ***or select GEOG & ENSP classes*** | |

Our program has added advantage of flexibility. The 28 units of elective in the Physical Sciences (and approved classes) allow us to pick key courses to allow the major to serve as a Foundational Science waiver to address the 12 Domains and the skills and standards laid out in the California Foundational-Level General Science Subject Matter Requirements and Program Standards. www.ctc.ca.gov/educator-prep/standards/SSMP-Foundational-Science.pdf By including an optional subset of courses inside the umbrella of electives we are able to support all areas outlined towards a Foundational Science waiver.

***For Science Waiver add these as elective***

| Course | Title | Unit | GE |
|---|---|---|---|
| BIOL 130 | Introduction to Cell Biology and Genetics | 4 | B2 |
| BIOL 131 | Biological Diversity and Ecology | 4 | |
| CHEM 107 | Introduction to Physical Science for Teachers | 3 | |
| GEOL 107 | Introduction to Earth Science (for teachers) | 3 | |
| GEOG 202<br><br>GEOG 302 | World Regional Geography<br>OR<br>World Regions in Global Context | 3<br><br>4 | D5 |
| AND | | | |
| GEOG 375<br><br>GEOL 110 | Natural Hazards<br>OR<br>Natural Disasters | 3-4 | |
| | | 20-22 | Total |
| | | 6 | GE |
| | | **14-16** | Electives |

The major depends on the creation of a new physical science course called "PHYS344: Practical Physical Science". This course would allow for additional upper divisional units as well as address content to be covered by 12 Domains to assist with creation of a science waiver. The course will be more applied in nature, exploring contemporary concepts in physics, chemistry, geology, and astronomy. Dr. Qualls, Dr. Han, and Dr. Jones all have extensive experience teaching conceptual physical science and in these applied areas.

The CSU system has a number of Physical Science Degrees. Our program coming in at 120 units and offered by the Department of Physics and Astronomy would be aligned with the liberal spirit and broad education spirit of the existing CSU programs.

CSU Physical Science Programs

| | | | |
|---|---|---|---|
| Channel Islands | BS | 120 sem | Applied Physics (Physical Science) |
| Chico | BA | 120 sem | Natural Sciences (Physical Science) |
| Chico | BS | 120 sem | Geosciences (Physical Science Education) |
| Dominguez Hills | BS | 130 sem | Physics (Physical Science) |
| East Bay | BS | 180 qtr | Environmental Science(Physical Science) |
| Sacramento | BA | 120 sem | Physics (Physical Science) |
| San Diego | BA | 120 sem | Physical Science (Single Subject Teaching) |
| San Luis Obispo | BS | 180 qtr | Liberal Studies (Physical Sciences) |
| Stanislaus | BA | 120 sem | Liberal Studies (Physics and Physical Sciences) |
| Stanislaus | BA | 120 sem | Physical Sciences(Environmental Sciences) |
| Stanislaus | BA | 120 sem | Physical Sciences (Earth and Space Sciences) |
| Stanislaus | BA | 120 sem | Physical Sciences (Applied Physics) |
| Stanislaus | BA | 120 sem | Physical Sciences (General) |