CSUF Physics Program Performance Review
Self Study Spring 2015

Contents

I. *Department overview*

Faculty and environment. Our program is well summarized by our recent faculty hires and our growth overall depicted in Figures 1 and 2. Including our hire this past January, we have added five new tenure-track faculty including two woman over the past five years with no retirements. (As of March 2015, we have an additional offer out for a full-time female faculty pending acceptance of the offer.) We are currently at an all-time high of 13 full time faculty up from an average of eight over the past two decades. Four of our 13 faculty are female. We now have over 100 majors—roughly double the number from five years ago and our previous 20-year average. We have over 20 masters students currently teaching almost all of our introductory physics and astronomy labs; historically we had none teaching. Our FTES climbed to an all-time high of 424 this past fall that required over 70 introductory labs sections taught each week compared to less than 40 per week historically. Last spring, we said goodbye to nine physics majors and 11 Masters candidates, the department's largest graduating masters class ever.

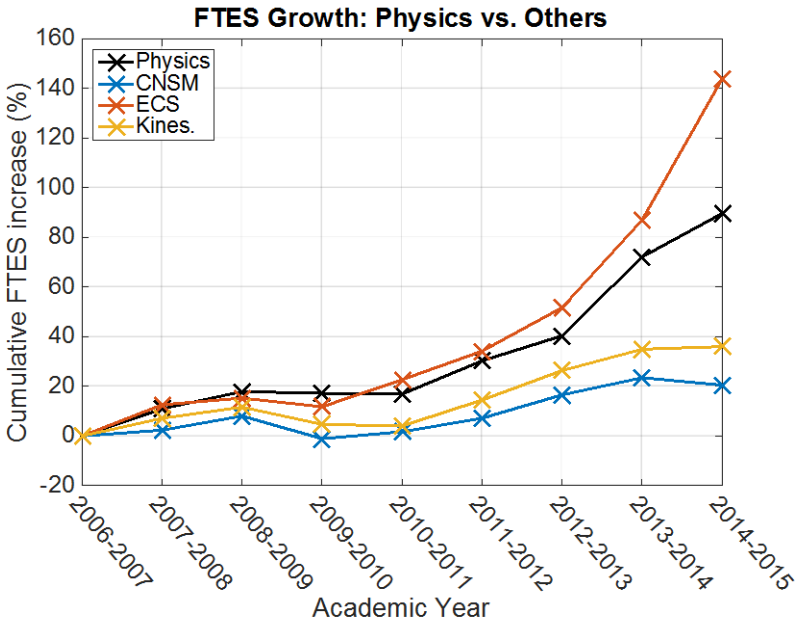

Figure 1. Comparison % growth in Physics FTES compared across the university since 2006. ECS is the College of Engineering and Computer Science. Kines is the Department of Kinesiology.

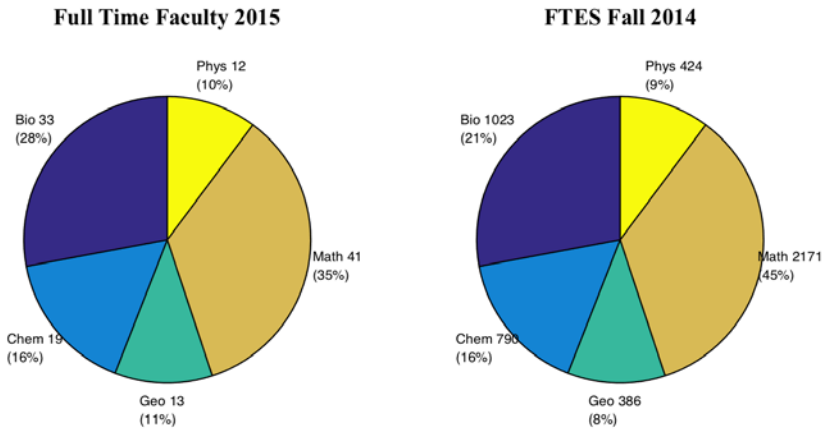

Figure 2. College[1] full-time faculty FTF S15 (left) and full-time equivalent students FTES F14 (right).

With our recent faculty hires, we have followed closely a plan we developed five years ago based on a few essential priorities. We have sought candidates not only with an active and rigorous scientific program but also ones able to articulate their fit in an institution with a focus on diversity and teaching as well as undergraduate and masters-level research.

We strive to be an accessible department where faculty, staff, and students know each other well and enjoy interacting and socializing in and out of the classroom and laboratories. We take pride in preparing and mentoring our students toward careers in science and teaching, both in the courses we teach and through their involvement in our own research. We graduate about 10 students each year, mostly into careers in industry and secondary education as well as into PhD programs. We are committed to teaching a wide range of scientific skills and technologies while developing critical-thinking tools that bridge a variety of industries, including engineering, electronics, communication, defense, and life sciences. Some 20% of our majors graduate with a minor or double major in math or engineering. Our Dan Black Phys-Bus Program offers a business-emphasis degree option that includes accounting, marketing, and entrepreneurial courses.

Student research opportunities. Faculty research areas and federal funding include

- atomic and molecular collision science
  - experiment—Morty Khakoo NSF, Greg Childers, Leigh Hargreaves
  - theory—Jim Feagin DOE
- condensed-matter science
  - theory—Ionel Tifrea
- fiber- and quantum-optical science, experiment and theory, and general relativity—Keith Wanser, Heidi Fearn

[1] Throughout this document, 'college' refers to the College of Natural Science and Mathematics CNSM, while 'university' refers to the campus as a whole.

- gravitational-wave astronomy
  - neutron-star astrophysics—Jocelyn Read NSF, NSF-MRI, Research Corp
  - black-hole simulation—Geoffrey Lovelace NSF, NSF-MRI, Research Corp
  - LIGO detection—Josh Smith NSF CAREER, NSF-MRI
- observational astronomy—Pat Cheng NSF
- physics education research—Mike Loverude NSF, Gina Passante

These activities generate a good deal of student participation in conference presentations and coauthors in peer-reviewed publications along with ongoing federal funding.

Last year 2014, every member of the department had one or more publications.

Figures 3 and 4 highlight the department's funding successes.

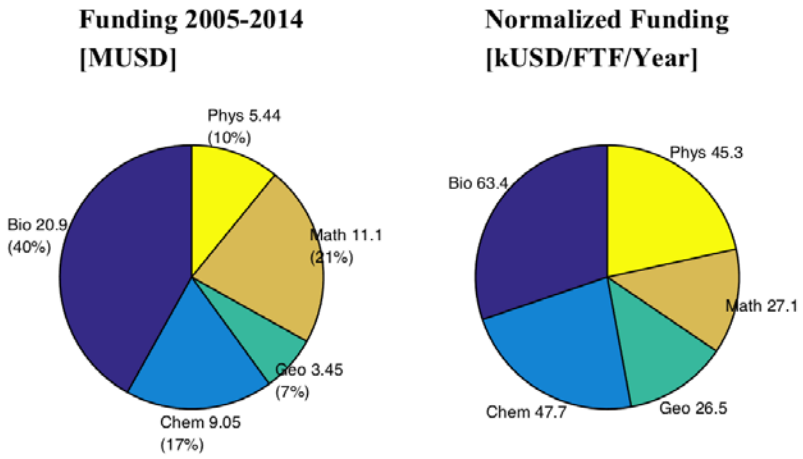

Figure 3. Total external funding percentages across the college since 2005 (left), and percentages normalized per full-time faculty FTF (right).

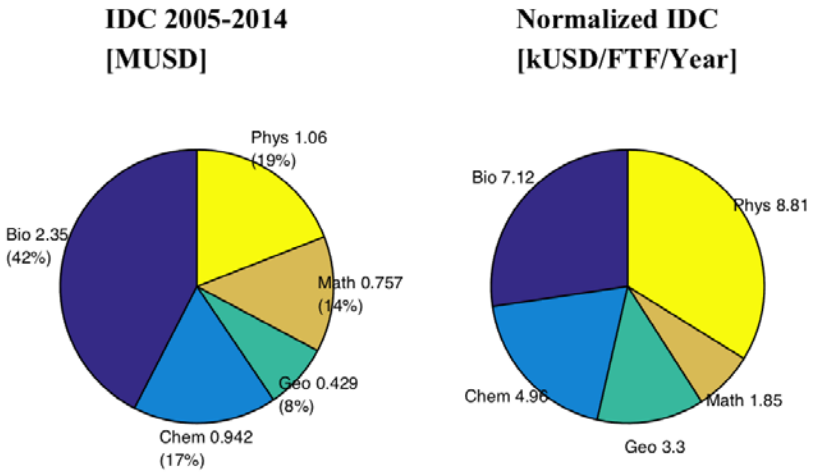

Figure 4. Total indirect cost IDC percentages across the college since 2005 (left), and percentages normalized per full-time faculty FTF (right).

Research Centers. The department is home to the *Gravitational-Wave Physics and Astronomy Center (GWPAC)* with a mission to support student research in gravitational-wave science. GWPAC director Josh Smith collaborates with center members Jocelyn Read and Geoffrey Lovelace and several at-large members. Josh is the recipient of an NSF CAREER Award and has been included on the 2014 roster of 40 top Orange County professionals under 40. Last summer, GWPAC received an MRI award (PI Geoffrey Lovelace) from the NSF to upgrade and expand its computing cluster, the first research cluster of its scale at CSUF.

CNSM is home to the *Catalyst Center* for the advancement of research in teaching and learning math education. Mike Loverude is director and PI of a FIPSE grant that has funded center activities for the last several years. Mike collaborates with faculty from five departments across campus and mentors junior faculty seeking external funding and writing proposals.

The college is also home to a new *Center for Computational and Applied Mathematics (CCAM)* with a mission to link research and students from across the college based on overlapping computational modeling approaches. The university has funded a computer cluster for the center, which went online this January. Geoffrey Lovelace is a computational director for the center.

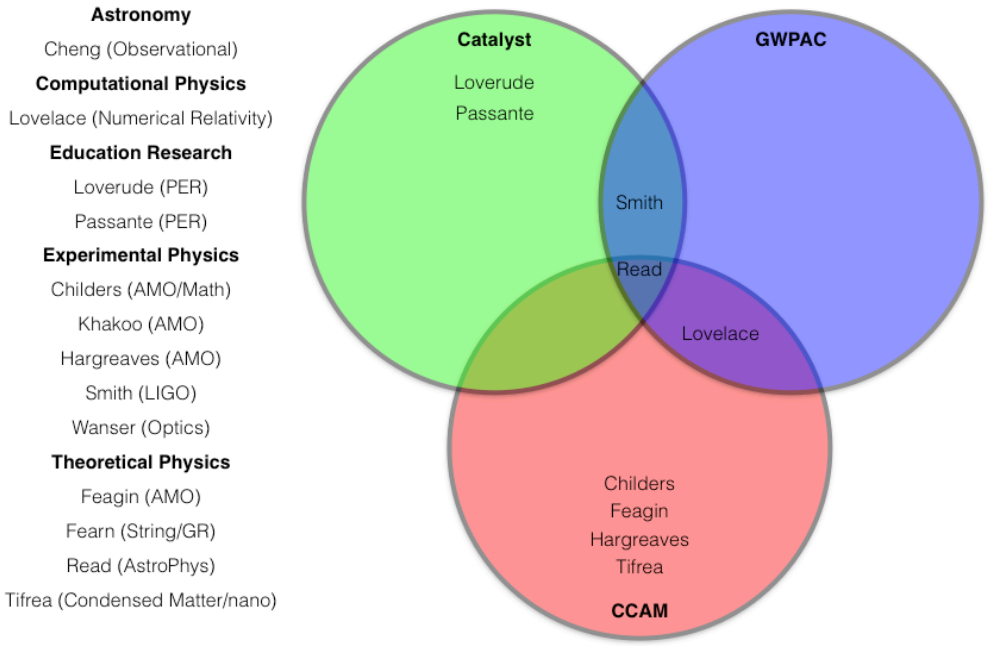

Figure 5. Faculty and Center research at a glance.

Lecture-demonstration collection. Over the past five years, the department has invested over $100K in soft money on upgrading and expanding the department's existing and already extensive lecture-demonstration collection. The funds derived from the generous

philanthropic support of department alumnus and longtime patron Dan Black as well as from our Ray Adams endowment, established through the estate of our department founder. Shovit Bhari, our staff tech extraordinaire, has been the driving force behind the effort and serves as the collection's curator. Shovit received the 2014 CNSM Staff Excellence Award. We have spent almost $50K of Dan Black support over the past three years to have SMART-Board™ technology throughout the department.

Lab course redesign. In 2010, we began an expansion of our introductory physics laboratory offerings 211L/212L and 225L/226L and for the next three years spent some $200K to purchase additional laboratory equipment and instrumentation. The dean allocated $150K as special one-time OEE, and we spent an additional $50K from our own Dan Black philanthropic funds. We thus roughly doubled in those three years our capacity for teaching our introductory physics labs. We are currently able to ensure that students enrolled in our physics lecture courses will have a seat in their co-requisite lab courses. These changes have also helped us meet the enormous growth in the College of Engineering and Computer Science *ECS* (see Fig. 1) over the past three years and eliminate a curriculum bottleneck. ECS growth continues, however, and our efforts to meet demand remain a work in progress.

For the past three years, Keith Wanser and Steve Mahrley have worked to modernize our introductory modern-physics laboratory course 227L. With some $50K of our own Dan Black funds, they have introduced several new experiments and rewritten the lab manual. Keith and Steve are currently working on an improved and streamlined approach to error analysis in our Phys 225L lab courses along with new experiments. They will extend their efforts to our other introductory lab courses over the next few semesters.

Academic advising. Greg Childers is our Undergraduate Program Coordinator and meets with our majors each semester for advising and curriculum planning. Department staff provides strong support tracking student progress and staying in touch with all our students. Several faculty across the department also informally share these duties with Greg and are readily available to talk to students and help them resolve issues and plan . Our entire faculty is involved in student research and we take pride in mentoring our students, especially with their curriculum and career planning.

Ionel Tifrea is our Masters Program Coordinator and does most of the student recruiting for the department and meets regularly with our masters students for advising and curriculum planning. Ionel is largely responsible for the success we have had in recruiting masters students, involving them in teaching lower division labs, and retaining a large fraction of them to graduation. The department staff also helps him coordinate with students to resolve issues quickly.

University service. Greg Childers is serving currently as chair of the university's GE Committee and is centrally involved in a major campus effort to reform GE assessment. Last

fall, Dean Bowman appointed Greg as the Faculty Assessment Fellow to the college to coordinate CNSM assessment and to chair the new CNSM Assessment Committee. Greg is working closely with Associate Vice President Peter Nwosu and his Director of Assessment and Educational Effectiveness Su Swarat in the office of Academic Programs and Accreditation. Leigh Hargreaves is serving on Greg's college committee as the Physics department's Assessment Coordinator.

Mike Loverude served three years on the steering committee for the university's 2012 on-site accreditation visit by the *Western Association of Schools and Colleges* (WASC) and served on two recent Dean searches for CNSM. Mike is currently serving on the university Faculty Personnel Committee and has been working closely with Bob Koch developing and coordinating the Helmsley project.

For the past year, Pat Cheng has served as faculty advisor for the department's supplemental instruction SI program. She currently coordinates and advises eight physics majors working in eight introductory physics courses as complementary sources of instructional support. We started our SI program five years ago.

Josh Smith continues to serve on the university Radiation Safety Committee, while Leigh Hargreaves has taken over duties on the CNSM Safety Committee.

Outreach. Four years ago, we sought a professional solution for an in-depth makeover of the department website physics.fullerton.edu. At the same time, we had websites created for our centers GWPAC and Catalyst. Again, we funded the projects with resources generously provided by Dan Black. The result was well received in the college, and the former dean contracted our website developer to renovate and coordinate websites across the college to have a similar look and feel.

Our website has thus become an outreach tool, and we maintain our webpages diligently to document and archive continuously all aspects of department life. Last year, we had our website professionally updated for better access on smart phones and tablets while adding an automated newsletter with a link for guest signup. According to Google Analytics, traffic to the site has grown steadily along with online contributions to the department through the website's Give buttons and links to *Support Cal State Fullerton*.

This past summer, Dan Black donated an additional $100,000 to the college and the department to purchase a portable planetarium for education and public outreach. Shovit researched and purchased the instrument and underwent extensive training with the manufacturer. Shovit serves as an interim planetarium curator coordinating instructional events with faculty for our astronomy labs and conducting community science-outreach for local area schools and other groups.

The student Physics Club has initiated a Physics Fair held one weekend each semester to generate excitement for science. The inaugural event last semester was a huge success

drawing several hundred local area children and their families and raised almost $2000 for the club. The college is considering expanding the event across all departments.

For the past few summers, several faculty have hosted summer STEM^2 students from local community colleges for summer research, and they will do so again this summer. The department works hard to encourage and foster support for underrepresented students in the department, and our majors and Physics Club leadership have done well the past several years to welcome underrepresented groups. For example, former Physics Club president Cinthia Padilla helped organize workshops at community colleges featuring Women in STEM designed to support women and provide them with a better understanding of what a four-year university would be like as well as a career in the STEM fields. She visited Citrus College once a week to talk to students and share her own experiences.

In addition, a number of students and faculty are members of the Society for Advancement of Hispanics/Chicanos and Native Americans in Science SACNAS. We have sent a strong contingent to the past four national conferences (San Jose, Seattle, San Antonio, LA). At these, Jocelyn Read, Mike Loverude and Josh Smith have chaired and presented in scientific sessions, and a dozen students have presented their research and engaged in networking and outreach events.

We have begun to connect better with our department alumni. In 2012, the department hosted an official opening for GWPAC involving LIGO leadership from around the country, with keynote speakers Kip Thorne (Caltech) and Gabriela Gonzalez (LSU). Working with Camille Harper, then our college DOD, we invited a number of alumni including Dan Black. Given the success of that event as a means to connect with alumni, we created last year an automated website newsletter that reaches out to all known alumni by default, though they have the option to opt out.

The total number of students enrolled in physics at CSUF has been increasing over the past decade. Although the university has admitted on average 69 freshmen each year into physics since 2008, only 12 students per year (17%) actually end up at CSUF. Similarly, on average 15 upper division transfer students are admitted each year, while on average only five actually come to campus. Thus, we have been working to increase the fraction of students accepted into physics that actually enroll.

Last spring, we attempted for the first time to reach out to admitted students who had not yet accepted. Working with admissions and records, we retrieved email addresses and phone numbers for those students, and sent them each a message congratulating them, welcoming them to the department, and describing what opportunities for research and career development we have to offer. For this first attempt, we had only partial contact information and were late in asking for it, so we only reached a subset of students. This spring, we are working with admissions to have accurate data early and should reach a higher fraction of uncommitted students.

University Strategic Plan. The department remains strongly aligned with the goals of the University Strategic Plan. Namely, we strive to:

- *Goal 1*—Develop and maintain a curricular and co-curricular environment that prepares students for participation in a global society and is responsive to work-force needs;
- *Goal 2*—Improve student persistence, increase graduation rates University-wide, and narrow the achievement gap for underrepresented students;
- *Goal 3*—Recruit and retain a high-quality and diverse faculty and staff;
- *Goal 4*—Increase revenue through fundraising, entrepreneurial activities, grants, and contracts.

In the following sections, we will underscore our long-term commitment to these goals and the Strategic Plan.

II. *Curriculum reform and program assessment*

Introductory physics redesign [Strategic Goals 1, 2]. Improved introductory physics courses are a key to engaging and retaining students in STEM disciplines, and lay the foundation for later studies. Research indicates that students, especially at-risk students, are more likely to learn and succeed in classes that encourage active engagement. The department has been working with Mike Loverude and Catalyst to examine possible redesigns of our introductory physics courses to transition from the traditional lecture format to activity-based peer instruction. These efforts have paralleled a collaboration by Josh Smith and Jocelyn Read with Mike over the past two years to introduce active learning materials and peer assistants into our Introductory Astronomy course to facilitate student learning and assessment.

Two years ago, we invited Professor Homeyra Sadaghiani from Cal Poly Pomona for a special colloquium to present her research on 'flipping the classroom' and the benefits for student conceptual learning and improving attitudes towards physics. A 'flipped' or 'inverted' classroom uses class time to engage in learning activities that are cognitively demanding, including class discussion and peer instruction. Traditional class content delivered in lecture is moved out of the classroom and facilitated by multimedia learning modules that also help hold students accountable for their work. Homeyra's General Physics course Phy 133 at Pomona was selected by the Chancellor's Office for one of the 'proven redesign summer eAcademies,' and five physics faculty along with Shovit attended a three-day workshop with Homeyra at Pomona in August 2013 in coordination with Ed Sullivan and the Provost. Last spring, with support from the Provost and the Chancellor's Office, Geoffrey Lovelace taught our introductory physics course for engineers as a 'flipped' classroom based on materials from Homeyra's workshop. Last spring, Homeyra spent her sabbatical from Pomona with Catalyst and was available to advise Geoffrey and help expand our redesign efforts. Last summer, Ionel Tifrea taught

introductory Phys 225 to include in-class peer instruction with the help of one of our senior SI instructors, masters candidate Bobby Wright.

Expanding STEM outreach and HIPs [Strategic Goals 2, 4]. Josh Smith's NSF CAREER award will provide a total of $450,000 over a five-year period to support an integrated research and education program in gravitational-wave science for himself and his students at CSUF. Josh proposed to work with nearby community colleges, building off of existing relationships established with STEM^2 and other programs, and in coordination with Mike Loverude and Catalyst. Josh will thus seek to establish a pathway for students to transfer to CSUF to take part in research and education in the physics department and our center for gravitational-wave physics and astronomy GWPAC.

This summer, Smith, Read, and Lovelace will resubmit a proposal to the NSF PAARE for a major bridge program entitled, "Catching a new wave: the CSUF-Syracuse partnership for advancing minority participation in gravitational-wave astronomy." The mission of this project will be to increase the number of students of color in gravitational-wave astronomy. It will strengthen an existing collaboration between CSUF and Syracuse University (SU), a PhD-granting institution. PAARE support will enable us to increase the diversity of students involved in gravitational-wave astronomy at the undergraduate and masters levels, and develop a pathway for them to enter the PhD program at SU, providing financial support and mentoring through their complete studies.

With a Major Research Instrumentation award from the National Science Foundation, and additional funding from the Research Corporation for Science Advancement, GWPAC has completed a substantial upgrade and expansion of its local computing cluster, the Orange county Relativity Cluster for Astronomy *ORCA*. The machine, housed in the University Data Center, now has 1500 gigabytes of memory, 30 terabytes of local storage, and 600 compute cores. This more than doubles the number of student projects that ORCA can support. Nousha Afshari, a physics major, is also supported by the NSF MRI as an computer system administrator, a profession in which women are acutely underrepresented.

Our Dan Black Phys-Bus Program is aimed at providing undergraduate physics majors with the training and experience needed to succeed in small business with entrepreneurial and technology-based orientations. We typically support two or three Phys-Bus scholars each year with a $2500 Dan Black Scholarship for up to four years. We coordinate our program with Professor John Jackson, director of the Center for Entrepreneurship in Mihaylo College. We are also working with Dean Bowman and Dan Black to expand this program across the college in a broader Science-Bus program modeled after Phys-Bus.

Curriculum expectations [Strategic Goals 1, 2]. We first drafted a curriculum map two years ago of the core courses we offer for our BS in Physics categorized by both the de-

partment and the University Learning Goals and Student Learning Outcomes (SLOs). Our current and updated SLOs and curriculum map are listed in *Table 1* in the Appendix.

While the department does not have a formal capstone course, we recognized in the process of creating our curriculum map that our upper-division Experimental Physics PHYS 481 fulfills a similar role. Every physics major in our BS degree program is required to take an upper-division lab, which typically means PHYS 481. This course brings together all the key skills and requirements physics majors are expected to acquire and covers contemporary physics content in an experimental setting. PHYS 481 thus uniquely incorporates all five of the physics departments' categories of SLOs. Thus we have begun to use student presentations and lab reports from this course as a source of data for program assessment.

We have thus ranked these sets of SLOs for each core course as *Introduced, Developed, or Mastered*.

Progress. Mike, Josh, and Jim drafted a rubric last spring to evaluate PHYS 481 project presentations of several student groups taking the course last spring with Greg. We used the guidelines outlined in *Strategic Goal 1 Develop and demonstrate an understanding of physics content* to draft the rubric. We discussed our strategy beforehand to focus on program assessment and avoid student grading, a mode we found to be somewhat difficult to avoid. We also met a day later to document our results. We feel 481 is an excellent tool to monitor overall program assessment easily 'meeting expectations.'

For the current academic year, our goal for program assessment is to focus on *SLO 3–Communication* with the requirement that 75% of oral presentations from PHYS 481 will be scored as 'meets' or 'exceeds' expectations in several criteria. Our current and updated rubric is listed in *Table 2* in the Appendix. This rubric is adapted from the Association of American Colleges and Universities (AAC&U) VALUE Rubric Development Project. The project makes available an extensive series of assessment rubrics from the most frequently identified criteria of learning from surveys of over 100 institutions of higher education.

Masters program evaluation. As we discuss below, Leigh Hargreaves is leading an effort to develop a new course, *Graduate Advanced Lab* PHYS 581 that will serve as a capstone experience for assessing our Masters program in parallel with our undergraduate program assessment with PHYS 481.

III. *Five-year plan*

Continuing service-course growth [Strategic Goal 2]. For the past four years we have worked to strengthen and expand our lower-division physics curriculum. With support from the college, we have completed cloning of our introductory life-science 211/212 and engineering 225/226 physics labs from an historic pair of lab spaces to currently four independent facilities, which allows us now to run these four labs in parallel throughout the week—over 70 lab sections taught each week last fall compared to less than 40 per week historically. We have thereby eliminated a longtime bottleneck in meeting lab demand for lecture enrollments. We now run labs five days a week 8 am to 10 pm (5pm Friday). We don't expect this rise in demand to diminish much over the next few years.

Continuing astronomy-course growth [Strategic Goal 2]. We have targeted our astronomy offerings in a similar fashion. There is significant untapped student interest in astronomy at CSUF, which historically has been lost to the community colleges. For the past three years, we have been working to expand our astronomy offerings to capture this demand and target students currently taking their GE science units elsewhere. Evidence from around the country indicates that students are reluctant to enroll in physics courses, and simply renaming the course from PHYS to ASTR generally increases enrollment. In 2012, the university approved our request to rename our GE *Introduction to Astronomy* PHYS 120 as ASTR 101. Fall 2012, Josh Smith, Jocelyn Read, and Greg Childers submitted a detailed proposal to add a laboratory companion course ASTR 101L, which was approved and first offered F13 and included in the 2013-2015 University Catalog. These new courses thereby fulfilled a GE B.3 requirement, and enrollments have been increasing steadily since.

Thus, as Figures 1 and 6 depict, our physics FTES and astronomy enrollments continue to grow at a record rate, and we expect it to continue to grow given the growth expectations of Kinesiology and the College of Engineering and Computer Science (CECS).

New Astronomy major [Strategic Goal 2]. A few physics majors take ASTR 101 purely out of interest, although the companion lab course ASTR 101L completes student GE B.3 credit. Many students leave ASTR 101 with an expressed interest in taking more astronomy. Currently, we lose those students—either they end their astronomy studies, or in some cases transfer to other universities. We would thus like to increase our astronomy course offerings and work to increase the number of astronomy students and thereby department majors.

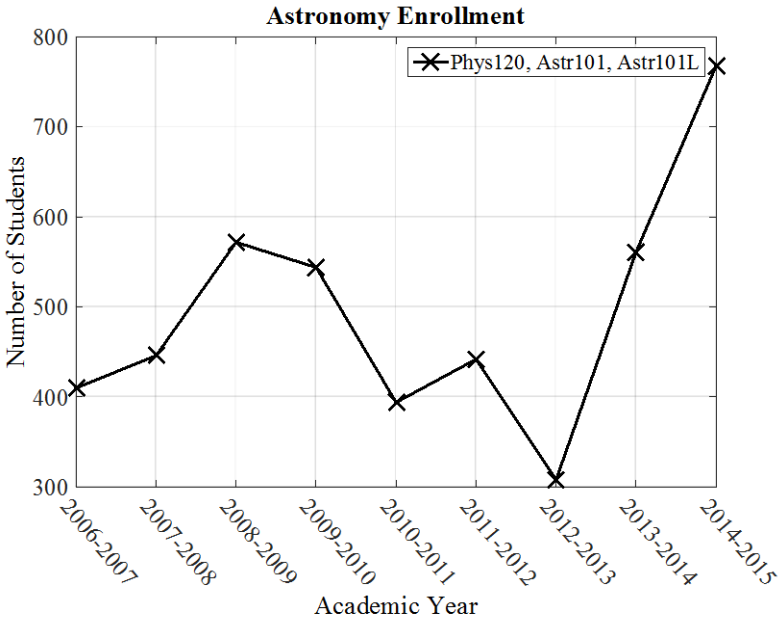

Figure 6. Department astronomy enrollments vs year since 2006.

A natural next step, therefore, would be the introduction of a new Astronomy major based on three new UD electives: Astrophysics, Gravitation and Black Holes, and Electromagnetic and Gravitational Astronomy. In addition to these UD electives, we would introduce a new LD elective 'Astronomy for Science Majors' that could form the basis for more direct recruiting into the major. Along with the members of *GWPAC*, Pat Cheng (observational astronomy) and Heidi Fearn (electromagnetic phenomena and gravity) form a critical mass for teaching these courses and conducting student research, which could also enhance our masters program. We have also discussed developing joint earth/space-science courses with the Geology department as an additional feature of the new major.

An Astronomy major would bring us our own students for about the same course-design effort as setting up a minor, where the students belong to another department.

Thus, a new astronomy major could be a promising area of recruitment for the department as well as new science students to CNSM in general. As shown in Figure 7, our major enrollment has grown the past two years to over 100 from a fairly constant 50 majors over the past 20 years, and with these changes we expect our enrollment could approach 200.

Masters program [Strategic Goals 1, 2, 4]. Our masters program has averaged 20 students enrolled in the past three years, and these students have been fully integrated into teaching almost all our introductory physics and astronomy labs. Our recent hires have been excited to integrate their own research experiences into our UD and masters level theory courses and have thus greatly strengthened and diversified our graduate

course offerings. Their research has also attracted masters students and grown the program. Our masters students are all involved with faculty research, primarily through independent research projects. In addition, since many of our undergraduates continue on for a masters degree, we expect growth of the undergraduate program would also lead to greater graduate enrollment.

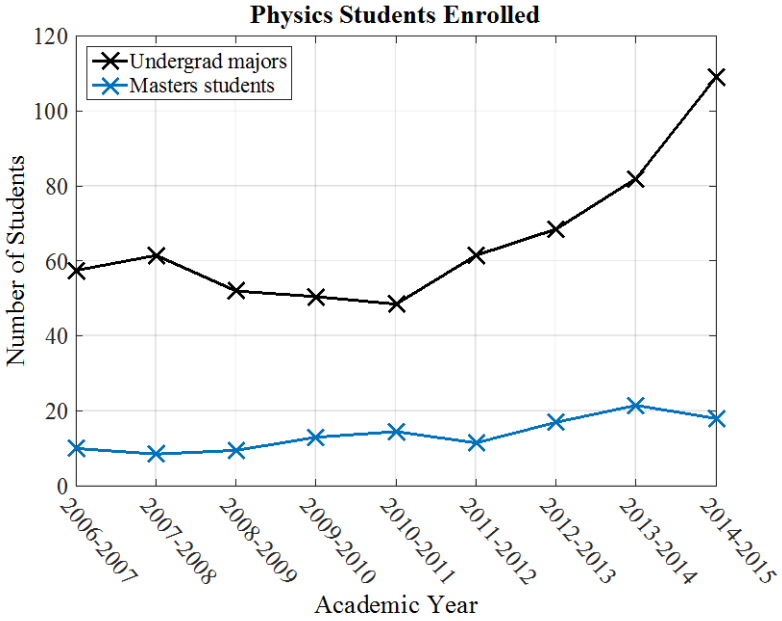

Figure 7. Number of Physics majors vs year since 2006.

Leigh Hargreaves is leading an effort to develop a new course, *Graduate Advanced Lab* PHYS 581, that would serve a dual role (i) providing a broadly-conceived advanced laboratory experience for masters students, and (ii) serving as a capstone experience for assessing our Masters program in parallel with our undergraduate program assessment with PHYS 481 (see Sec. II).

PHYS 581 will share the PHYS 481 facility, at least initially, and therefore have access to the 481 instrumentation we have invested in over the past five years. We have spent well over $150K in Dan Black donations and Eiker-Adams' endowment, as well as OEE to upgrade our 481 facility with TeachSpin™ kits, a variety of data acquisition instrumentation, and computers for analyzing data.

Thus, our advanced lab has been a strong source of endowment funds for us that we intend to continue to foster in alignment with Strategic Goal 4.

For 581, we are working to add five or so stations representing the experimental research efforts of faculty across the department that would allow more in-depth and longer-term studies of faculty research. Josh Smith has developed a tabletop 'mini-LIGO' interferometer, and Leigh Hargreaves and Shovit Bhari have begun the purchase of a

scattering chamber kit for introducing atomic and molecular collision science. The suite of stations will include fiber optics experiments and cluster-computing administration.

Commitment to Diversity in STEM [Strategic Goals 1, 2]. Women and Hispanic students are greatly underrepresented in physics and astronomy, particularly at the MS and PhD levels. CSUF is already a nationally recognized leader in undergraduate diversity, and our department's makeup mirrors that of the University as Figure 8 depicts. We have a demonstrated success recruiting underrepresented minority URM students into our research efforts including presentations at national and international conferences and co-authoring peer-reviewed publications. Of 13 full-time faculty currently in the department, four are woman (with another female faculty hire pending March 2015). Our department is thus well ahead of the national average as Figure 9 shows.

Faculty hiring [Strategic Goals 1, 3]. Including Gina Passante our newest hire in PER this past January, we are currently at an all-time high of 13 full time faculty. In the same five-year period, our FTES has more than doubled and we have seen little change in our part-time faculty needs. See Figures 1, 2, and 6, 7, 8. Along with the expected growth in our introductory-physics and astronomy courses and our major over the next few years, we feel we will need to hire three additional full-time faculty in the next five years. Moreover, in the next five to seven years, the department will be facing three likely retirements with Morty Khakoo, Keith Wanser, and Jim Feagin.

We feel that the most successful hiring strategy for achieving the strategic goals of the department and university is to target candidates that can (i) sustain and grow our current and longtime research and curricular strengths, and (ii) be flexible with cross-discipline student-based research across the college.

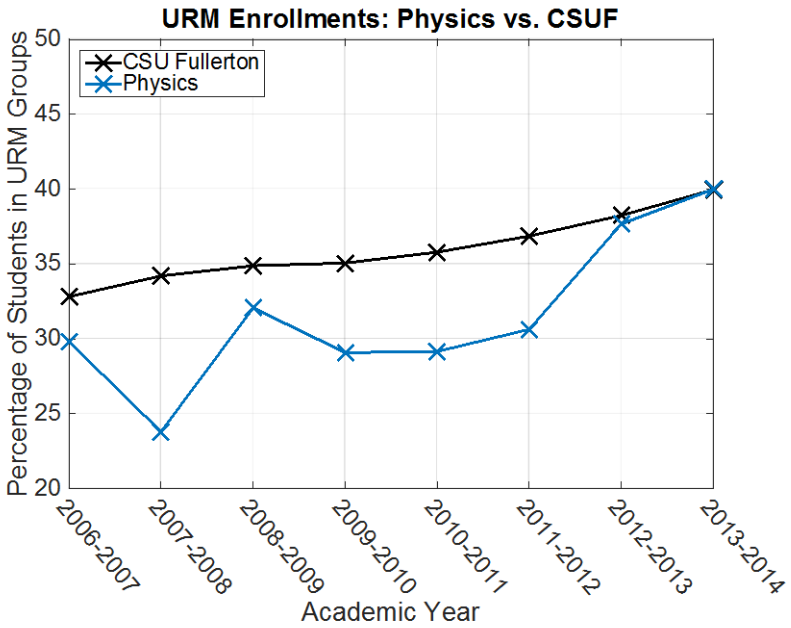

Figure 8. URM Physics majors vs year since 2006.

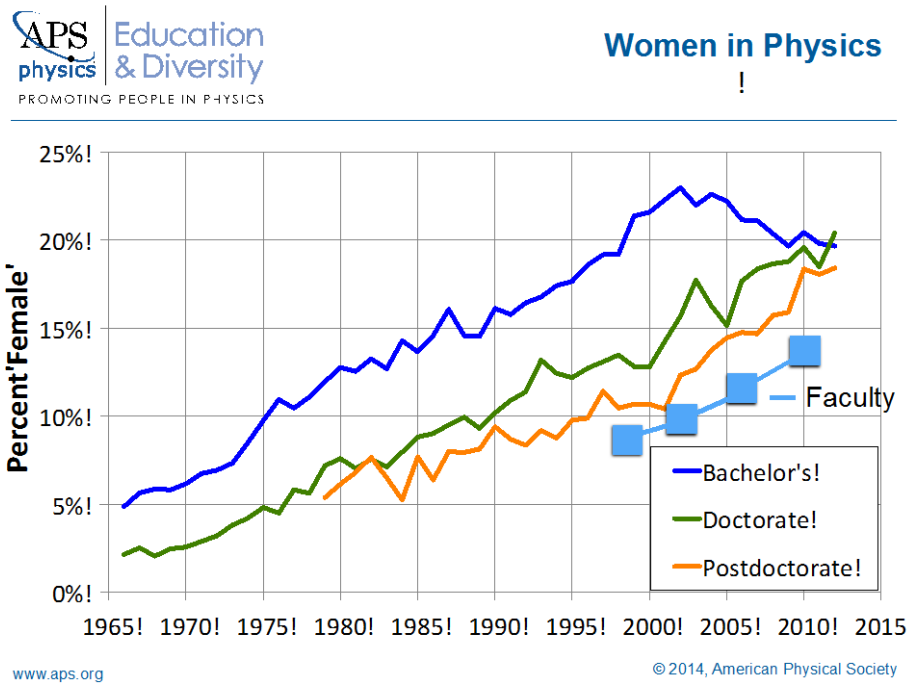

Figure 9. Percent woman in physics nationally as tracked by the American Physical Society.

As of February 2015 we have another offer out to Dr. Jackie Chini for a FT faculty-position in PER. (She's looking to solve a two-body problem with her physicist husband, who is also looking for an academic position in the area.) Our faculty search this past fall yielded several exceptional PER candidates, and we were approved for a double hire. Initially, we were hoping to identify a candidate with experience in astronomy education research AER, but were presented instead with a superior field of PER candidates.

Ideally, we feel strongly our next hire should be an experimentalist since three of our last four hires, including Passante, have been theorists. However, we appreciate that insufficient college resources—especially space and startup requirements—may limit our choices over the next couple of years. We argue here for three possibilities with less regard to their ordering.

(i) Computational Applied Physics. This search will target a theoretical physicist with broad computer modeling interests who would be equally conversant discussing data analysis with our experimentalists and their students or modeling say geophysics or biophysics data. This person would have a natural affinity for the college's *Center for Computational and Applied Mathematics* CCAM and foster cross-discipline interactions with faculty and students.

(ii) Experimental Physics. We will seek with this hire to balance the department better with laboratory–science opportunities, both curricular and research for our majors and masters students. The department has had great success securing funding for and in-

volving students in tabletop experiments. We would seek with this hire to enhance existing strengths of the department in atomic-molecular-optical AMO science, or optics including quantum and fiber optics, or nanoscience. We would also be open to biophysics and geophysics to provide synergies with other efforts in the college.

(iii) Cosmology/Astronomy. To take our growth in astronomy to the next level, we would seek additional expertise and broad interests and experience in both the science of the universe and in high-performance computing. We will seek to hire a young expert in astrophysics or cosmology. This person would help develop upper- and lower-division astronomy and cosmology courses critical to establishing the Astronomy major, and this person would have a keen interest in community outreach, including working with our portable planetarium toward the strategic goal of a permanent planetarium/science facility for the university. We also envision this hire having a role in the success of the college's Center for Computational and Applied Mathematics CCAM.

IV. *Resource requirements*

Fulltime chair. As highlighted already, our department has experienced a rapid and significant growth over the past five years. We have hired five new tenure-track faculty with no retirements, and we are currently at an all-time high of 13 full time faculty up from an average of eight over the past two decades. We now have over 100 majors—roughly double the number from five years ago and our previous 20-year average.

Our TAs teach almost all of our introductory physics and astronomy labs, whereas historically we had no TAs teaching. The TAs have to be trained and supervised, which requires significant organization and scheduling. In addition, we now offer summer introductory physics courses and their co-requisite labs, so that along with student research in faculty labs, we now have students working year round throughout the department.

Our FTES climbed to an all-time high of 424 this past fall and required over 70 introductory labs sections taught each week compared to less than 40 per week historically. On average, our FTES is now over 40% that of Biology and over half that of Chemistry and surpasses the FTES of Geology. For the past three summers, we have been teaching introductory physics, while historically we have taught none. Likewise, new-student summer advising programs have been ramped up across the university, although all faculty in the department are on nine-month contracts. The Geology department is similar in size to physics but with no service-course load and has had a *full-time* chair for the past 10 years serving some 12-13 full-time faculty.

A full-time chair for the department is overdue given our enormous and continued growth and the corresponding increased workload across the department in the past five years. The chair should be in charge year round.

Infrastructure needs. The department needs space to accommodate ongoing growth. We will convert two rooms currently used for part-time faculty office space to laboratory and office space for our new faculty hire arriving in the fall. We will thus require in the fall office space for some 10 displaced part-time faculty. We provide a handful of shared desk space in our student study hall for our TAs to hold office hours, while other departments in the college have dedicated office space for TAs.

We currently have neither lab nor office space for future new hires.

Last summer, to minimize an historic scheduling bottleneck, we converted a lecture-demo and laboratory setup room to serve as an additional laboratory facility to allow us to schedule independently our four introductory physics lab courses 211/212 and 225/226 throughout the week. Currently, these four labs are operating at about 90% capacity, and we have no other rooms in the department for expansion. Moreover, further expansion will require we clone the equipment and instrumentation in our current facilities. We cloned our two current facilities to four in years 2010-2013 with some $200K in special one-time OEE and Dan Black philanthropic funds.

Our introductory astronomy lab enrollments have been growing steadily the past two years and our ASTR 101L laboratory schedule in MH606 is currently at 95% capacity. We are looking to expand our 101L offerings in the fall in MH637, which is owned by Geology and currently used most of the week for GEO 102 and 410/420.

We spent $8K of our own OEE last summer on new furniture to refurbish our small tutoring center in MH600 to multitask the space for our growing Supplemental-Instruction SI program. Our SI program will likely continue to grow and require access to other SI facilities across the college.

Other departments in the college have much larger facilities, which we need access to.

OEE needs. The department has severely outgrown its historic allotment of OEE. Except for a one-time special allocation for lower-division lab expansion three years ago, our baseline OEE has remained roughly fixed for the past six years.

Additional instructional tech. The department has severely outgrown its historic allotment of just two instructional techs. Steve Mahrley is charged with the maintenance and weekly setup of the introductory physics labs across the department. Besides lab development, Steve also helps to maintain computers, printers, and computer networks throughout the department. Shovit Bhari is charged with curating the department's lecture demo collection and delivering the lecture demos for faculty, which could be a classroom anywhere on campus, along with managing the new portable planetarium and outreach. Shovit also orders and tracks all of the equipment purchased in the department including faculty grant purchases.

Over the past five years, the range of instructional-tech duties and responsibilities has more than doubled from their historic scope and justify an additional tech position.

Faculty startup needs. Our full-time faculty hire in Physics Education Research this past January accepted $65K in startup including a small lab and four-semesters of 3 WTU/semester teaching release. Our two previous theoretical hires received similar release but $55K in startup each. Our two previous experimental hires, Josh Smith four years ago and Leigh Hargreaves last spring, received similar teaching release and just over $100K in startup. However, Leigh received gift instrumentation from his PhD advisor at Flinders University in Australia, valued over $250K. In stark contrast, the physics department at CSULB is looking currently to hire an experimentalist and is offering ~$350K in startup.

Realistically, modern experimental physics requires laboratory startups in the $250-750K range, and we need to find ways to fund future startup at appropriate levels if CSUF is to remain competitive in STEM.

Machine-shop access. Our experimental-physics research labs rely on access to a machine shop for fabricating custom equipment. A machine shop is thus fundamental to the function of our labs and a key element to attracting future faculty in experimental physics. According to an MOU between CNSM and CECS, the physics department has access to the CECS/CNSM machine shop. This facility, led by Jon Woodland, does excellent work. However, over the past few years, the amount of time taken by the machine shop to complete even small jobs, such as aluminum boxes with custom-drilled holes, has grown to six months or longer. In some cases, the jobs are not completed, and faculty members are forced to contract at great expense with outside machine shops. We estimate that the machining requirements of the physics department as a whole are one or two 8-16 hour custom jobs per month from faculty, student, and staff projects.

Having restricted access to the campus machine shop is unacceptable for the long-term well being of the department.

We are requesting that our two colleges CNSM and CECS revisit the MOU to help us achieve improved access to the shop and a timelier turn-around on our projects. We need a better queuing system with better communication to facilitate having our jobs completed in an equitable and timely manner—for example, training students to assist with shop projects.

Frustrated access to large classrooms. To meet demand better across our introductory physics sequences, we have been offering large K2 lecture sections (> 90 enrollment) for the past four years *when we have been able to secure large enough lecture rooms*. This is of course a growing challenge across campus but key to avoiding bottlenecks in our life-science and engineering physics offerings.

Currently, we have access to a handful of timeslots in just *two* classrooms MH682 (cap 88) and SGMH 1406 (cap 120), whereas the other departments in the college share access to several large lecture rooms in our building MH. This shared access among the other departments is historical and has evolved little in the past 20 years.

We are requesting that the Dean and the college review the classrooms 'owned' by the departments to devise a fairer policy for accessing classrooms across the college.

Planetarium setup facility. Through one of many generous Dan Black donations, the department has purchased a portable planetarium—a STARLAB inflatable 7-meter dome with high-resolution digital projector. This facility accommodates up to 50 students at a time and makes possible daytime observing opportunities for our astronomy courses. The facility thus also serves as an excellent outreach tool for K-12 classes and community organizations.

To facilitate having the planetarium readily available both for our classes and for community events, we have initiated a partnership with the CSUF Arboretum to provide an indoor facility in which to erect the planetarium for collaborative outreach.

Other universities, such as CSUF Fresno, have successfully used portable planetariums as a philanthropic tool towards a permanent planetarium-science building, a path we are closely exploring with Dean Bowman, DOD Mike Karg, and Dan Black. We are working to identify *a dedicated professional to serve as planetarium curator*. In the interim, Shovit Bhari our instructional tech has happily taken on this task, a job he is very good at and much likes but which is taxing his already extremely busy workload with lecture-demo and lab development.

Appendix

Table 1. Updated Student Learning Outcomes and curriculum map

University learning goals (ULGs)	**Physics Student Learning Outcomes (SLOs)**	**Curriculum Map**
Demonstrate intellectual literacy through the acquisition of knowledge and development of competence in disciplinary perspectives and interdisciplinary points of view. *(Intellectual literacy)*	Students will solve problems by applying the primary physical theories: classical mechanics, thermodynamics, wave phenomena, electricity and magnetism, and modern physics.	I: 225, 226, 227 D: 300, 310, 330A, 340, 380 M: 320, 330B, 481, 499
Think critically, using analytical, qualitative and quantitative reasoning, to apply previously learned concepts to new situations, complex challenges and everyday problems. *(Critical thinking)*	Students will apply appropriate mathematical tools to solve physical problems.	I: 225, 226, 227 D: 300, 310, 320, 330A, 340 M: 330B, 481, 499
	Students will demonstrate understanding of scientific inquiry by designing experiments and analyzing experimental data.	I: 225L, 226L, 227L D: 380 M: 481, 499
Communicate clearly, effectively, and persuasively, both orally and in writing *(Communication)*	Students will clearly and concisely report scientific observations and analysis of experimental data.	I: 225, 226, 227 D: 380 M: 481, 499
Work effectively as a team member or leader to achieve a broad variety of goals. *(Teamwork)*	Students will demonstrate the ability to work collaboratively to collect and interpret data and draw conclusions.	I: 225L, 226L, 227L D: 380 M: 481, 499
Evaluate the significance of how differing perspectives and trends affect their communities. *(Community perspective)*		
Recognize their roles in an interdependent global community. *(Global Community)*		

I: Concept(s) introduced
D: Concept(s) developed
M: Concept(s) mastered

Table 2. SLO 3–Communication evaluation rubric

	Capstone **3**	**Milestone** **2**	**Benchmark** **1**	**Unsatisfactory** **0**
Organization	Logical order of information is optimized, with clear connections between points.	Logical order is sound, but some minor gaps in ideas between points.	Logical ordering is somewhat confusing at times.	Logical order of information is very difficult or impossible to follow
Language	Technical terms are all defined, used correctly and with consideration to the expertise of the audience.	Small mistakes in definition or use of technical terms, but not serious enough to detract from the audience's understanding.	Technical terms are poorly defined or used inappropriately for the expertise of the audience, which detracts from understanding the presentation.	Technical terms are used in such a way that makes the presentation very difficult for the audience to understand
Delivery	Speaks in a clear, controlled and audible voice and appears comfortable in front of an audience.	Speaker can clearly be heard by all members of the audience, but occasionally appears slightly anxious.	Some aspects of the presentation are difficult for some of the audience to hear or understand. Speaker seems nervous or uncomfortable.	Speaker is clearly uncomfortable and very difficult for most of the audience to understand clearly.
Visual aids	Visual aids are attractive, easily readable, and well laid out (not too busy or sparse), and helpful to understanding the presentation	Visual aids show good structure and are helpful to understanding the presentation, but some minor issues regarding layout (i.e., somewhat busy)	Some structure is evident, but visual aids do not help in understanding of the presentation	Visual aids are cluttered, unattractive or difficult to read and detract from understanding the presentation.
Context	Speaker clearly states the problem, including a clear description of why this problem is interesting to the broader scientific community.	Speaker soundly articulates the problem to be considered, but misses some points in describing the broader context	Speaker is unclear in describing the problem or makes no effort to place the problem into a broader context	Speaker makes no attempt to outline either the basic problem they are attempting to solve or why the problem is interesting
Duration	Presentation is within +/- 5% of the allotted time frame.	Presentation is within +/- 10% of the allotted time frame.	Presentation is within +/- 25% of the allotted time frame.	Presentation is inconsistent with the allotted time frame.