Undergraduate Review
Department of Physics
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VI. Summary ............................................................................ 34
I. Introduction and Context

A. Self-Study Process
The first draft of this self-study was prepared by the chair and head-adviser, Henri Jansen. The tenure-line faculty met and used Google-Docs to create a long list of points to be included. Several faculty members added descriptions of relevant parts in the document. Significant contributors were: Henri Jansen, Corinne Manogue, and Janet Tate. All faculty members had the opportunity to contribute.

B. Overview
The Physics Department has 15 tenure-line faculty, one senior researcher, and five instructors conducting research and teaching in the undergraduate programs. The faculty has three recent NSF Career Award winners, five Fellows of the American Physical Society, and two Sloan Fellowship awardees. The research in the department is in solid state physics (6), optics (4), physics education (2), biophysics (2), and astrophysics (1). All these research areas have strong connections to other research groups on campus. Research expenditures are approximately $1M per year, and there are 45 graduate students. The department has approximately 120 undergraduate majors over the four years, who progress through a reformed curriculum called Paradigms in Physics. We provide instruction in physics service courses to about 2400 students every year.

C. Mission Statement and Goals
Official Mission Statement: The department has strong research programs in optics and condensed matter physics and an emerging emphasis on biophysics. Experimental, theoretical, and computational research seeks to understand the physics and applications of new materials and to answer fundamental questions about the dynamical behavior of biological and nanoscale systems. As home of the Paradigms in Physics upper-division curriculum project and an expanding program of reform in the lower-division service courses, our department has a strong culture of shared responsibility for curriculum development supported by physics education research. We particularly value collaborative interdisciplinary projects that span departments within the College of Science and with other colleges, especially Engineering and Education.

The Department of Physics contributes to the economic and social well-being of Oregon, the United States and the world by producing graduates whose knowledge of physics distinguishes them as scientifically literate, critical thinkers who are adept at understanding, articulating, and solving problems in science. Our graduates contribute to society as researchers, technology developers, teachers, and problem solvers of all kinds. Our researchers lead nationally and internationally recognized research programs and collaborate with industry to apply basic science to technology and with other educational institutions to improve physics instruction.

Our research program aligns with the Research Agenda articulated by the OSU Research Office, particularly with regard to the healthy spectrum of fundamental and applied research that is conducted
collaboratively with external and internal partners. Oregon State University and the University of Oregon are the only two physics departments in Oregon to grant the Ph.D. and M.S. in Physics. Portland State offers a Ph.D. in Applied Physics and M.S. in Physics. The physics programs are complementary; OSU’s program has cutting-edge experimental and computational research related to materials for photovoltaics, and energy management, as well as biosensors, photonics and optoelectronics.

Our commitment to sustain and accelerate improvements in student learning and experience through creation of outstanding academic and student engagement programs extends from the graduate program, where we have modernized the advanced curriculum, to the undergraduate program, where we have developed a curriculum that is a nationally recognized as an innovative, effective, and flexible way to teach physics to majors and minors, and to the introductory-level and service courses where we have committed significant resources to reform.

**D. Recent History of the Physics Department**

It is instructive to examine briefly the recent history of the department, as it sets the context for future decisions. The modern era began when Ken Krane assumed the chair in 1984, initiating a new hiring cycle after a number of years of stasis. By 1991, the department had 19 faculty members conducting research primarily in three fields: condensed matter, optics, and nuclear physics. Almost all of the current senior faculty members were hired during this period, three of them as part of dual-career hires within the College of Science. These new hires and the opening up of new research areas attracted a large influx of American graduate students, bringing us to a total of about 70-80 graduate students in the early 1990s. These students increased research effectiveness, and also enhanced delivery of introductory service courses. The department was teaching about 1000 students in introductory service courses and about 20-25 majors each year, all by tenured/tenure track faculty members. With new young faculty and the promise of growth, the Department in 1990 was on the upswing.

Political events in the early 1990s, particularly Oregon Measure 5 in 1990, dictated that further growth at OSU was not to be. In fact, the size of the entire OSU faculty was reduced by attrition, and this was particularly acute in Physics, already a small department, where the number of tenure-line faculty slowly decreased and then, worse, abruptly fell to 9 in 2003 due to PERS (retirement benefits) changes in the state of Oregon. The number of graduate students was at an all-time
low at 33. See Figure 1 for a graph of faculty and instructor numbers over time.

During this period, faculty members responded with several targeted strategies. Solid state physics remained relatively strong by establishing research connections and collaborations with researchers in Chemistry, Engineering and Materials Science, under the umbrella of the Center for Advanced Materials Research. The optics group did not have counterparts in other departments, and was in danger of losing critical mass. Most of the positions lost due to retirements were in the nuclear physics group, which was also competing for diminishing national funding. A decision was made to make no further hires in nuclear physics.

In 1997, a group of faculty members developed “Paradigms in Physics”, our reformed upper division-curriculum, with substantial support from the NSF. In a complementary path, we also recognized the need for physics students to learn modern computational methods, and we secured a large NSF grant to establish a degree in Computational Science. Both these efforts had natural connections with designing and evaluating curriculum and pedagogical strategies at the collegiate level, and as a result we initiated our current Physics Education research field.

To manage the teaching during this period of declining numbers, we hired fixed-term instructors, including some of the recent retirees. Mostly, the terms were year-to-year, but we also had to recruit instructors on an ad-hoc basis. Over time, we have been able to recruit a more stable group of experienced and dedicated instructors.

In 2001, we had joined the national PhysTEC program, one of six departments invited to do so, to help pioneer improved physics teacher preparation. On the graduate education front, we were one of four departments at OSU to develop, with Sloan Foundation funding, a Professional Science Masters degree. We recognized a need in industry for students with an advanced physics degree, who also had business and communication skills. Because of the large loss in faculty members in 2003 we were forced to leave PhysTEC and eventually to terminate the PSM program.

Responding to the dire need to increase the number of research active physics faculty, the College of Science authorized six hires at the Assistant Professor level in the early years of the new century, two of whom subsequently took jobs elsewhere, and five hires in the past three years. Coupled with three
retirements, we find ourselves in 2014, with 15 tenure-line faculty members, one senior researcher, and 5 recurring instructors. Our main research fields are solid state physics, optics, physics education research, and biophysics. We have a relatively young faculty, highly talented and energetic. Once again, the new influx of younger faculty has resulted in increased research productivity. However, unlike in 1990, the total number of faculty members remains small, and we face a challenge to deliver the level of research and instruction to which we aspire at a university where student enrollment has grown far faster than faculty numbers. See Figure 2 for enrollment growth at OSU during the same time period. According to the 2010 survey of physics degree-granting departments by the American Institute of Physics there are 192 departments that award a PhD as their highest degree. The average number of faculty FTE in these departments is 29, of which 5 are instructors. We are in the lowest quarter of faculty size for these departments.

II. Input Assessment

A. Organization and Administration

Organizational Chart
The Department of Physics is one of seven departments in the College of Science. See the current and previous organizational charts in Figures 3 & 4, below. The College of Science welcomed a new dean, Sastry Pantula, this past fall (2013).

Figure 3: Organizational Chart Starting 2014.
Figure 4: Organizational Chart, prior to 2014, showing shared personnel with Chemistry.

New Head
The current department chair has been in his position for over 15 years. Most faculty members have only experienced a single department chair; no one has experienced more than two. The chair’s position has been full-time, including two summer months of salary. All other departments in the College of Science are currently administered by a half-time chair or head, including only one summer month of salary. Many of these departments also have Associate and/or Assistant Chairs. In addition, our former undergraduate head advisor and assessment coordinator, David McIntyre, has, for the past year, been the interim Associate Dean of Research in the College of Science. The department chair has temporarily been taking over the head advisor duties. We are currently engaged in an open search for a new department head. We expect that the new head will implement changes to our administrative structure, including the appointment of associate/assistant heads, a new head undergraduate advisor, etc. We hope that the new structure will facilitate coordination among tasks, foster institutional memory, and ease the overall administrative burden, while nevertheless maintaining our department culture of—everyone pitches in to do whatever needs doing.

Support Staff
For this fiscal year 2013-2014 we have two and a half FTE in support staff.

We are in the process of implementing a new office staff structure where the office in the Physics Department relies on the work of an office manager who also is responsible for graduate matters, and an office specialist who is at the front desk but also is responsible for undergraduate matters. Our old structure relied on an office manager and three staff positions shared with the Department of Chemistry (in another building). We will continue to have common staff meetings with the Department of Chemistry, since that was a very useful aspect of our joint office in the past.
We share an electronics technician with the Department of Chemistry. We are also in the process deciding on how we can share machine shop functions with the Department of Chemistry.

**B. Degree Programs**

For a list of course requirements for the BS and BA degrees in physics, see Appendix A1. Course descriptions for all undergraduate physics courses can be found in Appendix A.2. In Appendix A.2, service courses are indicated with the qualifier (Service) and Baccalaureate Core courses with the qualifier (Bacc).

**The Physics Major: Paradigms in Physics**

Our department is nationally known for our innovative and unique upper division program, which has had continuous funding from the NSF since it began 17 years ago. The Paradigms in Physics program is a curriculum development project which has restructured the upper-division curriculum for majors to be more modern, flexible, and inclusive. The content is reordered to present physics the way professional physicists organize their own expert knowledge. Pedagogical approaches include interactive small-group learning, project-based classes, kinesthetic activities, and technology-based visualization activities, among others. Outcomes include 3 traditionally published textbooks and 1 free online text, 34 published articles, and numerous presentations. Dissemination includes over 200 activities posted on ComPADRE (the physics arm of the NSDL), workshops at national professional meetings and standalone summer workshops. Current projects are investigating student and expert understanding of, and developing curricular materials for, (i) middle-division electromagnetism content, (ii) partial derivatives, and (iii) synergies between a pair-programming based computational physics course and middle-division physics theory courses. We are THE physics program which is always asked to present the session on upper-division curriculum at the American Association of Physics Teachers’ New Faculty Workshop. We have just been awarded a Supplement to our NSF Paradigms grant to host a national workshop on the upper-division physics curriculum. A *Physics Today* article describing the Paradigms program can be found in Appendix B.

**Flexibility in the Physics Major/Minor**

**Physics Options:** Currently, on the undergraduate level the Department of Physics offers a BS and a BA degree in physics. Over twenty years ago we created several options for this degree, in order for the students to have some choice in their course schedule. The American Physical Society has found that creating such options attracts more students to the physics major. Current options are: Applied physics, Chemical Physics, Computational Physics, Geophysics, Mathematical Physics, Optical Physics, Physics Education and the most recently added Biophysics option. We are contemplating adding a Premed option, which would be an extension of

![Figure 5: Number of Engineering Physics B.S. degrees from 1962-2009.](image-url)
the biophysics option replacing four additional courses in the total program.

**Computational Physics:** We began the last decade with an award-winning Computational Physics major (CPUG) which had received $.5M in NSF funding for its development. In 2009, the university administration eliminated the degree program due to budget cuts and a low enrollment. (The degree program still formally exists until the one remaining student in the program graduates.) We have used these changes as an opportunity to improve our computational physics offerings to better serve our larger population of physics majors. Beginning in 2009, we redesigned our introductory computational physics course, PH265, to use visual Python to introduce students to scientific computing in a manner that better works with the physics taught early in the introductory PH 21x series. In 2012, we introduced a new computational lab sequence PH36x, which runs parallel to the junior-year Paradigms courses, and covers similar content from a computational perspective. This new 1-credit course is designed to fit into our students’ busy schedule, and reinforce content that students struggle with in the Paradigms. This course uses pair programming in a computational laboratory setting to enable students to learn to use computers effectively to solve physics problems. In 2013, we obtained a $124,000 NSF TUES grant to support the development, assessment and dissemination of this course. We hope soon to be able to require this sequence of all physics majors, since computation is a skill that is required by all of our students in the lab and in the job market.

**Engineering Physics:** Engineering physics was a very popular degree in the 1980’s, see graph. By 2008, the degree program attracted about 20 students per year, but graduated few students. Most of those students either switched to a pure physics degree, to a pure engineering degree, or to a dual degree. In 2008-09, the program was cancelled by the university administration due to budget considerations. (Like Computational Physics, this program remains officially on the books until the last few students graduate.) Although we were worried about the repercussions from the action of cancelling the engineering physics degree for the number of incoming students to the department, we have not seen any effects on numbers as more students switch from engineering to physics than before. We have designed a replacement in the applied physics option. However, the change from engineering physics to the applied physics option has put added pressure on our undergraduate thesis program since students are now required to do a research thesis in our department rather than a design course in engineering.

**Electronics sequence:** Our three term electronics sequence comprises the courses PH 411 and PH 412 Analog and Digital Electronics and PH 415 Computer Interfacing and Instrumentation. This sequence may be taken after introductory physics, so can include sophomore, juniors and seniors. The courses are primarily laboratory based, with some lecture component. Students learn how to design, build, and test electronic systems, and in PH 415 how to interface their electronics with a computer to both control an experiment and record measurements. These courses provide hands-on experience that students utilize in their senior thesis research projects and then later in employment. The American Physical Society has studied the characteristics of physics programs that place many undergraduate students in industry, and one important element was the offering of a course sequence like our electronics sequence in the form that we are offering it.
**Optics interdisciplinary sequence:** In the senior year, students may take a series of three optics courses that are offered jointly with the School of Electrical Engineering and Computer Science (EECS). The Physics Department course is PH 481 Physical Optics, and the two EECS course are ECE 482 (PH 482) Optical Electronic Systems and ECE 483 (PH 483) Guided Wave Optics. Each course is 4 units that include a 3-hour laboratory each week. The PH 481 course covers many of the basic concepts of optics such as interference, diffraction, and polarization, while the EECS courses cover applications in the areas of lasers, fiber optics and photodetectors. The PH 481 course is required for most options within the Physics major. All three optics courses are required for the Optics option of the physics major.

**The Physics Minor:** The Physics Minor is comprised of the PH 21x, the introductory calculus-based sequence, PH 314 Modern Physics, and 12 credits of upper-division courses including at least one theory course and at least one experimental course. Because our upper-division paradigms and capstone courses are broken up into small pieces, rather than being traditional year-long sequences, we find it easy to advise students into courses which create a well-rounded physics minor that is appropriate for each individual student’s career goals.

**Undergraduate Research/Thesis/WIC**

All physics undergraduates participate in faculty-mentored research and write a senior thesis. The graph shows the enrollment in the course. Most students work with our faculty for at least 3 terms, while others participate in external REU programs or corporate internships with an OSU Physics faculty member as co-advisor. The departmental WIC (writing intensive curriculum) course, PH403 Senior Thesis, is led by a faculty member, trained in the WIC seminar course, who guides the class through the writing process, ensuring that students practice the writing and oral presentation norms in physics, peer-review the content and writing, and discuss ethics and professional practice in science. All majors (approximately 20 per year over the last five years) take the course, which runs for 3 terms at 1 credit per term. The course culminates with a mini-conference where all students give 12-minute oral presentations in the style of a professional conference. Many students present their work in posters or talks in various other venues – regional or national meetings of the American Physical Society, undergraduate conferences at OSU. Several have co-authored scientific papers with their advisors. We advertise the program on the departmental website on the WIC page. A list of undergraduate thesis students and topics by year can be found in Appendix C.

**GRE seminar**

Every spring term we organize a seminar to prepare our juniors for the GRE Physics examination. Students meet one hour each week with the department chair and work on problems from previous exams. Students learn to discuss the problems from a physics problem solving perspective as well as...
from the perspective of a fast time-limited test in which one is asked to look for quick short-cuts that allow one to decide which answers are wrong.

**Attention to Professional Development of Undergraduates**

*Within the Paradigms Program:* The Paradigms Program was designed explicitly to pay attention to the professional development of students in multiple ways. The active engagement classroom atmosphere provides multiple opportunities for students to speak in front of the whole group and for us to discuss presentation skills. Our small-group activities encourage cooperation and group-problem solving. We encourage collaboration outside of class, but stress intellectual honesty by requiring students to acknowledge help and to recognize when seeking help is positive and when it is detrimental. PH421 and 424 have integrated laboratory activities that provide opportunities to discuss professional writing expectations. PH427 has a journal project where students independently study a paper in, typically, the American Journal of Physics, and present it to the class in a 10-minute talk and also write a synopsis that is shared with the class. AJP is an excellent “starter” journal, ideal for undergraduates. It has intellectually rich articles about well-known topics studied in classes, but is not forefront research that requires graduate-level knowledge.

**SPS:** The OSU chapter of SPS is thriving, with a membership of 56 students, and an active leadership. The students organize study and social evenings and play an active role in mentoring more junior students. Recently, they held an evening event to describe their research projects to juniors and sophomores. SPS members volunteer with the SPS advisor, Jim Ketter, to participate in Discovery Days, an OSU hands-on science outreach event that reaches 4,000 K-9 students each year.

**Women in Physics:** Undergraduate and graduate students, both women and men, meet to discuss matters of concern to women in science. Women faculty members are advisors to the group. The level of activity varies from year to year. The most recent project is to write a proposal to host a west coast undergraduate women in physics conference. In addition, each year, members of the group volunteer with advisor Janet Tate to host “tours” of physics during Discovering the Scientist Within event for middle school girls. Students engage in hand-on experiments that explore the natural world (including making ice cream with liquid nitrogen!).

**Undergraduate TAs:** Every year, about 5-10 undergraduates have the opportunity to be teaching assistants (TAs) for general physics laboratory sections, and a few are learning assistants (LAs) in the Studio/SCALE-UP classroom. They meet weekly with the course instructor to discuss pedagogy and specific labs and receive feedback from the instructor. We have no formal undergraduate TA training program, but we encourage participation in any of the training activities described below for graduate TAs.

**In research groups:** Research groups foster professional development of undergraduates by encouraging participation in local and regional conferences. The main examples are the annual meeting of the Northwest Section of the American Physical Society, and the bi-annual meeting of the Oregon Association of Physics Teachers, where undergraduates often give poster or oral presentations. Other activities that are routine for most of our undergraduates are purchasing supplies from vendors,
negotiating prices or interfacing with vendor support during the course of their research. They learn lab management skills and are given primary responsibility for particular tasks. Thus the well-being of the lab hinges on their success in the task. Discussion of ethical practice is part and parcel of the research experience and is reinforced in the formal PH 403 Senior Thesis course, where the students discuss conflict of interest, funding sources, ethical conduct of research and famous cases of fraud. Undergraduates are also encouraged to participate in the departmental colloquium and regular research seminars in solid state/optics, and teaching. The department hosts the yearly Yunker lecture which brings exceptional speakers to campus.

Social Events: Undergraduates are included in the social fabric of the department, and overall, we think that the undergraduates feel part of the family. We hold two yearly picnics, one just before the first week of the Fall term, and one at the end of the spring term, where our awards are given out. Attendance by undergraduates is increasing; these were primarily graduate events before five years ago. We recognize that we do not have undergraduate awards and we are planning to institute them. There is a yearly graduation dinner attended by the senior class, their families and faculty. About 2-3 faculty members attend each year. The department subsidizes the students’ attendance. Many faculty members hold a yearly dinner for their research groups. Because of the strong involvement of our undergraduates in research, they are always included in such events. A number of undergraduates are regular attendees at the weekly “coffee and cookies” before the departmental colloquium (and the colloquium itself!). The undergraduates self-organize social events, too – in particular the SPS sponsors movie nights and other professional events where social gathering is a feature (see above).

Outreach activities
In addition to the outreach activities mentioned above we have participated in summer camp sessions for programs like Outside the Box and Adventures in Learning, as well as for Winter Wonderings. We host visits from middle and high school classes. We work with local teachers who need to borrow equipment for their classes.

C. Lower Division Service courses
Our department offers the following service courses, which are required for a degree program in another discipline. General Physics with Calculus (PH211-2-3) for engineers and scientists, General Physics (PH201-2-3) for biologists and health and medical professionals, Inquiring into Physical Phenomena (PH111) for pre-education students, Energy Alternatives (PH313) for environmental science students, and Introductory Modern Physics (PH314) for some EE options. For catalogue descriptions of services courses in the physics department, see the designation (Service) on the list of catalogue description in Appendix A.2.

Brief history of reform efforts
The department has a long history with curricular reform in our service courses which has extended through several escalating phases. About twenty years ago Ken Krane, in our department, was the first at OSU to work with personal response systems to improve interactivity in large lectures. When more departments started to use these “clickers,” the university stepped in and enabled our current system where students can use one system for all their classes.
Later, for two years we experimented with true team teaching in the introductory physics classes when Pat Canan, a very successful Corvallis High School physics teacher, worked with the chair co-teaching the class, both being present in the classroom all the times. Although this was a powerful experiment, in the current financial climate it is clearly not sustainable.

When our faculty numbers fell abruptly in 2003, it became necessary to begin hiring increasing numbers of instructors. While our experiences were extremely poor at first, we have gradually been able to hire more experienced and dedicated instructors. Six years ago, we made the decision to hire a physics education research specialist, Dedra Demaree\(^1\), to spearhead a more holistic lower division reform, taking into account the many lessons we had learned from our upper division reform. We began a lower-division curricular group which meets every three weeks to discuss curricular matters in all lower division courses, including these service courses. The content of the service courses is decided by the faculty as a whole, after surveying the client departments. All instructors are expected to follow the same weekly schedule. Students have to be able to take any course any term and be at the same place at the end of the course. When we experiment with changing the order of chapters within a term and within a course, we discuss the consequences and outcomes if possible.

In 2008, we contributed to the planning of the remodel of Weniger 151, our largest lecture hall, by requiring that chairs can swivel, so students can form groups more easily. Next, we selected a modified Studio/SCALE-UP model for PH 211-2-3, and our department obtained funding through the OSU foundation to remodel Weniger 212 to accommodate this form of instruction. In this classroom redesign, students sit at round tables in three groups of three, and work on a series of problems or small hands-on experiments. Lecturing is minimized or non-existent. Because we did not have sufficient instructional resources, we did not transform to a full Studio model, completely without lectures, but adopted a hybrid model (2 hrs. lecture, 2 hrs. studio, 2 hrs. lab each week). At this moment we are only able to offer one section per term in this form.

In "Discipline-Based Education Research" (DBER), the National Research Council (2012) recommended ways to understand and improve learning in undergraduate science and engineering [http://www.nap.edu/catalog.php?record_id=13362](http://www.nap.edu/catalog.php?record_id=13362). In 2010, a group of senior education research and DBER faculty members began discussing how they might collaborate to improve the overall experience of Science, Technology, Engineering, and Mathematics (STEM) undergraduates at OSU. In 2011, this group formally identified itself as a faculty learning community called ESTEME (Enhancing STEM Education). In 2012, OSU inaugurated the new Center for Research in Lifelong STEM Learning which expects to welcome its permanent director this week! See Appendix D. In its first collaborative grant effort, the ESTEME group received a $1.3M NSF grant in January 2014 to expand Evidenced-Based Instructional Practices (EBIPs) in large-enrollment courses in five STEM disciplines across campus. As part of the National Science Foundation's Widening Implementation and Demonstration of Evidence-Based Reforms (WIDER) initiative on campus, we plan to expand our studio offering of PH21x to three sections per term, assuming that the university supports the extra demands on personnel.

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\(^1\) Dr. Demaree left OSU in spring 2013.
**TA Training**

Like other large universities, OSU relies on its Physics Department to teach introductory physics to thousands of non-physics majors, and effective delivery relies heavily on the service of graduate and undergraduate teaching assistants. TAs deliver about 8-9 contact hours weekly to each student in introductory physics and other laboratory courses such as Astronomy, and they also assist in the Paradigms sequence, the electronics sequence and the optics course in the major. We recognize the crucial role of TAs in our instructional mission, and we strive to provide them with the appropriate training and professional development.

Incoming graduate TAs participate in a 2-day orientation workshop to learn basic skills and interact with faculty and experienced TAs. In the Fall term, there is a mandatory weekly TA seminar in which they practice delivery skills, develop group activity strategies and learn rules and regulations and standard practice. All TAs meet weekly with instructors to discuss course content, student performance and general strategy. In the Winter and Spring, there is a weekly Teaching Seminar (optional) in which a faculty member guides discussion about pedagogical practice, curriculum issues, learning theory and many other topics. All TAs are made aware of, and encouraged to attend, seminars and workshops offered by OSU’s Center for Teaching and Learning. TAs are evaluated each term by the course instructor who attends at least one section, and peer-peer evaluation and feedback is strongly encouraged. The instructor files a formal evaluation and discusses that evaluation with each TA.

**D. Baccalaureate Core**

**List and description of courses**

In the Baccalaureate Core portion of OSU’s general education program, all undergraduate student are required to take 51 credits in courses designed to help them:

1. build their foundational skills like writing, speech, and mathematics;
2. gain knowledge and perspectives across academic fields and diverse cultures;
3. develop abilities of analysis, critical thinking, and problem solving.

For a complete list and catalogue description of baccalaureate core courses offered by the physics department, see the courses in Appendix A.2 with the designation (bacc.).

**Brief history and current reform of astronomy**

The baccalaureate core courses in astronomy have been a traditional element of our contributions to the bac core science category. We have always had several faculty members with a strong interest in astronomy, and they developed the original versions of these courses. About ten years ago we had to stop offering the 200 level versions of these courses because of the lack of personnel. At that time the lower level course PH104 was taught for a few years by a PhD student in Science Math Education, Matthew Price, who had been a high school physics and astronomy teacher and had an MS degree in physics. He introduced several new ideas, based on education research, into the course. After that, the course was either taught by our instructor, Jim Ketter, who is also our laboratory preparation person, or by another instructor on campus, Randy Milstein. Both these instructors have taken a strong outreach role as well, and (weather permitting) they take the telescopes out for general students to observe.
interesting phenomena, like the transition of Venus. We have been very fortunate to hire Davide Lazzati and Jay Rhee, both astronomers. Davide will be helping with the on-campus PH104 delivery, while Jay is responsible for transforming PH205-6-7 into an e-campus mode.

Teacher Preparation
PH111, Inquiring into Physics Phenomena, engages prospective elementary and middle school teachers in learning science in ways that reform documents recommend that they teach science. The course emphasizes questioning, predicting, exploring, and discussing what one thinks and why. With support from the National Science Foundation, we developed materials and strategies for integrating physics and literacy learning such as learning to speak clearly, listen closely, write coherently, read with comprehension, and make and critique media resources competently in physics. Each unit engages the prospective teachers in identifying resources upon which to build, developing powerful ideas based on evidence, using those powerful ideas to develop an explanation for an intriguing physical phenomenon, developing mathematical representations for the phenomenon, and then using those mathematical representations to estimate a quantity of interest. Units include the nature of light phenomena, the nature of thermal phenomena, the influence of light and thermal phenomena on local weather, the influence of light and thermal phenomena on global climate change, the nature of astronomical phenomena such as the phases of the moon, and reflection on science teaching and learning. As of 2013, this course has been identified as required for elementary education double degree majors, as the physical science component. (BIO 101 and GEO 201 are the other sciences courses identified as required). Note: This important course was developed and has been taught by Dr. Emily van Zee, who, since retirement from the University of Maryland, has been a part-time research faculty member in our department. We need to plan how to continue offering this important course when Prof. van Zee retires from her retirement. Other experiences within the physics department that can contribute to the preparation of future teachers are: participation as an undergraduate TA, participation in the teaching seminar (winter and spring) and education research seminars in mathematics and engineering, participation in a PER-based thesis or other research project.

E. Distance education
Computational physics: In 2007-2012 we offered computational physics, PH 46x developed by Rubin Landau, as distance courses. The content of these courses is particularly well suited to distance delivery. He introduced many very novel techniques to convey the content. For example, he used a presentation approach where part of the screen showed a white board with written text, another part showed the instructor explaining, and a third part showed relevant parts of the notes. They were linked together, and students could go back to any point in the lecture and all three screens would remain synchronized. Student feedback on the content was positive, but the number of students taking the course was small and several objected to the increased tuition cost associated with online delivery.

Astronomy: Beginning in fall 2013, we are developing distance versions of astronomy courses PH20x under the direction of astronomer Dr. Jay Rhee. These are baccalaureate core courses that are independent of each other. Astronomy offers one of the most obvious uses of on-line laboratories, since much of the work involves discussion and analysis of previously acquired images. Even in our conventional astronomy course, observational labs are limited because of inclement weather.
**Service Courses:** Our on-line course presence is significantly below that of other departments in the university with regard to service courses. It is partly driven by lack of teaching staff, but also partly by choice. Because a significant part of our curriculum reform effort has been based on developing in-class interactive activities and improving the large-lecture experience, we have come to believe that it is often not possible to deliver an equivalent quality educational experience on line, at least not without committing more faculty resources/student rather than fewer.

Further, we consider that *calculus-based introductory physics* falls under engineering accreditation rules that require laboratory-based courses. In PH21x, laboratory experiences are integrated into the curriculum. We have so far resisted divorcing the laboratory experience from the lecture experience because education research points to strong pedagogical reasons to keep them connected. The physics community has studied several possible forms of distance laboratories, each with a certain range of applicability, but no good answers have been found yet.

The *algebra-based courses* are part of the pre-medical sequence, and medical schools do not accept distance courses. All OSU pre-meds would be excluded from a distance version of introductory physics course at OSU. (We note an incongruous loophole: If a student takes a distance course at another university and transfers the course to OSU, the fact that it was a distance course is lost. Unless the medical schools require the submission of transcripts from all schools, the distance aspect might go undetected!)

**F. Honors College**

*Honors recitations:* Each term we offer two honors recitations, PH22xH, which run alongside the calculus-based introductory physics courses. Taught by faculty members, these recitations expose the students to the same material as the regular recitations, PH22x, but with added depth and complexity. Typical enrollments are 10-20 students.

*Honors seminars:* We offer honors seminars, HC407/PH407H, developed by faculty members: Physics and philosophy of time, Kenneth Krane; Warthogs and boa constrictors, Albert Stetz; Cosmology: History and nature of the universe, Albert Stetz.

*Honors introductory physics:* In 2007-08 and 2008-09, we taught PH20xH/PH21xH, an honors version of the introductory physics course to a combined student population from both the algebra-based and calculus-based sequences. We used a novel approach based on the “Matter and Interactions” textbook, different from the main-sequence versions of the courses. The different approach and text, though desirable intellectually, turned out to be problematic because the sequence of topics did not match that of the regular version, and students switched in and out of the honors courses on a term-by-term basis. After two years, we canceled the honors sequence because of insufficient teaching staff. We plan to reintroduce honors introductory physics when faculty numbers allow, but we will have to discuss how to track the main-sequence courses more closely.

**G. First Year Experience**

*PH199:* PH199 is a student-designed, 1-credit course offered in winter term to first-year students or
second year students proposing to switch majors. The course seeks to give students the information they say they need in their first or second year. It is similar to past versions of our overview course in that it delivered by several faculty members who discuss aspects of their research, but it differs significantly by offering hands-on activities and group discussion that illustrate basic principles of the physics involved. It was offered for the first time in the winter of 2013. Initial feedback was positive, and we will interview those participants in spring of 2015 after completion of their junior year to assess the impact of the PH199 experience.

*Research Open House:* Every April we organize a research open house where we present information about our research opportunities and have tours of the research laboratories. The goal of the open house is two-fold. We use the open house as a second connection to research for our physics majors; PH199 is the first one. We also advertise the open house in the introductory physics courses and use the open house as a recruiting tool.

*PH21x majors-only laboratory section:* Beginning in spring 2014, we will pilot a special laboratory section for the main sequence of the introductory calculus-based physics course. For physics majors only, it will be taught by the physics head adviser. We hope that this lab section will build a stronger identity for the physics majors in their first year.

*U Engage:* For the first time this fall, a physics department faculty member offered a seminar course (Working with Youth in the Community, Corinne Manogue) in the university wide, U Engage freshman orientation series, designed to help students learn and practice college success strategies.

### H. Incoming Student Information

*Admission criteria:* We do not have admission criteria. Students need to follow the standard university wide GPA rules. Figures 7 and 8 show SAT scores and high school GPA of our incoming junior class. We have found that these data are not meaningful predictors for success. We studied the correlation between the SAT scores, high school GPA, and OSU GPA for this cohort of students and found essentially no correlation at all.

Enrollment demographics can be found in Appendix E. In Figure 9 we compare the percentage of women in PH 320 with the national percentage of BS degrees awarded to women. This latter number has roughly remained constant at 21% in the last ten years. The last few years we have seen an increase in the number of women in
PH320. We have not studied further what caused this change, but we do plan on following up.

*Physics major declared at time of admission:* We do not make a strong effort to track majors in their first two years, but focus, instead, on providing students with the information that will enable them to make an informed choice of major. At the start of their study, they are often uncertain about what their major should be. They have limited exposure in high school, they have a different perspective on what a major is, they discover new fields, of they find out that skills required for the major of their choice are not compatible with them. In our department, we see about the same number of students in the initial START advising as we see coming into our junior year two years later. But the number of students common to both is less than half.

*Community College transfers:* A number of students transferring into our program have finished their preparation at a community college. We have a good collaboration with LBCC, the local college, and the lead physics person at LBCC, Greg Mulder, knows our program well. Students visit with the head adviser in our department during their time at LBCC and the head adviser also visits LBCC to talk with the students in their physics program. The lead physics instructors at two other colleges, Lane and Chemeketa, also know our program well, and students from those programs have had no problems due to a programmatic mismatch between the community college and us. We have not done any formal analysis of the performance of transfer students from the community colleges, but informal discussions with the students do not indicate that there are program dependent transfer specific issues. This agrees with the study in the College of Engineering, where it was found that these transfer students in their first term often have a somewhat lower GPA, but at graduation are indistinguishable from OSU students.

*Internal transfers:* Internal OSU transfers are mainly from the College of Engineering or from other science departments. This makes sense, because of the strong mathematics requirements in our first two years. Liberal arts students often have to make up two extra years of study, which is in many cases not practical. Transfers from the College of Engineering fall into two categories. Some students realize that their focus is more science-oriented instead of engineering oriented. Other students realize that their GPA is too low to be accepted into engineering upper-division professional school. The source of our internal transfers is consistent with what is observed in other physics departments where there is an engineering program.

I. Facilities

Classrooms
The Physics Department uses three classrooms that are under its own control rather than publicly
scheduled. These spaces have been remodeled using primarily funds from the OSU Foundation and maintained (minimally!) using physics department funds. These classrooms are:

**Weniger 304:** Capacity 36 students in a lecture format, 27 in an active-engagement format. Tables seat groups of three students in either a lecture or an active-engagement seating arrangement. Each table has a computer. Two overhead projectors and screens. Black and whiteboards on all walls. This room is used primarily for upper-division courses for majors and graduate courses.

**Weniger 212:** Capacity 72 students at tables which seat 9. Three computers at each table. 8 Starboards and one whiteboard on the walls. Capability to project the instructor’s computer, the whiteboard, student computers, or Starboards around the room. This room is used primarily for the reformed PH 21x sequence. (But see notes on capacity issues below.)

**Weniger 377:** Capacity 18 students at tables that seat 2. Overhead projector and screen. Blackboards on two walls. This room is used primarily for graduate classes.

**Lower-division Laboratory Space:** In the department we have four instructional laboratories that are used for the introductory physics sequences and one for astronomy. These labs for the introductory physics sequences are used from Monday afternoon through Friday evening, well over 40 hours per week. We also need time every weekend to switch the laboratory setups. The astronomy lab is used only 20 hours per week, but because of the specialized set-up we cannot use it for other regular events. We do use it during high school visits, for example. The instructional laboratory space for the electronics sequence is scheduled for use only for 6 hours per week, but students drop in during off times. Since projects take weeks to develop, this laboratory cannot be used for other courses. Another specialized instructional laboratory is our optics space, which was created with support from the Murdoch foundation. This lab has optical tables, and cannot be shared with other functions. We have a smaller teaching laboratory for the modern physics course, PH314. This room is used during two terms only. During these terms experimental set-up is time consuming, so other use is not possible. During the off term the space could be used for other purposes, but is too small for our introductory courses.

Underutilized is our instructional laboratory for the 300 level bac core courses. We recently acquired the space next to it, and we plan to remodel these spaces for an additional instructional laboratory for the introductory physics sequence and a second studio class-room.

**Computer labs**
We have a computer lab in room 412 that is available for students who are enrolled in a computational physics course or in solid state physics. The computers in this space were recently replaced, and are working well for students. Access to the lab is controlled by key card. Most students do not pay the $5 required to get a key card, which limits the usefulness of this space outside of class time.

Students also have access to computers in the Paradigms classroom (Weniger 304), the Studio classroom (Weniger 212) and lower division lab rooms.
SPS and Weniger 304F
The department provides three study rooms for undergraduate students: the SPS suite, used primarily by seniors, (Weniger 381 and 383), which comprises a lounge area and a quiet study room/library, and Weniger 304F, used primarily by juniors, which includes 8 computers and a printer, available 24/7 to all students taking upper-division physics courses. Access is loosely controlled by a key which is available for $5, but the room is usually available without a key because other students are present.

The Yunker library
The Yunker library was recently remodeled to provide space with computers and overhead projector for student presentations, group meetings, etc.

J. Budget
The budget for the physics department for the year 2012-2013 is given in appendix F.1. We are concerned that it is February and we do not yet have a final budget for the current fiscal year. Current information is in Appendix F.2. Notice that we are highly efficient: services and supplies represent only 3% of our total budget. A description of total departmental expenditures for the past 8 years is shown in Figure 10. These numbers include spending on Foundation accounts used for startup. Contributions to our budget from returned overhead (as a measure of research productivity), Figure 11, and summer courses (for which tuition returns directly to the department) Figure 12, are shown below. Research overhead in the years 1994 to 1997 contained a large amount of dollars related to John Gardner’s accessibility project, where he studied effective methods to make mathematical text available to vision-impaired students and researchers. The university returns 26% of returned overhead to the colleges generating the research income, and the
College of Science passes this on to the department. At the departmental level these funds are combined with all other funds to pay for regular instructional expenses. Summer income has increased dramatically in the last eight years. At Oregon State University 85% of the tuition dollars generated in summer are returned to the department offering the courses. We offer a complete algebra based sequence in summer, in a fast pace, in eleven weeks. Enrollments in those courses in summer have more than doubled in the last eight years. In addition, we now offer both the first and the last term of our calculus based sequence in summer, but each course takes eight weeks.

Our department has been very active in securing external grant funding for education research, curriculum development, and teacher preparation activities. Figure 13 is an approximate representation of this research income. The total amount of the research dollars awarded to OSU is divided equally over the years of a grant’s active life. This graph represents the total income to the university and not just to the department, because many of our educational projects are highly collaborative. Nevertheless, it is a valid demonstration of our interest in all scholarly educational aspects of our work.

K. Issues

Restrictions on enrollment and current capacity, etc.
The policy decision by the OSU’s administration to increase student enrollment is causing stress on our program at every level.

Upper-division: In the last few years the number of students in the junior year courses has been well over thirty. This includes students who have to retake courses and students who are physics minors. This number pushes what we can accommodate in a single section. Our paradigm courses are very interactive, with many student activities, and the quality of the student learning experience degrades rapidly when the number of students in the section increases beyond thirty. If we were to have fifty students starting the junior year we would need two sections, which would require additional faculty members. Another restriction on the number of students in the junior year is the size of our classroom, which can hold a maximum of thirty-six students in a lecture orientation, but a maximum of 27 in an active-engagement mode. This classroom was remodeled by our department about ten years ago. In the last two years we have used our studio classroom when enrollment was too large, but with the current plans of expanding studio delivery of service courses that will be harder to do.

Service Courses: We track the demand for seats in service courses by following historical data for enrollments. Because the size of our sections is determined by the size of the classrooms in Weniger Hall
we tend to add capacity in chunks of one hundred students. Adding an extra section is a real cost, because all our faculty members are already at a full load. Therefore, if we add a new section we have to add around 15k$ for instructors and teaching assistants. This is a real cost, and needs access dollars to back up.

*Lab space constraints:* The capacity for a given course is often determined by the availability of instructional laboratory space. In a given term we cannot offer more than 540 seats in a course offering of a term in the calculus based sequence, for example. The engineering enrollment in the past year showed that we were short at least one hundred seats this year, and therefore we decided to open a new section of PH211 in winter term for two hundred students. This section filled up very fast, but we do not have enrollment details yet. The aim for this section was the student population of engineering students who are in their second year, and for whom this would offer a last chance to finish the physics sequence in time for engineering Pro School. The enrollment in the current term of PH211 has 25% of the students repeating the course, about double the normal number.

*Studio space constraints:* Our studio room is currently used for our introductory physics course for engineers. Since we have only one section scheduled in studio mode the room can be shared with other instructors. Currently we schedule our paradigm courses in this room; the department of chemistry also uses the room for CH199 and CH637. After we expand the studio offering to three sections the room will be used for physics only. At that time our studio sections will occupy the room fully Tuesday through Thursday. Paradigm courses will still be scheduled in the same room, but other departments will need to find different accommodations.

**L. Data**

Appendix A.2 presents our student to faculty ratios. In terms of advising we distinguish between advising and mentoring. Mentoring takes place in research groups by research advisers. Advising is more focused on curricular issues. Over ten years ago we assigned every faculty member to a group of students. We noticed that advice given was very inconsistent and not always reliable, because it is very hard for all faculty members to remain current with all rules and regulations. Therefore we followed the model that was proposed by the American Physical Society and concentrated all advising activities. We had separate advisers for the three majors in our department. The head adviser looked after the physics majors, the developer of the computational physics program, Rubin Landau, looked after the computational physics majors, and the chair took care of the more complex advising for the engineering physics majors, which was awarded through the College of Engineering. After Rubin Landau retired the chair also took responsibility for the computational physics majors. With the appointment of David McIntyre as Interim Associate Dean the chair became the adviser for all majors.

Appendix G contains information about the status of our faculty.
III. Program Performance:

A. Assessment Process

The American Physical Society has taken an active role in many aspects of departmental affairs. Statements are issues regularly, either as guiding principles in which direction physics departments should develop, or as a reaction to events that should not have happened. Some relevant statements from the American Physical Society relevant to assessment of physics programs can be found in Appendix H.1.

Learning Outcomes

We have had three sets of learning outcomes (1997, 2004, 2012) which are presented in Appendix H.2-4. These learning outcomes were first developed as part of the paradigm program, and guided the development of the content of the paradigms and capstones. After six years of delivering our novel curriculum we saw the need for updates to the outcomes. In the last accreditation visit for the university learning outcomes became prominent in the visit, and our department used this opportunity for some lengthy debates that generated our current set of learning outcomes. We strongly believe that these outcomes reflect what we think a physics student at graduation should have mastered.

Curriculum Meetings and Documentation

Our department takes assessment of our program very seriously, and we believe that assessment goes beyond compiling numbers and giving tests. It also means that we have our finger on the pulse of the curriculum, and we talk to one another about the content, the delivery and the performance of students. And students are people with names – they’re not just statistics. To this end, each faculty member is assigned to two of three groups, introductory, upper-division and graduate, though any faculty member may attend any meetings. Each group meets every third week to discuss curriculum matters, paying attention to content, delivery, connectedness of the curriculum and how students perform. We also discuss future plans. The chair records minutes of the meeting on the departmental wiki Reports of weekly meetings of instructional groups and assessment reports (login and password available upon request). We find that our meetings keep us connected and focused on our teaching responsibilities and that without such a routine, discussion would be too infrequent. The de facto participation is one group per faculty member. A list of current topics being considered by the upper-division group can be found in Appendix H.3.

Exit Interviews

We conduct exit interviews with the seniors every year with both a written survey and in person. A typical set of interview questions can be found in Appendix H.4. The results of the exit interviews are discussed in the upper-division curriculum meetings and summarized in the yearly Assessment Report to the University.

Figure 14: FCI Gain versus Pretest Score
Standardized instruments and schedule

As part of our assessment process, we give the following “standardized” pre/post tests: FCI in PH 211 (pre/post); CSEM in PH 213 (pre/post); CUE in PH 320/422/431 (pre/mid/mid/post). Results for the multiple-choice FCI and CSEM are given in Appendix I.

Figure 14 shows our FCI gains in 16 courses over the past six years as a function of pretest score. The lines are taken from Hake. The red line indicates the average score of traditional lecture courses. The purple line indicates the average line for interactive engagement courses. The green line indicates the dividing line between low and medium gain courses. Green dots are represent results for our studio courses, blue dots the more traditional courses in spring term, orange dots the more traditional courses in fall term. Even though all our courses use clickers, the two courses below the green line were both taught in a very traditional manner, with very little active engagement. Fall term has lower pretest scores. Fall term classes enroll both students who are well prepared first year students and poorly prepared second year students. We are clearly making good progress, especially given the low amount of resources we have for these courses. With more attention to these courses (WIDER program!) and more resources we can definitely improve.

B. Student Assessment Data

See Appendix J for evidence of student involvement in research and internships, student awards and honors, student performance metrics, and credit hour production. Here we show some basic results. Figure 15 displays the final OSU GPA for the incoming class of juniors, defined by the enrollment in PH320 each fall term. This number is not completely accurate, because there are a few repeating students and minor students in the class, but those changes are small. These data support observations made during our curricular meetings. We had noticed that in the fall of 2009 the performance was somewhat weaker than usual.

We also correlate the OSU GPA for each year with the ratio of BS degrees in physics awarded to students in PH320. This ratio underestimates the actual
ratio by about ten percent, because of the presence of repeating students and minor students. See Figure 16. In the past we have analyzed correlations between introductory mathematics and physics grades and found that scores of B and lower are not correlated. In our graduation rate we see the same. Only when the average grade is a B-plus or higher do we see an increase in graduation rate with class GPA. This is not surprising. Both these numbers depend on the same factors like motivation. The only conclusion one can draw is that they have a common cause.

In Table 1 we present data for the last five fall terms for the number of students on honor roll and warning, probation, suspension. The fact that fall term 2010 is somewhat higher in suspensions correlates with the lower GPA in PH320 in 2009. One has to keep in mind that our numbers are small and that fluctuations therefore are very large. Also, the students on warning, probation, and suspension are mainly lower division students. Motivation for study is not always present. If we assume that we have an incoming class of 40 at START, and if we assume that we follow the first year retention rate as seen by the university, we expect to see at least around 10 students on probation and suspension each year. We actually see a lower number, which indicates that students who choose physics as a major early on might be more successful in their academic career. This is, however, a very tentative conclusion.

We show our credit hour production in Figures 17 and 18.
C. Faculty Performance Metrics

See Appendix K for information about faculty research, honors and awards.

The following figure shows the BS degree production as a function of the total faculty FTE in all PhD granting physics departments nationally. The figure was copied from the AIP web-site, and we apologize for the poor quality. The slope of the line connecting a data point and the origin shows the degree production per FTE and we are in the top 10 (out of 190) departments.

![Figure 19: Number of BS degrees awarded versus faculty FTE for 192 PhD granting Physics Departments](image)

Faculty SET scores (Student Evaluation of Teaching) are shown in Figure 20 through 23, below. The red line indicates the university average score for the last fall term by level. Our scores on the 100 level are above average, which reflects the popularity of our introductory astronomy course, PH104. At the 200 level we are clearly below average, which is no surprise. The majority of these courses are service courses for the engineering departments and the life-science departments. Our reform efforts in the last five years have increased the level of student learning in the introductory physics courses, as measured
by FCI, but also required more active engagement from the students. Fortunately, we now see a much larger proportion of active engagement courses on campus, which causes students to be more accepting of modern teaching methods. The OSU WIDER initiative will be of great help to further spread changes in teaching methods across science and engineering disciplines. The fact that courses taught differently from the majority score lower in SET is well documented nationally. Also, SET scores tend to anti-correlate with FCI scores, and our data agree with that trend. Our data set is too small, however, to draw any strong conclusions.

The SET scores on the 300 level are about average. This level represents an interesting mix of bac core courses and service courses. We are very happy to see that on the 400 level our SET scores are above average in general, which reflects the appreciation of our students for our paradigm program. There are two scores below three; both can be explained and causes have been addressed.
IV. Evaluative and Learning Outcomes Assessment

A. Program improvements as a result of learning outcomes assessment activities

As a result of our regular curricular meetings we constantly make changes to our program. These range from introducing multiple representations in quantum mechanics to creating a new interlude and partial derivatives machine to complete course rearrangements (switching the order of the spins and waves paradigms; switching the order of the classical mechanics and math methods capstones; switching the order of the periodic systems and central forces paradigms.)

B. Tracking of students into graduate school, jobs, and professions and teaching careers

We track our undergraduates and their progress as best we can, and we have good, but incomplete information. (i) All undergraduates write a biography that is published at our year-end senior thesis mini-conference, and which generally self-reports their plans for the following year. This usually yields good information about graduate or professional school plans and military or volunteer service, and some information about permanent jobs. (ii) Students are encouraged to establish a LinkedIn profile and connect to our departmental LinkedIn profile, a connection to which is displayed on the departmental home page. This tracking mechanism has the advantage that it is updated by the (former) students themselves and is therefore a current snapshot of our alumni. The LinkedIn profile is a recent innovation, just a few months old, but is already very useful as a tracking device (and is starting to gain traction as a networking hub for current and former students). Not all employment sectors find LinkedIn a useful professional resource, but it is extensively used in the high-tech and professional sectors and we have about 150 connections at present (with about 70 undergraduate alumni) and are continuing to work hard to recruit former students. (iii) Faculty and staff maintain connections with former students. We publish information that the former students are willing to share in our yearly newsletter.

With these efforts, we have a fairly good general idea of the careers of our students, but we do not have a central repository for all this information where we can easily pull up statistics to answer detailed questions about career trajectories. To give a flavor, of the 29 participants in the senior thesis class of 2013, 11 obtained jobs in the private sector, 5 continued to graduate school (Ph.D., M.S. or professional programs), 10 continued for a 5th year in the B.S. program, 1 entered a year of volunteer service and 2 are unknown. Further details are in Table 3.

C. Data

Graduation data:
In Table 2 we present information of all degrees awarded in the department. This includes the discontinued programs like the MS in Applied Physics. The number of graduate degrees scales with our total tenure-line faculty FTE similar to other universities. The number of undergraduate degrees is large for our faculty size. Because we require all our students to perform research and write a thesis, this strains the capacity of our research groups.

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*Professional viability of graduates:* This table below represents the PH403 (senior thesis) class participants from 2009-2013. PH 403 is required of all physics majors, and most, but not all, students take it in their final year. Engineering physics majors are not included unless they are also physics majors since they took engineering design rather than thesis.

The numbers represent the last known employment of the students. Some students listed under “graduate school” may now be employed, but we don’t know where. Students currently employed may also completed a graduate degree. Nonetheless, the numbers provide a useful snapshot. “Graduate school” includes Ph.D., Master’s, and other professional degrees in all disciplines, not only physics.
A very informative picture of the current employment of our students comes from a quick scan through the connections on who are tagged “undergraduate alum” the OSU Physics LinkedIn page. Access to the account is available to the review team upon request. The range of careers is truly impressive.

**Student and alumni satisfaction level:** Student satisfaction level is assessed in detail by our exit interviews. Our difficulties with assessing alumni satisfaction are detailed above.

**Employer assessment of quality of graduates:** We have not been able to attain this data.

**National program rankings:** Not applicable.

**Student performance on licensure/certificate/professional exams, where applicable (compared to national data):** Not applicable.

### D. Anecdotal Stories

**The Oregon connection:** We are particularly pleased that many of our undergraduates (and graduates) are remaining in Oregon and contributing to the state’s high-tech industry. Last year, of the 11 students whom we know entered the private sector, 9 took jobs in Oregon – at Intel (Hillsboro) and small companies in Albany, Corvallis and Portland, as well as one who started his own company called Specialty Aero (Creswell). Examples of earlier alumni who went directly into the private sector after the B.S. degree are: Jeff (B.S. 1993), a Senior Applications Engineer at Cascade Microtech in Portland, who regularly recruits at OSU; Casey (B.S. 1999), a director at PECI in Portland; Brandon (B.S.1998), a business development and product marketing engineer at FEI, Hillsboro; and Jeff (B.S. 1993), a program manager at Hewlett Packard (Corvallis).

**Teaching:** Our undergraduates also become teachers in high schools, community colleges and universities. Nate (B.S. 2007) went on to a Physics Ph.D. program at UC Santa Cruz and is now teaching at a community college in Texas. He says, “All the hard work at OSU really prepared me for grad school and I thank all the professors for working so hard to make me competitive in grad school. You all really did a fine job with those classes. I certainly appreciate all the work everyone put into making us understand physics. I thought that (the) Paradigms curriculum is really the way to go (for teaching classes).” Josh (B.S. 2006) did his senior thesis on developing the Paradigms portfolios wiki and became

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**Table 3: Employment of Physics Majors**

<table>
<thead>
<tr>
<th>Senior Thesis class of...</th>
<th>Total Number</th>
<th>Graduate School</th>
<th>Private Sector</th>
<th>Military</th>
<th>Educatio n*</th>
<th>Other</th>
<th>Unknow n</th>
<th>5th yr B.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>30</td>
<td>5</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>2012</td>
<td>17</td>
<td>11</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>2011</td>
<td>9</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2010</td>
<td>18</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>2009</td>
<td>13</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>
a high school physics teacher in Philomath, OR. Sam (B.S. 2012) is pursuing a Master’s degree in education after doing his senior thesis on developing projects for our introductory courses.

Graduate school: About 1/3 to 1/2 of our undergraduates obtain a further degree, either an M.S. or Ph.D. in Physics or related disciplines like physical oceanography, medical physics, or engineering en route to careers in research, business, and education. Shela (B.S. 1996) is now a research scientist at Stanford University after completing a Ph.D. in Electrical Engineering at Arizona State University. Jon (B.S. 2003) did a Ph.D. in Physics at Harvard, a postdoc at M.I.T. and went into intellectual property law. Dara (B.S. Hons. 2003) pursued an M.S. in Physics and is now a publications specialist with Vernier Software in Portland. This local company makes equipment for Physics labs and Dara came to OSU recently to discuss career opportunities with our students. Scott (B.S. Physics, Computational Physics and Math 2008) became a software engineer at Yelp after his Ph.D. in Applied Mathematics at Cornell.

V. Trends and Forecasts

A. Growth and Sustainability at OSU

The American Physical Society and the American Association of Physics Teachers have both called for dramatic increases in the number of physics majors and an increase in the number of students taking physics courses to support the growth of the STEM workforce which the nation so clearly needs. The dramatic growth in the enrollment at OSU since 2009 and the expected growth in the near future, offer us a unique opportunity to respond to this call. We have already discussed the challenges that this growth poses for us as it puts pressure on access to our lower-division large enrollment service courses and also to our nationally-known Paradigms in Physics program. We would like to discuss further here three other aspects of this growth.

Pressure on thesis/research opportunities

We are very proud of the involvement of our undergraduates in research and at present we provide an intensive research experience for each student that closely parallels that of the M.S. and Ph.D. students, albeit at a lower level. The research experience conforms to the APS statement 06.03 “Career Options for Physicists” that affirms the importance of “independent research in an undergraduate setting”. At present, our students perform research under the auspices of the WIC (Writing Intensive Curriculum) course required by the university in each major. We designate this course PH403, and a single faculty member is assigned to guide the writing and peer-preview aspects of the thesis writing. But the research itself is supervised by the faculty at large, and consumes substantial faculty and graduate student time. It is effectively an overload assignment, and its intensive nature means that research faculty can take on only one or two students. While the benefits to the undergraduates are always positive, the benefits to the research are less clear. In some cases, the undergraduates function essentially as graduate students and push the research forward. In other cases that does not happen. Because we have chosen, effectively, to require research by undergraduates, we have placed ourselves, and a few faculty members who take on the largest assignments in particular, under considerable stress. The bulk of the supervision in the last 10 years (since 2005) has been done by 4 faculty members. Of 146 thesis supervised, one faculty member has supervised 27, three between 10-15, five between 5-9
and nine between 1-4; 16 have been supervised outside of physics.

We have pursued two strategies to relieve the pressure, and are considering a third, but the problem remains unsolved.

(i) External summer REU and internship opportunities allow students to conduct their research off campus, with nominal co-supervision by (usually) the PH403 instructor. Five students of the 73 in the 2010, 2011, 2012 & 2013 classes have used this option.

(ii) Faculty members from outside physics supervise some research projects. Nine students of the 73 in the 2010, 2011, 2012 & 2013 classes have used this option.

(iii) We are considering a research-based course, where students work jointly on different aspects of a project under the supervision of a faculty member assisted by a TA. This could be a hybrid of an advanced lab and a research course tailored to a particular faculty member’s interest. The faculty member and TA would have a formal assignment, and hence recognition, and students would have scheduled time assigned for the project, which would speed progress. Those students who are motivated to work independently would still work with individual advisors and complete the PH403 course.

Remodel funding
There has been significant upgrade to the teaching space in Weniger Hall with university funds in the last three years. Physics’ input was sought and acted upon. We are very pleased – the improvements were long overdue. The large lecture hall (Weniger 151) has been remodeled with swivel seats and more spacing between rows to incorporate active engagement in large classes. Room acoustics and better projections systems are in place. Similar improvements have occurred in smaller classrooms. We have also developed new studio/scale-up space with departmental funds. There are several unfinished items that would further improve matters, and there are also teaching spaces that were not included in that remodel. We have developed a wish list that we maintain on our [remodel departmental wiki] page (login information upon request). We present at the wish list at every available opportunity. Succinctly summarized, the list is.

- **Large lecture classrooms**: larger whiteboards, lecture cams for better visibility and easy transfer of data.
- Classroom space, introductory physics: Duplicate Weniger 212 classroom by 2015 and again by 2017 to accommodate Studio/SCALE-UP.
- Classroom space, upper-division physics: Duplicate Weniger 304 by 2016 to accommodate anticipated expansion in enrollment in the major.
- Instructional laboratory space, upper division physics: Weniger 300 and 302 must be remodeled into a single, modern space for computer and electronics projects.
- Instructional laboratory space, introductory physics: Lack of instructional laboratory space for the introductory physics courses PH21x and PH20x limits the enrollment in these sequences. By 2017, we should construct two additional instructional laboratories in Weniger.
- Administrative space for large-enrollment classes: Need one centralized room with paper filing capacity for storing and returning all lower-division exams, homework, labs & other scored assignments. (Person-power to be part of TA duties of user departments).
Opportunities for Improved Teaching

The switch from standard lecture courses to a Studio model in more sections of our large enrollment courses would also allow us to implement several changes that could increase the flexibility of these courses for students with different learning needs. We envision adding special Studio sections for PH 211-2-3 to accommodate the needs of Honors student and at-risk students. We would also like to implement a Learning Assistants program in the model of the University of Colorado, using undergraduates who have just successfully completed the course as learning assistants in the studio setting. The University of Colorado and others have shown increased learning gains for both the students in the course and for the learning assistants themselves. They have also shown an increase in interest in K-12 teaching careers amongst the learning assistants.

B. Faculty

New faculty

We very much appreciate the recent tenure-line hires that we have been able to make and extend a warm welcome to our new colleagues.

Collaboration: Our hiring philosophy has been influenced by the recent funding trends that we have seen, especially at the NSF, which is moving away from a single investigator grant mode and rewarding instead large interdisciplinary collaborations and research centers. We search for faculty members who not only have strong individual research strengths, but who also have the potential to develop collaborations within our department or, even better, also with colleagues in other units on campus. We understand that such collaboration also requires changes in the ways in which we support and mentor new faculty and in the metrics that are used for the promotion and tenure process.

Research Areas: We have chosen to keep the number of research areas represented in the department large enough to offer some diversity of research experiences for students, but small enough to encourage collaboration. As our faculty numbers are finally beginning to rise toward our hoped-for parity with our aspirational peers, we are asking ourselves what new research areas might be fruitful to add to our department.

Teaching Mentoring: We have always considered the potential for excellent teaching to be an important factor in our hiring process. Indeed our SET scores show that, like Lake Wobegon, all our faculty are above average; we do not have consistent outliers. Nevertheless, it is typical for new faculty everywhere to have far more experience with research than with teaching. Further, the active-engagement strategies that we have developed here, as part of the Paradigms program are new to all new faculty members. Therefore, we have recently-instituted “teaching trios” as a means of providing feedback to faculty as they teach our classes and improve the classroom experience for students. Groups of three faculty members, typically representing a range of experience (introductory, upper-division and graduate classes) attend 2 of the others’ lectures during each term and meet to discuss their observations. The trios change each term so that all faculty members have a chance to connect with others.
C. Department Culture
We mention briefly here several changes we hope to make in the near future to our department culture.

Undergrad Awards
Our department sorely lacks recognition of undergraduate achievement. We will establish awards to recognize excellence in overall academic achievement, undergraduate research, undergraduate teaching, service to the department, and achievement in specific activities. This last award will recognize students who are not necessarily the straight-A students, but who have made exceptional progress or achieved under difficult circumstances. We will seek funding to allow these awards to have monetary benefits as well as prestige.

Departmental Graduation ceremony
Physics does not have an individual graduation ceremony at the department, but instead celebrates the end the year with an informal departmental spring picnic, and with a graduation dinner for the undergraduates. The informality is fun, and attendance is good. However, a formal reception at the department following the official graduation ceremony would bring students’ families to the department and offer an opportunity for connection between the faculty and a chance to show off our facilities at the one time of the year when undergraduates and their families are sure to be in attendance. Public acknowledgement of achievement would reach a wider audience. Such an event might raise the profile of the physics department with attendant recruiting and financial benefits.

VI. Summary
When we evaluate an undergraduate program is it useful to keep in mind the distinction made by Robert B. Barr and John Tagg in their 1995 paper “From Teaching to Learning -A New Paradigm for Undergraduate Education.” We quote from this paper: “In the Instruction Paradigm, the mission of the college is to provide instruction, to teach. The method and the product are one and the same. The means is the end. In the Learning Paradigm, the mission of the college is to produce learning. The method and the product are separate. The end governs the means.” Another salient quote from this paper, “To say that the purpose of colleges is to provide instruction is like saying that General Motors' business is to operate assembly lines.”

When we introduced our paradigms in physics program we transitioned from the Instruction Paradigm to the Learning Paradigm. We now focus on what our students learn and how they learn it, not on counting how many hours they spend in class. When we judge the performance of a student we do not necessarily check if the student got the correct answer (the GRE approach), but are much more interested to see if they followed the right approach. Do the students think like physicists is our central theme. When our students go into the real world, can they apply what they learned in our department to their new situations and be successful? We have only informal feedback from previous students who went to graduate school, telling us that they felt better prepared that their classmates. The STEM center at OSU has as one of its liens of inquiry how to define success of our undergraduates. It is very clear that they will not base the success on simple quantitative measures like the GPA. We would love to participate in such studies.
In summary, the physics major program at OSU is by all national norms an extremely successful program. We have been pioneers in developing the understanding how upper division students learn physics, and how they become physicists. We have been among the first departments nationwide that require students to perform research and to write a senior thesis. We are an important player at OSU in the improvement of lower division education. These aspects are critical elements of university programs.

We include here some questions for the review committee:

1. How can we continue to provide research/thesis opportunities for all students in the face of rapidly increasing numbers of physics majors?
2. How can we handle the space issues that we face?
3. How can we preserve the vibrancy of the Paradigms reform? What directions should it take in the next decade?
4. What resources are necessary for us to expand our reform of the large-enrollment lower-division courses—in studio format?—in another format?
5. What resources are necessary to preserve and expand our efforts in K-12 teacher preparation?
6. If we had five more tenure-line faculty members and/or increased numbers of instructors, what should be the focus of our expanded energy and effort?